

ratus available for the measurement of the active wave lengths causing the reaction, but inasmuch as the reaction does not take place in glass which is opaque below 3300 Å. U. and does take place in the light of an iron arc which emits nothing below 2200 Å. U., the active rays lie between these limits.

Summary

1. Schiff's reagent was found to give a red color under the influence of ultra-violet light upon exposure in a clear quartz tube.
2. Other triphenylmethane dyes that had been decolorized by sulfur dioxide, forming sulfonic acids, gave their characteristic colors under similar circumstances.
3. The color developed in each case was proved to be that of the dye itself.
4. It was shown that there were two reactions taking place: (1) a decolorizing reaction; and (2) a colorizing reaction which is photochemical.
5. The large quanta supplied by the ultra-violet light cause the velocity of the photochemical reaction to increase; hence a shifting of the equilibrium takes place.
6. The equilibrium in this system can be shifted by chemical and thermal as well as photochemical means.

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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF CALIFORNIA]

A REVISION OF THE ENTROPIES OF THE ELEMENTS

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In the future development of thermodynamic chemistry it is probable that some of the greatest advances will be made through two new thermodynamic principles.

The first of these is known as the Third Law of Thermodynamics, which, when stated with proper caution,¹ may now be regarded as one of the exact laws of nature. Such doubt as may have existed regarding the adequacy of its experimental verification we believe will be resolved by the further and more precise evidence which is to be adduced in the present article.

¹ See Lewis and Gibson, "The Third Law of Thermodynamics and the Entropy of Solutions and of Liquids," [THIS JOURNAL, 42, 1529 (1920)]. A more complete statement of the third law is given by Lewis and Randall, "Thermodynamics and the Free Energy of Chemical Substances," McGraw-Hill, New York (in press).

The other principle which we are about to discuss, and which concerns the entropy of monatomic gases, has an equal claim to consideration as an exact law of nature.

In chemical calculations based upon these principles, the entropies of the elements will play so large a part that they doubtless will become recognized as among the most important of all physico-chemical constants. Since the publication of the first table of the entropies of the elements² new data and new methods have become available which warrant a revision of that table.

The Entropy of Monatomic Gases

The entropy of a perfect gas, whose molal heat capacity at constant volume is $3/2R$, is given by the familiar expression

$$S = 3/2 R \ln T + R \ln V + \text{const.} \quad (1)$$

In the classical theory of thermodynamics no attempt was made to evaluate this constant which might, at will, have been assigned any finite or infinite value, positive or negative. However, since the adoption of Planck's suggestion to take the entropy of a certain class of substances as zero at the absolute zero of temperature, it has become possible to state the numerical value for the entropy of a substance in a given state. It therefore became a matter of interest to evaluate the constant in Equation 1 for various monatomic gases.

Sackur³ in such an investigation found that by adding a new term to the entropy equation, namely, $3/2R \ln W$, where W is the molecular weight of the gas, the residual constant is the same for different gases. Thus,

$$S = 3/2 R \ln T + R \ln V + 3/2 R \ln W + C \quad (2)$$

and C is independent of the nature of the gas.

This generalization, which at the time of its discovery could only roughly be verified, has stood the test furnished by the far more accurate and extensive determinations of entropy which have since been made.⁴ On the other hand, the numerical value of the constant C which Sackur calculated from certain speculations relating to the quantum theory, has not been corroborated; although a similar calculation of Tetrode⁵ comes nearer to the experimental value.

It has, however, recently been shown by Lewis⁶ that the constant C

² Lewis and Gibson, *THIS JOURNAL*, **39**, 2554 (1917).

³ Sackur, *Ann. Physik*, **36**, 598 (1911); **40**, 67 (1913).

⁴ See the paper by Tolman [*THIS JOURNAL*, **42**, 1185 (1920)] who obtained values for the entropies of numerous monatomic gases, with the aid of our previous entropy tables.

⁵ Tetrode, *Ann. Physik*, **38**, 434 (1912).

⁶ Lewis, *Phys. Rev.*, **18**, 121 (1921). This question is discussed more fully in the volume dedicated to Professor E. H. Hall; "Contributions from the Jefferson Physical Laboratory," Vol. 15, Cambridge, Mass.

can be calculated, with an accuracy far greater than can yet be attained by experiment, from other well known constants of nature. This calculation, which depends upon the theory of ultimate rational units,⁷ may be best presented by writing Equation 2 in the equivalent forms,

$$S = R \ln (T^{3/2} W^{3/2} V) + C \quad (3)$$

$$S = R \ln (C' T^{3/2} W^{3/2} V) \quad (4)$$

where $R \ln C' = C$.

Now, according to this theory of ultimate rational units, C' and C become unity and zero respectively when for W and V we substitute the mass of one molecule and the volume per molecule, and when mass, volume and temperature are expressed in the new units. For conversion we have the relation that 1 erg-cm. becomes $1/(4\pi e)^2$ in ultimate rational units (U.R.U.). Here e is the charge of an electron in ordinary electrostatic units, namely, 4.774×10^{-10} .

We thus find

$$C' = \frac{k^{3/2} c^3}{N^{5/2} (4\pi e)^6} = 3.252 \times 10^{-3} \quad (5)$$

where k is the gas constant for one molecule, 1.372×10^{-16} ; c is the velocity of light, 2.999×10^{10} , and N is the number of molecules in a mol, 6.059×10^{23} . From these values we find that in ordinary units $C = R \ln C' = -11.39$. Because of possible errors in the constants employed, this value is in doubt by about 0.01 unit. Equation 3 then becomes

$$S = R \ln (T^{3/2} W^{3/2} V) - 11.39. \quad (6)$$

Thus with the aid of these fundamental constants, the electron charge, the gas constant, Avogadro's constant, and the velocity of light, and with no further experimental information, we are able to calculate the entropy of any gas of known molecular weight, which obeys the perfect gas law, and which has the heat capacity characteristic of monatomic gases.

For tabulating entropies at 25° and 1 atmosphere, we may substitute for the temperature and volume (the latter from the gas law) and thus find for these conditions

$$S = 3/2 R \ln W + 25.70. \quad (7)$$

For only 4 monatomic gases have we experimental determinations of the entropy of sufficient accuracy to justify comparison with the theo-

TABLE I
ENTROPY OF FOUR MONATOMIC GASES AT 25° AND 1 ATMOSPHERE

	By expt.	Calc.		By expt.	Calc.
He.....	29.2	29.8	Cd.....	40.0	39.8
A.....	36.4	36.7	Hg.....	41.3	41.5

retical equation. Table I shows the remarkable agreement between the values calculated by Equation 7 and the experimental values in these

⁷ Lewis and Adams, *Phys. Rev.*, **3**, 92 (1914).

4 cases, the difference in no case exceeding the probable experimental error.

For helium and argon the experimental values are those given in the table of Lewis and Gibson. From the value for liquid mercury, given in that table, we have obtained the value for mercury vapor by adding the entropy change in vaporization as calculated from the very accurate vapor pressure measurements of Smith and Menzies,⁸ and of Menzies.⁹ From the formula which they give we may calculate immediately the entropy change in passing from liquid to gas, both at one atmosphere, and at $25^\circ = 298.1^\circ \text{K}$. We find $\Delta S = 23.50$, which, added to the entropy of liquid mercury, 17.80, gives the entropy of mercury vapor at this temperature and pressure, namely $S_{298} = 41.30$.

For the entropy of vaporization of cadmium we have used the value calculated by Tolman from the vapor pressure measurements of Egerton,¹⁰ namely, $\Delta S_{298} = 28.2$. Adding this to the value 11.8 which we are going to obtain for the entropy of solid cadmium from the measurements of Griffiths, we find for the vapor, $S_{298} = 40.0$.

We see, therefore, that the principle of Sackur, combined with the principle of ultimate rational units, leads to values of the entropy which agree with the experimental values within the limits of experimental error. The four gases which we have available for this comparison range in atomic weights from 4 to 200. Moreover, it has recently been shown by Tolman¹¹ that, at least in order of magnitude, the same equation is valid for free electrons with atomic weight 0.000544.

General Considerations Relating to the Entropy of Solids and of Diatomic Gases

It has been shown by Latimer¹² that also in the case of solids the atomic weight is the chief factor in determining the entropy. Indeed, by assuming it to be the sole factor, and using an equation similar in form to Equation 7, but with a different constant, he obtained values for the entropies of a large number of solids which agreed very closely with those obtained experimentally. In one or two cases, to which we shall allude later, he was able in this way to discover errors in the experimental data (or their interpretation) which entered into the table of Lewis and Gibson; such conclusions being later confirmed by new experiments or by re-inspection of the older data.

Nevertheless, such calculations as these cannot be completely valid, for the entropy of any substance must vary not only with the temperature but also with the volume, and if any completely general law can be obtained for the entropy of solids it must be one which involves not only atomic weight and temperature but also some quantity such as the atomic volume, or the constraint operating on the atoms of the solid. Evidently, however, the term due to such factors is either small or approximately

⁸ Smith and Menzies, *THIS JOURNAL*, **32**, 1434 (1910).

⁹ Menzies, *ibid.*, **41**, 1783 (1919).

¹⁰ Egerton, *Phil. Mag.*, **33**, 333 (1917).

¹¹ Tolman, *THIS JOURNAL*, **43**, 1592 (1921).

¹² Latimer, *ibid.*, **43**, 818 (1921).

constant in the salts, which Latimer employed chiefly, and his principle will be of much service is estimating the entropies of solid substances when exact experimental data are lacking.

Similar remarks may be made with regard to Latimer's calculation of the entropy of diatomic gases, where only the atomic weights are considered and not the constraints between the atoms. Here, also, the mass appears to be the predominant factor and the method is capable of predicting the approximate entropies of substances of this class, usually within one or two entropy units.

New Determinations of Atomic Entropies of Metals

Sodium.—Recent investigations by Griffiths and Griffiths,¹³ and by Günther,¹⁴ on the specific heat of metallic sodium are in accord with the data of Eastman and Rodebush¹⁵ which were used in the former table of Lewis and Gibson. Unfortunately the new work goes to no lower temperature. There is no change to be made in the former value for the entropy of sodium.

Potassium.—In the former calculation of the entropy of potassium, entire weight was given to the old calorimetric values for the heat of formation of potassium salts. In spite of the fact that the specific-heat measurements have not been carried to sufficiently low temperature to determine with any precision the value of Θ (the temperature at which $C_v = 3/2 R$), the results of Eastman and Rodebush show that no great error would be made by assuming $\log \Theta = 1.32$. Using this value and the graphical method of Lewis and Gibson we find for potassium $S_{298} = 16.6$.

Calcium.—Günther has investigated the heat capacity of calcium at lower temperatures than those employed by Eastman and Rodebush. His results fall very near to the curve formerly adopted, but a curve drawn through the points of both series leads to a slightly lower value for the entropy. In place of the former value, 11.0, we now find $S_{298} = 10.64$.

Aluminum.—The new data of Griffiths and Griffiths permit a slight improvement in the heat capacity of aluminum in the neighborhood of room temperature. In place of the former value of 6.9 we thence obtain $S_{298} = 6.82$.

Iron.—The former value for the entropy of iron based solely on the measurement of Dewar, was $S_{298} = 6.6$. The data of Günther at low temperatures and of Griffiths and Griffiths at higher temperatures do not fall upon quite the same curve, the specific heats of the former investigation being lower. It is probable that in the case of a metal like iron the specific heat will be found to vary appreciably with the previous mechanical

¹³ Griffiths and Griffiths, *Proc. Roy. Soc. (London)*, **90A**, 557 (1914).

¹⁴ Günther, *Ann. Physik*, [4] **63**, 476 (1920).

¹⁵ Eastman and Rodebush, *THIS JOURNAL*, **40**, 489 (1918).

and thermal treatment of the metal. Nevertheless, it is to be noted that in general the specific heats obtained by Günther are a little low. We have given a little more weight to the measurements of Griffiths and Griffiths and thus find $\log \theta = 2.016$, and $S_{298} = 6.71$.

Zinc.—The measurements of Griffiths and Griffiths lead to no appreciable change in the entropy. Instead of the former value 9.8 we find $S_{298} = 9.83$.

Cadmium.—Previously the only measurement which could be used for determining the entropy of cadmium was the one by Dewar which led to the value $S_{298} = 11.6$. The data of Griffiths and Griffiths lead to a slightly higher value, namely, $S_{298} = 11.80$.

Copper.—The specific heat of copper has been more fully investigated than that of any other substance. The newer work of Kamerlingh Onnes¹⁶ confirms previous experiments at low temperatures. The work of Griffiths and Griffiths at higher temperatures leads to a greater precision of the curve in the range where $C_p - C_v$ is appreciable. In place of the old value 8.0 we find $S_{298} = 8.18$.

Silver.—Here also the measurements of Griffiths and Griffiths lead to an insignificant change, and $S_{298} = 10.25$.

Lead.—Once more using the data of Griffiths and Griffiths, the entropy of lead is raised from 15.4 to $S_{298} = 15.53$.

Tin.—Between ordinary white tin and the gray tin which is stable below 19° the difference in entropy can be calculated from the measurements by Brönsted¹⁷ of the transition temperature and heat of transition. We thus find that at 25° the entropy of the white tin is greater by 1.87.

Brönsted has also measured the specific heats of the two forms at low temperatures, and from his measurements we find, by the graphical method of Lewis and Gibson; for white tin, $\log \theta = 1.688$, and $S_{298} = 11.17$; while for gray tin $\log \theta = 1.800$, and $S_{298} = 9.23$. The difference in entropies is 1.94 and the agreement between this value and the value 1.87 found above furnishes a remarkable confirmation of the third law.

Further Tests of the Third Law, and the Entropy of Some Non-Metals

The Chlorides of Some Heavy Metals.—In the paper of Lewis and Gibson six independent values of the entropy of chlorine were obtained, but with an average deviation from the mean of nearly 2 entropy units. Four of these values were obtained from the free energy and heat of formation of the chlorides of mercury, lead, silver and thallium. The probable errors in the calorimetric measurements of the heats of reaction were alone considered sufficient to account for the discrepancies.

In an investigation which is not yet entirely completed, Mr. R. H.

¹⁶ Kamerlingh Onnes, *Comm. Phys. Lab. Leiden*, No. 147 (1915).

¹⁷ Brönsted, *Z. physik. Chem.*, **88**, 479 (1914).

Gerke has obtained the electromotive force and the change in electromotive force with temperature for three cells, namely,

- (a) Ag, AgCl,¹⁸ HgCl, Hg; $E_{298} = 0.0455$; $dE/dT = 0.000338$
 (b) Pb, PbCl₂, AgCl, Ag; $E_{298} = 0.4901$; $dE/dT = -0.000186$
 (c) Tl, TlCl, AgCl, Ag; $E_{298} = 0.7788$; $dE/dT = -0.000048$.

In each case the electrolyte was molal potassium chloride or hydrochloric acid.

Now the entropy change, in each cell reaction, is very simply obtained by multiplying dE/dT by 23074, which is the factor that converts volt equivalents into calories. On the other hand, the same change in entropy may be calculated from the entropies of the metals and their chlorides, as obtained from specific heats, in this paper and in that of Lewis and Gibson. The values of ΔS , obtained by the two methods, are compared in Table II.

TABLE II

Reaction	$\Delta S(\text{e.m.f.})$	$\Delta S(\text{sp. heats})$
(a) $\text{Ag} + \text{HgCl} = \text{AgCl} + \text{Hg} \dots \dots \dots$	7.8	7.7
(b) $\frac{1}{2}\text{Pb} + \text{AgCl} = \frac{1}{2}\text{PbCl}_2 + \text{Ag} \dots \dots \dots$	-4.3	-4.3
(c) $\text{Tl} + \text{AgCl} = \text{TlCl} + \text{Ag} \dots \dots \dots$	-1.1	0.9

It is evident in the case of the chlorides of silver, mercury and lead that the former apparent deviations from the third law, amounting to several entropy units, are now completely eliminated.¹⁹ In the third reaction there is a discrepancy of two entropy units, but a re-inspection of the specific-heat data of thallos chloride shows that the value of the entropy obtained by Lewis and Gibson is unquestionably too high.

However, even if we give full value to the entropy of thallos chloride as formerly calculated, *the average apparent deviation from the third law in the case of these chlorides has been reduced tenfold.*

The Entropy of Chlorine.—Gerke has also studied the cell with chlorine and silver—silver chloride electrodes in molal hydrochloric acid. His present results give²⁰ $E_{298} = 1.1360$, $dE/dT = -0.00057$. Hence we find, $\text{Ag} + \frac{1}{2}\text{Cl}_2 = \text{AgCl}$; $\Delta S_{298} = -13.15$. Lewis and Gibson found for AgCl, $S_{298} = 23.4$; and we have found for Ag, $S_{298} = 10.25$. Hence we find for $\frac{1}{2}\text{Cl}_2$, $S_{298} = 26.3$. The same value would have been obtained by combining the e.m.f. and specific-heat data involving the other chlorides except that of thallium.

¹⁸ The silver chloride here used is that prepared by adding a chloride to a silver salt in aqueous solution. It is, therefore, presumably the same as that employed in the specific-heat measurements.

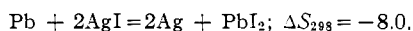
¹⁹ The exactness of the agreement between the two values of ΔS obtained in Reactions (a) and (b) must be somewhat fortuitous, since the data on the heat capacities of the chlorides do not permit great precision in the estimation of their entropies.

²⁰ These values combined with those for Cell (a) give the heat of formation of HgCl as 31400 cal., which is very close to the value 31500 as obtained by Nernst [*Z. physik. Chem.*, **2**, 23 (1888)], and by Varet [*Ann. chim. phys.*, [7] **8**, 102 (1896)].

Iodine.—In the former table the atomic entropy of iodine was given as 15.7. This value was based on specific heat measurements of Nernst. The more recent experiments of Günther²¹ showed that both his own measurements and those of Nernst were affected by some peculiar phenomenon which he believed to be a slow transition between two forms of iodine. It seems at present impossible to obtain any reliable value for the entropy of iodine from the specific heats.

However, we may determine the entropy through the third law by means of a measurement by Gerke of the temperature coefficient of the electromotive force of the cell Pb, PbI₂, Pb(ClO₄), PbI₂, I₂ (solid). He thus finds for the reaction $\text{Pb} + \text{I}_2 = \text{PbI}_2$; $\Delta S_{298} = -1.20$.

The entropy of lead iodide as obtained by Lewis and Gibson from specific-heat measurements was 41.3; we may obtain another value by using their entropy of silver iodide, our value for silver, and Gerke's measurement,



Whence for PbI₂, $S_{298} = 40.6$. We may take the average value for PbI₂, namely, $S_{298} = 41.0$.

We have found the entropy of lead to be 15.5, and combining these values with Gerke's value for the entropy of formation of lead iodide from lead and iodine, we find for I₂(s), $S_{298} = 26.6$, and therefore for $\frac{1}{2}\text{I}_2(\text{s})$, $S_{298} = 13.3$.

The heat of sublimation of iodine has been carefully measured by Baxter, Hickey and Holmes,²² from whose work we find $\Delta H_{298} = 15100$. Also from their vapor-pressure measurements we may calculate the free energy change, $\Delta F_{298} = 4630$. Hence $\Delta S_{298} = 35.2$, and combining this with the value for solid iodine we obtain for $\frac{1}{2}\text{I}_2(\text{g})$, $S_{298} = 30.9$.

Bromine.—The former value for the entropy of bromine was obtained from very meagre specific-heat data largely by analogy to iodine and chlorine. Since our new values for these elements are lower than those obtained from the specific heats, that for bromine presumably should be lowered by a corresponding amount. As a very rough estimate we shall therefore take for $\frac{1}{2}\text{Br}_2(\text{l})$, $S_{298} = 16.3$.

In this case, also, we may obtain the entropy change in vaporization from vapor-pressure measurements. Using the data of Ramsay and Young²³ we find for $\frac{1}{2}\text{Br}_2(\text{g})$, $S_{298} = 27.7$.

Oxygen.—In the case of oxygen we have three independent methods of determining the entropy, which afford a very good test of the third law. From the measurements of Eucken of the specific heats and heats of transi-

²¹ Günther, *Ann. Physik*, [4] **51**, 828 (1916).

²² Baxter, Hickey and Holmes, *THIS JOURNAL*, **29**, 127 (1907).

²³ Ramsay and Young, *J. Chem. Soc.*, **49**, 453 (1886).

tion of the various forms of oxygen, Lewis and Gibson found for $\frac{1}{2}\text{O}_2$, $S_{298} = 24.1$.

They also show how it is possible from the entropy of graphite and of carbon monoxide, and from the heat and the free energy change in the formation of carbon monoxide from carbon and oxygen, to calculate the entropy of oxygen. Hence for $\frac{1}{2}\text{O}_2$, $S_{298} = 22.8$.

A third very reliable calculation is now permitted by the measurements of Günther²¹ on the specific heat of mercuric oxide. From his data we find by the usual graphical methods for HgO , $S_{298} = 16.3$. From the heat of formation and free energy of formation of mercuric oxide, as obtained from various data by Lewis and Randall,²⁴ we find the entropy change in the formation of mercuric oxide from its elements, namely, $\Delta S_{298} = 26.1$. The entropy of mercury from the former table is 17.8, and by combining these several data, we find for $\frac{1}{2}\text{O}_2$, $S_{298} = 24.6$.

These three values, 24.1, 22.8 and 24.6 certainly agree within the limits of experimental error of the three methods, and we may finally take, as a weighted mean, 24.0.

Nitrogen.—New work by Kamerlingh Onnes²⁵ on the specific heat of solid and liquid nitrogen confirms in a most satisfactory manner the work of Eucken, and leads to no change in the value of the entropy of this element.

Hydrogen.—An entirely new method of determining the entropy of hydrogen is furnished by Equation 6, for Eucken has shown that below about 60° K hydrogen has the heat capacity of a monatomic gas, and under these conditions there can be little doubt that its entropy can be calculated as for a monatomic gas of atomic weight 2.²⁶ We may therefore calculate its entropy, say at the boiling point of liquid hydrogen, and then use the data of Eucken, as in the paper of Lewis and Gibson, to find the entropy at 25°. This gives us for $\frac{1}{2}\text{H}_2$, $S_{298} = 14.72$. This is more certain than any other determination of the entropy, and we may take it as the final value. Lewis and Gibson obtained 15.9 from the specific heat of ice and the third law, while they obtained 14.7 from the specific heat of hydrogen. In the meantime, however, Kamerlingh Onnes²⁷ has redetermined the heat of fusion of solid hydrogen, the specific heat of liquid hydrogen, and the vapor pressure of the latter, at several temperatures, whence we may obtain the entropy of vaporization; and these data lead to a value for the entropy of hydrogen which is 0.67 higher than the value which we have just obtained from the principle of ultimate rational units through Equation 6. But it is to be noted that this discrepancy

²⁴ Lewis and Randall, *THIS JOURNAL*, **36**, 1969 (1914).

²⁵ Kamerlingh Onnes, *Comm. Phys. Lab. Leiden*, **149** (1916).

²⁶ See Tolman, *THIS JOURNAL*, **42**, 1185 (1920).

²⁷ Kamerlingh Onnes, *Comm. Phys. Lab. Leiden*, 153 (1917).

is no greater than the uncertainty which probably still exists in the heat of vaporization and the heat of fusion of hydrogen.

Summary

In Table III we shall collect for reference all of the atomic entropies which have been so far calculated, also including the entropies of a number of elements in the state of monatomic gas, as calculated from Equation 7.

TABLE III
ATOMIC ENTROPIES AT ONE ATMOSPHERE AND 25

	S_{298}		S_{298}
Electricity (E^- , g).....	3.28	Copper.....	8.18
Hydrogen ($\frac{1}{2}H_2$).....	14.72	Zinc.....	9.83
Hydrogen (H).....	25.72	Zinc (g).....	38.17
Helium.....	29.83	Bromine ($\frac{1}{2}Br_2$, l).....	16.3
Lithium.....	7.6	Bromine ($\frac{1}{2}Br_2$, g).....	27.7
Lithium (g).....	31.48	Bromine (Br, g).....	38.77
Beryllium.....	7.3	Krypton.....	38.88
Carbon (diamond).....	0.6	Rubidium (g).....	38.97
Carbon (graphite).....	1.3	Zirconium.....	9.5
Nitrogen ($\frac{1}{2}N_2$).....	22.8	Molybdenum.....	7.5
Nitrogen (N).....	33.57	Ruthenium.....	6.9
Oxygen ($\frac{1}{2}O_2$).....	24.0	Rhodium.....	7.6
Oxygen (O).....	33.97	Palladium.....	8.9
Fluorine (F).....	34.48	Silver.....	10.25
Neon.....	34.66	Cadmium.....	11.80
Sodium.....	12.2	Cadmium (g).....	39.79
Sodium (g).....	35.06	Tin (white).....	11.17
Magnesium.....	8.3	Tin (gray).....	9.23
Aluminum.....	6.82	Iodine ($\frac{1}{2}I_2$, s).....	13.3
Silicon (metal).....	4.7	Iodine ($\frac{1}{2}I_2$, g).....	30.9
Phosphorus (P, g).....	35.95	Iodine (I, g).....	40.15
Sulfur (rhombic).....	7.6	Xenon.....	40.23
Sulfur (monoclinic).....	7.8	Cesium (g).....	40.28
Sulfur (S, g).....	36.04	Lanthanum.....	13.7
Chlorine ($\frac{1}{2}Cl_2$, g).....	26.3	Cerium.....	13.8
Chlorine (Cl, g).....	36.35	Tungsten.....	8.4
Argon.....	36.70	Osmium.....	7.8
Potassium.....	16.6	Iridium.....	8.7
Potassium (g).....	36.63	Platinum.....	10.0
Calcium.....	10.64	Gold.....	11.0
Calcium (g).....	36.71	Mercury (l).....	17.8
Titanium.....	6.6	Mercury (g).....	41.51
Chromium.....	5.8	Thallium.....	14.6
Manganese.....	7.3	Lead.....	15.53
Iron.....	6.71	Niobium.....	41.81
Cobalt.....	7.2	Thorium.....	13.6
Nickel.....	7.2	Uranium.....	11.1

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