III. *Investigations of the Specific Heat of Solid Bodies.*

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I. *Historical Introduction.*

1. About the year 1780 it was distinctly proved that the same weights of different bodies require unequal quantities of heat to raise them through the same temperature, or on cooling through the same number of thermometric degrees, give out unequal quantities of heat. It was recognized that for different bodies the unequal quantities of heat, by which the same weights of different bodies are heated through the same range, must be determined as special constants, and considered as characteristic of the individual bodies. This newly discovered property of bodies Wilke designated as their *specific heat*, while Crawford described it as the comparative heat, or as the *capacity* of bodies *for heat.* I will not enter upon the earliest investigations of Black, Irvine, Crawford, and Wilke, with reference to which it may merely be mentioned that they depend essentially on the thermal action produced when bodies of different temperatures are mixed, and that Irvine appears to have been the first to state definitely and correctly in what manner this thermal action (that is, the temperature resulting from the mixture) depends on the original temperature, the weights, and the specific heats of the bodies used for the mixture. Lavoisier and Laplace soon introduced the use of the ice-calorimeter as a method for determining the specific heat of bodies; and J. T. Mayer showed subsequently that this determination can be based on the observation of the times in which different bodies placed under comparable conditions cool to the same extent by radiation. The knowledge of the specific heats of solid and liquid bodies gained during the last century, and in the first sixteen years of the present one, by these various methods, may be left unmentioned. The individual determinations then made were not so accurate that they could be compared with the present ones, nor was any general conclusion drawn in reference to the specific heats of the various bodies.

2. Dulong and Petit's investigations, the publication of which commenced in 1818, brought into the field more accurate determinations, and a general law. The investigations of the relations between the specific heats of the elements and their atomic weights date from this time, and were afterwards followed by similar investigations into the relations of the specific heats of compound bodies to their composition. In order to give a general view of the results of these investigations, it is desirable to present, for the elements mentioned in the sequel, a synopsis of the atomic weights assumed at different

times, and of certain numbers which stand in the closest connexion with these atomic weights.

	Berzelius's atomic weights.	Regnault's thermal atomic weights.	Usual equivalent weights.	Modern atomic weights.
Aluminium	Al = 13·7	Al = 13·7	Al = 13·7	Al = 27·4
Antimony	Sb = 61	Sb = 61	Sb = 122	Sb = 122
Arsenic	As = 37·5	As = 37·5	As = 75	As = 75
Barium	Ba = 68·5	Ba = 68·5	Ba = 68·5	Ba = 137
Bismuth	Bi = 105	Bi = 105	Bi = 210	Bi = 210
Boron	B = 10·9	B = 10·9	B = 10·9	B = 10·9
Bromine	Br = 40	Br = 40	Br = 80	Br = 80
Cadmium	Cd = 56	Cd = 56	Cd = 56	Cd = 112
Calcium	Ca = 20	Ca = 20	Ca = 20	Ca = 40
Carbon	C = 6	C = 12	C = 6	C = 12
Chlorine	Cl = 17·75	Cl = 17·75	Cl = 35·5	Cl = 35·5
Chromium	Cr = 26·1	Cr = 26·1	Cr = 26·1	Cr = 52·2
Cobalt	Co = 29·4	Co = 29·4	Co = 29·4	Co = 58·8
Copper	Cu = 31·7	Cu = 31·7	Cu = 31·7	Cu = 63·4
Fluorine	Fl = 9·5	Fl = 9·5	Fl = 19	Fl = 19
Gold	Au = 98·5	Au = 98·5	Au = 197	Au = 197
Hydrogen	H = 0·5		H = 1	H = 1
Iodine	I = 63·5	I = 63·5	I = 127	I = 127
Iridium	Ir = 99	Ir = 99	Ir = 99	Ir = 198
Iron	Fe = 28	Fe = 28	Fe = 28	Fe = 56
Lead	Pb = 103·5	Pb = 103·5	Pb = 103·5	Pb = 207
Lithium	Li = 7	Li = 3·5	Li = 7	Li = 7
Magnesium	Mg = 12	Mg = 12	Mg = 12	Mg = 24
Manganese	Mn = 27·5	Mn = 27·5	Mn = 27·5	Mn = 55
Mercury	Hg = 100	Hg = 100	Hg = 100	Hg = 200
Molybdenum	Mo = 48	Mo = 48	Mo = 48	Mo = 96
Nickel	Ni = 29·4	Ni = 29·4	Ni = 29·4	Ni = 58·8
Nitrogen	N = 7	N = 7	N = 14	N = 14
Osmium	Os = 99·6	Os = 99·6	Os = 99·6	Os = 199·2
Oxygen	O = 8		O = 8	O = 16
Palladium	Pd = 53·3	Pd = 53·3	Pd = 53·3	Pd = 106·6
Phosphorus	P = 15·5	P = 15·5	P = 31	P = 31
Platinum	Pt = 98·7	Pt = 98·7	Pt = 98·7	Pt = 197·4
Potassium	K = 39·1	K = 19·55	K = 39·1	K = 39·1
Rhodium	Rh = 52·2	Rh = 52·2	Rh = 52·2	Rh = 104·4
Rubidium	Rb = 85·4		Rb = 85·4	Rb = 85·4
Selenium	Se = 39·7	Se = 39·7	Se = 39·7	Se = 79·4
Silicium	Si = 21		Si = 14	Si = 28
Silver	Ag = 108	Ag = 54	Ag = 108	Ag = 108
Sodium	Na = 23	Na = 11·5	Na = 23	Na = 23
Strontium	Sr = 43·8	Sr = 43·8	Sr = 43·8	Sr = 87·6
Sulphur	S = 16	S = 16	S = 16	S = 32
Tellurium	Te = 64	Te = 64	Te = 64	Te = 128
Thallium	Tl = 204	Tl = 102	Tl = 204	Tl = 204
Tin	Sn = 59	Sn = 59	Sn = 59	Sn = 118
Titanium	Ti = 25	Ti = 25	Ti = 25	Ti = 50
Tungsten	W = 92	W = 92	W = 92	W = 184
Zinc	Zn = 32·6	Zn = 32·6	Zn = 32·6	Zn = 65·2
Zirconium	Zr = 33·6		Zr = 44·8	Zr = 89·6

For each of the previous columns the relation of the numbers to each other is alone important, and not the number which is taken as unit or starting-point. Berzelius's atomic weights and Regnault's thermal atomic weights are corrected with the nearest and most trustworthy experimental determinations, without alteration of the bases for the adoption of these numbers. The numerical relations presented in the above Table require, from the chemical point of view, no further explanation. The relations of these numbers to the specific heat form the subject of the investigations which are presented in the sequel.

3. The experiments by which DULONG and PETIT[*] showed, in the case of mercury various solid metals, and glass, that the specific heat increases with increasing temperature, were made by the method of mixtures. They determined at ordinary temperatures the specific heats of a greater number of elements by the method of cooling[†]. They found that when the numbers in the first column in § 2 corresponding to the elements Bi, Pb, Au, Pt, Sn, Zn, Cu, Ni, Fe, and S (the Berzelian atomic weights) are multiplied by the respective specific heats of these bodies, approximately the same number is obtained; and that approximately the same number is also obtained when $\frac{1}{2}$ Ag, $\frac{1}{2}$ Te, and $\frac{2}{3}$ Co are multiplied by their corresponding specific heats. They were of opinion that the atomic weights of the elements could and should be so selected that, when multiplied by the specific heats, they should give approximately the same number as product. This observation and this view, which DULONG and PETIT stated in 1819 in the following manner, "The atoms of all simple bodies have all exactly the same capacity for heat," have since that time been known as DULONG and PETIT'S *Law*.

I shall not here dwell upon POTTER'S investigations on the specific heat of metals and on the validity of DULONG and PETIT'S law[‡], but proceed directly to discuss NEUMANN'S investigations, which rank worthily by the side of those of DULONG and PETIT.

4. In his "Investigation on the specific heat of Minerals," NEUMANN (in 1831) first published[§] more accurate determinations of the specific heats of solid compounds. He investigated a large number of such compounds, especially those occurring in nature, partly by the method of mixture, and partly by the method of cooling; and he determined the sources of error in both these methods, and the corrections necessary to be introduced. In a postscript to this paper, he mentioned that he continued the investigations with an apparatus which, compared with that he had previously used, promised far greater accuracy in the individual results, without needing tedious and troublesome reductions. This apparatus, by means of which the specific heats of solid bodies, which may be heated in a closed space surrounded by steam, can be determined with great accuracy, he has not described[||].

Of the general results of NEUMANN'S investigations, one must be particularly men-

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[*] Annales de Chimie et de Physique, [2] vol. vii. p. 142.

[†] Ibid. vol. x. p. 395.

[‡] Edinburgh Journal of Science, New Series, vol. v. p. 75, and vol. vi. p. 166. J. F. W. JOHNSTON'S remarks, vol. v. p. 278. I only know these papers from BERZELIUS'S 'Jahresbericht,' vol. xii. p. 17, and GEHLER'S 'Physicalisches Wörterbuch,' new edition, vol. x. part 1, p. 805 *et seq.*

[§] POGGENDORFF'S 'Annalen,' vol. xxiii. p. 1.

[||] PAPE (POGGENDORFF'S 'Annalen,' vol. cxx. p. 337) has recently described this apparatus. I have had no tioned, that a dimorphous substance has the same specific heat in its two conditions. This he showed was the case with arragonite and calcite, and with iron pyrites and marcasite. But the most important is the discovery that in analogous compounds the products of the atomic weights into the specific heats are approximately equal. NEUMANN stated this last observation in the following manner:—"In bodies of analogous chemical composition the specific heats are inversely as the stochiometrical quantities, or, what is the same, stochiometrical quantities of bodies of analogous chemical composition have the same specific capacity for heat." NEUMANN adduced 8 carbonates, 4 sulphates, 4 sulphides (Me S), 5 oxides (Me O), and 3 oxides ($Me_2 O_3$), as showing this regularity, which is to be denoted as NEUMANN'S law *.

5. Soon after the publication of NEUMANN'S researches in 1833, AVOGADRO published † a "Memoir on the Specific Heat of Solid and Liquid Bodies." He there gave a number of determinations of the specific heat of solid bodies made by the method of mixture. As far as can be ascertained by comparison with the most trustworthy of our newer determinations, these results are by no means so accurate as those of NEUMANN; but they are far more accurate than those which had been obtained up to about 1830, and many of them come very close to the best of our modern results. It would be unjust to AVOGADRO'S determinations ‡ to judge them all by one case, in which he obtained a totally erroneous result (for ice, by a modified method); and by the circumstance that in a subsequent memoir § he gives specific heats for several elements as deduced from his experiments, which are decidedly incorrect ||. AVOGADRO recognizes the validity of DULONG and PETIT'S law. With reference to the specific heats of compound bodies, he considers that he had established, with tolerable probability, that for solid and liquid bodies the same regularity prevails which he had previously deduced for gases from DULONG'S experiments. That is, "that the specific heat of the atom of a compound body is equal to the square root of the integral or fractional number expressing the atoms or parts of atoms which go to form the atom of the compound body such as it exists in the solid or liquid state, taking as unity the specific heat of the atom of a simple body in the samestate." He observes that there is a difficulty incidental to the application of this law to solid and liquid bodies, which is not met with in the case of gaseous bodies, in which the composition by atoms or by volumes is held to be directly given by

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opportunity of seeing NEUMANN'S memoir cited by PAPE, "Commentatio de emendenda formula per quam calores corporum specifici ex experimentis methodo mixtionis institutis computantur." Regiomonti, 1834.

* The objections of REGNAULT (Ann. de Chim. et de Phys. [3] vol. i. p. 131) as to the inadequacy of the proofs adduced by NEUMANN in support of the law do not apply.

† Ann. de Chim. et de Phys. [2] vol. lv. p. 80, as an abstract from 'Memorie della Società Italiana delle Scienze residente in Modena,' t. xx. Fascicolo 2 di fisica'.

‡ They are also found in GMELIN'S 'Handbuch der Chemie,' 4 Auflage, vol. i. in the Tables, pp. 215–218 *et seq.*

§ Ann. de Chim. et de Phys. [2] vol. lvii. p. 113.

|| I only know AVOGADRO'S investigations from the abstracts published in the Ann. de Chim. et de Phys., and am not aware whether the bold corrections of AVOGADRO urged by REGNAULT (Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 10) were used in all his experiments, or only in some.

observation. This difficulty consists in knowing what constitution is to be assigned to the body in question for the solid or liquid condition; this constitution, from the conclusions derived from his theoretical considerations, would often be different from that which the body has in the state of gas or vapour. His considerations led him to assume the atomic weights of many elements different from those which BERZELIUS had given: AVOGADRO described the atoms, to which the weights assumed by him refer, as *thermal atoms*.

6. R. HERMANN published in 1834 a memoir "On the Proportions in which Heat unites with the Chemical Elements and their Compounds, and on the Combining Weights considered as quotients of the capacity for Heat of Bodies into their Specific Gravities"*. He gives there a great number of determinations of the specific heat of solid bodies (of a few elements, but chiefly of compound bodies). He made a few experiments in which he used LAVOISIER and LAPLACE'S calorimeter†; but by far the greater number of determinations are made by the method of cooling ‡. Many of his results approach very closely to those which are at present considered accurate, but they are in so far untrustworthy that a considerable number among them are decidedly incorrect.

As for HERMANN'S theoretical results, it must be borne in mind that, regarding matter as he does, not from the point of view of the atomic but of the dynamical theory, he puts the idea of combination weights in the place of the idea of atomic weights. The propositions which he endeavours to establish are the following. The quotients obtained by dividing the specific gravities of the elements § in the solid state by their specific gravities in the gaseous state, are either equal or stand to each other in simple ratios; they are 1, 2 . . . . . . 15 times as much as a certain base. The same is the case with the products of the specific gravities of the solid elements into their specific heats, that is, with their relative heat; and the number indicating the multiple for a given element is the same for both the above relations. It follows from this that the combining weights m of the elements are proportional to the quotients of their relative heats into their specific gravity in the solid condition; that the products of the specific heats and the combining weights for different elements are equal to a constant, and that from the known combining weight of an element its specific heat in the solid form may be calculated (it is equal to $\frac{0 \cdot 375}{m}$, where m is the combining weight of the substance in question referred to oxygen $= 1$). For several elements (phosphorus,

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* Nouveaux Mémoires de la Société Impériale des Naturalistes de Moscou, vol. iii. p. 137.

† HERMANN tried to alter this apparatus so as to make it serve for measuring the change of volume which takes place when ice melts; but he did not further follow this application of the modified apparatus.

‡ They are found not quite complete in GMELIN'S 'Handbuch der Chemie,' 4 Auflage, in the Tables, pp. 215–218 *et seq.*

§ HERMANN considers that the specific gravities of the elements in the state of gas or vapour are either obtained by observation, or may be theoretically deduced by assuming that they are in the ratio of the combining weights.

tellurium, cadmium, and silver for instance) atomic weights are taken which differ from those of BERZELIUS. In the case of the sulphides, the specific heats may be calculated from those of the constituents, assuming that the specific heats of the elements in these compounds are the same as in the free state. The same holds good for several chlorides and for basic metallic oxides, if the specific heats of chlorine and of oxygen, as given by the above formula, are taken as basis. But in acids a smaller specific heat must be taken for oxygen (one half in several acids and null in phosphoric acid); and there are even compounds (cassiterite, *e. g.*, or arsenious acid), in which the same element is contained partly with the normal and partly with the modified specific heat*. For oxygen salts it is to be assumed that both the acid and the base have the same specific heat as in the free state, and hence the specific heat of one constituent (of the acid, for instance) may be calculated, if that of the salt and that of the other constituent (the base) is known; and it is also found that the specific heat of chromic acid in the neutral and in acid chromate of lead is the same.

This memoir of HERMANN'S did not become much known. Unacquainted with it, other philosophers have subsequently developed independently similar opinions.

7. In 1835 RUDBERG described a method†, which, by ascertaining the heat developed when salts are dissolved in water, in experiments in which the proportion of the salt to the water was constant, but the temperature of the salt varied, should give a means of at once determining the specific heat of the salt, and of the heat which was either absorbed or became free. Yet the numbers which he obtained from his experiments for the specific heat of solid salts are undoubtedly erroneous.

DUMAS‡ (in 1838) discussed the possibility of determining the specific heat of organic bodies by the following process. A platinum vessel containing the substance in question, along with a thermometer, is to be heated to 30° or 40°, and then brought into a vessel provided with a second thermometer, and containing water, the temperature being about 5° or 6° lower than that of the surrounding room. When the temperature has risen to the same extent above that of the room, both thermometers are to be observed. I know no determinations made by this method.

8. In 1840 REGNAULT commenced the publication of a series of important investigations on specific heat which he had made. As they are generally known, I may be more brief in enumerating the contents of the individual publications. In the first which he published, REGNAULT developed § the reasons which led him to prefer the method of mixture to other processes for determining the specific heats of solid bodies;

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* HERMANN designates such compounds as hermaphrodites. He thinks that an acid and a base may have the same composition, and that they may form salts with each other. Cassiterite, for instance, he considers to be stannate of binoxide of tin.

† BERZELIUS'S 'Jahresbericht,' vol. xv. p. 63. POGGENDORFF'S 'Annalen', vol. xxxv. p. 474.

‡ DUMAS'S "Thèse sur la question de l'action du calorique sur les corps organiques" (Paris, 1838) Ann. der Pharm. und Chem. vol. xxviii. p. 151.

§ Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 5.

he described his mode of executing this method, and published the results obtained for a great number of elements. In a second memoir [*] he gave the specific heats of several metallic alloys containing metals in simple atomic ratios, and of a great number of solid chemical compounds; and he published comprehensive experiments on the specific heat of carbon in its different conditions. The investigations announced in the first memoir [†] on the specific heat of organic compounds, as well as those promised in the second memoir [‡] on the specific heat of sulphur at different temperatures, have not to my knowledge been published. But in a third memoir [§] REGNAULT has investigated the difference in the specific heats of certain metals according as they are hardened or soft, and also with reference to sulphur according as it is in the native crystallized form, or has solidified a longer or shorter time after being melted; and he has more especially tried to impart greater certainty to the method of cooling. In his subsequent investigations, however, he has only used the method of mixture as being the more certain. These investigations [||] have given the specific heats of a large number of solid elements, and also of individual compounds.

By his investigations REGNAULT has removed some objections which seemed to affect DULONG and PETIT's law, and has given a great number of new cases in which it applies. He considers [¶] this law to be universally valid, and discusses the reasons why for individual elements the specific heats found do not quite agree with the law, but only approximately. In his view the atomic weight of an element is to be so taken that it agrees with DULONG and PETIT's law. He took the atomic weight of silver and of the alkaline metals half as great, and that of carbon twice as great as BERZELIUS had done. Yet with regard to selecting, by means of the specific heat, from among the numbers which the chemical investigations of an element has given as admissible, that which is the correct one, REGNAULT does not always express himself decidedly. In the case of carbon [**] and of silicium [††] he mentions the possibility of their disagreement with DULONG and PETIT's law. He proved the validity of NEUMANN's law for a number of cases very considerably greater than that on which it had originally been based; and he expressed it in a much more general form [‡‡]. "In all compounds of analogous atomic composition, and similar chemical constitution, the specific heats are approximately inversely proportional to the atomic weights. REGNAULT designates the numbers agreeing with this law as thermal atomic weights. He has either determined them directly from the numbers found for the specific heats of the elements in the free

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[*] Ann de Chim. et de Phys. [3] vol. i. p. 129.

[†] Ibid. [2] vol. lxxiii. p. 71.

[‡] Ibid. [3] vol. i. p. 205.

[§] Ibid. [3] vol. ix. p. 322.

[||] Ibid. [3] vol. xxvi. pp. 261 & 268; vol. xxxviii. p. 129; vol. xlvi. p. 257; vol. lxiii. p. 5. Comptes Rendus, vol. lv. p. 887.

[¶] Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 66; further, [3] vol. xxvi. p. 261, and vol. xlvi. p. 257.

[**] Ibid. [3] vol. i. p. 205. But both before and after (Ibid. [2] vol. lxxiii. p. 71, and [3] vol. xxvi. p. 263) REGNAULT inclined to the view that carbon, with the equivalent=12, and the specific heat found for wood-charcoal, must be considered as obeying DULONG and PETIT's law.

[††] Ibid. vol. lxiii. p. 30.

[‡‡] Ibid. vol. i. p. 199.

state, applying DULONG and PETIT's law, or indirectly by ascertaining the specific heat of solid compounds, assuming NEUMANN's law; or finally (and only in a few cases), he has determined them by means of their probable analogies. These are the atomic weights given in the second column of the Table in § 2.

With regard to the relations of the specific heats of solid compounds to those of their constituents, REGNAULT has shown [*] that with metallic alloys, at a considerable distance from their melting-points, the specific heats may be calculated from those of their constituents in tolerable accordance with the experimental results, assuming that the specific heats of the metals are the same in the alloys as in the free state. The investigation, whether for true chemical compounds there is a simple relation between their specific heats and those of their constituent elements, REGNAULT has reserved [†] till the conclusion of his experiments on the specific heats of gaseous bodies [‡]. To my knowledge he has published nothing for solid bodies. But in 1862, with reference to the relations which had been recognized between the specific heats and atomic weights of solid, simple or compound bodies, he spoke as follows [§]. "It is true that these laws, in the case of solid bodies, only apply approximately to simple bodies and those compounds of least complex constitution; for all others it is impossible to pronounce anything in this respect." From some remarks of REGNAULT in reference to carbon [||] and silicium [¶] he considers it possible, or probable with certain elements, that they have a different specific heat in their compounds to that which they have in the free state.

9. In 1840 DE LA RIVE and MARCET published [**] investigations on the specific heat of solid bodies. They made their determinations by the method of cooling. They found that, assuming BERZELIUS's atomic weights, selenium, molybdenum, and wolfram fall under DULONG and PETIT's law, which they consider as universally valid; but that carbon forms an exception, and they consider it as probable that its true atomic weight has not yet been ascertained. For several sulphides they found a greater specific heat than was calculated for them, assuming that their constituents have in them the same specific heat as in the free condition. They think that for solid as well as for liquid and gaseous compounds the law governing the specific heat is still unknown. A subsequent memoir by these physicists [††] treated of the specific heat of carbon in its various conditions.

10. In 1840 [‡‡] H. SCHRÖDER made an investigation as to what volumes are to be assigned to the constituents of solid and liquid compounds when contained in those compounds. In his memoirs on the subject, he expressed the view that the specific heat of compounds depends on the specific heats of the constituents in that particular

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[*] Ann. de Chim. et de Phys. [3] vol. i. p. 183.

[†] Ibid. p. 132.

[‡] REGNAULT has made known the results of these experiments in 1853 by a preliminary account in the Comptes Rendus, vol. xxxvi. p. 676, and more completely in 1862 in his 'Relation des expériences pour déterminer les lois et les données physiques nécessaires au calcul des machines à feu,' vol. ii. p. 3.

[§] Relation, &c. vol. ii. p. 289.

[||] Ann. de Chim. et de Phys. [3] vol. i. p. 205.

[¶] Ibid. [3] vol. lxiii. p. 31.

[**] Ibid. [2] vol. lxxv. p. 113.

[††] Ibid. [3] vol. ii. p. 121.

[‡‡] POGGENDORFF's 'Annalen,' vol. l. p. 553.

state of condensation in which they are contained in the compounds in question. In 1841 [*], reasoning from the results of REGNAULT'S experiments, he endeavoured to show that the atomic heat (that is the product of the atomic weight into the specific heat) of a compound is equal to the sum of the atomic heats for the states of condensation in which the elements are contained in the compound, and to ascertain what atomic heats are to be assigned to certain elements in certain compounds. On the assumption that the atomic heat of metals in compounds is as great as in the free state, he endeavoured to determine the atomic heat of oxygen, sulphur, &c. in certain compounds of these elements with the metals; he came to the conclusion that an element (sulphur for instance) may in some compounds have an atomic heat different from that which it has in the free state; and the same element (sulphur or oxygen for instance) may have different atomic heats in different compounds; but the changes in the atomic heat of an element always ensue in simple ratios. I cannot here adduce the individual results, which he obtained when he inferred the atomic heat of an element in a compound by subtracting from the atomic heat of the compound the atomic heat of the other elements in it, which he had calculated either from direct determinations of their specific heat, or from previous considerations. The essential part of SCHRÖDER'S conception is that in this manner the atomic heat of a body, as a constituent of a compound, may be indirectly determined; and the result is that the atomic heat, at any rate of some elements in compounds, is different from what it is in the free state, and may be different in different compounds, and that the changes are in simple ratios. SCHRÖDER considered also that there was probably a connexion between these changes and those of the volumes of the elements, without, however, stating how from the one change the other might be deduced.

11. L. GMELIN (in 1843) considered it as inadmissible, from the chemical point of view, to assign throughout such atomic weights to the elements as to make them agree with DULONG and PETIT'S law. Certain exceptions must be admitted. Comparing the specific heats of oxygen, hydrogen, and nitrogen for the gaseous state with the specific heats of other elements in the solid state, he came to the conclusion that if the numbers given in § 2 as the equivalents ordinarily assumed be taken as atomic weights, the atomic heat of hydrogen, of nitrogen, and by far the greater number of the elements is equal to about 3·2; several of them twice as great, that of oxygen one-half, that of carbon (as diamond) one-fourth as great. With reference to the dependence of the atomic heats of the compounds on those of the elements, GMELIN expressed the opinion [‡] that in general the elements on entering into compounds retain the atomic heats they have in the free state, but for individual elements, especially for oxygen and carbon, it must be assumed that their atomic heat changes in simple ratios with the compounds into which they enter.

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[*] POGGENDORFF'S 'Annalen,' vol. lii. p. 269. [†] L. GMELIN'S 'Handbuch der Chemie,' 4th ed. vol. i. p. 217.

[‡] Ibid. p. 222: compare an earlier remark of GMELIN which applies to this subject (1840) in the new edition of GEHLER'S 'Physikalisches Wörterbuch,' vol. ix. p. 1941.

12. Wœstyn was also of opinion[*] that the specific heats of the elements remain unchanged when they enter into chemical compounds. In 1848 he stated as a general proposition; "The quantity of heat necessary to raise the temperature of the atomic weight of a body through 1° is equal to the sum of the quantities of heat necessary to raise the temperature of the atoms, and fractions of atoms, through 1°". If A is the atomic weight and C the specific heat of a compound, a_1, a_2, a_3 . . . . the atomic weights[†], and c_1, c_2, c_3 . . . . the specific heats of the elements contained in it, and n_1, n_2, n_3 . . . . the numbers which express how many atoms of each element are contained in an atom of the compound, then

$$AC = n_1a_1c_1 + n_2a_2c_2 + n_3a_3c_3 \ldots\ldots$$

As a proof of this law, he compared the calculated values of AC of several compounds (metallic iodides and sulphides) and alloys with the observed values, taking Regnault's determinations of the specific heats of the elements and of the compounds. It follows, further, from that proposition, that if the formula and the values for several compounds are compared with each other, there must be the same differences of the values AC for the same differences of formulæ. Wœstyn showed by a number of examples that this is so approximately. By means of this law, the product of the specific heat and the atomic weight for one constituent of a compound may be found, if this is known for the compound and the other constituents. Wœstyn deduced in this way the product for oxygen (by subtracting from the product for different metallic oxides that found for the metals, and from chlorate of potass that for chloride of potassium) to be 2·4 to 2·1 (O.=8), and for chlorine 3·0 to 3·5 (Cl.=17·75). Wœstyn finally expressed a doubt whether Neumann's law is universally applicable. He laid stress on the circumstance that when two elements give different products, the difference is also met with in the products for their analogous compounds; and, for instance, the greater products which mercury and bismuth have in comparison with other elements, are also met with in the compounds of these metals.

13. Garnier (in 1852) developed the view[‡], that not only in the case of elements are the atomic weights A[§] inversely proportional to the specific heats C, but that the same is the case with water[||] and solid compounds in whose atom n elementary atoms are contained, if the so-called mean atomic weight $\frac{A}{n}$ be compared with the specific heat C; for elements $A \times C = 3$, and for compound bodies $\frac{A}{n} \times C = 3$ (if O=8). He endeavoured to prove this from Regnault's determinations of specific heats. From the latter equation he calculated the specific heat for several compounds. In the case of the basic oxides, sulphides, chlorides, bromides, and iodides, his calculated results agree tolerably

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[*] Ann. de Chim. et de Phys. [3] vol. xxiii. p. 295.

[†] Wœstyn based his considerations on Regnault's thermal atomic weights.

[‡] Comptes Rendus, vol. xxxv. p. 278.

[§] If Regnault's thermal atomic weights are taken.

[||] I shall in § 93 return specially to the question how often the specific heat of liquid water was compared with that of solid bodies.

with the observed ones; this is less the case with metallic acids and oxygen salts, for which calculation mostly gives results far too large. Garnier[*] drew, further, from the above proposition the conclusion, that the atomic weight of hydrogen, chlorine, &c. must in fact be taken only half as great as the equivalent weight; for only by assuming this smaller atomic weight is the mean atomic weight such that its product with the specific heat is near 3.

In 1852 Bancalari[†] repeated that the specific heat of an atom of a compound body (that is, its atomic heat) is equal to the sum of the specific heats of the individual constituent simple atoms, and showed, from a series of examples (oxides, chlorides, sulphates, and nitrates), that, according to that proposition, the atomic heats of many compounds may be calculated in tolerable approximation with those derived from Regnault's experimental investigations, if, for the elements which he investigated, the atomic heats derived from his determinations be taken as a basis, that is, for oxygen ($O=8$) the atomic heat 1·89; for chlorine ($Cl=17·75$) 3·21; for nitrogen ($N=7$) 3·11.

Cannizaro (in 1858[‡]) has used the proposition, that, in the sense above taken, universally $\frac{AC}{n}=$ a constant, for the purpose of ascertaining the value of n for the atomic weight of different compounds, and therewith ascertaining the atomic weight of elements which are contained in these compounds.

14. Besides those of Regnault, but few experimental determinations of the specific heats of solid bodies have been published. Bede[§] and Byström[||] have published investigations on the specific heat of several metals at different temperatures[¶]: both sets of experiments were made by the method of mixtures. From the year 1845, Person[**], in his investigations on the specific heat of ice, then on the latent heats of fusion, and their relations to the specific heats in the solid and liquid condition, has determined the specific heat for several solid substances, especially also for some hydrated salts. He worked more especially by the method of mixture. He observed[††], in the case of these

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[*] Comptes Rendus, vol. xxxvii. p. 130.

[†] An abstract from Memorie della Accademia delle Scienze di Torino, [2] vol. xiii. p. 287, in the Archives des Sciences Physiques et Naturelles, vol. xxii. p. 81. I only know the contents of this memoir from this abstract.

[‡] Il Nuovo Cimento, vol. vii. p. 321. Piazza also gives a statement of this speculation in his pamphlet, 'Formole atomistiche et typi chimici,' 1863. I only know this from a notice in the Bulletin de la Société Chimique de Paris, 1863.

[§] An abstract from the Bulletin de l'Académie des Sciences de Belgique, vol. xxii. p. 473, and the Mémoires Couronnés par l'Académie de Belgique, vol. xxvii., appeared in the Bericht über die Fortschritte der Physik im Jahre 1855, dargestellt von der physicalischen Gesellschaft zu Berlin, p. 379.

[||] Abstract from the Översigt of Stockholm Vetenskaps-Akademiens Förhandlingar, 1860, in the same Jahresbericht, 1800, p. 369.

[¶] To the experiments of Dulong and Petit on this subject, mentioned in § 3, Pouillet's determinations of the specific heat of platinum at different temperatures must be added (Comptes Rendus, vol. ii. p. 782).

[**] Comptes Rendus, vol. xx. p. 1457; xxiii. pp. 162 & 366. Ann. de Chim. et de Phys. [3] vol. xxi. p. 295; xxiv. p. 129; xxvii. p. 250; xxx. p. 78.

[††] Person expressed this in 1845 (Comptes Rendus, vol. xx. p. 1457), with regard to his determinations of

salts, that their specific heats may be calculated in close approximation with those found experimentally on the assumption that the constituents, anhydrous salt and water considered as ice, have the same specific heats in them as in the free state. By the same method, ALLUARD* (in 1859) determined the specific heat of napthalene. SCHAFARIK†, lastly, has executed by the method of mixtures a series of experiments on the determination of the specific heats of vanadic, molybdic, and arsenious acids.

Quite recently (1863), PAPE‡ has published investigations on the specific heat of anhydrous and hydrated sulphates. He worked by the method of mixture, which he modified in the case of salts rich in water, by placing them in turpentine, and observing the increase of temperature produced in the salt and in the liquid by immersing heated copper. As a more general result, PAPE finds that for hydrated sulphates of analogous formulæ, the products of the specific heats and the equivalents are approximately equal; and further, that with sulphates containing different quantities of water, the product of the specific heat and the equivalent increases with the quantity of water, in such a manner, that to an increase of each one equivalent there is a corresponding increase in the product.

15. In the preceding paragraphs I have collated, as far as I know them, the investigations on the specific heat of solid bodies, on the relations of this property to the atomic weight, and on the connexion with the chemical composition of a substance. The views which have been expressed relative to the validity of DULONG and PETIT'S § and of NEUMANN'S laws, and also as to the question whether the elements enter into chemical compounds with the same specific heats which they have in the free state or with modified ones, have been various and often discordant. In this respect it may be difficult to express an opinion which has not been already either stated or hinted at, or which at any rate cannot be naturally deduced from a view previously expressed.

The results to which my investigations on the specific heats of solid bodies have led me are the following:—Each solid substance, at a sufficient distance from its melting-point, has a specific heat, which may vary somewhat with physical conditions (temperature, greater or less density, amorphous or crystalline conditions, &c); yet the variations are never so great as must be the case if a variation in the specific heat of a body is to

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the specific heat of crystallized borax and of ordinary phosphate of soda. He has subsequently published the results of his experiments for the latter salt (Ann. de Chim. et de Phys. [3] vol. xxvii. p. 253), but I cannot find the number which he found for crystallized borax.

* Ann. de Chim. et de Phys. [3] vol. lvii. p. 438.

† Berichte der Wiener Akademie der Wissenschaften, vol. xlvii. p. 248.

‡ POGGENDORFF'S 'Annalen,' vol. cxx. pp. 337 & 579.

§ The universal validity of this law was also defended by BREDOW, "On the relation of the Specific Heat to the Chemical Combining Weight." Berlin, 1838. I only know this paper from the mention of it in the new edition of GEHLER'S 'Physicalisches Wörterbuch,' vol. x. p. 818. It is also admitted by MANN, in his attempt to deduce this law from the undulatory theory of heat. (1857: SCHLÖMILCH and WITZSCHEL'S 'Zeitschrift für Mathematik und Physik,' II. Jahrgang, p. 280); and by STEFAN, in his investigation on the bearing of this law on the mechanical theory of heat (1859: Berichte der Wiener Akademie, vol. xxxvi. p. 85).

be held as a reason for explaining why the determinations of the specific heats of solid elements do not even approximately obey DULONG and PETIT'S law, nor those of solid compounds of analogous chemical constitution NEUMANN'S law. Neither law is universally valid, although I have found that NEUMANN'S law applies in the case of many compounds of analogous atomic composition, to which, on account of their totally different chemical deportment, different formulas are assigned; and even in cases in which these laws have hitherto been considered as essentially true, the divergences from them are material. Each element has the same specific heat in its solid free state and in its solid compounds. From the specific heats to be assigned to the elements, either directly from experimental determination, or indirectly by calculation on the basis of the law just stated, the specific heats of their compounds may be calculated. I show the applicability of this by a great number of examples.

In reference to this calculation of the specific heats of solid bodies I may here make a remark. The agreement between the results of calculation and experiment is often only approximate; it is then natural to urge that the two ought really to agree more closely. To that the question may be allowed: What means are there of even approximately predicting and calculating beforehand the specific heat of any inorganic or organic solid compound when nothing but its empirical formula is given? to which among the numbers 0·1, 0·2, 0·3 . . . . . . may it come nearest? The cases in which differences exist between calculation and observation, enumerated in § 103 to 110, may be set against *this* uncertainty.

My proof of the propositions given above is based on determinations made by earlier inquirers, and on a not inconsiderable number of my own. I first describe the method by which I worked, and then give the results which I have obtained by its means.

PART II.—DESCRIPTION OF A METHOD OF DETERMINING THE SPECIFIC HEAT OF SOLID BODIES.

16. I have worked by the method of mixture. It is not necessary for me to discuss the advantages which this method has over that of the ice-calorimeter, at any rate in requiring smaller quantities; nor, as compared with the method of cooling, need I discuss the uncertainties and differences in the results for the same substance, which are incidental to the use of this method, and which REGNAULT has detailed*.

The method of mixtures has been raised by NEUMANN and by REGNAULT to a high degree of perfection. Although by NEUMANN'S method it is possible to determine more accurately the temperature to which the body investigated is heated, REGNAULT'S method allows larger quantities to be used. REGNAULT'S process gives the specific heats of such substances as can be investigated by it as accurately as can at all be expected in the determination of this property. In the case of copper and steel, it is not merely possible to determine their specific heats by its means, but also to say whether and how

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* Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 14; [3] vol. ix. p. 327.

far there is a difference in the first metal according as it has been heated or hammered, and in the second, according as it is soft or hard. It may be compared with a goniometer, which not only measures the angles of a crystal, but also the differences in the angle produced by heat; or it may be compared to a method for determining the specific gravity of a body, by which not only this property, but also its changes with the temperature may be determined. But along with such methods, simpler ones, though perhaps less accurate, have also their value. Which method is the most convenient or which ought to be used in a given case, depends on the question to be decided by the experiment, or on the extent to which the property in question is constant in the substance examined.

In regard to the relations of the specific heat of solid bodies to their atomic weight and to their composition, REGNAULT'S determinations have shown that both DULONG and PETIT'S and NEUMANN'S law are only approximate, and that even the accuracy in determining the specific heat which REGNAULT attempted, and obtained, could not show that these laws were quite accurate.

Although the description of REGNAULT'S mode of experimenting is so widely known, yet it cannot be said to have become the common property of physicists, or to have found an entrance into the laboratories of chemists, to whom the determination of the specific heat is interesting from its relation to the atomic weight. Very few experiments have been made by this method other than the determinations of REGNAULT. The method depends on the use of an apparatus which is tolerably complicated and takes up much room. Each experiment requires a long time, and for its performance several persons are required. REGNAULT has usually worked with very considerable quantities of the solid substance, and in by far the majority of cases at temperatures (usually up to 100°) which many chemical preparations, whose specific heats it is important to know, do not bear. In the sequel I will describe a process, for the performance of which the apparatus can be readily constructed, and for which one operator is sufficient; by which, moreover, the determination of specific heat can be made with small quantities of the solid substance and at a moderate temperature. But the method as I have used it has by no means the accuracy of that of REGNAULT. In § 18 I shall discuss the advantages for which some of the accuracy which characterizes REGNAULT'S method is sacrificed; but I may here remark that the results obtained by the method which I have used are capable of increased accuracy, provided the experiments are executed on a larger scale and within greater ranges of temperature.

17. The principle which forms the basis of my method is as follows:—To determine the total increase of temperature produced when a glass containing the substance to be investigated, covered by a liquid which does not dissolve it, the whole previously warmed, is immersed in cold water; to subtract from the total increase of temperature that due to the glass and the liquid in it, and to deduce from the difference, which is due to the solid substance, its specific heat.

If, in regard to gain or loss of heat, the glass, in so far as it comes in contact with water, is equivalent to x parts of water, if f is the weight of the liquid in it, y its specific heat, m the weight of the solid substance, M the weight of the water in a calorimeter, including the value in water of the immersed part of a thermometer and of the calorimeter, T the temperature to which the glass and its contents have been heated before immersion in water, and T′ the temperature to which the glass sinks when immersed in the water, while the temperature of the latter rises from t to t', then the specific heat (sp. H.) of the solid substance is

$$\text{sp. H} = \frac{M(t'-t) - (x+fy) \,.\, (T-T')}{m(T-T')}.$$

In the sequel I shall discuss more specially the manner in which the individual magnitudes in this equation were determined: I will first give a description of the apparatus and method which I used*.

The glass vessel in which the substance is confined (Plate XX. a in fig. 1) is a tube of glass, the bottom of an ordinary test-tube. In it fits, but not air-tight, a cork c, which is pressed between two small brass plates that are screwed to a wire b. The solid substance to be investigated, in the form of thin cylinders, or in small pieces the size of a pea, along with a liquid of known specific heat, which does not dissolve it, are placed in the tube in such a manner that the liquid covers the solid substance, and that there is a space between the liquid and the cork when it is inserted. The glass, when the cork is fitted, may be suspended to the balance by the wire b. Three weighings (1) of the empty glass, (2) after introducing the solid substance, and (3) after introducing the liquid, give the weight of the solid substance (m) and of the liquid (f).

The heating apparatus (fig. 1) serves to raise the temperature of the glass with its contents. The glass is dipped in a mercury-bath A near its upper edge, and retained by a holder E. The mercury-bath, which consists of a cylindrical glass vessel, is suspended by means of a triangle round the neck of the vessel in an oil-bath B, which stands on a tripod C, and can be heated by a spirit-lamp D. A thermometer d†, fixed to the holder F, is also immersed in the mercury-bath.

The flame of the spirit-lamp may be regulated so that the thermometer d indicates the same temperature for a long time ‡. If it may be assumed that the contents of the glass a have also risen to this temperature, then the wire b being firmly held in the right-hand by its hook, and the clamp of the holder E in the left, the glass a is rapidly removed from the heating vessel to the calorimeter H (fig. 2). This is almost the only part of the entire experiment which really requires much practice; the transference of

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* All figures on the Plate are one-third of the natural size.

† Fig 7 shows in section how the glass with its contents and the thermometer dip in the mercury-bath and this in the oil-bath.

‡ In order to obtain temperatures constant at about 50°, a spirit-lamp with a thin wick is used, and this is pressed in the sheath so that the alcohol-vapour above it burns with a very small flame. The position of the wick and the intensity of the flame may be conveniently regulated if the upper part of the wick is surrounded by a spiral of thin copper wire whose ends project from the sheath.

the glass *a* from the one vessel to the other must be effected in an instant, and none of the liquid in the glass must touch the cork.

The calorimeter H stands upon a support G (fig. 2)*, on which there is an oval metal plate *o*. In this there are three depressions, in which fit the three feet of the calorimeter (they are made of very thin hard brass wire). The calorimeter is oval-shaped, and is made of the very thinnest brass plate. In it a brass stirrer fits, made of two parallel plates of brass of the same thinness, which are joined below by thin wires, and provided with a thin wire ending in a little button *i*, which serves as handle. The plates of the stirrer are perforated in such a manner that the glass *a* and a thermometer can be passed through them. Fig. 4 shows more distinctly the construction of the stirrer, also the section of the calorimeter.

For the experiments, the calorimeter is always filled, as nearly as possible, with the same quantity of water†. The stirrer is immersed, and a thermometer *f* dipping in the water gives its temperature, which is kept uniform by an upward and downward uniform motion of the stirrer. When the tube *a* is brought into the water of the calorimeter, it is fastened‡ in the clamp of the holder K, which is arranged like the pincettes used for blowpipe experiments, so that it stands on the bottom of the calorimeter, and then the stirrer is set to work. This motion of the stirrer, and therewith of the water, must be moderate and uniform in all experiments; this is of some importance for the uniformity and comparability of the experiments. The temperature indicated by the thermometer *f* rises and soon attains its maximum, which continues for some time, and can be observed with certainty. With this the experiment is concluded. The tube *a* can be taken from the calorimeter, dried, and used for a new experiment.

The increase of temperature produced in the calorimeter by the tube *a* and its contents, would be incorrectly given if the warmth of the body of the operator, who moves the stirrer and observes the thermometer, acted on the calorimeter. This is prevented by a glass screen *g g g g*, fig. 2, which is fitted in the brackets *h h*, and above which the handle of the stirrer projects.

18. This process for determining the specific heat of solid bodies, the details of which are more minutely discussed in the sequel, has advantages over those hitherto prin-

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* In making the experiment, the actual distance between the calorimeter and the heating apparatus must be greater than is indicated in the figure, but not so great that the glass *a* cannot, by a rapid motion of the arm, be transferred from the mercury-bath to the calorimeter.

† This is most conveniently effected by laying across it a bridge with a stem directed downwards (fig. 3), and adding water until it touches the point of the stem; and the calorimeter, which now contains almost the requisite quantity of water, is placed on the balance, and the filling completed by means of the dropping-flask (fig. 8). The construction of the latter is readily intelligible: it is held by the cork between two fingers, and by approaching the hand to the bottom of the flask water commences to drop. When the flask is not in use the tube, which fits air-tight in the cork, is raised, so that it does not dip in the water, and thus the water is prevented from escaping.

‡ Fig. 5 shows in a section the glass *a*, with its contents, and the thermometer *f* immersed in the water of the calorimeter.

cipally used, which I will here mention. The use of the mercury-bath makes it possible readily to produce, and maintain for any adequate length of time, any temperature desirable in such experiments. The mercury-bath [*] shares with the air-bath the advantage that, to the substance heated in it (in this case the tube and contents), nothing adheres when it is removed which might influence the thermal effect in the calorimeter. It has over the air-bath the advantage, that any body placed in it takes the temperature of the surrounding medium much more quickly through its entire mass. The communication of heat to the solid substance is materially promoted by the circulation of the liquid between its particles; the time necessary for the entire contents of the glass to become equally heated is a very short one[†]. Moreover this very circulation of the liquid between the particles of the solid ensures a quicker and more uniform transmission of the heat of the contents of the glass to the water of the calorimeter; the maximum temperature of this water is soon attained[‡], although the transmission of the excess of temperature must take place through the sides of the glass.

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[*] In 1848 I already used such a one for heating liquids enclosed in glass tubes, in determining their specific heats (POGGENDORFF's 'Annalen,' vol. lxxv. p. 98).

[†] In experiments on the scale on which I made them, when the mercury-bath had once been raised to the requisite temperature, it only required ten minutes' immersion of the glass in the bath to impart to it the temperature of the bath. A more prolonged heating was found to be useless in all cases in which I tried it. In the experiments to be subsequently described, the heating was continued about ten minutes; in most cases less would have been sufficient. In REGNAULT's experiments (Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 22), in which the substance (in much larger quantities it is true) was heated in a space nearly surrounded by steam, a thermometer placed in the substance indicated after about two hours an almost constant position (always one or two degrees lower than the temperature of the steam); and then it was found convenient to continue this heating for at least an hour, in order to see that the temperature did not change, and to be certain that the substance had the temperature indicated by the thermometer throughout its entire mass. In NEUMANN's experiments, the space in which the substance to be heated is contained is smaller and more completely surrounded by vapour. The time necessary for heating the substance uniformly must be smaller, and the temperature must be nearer that of the surrounding vapour. According to PAPE (POGGENDORFF's 'Annalen,' vol. cxx. p. 352), a thermometer placed in the above space, if surrounded by steam for forty-five to sixty minutes, gives exactly the temperature of this steam.

[‡] In several experiments I determined the time which elapsed between immersing the glass with contents in the water of the calorimeter and its attaining a maximum. Under the circumstances, which I subsequently give more specially, and which, as far as possible, were maintained in all experiments, this time was always less than two minutes, if the liquid could circulate between compact pieces of the solid substance. What I have said above justifies, I think, my not having made, in experiments with such substances, a correction for the loss of heat which the calorimeter experiences between the moment of immersing the glass and the establishment of a maximum temperature. In substances which form a fine powder or a porous mass, or in general in cases in which the circulation stagnates, the maximum temperature is more slowly attained, the above loss of heat is more considerable, and the numbers for the specific heats are then somewhat too small. I shall recur to this again in enumerating the experiments in § 41 with chromium, and in § 52 with chloride of chromium. In a few cases I have endeavoured to diminish this error, and to promote the circulation of the liquid by pressing the porous substance into small disks. I must leave it as an open question whether more accurate results would not be obtained for such substances if they were formed by means of a suitable cement into compact masses, and then the thermal action of the cement thus added taken into account.

The apparatus which I have just described is very simple. It is readily constructed; the chief point is to have two thermometers which have been compared with each other, one of them (*f*) graduated in tenths of a degree, while on the other (*d*) the tenth of a degree can be observed with certainty. The apparatus does not require much space; yet, while the experiment is being made, rapid changes in the temperature of the surrounding air must be avoided. One observer only is required (all the experiments described in the sequel have been made without assistance). The experiments which I shall communicate prove that, by means of this apparatus, the specific heat of solid substances, even when only small quantities are taken (in most cases I worked with only a few grammes), may be determined with an accuracy not much less than that attained with larger quantities in more complicated processes.

19. Yet, it is true, the accuracy of the results obtained by this process appears to be inferior to that attainable by the use of NEUMANN'S or of REGNAULT'S methods. I have investigated many substances, determinations of which have also been made by these physicists. I do not find that the numbers I have obtained deviate in one special direction from those which these physicists have found, which moreover sometimes differ considerably among themselves*; but that the certainty of the results I have obtained is less, is shown by the fact that the results of different experiments with the same substance agree less closely with one another than do those of REGNAULT and of NEUMANN.

That my determinations are less accurate is probably least due to the circumstance that I did not use certain corrections, for instance, that I did not allow for the loss of heat in the calorimeter between the time when the heated body was immersed and the maximum temperature was attained†. I have endeavoured to diminish the uncertainty of the results from this source by having the temperature of the water in the calorimeter, before immersing the heated body, somewhat lower than that of the surrounding air. I have endeavoured to ensure comparability in my results for different substances by always operating as much as possible under the same circumstances; that is, I endeavoured always to produce in the water of the calorimeter the same excess of temperature over that of the surrounding air. Without depreciating the interest and value of such corrections, I think that their application may be omitted if their practical importance is inconsiderable, and the increased difficulties which they necessitate proportionally large. It must be considered, in reference to such corrections, how far the accuracy, which the results obtained by their means claim, is not more apparent than real‡. And further, that these corrections, where the conditions for their application really exist, are not considerable; while, where they exert a considerable influence on the result, they may be uncertain, because the suppositions made in their development

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* PAPE, in POGGENDORFF'S 'Annalen,' vol. cxx. p. 579, discusses the probable causes of these differences.

† Another correction, which appears to me to be more important for the experiments in question, is, that the contents of the glass at the time at which the temperature of the water is at its maximum may be at a somewhat higher temperature. This I have approximately taken into account. Compare §§ 23 & 24.

‡ It is unnecessary to adduce examples where such corrections, proceeding from as comprehensive a basis as

are less applicable. But more especially can such corrections be disregarded when, as in the case with my determinations, other circumstances diminish more materially the accuracy of the results to be obtained.

Such circumstances in my experiments are, that I worked on a small scale in every respect. I could only heat the solid investigated together with a liquid to 50°, and in many cases not even to this. In NEUMANN'S and in REGNAULT'S experiments, on the contrary, the solid was usually heated to near 100°, and the difference in temperature, T—T′ (compare § 17), obtained in the latter experiments was usually thrice as great as in mine. In REGNAULT'S experiments (in NEUMANN'S the details are not given) the quantity of substance taken was, on the average, twenty times as much, and the weight of water in the calorimeter about eighteen times as much as in mine*: hence in the latter experiments the unavoidable accidental errors of observation must be greater than in the former.

But there is a still more important circumstance which makes the accuracy to be hoped for from my experiments less than that to be expected from REGNAULT'S and NEUMANN'S experiments. In the latter methods the increase in the temperature of the water of the calorimeter is entirely, or is almost entirely produced by the solid under examination. In my experiments, on the contrary, this increase is produced by the glass, the solid, and the liquid in the glass. The thermal action due to the solid is only a part of the entire thermal action observed, and if from the latter that due to the liquid and to the glass is subtracted, all uncertainties in the assumptions as to the thermal action of the

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possible, lose their significance from necessary simplifications, and their practical importance becomes finally very slight. The amount of correction is then to be pronounced as having no influence on the final result. It is more important to take into account the following. The trustworthiness of the specific heat to be assigned to any particular compound depends upon the certainty of the determination of the physical property, and upon the certainty of the knowledge of the composition of the body in question; that is, in how far this compound corresponds to a given formula. The greatest trouble which can be taken in that determination, the consideration of all sources of error which are possible in the physical experiment, the most complete exposition of the corrections which by developing conclusions from more or less certain assumptions may be formulated in one expression, and the most conscientious application of these corrections,—all this may be paralyzed by the circumstance that the composition of the body in question is not, as it were, the ideal, not corresponding accurately to the formula. The partial substitution, if even to a very small extent, of one constituent by an isomorphous one, the attraction of water by a hygroscopic substance before and during the experiment, the presence of some mother-liquor in a crystallized salt, the loss of some water in drying a hydrated substance, so that this has not exactly the composition corresponding to the formula,—all these sources of error, which can scarcely be taken into account, may easily exercise an influence on the final result, whose magnitude far exceeds that of certain corrections applied to the physical part of the determination. It lies in the nature of the case that in such investigations, in some cases bodies of well-known, in other cases bodies of less well-known composition are taken. I tried to be certain what substances could be considered as of definite composition and what of doubtful composition, especially where the relations between the specific heat and the atomic weight or chemical composition were under discussion.

[*] About sixty solids have been investigated both by REGNAULT and myself; for about thirty the weights which he used in his determinations are twenty times as much as in mine or more.

liquid and that of the glass are concentrated on the remainder, on the thermal action of the solid substance from which its specific heat is to be deduced. The results obtained by my method are less accurate when the residue is only a small fraction of the total result from which it is deduced. In individual cases, where this was unavoidable, I shall have to remark upon it.

It may be said in favour of my method that, for a number of solid substances, no other method yet attempted is applicable either at all or with more prospect of a successful result. But this is less important than the proof furnished by my examination of very many substances, whose specific heat has been already determined by NEUMANN and by REGNAULT, that the specific heat of bodies may be determined by my method with an accuracy quite sufficient for many comparisons. But there are cases in which it is even advantageous not to heat the solid alone, but in conjunction with a liquid, and to bring them together into the water of the calorimeter. The chemical nature of the solid may necessitate this; as, for example, when it readily alters on being heated in the air (compare § 34 in reference to amorphous boron); its physical structure may also render it desirable, as for instance if the substance has a large surface as compared with its mass, or is so porous that the thermal action due to humectation, and first observed by POUILLET [*], takes place. REGNAULT has shown that this may be considerable [†]; he states that for this reason the specific heat of some substances is found about $\frac{1}{30}$ too great. He appears to have estimated this thermal action by ascertaining the increase of temperature produced in the water of the calorimeter when the porous substance, whose temperature is that of the water and of the surrounding air, is dipped in it. But this action is probably far more considerable if, while heated, it is immersed in the water, because it then contains less air confined on its surface and in its pores [‡], and surface action can then act more intensely upon the liquid. The influence of this source of error cannot be measured exactly. It is unequal in different substances. In platinum it is small (REGNAULT found by his method that the specific heat of spongy platinum did not materially differ from that of massive pieces), while it may be con-

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[*] Ann. de Chim. et de Phys. [2] vol. xx. p. 141.

[†] Ann. de Chim. et de Phys. [3] vol. i. p. 133. REGNAULT preferred to immerse the heated porous substances, when they could be obtained in coherent pieces, directly in the water of the calorimeter. If they were enclosed in thin tubes and immersed, the equalization of temperature proceeded too slowly. REGNAULT abstained from enclosing at the same time a sufficient quantity of water in the tube to promote the circulation, because in that case the thermal action of the solid was only a fraction of that of the water added, on which the entire source of error falls. REGNAULT found also (ibid. p. 142) that in immersing anhydrous baryta, strontia, and lime in most carefully dehydrated oil of turpentine, there is such a thermal action that no useful result is to be obtained by his method for these oxides.

[‡] To the examples already known, which show what influence temperature exerts on the quantity of air absorbed in a porous body, REGNAULT has added a very instructive one (Ann. de Chim. et de Phys. [3] vol. lxiii. p. 32). If amorphous boron, formed into disks by pressure in a steel mortar, was strongly cooled and then immersed in the water of the calorimeter (at the mean temperature), so considerable a disengagement of absorbed air was produced, that REGNAULT was compelled to give up the determination of the specific heat by this method.

siderable for porous charcoal (in fact POUILLET'S experiments make this probable). This source of error is excluded in my method.

20. In order to appreciate the trustworthiness of the results arrived at by my mode of experiment, it is important to state with what amount of accuracy the data of observation and the ancillary magnitudes were determined. I will give this statement in what now follows.

For observing the temperature of the water in the calorimeter I used thermometers made by GEISSLER of Bonn, which the kindness of Professor BUFF, Director of the Physical Cabinet in Giessen, placed at my disposal. In these thermometers the tube consists of a fine glass thread drawn out at the lamp. The bulb is cylindrical, very thin in the glass, and contains but little mercury. On one (*b*) 1° C. corresponds to a length of almost 5 millims. on the scale, and on the other (*r*) to almost 4·5 millims. Tenths of a degree can be read off directly on the scale, and it is easy to learn to estimate hundredths safely. I have repeatedly compared these two thermometers, between 7° and 24°, with two normal thermometers of my own construction, which agree very well with each other, and on one of which a division corresponds to 0°·4878, and the other to 0°·4341. The differences of the indications between the GEISSLER'S thermometers and these could be considered as constant within those limits; for the differences thus observed all the readings made with the GEISSLER'S thermometers had to be corrected to make them comparable with the indications of the normal thermometer.

The temperature of the mercury-bath was ascertained by means of one of these normal thermometers, and the indications of this thermometer immersed in the bath (*d* in fig. 1.) corrected for the lower temperature of the mercury thread out of the bath; this latter temperature was given with adequate approximation by the second thermometer, *e*.

21. The weight of the thin sheet-brass calorimeter, together with stirrer, was 11·145 grms.* Taking the specific heat of brass, according to REGNAULT, at 0·09391, the calorimetric value in water of this mass of metal is 1·046 grm. Considering that the calorimeter in the experiments was not quite filled with water, but about $\frac{1}{6}$th remained empty, even after introducing the tube, I put the value in water at 0·872.

In determining the calorimetric water value of the immersed parts of the thermometers *r* and *b*, the following experiments were made. The weight of water in the calorimeter, together with the reduced weight of the metal, was 30·87 grms. When the thermometer *r* heated to 33°·86 was immersed, the temperature rose from 10°·73 to 10°·85; the immersion of the thermometer *b* at a temperature of 37°·53 caused a rise from 10°·61 to 10°·76. In both cases the temperature of the water was indicated by means

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* At the beginning of these investigations. During their progress the calorimeter was cleaned and dried with bibulous paper a countless number of times, so that its weight diminished by about 0·04 grm. in the course of the experiments. In determining the weight of water used in each experiment, the weight which the calorimeter actually had at the time was taken as basis.

of the other thermometer, the reduced value of which might be neglected under these circumstances. These experiments gave 0·16 as the reduced value of the thermometer *r*, and 0·17 as the reduced value of the thermometer *b*. The thermometers have very nearly the same dimensions. Hence I put the reduced value of the calorimeter (that is, of the part of the metal concerned), of the stirrer, and of the immersed part of the thermometer at 1·04 grm. Even if this determination is a few tenths out, it is scarcely appreciable as compared with the quantity of water in the calorimeter. In all following experiments this was between 25·85 and 25·95 grms.

All the subsequent determinations depend on fixing differences of weights and of temperatures. The accuracy of the results depends on the precision with which both kinds of magnitudes are ascertained; and it is useless to determine the weights to $\frac{1}{1000}$ or nearer, if the differences in temperature cannot be determined more accurately than to $\frac{1}{200}$ or $\frac{1}{300}$. I have weighed to centigrammes instead of to milligrammes, by which the time necessary for the weighings was much shortened, and their accuracy not materially lessened.

22. The reduced value x remained to be determined of the glasses (cylindrical tubes of thin glass, see § 17), or, rather, of that part which was immersed in the water of the calorimeter, the quantity of which was always the same. In the following, T is the temperature to which the glass in the mercury-bath was heated (compare fig. 1), M the quantity of water in the calorimeter + the reduced value in water of the other parts of the latter, which required to be taken into account, t the temperature of the water in the calorimeter when the glass was immersed (fig. 2), and τ the temperature to which the water became heated, and which must be considered as that to which the glass cooled*. We have then

$$x=\frac{M(\tau-t)}{T-\tau}.$$

In my experiments I used three glasses, which may be called 1, 2, and 3. To ascertain the reduced value of glass 1, I made the following determinations:—

Temperature of Air 15°·8.

T.	τ.	t.	M.	x.
°	°	°	grms.	
78·54	17·23	15·72	26·98	0·664
74·38	17·16	15·78	26·97	0·651
75·51	17·14	15·72	26·92	0·655
76·06	17·15	15·73	26·945	0·649
77·32	17·22	15·74	26·96	0.664
			Mean . .	0·657

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* If the cork which closes the glass, and by means of the wire passing through it enables it to be handled, is moist, incorrect and discordant values are obtained for it, owing to the evaporation of water in the empty glass so long as this is in the mercury-bath, and to the condensation of aqueous vapour in the glass when it is immersed in the calorimeter.

I subsequently made a second series of experiments to determine the reduced value for glass 1, which gave the following results:—

Temperature of the Air 19°·9–19°·8.

T.	τ.	t.	M.	x.
°	°	°	grms.	
78·50	21·32	19·93	26·99	0·656
81·86	21·47	20·03	26·98	0·643
80·42	21·43	20·02	26·98	0·645
79·77	21·42	20·03	26·935	0·642
80·14	21·51	20·12	26·955	0·639
			Mean . .	0·645

The mean of these two means, 0·657 and 0·645, gives as the reduced value in water of glass 1, 0·651 grm.

To obtain the water value for glass 2, I made the following determinations:—

Temperature of the Air 12°·0–12°·5.

T.	τ.	t.	M.	x.
°	°	°	grms.	
75·87	13·53	12·43	26·94	0·475
77·05	13·46	12·31	26·96	0·488
76·71	13·68	12·54	26·975	0·488
75·97	13·76	12·65	26·95	0·481
78·60	13·83	12·62	26·95	0·503
			Mean . .	0·487

The reduced value for glass 2 is hence = 0·487 grm. This glass broke before I made a second series of experiments to ascertain its reduced value.

I made two series of experiments to determine the reduced value of glass 3. The first gave the following results:—

Temperature of the Air 19°·3–19°·5.

T.	τ.	t.	M.	x.
°	°	°	grms.	
81·00	20·33	19·31	26·98	0·454
80·03	20·83	19·84	26·965	0·451
80·22	20·93	19·94	26·98	0·451
84·06	21·04	20·02	26·945	0·436
81·90	20·93	19·93	26·975	0·442
			Mean . .	0·447

The second series of experiments gave the following results:—

Temperature of the Air 19°·9–19°·8.

T.	τ.	t.	M.	x.
°	°	°	grms.	
80·41	21·08	20·06	26·965	0·464
79·64	21·10	20·09	26·965	0·465
79·98	21·12	20·12	26·96	0·458
80·22	21·12	20·12	26·985	0·457
79·53	21·10	20·12	26·965	0·452
80·52	21·13	20·14	26·96	0·450
			Mean . .	0·458

The reduced value of glass 3 = 0·453 grm., the average of the mean numbers of both series of experiments.

23. In those experiments in which a glass containing a liquid and perhaps a solid substance is immersed, while warm, in the water of the calorimeter, it may be asked if, when the water has become heated to a certain maximum temperature, the contents of the glass have actually cooled to the same temperature. In earlier experiments made by the method of mixture, it was at once assumed that the temperature assumed by the water of the calorimeter after immersing the solid was actually that also to which the immersed body sank. NEUMANN has taken into account that the immersed body, when the water shows its maximum temperature, may have a somewhat higher temperature *. AVOGADRO has also taken this into account †, and REGNAULT has also allowed for this circumstance in the case in which the mass, immersed in the water of the calorimeter, is a bad conductor of heat ‡. A correction for this fact is certainly inconsiderable and unnecessary if the immersed body conducts heat well, and the range of temperature through which it cools in the liquid is great. This interval of temperature was in my experiments considerably smaller than in those of NEUMANN and of REGNAULT; and as in my experiments the excess of heat of the contents of the glass had to pass through its sides to the water of the calorimeter, it might be doubted whether, when the temperature of the water was at its maximum, this temperature could be considered as that of the contents of the glass.

I have endeavoured to answer these questions experimentally. A glass, such as was used for holding the solid investigated and a liquid, was filled with water, and a perforated cork fitted, by means of which the glass could be handled, and which permitted the introduction of a thermometer into the water within the glass. The glass filled with water was warmed, and then placed in the calorimeter filled with water; a thermometer A, passing through the cork, showed the temperature of the water in the glass;

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* In the memoirs mentioned in § 4, PAPE has also discussed and applied the correction to be made for the above circumstance (POGGENDORFF's 'Annalen,' vol. cxx. p. 341).

† Ann. de Chim. et de Phys. [2] vol. lv. p. 90. ‡ Ibid [2] vol. lxxiii. p. 26.

a second, B, showed that of the calorimeter water. If the glass filled with the warmer water is immersed in the cold water, the following circumstances are observed*. A sinks very rapidly, while B rises more slowly; if B shows the maximum temperature for the water of the calorimeter (this temperature being called t'), A gives a higher temperature (T) for the contents of the glass. B then slowly sinks and A follows it, while the difference between t' and T' always becomes smaller. In the two following series of experiments I have endeavoured to determine by how much, under certain conditions, the temperature T' of the water in the glass exceeds the maximum temperature t' of the water in the calorimeter when this maximum temperature as such is observed. I obtained the following results: the temperature of the air in the experiments was 13°·2–13°·5.

Experiments with Glass 1.			Experiments with Glass 2.		
T'.	t'.	Difference.	T'.	t'.	Difference.
15°·51	15°·13	0°·38	15°·71	15°·50	0°·21
14·96	14·72	0·24	15·96	15·65	0·31
16·11	15·94	0·17	15·16	14·91	0·25
15·56	15·36	0·20	14·76	14·47	0·29
14·24	14·05	0·19	14·66	14·33	0·33
15·96	15·64	0·32	15·56	15·24	0·32

A closer agreement in the numbers expressing the difference between T' and t' is difficult to attain, since a certain time is necessary to observe the occurrence of the maximum temperature, and during the time in which the thermometer B remains constant, the thermometer A still sinks; according to the moment at which the maximum temperature is considered to be established, this difference may be obtained different, and the smaller the later the observation is made. Moreover the magnitude of this difference between T' and t' depends on the difference between t' and the temperature of the air. I have always endeavoured to work under the same circumstances, and especially to arrange the experiments so that the maximum temperature of the water in the calorimeter did not exceed by more than 2° the temperature of the air†. For these experiments and the apparatus which I used, I assumed, on the basis of the preceding experiments, that if the water of the calorimeter had assumed its maximum temperature t', the contents of the glass were 0°·3 higher; that is, I put throughout T', the temperature to which the contents of the glass immersed in the calorimeter had fallen, $=t'+0^{\circ}{\cdot}3$.

24. It is a matter of course that, in introducing this correction for obtaining the tem-

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* In these experiments, in order to ensure uniformity in the temperature of the water, the stirrer was kept in continual motion, and the same process followed as in ascertaining the specific heat.

† A preliminary experiment shows how cool the water in the calorimeter ought to be. Water which is somewhat cooler than the surrounding air, may be kept in stock for such experiments by placing it in a cylindrical flask covered externally with filtering paper, and standing in a dish of water, so that the paper is always moist. To warm the water in the calorimeter, it was merely necessary, with apparatus of the dimensions I used, to lay the hand on it for a short time.

perature of the contents of the glass at the time the maximum temperature has been attained in the calorimeter, it is unnecessary to give the indications of T′ in hundredths of a degree; and since the temperature T, to which the glass with its contents was heated in the mercury-bath, only serves to deduce the difference T—T′, it is unimportant in giving this temperature to do so in hundredths of a degree. The accuracy of the determinations of specific heat, in so far as it depends on determinations of temperature, is limited by the accuracy with which the difference of T—T′ and $t'-t$ are determined (where t is the original temperature of the water in the calorimeter, and the other letters have the meanings previously assigned to them). To have one of these differences very accurately, while the other is much less accurately determined, avails nothing for the accuracy of the final results. It is at once seen that in my experiments, and especially in those of Neumann and Regnault, the hundredths of a degree have a greater significance for the small difference $t'-t$, than the tenths of a degree for the great difference T—T′.

The correction for educing the value of T′, which I have just discussed, is of course more important the smaller the difference T—T′; for most of my experiments in which this difference is about 30°, the significance of this correction is inconsiderable, if the contents of the glass be a good conductor. I give a few numbers. The experiments given in § 25 on the specific heat of mercury, which, by using this correction, give it at 0·0335 in the mean, give it =0·0331 if this correction is neglected, that is, T′ made=t'. The fourth series of experiments, given in § 27, for determining the specific heat of coal-tar naphtha A, give it at 0·425 when this correction is made, and at 0·420 when it is omitted. The first series of experiments in § 33, for determining the specific heat of sulphur, give it at 0·159 when this correction is used, and at 0·152 when it is neglected. Whether in all such cases T′ is put $=t'$, or$=t'^{\circ}+0^{\circ}\cdot 3$, is of inconsiderable importance. The correction in question is inadequate if the substance in the glass is a bad conductor; for example, when the solid in the glass is a pulverulent or porous mass, in which the moistening liquid stagnates (compare § 18). That, under such circumstances, the numbers obtained for the specific heat are found somewhat too small must be remembered in § 41 in the case of chromium, and in § 52 in the case of chloride of chromium. Too small numbers are also obtained, if in the experiments the maximum temperature of the cooling water exceeds that of the air by much more than 2°. Such experiments are not comparable with the others, for example, with those made for the purpose of ascertaining the ancillary magnitudes occurring in the calculation of the results; for them this correction is inadequate, and the loss of heat which the contents of the calorimeter experiences between the time which elapsed between immersing the glass and the establishment of the maximum temperature is too great. By individual examples in § 25 in the case of water, in § 39 in the case of copper, and § 41 in the case of iron, I shall call to mind how this source of error may give somewhat too small numbers for the specific heat; but I have always tried to avoid this error, since I saw its importance in my first preliminary experiments.

25. I first attempted to test my method by some experiments in which water or mercury was placed in the calorimeter. For the specific heats of these liquids the following numbers were obtained, calculated by the formula

$$\text{sp. H}=\frac{\text{M}\,(t'-t)-x\,(\text{T}-\text{T}')}{f\,(\text{T}-\text{T}')},$$

in which the signification of f is manifest from what follows, that of the other letters from what has been given before.

In the experiments in which a readily vaporizable liquid was contained in the glass, such as water, or coal-tar naphtha, a sensible formation of vapour took place, although the temperature did not exceed 50°. If the glass containing the liquid was heated in the mercury-bath (compare fig. 7), vapour was formed in the empty space below the cork which served as stopper; if the glass was then brought into the water of the calorimeter, this vapour condensed and settled partially on the stopper. The stopper did not act materially on the water of the calorimeter (see fig. 5). The quantity of liquid in the glass which acted directly on the water of the calorimeter, decreased somewhat in each experiment; but this decrease is very inconsiderable. In the following experiments f denotes first the weight of the liquid in the glass at the commencement of the experiment, and at last its weight at the end of the experiments, that is, after subtracting the liquid which had vaporized and condensed on the stopper. After the end of the experiment the stopper was dried to remove the liquid, and by another weighing of the glass, together with its contents and stopper, the weight of the liquid still contained in the glass was obtained. The decrease of weight of the liquid in the glass was always found to be inconsiderable, and might without any harm have been neglected; for the last experiment of a series I have always taken the diminished weight of the liquid into account, but for those between the first and the last I have neglected the diminution of the weight of the liquid in the glass. What I have here said explains a remark of frequent subsequent use, "after drying the stopper." In reference to the influence of the formation of vapour on the accuracy of the results obtained for the specific heat of the individual substances, compare § 38.

Two series of experiments in which water was contained in the glass, gave the following results for the specific heat of this liquid:—

Experiments with Glass 1. Temperature of the Air 19°·0.

T	T'.	t'.	t.	M.	f.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.	
45·2	20·9	20·62	16·83	26·945	3·43	0·651	1·035
46·6	21·2	20·92	17·03	26·935	,,	,,	1·013
47·4	21·3	20·96	17·03	26·965	3·42*	,,	0·997

* After drying the stopper.

Experiments with Glass 3. Temperature of the Air 19°·0.

T.	T′.	*t′*.	*t*.	M. grms.	*f*. grms.	*x*. grm.	sp. H.
46°·8	21°·1	20°·76	17°·03	26·95	3·445	0·453	1·004
46·8	21·1	20·83	17·12	26·985	„	„	0·999
47·0	21·2	20·93	17·22	26·935	3·435[*]	„	0·996

The value found for the specific heat of the contents of the glass comes very near the number 1, assumed for the specific heat of water[†].

Determinations in which mercury was contained in the glass gave the following results for the specific heat of the contents of the glass.

Experiments with Glass 1. Temperature of the Air 13°·8–14°·4.

T.	T′.	*t′*.	*t*.	M. grms.	*f*. grms.	*x*. grm.	sp. H.
51°·1	16°·8	16°·50	13°·41	26·945	53·015	0·651	0·0335
48·5	16·8	16·48	13·64	26·95	„	„	0·0333
45·2	16·5	16·20	13·63	26·965	„	„	0·0333

Experiments with Glass 2. Temperature of the Air 13°·8–14°·4.

T.	T′.	*t′*.	*t*.	M. grms.	*f*. grms.	*x*. grm.	sp. H.
50°·0	17°·1	16°·79	13°·74	26·935	60·015	0·487	0·0335
45·6	16·7	16·41	13·72	26·935	„	„	0·0337

The mean of these five determinations gives 0·0335 for the specific heat of mercury, in accordance with the results found by other observers for this metal (0·0330 between 0° and 100°, Dulong and Petit; 0·0333, Regnault).

26. For the liquid which is to be placed in the glass along with the substance whose specific heat is to be investigated, I could in many cases use water; but many substances, the

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[*] After drying the stopper.

[†] In § 24 it was mentioned that the numbers obtained for the specific heat of the contents of the glass are somewhat too small, if the maximum temperature of the water in the calorimeter, *t′*, exceeds the temperature of the air by much more than 2°. As an example I give the following determinations, in which the glass used contained water.

Experiments with Glass 1. Temperature of the Air 13°·5–13°·8.

T.	T′.	*t′*.	*t*.	M. grms.	*f*. grms.	*x*. grm.	sp. H.
46°·5	18°·1	17°·81	13°·64	26·94	3·40	0·651	0·976
43·9	16·7	16·38	12·33	26·955	„	„	0·989

Experiments with Glass 2. Temperature of the Air 13°·5–13°·8.

T.	T′.	*t′*.	*t*.	M. grms.	*f*. grms.	*x*. grm.	sp. H.
49°·1	18°·3	18°·03	13°·37	26·94	3·66	0·487	0·981
47·6	18·3	18·04	13·66	26·99	„	„	0·969
47·0	17·5	17·22	12·73	26·97	3·65[*]	„	0·991

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[*] After drying the stopper.

determination of which is important, dissolve in water, and hence I had to use a different liquid. Coal-tar naphtha has the advantage that it is a mobile liquid, does not dissolve most salts, and does not resinify in contact with the air; but besides the disagreeable odour, with continuous working, respiring air charged with its vapour appears to act injuriously on the organs of the voice. As compared with water, coal-tar naphtha has the disadvantage, that its specific heat must be specially determined, and any possible uncertainty in this is transferred to the determination of the specific heat of the solid substance; but the thermal action of a given volume of naphtha is only about $\frac{1}{3}$ that of the same volume of water[*]; and in experiments in which the thermal action of a solid substance is determined, along with that of the necessary quantity of liquid which is contained with that substance in a glass, the thermal action due to the solid is a larger fraction of the total if coal-tar naphtha is used than if water is the liquid, which is a favourable circumstance in the accurate determination of specific heat. As it was more especially important for me to obtain comparability in the results for specific heat, I have, for a great many substances which are insoluble in water, and for whose investigation water might have been used, also employed coal-tar naphtha. Water was used for a few substances which are soluble in coal-tar naphtha (sulphur, phosphorus, sesquichloride of carbon, for instance). Several substances I determined both with water and with naphtha; the results thus obtained agree satisfactorily. To the question as to whether any possible change in the specific heat of naphtha with the temperature can be urged against the use of this liquid, I shall return in § 29.

27. The coal-tar naphtha A which I principally used in the subsequent experiments was prepared from the commercial mixture of hydrocarbons $C_n H_{2n-6}$, by purifying it by means of sulphuric acid, treating the portion which distilled between 105° and 120° with chloride of calcium for six days, then again rectifying it, and collecting separately that which passed between 105° and 120°. This liquid had the specific gravity 0·869 at 15°; in determining its specific heat I made four series of experiments, two at first when I was engaged on experiments in which I used this naphtha, and two towards the end.

I.—Experiments with Glass 1. Temperature of the Air 12°·1–12°·9.

T.	T'.	t'.	t.	M.	f.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.	
46·1	13·8	13·51	11·24	26·99	2·875	0·651	0·433
48·6	14·0	13·71	11·24	26·945	2·875 [†]	„	0·443
45·5	14·1	13·83	11·59	26·97	2·975 [‡]	„	0·439
45·3	14·3	14·01	11·80	26·94	2·970 [†]	„	0·428
					Mean	. . .	0·436

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[*] The specific heat of the coal-tar naphtha A, with which I made most of my experiments, is 0·431, and its specific gravity at 15°=0·869.

[†] After drying the stopper.

[‡] After adding some naphtha.

II.—Experiments with Glass 2. Temperature of the Air 12°·1–12°·7.

T.	T'.	t'	t.	M. grms.	f. grms.	x. grm.	sp. H.
49°·0	13°·8	13°·53	11°·02	26·955	3·28	0·487	0·438
45·9	14·1	13·83	11·50	26·93	3·48 *	„	0·427
43·3	14·2	13·86	11·73	26·95	„	„	0·427
46·6	14·5	14·23	11·85	26·95	3·475 †	„	0·435
					Mean	. . .	0·432

III.—Experiments with Glass 1. Temperature of the Air 16°·7.

T.	T'.	t'.	t.	M. grms.	f. grms.	x. grm.	sp. H.
51°·4	18°·6	18°·32	16°·02	26·98	2·895	0·651	0·429
51·5	18·4	18·06	15·73	26·97	„	„	0·431
51·5	18·4	18·14	15·81	26·985	„	„	0·431
51·0	18·5	18·22	15·93	26·96	2·88†	„	0·434
					Mean	. . .	0·431

IV.—Experiments with Glass 3. Temperature of the Air 16°·7.

T.	T'.	t'.	t.	M. grms.	f. grms.	x. grm.	sp. H.
51°·7	18°·7	18°·43	16°·22	26·935	3·195	0·453	0·423
50·7	18·6	18·32	16·14	26·935	„	„	0·431
50·7	18·6	18·27	16·13	26·95	„	„	0·421
50·2	18·6	18·26	16·14	26·93	3·18 †	„	0·426
					Mean	. . .	0·425

The average of the means of these four series of experiments, 0·436, 0·432, 0·431, 0·425, gives 0·431 as the specific heat of the coal-tar naphtha A between 14° and 52°; this value is taken in calculating the experiments in the following section.

28. If it were only a question as to the determination of the specific heat of this naphtha, the method described in the preceding might be advantageously replaced by another. For by this method the specific heat of the liquid must be found somewhat too great, owing to the fact that in the empty space in the glass under the stopper a distinct quantity of vapour is formed, which condenses when the glass is dipped in the water of the calorimeter (compare § 25). Direct experiments ‡, in which this formation of vapour was almost entirely avoided, have shown that the method used for the previous determinations, that is, the use of glasses for heating the liquid in which a

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* After adding some naphtha.

† After drying the stopper.

‡ I determined the specific heat of coal-tar naphtha A, using a glass in which only very little vapour could form above the heated liquid. This glass (which I used in experiments for the determination of the specific heat of liquid compounds) had a narrow neck, and was filled so that there was very little space in which vapour could form; the calorimetric value of this glass, in so far as it was immersed in the water of the

relatively considerable space above the liquid remains empty, gives the specific heat of readily vaporizable liquids somewhat too high, but that at the same time this influence of the formation and condensation of vapour is very small in the conditions under which I worked*.—The number 0·431 obtained in the previous determinations expresses the thermal action due to the cooling of 1 grm. naphtha A through 1° in my experiments, which thermal action depends to by much the greatest extent on the specific heat of this liquid, and only to a very small extent on the condensation of the previously formed vapour. In calculating the experiments communicated in the third section, that number is taken as the expression for the thermal action of naphtha, which is put as proportional to the weight of the latter. This is, strictly speaking, not accurate, in so far as the thermal action arising from condensation of vapour only depends on the magnitude of the empty space and the temperature, and not on the quantity of naphtha in the glass. But the small possible inaccuracy due to this cause in my experiments is not to be compared with other uncertainties. The manner in which I have taken into account the naphtha contained in the glass corresponds most accurately to the actual conditions of the experiment, when this thermal action is most considerable (only naphtha in the glass); and if my mode of calculation less satisfies these conditions (less naphtha in the glass), the entire amount is less considerable, and the influence of that which might be missed in that calculation, a vanishing quantity.

29. My experiments have been made at very different temperatures. The temperature of the air was often something under 10°, sometimes above 20°. These numbers represent the limits to which the liquid in the glass, together with the solid substance cooled in the calorimeter. In most experiments I heated the glass with its contents to about 50°, in some cases not so high. Now, for the various intervals of temperature within which the liquid in the glass cooled, can its specific heat be assumed to be always the same? For water this may be done, and for coal-tar naphtha I did not

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calorimeter (comp. fig. 6), was = 0·688 grm. A series of experiments in which this glass was used to determine the specific heat of the naphtha A gave the following results:—

Temperature of the Air 15°·5–15°·6.

T.	T'.	t'.	t.	M. grms.	f. grms.	x. grm.	sp. H.
52°·5	17°·8	17°·53	14°·93	26·945	3·205	0·688	0·415
49·6	17·4	17·13	14·73	26·955	„	„	0·412
50·9	17·6	17·29	14·83	26·96	„	„	0·407
50·5	17·6	17·26	14·83	26·975	„	„	0·407
51·6	17·7	17·38	14·84	26·985	„	„	0·416
50·9	17·8	17·47	15·03	26·94	„	„	0·405
						Mean . . .	0·410

* This is seen from the experiments on water communicated in § 25, and from the subsequent determinations in the next section, in which water was contained in the glass along with the solid substance.

doubt it while engaged in my experiments. I first, when they were finished, became acquainted with REGNAULT'S * investigations on the specific heat of liquids at various temperatures; according to these experiments the specific heat of some liquids considerably increases with the temperature. I have not directly investigated coal-tar naphtha in this respect, but it is probable that the specific heat of this mixture of hydrocarbons $Ꞓ_n H_{2n-6}$, alters but little with the temperature, and it is certain that this change is without influence on the accuracy of my determinations of the specific heats of solid substances. REGNAULT'S experiments †, made by the method of cooling, show no change for benzole, $Ꞓ_6 H_6$, between 20° and 5°, while there is a distinct change in the case of alcohol. For pure benzole ‡ I found the specific heat by the method of mixture to be 0·450 between 46° and 19°; REGNAULT § found it between 71° and 21° to be 0·436. These numbers, obtained with different preparations, are not indeed comparable for a decision of the question just discussed, but they render improbable a considerable increase in the specific heat of benzole with the temperature. What I more especially lay weight upon is this: the specific heats of solids which I have determined at various temperatures, by their agreement with the numbers previously found by others, do not indicate any influence of a change of specific heat of naphtha with the temperature.

30. My stock of the naphtha, discussed in § 27, was used before I had investigated all the solid substances, for which a determination of the specific heat appeared necessary. Another quantity of the same coal-tar naphtha was subjected to the same treatment as indicated there, and the portion passing over between 105° and 120° used for the remainder of the experiments. To ascertain the specific heat of this naphtha B, I made the four following series of experiments:—

I.—Experiments with Glass 1. Temperature of the Air 18°·1–18°·3.

T.	T'.	t'.	t.	M.	f.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.	
51·5	19·6	9·33	17·22	26·96	2·70	0·651	0·419
52·7	19·9	19·64	17·49	26·95	„	„	0·413
50·5	19·8	19·54	17·51	26·99	„	„	0·420
49·9	20·0	19·73	17·75	26·995	2·695 ‖	„	0·422
					Mean	. . .	0·418

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[*] Relation des expériences . . . . pour déterminer les lois et les données physiques nécessaires au calcul des machines à feu, vol. ii. p. 262 (1862).

[†] Ann. de Chim. et de Phys. [3] vol. ix. pp. 336 & 349.

[‡] POGGENDORFF'S 'Annalen,' vol. lxxv. p. 107.

[§] Relation, etc. . . . ., vol. ii. p. 283.

[‖] After drying the stopper.

II.—Experiments with Glass 3. Temperature of the Air 18°·1–18°·3.

T.	T'.	*t'*.	*t*.	M. grms.	*f.* grms.	*x.* grm.	sp. H.
51°·4	19°·7	19°·36	17°·32	26·94	3·085	0·453	0·415
51·5	19 9	19·63	17·56	26·965	„	„	0·426
49·1	19·9	19·61	17·73	26·955	„	„	0·416
50·5	20·1	19·82	17·86	26·98	3·08 *	„	0·418
					Mean	. . .	0·419

III.—Experiments with Glass 1. Temperature of the Air 17°·8–18°·3.

T.	T'.	*t'*.	*t*.	M. grms.	*f.* grms.	*x.* grm.	sp. H.
52°·2	19°·8	19°·49	17°·27	26·97	2·80	0·651	0·427
50·6	20·0	19·73	17·64	26·96	„	„	0·425
51·2	20·2	19·92	17 82	26·98	„	„	0·420
51·3	20·2	19·86	17·76	26·99	„	„	0·418
50·4	20·2	19·86	17·85	26·95	2·785 *	„	0·410
					Mean	. . .	0·420

IV.—Experiments with Glass 3. Temperature of the Air 18°·4.

T.	T'.	*t'*.	*t*.	M. grms.	*f.* grms.	*x.* grm.	sp. H.
50°·2	19°·7	19°·43	17°·33	26·96	3·31	0·453	0·424
50·1	20·1	19·77	17·66	26·99	„	„	0·416
52·5	20·2	19·87	17·65	26·96	„	„	0·423
50·1	20·1	19·83	17·82	26·95	„	„	0·409
51·4	20·2	19·93	17·82	26·97	3·29 *	„	0·417
					Mean	. . .	0·418

The average of the means of these four series of experiments, 0·418, 0·419, 0·420, 0·418, gives 0·419 for the specific heat of coal-tar naphtha B between 20° and 50°.

In the preceding method of experiment, whether water or naphtha of the kind described is contained in the vessel, a temperature much higher than 50° cannot be employed; for otherwise the quantity of liquid evaporating and condensing on the stopper becomes far too considerable. Perhaps with hydrocarbons of higher boiling-points higher temperatures might be ventured upon: I have no experiments on this subject.

PART III.—DETERMINATION OF THE SPECIFIC HEAT OF INDIVIDUAL SOLID SUBSTANCES.

31. By the method whose principle and mode of execution have been discussed in the preceding, I have determined the specific heat of a large number of solid substances. I

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* After drying the stopper.

should have liked to include a still larger number of bodies in my investigations; but a limit was put by the straining of the eyes from constant reading of finely divided scales, and by the injurious action which the long-continued working with coal-tar naphtha produces.

My crystallographic collection furnished me with much material for investigating the specific heat of both naturally occurring and artificially prepared substances, but for much more I have to thank others. By far the greater part of the chemical preparations investigated I obtained from the Laboratory of the University of Giessen, through the kindness of the Director, Professor Will, and of the assistants, Professor Engelbach, to whom my thanks are especially due, Drs. Körner and Dehn. Professor Wöhler, of Göttingen, placed a number of chemical preparations at my disposal. Professor Bunsen, of Heidelberg, has helped me to the investigation of some rubidium-compounds. Platinum and iridium I have been furnished with by M. Heræus, the proprietor of the well-known platinum-manufactory in Hanau. I have had a very large number of minerals from the mineral collection of the University of Giessen, through the kindness of the Director, Professor Knop; and to obtain the necessary quantity of dioptase, Professors Blum of Heidelberg, and Dunker of Marburg, have contributed.

32. The signification of the letters in the statement of the following experiments and their calculation is clear from § 17; in reference to the value of the numbers for M, compare § 21, for x § 22, for T′ § 23, for y § 27 and § 30.

It would require too much space always to give the comparison of my results with those of other observers. I can only do this in individual cases where there are considerable differences and their discussion is of importance. For other substances, where there are recent observations by trustworthy observers, the Tables in § 82 to § 89 give data for comparison.

33. *Sulphur*: pieces of transparent (rhombic) crystals from Girgenti. I made three series of experiments with this substance.

I.—Experiments with Water. Glass 1. Temperature of the Air 13°·2.

T.	T′.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·8	15·5	15·24	11·74	26·95	4·16	1·765	1·000	0·651	0·168
46·0	16·2	15·93	12·52	26·935	„	„	„	„	0·160
45·2	16·0	15·73	12·42	26·945	„	„	„	„	0·153
45·8	16·4	16·05	12·74	26·96	„	1·75*	„	„	0·153
							Mean	. . .	0·159

* After drying the stopper: compare § 25.

II.—Experiments with Water. Glass 2. Temperature of the Air 13°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·8	16·4	16·07	12·36	26·96	4·815	2·09	1·000	0·487	0·171
47·3	16·6	16·33	12·46	26·95	„	„	„	„	0·170
44·1	16·5	16·15	12·74	26·925	„	„	„	„	0·156
45·1	16·6	16·28	12·77	26·96	„	2·07[*]	„	„	0·159
							Mean . . .		0·164

Both these series of determinations are from the time when I first worked at this subject. Towards the end, when I had acquired tolerable readiness, I made a third series, which agreed very closely with the results previously obtained.

III.—Experiments with Water. Glass 3. Temperature of the Air 17°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
43·7	19·1	18·83	15·79	26·99	4·92	2·065	1·000	0·453	0·166
43·5	19·1	18·84	15·84	26·97	„	„	„	„	0·162
43·3	19·2	18·92	15·92	26·94	„	„	„	„	0·170
43·1	19·2	18·87	15·93	26·98	„	2·05[*]	„	„	0·166
							Mean . . .		0·166

Taking the mean of the means obtained in the three series of experiments, 0·159, 0·164, 0·166, we obtain 0·163 as the specific heat of rhombic sulphur between 17° and 45°. By the method of cooling, Dulong and Petit found the specific heat of sulphur at the mean temperature to be 0·188; Neumann found 0·209 by the method of mixture; for sulphur which had been purified by distillation, fused and cast in rolls, Regnault found[†] the specific heat between 14° and 98° to be 0·2026. In these experiments a development of heat depending on a change from amorphous sulphur into rhombic-crystallized appears to have cooperated, and to have caused the circumstance observed by Regnault, that after immersing the heated sulphur in the water of the calorimeter, the maximum temperature was only set up after an unusually long time. Sulphur which has solidified after being melted, usually contains an admixture of amorphous sulphur, the greater the more the melting-point has been exceeded, which at the ordinary temperature passes slowly, at 100° more rapidly, into crystallized, accompanied by disengagement of heat. The transformation of the sulphur set up by the heating, and continued in the water of the calorimeter, brought about this slow appearance of the maximum temperature, and made the specific heat appear too great; for Regnault's subsequent determinations[‡], also made between 97° and 99° and the mean temperature, gave it considerably less: 0·1844 for freshly melted sulphur (in which

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[*] After drying the stopper.

[†] Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 50.

[‡] Ibid. [3] vol. ix. pp. 326 & 344.

superfusion had been avoided?); 0·1803 for sulphur which had been melted two months; 0·1764 for what had been melted two years (and which had then given 0·2026); 0·1796 for sulphur of natural occurrence. The difference between the latter result and my own doubtless depends, partially at least, on the fact that Regnault's determination was made between 14° and 99° (the latter of which temperatures is very near the melting-point of rhombic sulphur); mine was made between 17° and 45°[*].

Tellurium: crystalline pieces[†].

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·6–19°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·8	20·4	20·07	17·96	26·93	10·80	1·93	0·431	0·453	0·0486
51·3	20·3	20·02	17·93	26·98	"	"	"	"	0·0495
51·5	20·7	20·36	18·33	26·93	"	"	"	"	0·0454
51·0	20·7	20·43	18·43	26·955	"	1·91[‡]	"	"	0·0466
							Mean	. . .	0·0475

34. *Boron.*—I have made some experiments with this substance, which have some interest for the question whether this body has essentially different specific heats in its different modifications; but the results are not very trustworthy, owing to the spongy nature of the amorphous boron and the doubtful purity of the crystallized variety.

The *amorphous Boron* [§] which I investigated was pressed in small bars, and had stood several days *in vacuo* over sulphuric acid.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·0–17°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grm.	grms.		grm.	
49·0	18·7	18·73	16·36	26·955	1·52	2·515	0·431	0·651	0·246
48·1	18·6	18·55	16·23	26·965	"	"	"	"	0·254
48·0	18·6	18·64	16·33	26·95	"	"	"	"	0·252
47·9	18·7	18·72	16·42	26·95	"	2·49[‡]	"	"	0·262
							Mean	. . .	0·254

Even if the results of the individual experiments agree tolerably with each other they are not very trustworthy; for the quantity of boron (only 1½ grm.) is very small, and the amount of heat due to the boron is a very small part of the total (comp. § 19). Yet I do not consider the result of the above series of experiments (that between 18° and 48° the specific heat of amorphous boron is about 0·254) as being very far from

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[*] There is nothing known certainly as to whether the different modifications of sulphur have essentially different specific heats. Marchand and Scheerer's experiments on brown and yellow sulphur made by the method of cooling, compare in Journal für Prakt. Chemie, vol. xxiv. p. 153.

[†] "Obtained from Vienna, and obviously distilled."—Wöhler.

[‡] After drying the stopper.

[§] "Prepared from boracic acid by sodium, and treated with hydrochloric acid."—Wöhler.

the truth. There are no considerable accidental errors of observation in these experiments, to judge from their agreement with one another. Of the constants for calculating the experiments, x and y must be taken into account in regard to any possible uncertainty. It has been assumed that $x=0·615$ and $y=0·431$; if we took $x=0·63$ and $y=0·41$, the specific heat as the mean of four experiments would be $=0·30$; if x were 0·67 and y 0·45, the specific heat would be 0·21. But from what has been communicated in § 22 and § 27 in reference to the determination of x and y, it cannot be assumed that any possible uncertainty in reference to these values can reach either of the above limits. It can be assumed with the greater certainty that the specific heat of amorphous boron is between 0·2 and 0·3 and nearly 0·25, because x and y could not simultaneously both be found too great or too small (if x had been too small y would have been too great, and *vice versâ*).

Crystallized Boron *.

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·9–18°·7.

T.	T′.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·9	20·8	20·52	18·53	26·94	2·82	1·53	0·431	0·453	0·237
51·3	20·8	20·52	18·52	26·975	”	”	”	”	0·233
51·5	20·8	20·53	18·53	26·985	”	”	”	”	0·229
51·4	20·8	20·46	18·43	26·99	”	1·52†	”	”	0·222
							Mean . . .		0·230

Hence the specific heat of the crystallized (adamantine) boron investigated is 0·230 between 21° and 51°; it is pretty near that found for amorphous boron, 0·254. REGNAULT found‡ (between 98° and 100° and the mean temperature) 0·225 for a specimen of crystallized boron prepared by ROUSSEAU; 0·257 for one prepared by DEBRAY; 0·262 for one obtained from DEVILLE; and 0·235 for a specimen of graphitic boron prepared by DEBRAY. The specific heat of amorphous boron could not be determined by REGNAULT's method, because, when heated to 100° in air, it partially oxidizes into boracic acid with disengagement of heat (three experiments, in which the quantity of boracic acid formed was determined, and its specific heat, but not the thermal action due to the formation of hydrated boracic acid in immersion in water allowed for, gave respectively 0·405, 0·348, and 0·360, which numbers REGNAULT does not consider as even approximately representing the specific heat of amorphous boron), and when greatly cooled disengages a quantity of air when immersed in warmer water, which renders the results uncertain.

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* "Made in Paris, probably by ROUSSEAU, and doubtless by melting borax with aluminium. To conclude from its external appearance, it probably contained some aluminium and carbon: compare the analysis in Ann. der Chem. und Pharm. vol. ci. p. 347."—WÖHLER.

† After drying the stopper.

‡ Ann. de Chim. et de Phys. [3] vol. lxiii. p. 31.

35. *Phosphorus.*—I have only made a few determinations with ordinary yellow phosphorus, which was cast in sticks.

Experiments with Water. Glass 1. Temperature of the Air 10°·9.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
38·8	13·5	13·20	10·05	26·95	3·075	2·065	1·000	0·651	0·208
33·8	12·9	12·62	10·03	26·97	„	„	„	„	0·204
35·5	13·2	12·91	10·17	26·93	„	2·06*	„	„	0·195
							Mean	. . .	0·202

The specific heat of yellow phosphorus, as deduced from these determinations, is somewhat greater than that found by REGNAULT, doubtless because in my experiments the upper limit of temperature, T′, was nearer the melting-point of phosphorus, 44°. Compare § 82.

Antimony.—Purified by LIEBIG's method; crystalline pieces.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·7.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	°	grms.	grm.		grm.	
46·4	16·0	15·65	13·42	26·945	12·245	1·925	0·431	0·487	0·0539
44·9	15·9	15·64	13·54	26·98	„	„	„	„	0·0520
44·2	15·8	15·53	13·52	26·96	„	1·91*	„	„	0·0496
							Mean	. . .	0·0518

II.—Experiments with Water. Glass 1. Temperature of the Air 15°·8–16°·1.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·0	17·9	17·60	14·22	26·945	11·835	2·095	1·000	0·651	0·0519
45·1	17·9	17·64	14·25	26·96	„	„	„	„	0·0519
45·0	17·9	17·64	14·25	26·965	„	„	„	„	0·0530
45·4	18·1	17·76	14·34	26·955	„	2·085*	„	„	0·0542
							Mean	. . .	0·0528

From these determinations, the average of the means of both series of determinations, 0·0518 and 0·0528, the number 0·0523 is the specific heat of antimony between 17° and 45°.

Bismuth.—Purified by melting with nitre, and cast in small bars. In the case of this metal also, I have made a series of determinations with coal-tar naphtha in the glass, and one with water.

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* After drying the stopper.

I.—Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·9–18°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·8	20·6	20·33	18·33	26·99	20·71	1·70	0·431	0·453	0·0291
50·3	20·7	20·42	18·43	26·955	„	„	„	„	0·0302
50·1	20·6	20·33	18·37	26·955	„	„	„	„	0·0292
50·9	20·7	20·40	18·42	26·955	„	1·685*	„	„	0·0284
							Mean	. . .	0·0292

II.—Experiments with Water. Glass 1. Temperature of the Air 16°·7–16°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·2	18·7	18·44	15·25	26·97	19·43	1·995	1·000	0·651	0·0309
45·5	18·9	18·57	15·36	26·965	„	„	„	„	0·0313
45·0	18·9	18·64	15·47	26·975	„	„	„	„	0·0324
46·0	18·1	18·82	15·56	26·99	„	1·985*	„	„	0·0327
							Mean	. . .	0·0318

From these determinations we get for the specific heat of bismuth between 30° and 48° the number 0·0305.

36. *Carbon.*—It is known how different are the numbers obtained for the specific heat of carbon in its different forms. I have determined the specific heat for comparatively only a few of the modifications of carbon—for gas-carbon, for natural and artificial graphite. Before the experiment each of these substances was strongly heated for some time in a covered porcelain crucible, and then allowed to cool, and immediately transferred into the glass for its reception, and, after weighing, naphtha poured over it.

Gas-carbon from a Paris gas-works; very dense, of an iron-grey colour, and left very little ash when calcined†. It was used in pieces the size of a pea, and two series of experiments were made.

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* After drying the stopper.

† This carbon, as well as the above-mentioned varieties of graphite, was analyzed in the Laboratory at Giessen by Mr. Huber. The gas-carbon gave, when placed in a platinum boat and burned in a stream of oxygen,—

	I.	II.	III.	IV.	V.
Carbon........	97·19	98·25	97·73	98·08	98·55
Hydrogen	0·53	0·15	0·68	0·37	1·00
Ash	0·61	0·62	0·73	0·23	0·69
	98·33	99·02	99·14	98·68	100·24

I. Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·9–19°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·9	20·8	20·53	18·13	26·955	3·135	1·825	0·431	0·651	0·184
52·6	20·9	20·63	18·26	26·98	,,	,,	,,	,,	0·185
51·7	20·7	20·42	18·06	26·97	,,	,,	,,	,,	0·196
52·4	20·9	20·58	18·23	26·98	,,	1·805*	,,	,,	0·186
							Mean . . .		0·188

II.—Experiments with Naphtha A. Glass 3. Temperature of the Air 20°·5–20°·8.

T.	T'.	t'	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·6	22·6	22·33	20·23	26·985	3·345	1·935	0·431	0·453	0·180
52·2	22·5	22·23	20·14	26·985	,,	,,	,,	,,	0·183
52·3	22·5	22·20	20·12	26·965	,,	,,	,,	,,	0·179
52·5	22·6	22·31	20·22	26·955	,,	1·91*	,,	,,	0·182
							Mean . . .		0·181

These determinations give as the average of the means of both sets of experiments the number 0·185 as the specific heat of gas-carbon between 22° and 52°.

Natural graphite from Ceylon. Left very small quantities of ash when calcined†.

I.—Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·9–19°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·4	20·8	20·48	18·13	26·975	4·025	2·085	0·431	0·453	0·179
51·4	20·8	20·51	18·13	26·99	,,	,,	,,	,,	0·186
51·8	20·8	20·54	18·15	26·975	,,	,,	,,	,,	0·181
52·0	20·8	20·54	18·13	26·99	,,	2·06*	,,	,,	0·183
							Mean . . .		0·183

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[*] After drying the stopper.

[†] In Mr. HUBER's analyses this substance was placed in a platinum boat, then burned in a porcelain tube in oxygen.

	I.	II	III.
Carbon........	..	99·11	98·52
Hydrogen	..	0·17	0·06
Ash	0·26	0·27	0·51
		99·55	99·09

The residual porous ash left after the combustion was tolerably white, with admixed red particles.

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·0–18°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·9	21·1	20·77	18·22	26·97	3·515	1·935	0·431	0·651	0·174
52·2	21·0	20·73	18·31	26·96	„	„	„	„	0·176
52·1	21·2	20·86	18·52	26·94	„	„	„	„	0·158
53·0	21·0	20·73	18·32	26·97	„	„	„	„	0·155
52·8	21·0	20·73	18·33	26·965	„	1·91*	„	„	0·160
							Mean	. . .	0·165

III.—Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·9–20°·0.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·6	21·9	21·55	19·33	26·97	3·90	2·05	0·431	0·453	0·174
51·3	22·0	21·71	19·52	26·955	„	„	„	„	0·174
51·5	22·0	21·70	19·52	26·97	„	„	„	„	0·168
51·5	21·9	21·63	19·42	26·96	„	2·04*	„	„	0·175
							Mean	. . .	0·173

The average of the means of these three series of determinations, 0·183, 0·165, and 0·173, gives 0·174 as the specific heat of Ceylon graphite between 21° and 52°.

Iron graphite from Oberhammer, near Sayn, separated upon black ordnance iron. Thin, very lustrous laminæ, freed from iron by treatment with aqua regia as much as possible, yet not completely[†].

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[*] After drying the stopper.

[†] This iron graphite, according to Mr. HUBER's analyses, in which it was also burned in oxygen in a platinum boat placed in a porcelain tube, gave the following results:—

	I.	II.	III.
Carbon........	97·01	96·12	96·37
Hydrogen	..	0·12	0·18
Ash	4·88	4·87	3·99
	101·89	101·11	100·54

It is probable that both in this graphite and in that of natural occurrence, the hydrogen is not essential, but arises from hygroscopic moisture. The residual ash contained porous particles consisting of sesquioxide of iron and silica, and also small pellets, covered externally with a layer of magnetic oxide of iron: these dissolved in hydrochloric acid at first quietly, and afterwards under disengagement of hydrogen; and in the solution small blisters of graphite could be perceived. It is owing to the oxidation of the iron that the sum of the constituents in all cases exceeds 100.

I. Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·0–18°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
52·5	20·8	20·53	18·21	26·955	2·51	2·445	0·431	0·453	0·186
52·9	21·1	20·84	18·54	26·98	„	2·565*	„	„	0·156
51·4	20·9	20·64	18·43	26·94	„	„	„	„	0·157
52·0	20·9	20·60	18·33	26·99	„	2·545†	„	„	0·168
							Mean . . .		0·167

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·9–20°·0.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
52·1	21·9	21·57	19·32	26·94	2·48	2·205	0·431	0·651	0·164
51·7	22·0	21·66	19·45	26·97	„	„	„	„	0·163
51·5	22·0	21·73	19·54	26·98	„	„	„	„	0·162
51·5	22·0	21·66	19·46	26·945	„	2·19†	„	„	0·167
							Mean . . .		0·164

The average of the means of both these series of experiments, 0·167 and 0·164, gives 0·166 as the specific heat of iron graphite between 22° and 52°.

The results previously known in reference to the specific heat of carbon, differ greatly for its different conditions, as also do the results obtained by different inquirers and by different methods for the same condition. But even leaving out of consideration the numbers obtained by De la Rive and Marcet by the method of cooling, there are still considerable differences between Regnault's results, obtained by the method of mixture, and my own. Regnault found for animal charcoal 0·261, for wood-charcoal 0·241, for gas-carbon 0·209, for natural graphite 0·202, for iron graphite 0·197, for diamond 0·1469; his experiments gave greater numbers for the same substance than my own. I think that exactly for a substance like carbon in its less dense modifications, my method promises more accurate results than that of Regnault. Even in mine, the substance, after being strongly heated before the experiment, might absorb gases or aqueous vapour, which would make the specific heat too great. But in Regnault's method this source of error might also operate, and more especially also the source of error due to the disengagement of heat when porous substances are moistened by water. These sources of error, which affect the determination of the specific heat of the various modifications of carbon and make it too high, have the more influence the looser and the more porous the substance investigated. I believe that the only certain determination of the specific heat of carbon is that of diamond, and all other determinations are too high, owing to various circumstances, and in Regnault's experiments with wood and animal charcoal, &c., owing to the heat disengaged when these substances are moistened by water.

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* After some more naphtha had been added.

† After drying the stopper.

37. *Silicium.*—I have investigated this substance in four different modifications.

Amorphous Silicium *.—For the experiments picked coherent pieces were used, which had stood for several days *in vacuo* over sulphuric acid.

Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·2.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grm.	grms.		grm.	
51·5	20·7	20·38	18·13	26·95	1·095	2·88	0·431	0·453	0·251
50·0	20·8	20·54	18·46	26·975	,,	,,	,,	,,	0·208
50·4	21·0	20·66	18·55	26·98	,,	,,	,,	,,	0·221
50·5	20·9	20·59	18·52	26·935	,,	2·87†	,,	,,	0·177
						Mean	.	. .	0·214

The very discordant results of these experiments are very little trustworthy; the quantity of silicium, 1 grm., was too small, and its thermal action inconsiderable as compared with that of the other substances immersed with it in the water of the calorimeter.

Graphitoidal Silicium ‡.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·7–17°·2.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·0	18·8	18·51	16·34	26·965	3·155	1·83	0·431	0·453	0·182
52·3	19·1	18·82	16·59	26·975	,,	,,	,,	,,	0·181
51·1	18·9	18·62	16·44	26·98	,,	,,	,,	,,	0·185
50·4	18·8	18·52	16·43	26·95	,,	1·81†	,,	,,	0·174
						Mean	.	. .	0·181

Crystallized Silicium.—Grey needles §.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·1.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·8	21·1	20·83	18·53	26·94	2·395	1·955	0·431	0·651	0·168
52·6	21·0	20·74	18·52	26·975	,,	,,	,,	,,	0·168
52·3	21·0	20·72	18·52	26·98	,,	,,	,,	,,	0·168
51·9	21·0	20·66	18·53	26·975	,,	1·935†	,,	,,	0·156
						Mean	.	. .	0·165

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* "Prepared from silicofluoride of potassium by means of sodium."—WÖHLER.

† After drying the stopper.

‡ "Obtained by melting silicofluoride of potassium, or sodium, with aluminium; the aluminium was then extracted with hot hydrochloric acid, and the oxide of silicium with fluoric acid."—WÖHLER.

§ "This silicium was prepared from the silicofluoride of potassium, or sodium, by sodium and zinc, and the lead (from the zinc) removed by nitric acid. Whether it was afterwards treated with hydrofluoric acid I cannot say, but probably so. It was quite unchanged when heated in the vapour of hydrochlorate of chloride of silicium (passed by means of hydrogen). Probably it contained, however, like all silicium reduced by zinc, a trace of iron, which appears when it is heated in chlorine. An experiment with another portion of such silicium gave, however, so little iron that its quantity could not be determined."—WÖHLER.

*Fused Silicium**.

Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·9–18°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·0	20·5	20·24	18·40	26·97	4·17	1·555	0·431	0·651	0·142
50·5	20·7	20·43	18·52	26·96	„	„	„	„	0·139
49·7	20·6	20·27	18·42	26·965	„	„	„	„	0·136
50·8	20·7	20·43	18·52	26.94	„	1·145†	„	„	0·136
							Mean . . .		0·138

38. *Tin*: reduced from the oxide, cast in small bars.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·8–18°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·4	19·8	19·46	17·14	26·965	14·835	1·385	0·431	0·651	0·0493
51·4	19·9	19·62	17·23	26·98	„	„	„	„	0·0539
51·3	20·0	19·72	17·34	26·95	„	„	„	„	0·0540
51·5	20·3	20·03	17·65	26·995	„	1·365†	„	„	0·0553
							Mean . . .		0·0531

II.—Experiments with Water. Glass 1. Temperature of the Air 15°·5–15°·9.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·1	17·5	17·24	14·13	26·975	14·62	1·595	1·000	0·651	0·0543
46·4	17·5	17·24	13·94	26·985	„	„	„	„	0·0571
45·6	17·6	17·34	14·14	26·99	„	„	„	„	0·0574
45·7	17·6	17·34	14·14	26·95	„	1·58†	„	„	0·0573
							Mean . . .		0·0565

The average of the means of these two series of observations gives 0·0548 as the specific heat of tin between 19° and 48° at 0·0548.

Platinum: several pieces of fused platinum and of thick platinum wire.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·8–18°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·5	20·4	20·14	17·23	26·96	23·625	2·225	0·431	0·651	0·0322
52·8	20·0	19·65	16·73	26·975	„	„	„	„	0·0335
51·5	20·0	19·73	16·95	26·96	„	„	„	„	0·0326
50·9	20·0	19·74	17·05	26·96	„	2·205†	„	„	0·0316

I have also made a few experiments with a piece of fused *iridium* which M. Heræus gave me.

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* Wöhler had obtained it from Deville; it formed a cylindrical piece.

† After drying the stopper.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·8–18°·2.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·8	19·5	19.24	16·93	26·995	16·66	2·04	0·431	0·453	0·0359
51·0	19·6	19·26	16·95	26·97	„	„	„	„	0·0391 ?
50·0	19·5	19·24	17·06	26·965	„	„	„	„	0·0357
50·5	19·6	19·34	17·13	26·93	„	2·03 *	„	„	0·0359

Excluding the second experiment, which is obviously uncertain, these determinations give 0·0358 as the specific heat of iridium. This iridium was not free from metals of smaller atomic weight and greater specific heat. For various specimens of impure iridium, REGNAULT (Ann. de Chim. et de Phys. [2] vol. lxxiii. p. 53; [3] vol. xlvi. p. 263; vol. lxiii. p. 16) found 0·0368, 0·0363, 0·0419, and for almost pure iridium 0·0326.

39. *Silver*: pure, cast in bars.

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·9–19°·1.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·1	21·1	20·82	18·15	26·975	21·51	1·585	0·431	0·453	0·0552
51·5	21·1	20·77	18·14	26·99	„	„	„	„	0·0557
51·4	20·9	20·62	17·94	26·98	„	„	„	„	0·0574
50·9	21·0	20·65	18·06	26·95	„	„	„	„	0·0557
51·0	21·1	20·83	18·25	26·965	„	1·565 *	„	„	0·0558
							Mean	. . .	0·0560

Copper.—Commercial copper wires †.

I.—Experiment with Naphtha A. Glass 1. Temperature of the Air 13°·2.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·3	15·9	15·64	12·64	26·985	16·505	1·675	0·431	0·651	0·0895
46·2	15·1	14·82	11·43	26·97	„	„	„	„	0·0949
45·7	15·2	14·91	11·63	26·97	„	„	„	„	0·0926
47·7	15·2	14·93	11·43	26·98	„	1·67 *	„	„	0·0930
							Mean	. . .	0·0925

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* After drying the stopper.

† With reference to what has been said in § 24, I here communicate a series of experiments (one of my earliest) where *t'* was much more above the temperature of the air than usual, and hence too small numbers were obtained for the specific heat of the substance in question.

Experiments with Naphtha A. Glass 2. Temperature 13°·8.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·6	16·5	16·23	13·02	26·98	18·33	1·96	0·431	0·487	0·0897
48·5	16·9	16·64	13·21	26·97	„	„	„	„	0·0870
43·7	16·5	16·15	13·21	26·98	„	1·95*	„	„	0·0867

* After drying the stopper.

II.—Experiments with Naphtha B. Glass 3. Temperature of the Air 19°·4–19°·0.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
55·0	21·9	21·62	18·06	26·96	19·725	1·56	0·419	0·453	0·0909
54·1	21·4	21·11	17·60	26·965	„	„	„	„	0·0906
53·6	21·2	20·86	17·36	26·99	„	„	„	„	0·0917
54·2	21·3	20·96	17·44	26·98	„	„	„	„	0·0902
51·7	21·2	20·85	17·55	26·965	„	1·545 *	„	„	0·0921
							Mean . . .		0·0911

III.—Experiments with Water. Glass 1. Temperature of the Air 18°·4–18°·7.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·7	20·8	20·50	16·17	26·95	18·26	1·625	1·000	0·651	0·0965
50·0	20·6	20·32	15·93	26·96	„	„	„	„	0·0958
49·5	20·8	20·50	16·22	26·93	„	„	„	„	0·0953
47·9	20·9	20·62	16·64	26·945	„	1·615 *	„	„	0·0934
							Mean . . .		0·0953

According to these determinations, the mean of the average results 0·0925, 0·0911, 0·0953, the number 0·093 represents the specific heat of copper between 20° and 50°.

40. *Lead*: reduced from sulphate of lead and cast in small bars.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·9–18°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·5	20·6	20·33	18·23	26·995	19·93	1·465	0·431	0·651	0·0308
50·5	20·7	20·43	18·35	26·975	„	„	„	„	0·0302
50·9	20·7	20·44	18·35	26·965	„	„	„	„	0·0293
50·5	20·6	20·32	18·24	26·94	„	1·445 *	„	„	0·0302
							Mean , . .		0·0301

II.—Experiments with Water. Glass 1. Temperature of the Air 15°·5–15°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·0	17·5	17·21	14·02	26·96	24·845	1·56	1·000	0·651	0·0325
45·3	17·6	17·32	14·23	26·985		„	„	„	0·0322
45·9	17·7	17·42	14·25	26·945	„	„	„	„	0·0329
46·1	17·9	17·61	14·43	26·985	„	1·55 *	„	„	0·0339
							Mean . . .		0·0329

The mean of the averages of both series of experiments, 0·0301 and 0·0329, gives for the specific heat of lead between 19° and 48° the number 0·0315

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* After drying the stopper.

Zinc: purified, cast in small bars.

I.—Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·8–18°·9.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·5	20·5	20·22	17·23	26·995	15·555	1·745	0·431	0·453	0·0899
51·1	20·3	19·95	16·96	26·985	„	„	„	„	0·0909
51·7	20·6	20·25	17·24	26·99	„	„	„	„	0·0905
50·9	20·5	20·23	17·25	26·945	„	1·72 *	„	„	0·0930
							Mean . . .		0·0911

II.—Experiments with Water. Glass 1. Temperature of the Air 16°·0–16°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
43·0	17·7	17·43	13·82	26·98	14·25	1·855	1·000	0·651	0·0943
43·1	18·1	17·84	14·26	26·965	„	„	„	„	0·0951
42·7	18·1	17·82	14·32	26·96	„	„	„	„	0·0933
42·7	18·4	18·05	14·54	26·99	„	„	„	„	0·0977
42·9	18·5	18·23	14·74	26·97	„	1·845 *	„	„	0·0956
							Mean . . .		0·0952

These determinations give 0·0932 as the mean of the means of the two series of determinations for the specific heat of zinc between 19° and 47°.

Cadmium: cast in small bars.

Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·9–19°·1.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·7	21·0	20·72	18·24	26·955	13·335	1·555	0·431	0·651	0·0542
51·6	20·9	20·56	18·23	26·97	„	„	„	„	0·0544
51·9	20·8	20·47	18·12	26·98	„	„	„	„	0·0538
52·3	20·8	20·52	18·14	26·975	„	1·535 *	„	„	0·0544
							Mean . . .		0·0542

Magnesium: metallic globules and masses comminuted†.

Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·6–19°1.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·3	20·6	20·32	17·74	26·995	3·485	1·42	0·431	0·651	0·249
51·8	20·6	20·26	17·83	26·97	„	„	„	„	0·240
51·0	20·6	20·33	17·94	26·99	„	„	„	„	0·247
51·6	21·0	20·72	18·33	26·96	„	1·40 *	„	„	0·244
							Mean . . .		0·245

* After drying the stopper.

† "The magnesium was prepared by the methods of DEVILLE and CARON, and WÖHLER. The reguline masses were not remelted, but treated with dilute hydrochloric acid, then washed with water and dried at a gentle temperature."—ENGELBACH.

Iron: pieces of iron wire.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·6	16·2	15·92	12·52	26·97	17·565	1·46	0·431	0·487	0·108
45·4	15·1	14·83	11·33	26·95	„	„	„	„	0·114
46·0	15·1	14·77	11·22	26·935	„	„	„	„	0·113
46·2	15·2	14·91	11·34	26·98	„	1·455 *	„	„	0·113
							Mean . . .		0·112

II.—Experiments with Water. Glass 1. Temperature of the Air 16°·8–17°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
43·2	18·8	18·46	15·02	26·985	15·57	1·425	1·000	0·651	0·111
42·9	19·1	18·84	15·47	26·975	„	„	„	„	0·112
43·6	19·3	19·04	15·62	26·99	„	„	„	„	0·111
42·5	19·3	19·01	15·72	26·985	„	1·42 *	„	„	0·113
							Mean . . .		0·112

The means of both series of experiments give for the specific heat of iron between 17° and 44° the number 0·112.

With reference to what has been said in § 24, the following series of experiments made at the beginning of my investigation are given, in which *t′* exceeded the ordinary temperature much more than usual, and hence the numbers for the specific heat of iron were found somewhat too small.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
48·1	16·4	16·12	12·73	26·93	15·57	1·185	0·431	0·651	0·111
44·5	16·3	15·97	13·03	26·905	„	„	„	„	0·106
45·7	16·6	16·26	13·23	26·97	„	„	„	„	0·106
47·0	16·7	16·43	13·23	26·96	„	1·17 *	„	„	0·103

Another source of error which may make the numbers for the specific heat of the substance investigated too small, has been discussed in § 18 and 24,—the circumstance, namely, that the substance may fill the glass so densely as to impede the circulation of the liquid, or make it impossible. This circumstance made the numbers for the specific heat of *chromium*, which were obtained from the following series of observations, too small. The chromium was reduced from chloride of chromium according to WÖHLER's method by means of zinc (Ann. der Chem. und Pharm. vol. cxi. p. 230); the heavy, finely crystalline powder deposits in the glass as a dense mass impeding the circulation. The following results were obtained:—

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* After drying the stopper.

Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·8–19°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grm.	grms.	grms.		grm.	
51·2	21·6	21·34	18·96	26·965	6·725	2·405	0·431	0·453	0·101
51·2	21·6	21·33	18·95	26·97	,,	,,	,,	,,	0·101
50·8	21·5	21·24	18·92	26·945	,,	,,	,,	,,	0·096
51·8	21·5	21·22	18·81	26·99	,,	2·36 [*]	,,	,,	0·101

As the atomic weight of chromium is somewhat smaller than that of iron, it is to be supposed that the specific heat of chromium is somewhat greater than that of iron.

Aluminium: a piece of a small bar[†].

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·6–18°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·3	20·9	20·64	18·03	26·98	5·916	1·45	0·431	0·453	0·197
51·9	20·7	20·44	17·83	26·995	,,	,,	,,	,,	0·200
52·2	20·9	20·62	17·95	26·97	,,	,,	,,	,,	0·207
51·0	20·8	20·47	17·93	26·975	,,	1·435 [*]	,,	,,	0·202
							Mean . . .		0·202

42. *Hemisulphide of Copper*, $\text{Ꞓu}_2\text{S}$[‡]. *Copper-glance* was investigated; a dense specimen with conchoidal fracture from Liberty Mine in Maryland and a crystallized specimen of unknown locality, which also I tested as to its purity.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·6	19·0	18·72	15·74	26·995	8·775	1·595	0·431	0·651	0·120
52·0	18·9	18·58	15·65	26·995	,,	,,	,,	,,	0·120
52·6	19·0	18·72	15·74	26·99	,,	,,	,,	,,	0·120
51·6	18·8	18·53	15·63	26·96	,,	1·58 [*]	,,	,,	0·120
							Mean . . .		0·120

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[*] After drying the stopper.

[†] "By remelting Paris aluminium, by which it became poorer in iron; contains probably still some iron and silicium."—WÖHLER.

[‡] All formulæ of compounds whose specific heat is discussed in the following are written under the assumption of the new atomic weights (see § 2).

Sulphide of Mercury, HgS. Pieces of a sublimed cake of cinnabar *.

Experiments with Naphtha A. Glass 1. Temperature of the Air 20°·3–21°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·9	22·2	21·94	19·79	26·95	13·44	1·565	0·431	0·651	0·0516
51·8	22·3	22·02	19·80	26·95	„	„	„	„	0·0523
51·2	22·4	22·05	19·92	26·98	„	„	„	„	0·0499
51·8	22·4	22·14	19·93	26·98	„	1·55 †	„	„	0·0528
							Mean . . .		0·0517

Sulphide of Zinc. Zn S. Fragments of crystals of black *Zinc-blende* from Bohemia.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·8	16·3	16·02	13·18	26·975	7·00	1·64	0·431	0·651	0·123
46·7	16·1	15·83	13·33	26·935	„	„	„	„	0·120
44·1	15·9	15·63	13·32	26·94	„	„	„	„	0·121
44·8	16·2	15·93	13·63	26·94	„	„	„	„	0·116
43·1	15·9	15·63	13·42	26·97	„	1·625 †	„	„	0·120
							Mean . . .		0·120

Sulphide of Lead, Pb S. Cleavage fragments of *Galena* from the Harz.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·5–14°·9.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·3	16·4	16·05	13·34	26·93	13·835	1·78	0·431	0·651	0·0486
48·6	16·4	16·05	13·54	26·975	„	„	„	„	0·0495
45·7	16·1	15·83	13·53	26·95	„	„	„	„	0·0489
48·4	16·2	15·94	13·44	26·925	„	1·765 †	„	„	0·0490
							Mean . . .		0·0490

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* This cinnabar was found, on being tested, to be free from admixed uncombined sulphur. In experiments with another specimen of beautiful crystalline appearance, I obtained considerably greater numbers for the specific heat.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·3–16°·6.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·0	18·5	18·23	15·72	26·975	9·805	1·72	0·431	0·651	0·0582
51·5	18·4	18·14	15·76	26·96	„	„	„	„	0·0557
52·0	18·4	18·13	15·73	26·99	„	„	„	„	0·0546
51·6	18·5	18·16	15·81	26·97	„	1·70†	„	„	0·0542

But the Naphtha which had been in contact with this cinnabar, left on evaporation a considerable quantity of sulphur, the admixture of which made the specific heat too large.

† After drying the stopper.

43. *Sulphide of Copper and Iron*, $\mathrm{Cu\,Fe\,S_2}$, or $\mathrm{Cu_{\frac{1}{2}}\,Fe_{\frac{1}{2}}\,S}$. Crystals and fragments of crystalline masses of *Copper pyrites* from Dillenburg.

Experiments with Water. Glass 1. Temperature of the Air 17°·2–17°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·5	19·1	18·82	15·22	26·975	7·365	1·825	1·000	0·651	0·128
48·0	19·4	19·12	15·44	26·985	,,	,,	,,	,,	0·135
47·6	19·5	19·23	15·65	26·975	,,	,,	,,	,,	0·131
48·1	19·6	19·25	15·64	26·985	,,	,,	,,	,,	0·128
47·6	19·5	19·23	15·64	26·94	,,	1·81*	,,	,,	0·133
							Mean	. . .	0·131

Bisulphide of Iron, $\mathrm{Fe\,S_2}$. Small crystals and crystalline fragments of *Iron pyrites* from Dillenburg.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·3.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·1	16·0	15·66	12·74	26·92	10·11	1·81	0·431	0·487	0·125
46·2	15·9	15·61	12·77	26·93	,,	,,	,,	,,	0·124
47·1	16·0	15·74	12·87	26·97	,,	,,	,,	,,	0·121
47·9	16·2	15·87	12·95	26·93	,,	1·795*	,,	,,	0·121
							Mean	. . .	0·123

II.—Experiments with Water. Glass 3. Temperature of the Air 17°·4–17°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·1	19·7	19·43	15·33	26·97	10·145	2·295	1·000	0·453	0·127
47·5	19·7	19·42	15·23	26·955	,,	,,	,,	,,	0·130
47·6	19·8	19·47	15·33	26·965	,,	,,	,,	,,	0·125
47·4	19·8	19·52	15·36	26·945	,,	2·28*	,,	,,	0·131
							Mean	. . .	0·128

The average of the means of both these series of experiments, 0·123 and 0·128, makes the specific heat of iron pyrites between 18° and 47°=0·126.

44. *Suboxide of Copper*, $\mathrm{Cu_2O}$. A crystalline fine-grained *Red copper-glance* of conchoidal fracture was used for investigation.

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* After drying the stopper.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·7.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·6	18·7	18·36	15·80	26·97	8·67	1·635	0·431	0·453	0·109
51·0	18·6	18·26	15·73	26·995	„	„	„	„	0·110
50·8	18·6	18·26	15·72	26·96	„	„	„	„	0·112
52·3	18·6	18·33	15·66	26·95	„	1·625 *	„	„	0·113
							Mean . . .		0·111

Oxide of Copper, CuO. Granular freshly ignited oxide of copper.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·1–17°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·1	19·2	18·86	16·23	26·965	6·295	1·85	0·431	0·651	0·123
52·0	19·3	18·95	16·23	26·985	„	„	„	„	0·126
51·1	19·4	19·11	16·43	26·94	„	„	„	„	0·132
50·8	19·4	19·07	16·43	26·97	„	1·83 *	„	„	0·131
							Mean . . .		0·128

Oxide of Lead, PbO. Larger pieces of litharge freed by the sieve from the finer particles.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·4–17°·6.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·5	19·1	18·83	16·51	26·965	10·17	2·11	0·431	0·453	0·0559
50·4	19·1	18·84	16·63	26·95	„	„	„	„	0·0532
49·2	19·0	18·73	16·56	26·98	„	„	„	„	0·0567
48·5	19·0	18·73	16·63	26·985	„	2·10 *	„	„	0·0554
							Mean . . .		0·0553

Oxide of Mercury, HgO. Crystalline pieces of *Mercurius præcipitatus per se*, freed by the sieve from finer particles.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·4–17°·6.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·1	19·3	19·03	16·64	26·985	8·45	1·925	0·431	0·651	0·0506
52·0	19·1	18·83	16·46	26·975	„	„		„	0·0547
51·5	19·1	18·83	16·53	26·935	„		„	„	0·0510
50·4	19·1	18·82	16·56	26·965	„	1·915 *	„	„	0·0557
							Mean . . .		0·0530

Hydrate of Magnesia, $\text{MgO}+\text{H}_2\text{O}$. Transparent cleavage laminæ of *Brucite* from Texas in Pennsylvania. Dried at 40°–50°.

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* After drying the stopper.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·9	19·4	19·13	16·02	26·985	3·59	2·29	0·431	0·453	0·318
52·2	19·5	19·23	16·12	26·99	„	„	„	„	0·314
48·2	19·3	19·04	16·32	26·95	„	„	„	„	0·305
49·2	19·6	19·32	16·53	26·985	„	2·27 *	„	„	0·310
							Mean . . .		0·312

45. *Spinelle*, $MgAl_2O_4$†. Transparent crystalline grains from Ceylon of octahedral form.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·6	13·8	13·52	10·88	26·925	5·025	1·325	0·431	0·651	0·202
44·1	13·5	13·23	10·68	26·965	„	„	„	„	0·204
46·0	13·8	13·46	10·84	26·96	„	„	„	„	0·193
44·8	13·9	13·55	11·04	26·975	„	1·32 *	„	„	0·193
							Mean . . .		0·198

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·7	14·1	13·83	11·47	26·935	5·025	1·265	0·431	0·487	0·195
46·1	13·8	13·54	11·14	26·95	„	„	„	„	0·193
46·2	13·2	12·85	10·33	26·975	„	„	„	„	0·205
48·0	13·8	13·45	10·93	26·95	„	1·26 *	„	„	0·190
							Mean . . .		0·196

I subsequently received another quantity of spinelle grains, also from Ceylon, and have made the following series of experiments with this material.

III.—Experiments with Naphtha A. Glass 1. Temperature of the Air 15°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·6	17·7	17·36	14·53	26·94	7·53	1·34	0·431	0·651	0·187
47·5	17·8	17·46	14·53	26·96	„	„	„	„	0·190
47·6	17·8	17·54	14·63	26·965	„	„	„	„	0·187
48·4	17·8	17·54	14·54	26·95	„	1·32 *	„	„	0·189
							Mean . . .		0·188

* After drying the stopper.

† Abich's analysis of red spinelle from Ceylon (Rammelsberg's 'Handbuch der Mineralchemie,' p. 161), gave the following results compared with those calculated by the above formula:—

	Al_2O_3.	Cr_2O_3.	MgO.	FeO.	SiO_2.	Total.
Analysis........	69·01	1·10	26·21	0·71	2·02	99·05
Calculation......	71·99	„	28·01	„	„	100·00

These determinations give as the average of the means of the three series of experiments (0·198, 0·196, and 0·188) 0·194 for the specific heat of spinelle between 15° and 46°.

Chrome Iron Ore, $\mathrm{Mg}_{\frac{1}{2}}\,\mathrm{Fe}_{\frac{1}{2}}\,\mathrm{Cr}_{\frac{3}{2}}\,\mathrm{Al}_{\frac{1}{2}}\,\mathrm{O}_4$*. Fragments of granular pieces, partly distinctly crystalline, of chrome iron ore from Baltimore.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·2–13°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·6	16·4	16·12	13·14	26·97	7·625	1·63	0·431	0·651	0·163
46·9	16·5	16·24	13·38	26·985	„	„	„	„	0·155
46·8	16·4	16·13	13·24	26·925	„	„	„	„	0·158
46·4	16·4	16·13	13·28	26·955	„	1·61 †	„	„	0·159
							Mean . . .		0·159

Magnetic Iron Ore, $\mathrm{Fe}_3\,\mathrm{O}_4$. Small crystals and crystalline fragments from Pfitsch in Tyrol.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·0.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·1	13·9	13·64	10·54	26·96	9·07	1·43	0·431	0·651	0·156
47·4	13·8	13·53	10·23	26·97	„	„	„	„	0·152
49·1	14·1	13·84	10·42	26·98	„	„	„	„	0·151
47·6	14·1	13·83	10·54	26·92	„	1·415 †	„	„	0·152
							Mean . . .		0·153

II.—Experiments with Water. Glass 3. Temperature of the Air 19°·5–19°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
43·5	21·6	21·32	18·02	26·985	10·625	1·925	1·000	0·453	0·159
42·7	21·6	21·32	18·13	26·99	„	„	„	„	0·160
43·0	21·6	21·33	18·12	26·97	„	1·91 †	„	„	0·158
							Mean . . .		0·159

These determinations give as the mean of the averages of the two sets of experiments, 0·156 for the specific heat of magnetic iron ore between 18° and 45°.

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* The admissibility of this formula for the ore investigated follows from the following comparison of the results calculated from it, with those which ABICH had obtained (RAMMELSBERG's 'Handbuch der Mineralchemie,' p. 172) by the analysis, *a* of compact, *b* of crystallized chrome iron ore from Baltimore.

		Cr_2O_3.	Al_2O_3.	Fe O.	Mg O.	Total.
Analysis	*a*	55·37	13·97	19·13	10·04	98·51
	b	60·04	11·85	20·13	7·45	99·47
Calculation		58·32	13·11	18·37	10·20	100·00

† After drying the stopper.

46. *Sesquioxide of Iron*, $Fe_2 \Theta_3$. Crystals and crystalline pieces of *specular iron* from St. Gotthard.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·4–12°·3.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·0	14·8	14·47	11·38	26·97	7·51	1·74	0·431	0·651	0·158
46·4	14·7	14·43	11·43	26·975	„	„	„	„	0·153
45·8	14·7	14·44	11·52	26·925	„	„	„	„	0·150
45·8	15·0	14·73	11·83	26·98	„	1·72 [*]	„	„	0·153
							Mean	. . .	0·154

II.—Experiments with Water. Glass 1. Temperature of the Air 19°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·1	21·5	21·17	17·81	26·97	8·845	1·935	1·000	0·651	0·161
43·6	21·6	21·26	18·01	26·985	„	„	„	„	0·158
42·5	21·5	21·23	18·12	26·985	„	„	„	„	0·159
42·8	21·6	21·33	18·22	26·98	„	1·92 [*]	„	„	0·157
							Mean	. . .	0·159

The specific heat of specular iron between 18° and 45°, according to these determinations, is 0·157, the mean of the averages of both series of experiments 0·154 and 0·159.

Iserine, $Fe_{\frac{5}{4}} Ti_{\frac{3}{4}} \Theta_3$ [†]. Indistinct crystalline grains from the Iserwiese in the Riesengebirge.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·2–13°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·6	17·1	16·77	13·43	26·975	11·145	1·415	0·431	0·487	0·176
47·0	16·7	16·43	12·97	26·98	„	„	„	„	0·178
46·5	16·6	16·33	12·93	26·93	„	„	„	„	0·176
47·0	16·9	16·56	13·15	26·98	„	1·39 [*]	„	„	0·177
							Mean	. . .	0·177

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[*] After drying the stopper.

[†] This formula corresponds to the composition assumed by RAMMELSBERG (Handbuch der Mineralchemie, pp. 413, 1015) for iserine from the Iserwiese, namely, 3 $(FeO\ Ti\ O_2)+Fe_2\ O_3$.

Oxide of Chromium, $\mathrm{Cr}_2\mathrm{O}_3$. Crystalline crusts prepared from oxychloride of chromium.

Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·1	21·5	21·23	18·53	26·955	5·405	2·255	0·431	0·453	0·176
51·5	21·2	20·93	18·22	26·955	„	„	„	„	0·181
53·1	21·4	21·06	18·25	26·945	„	„	„	„	0·178
52·1	21·2	20·94	18·23	26·99	„	2·245 *	„	„	0·175
							Mean . . .		0·177

Hydrated Sesquioxide of Manganese $\mathrm{Mn}_2\mathrm{O}_3+\mathrm{H}_2\mathrm{O}$ †. Fragments of good crystals of *Manganite* from Ihlefeld in the Harz, dried at 40° to 50°.

Experiments with Naphtha A. Glass 3. Temperature of the Air 14°·6–14°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·0	17·1	16·82	13·83	26·985	8·31	1·855	0·431	0·453	0·174
45·6	17·0	16·69	13·83	26·94	„	„	„	„	0·173
45·7	17·0	16·73	13·85	26·92	„	1·845*	„	„	0·174
							Mean . . .		0·174

I made subsequently another series of experiments with a specimen from the same locality dried at the ordinary temperature.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·7–17°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·0	20·5	20·15	17·06	26·95	8·04	1·77	0·431	0·453	0·178
52·3	20·3	20·02	16·86	26·975	„	„	„	„	0·180
51·9	20·1	19·77	16·65	26·965	„	„	„	„	0·178
51·6	20·1	19·84	16·80	26·995	„	1·75*	„	„	0·174
							Mean . . .		0·178

The specific heat of manganite between 19° and 49° is 0·176, the mean of the averages of both series of determinations.

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* After drying the stopper.

† "Manganite dried at about 80°–90°, and then kept for half a day over sulphuric acid, gave in a water-determination, in which the water was collected in a chloride of calcium tube, 9·96 per cent. of water."—KNOP. The above formula requires 10·23 per cent. of water.

47. *Binoxide of Manganese*, $\text{Mn}\,\Theta_2$. Pyrolusite from Ilmenau, dried at 100°–110°[*].

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·4–14°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·6	17·0	16·70	13·41	26·955	6·32	2·06	0·431	0·651	0·162
48·5	16·9	16·63	13·63	26·945	„	„	„	„	0·161
45·9	16·9	16·61	13·86	26·93	„	„	„	„	0·161
44·0	16·9	16·64	14·13	26·97	„	2·04[†]	„	„	0·153
							Mean . . .		0·159

Titanic Acid, $\text{Ti}\,\Theta_2$. I have investigated the one quadratic modification, rutile, and the rhombic modification Brookite or Arkansite; I had no material for the investigation of anatase, the other quadratic modification.

Rutile. Fragments of crystals from Saxony and from France.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·5–13°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·9	16·0	15·73	12·63	26·95	8·055	1·60	0·431	0·651	0·159
47·6	16·1	15·78	12·73	26·97	„	„	„	„	0·158
45·2	15·9	15·56	12·73	26·965	„	„	„	„	0·156
45·6	16·1	15·84	13·01	26·965	„	1·58[†]	„	„	0·156
							Mean . . .		0·157

Brookite or Arkansite. Beautiful small crystals from hotsprings in Arkansas, purified by treatment with hydrochloric acid from adherent oxide of iron.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·1–16°·3.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·1	18·2	17·94	15·22	26·97	8·00	1·415	0·431	0·651	0·160
49·3	18·5	18·23	15·22	26·96	„	„	„	„	0·161
49·2	18·7	18·40	15·52	26·935	„	„	„	„	0·160
49·0	18·6	18·31	15·43	26·96	„	1·395[†]	„	„	0·163
							Mean . . .		0·161

[*] This pyrolusite was not pure binoxide, but probably contained some manganite also. In experiments made by Mr. Oeser in the Giessen laboratory, this pyrolusite, dried at 100° to 110°, gave, when heated in a current of dry air, the water being collected in a chloride of calcium apparatus, 1·21 per cent. of water; treated with oxalic acid, as much carbonic acid was disengaged as corresponded to 95·36 per cent. of binoxide. As the specific heat of manganite (0·176) does not very much differ from that found for pyrolusite (0·159), I neglected to introduce a correction for the small quantity of manganite.

[†] After drying the stopper.

Binoxide of Tin, $Sn\,\Theta_2$. Fragments of crystals of tinstone from Saxony.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·4	17·0	16·66	13·52	26·99	14·495	1·71	0·431	0·487	0·0906
46·6	16·4	16·14	13·33	26·925	„	„	„	„	0·0884
45·1	16·4	16·05	13·35	26·96	„	„	„	„	0·0905
45·7	16·3	16·04	13·32	26·98	„	1·695 *	„	„	0·0882
							Mean . . .		0·0894

48. *Silicic Acid*, $Si\,\Theta_2$. Pieces of transparent quartz (rock-crystal) from the Grimsel.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·7–17°·4.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·8	20·1	19·83	17·03	26·99	4·885	1·58	0·431	0·651	0·186
52·5	19·8	19·53	16·77	26·96	„	„	„	„	0·193
51·8	19·7	19·43	16·77	26·98	„	„	„	„	0·185
51·7	19·7	19·42	16·76	26·945	„	„	„	„	0·186
52·7	19·7	19·35	16·64	26·96	„	1·56 *	„	„	0·182
							Mean . . .		0·186

II.—Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·1–19°·4.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·5	21·0	20·74	18·36	26·985	5·135	1·635	0·431	0·453	0·185
51·0	21·1	20·79	18·45	26·96	„	„	„	„	0·185
52·6	21·2	20·92	18·45	26·955	„	„	„	„	0·187
52·6	21·2	20·89	18·42	26·97	„	1·62 *	„	„	0·189
							Mean . . .		0·187

III.—Experiments with Naphtha B. Glass 3. Temperature of the Air 17°·8–17°·9.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·0	20·0	19·69	17·27	26·98	5·645	1·70	0·419	0·453	0·175
50·5	19·9	19·64	17·14	26·97	„	„	„	„	0·184
50·0	20·1	19·82	17·40	26·99	„	„	„	„	0·181
50·0	20·0	19·66	17·22	26·975	„	1·685 *	„	„	0·178
							Mean . . .		0·180

* After drying the stopper.

IV.—Experiments with Water. Glass 1. Temperature of the Air 17°·8–18°·3.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·6	19·7	19·37	15·72	26·945	5·02	1·93	1·000	0·651	0·188
47·9	19·9	19·57	15·92	26·95	,,	,,	,,	,,	0·186
47·6	20·0	19·65	16·03	26·985	,,	,,	,,	,,	0·191
47·3	20·0	19·67	16·08	26·98	,,	1·915 *	,,	,,	0·196
							Mean	. . .	0·190

The average of these four means, 0·186, 0·187, 0·180, 0·190, gives 0·186 as the specific heat of quartz between 20° and 50°.

It was interesting to determine also the specific heat of amorphous silicic acid. I accordingly made experiments with opal and with hyalite, taking into account the water contained in these minerals. If the quantity of silica in the mineral taken is m, that of the water in it w, and z the specific heat of the water contained in the mineral, then, taking the other symbols in the sense hitherto assigned to them, the specific heat of the silica in the mineral can be calculated by the formula

$$\text{sp. H} = \frac{M(t'-t)-(x+fy+wz)(T-T')}{m(T-T')}.$$

But though the quantity of water contained in the (air-dried) minerals investigated is so small (scarcely exceeding 4 per cent.), the specific heat of silicic acid is found to be very different, according as (α) the specific heat z is put equal to 1, that of liquid water, (β) or equal to 0·48, that of solid water or ice (which is at least correct for far the greater part of the water of these minerals, *vide* § 97). I give as follows, under α and β, the numbers resulting from both calculations.

Noble Opal from Honduras: yellowish, colourless in small pieces. The air-dried mineral contained 4·3 per cent. of water; in the following experiments 4·12 grms. of opal were used, containing, therefore, 3·943 grms. of anhydrous substances (m) and 0·177 grm. of water (w).

Experiments with Naphtha B. Glass 3. Temperature of the Air 18°·5–18°·7.

T.	T′.	t′.	t.	M.	m.	w.	f.	y.	x.	sp. H.	
°	°	°	°	grms.	grms.	grm.	grm.		grm.	α.	β.
50·4	20·6	20·34	18·10	26·98	3·943	0·177	1·69	0·419	0·453	0·175	0·198
52·6	20·6	20·32	17·84	26·985	,,	,,	,,	,,	,,	0·191	0·214
51·9	20·6	20·32	17·92	26·98	,,	,,	,,	,,	,,	0·185	0·209
51·3	20·6	20·32	17·96	26·955	,,	,,	1·67 *	,,	,,	0·188	0·211
								Mean	. . .	0·185	0·208

Hyalite from Steinheim near Hanau. Small limpid spheroidal masses. The air-dried mineral contained 3·65 per cent. of water. In the following experiments 3·795

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* After drying the stopper.

grms. of hyalite were used, which therefore contained 3·656 grms. of anhydrous substance (*m*) and 0·139 grm. of water (*w*).

Experiments with Naphtha B. Glass 1. Temperature of the Air 17°·8–17°·9.

T.	T'.	*t'*.	*t*.	M.	*m*.	*w*.	*f*.	*y*.	*x*.	sp. H.	
°	°	°	°	grms.	grms.	grm.	grm.		grm.	*α*.	*β*.
50·4	19·8	19·50	17·26	26·98	3·656	0·139	1·345	0·419	0·651	0·170	0·190
50·8	19·8	19·51	17·23	26·98	„	„	„	„	„	0·172	0·192
50·4	19·8	19·53	17·27	26·97	„	„	„	„	„	0·175	0·194
51·4	19·8	19·53	17·21	26·98	„	„	1·33*	„	„	0·173	0·193
							Mean . . .			0·173	0·192

In another series of experiments 4·475 grms. of hyalite were used, containing 4·312 grms. anhydrous substance (*m*) and 0·163 grm. water (*w*).

Experiments with Water. Glass 1. Temperature of the Air 17°·1–17°·2.

T.	T'.	*t'*.	*t*.	M.	*m*.	*w*.	*f*.	*y*.	*x*.	sp. H.	
°	°	°	°	grms.	grms.	grm.	grm.		grm.	*α*.	*β*.
43·5	18·9	18·55	15·41	26·97	4·312	0·163	1·88	1·000	0·651	0·174	0·193
42·7	19·1	18·83	15·79	26·99	„	„	„	„	„	0·182	0·201
42·7	19·2	18·87	15·84	26·955	„	„	„	„	„	0·181	0·201
42·9	19·2	18·94	15·92	26·955	„	„	1·865*	„	„	0·175	0·195
							Mean . . .			0·178	0·197

The specific heat of amorphous silica must lie between the numbers standing under *α* and *β*, and coming nearer those under *β*. It does not seem to differ materially from that found for crystallized silica.

49. *Molybdic Acid*, Mo Θ_3. Greyish-white powder, which, when heated in a porcelain crucible, became permanently bright grey: the results are not trustworthy.

Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·5–20°·1.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·4	20·9	20·64	18·44	26·99	2·27	2·65	0·431	0·453	0·155
51·3	21·3	21·04	18·88	26·97	„	„	„	„	0·153
51·5	21·4	21·12	18·94	26·995	„	„	„	„	0·159
51·2	21·4	21·06	18·93	26·96	„	2·635*	„	„	0·149
							Mean . . .		0·154

* After drying the stopper.

Tungstic Acid, $\mathrm{W\!\!\!\!-}\,\Theta_3$. Yellow powder.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·5–20°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·1	21·3	21·02	18·60	26·98	6·89	1·965	0·431	0·651	0·0902
52·8	21·5	21·16	18·73	26·99	„	„	„	„	0·0868
50·5	21·4	21·14	18·84	26·965	„	„	„	„	0·0919
51·9	21·6	21·29	18·93	26·985	„	1·95*	„	„	0·0886
							Mean . . .		0·0894

Of the above pulverulent metallic acids only small quantities were used, and their thermal action was only a small proportion of the whole thermal action observed. The results can only be considered as approximations to the true specific heat.

50. *Chloride of Sodium*, Na Cl. Pure chloride of sodium fused.

Experiments with Naphtha A. Glass 1. Temperature of the Air 10°·9–11°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·8	12·3	11·97	9·34	26·91	3·65	1·57	0·431	0·651	0·215
45·5	12·7	12·44	9·88	26·94	„	„	„	„	0·212
45·7	13·0	12·74	10·20	26·99	„	1·56*	„	„	0·212
							Mean . . .		0·213

Almost clear pieces of rock-salt, sharply dried.

Experiments with Naphtha A. Glass 2. Temperature of the Air 10°·9–11°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·8	12·6	12·32	9·63	26·95	3·955	2·025	0·431	0·487	0·225
45·8	13·0	12·73	10·04	26·935	„	„	„	„	0·214
44·6	13·3	13·01	10·43	26·95	„	2·015 *	„	„	0·219
							Mean . . .		0·219

Chloride of Potassium, K Cl. Pure salt fused †.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·1–12°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·3	14·0	13·73	11·24	26·98	3·665	2·265	0·431	0·487	0·168
45·7	14·2	13·86	11·44	26·99	„	„	„	„	0·167

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* After drying the stopper.

† These experiments with fused chloride are more trustworthy than those with crystallized salt, which, however, are very near; for the latter, in loose crystals, only in small quantity, filled the glass used in the determinations. The experiments with sharply dried crystallized chloride of potassium gave the following results:—

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 10°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·0	12·7	12·41	9·98	26·95	3·685	1·915	0·431	0·487	0·178
45·6	12·8	12·53	10·15	26·96	„	„	„	„	0·175
46·4	13·0	12·74	10·34	26·955	„	„	„	„	0·169
45·0	12·9	12·64	10·34	26·975	„	1·90 *	„	„	0·170

The mean of the preceding six determinations gives 0·171 as the specific heat of chloride of potassium between 13° and 46°.

Chloride of Rubidium, Rb Cl. Pure salt fused.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·3–14°·5.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·9	16·1	15·84	13·64	26·96	5·22	1·835	0·431	0·487	0·112
46·0	16·2	15·92	13·83	26·975	„	„	„	„	0·118
44·3	16·2	15·93	14·00	26·94	„	„	„	„	0·110
43·8	16·4	16·13	14·26	26·98	„	1·82*	„	„	0·109
						Mean . . .			0·112

51. *Chloride of Ammonium*, NH$_4$ Cl. I have made five series of experiments with different forms of this salt.

Chloride of Ammonium, crystallized from pure aqueous solution in very small octahedra.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·1–11°·8

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grm.	grms.		grm.	
51·3	13·7	13·43	10·39	26·96	1·445	2·255	0·431	0·651	0·387
44·9	13·7	13·44	10·93	26·99	„	„	„	„	0·380
44·6	14·0	13·70	11·26	26·905	„	2·245*	„	„	0·365
						Mean . . .			0·377

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·1–12°·2.

T.	T′	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·1	13·7	13·39	11·11	26·945	1·795	2·485	0·431	0·651	0·166
47·0	14·1	13·84	11·42	26·96	„	„	„	„	0·145

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·9.

45·6	14·5	14·22	11·90	26·945	2·365	2·125	0·431	0·651	0·187
45·7	14·4	14·14	11·90	26·98	„	„	„	„	0·154
46·5	14·7	14·43	12·14	26·955	„	2·115*	„	„	0·160

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* After drying the stopper.

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·9.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grm.	grms.		grm.	
47·0	14·5	14·24	11·45	26·93	1·88	2·495	0·431	0·487	0·399
45·0	14·8	14·46	11·93	26·98	„	„	„	„	0·371
45·1	14·8	14·46	11·93	26·99	„	2·485*	„	„	0·370
						Mean . . .			0·380

Only a small quantity of this finely crystallized chloride of ammonium goes into the glasses which I used for the experiments. Hence I also investigated chloride of ammonium in more compact pieces.

Long fibrous pieces from a sublimation cake:

III.—Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·1–11°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·5	13·9	13·63	10·73	26·97	2·76	2·20	0·431	0·487	0·377
45·1	14·2	13·92	11·07	26·97	„	„	„	„	0·381
44·2	14·2	13·93	11·20	26·98	„	2·19*	„	„	0·371
						Mean . . .			0·376

From the so-called "gas liquor," NOELLNER has prepared a very pure chloride of ammonium, apparently in quadratic trapezoedra. With such crystals, 8 to 10 millims. long, I made the following determinations:—

IV.—Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·1–13°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grm.	grms.		grm.	
48·5	15·9	15·63	12·84	26·99	1·978	2·085	0·431	0·651	0·384
44·7	16·0	15·73	13·32	26·93	„	„	„	„	0·360
44·8	16·0	15·70	13·32	26·97	„	2·075*	„	„	0·346
						Mean . . .			0·363

Finally, I examined chloride of ammonium which had crystallized, from a solution containing urea, in beautiful transparent cubes of 2 to 3 millims. in the side.

V.—Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·1–13°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·2	16·0	15·73	13·05	26·92	2·595	2·34	0·431	0·487	0·376
44·4	16·1	15·83	13·25	26·975	„	„	„	„	0·371
45·7	16·4	16·08	13·45	26·96	„	2·33*	„	„	0·358
						Mean . . .			0·368

The mean of the means of the five series of determinations, 0·377, 0·380, 0·376, 0·363, 0·368, gives 0·373 for the specific heat of chloride of ammonium between 15° and 45°.

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* After drying the stopper.

52. *Chloride of Mercury*, $\mathrm{Hg\,Cl_2}$. Well-dried crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 9°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·2	11·5	11·17	8·86	26·985	6·07	1·885	0·431	0·651	0·0636
44·3	11·2	10·90	8·50	26·99	„	2·105*	„	„	0·0657
46·1	11·5	11·21	8·72	26·915	„	2·10†	„	„	0·0628
							Mean . . .		0·0640

Chloride of Magnesium, $\mathrm{Mg\,Cl_2}$. Pieces of a beautiful preparation which had solidified with crystalline structure after being melted.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·5	14·8	14·53	12·13	26·98	2·235	2·01	0·431	0·651	0·207
46·4	15·0	14·72	12·43	26·98	„	„	„	„	0·201
45·6	15·1	14·84	12·63	26·96	„	2·115*	„	„	0·175
46·9	15·3	15·03	12·73	26·945	„	2·105†	„	„	0·180
							Mean . . .		0·191

Chloride of Barium, $\mathrm{Ba\,Cl_2}$. Pieces of a specimen which was of a dead white colour after solidifying.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·2	16·2	15·87	13·64	26·975	6·795	1·72	0·431	0·651	0·0902
48·0	16·3	16·02	13·64	26·96	„	„	„	„	0·0930
47·1	16·3	16·03	13·73	26·945	„	„	„	„	0·0912
46·4	16·2	15·94	13·73	26·97	„	1·705†	„	„	0·0865
							Mean . . .		0·0902

Crystallized Chloride of Barium, $\mathrm{Ba\,Cl_2 + 2H_2O}$. Crystals dried *in vacuo*.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·1–16°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·5	17·6	17·34	15·04	26·975	5·055	2·14	0·431	0·453	0·168
47·1	17·8	17·50	15·03	26·955	„	„	„	„	0·177
47·0	18·0	17·74	15·33	26·975	„	„	„	„	0·171
46·2	18·2	17·94	15·63	26·965	„	2·125†	„	„	0·169
							Mean . . .		0·171

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* After adding some more naphtha. (The naphtha was apparently sucked up by the crystals of chloride of mercury, hence more naphtha was added. The liquid formed a smeary border at the side of the glass, but there was no deliquescence of the crystals in the naphtha.)

† After drying the stopper.

Chloride of Chromium, $\mathrm{Cr_2\,Cl_6}$. Violet insoluble chloride of chromium twice boiled out with water, washed and dried at 130°. As a porous mass this substance is but ill suited for an accurate determination of the specific heat. I pressed it, by means of a glass rod, in a glass tube into small disks, between which the naphtha could circulate. The object of this is to prevent a stagnation of the liquid absorbed by the solid mass, in consequence of which the water of the calorimeter assumes its maximum more slowly, and hence the specific heat is found too low (compare §§ 18 & 24); but this object is not quite attained in this way[*].

Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·4–11°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·5	13·2	12·86	10·32	26·93	3·165	2·095	0·431	0·651	0·139
47·5	13·0	12·73	10·13	26·97	,,	,,	,,	,,	0·151
43·8	12·9	12·63	10·33	26·945	,,	,,	,,	,,	0·143
46·0	13·0	12·65	10·21	26·94	,,	2·085[†]	,,	,,	0·140
							Mean	. . .	0·143

I should have liked to determine the specific heat of a solid metallic chloride of the formula $\mathrm{R\,Cl_3}$, and tried with chloride of antimony, but it coloured naphtha yellow when poured upon it, and became itself milky white, forming a heavy layer below the naphtha, and fused completely a little above 40°.

53. *Chloride of Zinc and Chloride of Potassium*, $\mathrm{Zn\,K_2\,Cl_4}$. Crystals dried at 100° to 110°[‡].

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·3–14°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
48·7	16·2	15·93	13·53	26·915	3·01	2·02	0·431	0·651	0·155
47·1	16·3	16·04	13·77	26·965	,,	,,	,,	,,	0·155
46·5	16·4	16·12	13·92	26·955	,,	,,	,,	,,	0·150
44·1	16·4	16·14	14·13	26·94	,,	2·00[†]	,,	,,	0·147
							Mean	. . .	0·152

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[*] The above source of error was of more importance, and the experiments gave far lower numbers for the specific heat of chloride of chromium when this body was not formed in disks, but just placed in the vessel and moderately lightly pressed. The following results were obtained in this manner:—

Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·4	13·4	13·12	10·52	26·915	2·425	3·035	0·431	0·487	0·134
45·6	13·8	13·53	11·04	26·985	,,	,,	,,	,,	0·131
45·7	13·8	13·52	11·02	26·99	,,	,,	,,	,,	0·132
45·6	13·8	13·48	11·02	26·95	,,	3·015[†]	,,	,,	0·123

[†] After drying the stopper.

[‡] “These crystals were deposited from a solution which contained for one equivalent of chloride of potassium

Hydrated Chloride of Copper and Potassium, $\text{Ꞓu}\,K_2\,Cl_4+2H_2\,\Theta$. Air-dried crystals.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·0–17°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·4	19·1	18·80	16·33	26·95	4·085	1·86	0·431	0·453	0·197
50·4	19·0	18·66	16·26	26·94	„	„	„	„	0·197
50·0	19·1	18·77	16·43	26·955	„	„	„	„	0·193
49·2	19·0	18·68	16·35	26·95	„	1·84*	„	„	0·204
							Mean . . .		0·197

Chloride of Tin and Potassium, $Sn\,K_2\,Cl_6$. Crystals dried at 105°.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·4–17°·3.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·1	18·3	17·97	15·70	26·96	5·305	1·77	0·431	0·453	0·134
51·1	18·7	18·42	16·12	26·93	„	„	„	„	0·131
49·5	18·7	18·36	16·19	26·955	„	„	„	„	0·129
49·1	18·8	18·52	16·34	26·965	„	1·76*	„	„	0·137
							Mean . . .		0·133

Chloride of Platinum and Potassium, $Pt\,K_2\,Cl_6$. Well-formed small crystals.

Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·5–11°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·3	13·2	12·91	10·55	26·93	7·25	1·55	0·431	0·487	0·122
46·1	13·4	13·06	10·67	26·975	„	„	„	„	0·113
47·9	13·5	13·18	10·68	26·975	„	„	„	„	0·111
48·1	13·5	13·23	10·76	26·98	„	1·535*	„	„	0·107
							Mean . . .		0·113

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at least two equivalents of chloride of zinc. In the analyses (the potassium was not determined) there were—

Found........ 24·0 per cent. Zinc, 49·3 and 49·6 Cl.
Calculated .... 22·85 per cent. Zn, 49·75 per cent. Cl, and 27·40 K.

"The crystals were only pressed between paper, and hence were impregnated with some mother-liquor, which explains the excess of zinc found."—Engelbach.

* After drying the stopper.

54. *Fluoride of Calcium*, $\mathrm{Ca\,Fl_2}$. Cleavage pieces of fluor-spar from Münsterthal in Baden.

Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·4–19·1.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·5	20·7	20·42	17·67	26·985	5·675	1·56	0·431	0·651	0·206
49·9	20·4	20·07	17·33	26·94	„	„	„	„	0·208
50·1	20·5	20·22	17·43	26·97	„	„	„	„	0·215
49·9	20·6	20·26	17·53	26·965	„	„	„	„	0·209
50·5	20·8	20·49	17·75	26·98	„	1·54*	„	„	0·207
							Mean . . .		0·209

Cryolite, $\mathrm{Al\,Na_3\,Fl_6}$. Comminuted cryolite from Greenland, smartly dried.

Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·2–19°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·6	21·5	21·21	18·44	26·975	5·55	1·775	0·431	0·453	0·243
50·0	21·5	21·15	18·43	26·965	„	„	„	„	0·244
49·6	21·5	21·17	18·53	26·965	„	„	„	„	0·237
50·6	21·6	21·27	18·56	26·985	„	„	„	„	0·235
51·0	21·6	21·34	18·62	26·99	„	1·75*	„	„	0·232
							Mean . . .		0·238

55. *Cyanide of Mercury*, $\mathrm{Hg\,C_2\,N_2}$. Well-dried crystals.

Experiments with Naphtha A. Glass 2. Temperature of the Air 9°·2.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·2	11·2	10·86	8·34	26·935	6·555	1·955	0·431	0·487	0·100
47·0	11·5	11·23	8·62	26·965	„	„	„	„	0·098
49·5	11·7	11·43	8·64	26·955	„	„	„	„	0·099
43·7	11·5	11·22	8·84	26·95	„	1·94*	„	„	0·101
							Mean . . .		0·100

Cyanide of Zinc and Potassium, $\mathrm{Zn\,K_2\,C_4\,N_4}$. Distinct crystals. I made four series of experiments with this substance.

Crystals dried *in vacuo*.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·8–11°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·9	13·8	13·53	11·13	26·96	2·515	2·195	0·431	0·487	0·257
48·0	13·9	13·64	11·13	26·93	„	„	„	„	0·218
46·9	13·9	13·57	11·12	26·94	„	„	„	„	0·225
45·0	13·9	13·63	11·34	26·975	„	2·175*	„	„	0·223
							Mean . . .		0·231

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* After drying the stopper.

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·4–12°·3.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·5	14·5	14·15	11·83	26·97	2·465	2·225	0·431	0·487	0·232
46·7	14·5	14·22	11·74	26·97	„	„	„	„	0·256
45·2	14·3	13·96	11·72	26·945	„	2·17[*]	„	„	0·215
45·2	14·5	14·23	11·95	26·92	„	„	„	„	0·234
							Mean	. . .	0·234

Crystals dried at 100°.

III.—Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·8–11°·5.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·6	13·5	13·20	10·74	26·955	2·415	1·665	0·431	0·651	0·263
48·5	13·8	13·53	10·96	26·99	„	„	„	„	0·261
44·3	13·6	13·26	11·05	26·99	„	„	„	„	0·238
45·2	13·6	13·32	11·04	26·93	„	1·655[†]	„	„	0·240
							Mean	. . .	0·251

IV.—Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·2–11·3.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·4	13·3	13·04	10·43	26·94	2·255	1·78	0·431	0·651	0·235
46·7	13·4	13·11	10·62	26·98	„	„	„	„	0·266
49·2	13·6	13·33	10·72	26·955	„	„	„	„	0·247
48·0	13·5	13·22	10·73	26·97	„	1·765[†]	„	„	0·237
							Mean	. . .	0·246

The specific heat of cyanide of zinc and potassium between 14° and 46° is 0·241 as the mean of the averages of the four series of determinations, 0·231, 0·234, 0·251, 0·246.

Crystallized Ferrocyanide of Potassium, $\mathrm{Fe\,K_4\,C_6\,N_6+3\,H_2\,O}$. Fragments of air-dried crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·6	21·3	21·03	18·46	26·98	3·425	1·69	0·431	0·651	0·288
51·3	21·1	20·82	18·22	26·98	„	„	„	„	0·275
51·0	21·0	20·74	18·14	26·97	„	„	„	„	0·280
51·0	21·1	20·84	18·26	26·965	„	1·675[†]	„	„	0·278
							Mean	. . .	0·280

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[*] After removing some naphtha on the stopper.

[†] After drying the stopper.

Ferridcyanide of Potassium, $\mathrm{Fe\,K_3\,C_6\,N_6}$. Well-formed crystals, smartly dried.

Experiments with Naphtha A. Glass 2. Temperature 13°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
48·5	15·3	15·01	12·23	26·95	3·63	2·025	0·431	0·487	0·247
45·1	15·0	14·66	12·20	26·92	„	„	„	„	0·232
47·1	15·5	15·23	12·68	26·975	„	„	„	„	0·225
44·4	15·3	15·00	12·64	26·98	„	2·015*	„	„	0·229
						Mean	.	. .	0·233

56. *Nitrate of Soda*, $\mathrm{Na\,N\Theta_3}$. Crystallized salt, briskly dried.

Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·2	14·3	13·95	11·02	26·91	3·645	2·25	0·431	0·487	0·258
46·2	14·9	14·55	11·82	26·945	„	„	„	„	0·245
46·5	14·3	14·02	11·13	26·93	„	„	„	„	0·263
44·3	14·1	13·84	11·15	26·945	„	2·235*	„	„	0·261
						Mean	.	. .	0·257

Fused Salt.

Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·8	13·9	13·62	10·57	26·98	3·92	1·66	0·431	0·651	0·271
43·9	14·3	14·03	11·43	26·065	„	„	„	„	0·256
43·6	14·6	14·33	11·83	26·925	„	„	„	„	0·243
46·4	14·5	14·22	11·43	26·965	„	1·65*	„	„	0·254
						Mean	.	. .	0·256

Nitrate of Potass, $\mathrm{K\,N\,\Theta_3}$. Smartly dried crystallized salt.

Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·1–12°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·2	14·2	13·88	11·43	26·93	3·105	1·845	0·431	0·651	0·242
46·5	14·4	14·14	11·56	26·99	„	„	„	„	0·233
45·6	14·3	14·03	11·53	26·97	„	„	„	„	0·228
44·7	14·0	13·74	11·31	26·98	„	1·83*	„	„	0·224
						Mean	.	. .	0·232

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* After drying the stopper.

Fused Salt.

Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·1–12°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·6	14·5	14·20	11·53	26·94	3·745	2·035	0·431	0·487	0·234
45·9	14·4	14·14	11·56	26·935	„	„	„	„	0·225
46·1	14·3	14·03	11·44	26·96	„	„	„	„	0·222
44·7	14·1	13·83	11·32	26·96	„	2·02*	„	„	0·228
							Mean	. . .	0·227

57. *Nitrate of Ammonia*, $N_2H_4\Theta_3$. Vitreous transparent pointed crystals, like those of nitre; dried *in vacuo* over sulphuric acid.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 10°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
32·3	12·7	12·43	10·53	26·92	2·555	2·41	0·431	0·487	0·424
31·1	12·8	12·52	10·66	26·945	„	„	„	„	0·475
29·2	12·6	12·33	10·63	26·92	„	„	„	„	0·482
33·5	13·1	12·81	10·74	26·93	„	2·405*	„	„	0·473
							Mean	. . .	0·463

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·4–15°·0.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
32·4	15·9	15·57	14·02	26·96	2·025	2·29	0·431	0·487	0·455
30·8	15·7	15·44	14·03	26·975	„	„	„	„	0·449
31·5	16·0	15·66	14·23	26·95	„	„	„	„	0·435
32·9	16·2	15·93	14·37	26·97	„	„	„	„	0·449
							Mean	. . .	0·447

The specific heat of nitrate of ammonia between 14° and 31° is as the mean of the averages of both series of experiments, 0·463 and 0·447, =0·455. The crystals were quite unchanged at this temperature. In these experiments the difference of temperature T−T′ was but small, and it would not be surprising to find even greater deviations among the individual results than are exhibited by the above numbers in the last column. Nitrate of ammonia cannot be heated much above 30°, because it then undergoes a molecular change, which apparently is accompanied by disengagement of heat. This was observed in a series of experiments in which the heat was raised to 45° or 48°; the crystals which, dried *in vacuo*, were originally of a vitreous lustre and transparent, became, like the crystals dried at 100°, milky-white, porous,

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* After drying the stopper.

and absorbent of naphtha. In these experiments the following numbers were obtained.

Experiments with Naphtha A. Glass 2. Temperature of the Air 12°·1–12°·4.

T.	T'.	t'.	t.	M.	m.	f.	y	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·9	14·8	14·53	11·23	26·935	2·69	2·295	0·431	0·487	0·549
45·9	14·9	14·62	11·23	26·94	,,	,,	,,	,,	0·546
47·6	14·6	14·32	10·70	26·925	,,	2·445*	,,	,,	0·531
46·4	15·0	14·73	11·24	26·98	,,	2·425†	,,	,,	0·545

The numbers for the specific heat of nitrate of ammonia are throughout greater than those found between 14° and 31°; and probably because through the heating to 45° or 48° the change was set up *during* the experiments. Experiments with nitrate of ammonia in which, by drying at 100°, this change had been effected before making the experiments, gave numbers which more closely approach the first set, though somewhat greater, and on the whole not very concordant. I obtained in a series of experiments the following results with dull milky crystals dried at 100°.

Experiments with Naphtha A. Glass 1. Temperature of the Air 9°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·0	12·3	11·95	8·96	26·975	2·03	1·77	0·431	0·651	0·519
45·6	12·3	12·03	9·01	26·935	,,	,,	,,	,,	0·507
44·9	12·6	12·26	9·32	26·965	,,	1·90*	,,	,,	0·485
45·1	12·5	12·24	9·31	26·98	,,	,,	,,	,,	0·470
45·4	12·6	12·33	9·32	26·965	,,	2·08‡	,,	,,	0·457

Crystals dried at 100°–110°, which apparently had been softened, gave the following numbers.

Experiments with Naphtha A. Glass 1. Temperature of the Air 12°·1–12°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·6	14·2	13·93	11·03	26·97	2·095	1·91	0·431	0·651	0·524
43·6	14·4	14·13	11·42	26·935	,,	,,	,,	,,	0·489
47·8	14·8	14·54	11·44	26·975	,,	2·04*	,,	,,	0·479
46·5	14·6	14·32	11·23	26·96	,,	2·02†	,,	,,	0·520

I do not know the nature of the change which nitrate of ammonia undergoes just above 40°.

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* After adding some naphtha. † After drying the stopper. ‡ After more naphtha.

58. *Nitrate of Strontia*, $\mathrm{Sr\,N_2\,\Theta_6}$. Crystallized, dried at 100°.

Experiments with Naphtha A. Glass 3. Temperature of the Air 14°·9–16°·0.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·0	16·6	16·33	13·95	26·955	4·575	2·10	0·431	0·453	0·180
46·8	17·1	16·83	14·43	26·95	„	„	„	„	0·179
46·7	17·1	16·84	14·44	26·935	„	„	„	„	0·180
47·9	17·2	16·93	14.43	26·975	„	2·085*	„	„	0·185
							Mean	. . .	0·181

Nitrate of Baryta, $\mathrm{Ba\,N_2\,\Theta_6}$. Crystals dried at 100°.

Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·3–13°·4.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
48·7	15·3	15·23	12·52	26·98	4·995	2·255	0·431	0·487	0·149
48·5	15·4	15·13	12·43	26·985	„	„	„	„	0·149
47·1	15·5	15·23	12·72	26·955	„	„	„	„	0·137
46·1	15·6	15·32	12·85	26·95	„	2·24*	„	„	0·146
							Mean	. . .	0·146

Nitrate of Lead, $\mathrm{Pb\,N_2\,\Theta_6}$. Crystals dried at 100°.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·3–13°·4.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·8	15·7	15·35	12·73	26·925	7·955	1·675	0·431	0·651	0·113
48·2	15·8	15·53	12·82	26·98	„	„	„	„	0·111
48·1	16·1	15·83	13·22	26·965	„	„	„	„	0·104
45·0	15·9	15·57	13·15	26·99	„	1·655*	„	„	0·111
							Mean	. . .	0·110

59. *Chlorate of Potass*, $\mathrm{K\,Cl\,\Theta_3}$. Pure well-dried crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·4–17°·3.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
50·6	18·4	18·12	15·63	26·97	2·485	2·18	0·431	0·651	0·199
50·0	18·6	18·25	15·83	26·945	„	„	„	„	0·196
48·3	18·8	18·45	16·22	26·95	„	„	„	„	0·180
48·4	18·8	18·53	16·24	26·96	„	2·165*	„	„	0·202
							Mean	. . .	0·194

* After drying the stopper.

Crystallized Chlorate of Baryta, $\text{Ba}\,\text{Cl}_2\,\Theta_6+\text{H}_2\,\Theta$. Crystalline crusts, dried *in vacuo*.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·3–14°·4.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·7	16·1	15·83	13·53	26·97	3·02	2·135	0·431	0·651	0·151
46·2	16·2	15·92	13·62	26·915	”	”	”	”	0·163
46·5	16·1	15·76	13·45	26·95	”	”	”	”	0·158
46·5	16·1	15·83	13·53	26·99	”	2·13*	”	”	0·157
							Mean	. . .	0·157

Perchlorate of Potass, $\text{K}\,\text{Cl}\,\Theta_4$. Well-formed crystals.

Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·5.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·6	13·7	13·43	11·02	26·93	3·205	2·115	0·431	0·487	0·179
45·7	13·6	13·33	10·94	26·98	”	”	”	”	0·190
44·9	13·7	13·43	11·10	26·955	”	”	”	”	0·192
44·0	13·6	13·33	11·04	26·945	”	2·095*	”	”	0·199

Permanganate of Potass, $\text{K}\,\text{Mn}\,\Theta_4$. Crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·5.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·3	13·7	13·43	11·02	26·955	3·655	1·83	0·431	0·651	0·187
45·6	13·7	13·43	10·94	26·955	”	”	”	”	0·181
46·0	13·8	13·51	11·03	26·99	”	”	”	”	0·175
46·2	13·7	13·44	10·95	26·935	”	1·815*	”	”	0·173
							Mean	. . .	0·179

60. *Metaphosphate of Soda*, $\text{Na}\,\text{P}\,\Theta_3$. Prepared as a transparent vitreous mass by igniting phosphate of soda and ammonia.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·4–14°·5.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·1	16·7	16·37	13·54	26·92	4·70	1·845	0·431	0·487	0·227
48·3	16·8	16·45	13·75	26·975	”	”	”	”	0·219
43·1	16·5	16·23	13·96	26·92	”	”	”	”	0·216
43·3	16·7	16·44	14·23	26·935	”	1·83*	”	”	0·205
							Mean	. . .	0·217

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* After drying the stopper.

Phosphate of Silver, $Ag_3 P \Theta_4$: yellow powder dried at 110°. This substance, in the quantity I used, is but ill fitted for procuring accurate results. I have made two series of experiments with it, but the results obtained thereby are only to be considered as rough approximations.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 20°·5–20°·8.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·4	22·5	22·19	20·16	26·99	3·775	2·105	0·431	0·651	0·0895
52·0	22·4	22·14	20·12	26·955	„	„	„	„	0·0745 ?
51·5	22·5	22·16	20·13	26·965	„	„	„	„	0·0872
51·5	22·5	22·15	20·14	26·985	„	2·095*	„	„	0·0839
						Mean† . . .			0·0869

II.—Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·3–16°·6.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·1	18·4	18·12	15·72	26·955	4·545	2·555	0·431	0·453	0·0933
51·5	18·4	18·13	15·73	26·995	„	„	„	„	0·0887
51·8	18·5	18·22	15·76	26·94	„	„	„	„	0·0959
51·6	18·6	18·33	15·93	26·98	„	2·54*	„	„	0·0911
						Mean . . .			0·0923

The mean of both these means gives 0·0896 as the specific heat of phosphate of silver. This number, as already remarked, is but little trustworthy. But it may be concluded from these experiments that the specific heat of phosphate of silver cannot differ much from 0·09.

Phosphate of Potass, $K H_2 P \Theta_4$. Clear crystals dried at 110°.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·9–16°·0.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·8	16·9	16·56	14·21	26·96	3·95	1·575	0·431	0·651	0·200
48·0	17·2	16·89	14·43	26·965	„	„	„	„	0·209
47·5	17·4	17·09	14·71	26·96	„	„	„	„	0·203
48·0	17·2	16·92	14·43	26·995	„	1·56*	„	„	0·218
						Mean . . .			0·208

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* After drying the stopper.

† Excluding the second experiment.

Arseniate of Potass, $\mathrm{K\,H_2\,As}\,\Theta_4$. Clear crystals dried at 105°.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·3–14°·4.

T.	T'.	*t'.*	*t.*	M.	*m.*	*f.*	*y.*	*x.*	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·1	16·2	15·93	13·43	26·96	4·455	2·05	0·431	0·487	0·182
47·5	16·2	15·92	13·43	26·975	,,	,,	,,	,,	0·174
45·1	16·1	15·84	13·54	26·955	,,	,,	,,	,,	0·172
45·5	16·3	16·01	13·70	26·955	,,	2·045*	,,	,,	0·172
							Mean . . .		0·175

61. *Carbonate of Soda*, $\mathrm{Na_2\,C}\,\Theta_3$. Fused salt.

Experiments with Naphtha A. Glass 2. Temperature of the Air 15°·5.

T.	T'.	*t'.*	*t.*	M.	*m.*	*f.*	*y.*	*x.*	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
48·0	17·7	17·35	14·54	26·935	4·575	2·08	0·431	0·487	0·244
47·9	17·7	17·43	14·63	26·95	,,	,,	,,	,,	0·244
48·1	17·7	17·40	14·53	26·985	,,	,,	,,	,,	0·254
48·1	17·7	17·43	14·63	26·965	,,	2·055*	,,	,,	0·243
							Mean . . .		0·246

Carbonate of Potass, $\mathrm{K_2\,C}\,\Theta_3$. Fused salt.

Experiments with Naphtha A. Glass 1. Temperature of the Air 15°·5.

T.	T'.	*t'.*	*t.*	M.	*m.*	*f.*	*x.*	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.
47·4	17·4	17·14	14·75	26·975	3·045	1·96	0·651	0·215
47·5	17·4	17·12	14·73	26·975	,,	,,	,,	0·212
47·3	17·4	17·14	14·82	26·95	,,	,,	,,	0·196
45·6	17·5	17·21	15·02	26·96	,,	1·95*	,,	0·200
						Mean . . .		0·206

Carbonate of Rubidium, $\mathrm{Rb_2\,C}\,\Theta_3$. Fused salt.

Experiments with Naphtha A. Glass 2. Temperature of the Air 15°·5.

T.	T'.	*t'.*	*t.*	M.	*m.*	*f.*	*y.*	*x.*	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·3	17·7	17·38	14·80	26·965	6·855	1·95	0·431	0·487	0·127
47·1	17·4	17·13	14·70	26·955	,,	,,	,,	,,	0·128
46·8	17·6	17·33	14·94	26·97	,,	,,	,,	,,	0·128
45·8	17·6	17·33	15·16	26·93	,,	1·93*	,,	,,	0·110
							Mean . . .		0·123

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* After drying the stopper.

62. *Carbonate of Lead*, $Pb\,CO_3$. *Cerussite* from Washington mine, Davidson county, North Carolina: beautiful clear crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·2	16·3	16·03	13·16	26·95	11·42	1·90	0·431	0·651	0·0772
49·8	16·0	15·68	12·72	26·94	„	„	„	„	0·0779
47·4	15·9	15·60	12·80	26·94	„	„	„	„	0·0810
46·5	15·9	15·64	12·94	26·97	„	„	„	„	0·0797
43·2	15·8	15·55	13·14	26·96	„	1·885*	„	„	0·0795
							Mean	. . .	0·0791

Carbonate of Lime, $Ca\,CO_3$. I have investigated both the rhombic and the rhombohedral modification.

Arragonite. Fragments of clear crystals from Bilin, in Bohemia

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·1	16·8	16·53	13·25	26·965	6·445	1·94	0·431	0·487	0·195
46·6	16·0	15·70	12·73	26·98	„	„	„	„	0·201
45·8	16·1	15·83	12·94	26·975	„	„	„	„	0·216
44·0	16·0	15·74	13·03	26·965	„	„	„	„	0·200
44·3	15·9	15·63	12·86	26·955	„	1·92*	„	„	0·204
							Mean	. . .	0·203

Calcareous Spar. Cleavage pieces of transparent specimens from Auerbach, on the Bergstrasse.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·4–14°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·5	15·5	15·24	12·13	26·98	5·425	1·48	0·431	0·651	0·217
49·6	16·3	15·96	13·00	26·96	„	„	„	„	0·204
48·2	16·1	15·83	12·94	26·915	„	„	„	„	0·209
45·2	16·2	15·94	13·42	26·93	„	1·465*	„	„	0·195
							Mean	. . .	0·206

* After drying the stopper.

63. *Magnesian Spar*, $\mathrm{Ca_{\frac{1}{2}}\,Mg_{\frac{1}{2}}\,CO_3}$*. Specimens of magnesian spar from the Zillerthal.

Experiments with Naphtha A. Glass 3. Temperature of the Air 15°·1–15°·9.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
48·9	17·7	17·43	14·52	26·96	6·195	1·76	0·431	0·453	0·210
48·3	17·9	17·60	14·77	26·96	„	„	„	„	0·210
47·0	17·9	17·64	15·02	26·995	„	1·745†	„	„	0·198
							Mean	. . .	0·206

Spathic Iron, $\mathrm{Fe_{\frac{8}{11}}\,Mn_{\frac{2}{11}}\,Mg_{\frac{1}{11}}\,CO_3}$‡. Cleavage pieces of reddish crystals from Bieber, Hesse Cassel.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·6–14°·4.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·7	17·0	16·74	13·92	26·98	6·56	1·78	0·431	0·651	0·162
45·6	16·9	16·63	13·94	26·93	„	„	„	„	0·169
46·1	16·9	16·55	13·83	26·965	„	1·765†	„	„	0·168
							Mean	. . .	0·166

64. *Zircon*, $\mathrm{Zr\,Si\,O_4}$, or $\mathrm{Zr_{\frac{1}{2}}\,Si_{\frac{1}{2}}\,O_2}$. Hyacinth crystals from Ceylon.

Experiments with Naphtha A. Glass 1. Temperature of the Air 18°·4–19°·8.

T.	T′.	*t*′.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·2	20·6	20·33	17·46	26·945	9·69	1·32	0·431	0·651	0·135
50·2	20·8	20·54	17·83	26·955	„	„	„	„	0·131
51·0	21·0	20·74	18·01	26·97	„	„	„	„	0·127
52·0	21·2	20·87	18·03	26·96	„	„	„	„	0·131
51·1	21·3	21·03	18·24	26·93	„	1·30†	„	„	0·135
							Mean	. . .	0·132

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* The results of my analysis of this spar (Ann. der Chem. und Pharm. lxxxi. 50) are, compared with the numbers required by the above formula, as follows:—

	$\mathrm{CaO\,CO_2}$.	$\mathrm{MgO\,CO_2}$.	$\mathrm{FeO\,CO_2}$[a].	Total.
Found	54·3	42·2	3·7	100·2
Calculated	54·3	45·7	„	100·0

† After drying the stopper.

‡ The numbers found in my analysis of this spathic iron (Ann. der Chem. und Pharm. lxxxi. 51) are given below, compared with those calculated on the above formula.

	$\mathrm{FeO\,CO_2}$.	$\mathrm{MnO\,CO_2}$.	$\mathrm{CaO\,CO_2}$.	$\mathrm{MgO\,CO_2}$.	X[b].	Total.
Found	73·7	19·0	0·9	6·6	0·7	100·9
Calculated	74·7	18·6	„	6·7	„	100·0

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[a] With some $\mathrm{MnO\,CO_2}$.

[b] Insoluble in aqua regia.

Chrysolite, $Mg_{\frac{20}{11}}Fe_{\frac{2}{11}}SiO_4$[*]. From Dockweiler in the Eifel. Transparent to translucent bright green crystalline fragments.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·2–19°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·3	21·4	21·14	18·53	26·985	5·84	1·475	0·431	0·657	0·183
50·4	21·4	21·13	18·55	26·965	,,	,,	,,	,,	0·191
50·9	21·5	21·17	18·54	26·985	,,	,,	,,	,,	0·193
50·9	21·5	21·16	18·55	26·96	,,	,,	,,	,,	0·189
49·9	21·4	21·13	18·63	26·975	,,	1·45†	,,	,,	0·187
							Mean . . .		0·189

Olivine, $Mg_{\frac{20}{11}}Fe_{\frac{2}{11}}SiO_4$[‡]. From a spheroidal mass surrounded by lava from the Eifel.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·0–19°·6.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·5	21·6	21·26	18·53	26·975	6·37	1·425	0·431	0·651	0·188
51·4	21·3	20·97	18·22	26·975	,,	,,	,,	,,	0·188
51·5	21·6	21·25	18·52	26·975	,,	,,	,,	,,	0·188
52·1	21·8	21·52	18·72	26·97	,,	1·41†	,,	,,	0·194
							Mean . . .		0·187

65. *Wollastonite*, $CaSiO_3$. Pure pieces of Wollastonite from Finnland.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·0	19·4	19·12	16·33	26·955	5·31	1·81	0·431	0·651	0·179
50·5	19·1	18·76	16·01	26·945	,,	,,	,,	,,	0·175
50·0	19·2	18·92	16·19	26·98	,,	,,	,,	,,	0·181
50·7	19·4	19·13	16·40	26·97	,,	1·785†	,,	,,	0·176
							Mean . . .		0·178

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[*] An analysis by Professor Knop gave the following results, which are collated with the numbers required by the above formula:—

	SiO_2.	MgO.	FeO.	Al_2O_3.	Total.
Found	40·95	50·82	8·83	trace	100·60
Calculated	41·15	49·87	8·98	,,	100·00

[†] After drying the stopper.

[‡] This olivine has the same composition as the above chrysolite. Professor Knop found for this olivine the following numbers, which are compared with those required by the above formula:—

	SiO_2.	MgO.	FeO.	Al_2O_3.	Total.
Found	41·85	49·10	8·75	trace	99·70
Calculated	41·15	49·87	8·98	,,	100·00

Diopside, $Ca_{\frac{1}{2}}Mg_{\frac{1}{2}}SiO_3$. Fragments of a greenish and white crystal of the characteristic aspect of the diopside from Schwarzenstein in the Tyrol.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·3–16°·5.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
48·1	18·7	18·42	15·65	26·99	6·17	1·55	0·431	0·651	0·186
49·4	18·4	18·13	15·22	26·98	„	„	„	„	0·185
51·8	18·6	18·25	15·13	26·98	„	„	„	„	0·185
50·8	18·8	18·54	15·53	26·925	„	1·53*	„	„	0·186
							Mean . . .		0·186

Dioptase, $CuSiO_3+H_2O$. Fine crystals from the Kirgisensteppe.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·7–16°·4.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
49·8	18·9	18·63	16·04	26·94	5·545	1·80	0·431	0·453	0·186
50·3	19·1	18·76	16·17	26·95	„	„	„	„	0·182
50·3	18·9	18·64	16·05	26·99	„	„	„	„	0·180
48·5	18·9	18·58	16·13	26·945	„	1·79*	„	„	0·181
							Mean . . .		0·182

Orthoclase, $Al_2K_2Si_6O_{16}$. Cleavage pieces of a flesh-coloured reddish orthoclase from Aschaffenburg.

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·4–19°·1.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
50·6	20·2	19·86	17·42	26·945	5·185	1·78	0·431	0·453	0·182
49·6	20·3	20·00	17·63	26·95	„	„	„	„	0·185
51·1	20·5	20·15	17·71	26·94	„	„	„	„	0·179
51·2	20·5	20·21	17·73	26·965	„	1·77*	„	„	0·186
							Mean . . .		0·183

Albite, $Al_2Na_2Si_6O_{16}$. Fragments of white crystals from Pfunders, in Tyrol.

Experiments with Naphtha A. Glass 3. Temperature of the Air 18°·7–19°·8.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
52·4	20·3	20·04	17·44	26·955	4·835	1·84	0·431	0·453	0·194
50·7	20·8	20·53	18·14	26·975	„	„	„	„	0·188
50·1	20·9	20·63	18·30	26·935	„	„	„	„	0·187
52·0	21·1	20·82	18·33	26·955	„	„	„	„	0·192
50·4	21·3	21·04	18·73	26·97	„	1·82*	„	„	0·187
							Mean . . .		0·190

* After drying the stopper.

66. *Borate of Soda*, $\mathrm{Na_2B_4\Theta_7}$. Beautiful transparent vitreous pieces of fused borax.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·4.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
46·6	16·6	16·33	13·67	26·95	4.475	2·005	0·431	0·487	0·232
46·8	16·6	16·33	13·65	26·98	,,	,,	,,	,,	0·233
46·5	16·6	16·33	13·73	26·965	,,	,,	,,	,,	0·222
46·6	16·8	16·54	13·93	26·945	,,	1·99*	,,	,,	0·227
							Mean	. . .	0·227

Hydrated Borate of Soda, $\mathrm{Na_2B_4\Theta_7+10\,H_2\Theta}$. Crystallized borax dried in the air.

Experiments with Naphtha A. Glass 3. Temperature of the Air 16°·3–16°·5.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·9	18·7	18·43	15·43	26·98	3·38	1·745	0·431	0·453	0·387
50·3	18·4	18·13	15·15	26·95	,,	,,	,,	,,	0·388
49·1	18·5	18·16	15·33	26·96	,,	,,	,,	,,	0·381
49·5	18·8	18·45	15·61	26·945	,,	1·73*	,,	,,	0·383
							Mean	. . .	0·385

67. *Tungstate of Lime*, $\mathrm{Ca\,W\Theta_4}$. Crystals of *Scheelite* from Zinnwald in Bohemia.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·7–16°·4.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·3	19·3	19·00	16·27	26·96	11·575	1·34	0·431	0·651	0·0990
49·5	19·1	18·84	16·22	26·96	,,	,,	,,	,,	0·0946
50·5	19·0	18·71	15·94	26·97	,,	,,	,,	,,	0·0988
48·6	19·0	18·66	16·12	26·99	,,	1·325 *	,,	,,	0·0945
							Mean	. . .	0·0967

Wolfram, $\mathrm{Fe_{\frac{2}{5}}\,Mn_{\frac{3}{5}}\,WO_4}$†. Fragments of crystals from Altenberg in the Erzgebirge.

Experiments with Naphtha B. Glass 1. Temperature of the Air 19°·1–19°·0.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
52·1	21·1	20·83	18·14	26·985	11·455	1·525	0·419	0·651	0·0918
52·9	21·2	20·92	18·14	26·975	,,	,,	,,	,,	0·0939
54·0	21·2	20·92	18·04	26·97	,,	,,	,,	,,	0·0941
54·8	21·4	21·13	18·23	26·945	,,	1·51 *	,,	,,	0·0921
							Mean	. . .	0·0930

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* After drying the stopper.

† According to KERNDT's analysis of the wolfram of Altenberg (Rammelsberg's 'Handbuch der Mineral. Chemie,' p. 308).

Molybdate of Lead, $\mathrm{Pb\,M\,O_4}$. Comminuted crystals of Wülfenite (Gelbbleierz) from Bleiberg in Carinthia.

Experiments with Naphtha A. Glass 3 Temperature of the Air 17°·6–17°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
50·2	19·3	18·95	16·45	26·98	8·69	2·32	0·431	0·453	0·0840
50·0	19·2	18·92	16·43	26·97	„	„	„	„	0·0837
48·6	19·1	18·84	16·47	26·935	„	„	„	„	0·0818
49·3	19·3	19·01	16·62	26·98	„	2·295*	„	„	0·0814
							Mean	. . .	0·0827

68. *Chromate of Lead*, $\mathrm{Pb\,Cr\,O_4}$. For the investigation pieces of artificially prepared chromate of lead were used, which after fusion had solidified to an aurora-red mass of a fibrous crystalline structure, and with crystal needles on the surface.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·1–17°·9.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·0	19·0	18·74	16·22	26·975	10·60	1·93	0·431	0·453	0·0857
50·1	19·2	18·92	16·34	26·985	„	„	„	„	0·0931
49·6	19·2	18·93	16·42	26·975	„	„	„	„	0·0889
49·9	19·3	19·02	16·44	26·99	„	1·915*	„	„	0·0940
							Mean	. . .	0·0900

Chromate of Potass, $\mathrm{K_2\,Cr\,O_4}$. Crystals of the neutral salt dried at 105°.

Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·1–16°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·1	18·0	17·69	15·13	26·985	4·995	1·535	0·431	0·651	0·182
45·7	17·8	17·49	15·14	26·975	„	„	„	„	0·192
47·3	17·9	17·62	15·13	26·995	„	„	„	„	0·195
48·2	18·2	17·93	15·43	26·955	„	1·525*	„	„	0·188
							Mean	. . .	0·189

Acid Chromate of Potass, $\mathrm{K_2\,Cr_2\,O_7}$ Crystals of the so-called bichromate.

Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·1–19°·5.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·3	21·1	20·83	18·33	26·97	4·275	1·58	0·431	0·651	0·178
51·5	21·1	20·82	18·42	26·95	„	„	„	„	0·186
51·6	21·1	20·76	18·33	26·96	„	„	„	„	0·191
52·6	21·2	20·93	18·45	26·975	„	1·555*	„	„	0·189
							Mean	. . .	0·186

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* After drying the stopper.

69. *Sulphate of Soda*, $Na_2 S\Theta_4$. Crystalline crusts briskly dried.

Experiments with Naphtha A. Glass 1. Temperature of the Air 11°·2–11°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·2	12·8	12·52	9·94	26·97	3·465	1·73	0·431	0·651	0·236
47·8	13·2	12·93	10·14	26·93	„	„	„	„	0·224
46·1	13·2	12·93	10·25	26·95	„	„	„	„	0·230
46·6	13·6	13·32	10·69	26·975	„	1·715*	„	„	0·219
							Mean . . .		0·227

Sulphate of Potass, $K_2 S\Theta_4$. Crystal crusts sharply dried.

Experiments with Naphtha A. Glass 2. Temperature of the Air 11°·2–11°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
44·5	12·7	12·44	12·02	26·915	3·405	2·145	0·431	0·487	0·187
47·0	13·2	12·93	10·22	26·95	„	2·30†	„	„	0·200
45·9	13·3	13·02	10·41	26·95	„	„	„	„	0·200
43·1	13·3	13·03	10·67	26·95	„	2·275*	„	„	0·196
							Mean . . .		0·196

Acid Sulphate of Potass, $K H S\Theta_4$. Well-formed crystals dried at 100°‡. The salt became feebly red on the surface in contact with the coal-tar naphtha.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·0–17°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·7	19·4	19·12	16·43	26·94	3·445	1·85	0·431	0·651	0·251
50·4	19·3	19·01	16·36	26·945	„	„	„	„	0·245
50·5	19·3	18·97	16·34	26·96	„	„	„	„	0·239
51·9	19·4	19·05	16·32	26·965	„	1·83*	„	„	0·239
							Mean . . .		0·244

70. *Sulphate of Ammonia*, $N_2 H_8 S\Theta_4$. I made two series of experiments with this salt. Crystals dried *in vacuo* over sulphuric acid.

I.—Experiments with Naphtha A. Glass 2. Temperature of the Air 10°·9–11°·3.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
45·1	13·0	12·73	9·73	26·93	3·425	1·825	0·431	0·487	0·363
44·5	13·4	13·12	10·25	26·98	„	„	„	„	0·355
44·3	13·2	12·93	10·08	26·93	„	1·815*	„	„	0·350
							Mean . . .		0·356

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* After drying the stopper. † After adding some naphtha.

‡ Dr. Engelbach found the quantity of potass in these crystals to be 33·70 and 34·13 per cent. Calculated from the above formula 34·61 per cent. are required.

Crystals dried at 120°.

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 10°·9–11°·31.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
44·2	12·9	12·63	9·97	26·94	2·84	1·555	0·431	0·661	0·341
42·2	12·6	12·33	9·81	26·95	„	„	„	„	0·343
45·4	13·3	12·96	10·30	26·985	„	„	„	„	0·322
46·7	13·0	12·72	9·77	26·935	„	1·535*	„	„	0·368
							Mean . . .		0·344

The mean of the means of both series of experiments, 0·356 and 0·344, gives for the specific heat of sulphate of ammonia between 13° and 45° the number 0·350†.

71. *Sulphate of Lead*, $PbSO_4$. Fragments of transparent crystals of lead-vitriol from Müsen, near Siegen.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·6–17°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
48·3	19·6	19·33	16·90	26·975	12·575	1·47	0·431	0·651	0·0795
50·9	19·3	19·00	16·23	26·96	„	„	„	„	0·0858
49·9	19·3	19·01	16·33	26·985	„	„	„	„	0·0858
50·4	19·6	19·24	16·63	26·99	„	1·45*	„	„	0·0798
							Mean . . .		0·0827

Sulphate of Baryta, $BaSO_4$. Cleavage pieces of crystal of heavy spar from the Auvergne.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 15°·1–15°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·5	17·4	17·12	14·64	26·945	9·15	1·405	0·431	0·651	0·113
48·5	17·5	17·17	14·56	26·97	„	„	„	„	0·111
44·6	17·4	17·05	14·82	26·97	„	1·395*	„	„	0·105
							Mean . . .		0·110

* After drying the stopper.

† I had made a third series of experiments with large dry transparent crystals of sulphate of ammonia, but in which t′ exceeded more than usual the temperature of the air, and hence numbers were found for the body investigated which are somewhat too small.

Experiments with Naphtha A. Glass 2. Temperature of the Air 9°·7.

T.	T′	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
45·6	12·4	12·05	8·86	26·935	3·725	2·015	0·431	0·487	0·331
47·1	12·8	12·45	9·22	26·97	„	„	„	„	0·318
42·9	12·6	12·25	9·42	26·99	„	„	„	„	0·313
44·1	12·5	12·22	9·24	26·95	„	„	„	„	0·318
47·0	12·7	12·36	9·16	26·94	„	1·985[a]	„	„	0·314

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[a] After removing some naphtha from the stopper.

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·7–17°·2.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·9	19·0	18·65	16·13	26·96	7·77	1·68	0·431	0·651	0·106
50·9	19·0	18·74	16·14	26·94	„	„	„	„	0·106
49·0	19·0	18·67	16·22	26·96	„	1·665*	„	„	0·107
							Mean . . .		0·106

The mean of the means of these two sets of experiments gives 0·108 for the specific heat of heavy spar between 18° and 44°.

Sulphate of Strontia, $\mathrm{Sr\,SO_4}$. Crystals of celestine from Dornburg, near Jena.

Experiments with Naphtha A. Glass 3. Temperature of the Air 15°·6–16°·1.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·2	17·8	17·47	14·74	26·965	7·63	1·90	0·431	0·453	0·137
50·5	17·7	17·43	14·64	26·955	„	„	„	„	0·134
51·4	17·8	17·51	14·64	26·995	„	„	„	„	0·135
52·7	17·9	17·55	14·61	26·955	„	1·875*	„	„	0·133
							Mean . . .		0·135

72. *Sulphate of Lime*, $\mathrm{Ca\,SO_4}$. Small crystalline pieces of anhydrite.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·2–13°·7.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
46·1	15·6	15·33	12·72	26·98	5·305	1·715	0·431	0·651	0·173
46·5	15·5	15·22	12·53	26·93	„	„	„	„	0·178
45·7	15·6	15·34	12·74	26·92	„	„	„	„	0·176
43·6	15·7	15·44	13·11	26·94	„	1·70*	„	„	0·163
							Mean . . .		0·173

II.—Experiments with Water. Glass 3. Temperature of the Air 17°·9–18°·3.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
47·5	19·9	19·62	15·62	26·95	5·62	2·415	1·000	0·453	0·185
47·1	19·8	19·53	15·61	26·99	„	„	„	„	0·179
47·1	20·1	19·77	15·87	26·975	„	„	„	„	0·183
47·5	20·2	19·94	16·03	26·98	„	2·40*	„	„	0·180
							Mean . . .		0·182

The average of the means of these determinations gives 0·178 as the specific heat of anhydrite between 18° and 46°.

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* After drying the stopper.

Hydrated Sulphate of Lime, $\mathrm{Ca\,S\Theta_4+2\,H_2\,O}$. Cleavage pieces of transparent *Gypsum* from Reinhardtsbrunn, in Thüringen.

Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·2–13°·7.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grms.	y.	x. grm.	sp. H.
47·2	15·6	15·29	12·32	26·94	4·335	2·115	0·431	0·487	0·261
47·4	15·8	15·53	12·57	26·99	„	„	„	„	0·261
45·7	15·8	15·53	12·73	26·96	„	„	„	„	0·260
44·2	16·0	15·73	12·13	26·94	„	2·095*	„	„	0·252
							Mean . . .		0·259

73. *Crystallized Sulphate of Copper*, $\mathrm{Cu\,S\Theta_4+5\,H_2\,\Theta}$. Crystals of *Blue vitriol* dried in the air.

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·1–14°·2.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
50·8	16·4	16·08	12·82	26·99	4·12	1·65	0·431	0·651	0·290
47·3	16·4	16·05	13·12	26·965	„	„	„	„	0·290
46·7	16·5	16·16	13·34	26·99	„	„	„	„	0·281
45·0	16·6	16·26	13·63	26·965	„	1·635*	„	„	0·277
							Mean . . .		0·285

Crystallized Sulphate of Manganese, $\mathrm{Mn\,S\Theta_4+5\,H_2\,\Theta}$. Crystals of the salt isomorphous with blue vitriol.

Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·1–14°·2.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
48·5	16·7	16·42	13·23	26·945	4·12	1·97	0·431	0·487	0·332
45·7	16·4	16·14	13·24	26·945	„	„	„	„	0·323
46·5	16·7	16·43	13·53	26·98	„	„	„	„	0·313
44·0	16·8	16·53	13·85	26·945	„	1·955*	„	„	0·322
							Mean . . .		0·323

Crystallized Sulphate of Nickel, $\mathrm{Ni\,S\Theta_4+6\,H_2\,\Theta}$. Crystals of quadratic nickel vitriol dried *in vacuo*.

Experiments with Naphtha A. Glass 1. Temperature of the Air 15°·6–16°·1.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
52·5	18·0	17·74	14·61	26·97	3·60	1·655	0·431	0·651	0·307
50·3	17·7	17·42	14·37	26·995	„	„	„	„	0·322
51·5	17·7	17·36	14·24	26·985	„	„	„	„	0·313
52·8	18·1	17·82	14·62	26·94	„	1·63*	„	„	0·314
							Mean . . .		0·313

* After drying the stopper.

74. *Crystallized Sulphate of Magnesia*, $\mathrm{Mg}\,\mathrm{S}\Theta_4+7\,\mathrm{H}_2\,\Theta$. Air-dried crystals of Epsom salt. I have made two series of experiments with this salt. In one the temperature did not exceed 40°, and in the other did not attain 50°. In both cases the crystals remained transparent and unchanged.

I.—Experiments with Naphtha A. Glass 3. Temperature of the Air 19°·8–19°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
38·5	21·6	21·29	19·77	26·96	3·175	1·845	0·431	0·453	0·371
39·3	21·6	21·32	19·73	26·945	,,	,,	,,	,,	0·369
38·7	21·6	21·34	19·83	26·98	,,	,,	,,	,,	0·357
37·7	21·6	21·27	19·85	26·935	,,	1·835*	,,	,,	0·356
							Mean	. . .	0·363

II.—Experiments with Naphtha A. Glass 1. Temperature of the Air 16°·1.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
47·6	18·3	18·04	15·42	26·97	2·775	1·81	0·431	0·651	0·353
47·9	18·4	18·12	15·43	26·985	,,	,,	,,	,,	0·371
45·2	18·3	17·96	15·53	26·94	,,	,,	,,	,,	0·361
43·9	18·3	17·96	15·67	26·975	,,	1·795*	,,	,,	0·356
							Mean	. . .	0·360

These determinations give as the mean of the two series 0·362 for the specific heat of crystallized sulphate of magnesia below 50°†.

Crystallized Sulphate of Zinc, $\mathrm{Zn}\,\mathrm{S}\Theta_4+7\,\mathrm{H}_2\,\Theta$. Transparent crystals of white vitriol, dried in the air. In the determinations a heat but little over 50° could be employed; towards 50° the crystals undergo decomposition in the coal-tar naphtha‡.

Experiments with Naphtha A. Glass 1. Temperature of the Air 13°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
28·7	14·6	14·33	12·93	26·945	3·55	1·655	0·431	0·651	0·369
30·7	14·9	14·62	13·13	26·95	,,	,,	,,	,,	0·332

This series of experiments had to be interrupted here. I subsequently made another set.

* After drying the stopper.

† Above 50° the salt with 7 at. water of crystallization undergoes decomposition. A series of experiments in which the temperature exceeded 50° gave the following results.

Experiments with Naphtha A. Glass 3. Temperature of the Air 20°·3–21°·1.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·5	22·6	22·32	19·61	26·995	3·43	1·57	0·431	0·453	0·409
51·4	22·8	22·52	19·55	26·93	,,	,,	,,	,,	0·475
51·0	23·0	22·71	19·73	26·945	,,	,,	,,	,,	0·507
50·0	23·0	22·71	19·81	26·93	,,	1·56*	,,	,,	0·515

The results are as if more and more water in the free state had been eliminated. After the experiments the crystals were swollen, and externally milk white, still containing a clear nucleus inside.

‡ In the following series of experiments, in which a heat of towards 50° was employed, the crystals of white

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·4–15°·0.

T.	T′.	t′.	t.	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
30°·9	15°·7	15°·43	14°·03	26·93	3·49	1·645	0·431	0·651	0·321
32·3	16·0	15·65	14·13	26·96	„	„	„	„	0·331
30·8	15·8	15·52	14·03	26·95	„	„	„	„	0·377
32·8	16·1	15·83	14·23	26·97	„	1·635*	„	„	0·352

In all these experiments the crystals employed remained clear. The mean of the six experiments gives 0·347 as the specific heat of crystallized sulphate of zinc.

Crystallized Sulphate of Iron, $\mathrm{Fe\,S\Theta_4+7\,H_2\,\Theta}$. Dry crystals of green vitriol.

Experiments with Naphtha A. Glass 2. Temperature of the Air 16°·1.

T.	T′.	t′.	t.	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
47°·9	18°·6	18°·32	15°·56	26·93	3·47	1·91	0·431	0·487	0·354
47·5	18·6	18·25	15·55	26·925	„	„	„	„	0·347
46·0	18·5	18·21	15·64	26·955	„	„	„	„	0·348
44·6	18·4	18·13	15·73	26·96	„	1·895*	„	„	0·336
							Mean	. . .	0·346

Crystallized Sulphate of Cobalt, $\mathrm{Co\,S\Theta_4+7\,H_2\,\Theta}$. Crystals of the salt isomorphous with green vitriol. In the following experiments the crystals remained transparent[†].

Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·4–13°·2.

T.	T′.	t′.	t.	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
31°·6	14°·9	14°·63	12°·96	26·97	3·445	1·895	0·431	0·487	0·405
29·9	14·8	14·54	13·14	26·945	„	„	„	„	0·347
28·4	15·0	14·67	13·43	26·93	„	„	„	„	0·345
31·6	15·2	14·94	13·44	26·94	„	1·885*	„	„	0·338
							Mean	. . .	0·343[‡]

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vitriol undergo an essential change. At the end of the experiments they were opaque, and no longer detached, as before, but as if swollen up in the glass. These experiments gave the following numbers:—

Experiments with Naphtha A. Glass 1. Temperature of the Air 14°·8–14°·4.

T.	T′.	t′.	t.	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
47°·4	17°·0	16°·74	13°·62	26·94	3·465	1·695	0·431	0·651	0·399
47·6	17·0	16·72	13·62	26·945	„	„	„	„	0·389
45·1	16·9	16·63	13·77	26·975	„	1·655§	„	„	0·396
43·8	17·1	16·83	14·22	26·99	„	„	„	„	0·368

[*] After drying the stopper.

[†] In a series of experiments, in which the temperature amounted to 50°, the crystals of sulphate of cobalt with seven atoms of water underwent a change; they were opaque, and stuck in the glass as if swollen up; and the numbers found for the specific heat were considerably greater.

[‡] Excluding the first experiment. The temperature of the glass, together with the solid substance and the liquid, exceeded in all experiments the final temperature of the water in the calorimeter only by about 15°.

[§] After removing some naphtha from the stopper.

75. *Crystallized Sulphate of Magnesia and Potass,* $\mathrm{MgK_2S_2\Theta_8+6H_2\Theta}$. Well-shaped crystals.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·0–17°·2.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
51·0	19·4	19·13	16·43	26·99	4·135	1·735	0·431	0·453	0·267
51·0	19·3	19·02	16·33	26·965	„	„	„	„	0·263
50·0	19·3	19·02	16·43	26·96	„	„	„	„	0·260
50·2	19·4	19·06	16·44	26·95	„	1·715*	„	„	0·266
							Mean . . .		0·264

Crystallized Sulphate of Zinc and Potass, $\mathrm{ZnK_2S_2\Theta_8+6H_2\Theta}$. Well-shaped crystals; in both the following series they remained transparent and unchanged.

I.—Experiments with Naphtha A. Glass 1. Temperature of the Air 19°·8–19°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
40·2	21·7	21·37	19·73	26·925	3·965	1·535	0·431	0·651	0·271
40·6	21·7	21·42	19·75	26·935	„	„	„	„	0·269
40·2	21·7	21·38	19·73	26·955	„	„	„	„	0·275
39·8	21·7	21·40	19·83	26·925	„	1·52*	„	„	0·260
							Mean . . .		0·269

II.—Experiments with Naphtha A. Glass 2. Temperature of the Air 14°·8–14°·4.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
48·9	16·9	16·64	13·63	26·94	4·365	1·98	0·431	0·487	0·273
47·2	16·8	16·50	13·63	26·92	„	„	„	„	0·275
48·0	16·9	16·61	13·69	26·98	„	„	„	„	0·273
45·7	16·9	16·63	13·96	26·97	„	1·965*	„	„	0·267
							Mean . . .		0·272

The mean of the means of both series of experiments gives 0·270 as the specific heat of crystallized sulphate of zinc and potass between 19° and 40°–50°.

Crystallized Sulphate of Nickel and Potass, $\mathrm{NiK_2S_2\Theta_8+6H_2\Theta}$. Well-formed crystals.

Experiments with Naphtha A. Glass 2. Temperature of the Air 13°·3–13°·5.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·1	16·1	15·84	12·77	26·94	4·775	1·945	0·431	0·487	0·247
45·1	15·6	15·34	12·61	26·96	„	„	„	„	0·245
45·5	15·8	15·46	12·73	26·945	„	„	„	„	0·241
44·0	15·6	15·32	12·69	26·975	„	1·925*	„	„	0·247
							Mean . . .		0·245

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* After drying the stopper.

76. *Crystallized Sulphate of Alumina and Potass*, $\mathrm{Al_2 K_2 S_4 \Theta_{16} + 24 H_2 \Theta}$. Transparent air-dried crystals of alum.

Experiments with Naphtha A. Glass 1. Temperature of the Air 17°·2–17°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·1	19·5	19·16	16·55	26·98	2·87	1·595	0·431	0·651	0·362
49·6	19·1	18·83	16·12	26·985	„	„	„	„	0·369
49·0	19·3	18·96	16·32	26·99	„	„	„	„	0·370
49·5	19·3	18·95	16·23	26·96	„	1·58*	„	„	0·382
							Mean . . .		0·371

Crystallized Sulphate of Chrome and Potass, $\mathrm{Ȼr_2 K_2 S_4 \Theta_{16} + 24 H_2 \Theta}$. Air-dried crystals of chrome alum: they remained unchanged in the following experiments.

Experiments with Naphtha A. Glass 3. Temperature of the Air 17°·2–17°·4.

T.	T'	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·9	19·3	19·03	16·14	26·95	3·70	1·875	0·431	0·453	0·325
50·6	19·4	19·06	16·23	26·965	„	„	„	„	0·320
50·9	19·5	19·23	16·34	26·995	„	„	„	„	0·331
51·4	19·6	19·34	16·46	26·97	„	1·865*	„	„	0·320
							Mean . . .		0·324

77. *Chloride of Carbon*, $\mathrm{Ȼ_2 Cl_6}$. The determination of the specific heat of this, the so-called sesquichloride of carbon, has given me much trouble.

I first investigated, in two series of experiments, a preparation which, after melting in a small glass tube, had solidified in porcelain-like white crusts†.

I.—Experiments with Water. Glass 1. Temperature of the Air 18°·5–18°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
53·5	20·5	20·22	16·16	26·94	3·765	1·61	1·000	0·651	0·280
52·2	20·4	20·10	16·18	26·945	„	„	„	„	0·282
52·0	20·7	20·43	16·83	26·97	„	„	„	„	0·269
52·6	20·8	20·45	16·61	26·965	„	1·585*	„	„	0·271
							Mean . . .		0·276

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* After drying the stopper.

† Sesquichloride of carbon was prepared by continuously passing chlorine into crude chloride of ethylene in the sunlight, and washing the solidified product with water; it was then again treated with chlorine and washed with solution of soda and much water. The crystalline mass was afterwards repeatedly pressed between bibulous paper (by which a small quantity of an oily product was absorbed), dried in the air, then washed with cold alcohol, dried, and fused, and the parts which had crept up the sides separated when solid.—ENGELBACH.

II.—Experiments with Water. Glass 1. Temperature of the Air 17°·5–17°·4.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grm.	y.	x. grm.	sp. H.
50·2	19·8	19·54	15·54	26·955	3·525	1·995	1·000	0·651	0·256
50·1	19·6	19·33	15·31	26·94	„	„	„	„	0·257
50·5	19·7	19·36	15·24	26·96	„	„	„	„	0·272
49·2	19·7	19·43	15·52	26·97	„	„	„	„	0·263
47·8	19·7	19·36	15·62	26·99	„	1·965*	„	„	0·277
							Mean . . .		0·265

I should not have hesitated to take the number 0·27, the mean of the averages of both these series of determinations, as the normal specific heat of sesquichloride of carbon, and to consider it as sufficiently below the melting-point (according to FARADAY this is at 160°), if the connexion between the specific heat of solid bodies and their composition, discussed in § 96 *et seq.*, had not been known to me; but the specific heat of sesquichloride of carbon calculated therefrom is 0·177. This deviates from the number found in a manner which at first I could not understand. The idea that the specimen was impure was inadmissible[†]. To try whether the porcelain-like mass of sesquichloride which solidified on fusion had an essentially different specific heat from that not fused, I recrystallized the substance from ether, washed the crystals (which showed very distinctly the characteristic form of the body as described by BROOKE and LAURENT) with a little ether, and dried them at 100°. Dried at this temperature, without being melted, they were white, like porcelain, and gave now the following results.

III.—Experiments with Water. Glass 3. Temperature of the Air 18°·4–18°·7.

T. °	T'. °	t'. °	t. °	M. grms.	m. grms.	f. grms.	y.	x. grm.	sp. H.
49·2	20·6	20·34	16·53	26·935	3·835	2·06	1·000	0·453	0·280
49·2	20·7	20·42	16·62	26·94	„	„	„	„	0·281
49·0	20·8	20·53	16·81	26·95	„	2·05*	„	„	0·274
							Mean . . .		0·275

That is essentially the same specific heat as my earlier experiments gave. If now it was improbable that the specific heat of sesquichloride of carbon did not differ much from 0·27, I might, on the other hand, also consider it improbable that this compound would make an exception to the relation which I had found between specific heat and composition—a relation which holds good in hundreds of cases of solid bodies. Sesquichloride of carbon would be the only exception to the validity of this relation; but this single exception would be sufficient to disprove its universal applicability,

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* After drying the stopper.

[†] In the specimen I investigated, Mr. DEHN found 90·19 per cent. chlorine; the quantity calculated from the formula C_2Cl_6 is 89·88 per cent.

and to leave it undecided when, and in how many cases, other such exceptions might occur.

Although the great distance of the temperatures used in my experiments from the melting-point of sesquichloride of carbon made it improbable, it was yet possible that the specific heat of this body varies considerably at the temperatures which I used, and is only constant and normal at still lower temperatures. In the preceding experiments I had heated sesquichloride of carbon to 49°–52°; it was improbable that this body, at so great a distance from its melting-point (160°), should absorb latent heat in softening in appreciable quantity, yet the circumstance that this substance is brittle in the cold, but distinctly tougher at 50°, led me to determine the specific heat at lower temperatures than in the previous case. I made the two following series of experiments, *a* with sesquichloride crystallized from alcoholic, and *b* from ethereal solution: in both series the crystals dried at 100° were porcelain white in appearance.

a.—Experiments with Water. Glass 1. Temperature of the Air 17°·8.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
36·8	19·7	19·35	17·42	26·98	2·11	2·085	1·000	0·651	0·146
37·6	19·8	19·52	17·52	26·94	„	„	„	„	0·138
37·2	19·7	19·44	17·51	26·94	„	„	„	„	0·111
37·1	19·8	19·45	17·53	26·98	„	2·075*	„	„	0·127

b.—Experiments with Water. Glass 3. Temperature of the Air 17°·8.

T.	T'.	*t'*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
37·2	19·8	19·45	17·42	26·98	3·64	2·11	1·000	0·453	0·161
37·2	19·7	19·43	17·42	26·99	„	„	„	„	0·148
37·3	19·7	19·44	17·42	26·965	„	„	„	„	0·146
37·3	19·7	19·44	17·43	26·965	„	2·10	„	„	0·145

Both these series can only be considered as giving approximate results. In both the magnitude $T-T'$ is very small, not as much as 18°; in the series *a* the quantity of solid was moreover small, and its thermal action but a small fraction of the entire amount observed. The mean of the four experiments of the series *b* would give the specific heat between 20° and 37° at 0·15, and the first experiment of the series *a* agrees well with this. The specific heat here found between 20° and 37° comes very near that calculated from the composition, and is so much less than that found between 20° and 50°, that it is probable this substance may towards 50° absorb heat in softening, the amount of which may make the numbers for the specific heat too great.

To decide upon this point, I made two additional series of experiments in which, since the vessel containing sesquichloride of carbon and water could only be slightly heated

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* After drying the stopper.

(not to 40°), and the difference of temperature T − T′ accordingly was small, I used all possible care. I thus obtained the following results.

a. Crystals obtained from ethereal solution dried at 100°: milky white.

Experiments with Water. Glass 1. Temperature of the Air 16°·1–15°·7.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
37·1	18·1	17·84	15·64	26·94	3·58	1·845	1·000	0·651	0·174
37·1	18·2	17·92	15·73	26·99	„	„	„	„	0·176
37·2	18·0	17·72	15·63	26·985	„	1·835[*]	„	„	0·165
Temperature of the Air 16°·1.									
43·7	18·2	17·93	14·93	26·995	3·58	1·835	1·000	0·651	0·193
43·5	18·2	17·93	14·95	26·97	„	„	„	„	0·193
Temperature of the Air 16°·2.									
51·9	18·4	18·12	13·86	26·995	3·58	1·82	1·000	0·651	0·269
48·6	18·1	17·77	13·84	26·975	„	„	„	„	0·281

b. Clear crystals obtained from ethereal solution, dried by passing a current of dry air over them at the ordinary temperature.

Experiments with Water. Glass 3. Temperature of the Air 16°·2–15°·7.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
36·9	18·2	17·93	15·62	26·99	4·235	2·155	1·000	0·453	0·171
36·8	18·2	17·92	15·64	26·99	„	„	„	„	0·184
37·1	18·3	18·01	15·63	26·975	„	2·145[*]	„	„	0·193

Temperature of the Air 16·1°·–16°·2.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grms.		grm.	
43·4	18·1	17·84	14·63	26·99	4·235	2·145	1·000	0·453	0·195
43·4	18·2	17·90	14·70	26·96	„	„	„	„	0·195
Temperature of the Air 16°·2.									
52·0	18·9	18·63	14·05	26·955	4·235	2·125	1·000	0·453	0·272
47·3	18·1	17·83	13·73	26·945	„	„	„	„	0·285

In the last series of experiments, on heating to about 50° a change took place in the hitherto clear crystals; they became dull and resembled porcelain. By special experiments I found that transparent crystals of sesquichloride of carbon gradually heated in water underwent this change at 50°–52°.

These determinations leave no doubt that, as is the case with other substances[†], for

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[*] After drying the stopper.

[†] I call to mind the experiments of PERSON, who found (Ann. de Chim. et de Phys. [3] vol. xxvii. p. 263) for the specific heat of bees' wax melting at 61°·8,

Between −21° and +3°	6° and 26°	26° and 42°	42° and 58°
0·4287	0·504	0·82	1·72

temperatures near their melting-points, so also with sesquichloride of carbon at a temperature of 50° (that is more than 100° from its melting-point), the specific heat (or rather the number which is obtained for this in determinations) rapidly and considerably increases. From the last two series of experiments the specific heat of sesquichloride of carbon is

	Between 18° and 37°.	Between 18° and 43°.	Between 18° and 50°.
Mean of experiments: *a* . . .	0·172	0·193	0·275
„ „ *b* . . .	0·183	0·195	0·279
Average	0·178	0·194	0·277

The specific heat of sesquichloride of carbon increases much more between 43° and 50° than between 37° and 43°. It may be assumed that for temperatures below 37° the number found, 0·178, comes very near the true specific heat of this compound, that is, uninfluenced by heat of softening.

78. *Cane-sugar*, $C_{12} H_{22} O_{11}$. Dried crystalline fragments of clear sugarcandy.

Experiments with Naphtha A. Glass 3. Temperature of the Air 20°·6.

T.	T′.	*t*′.	*t*.	M. grms.	*m*. grms.	*f*. grm.	*y*.	*x*. grm.	sp. H.
49°·9	22°·2	21°·93	19°·75	26·96	3·165	1·625	0·431	0·453	0·306
51·4	22·6	22·26	20·03	26·94	„	„	„	„	0·295
51·4	22·6	22·30	20·05	26·965	„	1·62*	„	„	0·302
							Mean	. . .	0·301

Fine loaf-sugar was recrystallized from water, the mother-liquor washed off with dilute alcohol, the pure white crystals dried at 100°. They gave the following results.

Experiments with Naphtha B. Glass 1. Temperature of the Air 18°·5–18°·7.

T	T′.	*t*′.	*t*.	M. grms.	*m*. grms.	*f*. grm.	*y*.	*x*. grm.	sp. H.
51°·5	20°·9	20°·62	18°·16	26·945	2·915	1·54	0·419	0·651	0·299
51·6	20·7	20·43	17·95	26·95	„	„	„	„	0·297
50·3	20·6	20·33	17·94	26·985	„	1·52*	„	„	0·303
							Mean	. . .	0·300

I also examined amorphous cane-sugar. Crystals dried at 100°, as used in the preceding experiment, were melted in an oil-bath at 160°–170°, and the fused mass allowed to cool in the closed tube. The resultant amorphous amber-like viscous mass, exactly resembling colophony, was comminuted (as rapidly as possible to avoid the absorption of moisture), and gave the following results.

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[*] After drying the stopper.

Experiments with Naphtha B. Glass 1. Temperature of the Air 18°·0–18°·4.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·4	20·1	19·82	17·24	26·97	2·475	1·77	0·419	0·651	0·336
50·9	20·0	19·74	17·20	26·99	,,	,,	,,	,,	0·334
51·6	20·1	19·78	17·15	26·975	,,	,,	,,	,,	0·345
50·9	20·1	19·77	17·20	26·96	,,	1·75*	,,	,,	0·357
							Mean . . .		0·342

The pieces of amorphous sugar used for these experiments were clear even when the experiments were concluded. In the investigation of such a hygroscopic substance it is impossible to avoid with certainty any absorption of water; yet it seems to me improbable that the difference between the number 0·342 found for amorphous cane-sugar between 20° and 51°, and 0·301 for crystallized sugar between the same limits, depends on an absorption of water by the former; but it is probable that the greater specific heat found for amorphous sugar depends on the fact that at 50° even it contains some heat of softening. According to WÖHLER's observations, bodies in the amorphous condition have other, in general lower, fusing-points than those in the crystallized state†; crystallized cane-sugar melts at 160° C., amorphous between 90° and 100°; at the latter temperature the amorphous sugar may be drawn out in threads, but even at a lower temperature the softening begins.

Mannite, $C_6H_{14}O_6$. Crystallized mannite, dried at 100°, was melted in the oil-bath at 160°–170°, and the radiant crystalline mass was comminuted. It gave the following results‡.

Experiments with Naphtha B. Glass 3. Temperature of the Air 17°·1–17°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·1	19·3	18·92	16·57	26·98	2·56	1·815	0·419	0·453	0·318
51·6	19·4	19·12	16·64	26·93	,,	,,	,,	,,	0·336
51·0	19·5	19·19	16·82	26·965	,,	,,	,,	,,	0·319
51·3	19·6	19·31	16·92	26·93	,,	1·805*	,,	,,	0·321
							Mean . . .		0·324

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* After drying the stopper.

† Ann. der Chem. und Pharm. vol. xli. p. 155.

‡ I also worked with mannite which was crystallized in slender prisms and dried at 100°.

Experiments with Naphtha B. Glass 3. Temperature of the Air 17°·4.

T.	T'.	t'.	t.	M.	m	f.	y	x.	sp. H.
°	°	°	°	grms.	grms.	grms.		grns.	
49·5	19·2	18·85	16·61	26·95	2·13	2·14	0·419	0·453	0·302
51·3	19·3	19·03	16·64	26·94	,,	,,	,,	,,	0·311
50·5	19·3	19·04	16·74	26·98	,,	2·13*	,,	,,	0·302

I consider the somewhat larger numbers obtained by using the compact pieces which had been melted to be more correct.

79. *Tartaric Acid*, $C_4H_6O_6$. Dried fragments of larger crystals.

Experiments with Naphtha A. Glass 1. Temperature of the Air 20°·6.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·3	22·4	22·12	19·74	26·985	3·16	1·53	0·431	0·651	0·289
50·5	22·5	22·23	19·94	26·96	„	„	„	„	0·283
50·7	22·6	22·32	20·03	26·97	„	1·52*	„	„	0·282
							Mean . . .		0·285

Small crystals dried at 100°.

Experiments with Naphtha B. Glass 3. Temperature of the Air 18°·0–18°·4.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·1	20·0	19·68	17·15	26·97	3·57	1·69	0·419	0·453	0·289
50·9	20·0	19·72	17·20	26·99	„	„	„	„	0·291
51·3	20·0	19·73	17·18	26·97	„	„	„	„	0·290
50·5	19·9	19·63	17·13	26·97	„	1·68*	„	„	0·293
							Mean . . .		0·291

The average of the means of both series of experiments gives 0·288 as the specific heat of crystallized tartaric acid between 21° and 51°.

Crystallized Racemic Acid, $C_4H_6O_6+H_2O$. Fragments of air-dried transparent crystals, which remained clear in the experiments made with them.

Experiments with Naphtha B. Glass 1. Temperature of the Air 16°·4–16°·9.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·5	18·6	18·33	15·63	26·945	3·17	1·495	0·419	0·651	0·317
50·3	18·6	18·33	15·64	26·965	„	„	„	„	0·319
50·6	18·7	18·43	15·73	26·965	„	„	„	„	0·317
50·0	18·8	18·52	15·86	26·975	„	1·48*	„	„	0·324
							Mean . . .		0·319

Succinic Acid, $C_4H_6O_4$. Small crystals dried at 100°.

Experiments with Naphtha B. Glass 1. Temperature of the Air 17°·3–17°·7.

T.	T′.	*t′*.	*t*.	M.	*m*.	*f*.	*y*.	*x*.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·4	19·4	19·05	16·54	26·985	2·455	1·64	0·419	0·651	0·317
50·5	19·4	19·13	16·70	26·95	„	„	„	„	0·313
50·8	19·5	19·24	16·80	26·965	„	„	„	„	0·311
50·9	19·6	19·26	16·82	26·935	„	1·625*	„	„	0·313
							Mean . . .		0·313

* After drying the stopper.

80. *Formiate of Baryta*, $Ȼ_2 H_2 Ba Θ_4$. Beautiful clear crystals dried at 100°.

Experiments with Naphtha B. Glass 3. Temperature of the Air 18°·5–18°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
51·0	20·6	20·31	17·93	26·98	6·91	1·615	0·419	0·453	0·142
53·1	20·7	20·40	17·85	26·94	"	"	"	"	0·143
51·8	20·7	20·41	17·95	26·97	"	"	"	"	0·145
52·4	20·7	20·38	17·93	26·99	"	1·58*	"	"	0·141
						Mean . . .			0·143

Crystallized Neutral Oxalate of Potass, $Ȼ_2 K_2 Θ_4 + H_2 Θ$. Air-dried transparent crystals, which remained clear in the experiments made with them.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
49·4	19·3	19·00	16·52	26·995	3·57	1·765	0·419	0·651	0·233
49·3	19·4	19·12	16·62	26·95	"	"	"	"	0·241
49·0	19·5	19·15	16·72	26·945	"	"	"	"	0·232
50·0	19·6	19·26	16·73	26·97	"	1·755*	"	"	0·240
						Mean . . .			0·236

Crystallized Oxalate of Potass (quadroxalate), $Ȼ_2 H K Θ_4 + Ȼ_2 H_2 Θ_4 + 2 H_2 Θ$. Crystals dried in the air, which were also clear after the experiments.

Experiments with Naphtha B. Glass 3. Temperature of the Air 16°·7–16°·9.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·1	18·6	18·34	15·77	26·965	3·375	1·76	0·419	0·453	0·283
49·8	18·7	18·42	15·86	26·98	"	"	"	"	0·288
50·2	18·8	18·45	15·91	26·98	"	"	"	"	0·278
50·3	18·7	18·43	15·86	26·95	"	1·745*	"	"	0·282
						Mean . . .			0·283

Acid Tartrate of Potass, $Ȼ_4 H_5 K Θ_6$. Crystals dried at 100°.

Experiments with Naphtha B. Glass 3. Temperature of the Air 16°·6–16°·8.

T.	T'.	t'.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·8	18·6	18·32	15·73	26·965	3·89	1·69	0·419	0·453	0·259
51·0	18·6	18·34	15·72	26·95	"	"	"	"	0·262
50·6	18·7	18·41	15·85	26·935	"	"	"	"	0·257
50·3	18·6	18·34	15·84	26·965	"	1·675*	"	"	0·250
						Mean . . .			0·257

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* After drying the stopper.

Crystallized Tartrate of Soda and Potass, $\mathrm{C_4H_4NaKO_6+4H_2O}$. Fragments of transparent air-dried Seignette salt, which remained clear in the experiments made with them.

Experiments with Naphtha B. Glass 1. Temperature of the Air 16°·7–16°·9.

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·0	19·0	18·72	16·03	26·99	3·385	1·415	0·419	0·651	0·324
50·5	18·8	18·47	15·68	26·93	”	”	”	”	0·333
50·5	18·9	18·57	15·82	26·95	”	”	”	”	0·325
50·4	18·9	18·61	15·84	26·965	”	”	”	”	0·333
50·5	18·9	18·57	15·83	26·965	”	1·40*	”	”	0·325
							Mean . . .		0·328

Crystallized Acid Malate of Lime, $\mathrm{C_4H_4CaO_5+C_4H_6O_5+8H_2O}$. Small crystals dried over sulphuric acid, which remained clear in the following experiments:

T.	T′.	t′.	t.	M.	m.	f.	y.	x.	sp. H.
°	°	°	°	grms.	grms.	grm.		grm.	
50·8	19·4	19·11	16·55	26·985	2·76	1·89	0·419	0·453	0·346
50·1	19·5	19·20	16·73	26·965	”	”	”	”	0·337
50·5	19·6	19·34	16·84	26·94	”	”	”	”	0·339
50·4	19·6	19·27	16·82	26·97	”	1·865*	”	”	0·330
							Mean . . .		0·338

IV.—TABLE OF THE SUBSTANCES WHOSE SPECIFIC HEAT HAS BEEN EXPERIMENTALLY DETERMINED.

81. In the following I give a summary of those solid substances of known composition for which there are trustworthy determinations of the specific heat. I have endeavoured to make this summary complete; yet I have not thought it necessary to include all known determinations; for instance, all those referring to the metals most frequently investigated. But it appeared to me desirable to include completely the determinations of experimenters who have investigated a greater number of substances, in order to see how far the results obtained by different inquirers are comparable; in inserting the numbers which I found for many substances of which the specific heats had been already determined by others, I had no other intention than that of offering criteria for judging how far these determinations are comparable, and may be used for the considerations which are given in the fifth Division.

The determinations given in the following summary are principally due to Dulong and Petit (D. P.), Neumann (N.), Regnault (R.), and myself (Kp.). There are besides some of Person (Pr.), of Alluard (A.), and the recent investigations of Pape (Pp.) are also included. By far the largest number of these determinations have been made by the method of mixture. A few only of the elements investigated by Dulong and Petit,

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* After drying the stopper.

and some of the chemical compounds by NEUMANN have been determined by the method of cooling. Where it is not otherwise stated in reference to the temperature, all determinations refer to temperatures between 0° and 100°. Where the determination has been made beyond these limits, or where a more accurate statement of temperature is important, it is noticed. Where the same substance has been repeatedly investigated by the same observer, the result obtained for the purer preparation, and in general the most certain result, is taken.

In the following the chemical formula is given for each substance, the symbols used both here and subsequently, when not otherwise mentioned, refer to the numbers given in the last column of § 2 as the most recent assumptions for the atomic weights, the corresponding atomic weight, and the atomic heat, viz. the product of the specific heat and the atomic weight.

82. *Elements and Alloys.*

	Atomic weight.		Specific heat.		Atomic heat.
Ag	108		0·0557	D. P.	6·02
			0·0570	R.	6·16
			0·0560	Kp.	6·05
Al	27·4		0·2143	R.	5·87
			0·202	Kp.	5·53
As	75		0·0814	R.	6·11
Au	197		0·0298	D. P.	5·88
			0·0324	R.	6·38
B	10·9	Amorphous	0·254	Kp.	2·77
		Graphitoidal	0·235	R.	2·56
		Crystalline	0·230	Kp.	2·51
		”	0·225–0·262	R.	2·45–2·86
Bi	210		0·0288	D. P.	6·05
			0·0308	R.	6·47
			0·0305	Kp.	6·41
Br	80	Between −78° and 20°	0·0843	R.	6·74
Ꞓ	12	Wood charcoal	0·241	R.	2·89
		Gas carbon	0·204	R.	2·45
		”	0·185	Kp.	2·22
		Natural graphite	0·202	R.	2·42
		”	0·174	Kp.	2·09
		Iron graphite	0·197	R.	2·36
		”	0·166	Kp.	1·99
		Diamond	0·1469	R.	1·76
Ꞓd	112		0·0567	R.	6·35
			0·0542	Kp.	6·07
Ꞓo	58·8		0·1067	R.	6·27
Ꞓu	63·4		0·0949	D. P.	6·02
		Hammered	0·0935	R.	5·93
		Heated	0·0952	R.	6·04
			0·0930	Kp.	5·90
Ꞙe	56		0·1100	D. P.	6·16
			0·1138	R.	6·37
			0·112	Kp.	6·27
Ħg	200	Between −78° and −40°	0·0319	R.	6·38

	Atomic weight.		Specific heat.		Atomic heat.
I	127		0·0541	R.	6·87
~~Ir~~	198		0·0326	R.	6·45
K	39·1	Between –78° and ?	0·1655	R.	6·47
Li	7		0·9408	R.	6·59
~~Mg~~	24		0·2499	R.	6·00
			0·245	Kp.	5·88
~~Mn~~	55		0·1217	R.	6·69
~~Mo~~	96		0·0722	R.	6·93
Na	23	Between –34° and 7°	0·2934	R.	6·75
~~Ni~~	58·8		0·1092	R.	6·42
~~Os~~	199·2		0·0311	R.	6·20
P	31	Yellow, between 13° and 36°	0·202	Kp.	6·26
		„ „ 7° „ 30°	0·1895	R.	5·87
		„ „ –21° „ 7°	0·1788	Pr.	5·54
		„ „ –78° „ 10°	0·1740	R.	5·39
		Red „ 15° „ 98°	0·1698	R.	5·26
~~Pb~~	207		0·0293	D. P.	6·06
			0·0314	R.	6·50
			0·0315	Kp.	6·52
~~Pd~~	106·6		0·0593	R.	6·32
~~Pt~~	197·4		0·0314	D. P.	6·20
			0·0324	R.	6·40
			0·0325	Kp.	6·42
~~Rh~~	104·4		0·0580	R.	6·06
~~S~~	32		0·1880	D. P.	6·02
		Rhombic, between 14° and 99°	0·1776	R.	5·68
		„ „ 17° „ 45°	0·163	Kp.	5·22
Sb	122		0·0507	D. P.	6·20
			0·0508	R.	6·20
			0·0523	Kp.	6·38
Se	79·4	Amorphous, bet. –27° and 8°	0·0746	R.	5·92
		Crystalline, „ 98° „ 20°	0·0762	R.	6·05
		„ „ –18° „ 7°	0·0745	R.	5·92
Si	28	Graphitoidal	0·181	Kp.	5·07
		Crystallized	0·165	Kp.	4·62
		„	0·167–0·179	R.	4·68–5·01
		Fused	0·138	Kp.	3·86
		„	0·156–0·175	R.	4· –4·90
Sn	118		0·0514	D. P.	6·06
			0·0562	R.	6·63
			0·0548	Kp.	6·46
~~Te~~	128		0·0474	R.	6·07
			0·0475	Kp.	6·08
Tl	204		0·0336	R.	6·85
~~W~~	184		0·0334	R.	6·15
~~Zn~~	65·2		0·0927	D. P.	6·04
			0·0956	R.	6·23
			0·0932	Kp.	6·08

Alloys which only melt far above 100°.

	Atomic weight.	Specific heat.		Atomic heat.
$BiSn$	328	0·0400	R.	13.1
$BiSn_2$	446	0·0450	R.	20·1
$BiSn_2Sb$	568	0·0462	R.	26·2
$BiSn_2SbZn_2$	698·4	0·0566	R.	39·5
$PbSb$	329	0·0388	R.	12·8
$PbSn$	325	0·0407	R.	13·2
$PbSn_2$	443	0·0451	R.	20·0

83. *Arsenides and Sulphides.*

$CoAs_2$	208·8	Speis cobalt	0·0920	N.	19·2

As the locality of this mineral is not given, the formula and atomic weight are not certain. Metals replacing the cobalt can, however, have little influence on the atomic weight and the product.

Ag_2S	248	Fused	0·0746	R.	18·5
$CoAsS$	166	Cobalt glance	0·1070	N.	17·8
Cu_2S	158·8	Fused	0·1212	R.	19·2
		Copper glance	0·120	Kp.	19·1
$FeAsS$	163	Mispickel	0·1012	N.	16·5
AsS	107	Commercial	0·1111	N.	11·9
CoS	90·8	Fused	0·1251	R.	11·4
$Cu_{\frac{1}{2}}Fe_{\frac{1}{2}}S$	91·7	Copper pyrites	0·1289	N.	11·8
		,,	0·131	Kp.	12·1
FeS	88	Fused	0·1357	R.	11·9
HgS	232	Cinnabar	0·052	N.	12·1
		,,	0·0512	R.	11·9
		,,	0·0517	Kp.	12·0
NiS	90·8	Fused	0·1281	R.	11·6
PbS	239	Galena	0·053	N.	12·7
		,,	0·0509	R.	12·2
		,,	0·0490	Kp.	11·7
SnS	150	Fused	0·0837	R.	12·6
ZnS	97·2	Zinc-blende	0·1145	N.	11·1
		,,	0·1230	R.	12·0
		,,	0·120	Kp.	11·7
Fe_7S_8	648	Magnetic pyrites	0·1533	N.	99·3
			0·1602	R.	103·8
As_2S_3	246	Natural	0·1132	N.	27·8
Bi_2S_3	516	Artificial	0·0600	R.	31·0
Sb_2S_3	340	Natural	0·0907	N.	30·8
		Artificial	0·0840	R.	28·6
FeS_2	120	Marcasite	0·1332	N.	16·0
		Iron pyrites	0·1275	N.	15·3
		,,	0·1301	R.	15·6
		,,	0·126	Kp.	15·1
MoS_2	160	Natural	0·1067	N.	17·1
		,,	0·1233	R.	19·7
SnS_2	182	Aurum musivum	0·1193	R.	21·7

84. *Chlorine, Bromine, Iodine, and Fluorine compounds.*

	Atomic weight.		Specific heat.		Atomic heat.
$AgCl$	143·5	Fused	0·0911	R.	13·1
$CuCl$	98·9	"	0·1383	R.	13·7
$HgCl$	235·5	Sublimed	0·0521	R.	12·3
KCl	74·6	Fused	0·1730	R.	12·9
		"	0·171	Kp.	12·8
$LiCl$	42·5	"	0·2821	R.	12·0
$NaCl$	58·5	"	0·2140	R.	12·5
		"	0·213	Kp.	12·5
		Rock-salt	0·219	Kp.	12·8
$RbCl$	120·9	Fused	0·112	Kp.	13·5
NH_4Cl	53·5	Crystallized	0·373	Kp.	20·0
$BaCl_2$	208	Fused	0·0896	R.	18·6
		"	0·0902	Kp.	18·8
$CaCl_2$	111	"	0·1642	R.	18·2
$HgCl_2$	271	Sublimed	0·0689	R.	18·7
		Crystallized	0·0640	Kp.	17·3
$MgCl_2$	95	Fused	0·1946	R.	18·5
		"	0·191	Kp.	18·2
$MnCl_2$	126	"	0·1425	R.	18·0
$PbCl_2$	278	"	0·0664	R.	18·5
$SnCl_2$	189	"	0·1016	R.	19·2
$SrCl_2$	158·6	"	0·1199	R.	19·0
$ZnCl_2$	136·2	"	0·1362	R.	18·6
$BaCl_2+2H_2O$	244	Crystallized	0·171	Kp.	41·7
$CaCl_2+6H_2O$	219	Between −21° and 0°	0·345	Pr.	75·6
ZnK_2Cl_4	285·4	Crystallized	0·152	Kp.	43·4
PtK_2Cl_6	488·6	"	0·113	Kp.	55·2
SnK_2Cl_6	409·2	"	0·133	Kp.	54·4
Cr_2Cl_6	317·4	"	0·143	Kp.	45·4
$AgBr$	188	Fused	0·0739	R.	13·9
KBr	119·1	"	0·1132	R.	13·5
$NaBr$	103	" *	0·1384	R.	14·3
$PbBr_2$	367	"	0·0533	R.	19·6
AgI	235	"	0·0616	R.	14·5
CuI	190·4	"	0·0687	R.	13·1
HgI	327	Powder	0·0395	R.	12·9
KI	166·1	Fused	0·0819	R.	13·6
NaI	150	"	0·0868	R.	13·0
HgI_2	454	"	0·0420	R.	19·1
PbI_2	461	"	0·0427	R.	19·7
$CaFl_2$	78	Fluor-spar	0·2082	N.	16·2
		"	0·2149	R.	16·8
		"	0·209	Kp.	16·3
$AlNa_3Fl_6$	210·4	Cryolite	0·238	Kp.	50·1

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* The preparation contained carbonate of soda.

85. *Oxides.*

	Atomic weight.		Specific heat.		Atomic heat.
$\mathrm{Cu_2\Theta}$	142·8	Red copper ore	0·1073	N.	15·3
		„	0·111	Kp.	15·9
$\mathrm{H_2\Theta}$	18	Ice between −21° and −2°	0·480	Pr.	8·6
		„ 78° „ 0°	0·474	R.	8·5

DESAINS found the specific heat of ice between −20° and 0° to be 0·513; PERSON, between −20° and 0° = 0·504; HESS, between −14° and 0° = 0·533. PERSON is of opinion that ice, even somewhat below its melting-point, between −2° and 0°, absorbs heat of fusion.

$\mathrm{Cu\Theta}$	79·4		0·137	N.	10·9
			0·1420	R.	11·3
			0·128	Kp.	10·2
$\mathrm{Hg\Theta}$	216	Commercial	0·049	N.	10·6
		Crystalline	0·0518	R.	11·2
		„	0·0530	Kp.	11·4
$\mathrm{Mg\Theta}$	40		0·276	N.	11·0
			0·2439	R.	9·8
$\mathrm{Mn\Theta}$	71		0·1570	R.	11·1
$\mathrm{Ni\Theta}$	74·8	Feebly ignited	0·1623	R.	12·1
		Strongly ignited	0·1588	R.	11·9
$\mathrm{Pb\Theta}$	223	Fused	0·0509	R.	11·4
		Crystalline powder	0·0512	R.	11·4
		„ „	0·0553	Kp.	12·3
$\mathrm{Zn\Theta}$	81·2		0·132	N.	10·7
			0·1248	R.	10·1
$\mathrm{Mg\Theta + H_2\Theta}$	58	Brucite	0·312	Kp.	18·1
$\mathrm{Fe_3\Theta_4}$	232	Magnetic iron ore	0·1641	N.	38·1
		„ „	0·1678	R.	38·9
		„ „	0·156	Kp.	36·2
$\mathrm{MgAl_2\Theta_4}$	142·8	Spinelle	0·194	Kp.	27·7
$\mathrm{Mg_{\frac{1}{2}}Fe_{\frac{1}{2}}Cr_{\frac{3}{2}}Al_{\frac{1}{2}}\Theta_4}$	196	Chrome iron ore	0·159	Kp.	31·2
$\mathrm{Al_2\Theta_3}$	102·8	Sapphire	0·1972	N.	20·3
			0·2173	R.	22·3
$\mathrm{As_2\Theta_3}$	198	Opaque	0·1279	R.	25·3
$\mathrm{B_2\Theta_3}$	69·8	Fused	0·2374	R.	16·6
$\mathrm{Bi_2\Theta_3}$	468		0·0605	R.	28·3
$\mathrm{Cr_2\Theta_3}$	152·4		0·196	N.	29·9
			0·1796	R.	27·4
		Crystalline	0·177	Kp.	27·0
$\mathrm{Fe_2\Theta_3}$	160	Artificial, feebly ignited	0·1757	R.	28·1
		„ strongly ignited	0·1681	R.	26·9
		Specular iron	0·1692	N.	27·1
		„	0·1670	R.	26·7
		„	0·154	Kp.	25·1
$\mathrm{Fe_{5}Ti_{\frac{3}{4}}\Theta_3}$	155·5	Iserine	0·1762	N.	27·4
		„	0·177	Kp.	27·5
$\mathrm{Sb_2\Theta_3}$	292	Fused	0·0901	R.	26·3
$\mathrm{Mn_2\Theta_3 + H_2\Theta}$	176	Manganite	0·176	Kp.	31·0

	Atomic weight.		Specific heat.		Atomic heat.
$\mathrm{Mn\Theta_2}$	87	Pyrolusite	0·159	Kp.	13·8
$\mathrm{Si\Theta_2}$	60	Quartz	0·1883	N.	11·3
		"	0·1913	R.	11·5
		"	0·186	Kp.	11·2
$\mathrm{Si_{\frac{1}{2}}Zr_{\frac{1}{2}}\Theta_2}$	90·8	Zircon	0·1456	R.	13·2
		"	0·132	Kp.	12·0
$\mathrm{Sn\Theta_2}$	150	Cassiterite	0·0931	N.	14·0
		"	0·0933	R.	14·0
		"	0·0894	Kp.	13·4
$\mathrm{Ti\Theta_2}$	82	Artificial	0·1716	R.	14·1
		Rutile	0·1724	N.	14·1
		"	0·1703	R.	14·0
		"	0·157	Kp.	12·9
		Brookite	0·161	Kp.	13·2
$\mathrm{Mo\Theta_3}$	144	Fused	0·1324	R.	19·1
		Pulverulent	0·154 ?	Kp.	22·2
$\mathrm{W\Theta_3}$	232	"	0·0798	R.	18·5
		"	0·0894 ?	Kp.	20·7

86. *Carbonates and Silicates.*

$\mathrm{K_2C\Theta_3}$	138·2	Fused	0·2162	R.	29·9
		"	0·206	Kp.	28·5
$\mathrm{Na_2C\Theta_3}$	106	"	0·2728	R.	28·9
		"	0·246	Kp.	26·1
$\mathrm{Rb_2C\Theta_3}$	230·8	"	0·123	Kp.	28·4
$\mathrm{BaC\Theta_3}$	197	Witherite	0·1078	N.	21·2
			0·1104	R.	21·7
$\mathrm{CaC\Theta_3}$	100	Calc-spar	0·2046	N.	20·5
		"	0·2086	R.	20·9
		"	0·206	Kp.	20·6
		Arragonite	0·2018	N.	20·2
		"	0·2085	R.	20·9
		"	0·203	Kp.	20·3
$\mathrm{Ca_{\frac{1}{2}}Mg_{\frac{1}{2}}C\Theta_3}$	92	Bitter spar	0·2161	N.	19·9
		"	0·2179	R.	20·0
		"	0·206	Kp.	19·0
$\mathrm{FeC\Theta_3}$	116	Spathic iron	0·182	N.	21·1
		"	0·1934	R.	22·4

The minerals investigated doubtless contained part of the iron replaced by metals of lower atomic weight. The atomic weight and the product assumed above are somewhat too great.

$\mathrm{Fe_{\frac{8}{11}},Mn_{\frac{2}{11}}Mg_{\frac{1}{11}}C\Theta_3}$	112·9	Spathic iron	0·166	Kp.	18·7
$\mathrm{Mg_{\frac{9}{7}}Fe_{\frac{2}{9}}C\Theta_3}$	91·1	Magnesite	0·227	N.	20·7
$\mathrm{PbC\Theta_3}$	267	Cerussite	0·0814	N.	21·7
		"	0·0791	Kp.	21·1

Regnault found for precipitated carbonate of lead still containing water, the specific heat 0·0860.

	Atomic weight.		Specific heat.		Atomic heat.
$\mathrm{Sr\,C\,\Theta_3}$	147·6	Strontianite	0·1445	N.	21·3
		Artificial	0·1448	R.	21·4
$\mathrm{Ca\,Si\,\Theta_3}$	116	Wollastonite	0·178	Kp.	20·7
$\mathrm{Ca_{\frac{1}{2}}\,Mg_{\frac{1}{2}}\,Si\,\Theta_3}$	108	Diopside from Tyrol	0·1906	N.	20·6
		" "	0·186	Kp.	20·1
$\mathrm{Cu\,Si\,\Theta_3 + H_2\,\Theta}$	157·4	Dioptas	0·182	Kp.	28·7
$\mathrm{Mg_{\frac{20}{11}}\,Fe_{\frac{2}{11}}\,Si\,\Theta_4}$	145·8	Olivine	0·189	Kp.	27·6
		Crysolite	0·189	Kp.	27·6
		"	0·2056	N.	30·0
$\mathrm{Al_2\,K_2\,Si_6\,\Theta_{16}}$	557	Adularia	0·1861	N.	103·7
		Orthoclase	0·1911	N.	106·4
		"	0·183	Kp.	101·9
$\mathrm{Al_2\,Na_2\,Si_6\,\Theta_{16}}$	524·8	Albite	0·1961	N.	102·9
		"	0·190	Kp.	99·7

Borates, Molybdates, Tungstates, Chromates, and Sulphates.

$\mathrm{K\,B\,\Theta_2}$	82	Fused	0·2048	R.	16·8
$\mathrm{Na\,B\,\Theta_2}$	65·9	"	0·2571	R.	16·9
$\mathrm{Pb\,B_2\,\Theta_4}$	292·8	"	0·0905	R.	26·5
$\mathrm{Pb\,B_4\,\Theta_7}$	362·6	"	0·1141	R.	41·4
$\mathrm{K_2\,B_4\,\Theta_7}$	233·8	"	0·2198	R.	51·4
$\mathrm{Na_2\,B_4\,\Theta_7}$	201·6	"	0·2382	R.	48·0
		"	0·229	Kp.	46·2
$\mathrm{Na_2B_4\Theta_7 + 10H_2\Theta}$	381·6	Crystallized borax	0·385	Kp.	146·9
$\mathrm{Pb\,Mo\,\Theta_4}$	367	Yellow lead ore	0·0827	Kp.	30·4
$\mathrm{Ca\,W\,\Theta_4}$	288	Scheelite	0·0967	Kp.	27·9
$\mathrm{Fe_{\frac{2}{5}}\,Mn_{\frac{3}{5}}\,W\,\Theta_4}$	303·4	Tungsten	0·0930	Kp.	28·2
		"	0·0978	R.	29·7

The locality of the wolfram investigated by REGNAULT is not known, and the composition uncertain. But the change in the ratio in which iron and manganese are present in the mineral alters little in the atomic weight.

$\mathrm{Pb\,Cr\,\Theta_4}$	323.4	Fused	0·0900	Kp.	29·0
$\mathrm{K_2\,Cr\,\Theta_4}$	194·4	Crystallized	0·1851	R.	36·0
		"	0·189	Kp.	36·7
$\mathrm{K_2\,Cr_2\,\Theta_7}$	294·6	"	0·1894	R.	55·8
		"	0·186	Kp.	54·8
$\mathrm{K\,H\,S\,\Theta_4}$	136·1	"	0·244	Kp.	33·2
$\mathrm{K_2\,S\,\Theta_4}$	174·2	Fused	0·1901	R.	33·1
		Crystallized	0·196	Kp.	34·1
$\mathrm{Na_2\,S\,\Theta_4}$	142	Fused	0·2312	R.	32·8
		Crystallized	0·227	Kp.	32·2
$\mathrm{N_2\,H_8\,S\,\Theta_4}$	132	"	0·350	Kp.	46·2
$\mathrm{Ba\,S\,\Theta_4}$	233	Heavy spar	0·1088	N.	25·4
		"	0·1128	R.	26·3
		"	0·108	Kp.	25·2
$\mathrm{Ca\,S\Theta_4}$	136	Calcined gypsum	0·1966	R.	26·7
		Anhydrite	0·1854	N.	25·2
		"	0·178	Kp.	24·2

	Atomic weight.		Specific heat.		Atomic heat.
$\mathrm{CuS\Theta_4}$	159·4	Solid pieces	0·184	Pp.	29·3
$\mathrm{MgS\Theta_4}$	120	Dehydrated salt	0·2216	R.	26·6
		Solid pieces	0·225	Pp.	27·0
$\mathrm{MnS\Theta_4}$	151	,,	0·182	Pp.	27·5
$\mathrm{PbS\Theta_4}$	303	Artificial	0·0872	R.	26·4
		Lead vitriol	0·0848	N.	25·7
		,,	0·0827	Kp.	25·1
$\mathrm{SrS\Theta_4}$	183·6	Artificial	0·1428	R.	26·2
		Celestine	0·1356	N.	24·9
		,,	0·135	Kp.	24·8
$\mathrm{ZnS\Theta_4}$	161·2	Coarse powder	0·174	Pp.	28·0
$\mathrm{CuS\Theta_4+H_2\Theta}$	177·4	Pulverulent	0·202	Pp.	35·8
$\mathrm{MgS\Theta_4+H_2\Theta}$	138	Coarse powder	0·264	Pp.	36·4
$\mathrm{ZnS\Theta_4+H_2\Theta}$	179·2	Solid pieces	0·202	Pp.	36·2
$\mathrm{CaS\Theta_4+2H_2\Theta}$	172	Gypsum	0·2728	N.	46·9
		,,	0·259	Kp.	44·6
$\mathrm{CuS\Theta_4+2H_2\Theta}$	195·4	Pulverulent	0·212	Pp.	41·4
$\mathrm{ZnS\Theta_4+2H_2\Theta}$	197·2	Solid pieces	0·224	Pp.	44·2
$\mathrm{FeS\Theta_4+3H_2\Theta}$	206	,,	0·247	Pp.	50·9
$\mathrm{CuS\Theta_4+5H_2\Theta}$	249·4	Crystallized	0·285	Kp.	71·1
		,,	0·316	Pp.	78·8
$\mathrm{MnS\Theta_4+5H_2\Theta}$	241	,,	0·323	Kp.	77·8
		,,	0·338	Pp.	81·5
$\mathrm{NiS\Theta_4+6H_2\Theta}$	262·8	,,	0·313	Kp.	82·3
$\mathrm{CoS\Theta_4+7H_2\Theta}$	280·8	,,	0·343	Kp.	96·4
$\mathrm{FeS\Theta_4+7H_2\Theta}$	278	,,	0·346	Kp.	96·2
		,,	0·356	Pp.	99·0
$\mathrm{MgS\Theta_4+7H_2\Theta}$	246	,,	0·362	Kp.	89·1
		,,	0·407	Pp.	100·1
$\mathrm{ZnS\Theta_4+7H_2\Theta}$	287·2	,,	0·347	Kp.	99·7
		,,	0·328	Pp.	94·2
$\mathrm{MgK_2S_2\Theta_8+6H_2\Theta}$	402·2	,,	0·264	Kp.	106·2
$\mathrm{NiK_2S_2\Theta_8+6H_2\Theta}$	437	,,	0·245	Kp.	107·1
$\mathrm{ZnK_2S_2\Theta_8+6H_2\Theta}$	443·4	,,	0·270	Kp.	119·7
$\mathrm{Al_2K_2S_4\Theta_{16}+24H_2\Theta}$	949	,, alum	0·371	Kp.	352·1
$\mathrm{Cr_2K_2S_4\Theta_{16}+24H_2\Theta}$	998·6	,, chrome alum	0·324	Kp.	323·6

88. *Arseniates, Phosphates, Pyrophosphates and Metaphosphates, Nitrates, Chlorates, Perchlorates, and Permanganates.*

$\mathrm{KAs\Theta_3}$	162·1	Fused	0·1563	R.	25·3
$\mathrm{KH_2As\Theta_4}$	180·1	Crystallized	0·175	Kp.	31·5
$\mathrm{Pb_3As_2\Theta_8}$	899	Fused	0·0728	R.	65·4
$\mathrm{Ag_3P\Theta_4}$	419	Pulverulent	0·0896 ?	Kp.	37·5
$\mathrm{KH_2P\Theta_4}$	136·1	Crystallized	0·280	Kp.	28·3
$\mathrm{Na_2HP\Theta_4+12H_2\Theta}$	358	Between −21° and 2°	0·408	Pr.	146·1

The determination of the specific heat refers to the crystallized salt. For the fused and afterwards solidified salt Person found the specific heat between the same range of temperature considerably greater, $=0·68$ to $0·78$; but the mass obtained by solidifying the fused salt gradually alters (it becomes crystallized again) with increase of volume, which is very considerable when the fused salt is allowed to cool very rapidly.

	Atomic weight.		Specific heat.		Atomic heat.
$Pb_3P_2\Theta_8$	811		0·0798	R.	64.7
$K_4P_2\Theta_7$	330·4	Fused	0·1910	R.	63·1
$Na_4P_2\Theta_7$	266	"	0·2283	R.	60·7
$Pb_2P_2\Theta_7$	588	"	0·0821	R.	48·3
$NaP\Theta_3$	102	"	0·217	Kp.	22·1
$CaP_2\Theta_6$	198	"	0·1992	R.	39·4
$AgN\Theta_3$	170	"	0·1435	R.	24·4
$KN\Theta_3$	101·1	"	0·2388	R.	24·1
		"	0·227	Kp.	22·9
		Crystallized	0·232	Kp.	23·5
$K_{\frac{1}{2}}Na_{\frac{1}{2}}N\Theta_3$	93	Fused*	0·235	Pr.	21·9
$NaN\Theta_3$	85	"	0·2782	R.	23·6
		"	0·256	Kp.	21·8
		Crystallized	0·257	Kp.	21·8
$N_2H_4\Theta_3$	80	"	0·455	Kp.	36·4
$BaN_2\Theta_6$	261	"	0·1523	R.	39·8
		"	0·145	Kp.	37·9
$PbN_2\Theta_6$	331	"	0·110	Kp.	36·4
$SrN_2\Theta_6$	211·6	"	0·181	Kp.	38·3
$KCl\Theta_3$	122·6	Fused	0·2096	R.	25·7
		Crystallized	0·194	Kp.	23·8
$BaCl_2\Theta_6+H_2\Theta$	322	"	0·157	Kp.	50·6
$KCl\Theta_4$	138·6	"	0·190	Kp.	26·3
$KMn\Theta_4$	158·1	"	0·179	Kp.	28·3

89. *So-called Organic Compounds.*

HgC_2N_2	252	Crystallized cyanide of mercury	0·100	Kp.	25·2
$ZnK_2C_4N_4$	247·4	" cyanide of zinc and potassium	0·241	Kp.	59·6
$FeK_3C_6N_6$	329·3	Crystallized ferricyanide of potassium	0·233	Kp.	76·7
$FeK_4C_6N_6+3H_2\Theta$	422·4	Crystallized ferrocyanide of potassium	0·280	Kp.	118·3
C_2Cl_6	237	Between 18° and 37°	0·178	Kp.	42·2

The specific heat between 18° and 43° was found =0·194; between 18° and 50° =0·277.

$C_{10}H_8$	128	Between −26° and 18°	0·3096	A.	39·6

The specific heat of naphthaline was found to be 0·3208 between 0° and 20°, and 0·3208 between 20° and 65°.

$C_{27}H_{54}\Theta_2$	410	Between −21° and 3°	0·4287	Pr.	175·8
$C_{46}H_{92}\Theta_2$	676				289·8

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* Obtained as mass of constant melting-point (219°·8) by fusing equivalent quantities of nitrate of potass and nitrate of soda.

The first formula is that of one constituent of bees' wax, cerotic acid; the second is that of the other, palmitate of melissyle. In reference to the numbers found for the specific heat of bees' wax at higher temperatures, compare the last remark in § 77.

	Atomic weight.		Specific heat.		Atomic heat.
$\text{Ꞓ}_{12}H_{22}\Theta_{11}$	342	Crystallized cane-sugar	0·301	Kp.	102·9
		Amorphous cane-sugar	0·342	Kp.	117·0
$\text{Ꞓ}_6H_{14}\Theta_6$	182	Mannite	0·324	Kp.	59·1
$\text{Ꞓ}_4H_6\Theta_4$	118	Succinic acid	0·313	Kp.	36·9
$\text{Ꞓ}_4H_6\Theta_6$	150	Tartaric acid	0·288	Kp.	43·2
$\text{Ꞓ}_4H_6\Theta_6+H_2\Theta$	168	Racemic acid	0·319	Kp.	53·6
$\text{Ꞓ}_2H_2\text{Ba}\Theta_4$	227	Formate of baryta	0·143	Kp.	32·5
$\text{Ꞓ}_2K_2\Theta_4+H_2\Theta$	184·2	Neutral oxalate of potass	0·236	Kp.	43·5
$\text{Ꞓ}_4H_3K\Theta_8+2H_2\Theta$	254·1	Quadroxalate of potass	0·283	Kp.	71·9
$\text{Ꞓ}_4H_5K\Theta_6$	188·1	Acid tartrate of potass	0·257	Kp.	48·3
$\text{Ꞓ}_4H_4\text{NaK}\Theta_6+4H_2\Theta$	282·1	Seignette salt	0·328	Kp.	92·5
$\text{Ꞓ}_8H_{10}\text{Ꞓa}\Theta_{10}+8H_2\Theta$	450	Acid malate of lime	0·338	Kp.	152·1

The preceding Tables contain the material, obtained experimentally, which serves as subject and basis for the subsequent considerations on the relations of the specific heat of solid bodies to their atomic weight and composition.

PART V.—ON THE RELATIONS BETWEEN ATOMIC HEAT AND ATOMIC WEIGHT OR COMPOSITION.

90. I discuss in the sequel the regularities exhibited by the atomic heats of solid bodies, the exceptions to these regularities, and the most probable explanation of these exceptions. In regard to the views which I here develope, much has been already expressed or indicated in former speculations; in this respect I refer to the first part of this paper, in which I have given the views of earlier inquirers as completely as I know them, and as fully as was necessary to bring out the peculiar value of each. It is unnecessary, then, to refer again to what was there given; but I will complete for individual special points what is to be remarked from an historical point of view.

But before discussing these regularities, the question must be discussed whether the atomic heat of a given solid substance is essentially constant, or materially varies with its physical condition. It depends on the result of this investigation, how far it may with certainty be settled whether the general results already obtained are of universal validity, or whether exceptions to them exist.

The specific heat of a solid body varies somewhat with its temperature; but the variation of the specific heat with the temperature is very small, provided the latter does not rise so high that the body begins to soften. Taking the numbers obtained by REGNAULT for lead, by DULONG and PETIT, and by BEDE and by BYSTRÖM, for the specific heats of several metals at different temperatures, the conviction follows that the changes of specific heat, if not of themselves inconsiderable, are yet scarcely to be regarded in comparison with the discrepancies in the numbers which different observers have found for the specific heat of the same body at the same temperature. At temperatures at which a body softens, the specific heat does indeed vary considerably with the temperature (compare for example § 77); but these numbers, as containing already part of the latent heat of fusion, give no accurate expression for the specific heat, and are altogether useless for recognizing the relations between this property and the atomic weight or composition.

Just as little need the small differences be considered which REGNAULT found for a few metallic substances according as they were hammered or annealed, hard or soft.

For dimorphous varieties of the same substance, even where there are considerable differences in the specific gravity, the specific heats have not been found to be materially different (compare FeS_2, § 83; TiO_2, § 85; $CaCO_3$, § 86). The results obtained with these substances appear to me more trustworthy than those with graphite and the various modifications of boron and silicium, which moreover have given partly the same specific heat for the graphitoidal and adamantine modification of the same element. What trustworthy observations we now possess decidedly favour the view that the dimorphic varieties of the same substance have essentially the same specific heat.

91. The view has been expressed that the same substance might have an essentially different specific heat, in the amorphous and crystalline conditions. I believe that the differences of specific heat found for these different conditions depend, to by far the greatest extent, upon other circumstances.

The Tables in § 83 to § 89 contain a tolerable number of substances which have been investigated both after being melted, and also crystallized; there are no such differences in the numbers as to lead to the supposition that the amorphous solidified substance had a different specific heat to what it had in the crystallized state. No such influence of the condition has been with any certainty shown to affect the validity of DULONG and PETIT'S, or of NEUMANN'S law. I may here again neglect what the determinations of carbon, boron, or silicium appear to say for or against the assumption of a considerable influence of the amorphous or crystalline condition on the specific heat. REGNAULT found (§ 85) that the specific heat of artificially prepared (uncrystalline?) and crystallized titanic acid did not differ. According to my investigations (§ 48) silicic acid has almost the same specific heat in the crystallized and in the amorphous condition.

In individual cases, where the specific heat of the same substance for the amorphous and crystallized modification has been found to be materially different*, it may be shown that foreign influences affected the determination for the one condition. Such influences are especially: 1. That one modification absorbed heat of softening at the temperature of the experiment; that is doubtless the reason why the specific heat of yellow

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* DE LA RIVE and MARCET (Ann. de Chim. et de Phys. [2] vol. lxxv. p. 118) found the specific heat of vitreous to be different from that of opaque arsenious acid, and considered the fact to be essential; but their method was not fitted to establish such a difference. PAPE'S view, too (POGGENDORFF'S Annalen, vol. cxx. pp. 341 and 342), that it is of essential importance for the specific heat of hydrated sulphates whether the salts are crystallized or not, does not appear to me to be proved by what he has adduced.

phosphorus was found to be considerably greater at higher temperatures than that of red phosphorus, but not at low ones (compare § 82), that the specific heat of amorphous cane-sugar was found to be decidedly greater than that of crystallized (§ 78), and, according to REGNAULT's opinion, also that the specific heat of amorphous selenium between 80° and 18° was found much greater (=0·103) than that of the crystalline, while for lower temperatures there was no difference in the specific heats of the two substances (§ 82). 2. That in heating one modification its transition into the other is induced, and the heat liberated in this transition makes the numbers for the specific heat incorrect; in § 33 I have discussed the probability that this circumstance, in REGNAULT's first experiments with sulphur, gave the specific heat much too high, and it is possible that it was also perceptible in the above-mentioned experiments with amorphous selenium. 3. That in immersing heated porous bodies in the water of the calorimeter heat becomes free (compare § 19); I consider this as the reason why REGNAULT found the specific heat of the more porous forms of carbon so much greater than that of the more compact (compare § 36); and REGNAULT himself sees in this the reason why he found the specific heat of the feebly ignited and porous oxides of nickel and of iron greater than that of the same oxides after stronger heating (compare § 85).

From the importance of this subject for the considerations to be afterwards adduced, I have here had to discuss more fully what differences are real and what are only apparent in the numbers found for the specific heat of one and the same substance. Even if the apparent differences are often considerable, their importance diminishes, if allowance is made for the foreign influence which may have prevailed. In many cases, on the other hand, a body in totally different modifications has almost exactly the same specific heat if these foreign influences are excluded. It may, then, be said that, from our present knowledge, one and the same body may exhibit small differences with certain physical circumstances (temperature, different degree of density), but never so great that they may be taken as an explanation why a body decidedly and undoubtedly forms an exception to a regularity which might have perhaps been expected for it—provided that the determination of the specific heat, according to which the body in question forms an exception, is trustworthy, and kept free from foreign influences.

92. Among the regularities in the atomic heat of solid bodies, that found by DULONG and PETIT for the elements stands foremost. A glance at the atomic heats of the so-called elements collated in § 82, shows that for by far the greater number the atomic heats are in fact approximately equal. But the differences in the atomic heats, even of those elements which are usually regarded as coming under DULONG and PETIT's law, are often very considerable, even when the comparison is limited to those which are most easily obtained in a pure state, and even if numbers are taken for the specific heats which give the most closely agreeing atomic heats. REGNAULT * sought an explanation of the differences of the atomic heats of the elements in the circumstance that the latter could not be investigated in comparable conditions of temperature and density; further, that the numbers for the specific heat, as determined for solid bodies, contain, besides

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* Annal. de Chim. et de Phys. [2] vol. lxxiii. p. 66, and [3] vol. xlvi. p. 257.

the true specific heat (for constant volume), also the heat of expansion. As specific heat we can indeed only take the sum of the heats necessary for heating and for expansion. But it is not yet proved that the products of the first quantity (the specific heat for constant volume) and the atomic weights would agree better than the atomic heats now do; it is only a supposition, and even the very contrary may be possible with individual substances. Temperature has an influence on the specific heat of solid bodies, and to a different extent with different bodies. Even in this respect, also, all means are wanting by which the different temperatures at which bodies are really comparable can be known, and a comparison made of their atomic heats. The utmost possible is to determine the specific heat at such a distance from the melting-point that latent heat of softening can have no influence. It is impossible to say with certainty whether the atomic heats of bodies compared at other temperatures than those which are nearly identical (ranging about 90° on each side of 10°) will show a closer agreement. It is not probable. Changes in the specific heat of solid bodies, so long as they are unaffected by heat of softening, are small in comparison with the differences which the atomic heats of individual elements show. And it is well worth consideration that individual elements (phosphorus and sulphur, *e.g.*) at temperatures relatively near their melting-points, have not materially greater specific heats than other elements (iron and platinum, for example) at temperatures relatively distant from their melting-points, but, on the contrary, considerably smaller. As regards the influence of density on the specific heat, it is undoubtedly certain that the latter may somewhat vary with the former; but it is equally so that, in all cases in which substances of undoubted purity were examined and the sources of error mentioned (§ 91) excluded, this variation is too inconsiderable to give an adequate explanation of the differences of the atomic heats found for the various solid elements.

I need not here revert to the considerations developed in §§ 90 and 91, as to how far a difference in the physical condition of a solid substance exercises an essential influence on its specific heat; for whatever view may be held in reference to this influence, and generally in reference to the circumstances which alter the specific heat of a substance, and therewith the atomic heat, this is certain, that there are individual elements whose atomic heat is distinctly and decidedly different from that of most other elements. Such elements are, from § 82, first of all boron, carbon, and silicium.

The decision of the question whether these elements really form exceptions to DULONG and PETIT's law presupposes, besides a knowledge of their specific heat, a knowledge of their atomic weight also. There can be no exceptions to DULONG and PETIT's law, if, regardless of anything which may be in opposition to it, the principle is held to, that the atomic weights of the elements must be so taken as to agree with this law. As a trial whether this law is universally applicable, the atomic weights ought rather to be taken as established in another manner. It may be confessed that the determination of the true atomic weights by chemical and physico-chemical investigations and considerations is still uncertain, and many questions are still unanswered the settlement of which may influence that determination. But there seems now to be no more trustworthy basis for fixing the atomic weights of the elements than that of taking, as the atomic weights of the elements, the relatively smallest quantities which are contained in equal volumes of their gaseous or vaporous compounds, or of which the quantities contained in such volumes are multiples in the smallest numbers; and no better means appear to exist for determining the atomic weights of those elements the vapour-densities of whose compounds could not be determined, than the assumption that in isomorphous compounds the quantities of the corresponding elements are as the atomic weights of the latter. On this basis, and using this means, the numbers for the atomic weights have been determined which are contained in the last column of the Table in § 2, and are used in § 82 *et seq.* The atomic weights B=10·9, C̵=12, S̵i=28, cannot be changed for others. That the atomic weights of tin and silicium are as 118 to 28, is further proved by the isomorphism of the double fluorides. But to these atomic weights correspond atomic heats which are far smaller than those found for most other elements. From the chemical point of view it is inadmissible to take the atomic weights of boron, carbon, and silicium * in such a manner as to make their atomic heats agree with DULONG and PETIT'S law. In any case these three elements form exceptions to DULONG and PETIT'S law. The sequel will show that this is the case with many other elements.

93. In many compounds the regularity is observed, that by dividing their atomic heat by the number of elementary atoms contained in one molecule of the compound, a quotient is obtained which comes very near the atomic heat of most of the elements—that is, 6·4. This is found in the alloys enumerated in § 82, and also in a great number of compounds of definite proportions. A few of the most important cases may be given here. For speiscobalt, $\mathrm{Co\,As_2}$ (compare § 83), this quotient is $\frac{19\cdot2}{3}=6\cdot4$; for the chlorine compounds, R Cl and R̵ Cl†, the mean of the atomic heats given in § 84 is 12·8, and the quotient $\frac{12\cdot8}{2}=6\cdot4$. Of the chlorine compounds, R̵ $\mathrm{Cl_2}$, the mean atomic heat of all the determinations in § 84 is 18·5, and the quotient $\frac{18\cdot5}{3}=6\cdot2$. It is also very near this value in the double chlorides; in Z̵n $\mathrm{K_2\,Cl_4}$ it is $\frac{43\cdot4}{7}=6\cdot2$, for R̵ $\mathrm{K_2\,Cl_6}$ (the mean of the determinations of P̵b $\mathrm{K_2\,Cl_6}$ and $\mathrm{Sn\,K_2\,Cl_6}$) it is $\frac{54\cdot8}{9}=6\cdot1$. For bromine compounds, R Br (both here and in the following examples the means are taken of the determinations in § 84), $\frac{13\cdot9}{2}=6\cdot9$; for P̵b $\mathrm{Br_2}$ $\frac{19\cdot6}{3}=6\cdot5$; for iodine compounds, RI and R̵I, $\frac{13\cdot4}{2}=6\cdot7$, and for the iodine compounds, R̵ $\mathrm{I_2}$, $\frac{19\cdot4}{3}=6\cdot5$.

But this regularity, though met with in many compounds, is by no means quite

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* For REGNAULT'S observation, whether, considering the specific heat which he found for silicium, its atomic weight is to be so taken that silicic acid contains 2 atoms of silicium to 5 of oxygen, compare Ann. de Chim. et de Phys. [3] vol. lxiii. p. 30. For SCHEERER'S remark, that according to the most probable specific heat of silicium its atomic weight must be taken so that for 1 atom of silicium there are 3 atoms of oxygen, compare POGGENDORFF'S 'Annalen,' vol. cxviii. p. 182.

† In the sequel R stands for a uni-equivalental and R̵ a polyequivalental atom of a metal.

universal. The oxygen compounds of the metals correspond to it in general the less the greater the number of oxygen atoms they contain as compared with that of metal. The mean atomic heat of the oxides $R\Theta$ in § 85 is 11·1, and the quotient $\frac{11·1}{2}=5·6$. The quotient for the oxides $R_2\Theta_3$ and $R_2\Theta_3$ (even excluding the determinations of alumina and boracic acid) is only $\frac{27·2}{5}=5·4$; for the oxides $R\Theta_2$ (even excluding the determinations for silicic acid and zircon) only $\frac{13·7}{3}=4·6$; for the oxides $R\Theta_3$, the mean of **Regnault's** determinations only $\frac{18·8}{4}=4·7$. Still smaller is the quotient for compounds which contain boron in addition to oxygen (*e. g.* for the compounds $RB\Theta_2$ (compare § 87) it is only $\frac{16·8}{4}=4·2$; for boracic acid, $B_2\Theta_3$, it is only $\frac{16·6}{5}=3·3$), and also for compounds which contain silicium in addition to oxygen (it is $\frac{11·3}{3}=3·8$ for silicic acid, $Si\Theta_2$, compare § 85), or which contain oxygen as well as hydrogen (for ice, $H_2\Theta$, it is only $\frac{8·6}{3}=2·9$*, compare § 85), or which contain hydrogen and carbon besides oxygen (*e. g.* it is only $\frac{36·9}{14}=2·6$ for succinic acid, $C_4H_6\Theta_4$, compare § 89). It may be said in a few words what are the cases in which this quotient approximates to the atomic heat of most elements, and what the cases in which it is smaller. It is near 6·4 in those compounds which only contain elements whose atomic heats, corresponding to **Dulong** and **Petit's** law, are nearly $=6·4$; it is smaller in compounds which contain elements not coming under **Dulong** and **Petit's** law and having a much smaller atomic heat than 6·4, and which are recognized as exceptions to this law, either directly, if their specific heat has been determined for the solid condition (compare § 92), or indirectly, if it be determined in the manner to be subsequently described.

94. The determinations of specific heat given in §§ 83 to 89 contain the proofs hitherto recognized for the law that chemically-similar bodies of analogous atomic constitution have approximately the same atomic heat; and a considerable number of new examples of the prevalence of this regularity are given by my determinations. The groups of analogous compounds need not again be collated, as **Neumann** has done for a smaller and **Regnault** for a larger number of groups and for individual elements contained in them. What I will here discuss is the prevalence, beyond the limits of our previous

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* Considering the atomic heat of liquid water to be 18, **Garnier** (Compt. Rendus, vol. xxxv. p. 278) thought that the quotient obtained by dividing the atomic weight by the number of elementary atoms in one atom of the compound, $\frac{18}{3}=6$, came near the atomic heat of the elements. But it requires no explanation that, in a comparison with the atomic heats of solid elements and solid compounds, that atomic heat must be taken for the compound $H_2\Theta$ which is obtained from the specific heat of ice, and not from that of water. **Garnier** is not alone in his error, which is rather to be ascribed to the circumstance that formerly both solids and liquids were compared, as regards their specific heat, in considerations how this property is influenced by the composition. **Hermann** more especially (Nouveaux Mémoires de la Société des Naturalistes de Moscou, vol. iii. p. 137) compared liquid water with solid compounds, as did also **Schröder** (**Poggendorff's** 'Annalen,' vol. lii. p. 279) and L. **Gmelin** in an early discussion of this subject (**Gehler's** 'Physicalische Wörterbuch, neue Bearbeitung,' vol. ix. p. 1942), while he subsequently (Handbuch der Chemie, 4. Aufl., vol. i. p. 220) more correctly compared the specific and the atomic heat of ice with that of other solid compounds.

knowledge, of the regularity, that compounds of analogous atomic constitution have approximately the same atomic heat.

To this belongs, first, the existence of this regularity in the case of chemically similar bodies, which exhibit an analogy of atomic constitution, when their formulæ are written with the atomic weights admitted in recent times for the elements, but which could not be recognized so long as the equivalents of the elements were taken as a basis, or the formula written, as by Regnault, with the use of the so-called thermal atomic weights.

The approximate equality of the atomic heats of analogous nitrates and chlorates, of the alkalies for example, had been already observed. The same character, the haloid, is ascribed both to carbonates and to silicates, but as these formulæ were formerly written, an analogy in the composition of chlorates and nitrates, or carbonates and silicates, could not be assumed. But salts of these four different classes, as well as arseniates and metaphosphates, have analogous atomic constitutions if we assume the recent atomic weights. The same salts have then also approximately equal atomic heats. We get the atomic heat

Of chlorate of potass, $\mathrm{K\,Cl\,\Theta_3}$, § 88	M*	24·8
„ the nitrates, $\mathrm{R\,N\Theta_3}$, in § 88.	M	23·0
„ metaphosphate of soda, $\mathrm{Na\,P\Theta_3}$, § 88		22·1
„ arseniate of potass, $\mathrm{K\,As\,\Theta_3}$, § 88		25·3
„ the carbonates, $\mathrm{RC\Theta_3}$, § 86	M	20·7
„ the silicates, $\mathrm{R\,Si\,\Theta_3}$, § 86	M	20·5

The differences in these approximately concordant atomic heats are partly essential and explainable. I come to this again (§ 95).

According to the more recent assumptions for the atomic weights, certain perchlorates, permanganates, and sulphates have analogous atomic composition, and these salts have also approximately equal atomic heats; this has been found to be

For perchlorate of potass, $\mathrm{K\,Cl\,\Theta_4}$, § 88		26·3
„ permanganate of potass, $\mathrm{K\,Mn\,\Theta_4}$, § 88		28·3
„ the sulphates, $\mathrm{RS\Theta_4}$, named in § 88	M	26·1

But approximate equality in the atomic heat is not only found in such compounds of analogous chemical composition as have similar chemical character, but also in such as have totally dissimilar chemical character.

The chemical character of protosesquioxide of iron (magnetic iron ore) is quite different from that of neutral chromate of potass. Sesquioxide of iron, or arsenious acid, have a chemical character totally different from nitrates or arseniates, or bodies of similar constitution But for the first-named compounds and for the last-named compounds, as respectively compared with each other, there is analogy in chemical composition and approximate equality of atomic heat. The atomic heat has been found to be

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* M signifies the mean of all determinations.

For magnetic iron ore, $\mathrm{Fe}_3\,\Theta_4$, § 85	M	37·7
„ chromate of potass, $\mathrm{K}_2\,\mathrm{Cr}\,\Theta_4$, § 87	M	36·4
„ sesquioxide of iron, $\mathrm{Fe}_2\,\Theta_3$, § 85	M	26·8
„ arsenious acid, $\mathrm{As}_2\,\Theta_3$, § 85		25·3
„ the nitrates, $\mathrm{RN}\Theta_3$, named in § 88		23·0
„ arseniate of potass, $\mathrm{K\,As}\,\Theta_3$, § 88		25·3

But there is even in a more extended sense approximate equality of atomic heat in bodies of analogous atomic composition. If the formulæ of the oxides, $\mathrm{R}\,\Theta_2$ (oxide of tin for instance) are doubled, they become $\mathrm{R}_2\,\Theta_4$, and are then analogous to those of the sulphates, $\mathrm{R\,S}\,\Theta_4$, or of tungstate of lime or of perchlorate of potass and other salts. To the formulæ thus made analogous equal atomic heats correspond. The following atomic heats have been found:—

Oxide of tin, $\mathrm{Sn}_2\,\Theta_4$, compare § 85	M	27·6
Titanic acid, $\mathrm{Ti}_2\,\Theta_4$, „	M	27·3
The sulphates, $\mathrm{R\,S}\Theta_4$, in § 87	M	26·1
Tungstate of lime, $\mathrm{Ca\,W}\,\Theta_4$, compare § 87		27·9
Perchlorate of potass, $\mathrm{K\,Cl}\,\Theta_4$, compare § 88		26·3
Permanganate of potass, $\mathrm{K\,Mn}\,\Theta_4$, compare § 88		28·3

If the formulæ of the oxides, $\mathrm{R}\Theta_2$, are trebled they become $\mathrm{R}_3\,\Theta_6$, analogous to those of the nitrates $\mathrm{R\,N}_2\,\Theta_6$ (nitrate of baryta, *e. g.*), and similar salts. Here also approximately equal atomic heats correspond to the formulæ thus made analogous. The atomic heats are as follows:—

Oxide of tin, $\mathrm{Sn}_3\,\Theta_6$, compare § 85	M	41·4
Titanic acid, $\mathrm{Ti}_3\,\Theta_6$, „	M	41·0
The nitrates, $\mathrm{R\,N}_2\,\Theta_6$, in § 88	M	38·1
Metaphosphate of lime, $\mathrm{Ca\,P}_2\,\Theta_6$, compare § 88		39·4

How little the atomic heat of compounds depends on their chemical character may be proved from a greater series of examples than those adduced in the preceding. It is, however, unnecessary to dwell upon this. The comparisons and considerations contained in the sequel complete what has here been developed as a proof of the principle that the atomic heat of bodies is independent of their chemical character.

95. The foregoing comparisons give examples of cases in which bodies of analogous atomic structure, with a totally different chemical character, have approximately the same atomic heat; they show that with reference to the atomic heat, monoequivalent and polyequivalent elementary atoms have the same influence, which, indeed, followed already from REGNAULT'S comparisons; that the atomic heat of a substance for its polyfold atomic formula may be compared with that of another substance for a simple atomic formula.

The preceding contains a generalization of NEUMANN'S law; but as certainly as this law is recognized in the preceding in a more general manner than was formerly assumed, as little is it universally applicable.

REGNAULT'S investigations have shown that NEUMANN'S law is not rigidly valid. Even for those compounds which contain the same element as electronegative constituent, and have similar atomic constitution, he found the atomic heats as much as $\frac{1}{10}$ to $\frac{1}{9}$ different from each other*. The reason of this he seeks in the same circumstances, which in his view prevent a closer agreement in the atomic weights of the elements (compare § 92).

Differences of this kind, and even still more considerable, occur in the atomic heats of compounds for which greater agreement in these numbers might be expected—of such compounds, that is, as contain elements of the same, or almost the same atomic heat combined with the same other element in the same atomic proportion. To this belongs the fact that the atomic heat has been found so different (§ 85) for the isomorphous compounds, magnetic iron ore (37·7), chrome iron ore (31·2), and spinelle (27·7), and for alumina (21·3) and for sesquioxide of iron (26·8). In the atomic heats of such analogous compounds there are differences for which, or rather for the magnitude of which, as furnished by our present observations, I know at present no adequate explanation.

But there is another kind of difference in the atomic heats of analogous compounds, which exhibits a regularity, and for which an explanation can be given. Certain elements impress on all their compounds the common characteristic, that their atomic heat is much smaller than that of most analogous compounds. The atomic heat of boracic acid, $B_2\,\Theta_3$, is only 16·6, while that of most other compounds, $\text{Ꞧ}_2\,\Theta_3$ and $R_2\,\Theta_3$, is between 25 and 28 (§ 85). The atomic heat of the borates, $R\,B\,\Theta_2$, is (§ 87) only 16·8, while that of $\text{Ꞧ}_2\,\Theta_2$, as the mean of the determinations in § 85, is 22·2. The atomic heat of $\text{Ᵽb}\,B_2\,\Theta_4$ is (§ 87) only 26·5, while that of $\text{Ꞙe}_3\,\Theta_4$ (§ 85) in the mean is 37·7. Similar results have been obtained for compounds of certain other elements, of carbon and of silicium for instance, that is, of those elements which in the free state have a smaller atomic heat than that of most other elements.

This observation leads to the question whether the elements enter into compounds with the atomic heats which they have in the free state, and in connexion with this, how far is it permissible to make an indirect determination of the atomic heat of the elements (in their solid state) from the atomic heats of their (solid) compounds.

96. The assumption that elements enter into compounds with the atomic heats they have in the free state would be inadmissible, if not only the atomic structure as expressed by the empirical formula, but also the grouping of the elements to proximate constituents, as is endeavoured to be expressed by the rational formula, influenced the atomic heat of the compounds. That the latter is not the case is very probable from the comparisons made in § 94, where approximately equal atomic heats were obtained for compounds of analogous empirical formulæ, even with the greatest dissi-

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* Ann. de Chim. et de Phys. [3] vol. i. p. 196.

milarity of chemical character. That that, which may be supposed and expressed by the so-called rational formula in reference to the internal constitution of compounds, does not affect the atomic heat, becomes more probable from the fact that chemically similar, and even isomorphous compounds, one of which contains an atomic group in the place of an individual atom in the other, exhibit dissimilar atomic heats. This is seen, for instance, in comparing analogous chlorine and cyanogen compounds ($Cy=CN$); the latter have far greater atomic heats. Thus the atomic heat

Of chloride of mercury, $HgCl_2$, § 84, is	18·0
„ cyanide of mercury, $HgCy_2$, § 89	25·2
„ chloride of zinc and potassium, ZnK_2Cl_4, § 84	43·4
„ cyanide of zinc and potassium, ZnK_2Cy_4, § 89	59·6

In like manner ammonium compounds ($Am=NH_4$) have atomic heats considerably greater than the corresponding potassium compounds. This is seen from the following Table:—

Chloride of potassium, KCl, § 84	M	12·9
„ ammonium, $AmCl$, § 84		20·0
Nitrate of potass, KNO_3, § 88	M	23·5
„ ammonia, $AmNO_3$, § 88		36·4
Sulphate of potass, K_2SO_4, § 87	M	33·6
„ ammonia, Am_2SO_4, § 87		46·2

97. That undecomposable atoms and atomic groups are contained in compounds with the atomic heats they have in the free state is further probable from the fact that the sum of the atomic heats of such atoms, or atomic groups, as when united form a certain compound, is equal or approximately equal to the atomic heat of this compound. For many compounds whose elements obey Dulong and Petit's law, what has been stated in § 93 contains the proof that the atomic heat of these compounds is equal to the sum of the atomic heats of the elementary atoms contained in one atom of the compounds. That this is also observed when atomic groups are supposed to be united, forming more complicated compounds, will be seen by bringing forward a few examples. The atomic heat has been found

For the oxides, RO, enumerated in § 85	M	11·1
„ sesquioxide of iron, Fe_2O_3, § 85	M	26·8
Sum for Fe_2RO_4		37·9
„ magnetic iron ore, Fe_3O_4, § 85	M	37·7
„ the oxides, RO, in § 85	M	11·1
„ the acids, RO_3, in § 85, according to Regnault	M	18·8
Sum for RRO_4		29·9
„ chromate of lead, $PbCrO_4$, § 87		29·0

For the oxides named in § 85, RO	M	11·1
„ binoxide of tin, SnO_2, § 85	M	13·8
Sum for RRO_3		24·9
„ sesquioxide of iron, Fe_2O_3, § 85	M	26·8
„ chromate of potass, K_2CrO_4, § 87	M	36·4
„ the acids, RO_3, in § 85 (REGNAULT)		18·8
Sum for K_2CrRO_7		55·2
„ acid chromate of potass, $K_2Cr_2O_7$, § 87	M	55·3
„ binoxide of tin, Sn_3O_6, § 85	M	41·4
„ base, R_2O_2, mean of determinations, § 85	M	22·2
Sum for R_5O_8		63·6
„ arseniate of lead, $Pb_3As_2O_8$, § 88		65·4

To this belongs the fact that water is contained in solid compounds with the atomic heat of ice*. The different determinations of the specific heat of this substance (§ 85) gave the atomic heat for greater distances from 0°, 8·6, and for temperatures nearer 0°, 9·1 to 9·2. The atomic heats have been found

			For H_2O.
For $BaCl_2+2H_2O$, § 84		41·7	
„ the chlorides, RCl_2, § 84	M	18·5	
Remains for $2H_2O$		23·2	11·6
„ $CaCl_2+6H_2O$, § 84		75·6	
„ the chlorides, RCl_2, § 84	M	18·5	
Remains for $6H_2O$		57·1	9·5
„ Brucite, $MgO+H_2O$, § 85		18·1	
„ the oxides, RO, § 85	M	11·1	
Remains for H_2O		7·0	7·0
„ dioptase, $CuSiO_3+H_2O$, § 86		28·7	
„ the silicates, $RSiO_3$, § 86	M	20·5	
Remains for H_2O		8·2	8·2
„ $Na_2B_4O_7+10H_2O$, § 87		146·9	
„ $Na_2B_4O_7$, § 87		47·1	
Remains for $10H_2O$		99·8	10·0
„ gypsum, $CaSO_4+2H_2O$, § 87	M	45·8	
„ the sulphates, RSO_4, § 87	M	26·1	
Remains for $2H_2O$		19·7	9·9

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* Even before PERSON (compare § 14) L. GMELIN had speculated (Handbuch der Chemie, [4] Aufl. vol. i. p. 223) whether from the atomic heats of anhydrous sulphate of lime and of ice that of gypsum could be calculated. The results of calculation deviated considerably from the atomic heat as deduced from the observed specific heat of gypsum; the specific heat, and therewith the atomic heat of ice, were at that time incorrectly known.

The Tables in § 84 to 89 contain data for several such comparisons, which lead to the same result as the preceding—that the atomic heat of water contained in solid compounds may, by subtracting the atomic heat of the anhydrous solid from that of the hydrated solid compound, be obtained in sufficient approximation to the atomic heat deduced from the direct determination of the specific heat of ice. The deviations from each other and from the atomic heat of ice as directly determined, which these indirect determinations exhibit, are not to be wondered at when it is considered that all uncertainties in the atomic heats, from whose difference the atomic heat of solid water is deduced, are concentrated upon this difference.

98. The view already expressed and defended (compare especially § 12 and 13), that atoms and atomic groups are contained in solid compounds with the same atomic heat which they have in the free state, is opposed to the view which has also been frequently expressed and defended—that the atomic heat of an element may in certain compounds differ from what it is in the free state, and may be different in different compounds. This view, and the reasons which may possibly be urged in its favour, must here be discussed.

The first statement of this view (compare § 6) simply goes to assert that the atomic heats of compounds may be calculated in accordance with the values resulting from the determinations of the specific heat, assuming that one constituent of the compound has the same atomic heat as in the free state, the other an altered one. What alteration is to be assumed depends merely on what assumption adequately satisfies the observed specific heat of the compound. The accuracy of the assumption is susceptible of no further control; the assumption itself cannot be regarded as an explanation of the observed atomic heat of the compound. And nothing is altered in this by assuming (compare § 6 and 11) that the changes in the atomic heat of a substance on entering into chemical compounds take place in more or less simple ratios.

A greater degree of probability must be granted to the view (compare § 10) that the atomic heats of the constituents of compounds, and the differences in the atomic heats of these bodies, according as they are combined or in the free state, depend upon the state of condensation in which these bodies are contained. If, for instance, from a consideration of the specific gravities or specific volumes (the quotient of the specific weights into the atomic weights) of compounds and of their constitutents, a conclusion could be drawn with some degree of certainty as to the state of condensation in which the latter are present in the former, and if definite rules could be given for the variations of the atomic heats with the state of condensation, the result of such an investigation, if it agreed with the observed results for the atomic heats of compounds, might be called an explanation of these observations. But what is here presupposed is partially not attained and partially not attempted. And, moreover, as far as can be judged from individual cases, the same element, when contained in different states of condensation, appears to have the same atomic heat. It has been attempted to deduce the state of condensation, or the specific volume of oxygen in its compounds with heavy metals, by subtracting from the specific volume of the oxide that of the metal in it, and considering the remainder as the volume of oxygen. It would follow from this that the specific volume of oxygen in suboxide of copper is much greater (about four times as great) than in oxide of tin. But if the atomic heat of oxygen be deduced by subtracting from the atomic heat of the oxide that of the metal in it, it is found that the atomic heat of oxygen in suboxide of copper and in oxide of tin gives almost exactly the same number. Hence it does not seem that the state of condensation in which a constituent may be contained in a compound has any material influence on the atomic heat of this constituent.

99. From all that has been said in the foregoing paragraphs the following must be adhered to. (1) Each element in the solid state, and at a sufficient distance from its melting-point, has *one* specific or atomic heat, which may, indeed, somewhat vary with physical conditions, different temperature, or density for instance, but not so considerably as to be regarded in considering in what relations the specific heat stands to the atomic weight or composition; and (2) that each element has essentially the same specific or atomic heat in compounds as it has in the free state. On the basis of these two fundamental laws it may now be investigated what atomic heats individual elements have in the solid free state and in compounds. Indirect deductions of the atomic heats of such elements as could not be investigated in the solid free state are from these propositions admissible: that from the atomic heat of a compound containing such an element the atomic heat of everything else in the compound is subtracted, and the remainder considered as the expression for the atomic heat of that element. Such indirect determinations of the atomic heat of elements may be uncertain, partly because the atomic heat of the compounds is frequently not known with certainty, as is seen from the circumstance that analogous compounds, for which there is every reason to expect the same atomic heat, are found by experiment to have atomic heats not at all agreeing; but more especially because the entire relative uncertainty in the atomic heats for a compound, and for that which is to be subtracted from its composition, is concentrated upon a small number, the residue remaining in the deduction. But when such deductions are made, not merely for individual cases, but for different compounds, and for entire series of corresponding compounds, they may be considered sufficiently trustworthy to make the speculations based upon them worthy of attention. Of course in indirectly deducing the atomic heat of an element, its simpler compounds, and those containing it in greatest quantity (measured by the number of atoms), promise the most trustworthy results.

100. For *Silver, Aluminium, Arsenic, Gold, Bismuth, Bromine, Cadmium, Cobalt, Copper, Iron, Mercury, Iodine, Iridium, Potassium, Lithium, Magnesium, Manganese, Molybdenum, Sodium, Nickel, Osmium, Lead, Palladium, Platinum, Rhodium, Antimony, Selenium, Tin, Tellurium, Thallium, Tungsten, and Zinc,* it may be assumed, from the determinations of their specific heat in the solid state (§ 82), that their atomic heats, in

accordance with Dulong and Petit's law, are approximately equal, the average being 6·4. I do not think that all these elements have really the same atomic heat, but think that some of them will subsequently be considered as exceptions to the above-mentioned law, as it will in the sequel be proved that several elements have an atomic heat differing from 6·4. But for none of the previously mentioned elements are the present data, and the presumed deviation of the atomic heat from that of other elements, sufficient to justify their being separated from them.

To the elements just mentioned *chlorine* must be associated from the close agreement of the corresponding chlorine, bromine, and iodine compounds (§ 84), and of the compounds $K\,Cl\,\Theta_3$, 24·8, and $K\,As\,\Theta_3$, 25·3 (§ 88). To the atomic heats of these latter compounds those of individual salts $K\,N\,\Theta_3$ approximate closely; the latter gave (§ 88) 21·8–24·4, mean 23·0, which on the whole agrees sufficiently closely with those found for the metallic oxides, $R_2\,\Theta_3$ (§ 85). I count *nitrogen* also among the elements whose atomic heat may be assumed at 6·4, like that of most other elements; without, however, considering the determination of the atomic heat of this element as very trustworthy. To deduce the atomic heat of this element with certainty, compounds are wanting which contain, besides nitrogen, elements whose atomic heat has been directly determined. The fact that the atomic heat of the nitrates, $R_2\,N_2\,\Theta_6$, was found (§ 88) in the mean to be 38·1, a third of which, 12·7, is somewhat less than the average atomic heat found for the oxides of heavy metals of the formula $R\,\Theta_2$, might be a reason for assigning to nitrogen a smaller atomic heat; while, on the other hand, the atomic heats of other nitrogen compounds, in which it is true other elements enter whose atomic heat is only indirectly determined, do not favour this view.

In the class of elements with the atomic heat about 6·4, *barium*, *calcium*, and *strontium* may be placed from the agreement in the atomic heats of their compounds with the atomic heats of corresponding compounds of such elements as have been found by the direct determination of their specific heat in the free solid state to belong to that class (compare the atomic heats of the compounds $R\,Cl_2$ in § 84, $R\,C\,\Theta_3$ in § 86, $R\,S\,\Theta_4$ in § 87, and $R\,N_2\,\Theta_6$ in § 88); further, *rubidium* (compare the atomic heats of the compounds $R\,Cl$ in § 84, and $R_2\,C\,\Theta_3$ in § 86); then also *chromium* (from the agreement in the atomic heats of $Cr_2\,\Theta_3$ and $Fe_2\,\Theta_3$, § 84), and *titanium* (from the agreement in the atomic heats of $Ti\,\Theta_2$ and $Sr\,\Theta_2$, § 84). To place *zirconium* in the same class has no other justification than that on this assumption the atomic heat of zircon may be calculated in accordance with that deduced from the observed specific heat of this mineral.

101. According to direct determinations of the specific heat, *sulphur* and *phosphorus* do not belong to this class. The more trustworthy determinations (for sulphur the last two, for phosphorus the last three of the numbers in § 82) assign to these elements the atomic heat 5·4. That sulphur has a smaller atomic heat than the elements discussed in the last paragraphs follows from the atomic heats of sulphur compounds, compared

with those of the corresponding compounds of such elements as have an atomic heat =6·4. The average atomic heat of compounds RS and $\text{Ɍ}S$ is 11·9, according to the determinations in § 83, while those of chlorine compounds RCl and $\text{Ɍ}Cl$ (§ 84) =12·8, that of the corresponding bromine compounds =13·9, and of the corresponding iodine compounds =13·4. In comparing more complicated sulphur compounds, sulphates, for instance, with other compounds of analogous composition, the same is met with; although such complicated compounds are of little value in giving data for deciding on such small differences. The specific heat of the simpler phosphorus compounds has not been investigated; for more complicated compounds, although they point to a smaller atomic heat for P than 6·4, the above remark also applies.

The determinations of the specific heat of *silicium* give for this element also a smaller atomic heat than 6·4 (compare § 82), and the same conclusion results from a comparison of the atomic heats of $Si\Theta_2$, and the oxides, $\text{Ɍ}\Theta_2$, of the silicates $\text{Ɍ}Si\Theta_3$, and the oxides $\text{Ɍ}_2\Theta_3$. The atomic heat to be assigned to silicium cannot as yet be settled with any degree of certainty. Direct determinations, varying considerably from each other, give a specific heat mostly greater than 4; while the numbers obtained indirectly, and themselves also not closely agreeing, are partly considerably smaller. If in the sequel I put the atomic heat of silicium at 3·8, corresponding to the lowest number found for the specific heat of this element, I do so for want of other and more certain data. I consider this number as quite uncertain.

The atomic heat of *boron*, from the direct determinations of the specific heat, is considerably smaller than 6·4; and the atomic heats of boron compounds confirm this, as was discussed in §§ 93 and 95. By comparing the atomic heats of such boron and sulphur compounds as contain along with boron and sulphur the same elements in the same proportions, the atomic heat of boron is found to be half that of sulphur. The atomic heat of $KB\Theta_2=16{\cdot}8$ is exactly half that found for $K_2S\Theta_4=33{\cdot}6$; the atomic heat of $\text{Ᵽ}bB_2\Theta_4=26{\cdot}5$ is almost exactly equal to that for $\text{Ᵽ}bS\Theta_4=25{\cdot}7$. Taking the atomic heat of S, in accordance with the above discussion, at 5·4, that of B would be 2·7; the numbers obtained directly for the atomic heat of boron (§ 82) from the experiments on the specific heat of this element agree with sufficient accuracy. In the sequel I take the atomic heat of B at 2·7. A smaller number is obtained in other comparisons; for instance, of the atomic heats of $B_2\Theta_3$ and of the oxides $\text{Ɍ}_2\Theta_3$, or of the salts $RB\Theta_2$ and the oxides $\text{Ɍ}_2\Theta_2$; but in such indirect determinations of the atomic heat, where such small numbers are to be determined, as is here the case with the atomic heat of boron, the results are very uncertain, owing to the fact that the entire uncertainty in the atomic heats of the compounds, and in the assumption that the elements corresponding to boron in compounds of analogous composition have really the atomic heat =6·4, is thrown on the final result.

Lastly, *carbon* also, from the direct determinations of its specific heat (§ 82), has a much smaller atomic heat than 6·4. The same result follows from a comparison of the atomic heats of carbon compounds: the atomic heat of the carbonates, $\text{Ɍ}_2\text{Ȼ}\Theta_3=28{\cdot}4$ as the mean of the determinations in § 86, is much smaller than that of $R_3\Theta_3(=3R\Theta)$, which is the mean of the numbers in § 85 =33·3; the atomic heat of the carbonates $RC\Theta_3$ =20·7, as the mean of the determinations in § 86, is much smaller than 27·1, the number found for $As_2\Theta_3$, $Bi_2\Theta_3$, $Cr_2\Theta_3$, $Fe_2\Theta_3$, and $Sb_2\Theta_3$ as the atomic heat of oxides $R_2\Theta_3$. I put the atomic heat of carbon at 1·8 for C, as deduced from the determination of the specific heat of its purest variety, diamond.

102. In the preceding paragraphs I have discussed the elements which, from the determinations of their specific heat in the solid free state, have a smaller atomic heat than about 6·4. There remain to be discussed a few elements whose atomic heats are also less than those of most other elements, but can only be deduced from those of their compounds.

To this category belongs *hydrogen*[*], even if the indirect determination of its atomic heat in the solid state is liable to the uncertainty just discussed. The atomic heat of water, $H_2\Theta$, is (§ 85) =8·6, and smaller by 7 than that of suboxide of copper, $Cu_2\Theta$, which was found in the mean to be 15·6; the atomic heat of hydrogen would thus be $\frac{7}{2}=3{\cdot}5$ less than that of the elements to which copper belongs, as regards its atomic heat; hence the former would be $6{\cdot}4-3{\cdot}5=2{\cdot}9$. The atomic heat of chloride of ammonium, NH_4Cl, has been found to be 20·0 (§ 84); the subtraction of the atomic heats for $N+Cl=6{\cdot}4+6{\cdot}4=12{\cdot}8$, leaves 7·2 as the atomic heat of 4H, and therefore 1·7 for that of H. The atomic heat of nitrate of ammonia, $N_2H_4\Theta_3$, is 36·4 (§ 88); subtracting therefrom as the atomic heat of $N_2+\Theta_3$, the number 27·1, which has previously been frequently mentioned as the atomic heat of oxides $R_2\Theta_3$, we have 9·3 as the atomic heat of 4H, that is 2·3 for that of H. I put in the sequel the atomic heat of *hydrogen* at 2·3.

That *oxygen* has a smaller atomic heat than 6·4, follows from the fact that the oxygen compounds of the metals have a considerably smaller atomic heat than the corresponding chlorides, iodides, or bromides. For instance, the atomic heat of the oxides $R\Theta$ is as the mean of the determinations in § 85 =11·1, while that of the chlorides RCl and RCl (§ 84), is 12·8, that of the corresponding bromides 13·9, and of the corresponding iodides 13·4. That of the oxides, $R\Theta_2$, as the mean of the determinations in § 85, of $Mn\Theta_2$, $Sn\Theta_2$, and $Ti\Theta_2$ is 13·7, while that of the chlorides RCl_2 (§ 85) is 18·5, and of the iodides $RI_2=19{\cdot}4$. Taking the atomic heat of the other elements, which are contained in the following compounds, at 6·4, the atomic heat of oxygen, as deduced from the atomic heat of the oxides $R\Theta$ (11·1 in the mean), is =4·7; as deduced from the oxides $R_2\Theta_3$ (27·1 as the mean of the oxides of this formula previously frequently mentioned), it is =4·8; from the above oxides, $R\Theta_2$ (13·7 in the mean), it is =3·7; it is found (compare § 88) from $KAs\Theta_3$ (25·3) to be 4·1; from $Pb_3As_2\Theta_8$ (65·4) to be 4·2; from $KCl\Theta_3$ (24·8) to be 4·0; from $KCl\Theta_4$ (26·3) to be 3·4; from $KMn\Theta_4$ (28·3) to be 3·9. In the sequel I take the round number 4 for the atomic heat of Θ.

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[*] L. GMELIN (Handbuch der Chemie, 4 Aufl. vol. i. pp. 216 and 222) ascribed to hydrogen the same capacity for heat as that of an equivalent quantity of lead or mercury (H=1, Cu=31·7, Hg=100); SCHRÖDER (POGGEND. Ann. vol. lii. p. 279) and CANNIZZARO (Il Nuovo Cimento, vol. vii. p. 342) ascribed to hydrogen the same atomic heat as that of most other elements (H=1, Cl=35·5, Cu=63·4, Hg=200).

Fluorine appears, lastly, to have a considerably smaller atomic heat than 6·4. The atomic heat of fluoride of calcium, $Ca\,Fl_2$, has been found to be (§ 84) only 16·4, considerably smaller than the corresponding chlorides, bromides, and iodides. I put the atomic heat of fluorine at $\frac{16·4-6·4}{2}=5$.

103. Taking, in accordance with what has just been said, the atomic heat which an element has in a solid compound,

At 6·4 for Ag, Al, As, Au, Ba, Bi, Br, Ca, Cd, Cl, Co, Cr, Cu, Fe, Hg, I, Ir, K, Li, Mg, Mn, Mo, N, Na, Ni, Os, Pb, Pd, Pt, Rb, Rh, Sb, Se, Sn, Sr, Te, Ti, Tl, W, Zn, and Zr,

At 5·4 for S and P, at 5 for Fl, 4 for O, 3·8 for Si, 2·7 for B, 2·3 for H, and 1·8 for C; and assuming that the atomic heat of a solid is given by the sum of the atomic heats of the elements in it, we obtain the atomic heats; and dividing them by the atomic weights, we obtain the specific heats, in sufficiently close agreement with the specific heats as obtained by direct determinations of this property.

In the following Table I give for all compounds for which the specific heat has been determined in a trustworthy manner, the specific heat calculated on these assumptions, compared with the numbers found experimentally. I give this calculation and this comparison in the same order which was followed in the synopsis § 82 to 89, and I refer to the latter as regards special remarks on the determinations. To distinguish the observers, N. again stands for NEUMANN, R. REGNAULT, Kp. KOPP, Pr. PERSON, A. ALLUARD, and Pp. PAPE.

Alloys. (Compare § 82.)

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.	
$Bi\,Sn$	328	12·8	0·0390	0·0400	R.
$Bi\,Sn_2$	446	19·2	0·0430	0·0450	R.
$Bi\,Sn_2\,Sb$	568	25·6	0·0451	0·0462	R.
$Bi\,Sn_2, Sb\,Zn_2$ . .	698·4	38·4	0·0550	0·0566	R.
$Pb\,Sb$	329	12·8	0·0389	0·0388	R.
$Pb\,Sn$	325	12·8	0·0394	0·0407	R.
$Pb\,Sn_2$	443	19·2	0·0433	0·0451	R.

104. *Arsenides and Sulphides.* (Compare § 83.)

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.					
$Co\,As_2$	208·8	19·2	0·0919	0·0920	N.				
$Ag_2\,S$	248	18·2	0·0734	0·0746	R.				
$Co\,As\,S$	166	18·2	0·110	0·107	N.				
$Cu_2\,S$	158·8	18·2	0·115	0·121	R.	0·120	Kp.		
$Fe\,As\,S$	163	18·2	0·112	0·101	N.				
$As\,S$	107	11·8	0·110	0·111	N.				
$Co\,S$	90·8	11·8	0·130	0·125	R.				
$Cu_{\frac{1}{2}}\,Fe_{\frac{1}{2}}\,S$	91·7	11·8	0·129	0·129	N.	0·131	Kp.		
$Fe\,S$	88	11·8	0·134	0·136	R.				
$Hg\,S$	232	11·8	0·0509	0·052	N.	0·0512	R.	0·0517	Kp.
$Ni\,S$	90·8	11·8	0·130	0·128	R.				

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.					
PbS	239	11·8	0·0494	0·053	N.	0·0509	R.	0·0490	Kp.
SnS	150	11·8	0·0787	0·0837	R.				
ZnS	97·2	11·8	0·121	0·115	N.	0·123	R.	0·120	Kp.
Fe_7S_8	648	88·0	0·136	0·153	N.	0·160	R.		
As_2S_3	246	29·0	0·118	0·113	N.				
Bi_2S_3	516	29·0	0·0562	0·060	R.				
Sb_2S_3	340	29·0	0·0853	0·0907	N.	0·0840	R.		
FeS_2	120	17·2	0·143	0·128–0·133	N.	0·130	R.	0·126	Kp.
MoS_2	160	17·2	0·107	0·107	N.	0·123	R.		
SnS_2	182	17·2	0·0945	0·119	R.				

105. *Chlorides, Bromides, Iodides, and Fluorides.* (Compare § 84.)

$AgCl$	143·5	12·8	0·0892	0·0911	R.				
$CuCl$	98·9	12·8	0·129	0·138	R.				
$HgCl$	235·5	12·8	0·0543	0·0521	R.				
KCl	74·6	12·8	0·172	0·173	R.	0·171	Kp.		
$LiCl$	42·5	12·8	0·301	0·282	R.				
$NaCl$	58·5	12·8	0·219	0·214.	R.	0·213–0·219	Kp.		
$RbCl$	120·9	12·8	0·106	0·112	Kp.				
NH_4Cl	53·5	22·0	0·411	0·373	Kp.				
$BaCl_2$	208	19·2	0·0923	0·0896	R.	0·0902	Kp.		
$CaCl_2$	111	19·2	0·173	0·164	R.				
$HgCl_2$	271	19·2	0·0708	0·0689	R.	0·640	Kp.		
$MgCl_2$	95	19·2	0·202	0·195	R.	0·191	Kp.		
$MnCl_2$	126	19·2	0·152	0·143	R.				
$PbCl_2$	278	19·2	0·0691	0·0664	R.				
$SnCl_2$	189	19·2	0·102	0·102	R.				
$SrCl_2$	158·6	19·2	0·121	0·120	R.				
$ZnCl_2$	136·2	19·2	0·141	0·136	R.				
$BaCl_2+2H_2O$ . .	244	36·4	0·149	0·171	Kp.				
$CaCl_2+6H_2O$ . .	219	70·8	0·323	0·345	Pr.				
ZnK_2Cl_4	285·4	44·8	0·157	0·152	Kp.				
PtK_2Cl_6	488·6	57·6	0·118	0·113	Kp.				
SnK_2Cl_6	409·2	57·6	0·141	0·133	Kp.				
Cr_2Cl_6	317·4	51·2	0·161	0·143	Kp.				
$AgBr$	188	12·8	0·0681	0·0739	R.				
KBr	119·1	12·8	0·107	0·113	R.				
$NaBr$	103	12·8	0·124	0·138	R.				
$PbBr_2$	367	19·2	0·0523	0·0533	R.				
AgI	235	12·8	0·0545	0·0616	R.				
CuI	190·4	12·8	0·0672	0·0687	R.				
HgI	327	12·8	0·0391	0·0395	R.				
KI	166·1	12·8	0·0771	0·0819	R.				
NaI	150	12·8	0·0853	0·0868	R.				
HgI_2	454	19·2	0·0423	0·0420	R.				
PbI_2	461	19·2	0·0416	0·0427	R.				
$CaFl_2$	78	16·4	0·210	0·208	N.	0·215	R.	0·209	Kp.
$AlNa_3Fl_6$ . . .	210·4	55·6	0·264	0·238	Kp.				

106. *Oxides.* (Compare § 85.)

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.					
Cu_2O	142·8	16·8	0·118	0·107	N.	0·111	Kp.		
H_2O	18	8·6	0·478	0·480	Pr.	0·474	R.		
CuO	79·4	10·4	0·131	0·137	N.	0·142	R.	0·128	Kp.
HgO	216	10·4	0·0481	0·049	N.	0·052	R.	0·053	Kp.
MgO	40	10·4	0·260	0·276	N.	0·244	R.		
MnO	71	10·4	0·146	0·157	R.				
NiO	74·8	10·4	0·139	0·159	R.				
PbO	22·3	10·4	0·0466	0·0512	R.	0·0553	Kp.		
ZnO	81·2	10·4	0·128	0·132	N.	0·125	R.		
$MgO+H_2O$	58	19·0	0·328	0·312	Kp.				
Fe_3O_4	232	35·2	0·152	0·164	N.	0·168	R.	0·156	Kp.
$MgAl_2O_4$	142·8	35·2	0·246	0·194	Kp.				
$Mg_{\frac{1}{2}}Fe_{\frac{1}{2}}Cr_{\frac{3}{2}}Al_{\frac{1}{2}}O_4$	196	35·2	0·179	0·159	Kp.				
Al_2O_3	102·8	24·8	0·241	0·197	N.	0·217	R.		
As_2O_3	198	24·8	0·125	0·128	R.				
B_2O_3	69·8	17·4	0·249	0·237	R.				
Bi_2O_3	468	24·8	0·0530	0·0605	R.				
Cr_2O_3	152·4	24·8	0·163	0·196	N.	0·180	R.	0·177	Kp.
Fe_2O_3	160	24·8	0·155	0·169	N.	0·167	R.	0·154	Kp.
$Fe_{\frac{5}{4}}Ti_{\frac{3}{4}}O_3$	155·5	24·8	0·160	0·176	N.	0·177	Kp.		
Sb_2O_3	292	24·8	0·0849	0·0901	R.				
$Mn_2O_3+H_2O$	176	33·4	0·189	0·176	Kp.				
MnO_2	87	14·4	0·166	0·159	Kp.				
SiO_2	60	11·8	0·197	0·188	N.	0·191	R.	0·186	Kp.
$Si_{\frac{1}{2}}Zr_{\frac{1}{2}}O_2$	90·8	13·1	0·144	0·146	R.	0·132	Kp.		
SnO_2	150	14·4	0·096	0·093	N.	0·093	R.	0·089	Kp.
TiO_2	82	14·4	0·176	0·172	N.	0·171	R.	0·159	Kp.
MoO_3	144	18·4	0·128	0·132	R.	0·154?	Kp.		
WO_3	232	18·4	0·0793	0·0798	R.	0·0894?	Kp.		

107. *Carbonates and Silicates.* (Compare § 86.)

K_2CO_3	138·2	26·6	0·192	0·216	R.	0·206	Kp.		
Na_2CO_3	106	26·6	0·251	0·273	R.	0·246	Kp.		
Rb_2CO_3	230·8	26·6	0·115	0·123	Kp.				
$BaCO_3$	197	20·2	0·103	0·108	N.	0·110	R.		
$CaCO_3$	100	20·2	0·202	0·203	N.	0·209	R.	0·205	Kp.
$Ca_{\frac{1}{2}}Mg_{\frac{1}{2}}CO_3$	92	20·2	0·220	0·216	N.	0·218	R.	0·206	Kp.
$Fe_{\frac{8}{11}}Mn_{\frac{2}{11}}Mg_{\frac{1}{11}}CO_3$	112·9	20·2	0·179	0·166	Kp.				
$Mg_{\frac{7}{9}}Fe_{\frac{2}{9}}CO_3$	91·1	20·2	0·222	0·227	N.				
$PbCO_3$	267	20·2	0·0757	0·0814	N.	0·0791	Kp.		
$SrCO_3$	147·6	20.2	0·137	0·145	N.	0·145	R.		
$CaSiO_3$	116	22·2	0·191	0·178	Kp.				
$Ca_{\frac{1}{2}}Mg_{\frac{1}{2}}SiO_3$	108	22·2	0·205	0·191	N.	0·186	Kp.		
$CuSiO_3+H_2O$	157·4	30·8	0·195	0·182	Kp.				
$Mg_{\frac{20}{11}}Fe_{\frac{2}{11}}SiO_4$	145·8	32·6	0·223	0·206	N.	0·189	Kp.		
$Al_2K_2Si_6O_{16}$	557	112·4	0·202	0·191	N.	0·183	Kp.		
$Al_2Na_2Si_6O_{16}$	524·8	112·4	0·214	0·196	N.	0·190	Kp.		

108. *Borates, Molybdates, Tungstates, Chromates, and Sulphates.* (Compare § 87.)

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.						
$KB\Theta_2$	82	17·1	0·209	0·205	R.					
$NaB\Theta_2$	65·9	17·1	0·260	0·257	R.					
$PbB_2\Theta_4$	292·8	27·8	0·0949	0·0905	R.					
$PbB_4\Theta_7$	362·6	45·2	0·124	0·114	R.					
$K_2B_4\Theta_7$	233·8	51·6	0·221	0·220	R.					
$Na_2B_4\Theta_7$	201·6	51·6	0·256	0·238	R.	0·229	Kp.			
$Na_2B_4\Theta_7+10H_2\Theta$	381·6	137·6	0·366	0·385	Kp.					
$PbMo\Theta_4$	367	28·8	0·0785	0·0827	Kp.					
$CaW\Theta_4$	288	28·8	0·100	0·0967	Kp.					
$Fe_{\frac{2}{5}}Mn_{\frac{3}{5}}W\Theta_4$	303·4	28·8	0·0949	0·0978	R.	0·0930	Kp.			
$PbCr\Theta_4$	323·2	28·8	0·0891	0·0900	Kp.					
$K_2Cr\Theta_4$	194·4	35·2	0·181	0·185	R.	0·189	Kp.			
$K_2Cr_2\Theta_7$	294·6	53·6	0·182	0·189	R.	0·186	Kp.			
$KHS\Theta_4$	136·1	30·1	0·221	0·244	Kp.					
$K_2S\Theta_4$	174·2	34·2	0·196	0·190	R.	0·196	Kp.			
$Na_2S\Theta_4$	142	34·2	0·241	0·231	R.	0·227	Kp.			
$N_2H_8S\Theta_4$	132	52·6	0·398	0·350	Kp.					
$BaS\Theta_4$	233	27·8	0·119	0·109	N.	0·113	R.	0·108	Kp.	
$CaS\Theta_4$	136	27·8	0·204	0·197	R.	0·185	N.	0·178	Kp.	
$CuS\Theta_4$	159·4	27·8	0·174	0·184	Pp.					
$MgS\Theta_4$	120	27·8	0·232	0·222	R.	0·225	Pp.			
$MnS\Theta_4$	151	27·8	0·184	0·182	Pp.					
$PbS\Theta_4$	303	27·8	0·0917	0·0872	R.	0·0848	N.	0·0827	Kp.	
$SrS\Theta_4$	183·6	27·8	0·151	0·143	R.	0·136	N.	0·135	Kp.	
$ZnS\Theta_4$	161·2	27·8	0·172	0·174	Pp.					
$CuS\Theta_4+H_2\Theta$	177·4	36·4	0·205	0·202	Pp.					
$MgS\Theta_4+H_2\Theta$	138	36·4	0·264	0·264	Pp.					
$ZnS\Theta_4+H_2\Theta$	179·2	36·4	0·203	0·202	Pp.					
$CaS\Theta_4+2H_2\Theta$	172	45·0	0·262	0·273	N.	0·259	Kp.			
$CuS\Theta_4+2H_2\Theta$	195·4	45·0	0·230	0·212	Pp.					
$ZnS\Theta_4+2H_2\Theta$	197·2	45·0	0·228	0·224	Pp.					
$FeS\Theta_4+3H_2\Theta$	206	53·6	0·260	0·247	Pp.					
$CuS\Theta_4+5H_2\Theta$	249·4	70·8	0·284	0·285	Kp.	0·316	Pp.			
$MnS\Theta_4+5H_2\Theta$	241	70·8	0·294	0·323	Kp.	0·338	Pp.			
$NiS\Theta_4+6H_2\Theta$	262·8	79·4	0·302	0·313	Kp.					
$CoS\Theta_4+7H_2\Theta$	280·8	88·0	0·313	0·343	Kp.					
$FeS\Theta_4+7H_2\Theta$	278	88·0	0·317	0·346	Kp.	0·356	Pp.			
$MgS\Theta_4+7H_2\Theta$	246	88·0	0·358	0·362	Kp.	0·407	Pp.			
$NiS\Theta_4+7H_2\Theta$	280·8	88·0	0·313	0·341	Pp.					
$ZnS\Theta_4+7H_2\Theta$	287·2	88·0	0·306	0·347	Kp.	0·328	Pp.			
$MgK_2S_2\Theta_8+6H_2\Theta$	402·2	113·6	0·282	0·264	Kp.					
$NiK_2S_2\Theta_8+6H_2\Theta$	437	113·6	0·260	0·245	Kp.					
$ZnK_2S_2\Theta_8+6H_2\Theta$	443·4	113·6	0·256	0·270	Kp.					
$Al_2K_2S_4\Theta_{16}+24H_2\Theta$	949	317·6	0·335	0·371	Kp.					
$Cr_2K_2S_4\Theta_{16}+24H_2\Theta$	998·6	317·6	0·318	0·324	Kp.					

109. *Arseniates, Phosphates, Pyrophosphates and Metaphosphates, Nitrates, Chlorates, Perchlorates, and Permanganates.* (Compare § 88).

	Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.			
$K As \Theta_3$	162·1	24·8	0·153	0·156	R.		
$K H_2 As \Theta_4$ . . .	180·1	33·4	0·185	0·175	Kp.		
$Pb_3 As_2 \Theta_8$ . . .	899	64·0	0·0712	0·0728	R.		
$Ag_3 P \Theta_4$	419	40·6	0·0969	0·0896 ?	Kp.		
$K H_2 P \Theta_4$ . . .	136·1	32·4	0·238	0·208	Kp.		
$Na_2 H P \Theta_4 + 12 H_2 \Theta$	358	139·7	0·390	0·408	Pr.		
$Pb_3 P_2 \Theta_8$	811	62·0	0·0764	0·0798	R.		
$K_4 P_2 \Theta_7$	330·4	64·4	0·195	0·191	R.		
$Na_4 P_2 \Theta_7$	266	64·4	0·242	0·228	R.		
$Pb_2 P_2 \Theta_7$	588	51·6	0·0878	0·0821	R.		
$Na P \Theta_3$	102	23·8	0·233	0·217	Kp.		
$Ca P_2 \Theta_6$	198	41·2	0·208	0·199	R.		
$Ag N \Theta_3$	170	24·8	0·146	0·144	R.		
$K N \Theta_3$	101·1	24·8	0·245	0·239	R.	0·230	Kp.
$K_{\frac{1}{2}} Na_{\frac{1}{2}} N \Theta_3$ . . .	93	24·8	0·267	0·235	Pr.		
$Na N \Theta_3$	85	24·8	0·292	0·278	R.	0·257	Kp.
$N_2 H_4 \Theta_3$	80	34·0	0·425	0·455	Kp.		
$Ba N_2 \Theta_6$	261	43·2	0·166	0·152	R.	0·145	Kp.
$Pb N_2 \Theta_6$	331	43·2	0·130	0·110	Kp.		
$Sr N_2 \Theta_6$	211·6	43·2	0·204	0·181	Kp.		
$K Cl \Theta_3$	122·6	24·8	0·202	0·210	R.	0·194	Kp.
$Ba Cl_2 \Theta_6 + H_2 \Theta$.	322	51·8	0·161	0·157	Kp.		
$K Cl \Theta_4$	138·6	28·8	0·208	0·190	Kp.		
$K Mn \Theta_4$	158·1	28·8	0·182	0·179	Kp.		

110. *Organic Compounds.* (Compare § 89).

		Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.	
Cyanide of mercury	$Hg C_2 N_2$	252	22·8	0·091	0·100	Kp.
„ zinc and potassium . .	$Zn K_2 C_4 N_4$	247·4	52·0	0·210	0·241	Kp.
Ferrocyanide of potassium . . .	$Fe K_3 C_6 N_6$	329·3	74·8	0·227	0·233	Kp.
Ferricyanide of potassium . . .	$Fe_4 K_4 C_6 N_6 + 3 H_2 \Theta$.	422·4	107·0	0·253	0·280	Kp.
Chloride of carbon	$C_2 Cl_6$	237	42·0	0·177	0·178	Kp.
Napthaline . .	$C_{10} H_8$	128	36·4	0·284	0·310	A.
Cerotic acid . . .	$C_{27} H_{54} \Theta_2$	410	108·8	0·441	0·429	Pr.
Palmitate of melissyle	$C_{46} H_{92} \Theta_2$	676	302·4	0·447		
Cane-sugar . . .	$C_{12} H_{22} \Theta_{11}$	342	116·2	0·340	0·301	Kp.
Mannite	$C_6 H_{14} \Theta_6$	182	67·0	0·368	0·324	Kp.
Succinic acid . .	$C_4 H_6 \Theta_2$	118	37·0	0·314	0·313	Kp.
Tartaric acid . .	$C_4 H_6 \Theta_6$	150	45·0	0·300	0·288	Kp.
Racemic acid . .	$C_2 H_6 \Theta_6 + H_2 \Theta$ . . .	168	53·6	0·319	0·319	Kp.
Formiate of baryta	$C_2 H_2 Ba \Theta_4$	227	30·6	0·135	0·143	Kp.
Oxalate of potass	$C_2 K_2 \Theta_4 + H_2 \Theta$ . . .	184·2	41·0	0·223	0·236	Kp.

		Atomic weight.	Atomic heat. Calculated.	Specific heat. Calculated.	Specific heat. Observed.	
Quadroxalate of potass	$Ꞓ_2 H_3 K Θ_8 + 2 H Θ$ . .	254·1	69·7	0·274	0·283	Kp.
Bitartrate of potass	$Ꞓ_4 H_5 K Θ_6$	188·1	49·1	0·261	0·257	Kp.
Seignette salt . .	$Ꞓ_4 H_4 Na K Θ_6 + 4 H_2 Θ$	282·1	87·6	0·311	0·328	Kp.
Bimalate of potass .	$Ꞓ_8 H_{10} Ꞓa Θ_{10} + 8 H_2 Θ$.	450	152·6	0·339	0·338	Kp.

111. The preceding synopsis shows, for the great majority of substances contained in it, an adequate agreement between the observed specific heats and those calculated on such simple assumptions. In estimating the differences, the extent must be remembered to which various observers differ for the same substance. It must be considered that the present better determinations of the specific heat, even those made by the same experimenter, for substances where it may be expected that NEUMANN'S law applies, do not exactly agree with it, not more nearly than within $\frac{1}{10}$ or $\frac{1}{9}$ of the value; and that for those elements which are considered here as obeying DULONG and PETIT'S law, even greater deviations occur between the numbers found experimentally and those to be expected on the assumption of the universal validity of this law. (These deviations, *i. e.* the differences between the atomic heats found for these elements, are seen from § 82.) The extent to which the experimentally determined specific heats deviate from such a law, NEUMANN'S for instance, in bodies for which calculation takes it as applying, gives of course the means of judging what differences may occur between the observed and calculated numbers without invalidating the admissibility of the calculation attempted. And it is as much a matter of course that, in those bodies in which a marked deviation from NEUMANN'S law has been already mentioned (compare § 95), a greater difference is found in the present synopsis between calculation and observation.

I consider the agreement between calculation and observation, as shown in the synopsis § 103 to 110, as in general sufficient for a first attempt of that kind. But it need scarcely be mentioned that I by no means consider the calculated as more accurate than the observed numbers, or among several numbers consider that the most accurate which is nearest the calculated; for that, the bases of calculation are much too uncertain. The list of atomic heats given at the commencement of § 103 is scarcely much more accurate than were the first tables of atomic weights; but just as the latter have experienced continual improvements, and thus what was at first only an approximate agreement between the calculated and observed composition of bodies has been brought within considerably narrower limits, and apparent exceptions been explained, so, in like manner, will this be the case for ascertaining what atomic heats are to be assigned to the elements, and how the atomic heats of compounds may be deduced therefrom. This much, however, may even now be said, that while formerly for many solid substances a statement of the specific heat could in no way be controlled, a concealed source of error for the determination of this property was not indicated, and an error which materially altered the number for this property could not be recognized, at present, even if only roughly, such a control is possible. Compare § 77.

PART VI.—CONSIDERATIONS ON THE NATURE OF THE CHEMICAL ELEMENTS.

112. The proof given in the preceding that DULONG and PETIT'S law is not universally valid, justifies certain conclusions, in reference to the nature of the so-called chemical elements, which may here be developed.

What bodies are to be regarded as chemical elements? Does the mere fact of indecomposability determine this? or may a body be indecomposable in point of fact and yet from reasons of analogy be regarded not as an element but as a compound? The history of chemistry furnishes numerous examples of cases in which sometimes one and sometimes another mode of view led to results which at present are regarded as accurate. The earths were in 1789 indecomposable in point of fact, when LAVOISIER expressed the opinion that they were compounds, oxides of unknown metals. LAVOISIER'S argumentation was based on the fact that the earths enter as bases into salts, and that it was to be assumed in regard to all salts, that they contained an oxygen acid and an oxygen base. But the view, founded on the same basis, that common salt contains oxygen, and the subsequent view that what is now called chlorine contained a further quantity of oxygen besides the elements of an oxygen acid, did not find an equally permanent recognition. On the basis of the actual indecomposability of chlorine, DAVY maintained from about 1810 its elementary character; and this view has become general, especially since BERZELIUS, after a long struggle against it, adopted it, more I think because he was outvoted than because he was convinced.

Almost all chemists of the present time consider chlorine, and in conformity therewith bromine and iodine, as elementary bodies; but the persistence is known with which SCHÖNBEIN attacks this view, and adheres to the opinion that these bodies are oxygen compounds, peroxides of unknown elements. Is there anything which enables us to decide with more certainty on the elementary nature of chlorine and the analogous bodies than has hitherto been the case?

No one can maintain that the bodies which chemists regard as elements are absolutely simple substances. The possibility must be confessed that they may be decomposed into still simpler bodies; how far a body is to be regarded as an element is so far relative, that it depends on the development of the means of decomposition which practical chemistry has at its disposal, and on the trustworthiness of the conclusions which theoretical chemistry can deduce. A discussion as to whether chlorine or iodine is an elementary body can only be taken in the sense whether chlorine is as simple a body as oxygen or manganese, or nitrogen; or whether it is a compound body, as peroxide of manganese or peroxide of hydrogen for example.

If DULONG and PETIT'S law were universally valid, it would not merely indicate for chemical elements a relation between the atomic weight and the specific heat in the solid state, but it could be used as a test for the elementary nature of a body whose atomic weight is known. That iodine, from a direct determination of specific heat, and chlorine by an indirect determination had atomic heats agreeing with DULONG and

Petit's law, would be a proof that iodine and chlorine, if compounds at all, are not more so than other so-called elements for which this law is regarded as valid.

According to Neumann's law, compounds of analogous atomic composition have approximately the same atomic heats. In general, bodies, whose atom consists of a greater number of indecomposable atoms, or is of more complicated composition, have greater atomic heats. In these compounds, more especially those whose elements all follow Dulong and Petit's law, magnitude of atomic heat is exactly a measure of the complexity or of the degree of composition (compare § 93). If Dulong and Petit's law were valid, it could be concluded with great positiveness that the so-called elements, if they are compounds of unknown and simpler substances, are compounds of the same order. It would be a remarkable result that the act of chemical decomposition had everywhere found its limit at such bodies as those which, if compound at all, have with every difference of chemical deportment the same degree of composition. Imagine the simplest bodies, probably as yet unknown to us, the true chemical elements, forming a horizontal spreading layer, and piled above them, the simpler and then the more complicated compounds; the universal validity of Dulong and Petit's law would include the proof, that all elements at present assumed by chemists lay in the same layer, and that chemistry in recognizing hydrogen, oxygen, sulphur, chlorine, and the different metals as indecomposable bodies, had penetrated to the same depth in that field of inquiry, and had found at the same depth the limit to its penetration.

This result I formerly propounded[*] when I still believed in the validity of Dulong and Petit's law. But with the proof that this law is not universally true, the conclusion to which this result leads loses its justification. Starting now from the elements recognized in chemistry, we must rather admit that the magnitude of the atomic heat of a body depends not only on the number of elementary atoms contained in one atom of it, or on the complexity of the composition, but also on the atomic heat of the elementary atoms entering into its composition; it appears now possible that a decomposable body may have the same atomic heat as an indecomposable one.

To assume in chlorine the presence of oxygen, and to consider it as analogous to peroxide of manganese, or in general to the peroxide of a biatomic element[†], is less in accordance with what is at present considered true in chemistry, than to consider it as the peroxide of a monoequivalent element, analogous to peroxide of hydrogen. It is remarkable that peroxide of hydrogen, in the solid state or in solid compounds, must have almost as great an atomic heat (for HΘ $2{\cdot}3+4=6{\cdot}3$) as those elements which obey Dulong and Petit's law, and especially as iodine, bromine, and chlorine, according to the direct and to the indirect determination of their atomic heat; the same must be the case for the analogous peroxides of such still unknown elements as have an atomic heat

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[*] "On the Difference of Matter from the Empirical point of view," an Academical Discourse. Giessen, 1860.

[†] I will not omit to mention that equivalent weights of iodine and peroxide of manganese have almost equal capacity for heat. As regards oxidizing action, 127 of iodine corresponds to 43·5 peroxide of manganese; Regnault found the specific heat of the former =0·0541; I found that of the latter =0·159;

$$127\times0{\cdot}0541=6{\cdot}87;\ 43{\cdot}5\times0{\cdot}159=6{\cdot}92.$$

as great as that of hydrogen. As far as may be judged from its specific heat, chlorine *may* be such a peroxide; but this consideration shows no necessity for assuming that it actually is so.

In a great number of cases the atomic heat of compounds gives more or less accurately a measure for the degree of complexity of their composition*. And this is the case also with such compounds as are comparable in their chemical deportment to undecomposed bodies. If cyanogen or ammonium had not been decomposed, or could not be so with the means at present offered by chemistry, the greater atomic heats of their compounds, compared with those of analogous chlorine or potassium compounds (compare § 96), and of cyanogen and ammonium as compared with chlorine and potassium, would indicate the more complex nature of those so-called compound radicals. The conclusion appears admissible that for the so-called elements the directly or indirectly ascertained atomic heats are a measure for the complexity of their composition. Carbon and hydrogen, for example, if not themselves simple bodies, are more so than silicium or oxygen; and still more complex compounds are the elements which are now considered as following Dulong and Petit's law; with the restriction, however, that for these also the atomic heats may be more accurately determined and differences proved in them which justify similar conclusions†. One might be tempted, by comparing atomic heats, to form an idea how the more complex of the present indecomposable bodies might be composed of more simple ones, just as such a comparison has been shown to be possible for chlorine; but it is at once seen that to carry out such an attempt the atomic heats of the elements, especially those which can only be indirectly determined, are not settled with adequate certainty.

It may appear surprising, or even improbable, that so-called elements which can replace each other in compounds, as, for instance, hydrogen and the metals, or which enter into compounds as isomorphous constituents, like silicium and tin, should possess unequal atomic heats and unequal complexity of composition. But this is not more surprising than that indecomposable bodies, and those which can be proved to be compound, as, for example, hydrogen and hyponitric acid, or potassium and ammonium, should replace one another, preserving the chemical character of the compounds, and even be contained as corresponding constituents in isomorphous compounds.

I have here expressed suppositions in reference to the nature of the so-called elements which appear to me based on trustworthy conclusions from well-proved principles. It is

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* The differences in the atomic heats of the elements are of course most distinctly seen in their free state, but in their analogous compounds these differences are the less prominent the more complex the compounds, that is, the greater the number of atoms of the same kind and the same atomic heat which are united to those elementary atoms whose atomic heat is assumed to be unequal. The difference in the atomic heats of C and As, for instance (1·8 and 6·4), is relatively far greater than for $\mathrm{Ca\,C\,O_3}$ and $\mathrm{K\,As\,O_3}$ (20·2 and 24·8).

† It is possible, for example, that certain indecomposable bodies which only approximately obey Dulong and Petit's law, are analogous compounds of simpler substances of essentially different atomic heat: the approximate agreement of the atomic heats of such indecomposable bodies would then depend on a similar reason to that for the atomic heats of $\mathrm{Ca\,C\,O_3}$ and $\mathrm{K\,As\,O_3}$. Compare the previous note.

in the nature of the case that the certain basis of fact and of what can be empirically demonstrated must be left. It must also not be forgotten that these conclusions only allow something to be supposed as to which of the present indecomposable bodies are more complex and which of simpler composition, and nothing as to the question what simpler substances may be contained in the more complex ones. The consideration of the atomic heats may say something as to the structure of a compound atom, but in general gives no clue as to the qualitative nature of the simpler substances used in the construction of the more complex atoms. But even if these suppositions are not free from uncertainty and imperfection, they appear worthy of attention in a subject which, for science, is still so much in darkness, as is the nature of the indecomposable bodies.

Fig. 3.

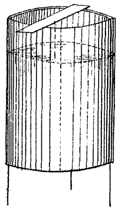


Fig. 5.

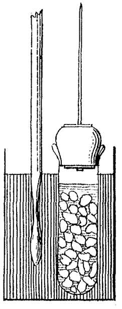


Fig. 6.

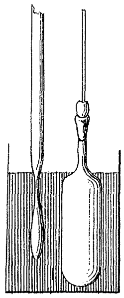


Fig. 8.

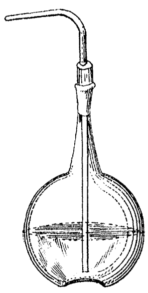


Fig. 4.

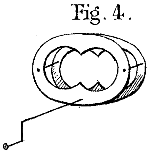


Fig. 7.

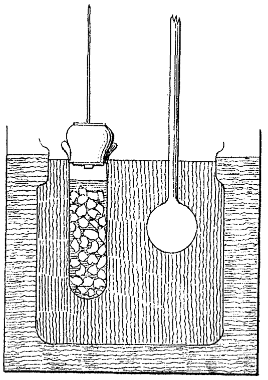


Fig. 1.

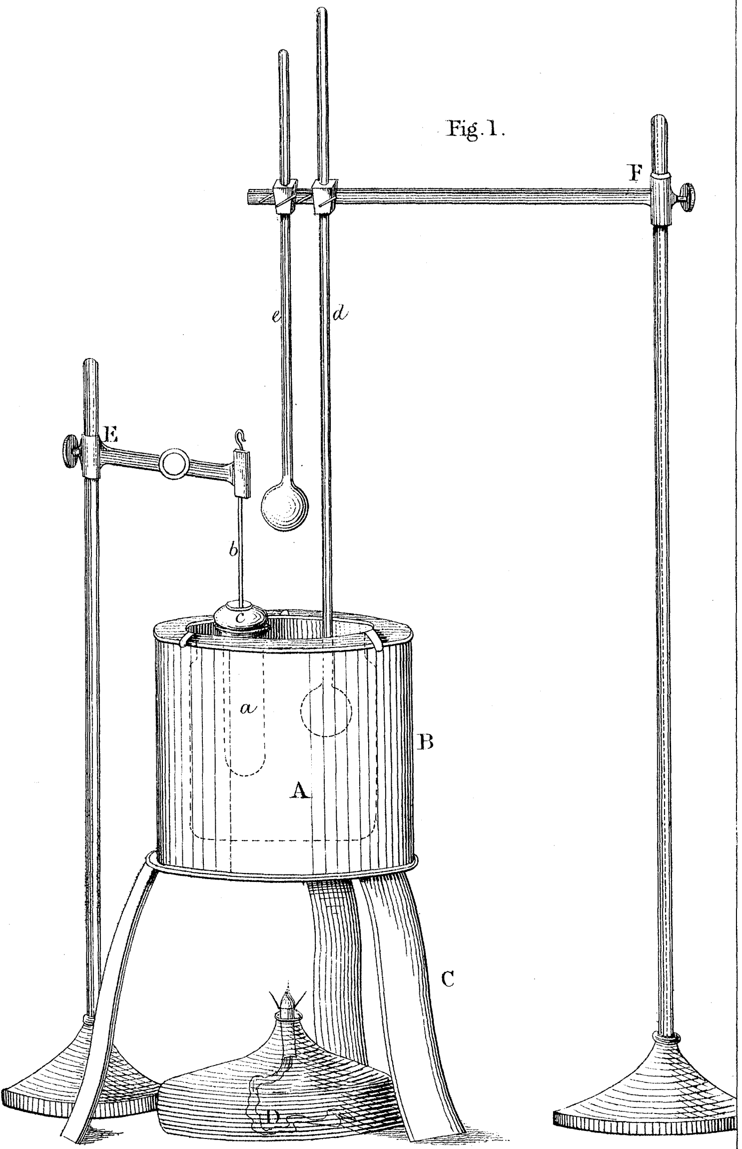
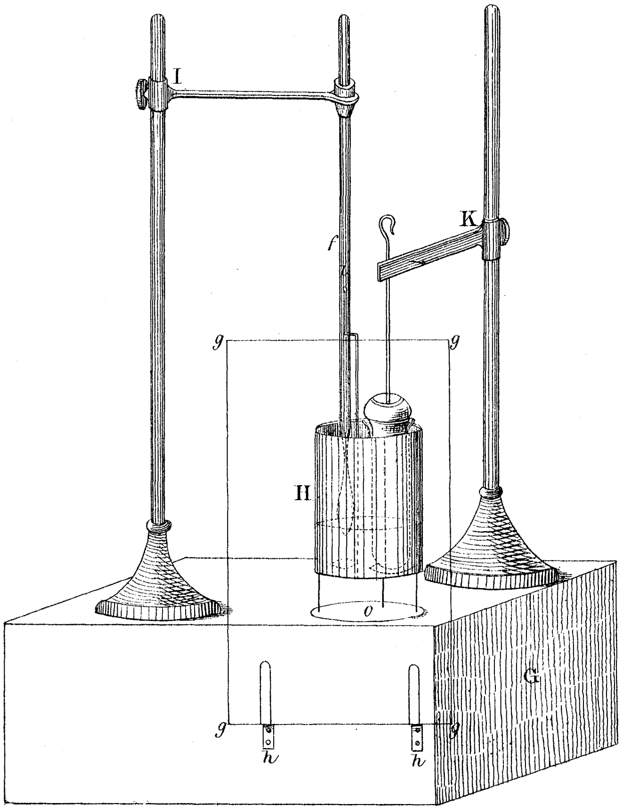


Fig. 2.



J. Basire, lith.