XIII. *Observations on the best Methods of producing artificial Cold. By Mr.* Richard Walker. *Communicated by* Martin Wall, *M. D. F. R. S.*

Read May 14, 1795.

HAVING already investigated the *means* of producing artificial cold, and at the conclusion of my last paper (on the congelation of quicksilver) dismissed *that part* of the subject, the best method of making use of those means naturally becomes a desideratum; to that therefore I have lately given my attention, and flatter myself that the following observations may be considered as an useful appendix to my former papers. The freezing point of quicksilver being now as determined a point on the scale of a thermometer, *viz.* — 39°, as the freezing point of water; and as this metal, exhibited in its solid state, affords an interesting as well as curious phænomenon; I shall apply what I have to say principally to that object.

Frequent occasions having occurred to me of observing the superiority of snow, in experiments of this kind, to salts, even in their fittest state, that is, fresh crystallized, and reduced to very fine powder, I resolved upon adopting a kind of artificial snow.

The first method which naturally presented itself, was by condensing steam into hoar-frost; this answered the purpose, as might be expected, exceedingly well; but the difficulty and expence of materials in collecting a sufficient quantity, determined me to relinquish this mode for another, by which I can easily and expeditiously procure ice in the fittest form for experiments of this kind; the method I mean, is by first freezing water in a tube, and afterwards grinding it into very fine powder. Thus possessed of the power of making ice, and afterwards reducing it to a kind of snow, the congelation of quicksilver becomes a very easy and certain process; for by the use of a very simple apparatus (Tab. XXIII. fig. 1.) quicksilver may be frozen perfectly solid, in a few minutes, wherever the temperature of the air does not exceed 85°, thus: one ounce of nitrous acid is to be poured into the tube *b* of the vessel, observing not to wet the side of the tube above with it; a circular piece of writing paper of a proper size is to be placed over the acid, resting upon the shoulder of the tube, and the paper brushed over with some melted white wax; thus prepared, the vessel is to be inverted, and filled with a mixture of diluted nitrous acid, phosphorated soda, and nitrous ammoniac, in proper proportions for this * temperature, and tied over securely, first with waxed paper, and upon that a wet bladder.

The vessel being then turned upright, and placed in a shallow vessel, *viz.* a saucer or plate, an ounce and a half of rain or distilled water is to be poured into the tube, which is to be covered with a stopper or cork, and, as soon as frozen solid, ground to very fine powder, an assistant holding it firmly and steadily the while; observing occasionally to work the instrument in different directions up and down, that no lumps

* I have, by a very accurate preparation of this mixture, sunk a thermometer from 85° (temperature of the vessel and materials) to + 2°.

may be formed. When the whole of the ice is thus reduced to powder, and the lumps, if any, broken, the frigorific mixture is to be let out quickly, by cutting or untying the string, and removing the bladder, &c. which confines it; a communication made, by forcing a rod of glass or wood through the partition; and the whole mixed expeditiously together.

In this climate, a mixture much less expensive will be sufficient, *viz.* that composed of diluted nitrous acid, GLAUBER's salt, sal ammoniac, and nitre; a mixture of this kind sinking a thermometer in the warmest weather to near 0°. At the temperature of 70°, or a little higher, the quantity of diluted nitrous acid may be about one-fourth less than is mentioned in the Table, for 50°.

These methods are the most expeditious, and attended with the least trouble; but as ice may be used with equal certainty, and with much less expence, I shall give a particular detail of an experiment made with the use of it, first mentioning a preparatory experiment, to which I was immediately led by the recollection that Sir CHARLES BLAGDEN, in his paper "on the "point of congelation," (Phil. Trans. Vol. LXXVIII.) had found that common sal ammoniac and common salt, mixed with snow, produced a cold of — 12°, whereas the latter used alone with snow produces only — 5°. I used a mixed powder of equal parts of common sal ammoniac and nitre with the common salt, by which the thermometer sunk to — 18°; and when I used nitrous ammoniac with common salt, to — 25°; this cold I could not increase by the addition of any other salts, nor could I equal it by any other combination of salts: those I tried were GLAUBER's salt, salt of tartar, soda, and sal catharticus amarus; by several trials, I found the best proportions to be, snow or pounded ice twelve parts, common salt five parts, and of nitrous ammoniac, or a powder of equal parts sal ammoniac and nitre mixed, five parts; or *one-third* of common salt, when I used that *alone*, with snow or pounded ice.

My apparatus then (Dec. 28th last) consisted of two vessels (fig. 3. and 4); an instrument, (fig. 6.) to grind or rather scrape the ice to powder; a kind of spatula (I use a marrow-spoon) to stir the powder occasionally; a thermometer (fig. 8.); and a small thermometer glass with the bulb three-fourths full of quicksilver (fig. 7.). I filled the vessel, fig. 3, holding when inverted two pints, *stratum super stratum*, with pounded ice, common salt, and a powder consisting of equal parts sal ammoniac and nitre mixed together; by first putting in six ounces of pounded ice, then two ounces and a half of common salt, and, after stirring these well together, two ounces and a half of the mixed salts, mixing the whole well together; this was repeated in the same manner until the vessel was quite full; it was then tied over securely with a wet bladder, turned upright, and one ounce and a half of rain water poured into the tube through a funnel, the tube covered with a cork, and the vessel left undisturbed till the water was frozen perfectly solid. The instrument for grinding it was then put in to acquire cold, whilst the vessel, fig. 4, holding a pint, was filled in the same manner, with the same proportions of materials, a bladder tied over it, set upright, and one ounce of fuming nitrous acid poured in to be cooled. The ice was then ground to powder, and when finished, the nitrous acid being found to have acquired a sufficient degree of cold, *viz.* — 13°, the frigorific mixture of ice and salts was let out of the vessel which contained the nitrous acid; and the powdered ice (still surrounded by its frigorific mixture) added to the acid as quick as possible; when the thermometer sunk to near — 50°, and the mixture soon froze the quicksilver in the glass bulb. In this experiment, 18 minutes were required to freeze the water perfectly solid; and 15 to reduce the ice, by moderate labour, to very fine powder. The experiment was over in 55 minutes; and the temperature of the preparatory cooling mixture then found to be — 10°.

I had a spirit thermometer by me, but a mercurial thermometer being much more sensible, and consequently descending much quicker, I prefer it in experiments made merely to freeze quicksilver; knowing from experience how the congelation is going on, from the irregular descent of the mercury when a few degrees below its freezing point; and from having usually found that the quicksilver in the thermometer glass begins to freeze, as soon as the mercurial thermometer reaches — 40°.

Whenever I have occasion to use ice in summer for this purpose, I usually pound together first some ice and salt in a stone mortar, about two parts of the former to one of the latter; throw this away, and wipe the pestle and mortar perfectly dry; the mortar being thus cooled, the ice may afterwards be pounded small without melting.

And as a mixture made of snow, or ice in powder, and salts, does not give out its greatest cold till it is become partially liquid, by the action of the ice and salts on each other; it is necessary that the whole be stirred well together, till it is become of an uniformly moist *pulpy* consistence, especially since in becoming liquid the mixture shrinks so much, that if this be not attended to the vessel will not be near full, and consequently the upper part of the tube not surrounded, as it ought to be, by the frigorific mixture. The dissolution of the ice and salts may, if required, be hastened by adding occasionally a little water; but then the cold produced will be less intense, and not so durable.

That particular form of the vessel, in which the ice is made and reduced to powder, is chosen, because it subjects the powdered ice in the tube to the constant action of the freezing mixture, without which it would be less fit, particularly in warm weather, for the intended use, and because in it the ice is not liable to be impregnated with the salts of the mixture, by which it would be utterly spoiled: and *that* for cooling the nitrous acid, and making the second mixture in, because it is steady, and is besides insulated as it were from the external warm air, and surrounded in its stead by an atmosphere much colder.

It is scarcely necessary to add, that when snow which has never thawed can be procured, it may be cooled in this apparatus by a mixture of snow (instead of the pounded ice), and the salts, and the trouble of reducing the ice into powder saved.

I prefer the red fuming nitrous acid, because, as I have observed in a former paper, it requires no dilution. Being under the necessity at one time of using the pale nitrous acid, I found it required to be diluted with one-fifth its weight of water. The best and only way of trying or reducing any acid to the proper strength, is by adding snow, as Mr. Cavendish directs, or the powdered ice to it, until the thermometer cease to rise; then cool the acid to the same temperature of the snow again, add more snow, which will make the thermometer rise again, though less; cool it again, and repeat this, until the addition of snow or powdered ice will not make the thermometer rise: to be very accurate, it should be reduced in this manner to the proper strength, at the temperature, whatever it be, at which the nitrous acid and snow, or powdered ice, are to be mixed together when cooled.

In the course of my experiments I have endeavoured to ascertain the comparative powers of ice to produce cold with nitrous acid, in the different forms I have had occasion to use it. The result is, that fresh snow sunk a thermometer to $-32°$; ground ice to $-34°$; and the most rare frozen vapour to below $-35°$; the vessel and materials each time being $+30°$.

The vessels for these mixtures, particularly that in which the quicksilver is to be frozen, should be thin, and made of the best conductors of heat; first, because thin vessels rob the mixture of less cold at mixing, *i. e.* if two mixtures of the same kind are made, one in a thin, the other in a thick vessel, the former will be coldest; secondly, because the air is a sufficiently bad conductor; and thirdly, for the very obvious reason, that the cold is transmitted through them quicker.

For these reasons, and from the difficulty I have found in procuring vessels of glass, which are undoubtedly fittest for experiments of this kind, I have used tin; which is readily had in any form, and if coated with wax, is sufficiently secured against the action of the acids.

I give the inside such a coating, by pouring melted white wax into the vessel, previously clean and dry, and turning it about by hand, so as to leave no point of the metal uncovered for the acid to act on, pouring the surplus away.

In the experiment above described, I used a single vessel for cooling the nitrous acid; a cupping-glass (represented by the dotted line at *b*, fig. 4.) being cemented into the tin, and thereby forming that part in which the nitrous acid was first cooled, and the mixture afterwards made in which the quicksilver was frozen: but, from the trouble and impediments arising from letting out the mixture, and clearing the bottom from the lumps of ice, &c. adhering to it, I was led to the addition of the other part (fig. 5.) by which all these difficulties are got rid of, and it is besides a much more comfortable and neat way of conducting it; the upper part which contains the nitrous acid being lifted off and placed on the table, immediately before the powdered ice is added.

The whole of this apparatus may be of tin, that part *only* (when the *cooling* mixtures are made *without* using any corrosive acid) in which the acid mixture is to be made, being previously coated in the manner above mentioned; or a thin glass tumbler of a proper size may be cemented in.

I have occasionally used a thin glass tumbler for the mixture in which the quicksilver is to be frozen, immersing it with the acid in a frigorific mixture till the acid is sufficiently cooled, then adding the ground ice to it, previously removing the tumbler out of the frigorific mixture, as in the experiment above mentioned; this simplifies the apparatus, but is less convenient on many accounts.

The scale of this apparatus may be diminished or increased at the will of the operator; for there is no doubt that a small quantity of quicksilver may be frozen at any time with one-fourth of this quantity, with an apparatus of this kind, by any one conversant in such experiments.

I have frequently frozen quicksilver, by mixing together, at 0°, three drams of ground ice with two drams of nitrous acid.

Whenever the intention is, as in these experiments, to cool the materials to *nearly* the same temperature with the frigorific mixture in which they are immersed, the proportion of the frigorific mixture to the intended mixture (or materials to be cooled) should not be *less* than twelve to one; a greater disproportion is still better.

By attending to the directions *particularly* mentioned in the experiment made on Dec. 28th, a thermometer may be *always* dispensed with; the proportions of the materials to be cooled being exactly adjusted; and *when* they are to be mixed precisely determined, by the time employed in grinding the ice to powder. The proportions of snow, or pounded ice, and salt, or salts, may be guessed sufficiently near without weighing, unless in very *nice* experiments.

Imagining that a recapitulation of the different mixtures, described in my former paper, for producing artificial cold, brought into one view might not be unuseful, I have subjoined a Table of the salts, their powers of producing cold with the different liquids, and the proportions of each, according to a careful repetition of each; the temperature being 50°.

Salts.	Liquor.		Temperature, or cold produced.
* Sal ammoniac 5, nitre 5	water	16	+10°
Sal ammoniac 5, nitre 5, GLAUBER's salt 8 – –	———	16	+4°
* Nitrous ammoniac 1 –	———	1	+4°
Nitrous ammoniac 1, sal soda 1	———	1	—7°
GLAUBER's salt 3 –	d. nitr. acid	2	—3°
GLAUBER's salt 6, sal ammoniac 4, nitre 2 – –	———	4	—10°
GLAUBER's salt 6, nitrous ammoniac 5 – –	———	4	—14°
Phosphorated soda 9 –	———	4	—12°
Phosphorated soda 9, nitrous ammoniac 6 – –	———	4	—21°
GLAUBER's salt 8 –	marine acid	5	—0°
GLAUBER's salt 5 –	d. vitr. acid	4	+3°

N. B. I have chosen the temperature of 50°, because the materials may at any time, by immersion in water drawn from a spring, be cooled nearly to that temperature, and the experiment for freezing with any of these mixtures commence there.

* The salts from each of these may be recovered by evaporating the mixture to dryness, and used again repeatedly.

N. B. The figures after each salt, and after the liquor, signify the proportion of parts, by Troy weight, to be used; the trouble of weighing the *water* may be saved by observing, that a full ounce of it by wine measure corresponds exactly with one ounce of it by Troy weight; likewise it must be noticed, when more kinds of salt than one are used, to add them to the liquor one after the other, in the order they stand in the Table: beginning on the left hand, and stirring the mixture well between each addition: d. nitr. acid, is red fuming nitrous acid two parts, and rain, or distilled water one part, At a higher temperature than 50°, the quantity of the salts must be increased, and the effect will be proportionably greater; at a lower temperature diminished, when the effect will be proportionably less.

It must be observed, that to produce the greatest effect by any frigorific mixture, the salts should be fresh crystallized,* not damp, and newly reduced to very fine power; the vessel in which they are made very thin, and just large enough to contain the mixture; and the materials mixed intimately together, as quickly as possible, the proper proportions at any temperature (those in the Table being adjusted for the temperature of 50° *only)* having been *previously* tried, by adding the powdered salts gradually to the liquid, till the thermometer ceased to sink; observing to produce the full effect of one salt before a second is added, and likewise of the second before a third is added. Neither soda, phosphorated soda, nor GLAUBER's salt should be mixed with nitrous ammoniac, or the powder composed of sal ammoniac and nitre, unless at a low temperature, *i. e.* below 0°, but pounded and kept apart.

In the experiments alluded to in the Table, the precaution of fresh crystallizing the salts was not observed, because I chose to give the ordinary effects only; I therefore then used salts in their common state, taking care, however, to choose such as had not in the least effloresced.

Since it is always useful, and generally absolutely necessary,

by weight, well agitated together, and become cool: d. vitr. acid, is strong vitriolic acid, and rain, or distilled water, equal parts, by weight, thoroughly mixed (very cautiously) and cooled.

* Soda, phosphorated soda, and GLAUBER's salt, are best crystallized afresh, because their effect, especially the two last in the acids, depends upon the quantity of water they contain in a solid state.

to know how much room in a vessel the several materials take up separately, and when mixed, it will be right to observe, that snow, or ice in powder, at near 0°, occupy in measure nearly two-thirds more than their weight; that is, one ounce weight of water will, when in the form of snow, or ice ground to powder, nearly fill a vessel which holds three ounces wine measure; powdered salts nearly double their weight; strong nitrous acid about three-fourths its weight; and a mixture made of salts and diluted nitrous acid, measures rather less than two-thirds of the weight of the ingredients. Without a previous knowledge of this, it is impossible to adjust the size of the vessels to the mixtures which are to be made; because, in most nice experiments of this kind, the height to which a vessel will be filled is indispensably necessary to be known beforehand.

The long continuance of the late frost having afforded me opportunities of repeating these experiments in various ways, I shall mention briefly the result of such as appear to me to be material.

I have found, that ice may be ground so fine as to be equal to frozen vapour, and the harder it is frozen the finer it is ground, but with more labour:

That quicksilver may be frozen by cooling the nitrous acid only, saving the trouble and inconvenience of cooling the snow likewise; either by adding snow at + 32°, to nitrous acid at — 29°; or snow at + 25°, to nitrous acid at — 20°; or snow at + 20° to nitrous acid at — 12°; most winters offer an opportunity of doing it in this way; the nitrous acid may be cooled in a mixture of snow and nitrous acid:

That it may likewise be frozen, by mixing expeditiously together snow and nitrous acid, when the temperature of each is + 7°:

Or by mixing ground ice and nitrous acid at + 10°.

Hence it follows, that the cold of this climate offers occasionally opportunities of freezing quicksilver, without previously cooling by art the materials to be mixed; for I have once seen the thermometer at + 6°, and others, I believe, have seen it lower.

I expected an opportunity would have offered this winter, but the lowest point I saw my thermometer at, this season, was only + 10°; at this temperature, I mixed nitrous acid (cooled out of doors to the temperature of the air) and snow, on January 23d last; but the cold produced was not quite sufficient to freeze the quicksilver, although very near it, as indicated by a thermometer. From what I have observed *since* these latter experiments were made, I think it may be reasonably expected, that powdered ice and nitrous acid at + 14°, or snow at + 10°, will succeed, if mixed expeditiously.

Strong spirit of vitriol, whose specific gravity is 1,848, required to be diluted with half its weight of water, and produced with snow at the temperature of + 30°, about eight degrees less than with nitrous acid, sinking the thermometer to — 24°; four parts of the diluted vitriolic acid required, at that temperature, six parts of snow.

It perhaps will be remarked, that I have taken no notice before of the vitriolic acid. The reason is, because the freezing point of quicksilver being 39°, it may be frozen tolerably hard by a mixture of nitrous acid with snow, or ground ice, though the utmost degree of cold this acid can produce with snow is — 46°; which degree of cold may be produced by mixing the snow or ground ice and nitrous acid at 0°.

If it be required to make it perfectly solid and hard, a mixture of equal parts of the diluted vitriolic acid and nitrous acid should be used with the powdered ice, but then the materials should not be less than — 10° before mixing.

If a still greater could be required than a mixture of this kind can give, which is about — 56°, the diluted vitriolic acid *alone* should be used with snow or powdered ice, and the temperature at which the materials are to be mixed not less than — 20°.

Select, according to the intention, either of the three following mixtures:

First, snow or pounded ice two parts, and common salt one part, which produces a cold of — 5°:

Second, snow or pounded ice twelve parts, common salt five parts, and a powder, consisting of equal parts of common sal ammoniac and nitre mixed, five parts, which produces a cold of — 18°:

Third, snow or pounded ice twelve parts, common salt five parts, and nitrous ammoniac in powder five parts, which produces a cold of — 25°.

The proportions which I have found to be the best for mixing the snow or powdered ice with the different acids, at different temperatures, are these; *viz.* at + 30°, seven of the former to four of the nitrous acid; at + 5° (with a trifling allowance, if any, for a few degrees above or below), three to two; at — 12°, four to three, with the mixed acids; and at — 20°, with the diluted vitriolic acid, equal parts.

If it be required to prepare the materials in a frigorific mixture, without the use of *ice*, a mixture of the proper strength may be chosen from the Table.

It is immaterial, when the exact proportions of each are known, whether the powdered ice be added to the acid, or the acid poured upon that, provided the powdered ice be kept stirred to prevent lumps forming, and the materials be mixed as quick as possible. But when the proportion is not known, it is better to be provided with more powdered ice than is expected to be wanted; and add it to the acid by degrees, until the greatest effect is produced, as shewn by a thermometer.

The consistence is a pretty sure guide to those accustomed to mixtures of this kind; *viz.* when fresh additions of snow or ice do not readily dissolve in the acid, though well stirred, and the mixture acquires a thickish flocculent appearance.

Snow, or powdered ice, that have ever been subjected to a cold less than freezing are spoiled, or rendered much less fit for experiments of this kind.

I prefer the method of adding the powdered ice or snow to the acid in a *separate* vessel, principally because the size of that vessel may be *exactly* adjusted to the quantity of mixture it is to contain.

A mixture made of diluted nitrous acid, phosphorated soda, and nitrous ammoniac (by much the most powerful of any compounded of *salts* with acids), prepared with the greatest accuracy, is not quite equal to a mixture of snow and nitrous acid, each mixed at $+ 30°$, although very nearly so.

Though quicksilver may be frozen by salts dissolved in acids, it is necessary that the materials be cooled, previously to mixing, much lower than when snow or ground ice are used.

If it be required to mix the powdered salts and acids at a low temperature, the best method is this: put first the nitrous ammoniac into the tube of such an apparatus as fig. 1. shaking it down level, gently pressing the upper surface smooth; then the phosphorated soda or GLAUBER's salt; cover this with a circular piece of writing paper, and pour a little melted white wax upon it, and when cold, pour upon this the diluted nitrous acid; immerse this in a frigorific mixture till it is sufficiently cold, as found by dipping the thermometer into the liquor occasionally; force a communication through, and stir the whole thoroughly together, contriving that the upper stratum of salt, that is, the phosphorated soda or GLAUBER's salt, be mixed with the liquor first, and then the nitrous ammoniac; the powdered salts do not require stirring whilst cooling, like snow, for however hard they are frozen, they will readily dissolve in the acid; care must be taken that the partition be perfect between the salts and the liquor; and that in this, and every instance where the materials are to be cooled, they be immersed *below* the surface of the frigorific mixture. The strength of the red fuming nitrous acid used in these experiments, I found to be 1,510, and that of the vitriolic acid 1,848.

I have thought it better, for the sake of brevity, *not* to use in this, as in my former papers, the new chemical names, especially as the old ones are more generally known.

These experiments were chiefly made in a warm room, not far from the fire side.

I have now finished my proposed plan respecting the best modes of conducting experiments on cold, in which it will appear, that I have reduced the congelation of quicksilver, in any climate at any season, to as certain, and almost as easy a process, as that I originally set out with, for the freezing of water (Phil. Trans. Vol. LXXVII.); *viz.* by previously cooling the materials in one mixture, to produce the effect in a second. It may very likely appear to some, that I have been too minute in a few particulars; yet as perhaps experiments of this kind, all circumstances considered, are inferior to few in the delicacy required to make them succeed completely, I trust I shall be excused by those who choose to repeat them, particularly such as are not in the habit of making experiments of this kind; especially if it secure them from an unsuccessful attempt, and that, perhaps, without being able to account for it.

Oxford,
March 1st, 1795.

It is very well known, that vitriolic ether will produce sufficient cold by evaporation to freeze water; this circumstance is noticed by many, and several different methods have been proposed, particularly one by Mr. CAVALLO, with a very ingenious apparatus for the purpose (Phil. Trans. Vol. LXXI.); nevertheless, as I am upon the same subject, and the following experiments differ, as well in the effect produced as in the particular mode of conducting them, from any I have met with, I have ventured to mention them.

June 29th, 1792, temperature of the air 71°, I sunk a thermometer (the bulb being covered with fine lint tied over it, and clipped close round), by dipping it in ether, and fanning it, to 26°; then, by exposing the thermometer to the brisk thorough air of an open window, to 20°; and again, by using some of the same ether, but which had been purified by agitating it with eight times its weight of water, applied exactly as in the last experiment, the thermometer sunk to 12°. Water tried in the same manner, at the same temperature, sunk the thermometer to 56°.

A whirling motion was given the thermometer during each experiment.

The lint was renewed for each experiment, and the bulb required to be dipped into the ether thrice; the first time sufficiently to soak it, after which the thermometer was held at the window till it ceased to sink; then a second *quick* immersion, and likewise a third, exposing the thermometer in like manner after *each* immersion.

In this manner a little water in a small tube may be frozen presently, by good ether *not purified*, at any time, especially if a small wire be used to scratch or scrape the sides of the tube, below the surface of the water.

During the warmest weather of last summer I frequently froze water in this way.

EXPLANATION OF THE PLATE. (Tab. XXIII.)

Fig. 1. is a vessel in one piece, open at the bottom; *a, a*, the body, holding inverted two pints; *b*, the tube, holding five ounces; the lower or smaller part (formed by a contraction, or lessening of the tube in diameter, merely for the purpose of leaving a small shoulder for a temporary partition), holding rather *less* than one-fifth of the whole.

Fig. 2. is a vessel consisting of two parts; *a, a*, the body,

holding two pints; *b*, the tube, holding five ounces, which, together with the lid *c*, forms a cover to take off and on the vessel.

N. B. This vessel may, if preferred, be used instead of fig. 1. the parts corresponding with it, except in not being open at bottom, and the continuation of the tube upwards *just sufficient* to serve for a handle.

Fig. 3. is a vessel in one piece, open at the bottom, holding when inverted two pints; *b*, the tube, holding four ounces and a half.

Fig. 4. a vessel open at bottom, holding inverted one pint.

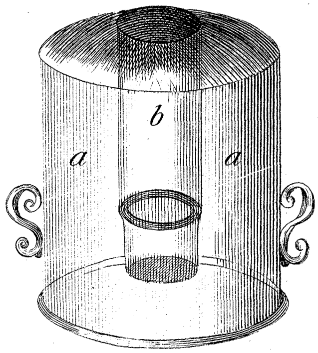
Fig. 5. a cover to fig. 4. *a, a*, the body, fitting exactly over, and *b* the cup-part (holding three ounces), fitting exactly within, the corresponding parts of fig. 4.

Fig. 6. the instrument for grinding the ice into powder; it works upon a short centre point, and has the edge bevilled contrary ways on each side the point, so as to follow. The fineness of the powder is regulated by the degree of pressure used. The handle is wood, the rest metal: *a*, is a sliding cover, fitting on the tube in which the ice is ground, to exclude the external air, and to keep the instrument steady; *b*, is the shoulder or guard, to prevent the point of the instrument from touching, so as to endanger injuring the bottom of the tube. It should be made so as to fit, without grating the inside of the tube in using.

The tubes of each of the vessels should be somewhat shorter than the vessel, so as not quite to reach the bottom of it.

Fig. 7. a thermometer glass, with the bulb three-fourths full of quicksilver.

Fig. 1



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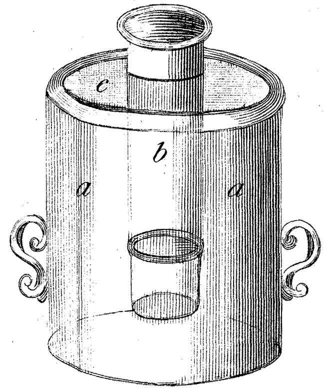

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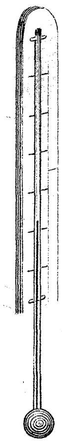

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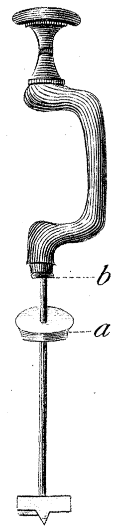

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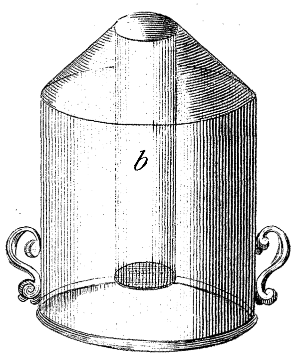

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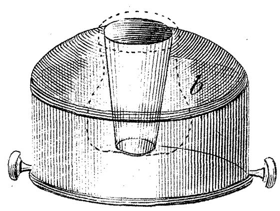

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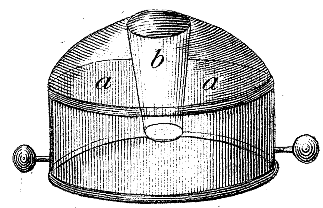

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Fig. 8. a thermometer, with the lower part of the scale-board turned up with a hinge, for the convenience of taking the temperature of small quantities, or of mixtures in which mineral acids form a part.

N. B. These vessels are represented as in glass, that being undoubtedly fittest for purposes in which corrosive acids are to be used.