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To cite this article: John Biddle Esq. (1808) XXVIII. On the contraction which takes place in mercury at low temperatures by abstraction of heat;—and on the ratio of contraction between mercury, alcohol, water, and silver , Philosophical Magazine Series 1, 30:118, 134-153, DOI: [10.1080/14786440808563787](https://doi.org/10.1080/14786440808563787)

To link to this article: <http://dx.doi.org/10.1080/14786440808563787>

Published online: 18 May 2009.

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while cold, or assisted by the steam when it becomes hot, it is instantly condensed into an impalpable powder, possessing all the qualities of calomel in its most perfect state. The calomel, when thus prepared, is purer, whiter, and more attenuated, than that obtained by grinding. It is proper to wash the product over with water, before it is dried, to rid it of any coarser particles which may form about the mouth of the crucible.

XXVIII. *On the Contraction which takes place in Mercury at low Temperatures by Abstraction of Heat ;—and on the Ratio of Contraction between Mercury, Alcohol, Water, and Silver.* By JOHN BIDDLE, Esq. of Birmingham.

Birmingham, February, 1808.

To Mr. Tilloch.

SIR,

A LETTER from M. Tardy de la Brossy, dated Joyeuse, (Ardeche) October 13th, 1805, addressed to Professor Pictet, of Geneva, has appeared in your Magazine [vol. xxiv. p. 322]. It contains observations on some experiments which I had the pleasure of showing to the Philosophical Society here on the specific gravity of mercury in its frozen state, which experiments were communicated to the public through the medium of Mr. Nicholson's Journal for April 1805. The observations of M. Tardy de la Brossy have induced me to look over the original papers, containing the results of those experiments, with some attention; and, with deference to the opinions of that gentleman (though I fear some inaccuracy exists), I must, in defence of my experiments generally, and the deductions made from them, request you to communicate a few experiments and observations through the channel of your Magazine.

M. Tardy de la Brossy, after avowing the object of his communication to be "the extension of truth, and the removal of error," proceeds to describe the result of some of my former experiments, and to make his observations on my calculations from them, to which I would refer; but if he

he had added experiment to his calculations, he would have been convinced that the principles on which I proceeded are just, and that one source of difference in our opinions arises from the *partial* application of the mode of reasoning which he uses. For, admitting with him the specific gravity of the alcohol employed to be $\cdot 810$ nearly, or $\cdot 8141$ where water is $1\cdot 000$, and that 1000 grains of mercury would exhibit a loss of weight in alcohol of the temperature stated, of $59\cdot 8$, when weighed by the hydrostatic balance, yet it does not appear to me necessary to suppose, *à priori*, so long as each of these substances remains in a fluid state, that the ratio of their densities should differ when uniformly subjected to the lower degrees of heat. As, however, my former experiments were not made with a view to discover the contraction of the volume of the alcohol, I made no observation relating to it, and now think it right to investigate the subject by experiment.

A. I first distilled mercury as before, with great care, using only that 30 per cent. of the whole which first came over in the distillation, esteeming it the most pure. I found, by the hydrostatic balance, the specific gravity of this to be $13\cdot 613$, as 1000 grains lost in distilled water $73\cdot 4$ at the temperature 50 of Fahrenheit's scale.

B. I took alcohol from the same parcel which I had used in my former experiments, and filling a light glass bottle formed with a long narrow neck for the purpose, it was found to weigh $\cdot 8141$, when water weighed $1\cdot 000$ at the temperature of 48° nearly.

C. Having obtained a mass of very pure silver, procured from luna cornea, 1000 gr. lost in distilled water $97\cdot 8$, the specific gravity of which was thereby found to be $10\cdot 225$; but by hammering it into a form convenient for my purpose the specific gravity increased to $10\cdot 362$, the loss of weight being $96\cdot 5$ at 50° of temperature. At the following temperatures the variations of loss of weight are expressed in the second column, the consequent specific gravities in the third, according to the usual mode of calculation, and in the fourth is shown the loss of weight in alcohol:—parts of a series of observations from experiments, that are given more

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at large in the table containing a general comparison of the several experiments.

1	2	3	4
Degrees of heat according to Fahrenheit's scale.	Loss of weight of 1000 gr. of silver in distilled water.	Specific gravity of silver when water is 1.000.	Loss of weight of 1000 gr. of silver weighed in alcohol.
200	94	10.638	
185	94.4	10.593	
175	94.6	10.570	
158	95.2	10.504	
150	95.3	10.493	
130	95.5	10.471	75.4
102	95.9	10.428	76.2
80	96.3	10.384	77.6
66	96.4	10.373	78.5
55	96.4	10.373	
50	96.5	10.362	78.6
34	96.5	10.362	79.4
21	—	—	80
9	—	—	80.5
0	—	—	81
20	—	—	81.6
32	—	—	82.5
54	—	—	83
56	—	—	83.1

D. By the following experiments I then proceeded to ascertain the specific gravity of mercury and silver at various temperatures, from 100° above zero to more than 40° below it, with a wish to obtain a ratio of contraction between mercury and silver, and between each of these and alcohol. For this purpose two hydrostatic balances were so placed that the metals suspended from them might fall into a glass vessel containing alcohol.

I then attached 1000 grains of silver to one balance, by a wire 12 inches long, weighing only $\frac{7}{10}$ of a grain; and to the other 1000 grains of mercury, in a small glass bucket weighing 101 $\frac{2}{10}$ grains, suspended by a wire nearly 4 inches long, weighing $\frac{2}{10}$ grain.

Then also suspending in the alcohol a good thermometer, marked

marked for low temperatures, and having provided a quantity of muriate of lime and snow, I reduced the temperature of the alcohol and metals, as in my former experiments the subject of M. Tardy de la Brossy's observations, and obtained the results expressed in the following table.

1	2	3	4	5	6	7
Specific gravity of silver if the alcohol does not increase in density.	Loss of weight of 1000 gr. of silver weighed in alcohol by the hydrostatic balance.	Temperatures according to Fahrenheit's scale.	Loss of weight of 1000 gr. of mercury and the glass bucket.	Loss of weight of the glass bucket alone weighing 101.9 gr.	Loss of weight of mercury alone.	Specific gravity of mercury if alcohol does not increase in density.
10.680	76.2	100	82.6	24.3	58.3	13.963
10.518	77.4	60	85.0	25.3	59.7	13.636
10.362	78.56	50	85.3	25.5	59.8	13.613
10.359	78.3	44	85.5	25.6	59.9	13.589
10.208	79.7	20	86.6	26	60.6	13.433
10.290	79.9	6 or 7	86.7	26.1	60.6	13.433
10.037	81.1	0	86.9	26.2	60.7	13.411

In an examination of the 1st and 2d columns of this table relating to silver, it being previously known that 10.362 is the specific gravity of silver, and that .8141 is the specific gravity of alcohol at 50° of Fahrenheit, where water is 1.000, it appears, following the general mode of calculation in which the loss of weight is made the divisor of the quantity weighed, and the quotient expresses the specific gravity, that as at 100 degrees of heat the divisor for the quantity of metal is less, and at zero greater, that at zero the specific gravity is less, and at 100 degrees above it the specific gravity is greater:—A conclusion opposing a general law, which therefore we cannot admit.

To account for this apparent inaccuracy of result, we must direct our attention to the alcohol employed, and see if, in the comparison of the *fluid* alcohol and the *solid* silver, this appearance of contradiction to an established law does not arise from the contraction of the fluid. Of this it will be difficult to bring visible proof to the extent required; for if I put into a glass tube alcohol, of which the weight is known,

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known, and expose it to different temperatures from 100 to 50 degrees, it will contract; but whilst the fluid contracts, the glass which contains it contracts also, and shows only the difference of the contraction between the fluid and glass:—however, as we know that silver by heating cannot become specifically heavier, or by cooling specifically lighter, in these experiments which are evidently a comparison of densities, the alcohol must become more dense by deprivation of heat.

The third column of this table contains the temperatures.

In the 4th column the 1000 gr. of mercury and the glass bucket containing it appear together to have varied at the two extremes in loss of weight 4.3.

By the 5th column it is shown that the glass bucket alone varied at the two extremes in loss of weight 1.9.

By the 6th column it appears that 2.4 only can be stated to belong indispensably to a variation of the respective densities of the mercury and alcohol in the changes of temperature from 100° to zero. The other variations, I presume, arise from some inaccuracy, such as making the observations when the fluids were at different temperatures.

By the 7th column are shown the different specific gravities of the mercury, by calculation from the loss of weight, supposing the density of the alcohol the same throughout: from this it appears that the density of mercury is greatest at the highest temperature, and least at the lowest; but as this cannot be actually the case, it is obvious that the alcohol increases in density; and this appears also from the results of the 2d column relating to silver, at C.

For the specific gravities of alcohol at various temperatures, I must refer to the calculations at I., made from the following experiments, and which are contained also in a general table of results.

E. I procured the bladder of a rabbit, and washed it well with alcohol. It weighed 7 grains in air; and having annealed a wire about 9 inches long, the weight of which was $\frac{6}{10}$ ths of a grain in air, I found that the bladder and wire, when sunk in alcohol to a certain mark on the wire, weighed 2.5 grains only, at the temperature 45°.

This

This bladder was filled with mercury, not quite pure, then suspended by the wire; and when one end of the wire was attached to the balance, it was found to contain 5276 grains; weighed in alcohol, it lost 321.5, from which deducting the weight of the bladder and wire in alcohol, 2.5, it appears that the loss of the 5276 grains of mercury, when the thermometer is suspended in the alcohol

at 45° of temperature, is 319

65 the mercury loses 315 less by 4

93 — — 312 — 7

100 — — 311 — 8

112 — — 309 — 10

118 — — 308 — 11

125 — — 307 — 12

130 — — 306.5 — 12.5

135 — — 306 — 13 { The alcohol now in agitation by the heat could make no higher observation.

130 — — 306.5 — 12.5

125 — — 307 — 12

123 — — 307.5 — 11.5

120 — — 308 — 11

118 — — 308.5 — 10.5

117 — — 309 — 10

113 — — 309.5 — 9.5

111 — — 310 — 9

108 — — 310.5 — 8.5

104 — — 314 — 8

100 — — 311.5 — 7.5

97 — — 312 — 7

93 — — 312.5 — 6.5

89 — — 313 — 6

85 — — 313.5 — 5.5

83 — — 314 — 5

80 — — 315 — 4

78 — — 316 — 3

76 — — 317 — 2

70 — — 317.5 — 1.5

68 — — 318 — 1

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at 65 the mercury loses 318·5 less by 0·5

62	—	—	319	—	0
50	—	—	320	more by	1
45	—	—	320·5	—	1·5
40	—	—	321	—	2
36	—	—	321·5	—	2·5
34	—	—	322	—	3
27	—	—	323·5	—	4·5
14	—	—	324	—	5
5	—	—	324·5	—	5·5
0	—	—	325·5	—	6·5
5 below zero			326·5	—	7·5
18	—	—	327·5	—	8·5
21	—	—	328	—	9

We may observe in this experiment that some difference is occasioned by the direction in which the heat passes, whether from without to the alcohol, and thence to the mercury, as in the first part of these observations from 45° to 135°; or from within from the mercury to the alcohol, as from 135° to zero and 21° below: and it appears that the temperature was not the same in these two fluids when the observations were made; for when I weighed the same mercury with a hole in the bladder to introduce the bulb of a thermometer, that I might observe the variation of loss of weight when the alcohol and mercury were at the same temperature exactly, it showed the mean of these variations to be correct. So that in comparing 5276 parts of mercury with alcohol, there is a variation in the contraction of these two fluids expressed by 22 of loss of weight in passing through 156 degrees of temperature. In comparing 1000 parts of mercury with alcohol, it follows that there is a variation of loss of weight in 156 degrees of temperature expressed by 4·17, which shows ·0267 is the loss of alcohol in each degree greater than that of mercury.

If these two fluids were to contract by deprivation of heat in the ratio of their specific gravities, it is obvious that the loss of weight shown by the hydrostatic balance would be the same through all the changes of temperature, the changes being the same in both fluids at the time of observation.

It

It is therefore of material consequence to this inquiry to know in what degree equal bulks of mercury and alcohol increase together, without the hydrostatic balance denoting the alteration by any change of loss of weight; for this purpose we must look to D, and forward to the experiment G, and the calculations from them at L and I, where we shall find a rule for discovering the specific gravity of alcohol.

F. To find the proportion of contraction between mercury and water, I took 3024 grains of mercury in a bladder, as before; and weighing it in distilled water by the hydrostatic balance, the mercury and water heated to the temperature

200	the mercury lost	217·4	These 3 observations were unsatisfactory, the water having risen in vapour and condensed on the balance.
195	—	217·6	
190	—	217·8	
185	—	218	
180	—	218·2	
175	—	218·4	
170	—	218·6	
165	—	218·8	
160	—	219·1	
155	—	219·4	
150	—	219·7	
145	—	220	
135	—	220·3	
130	—	220·4	
125	—	220·5	
120	—	220·6	
110	—	220·8	
98	—	221·1	
88	—	221·3	
78	—	221·5	
68	—	221·7	
58	—	221·9	
50	—	222·1	

Thus, at 200° of temperature mercury would appear of greater specific gravity than when at 50°, following the general mode of calculation; but if we suppose the water is more

3 contracted

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contracted than mercury by abstraction of heat, and attribute to that the difference of loss of weight, then, in comparing 3024 of mercury with water, there is a variation in the contraction of these two fluids expressed by 4.7 loss of weight in passing through 150 degrees of temperature. In comparing 1000 of mercury with water, a variation of loss in 150° is expressed by 1.5542.

G. The following experiment was made before many of my philosophical friends with mercury, described before, of the specific gravity of 13.613, suspended by a very fine wire 10 inches long, weighing only $\frac{1}{100}$ of a grain;—the barometer standing at 29.8, the thermometer at 35.

1000 grains of mercury with 750 grains of alcohol, as before described, were put into a thin glass vessel, made for the purpose, round at the bottom, and increasing in diameter gradually to near the top, so that the mercury might be easily suspended in the alcohol by a wire introduced into it whilst fluid. These were placed in the centre of a mixture of 4 pounds of snow and 4 pounds of muriate of lime, at 12 o'clock at noon: at 5 minutes past a thermometer placed in the frigorific mixture fell to 52° below zero, then to 54 and to 60. The mercury in the tube of the thermometer appeared frozen: it was withdrawn, and when exposed to the air a few seconds, suddenly fell to 140° on the scale, in consequence of the mercury in the tube again becoming fluid, and occupying the vacuum which had been occasioned by the contraction of the mercury in the bulb after that which was in the tube had become solid: it was then immediately returned to its place in the mixture of snow and muriate of lime; it had remained at 140° for several minutes when taken out and exposed to the air, so that the mercury still in the tube was again made fluid; it instantaneously sunk into the bulb much below 270°, the lowest point on the scale. During this time the mercury and alcohol, very much reduced in temperature, were removed from the above mixture, and placed in a second mixture of 3 pounds of snow and 3 pounds of muriate of lime: the whole was then placed in the first mixture; and at the moment of the crystallization of the mercury, the wire, already partly attached, was by raising

raising it gently, drawn from the side to the centre of the surface of the mercury. When it was fixed and the whole was solid, it became necessary to withdraw the glass, and expose it a moment to the air of the room, until that part of the mercury attached to the glass was softened; then, by keeping one hand drawing gently at the wire, the whole of the mercury was suspended, and, with the alcohol, immediately returned to its place in the cooling mixture; the mercury was now suspended from the hydrostatic balance by the wire fixed in it, and weighed with great accuracy;—and the following observations were made from the time the second quantities of muriate of lime and snow were mixed.

In 5 minutes the mercury was crystallizing.

10	—	became nearly solid.
30	—	quite solid—withdrawn.
40	—	having been replaced.
50	—	suspended in the alcohol, and weighed by the hydrostatic balance with great care, lost — 60·8

60 minutes the mercury and alcohol having been a little withdrawn, the mercury lost 60

85 minutes the mercury lost 59·9 it was now so nearly fluid, there was splendour on the surface.

130 minutes the mercury lost 60·8

145 ——— 60·3

150 ——— 60·1

160 ——— 60·3

170 ——— 60·1 { having been withdrawn, and the temperature increased.

175 ——— 60·7

180 ——— 61

As I could not decrease the heat so as to indicate a greater loss than 61, and my own body during these three hours having suffered an unusual and partial deprivation of heat, I withdrew the mercury and alcohol, not doubting, if it could have answered any purpose, by these means to have been able to have kept the mercury solid some hours longer, the surrounding substances having lost so much heat.

We see from the observations made in this experiment, that

59·9

59·9 is the least diminution in the weight of mercury when weighed in a solid state in alcohol, and that it is at this moment when their specific gravities are furthest from each other; for we may observe that at almost the next degree of temperature to that in which the mercury loses its fluidity, whilst the alcohol preserves its fluid form, the mercury appears to become of less specific gravity, as it loses 60; which gives, according to calculation at L, only 14; but the fact appears to me to be, that alcohol proceeds in the ratio of a fluid by decrease of temperature, and that mercury, having obtained a solid form, follows the ratio of contraction of a solid; therefore their densities approach each other. I should have ascribed this greater loss of weight to the particles of the mercury at the moment of crystallization occupying, in consequence of their new arrangement, more space than at the moment before it became solid, as with some of the metals is known to be the case, had I not carefully observed the passage of this metal in other experiments, where I had an opportunity of seeing the contraction proceed very distinctly; and had not the mercury, also proceeding to still lower temperatures, lost from 60, 60·1, 60·3, 60·7, 60·8, and 61, long after the whole had become solid, and was suspended by the wire: thus, 61 is the greatest diminution of weight by the abstraction of heat which I could obtain, and I am of opinion that the space described by these changes of loss of weight denotes a range of many degrees of temperature: how much greater the density may then be than that stated at L, I cannot presume to say; but as it takes, with some probability, a proportion of contraction approaching to that of silver, it certainly appears improbable that it should reach the specific gravity which my former calculation from a single observation led me to attribute to it. I am therefore inclined to believe there was some inaccuracy in weighing the silver by the hydrostatic balance, when by my former experiments I gave 88·1, the quantity of loss of 1000 grs of silver:—from many observations in this laborious train of inquiry, it seems hardly possible that the former could have been correct; for if the alcohol and silver continued to contract in the same proportion from 56° below zero, as they do from 64° above zero to that temperature, it would appear that an abstraction of heat must necessarily have taken

taken place equal to 120° more, or to 176° below zero, which I can hardly suppose, though the mercurial thermometer used in these experiments fell lower than 270° below zero. If my former statement be erroneous, it certainly is not attributable to the mode of calculation, as apprehended by M. Tardy de la Brossy. As it does not appear that he had made any experiment on the subject, he could not have anticipated this inaccuracy in the weight of silver: and as he says that only a few grains of the increased gravity of the mercury was attributable to the alcohol, he could not be aware of the great increase of the specific gravity of alcohol shown at I, by the same mode of calculation used in my essay, the subject of his animadversions.

It is still, however, obvious, that mercury would not be of the specific gravity which I attributed to it, unless it had followed the same rate of contraction after it became solid as it did whilst fluid: the evidence of the increased loss of weight is so much against me, that I cannot defend that experiment; and I would now be understood to carry my observations on the specific gravity of mercury, with accuracy, to the point of congelation only; or to state that near 56° below zero its specific gravity is $14\cdot465$, as by calculation at L. Then, if we attribute to mercury in a solid state nearly double the contraction of silver as at H, or $\cdot00100$ in each degree, as it is near to its point of fluidity, we shall arrive only at the specific gravity $14\cdot485$, as is shown at M.

To ascertain whether the silver at C, with which I proposed to compare the mercury, had expanded or contracted by the deprivation of heat to which it had been exposed,

H—I took an ingot of silver, 16 inches long, 2 inches wide, and half an inch thick, weighing nearly 100 ounces; and provided an instrument for the purpose of measuring accurately the contraction and expansion of the silver, by fixing in a piece of well baked wood two centre pins, exactly 15 inches from each other, one of them very fine, for the purpose of striking an arch of a circle on the surface of the silver, when the other was fixed in a perforation made in the silver by the centre itself. Then, on the surface of the bar of silver, heated to a pale red, an arch was described with

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this instrument; and when again reduced to the temperature of 50 degrees, another arch was drawn :—the contraction of the bar of silver between the two points appeared to equal $\frac{1}{85}$ th part of its dimensions.

The silver was then heated to 200° of temperature of Fahrenheit's scale, by boiling it in water, and gradually cooling; an arch of a circle was then struck on the surface of the silver: reducing it to 150° of temperature, another arch was struck with the same unvaried centre pins, which showed evident contraction in the bar of silver: again, at 100° of temperature another arch was described; and a fourth, at 50°, showed that the silver had contracted in the deprivation of 150° of temperature $\frac{1}{340}$ th part of its length.

Then, similar parallelopipedons being to each other as the cubes of their homologous sides, the increased specific gravity is shown by multiplying the specific gravity at 50°, namely, 10·362, by the cube of 341; and dividing it by the cube of 340, which equals 10·4537; ·0917, therefore, is the difference in 150° of heat; or ·0006114 is the contraction of silver in each degree; which, from the way this experiment is performed, I call its *visible contraction*. From it the specific gravities at the several temperatures below are calculated :—

At 200° silver is of the specific gravity 10·2702

150	—	—	10·3908
135	—	—	10·3100
117	—	—	10·3210
100	—	—	10·3314
50	—	—	10·3620
0	—	—	10·3925
50 below zero		—	10·4231
52	—	—	10·4243
56	—	—	10·4268

I. Then, if 10·4268 be the specific gravity of silver at 56° below zero, and weighed in alcohol at that temperature, by calculation from its loss of weight at C, it will appear to be 9·796, by taking ·8141 as the supposed density of alcohol, dividing the quantity 1000 by the loss 83·1, multiplying the quotient 12·033 by ·8141, and dividing by 1·000, the

the specific gravity of water, the result of this being 9·796; What then is the *specific gravity of the alcohol*—if not 8141?

It is found by this rule :—

Divide 1000, the quantity weighed, by the loss of weight, and by the quotient divide the density of silver, according to its visible contraction; the quotient will be the specific gravity of the alcohol, or fluid in which it is weighed.

Thus, at the temperature 56° below zero, the loss of weight is 83·1; by which, if 1000 (the quantity weighed) be divided, the quotient is 12·033, by which 10·4268 (the density of silver according to its visible contraction) is divided; and the quotient is ·8665, the specific gravity of the alcohol at 56° below zero. Thus, ·0524 is the sum of variation of the specific gravity of alcohol in 106°, or 00049434 is the variation in each degree of temperature: from it the specific gravities at these several temperatures are calculated.

At 135° the specific gravity of alcohol is ·77208

117	————	————	·78098
100	————	————	·78938
50	————	————	·81410
zero	————	————	·83882
50 below zero		————	·86353
52	————	————	·86482
56	————	————	·86650

K. Then taking the specific gravity of the alcohol at any certain temperature, and the loss expressed at C; What will be the *specific gravity of the silver* according to C?

It is found by this rule :—

Divide 1000 (the quantity weighed) by the loss of weight, and multiply the quotient by the specific gravity of the alcohol or fluid in which it is weighed.

Thus, at 56° below zero the loss of weight is 83·1, according to C; by which if 1000 be divided, the quotient is 12·0337; which, multiplied by ·8665, the density of alcohol, as at I, in that temperature the product is 10·427, the specific gravity of silver at 56° below zero.

Then, having ascertained the specific gravity of silver and

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of alcohol at several points of the scale of temperature by calculations at I, from experiments at H, the calculation of the specific gravity of mercury is thus performed :—

L.—Divide the quantity by the loss, and multiply the quotient by the specific gravity of the alcohol at such temperature.

Thus, mercury at G, in the temperature of 56° below zero, appears to be of the specific gravity 14·465. For dividing 1000 by 59·9, the least loss in the solid state, and multiplying the quotient 16·694 by ·8665, the specific gravity of alcohol at that temperature, the product is 14·465.

Then if mercury in 106°, from 50° above to 65° below zero, increases in specific gravity from 13·613 to 14·465, namely ·852, which gives ·00804 each degree; this sum, multiplied into the number of degrees from 50° above zero, gives the specific gravity of mercury at that degree, if deducted when above 50 from 13·613, or added to the same when below 50°.

Thus at 135° above zero, which from 50° is 85°, if the sum ·00804 be multiplied by 85, the product is ·6834; which subtracted from 13·613, the specific gravity of mercury at 50°, gives 12·9296, the specific gravity of mercury at 135° of temperature.

At 200° the specific gravity of mercury is 12·407

150	—	—	12·809
135	—	—	12·929
117	—	—	13·074
100	—	—	13·211
50	—	—	13·613
0	—	—	14·015
50 below zero	—	—	14·417
52	—	—	14·433
56	—	—	14·465

Then, to see if the alcohol in which the mercury was weighed at G obtains by the same mode of calculation a specific gravity, according with the calculations at I, from the experiments at H on silver,—observe the rule at I.

At the temperature 56° below zero, the loss of weight is 59·9 on the quantity 1000; by which if it be divided, 16·694 is

is the quotient; this again dividing the specific gravity of the mercury 14·465, the quotient is at this temperature ·8665, the specific gravity of the alcohol according to G, which agrees with the calculations from the loss of weight of silver by experiments at H, and calculations at I, it there appearing that ·8665 is the specific gravity of the alcohol.

M. Supposing the mercury weighed by the hydrostatic balance at G in a solid form, during the variations in the loss of weight from 59·9 to 61, to have passed through 20° of temperature to 76° below zero, and to have increased ·001 each degree, then mercury in a solid state will have arrived at the specific gravity 14·485, and the alcohol in which it is weighed with a loss of weight of 61 will consequently be of greater specific gravity.

For if alcohol at 56° below zero was of the specific gravity ·8665, as at I, the mercury losing 59·9, as at G, and at a lower temperature the same mercury weighed in the same alcohol lost 61, it will appear that the alcohol must have increased in specific gravity; for if 59·9 be ·8665, 61 will be ·8842, the mercury remaining at 14·465, as at L: but as we have reason to state, it passes on to 14·485 at 76° below zero, then the specific gravity of the alcohol must appear to be ·8854; because if 14·485 increases ·001 each degree, ·8842 will increase ·000061; which sum, multiplied by 20, equals ·001220; this, added to ·8842, equals ·8854.

N. We observe at F, 3024 of mercury lose 222·1 at 50° of temperature; at 200° of temperature it loses 217·4; and by calculations at L, the specific gravity of the mercury so weighed was shown to be 12·407 at that degree of heat.

Then by the rule at I:—

If 3024 be divided by 217·4, the quotient is 13·909, which sum dividing 12·407, the known gravity of mercury at L, the specific gravity of the water will consequently appear to be ·8920: this deducted from 1000, the specific gravity of water at 50° of temperature, leaves ·1080, the sum of difference in 150 degrees, and

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At the following temperatures water is of the specific gravity stated:

200°	—	·8920
150	—	·9306
135	—	·9419
117	—	·9537
100	—	·9661
50	—	1·0000

and as ·1080 is the sum of difference in 150°, this sum ·00072 expresses nearly the variation in each degree.

We find from the data obtained in these experiments a *ratio of contraction* between mercury, alcohol, water, and silver of equal volume.

Mercury at L is	·00804
Alcohol at I is	·0004943
Water from F above	·0007200
Silver at H is	·0006114

What will be the proportionate contraction of each, that of mercury being supposed 100?

As the increased specific gravity of mercury is to the supposed number, so is the increased specific gravity of either to the number required.

If 00804 be 100, what will

{	0004943 = 6·144	Contraction of alcohol
	0037200 = 8·955	— water
	0006114 = 7·604	— silver

of equal volume, when that of mercury is 100.

If we suppose water to be 1·0000
then mercury will be 11·1666
alcohol ·6865
silver ·8491

As in the hydrostatic balance the comparison relates to *equal volumes* of the thing weighed, and the fluid in which it is weighed; What will be the ratio of contraction of *equal weights* of each of the above?

As the specific gravity of either is to the specific gravity of mercury, so is the ratio of contraction of equal volumes to the ratio of contraction of equal weights.

As ·8141 : 13613 :: 0004943 = 008265 alcohol.

As 1·000 : 13613 :: 0007200 = 009801 water.

As 10·362 : 13613 :: 0006114 = 000803 silver.

008040 mercury.

Table

at low Temperatures.

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Table of Results of the foregoing Experiments, with some Calculations from them.

Specific gravity of alcohol calculated from loss at C, and the visible contraction of silver at H as at I.	Specific gravity of silver calculated from loss at C, and its visible contraction at H as at K.	Specific gravity of silver calculated from its visible contraction at H.	Loss of weight of 1000 of silver weighed in alcohol at C.	Temperature of Fahrenheit's scale.	Loss of weight of 1000 of mercury weighed in alcohol at E and G.	Specific gravity of mercury calculated from the various densities of alcohol at E and G as at L.	Loss of weight in 1000 of mercury weighed in water at A and F.	Specific gravity of water calculated from loss at F, and the specific gravity of mercury at G.
7720	10·240	10·270		200		12·407	71·88	·8920
				175			72·26	
		10·300		150		12·809	72·65	·9306
		10·310		135				
7810	10·276	10·321	75·4	130	58	12·929	72·76	·9419
			76	117	58·47	13·074		
			—4	108				
			—7	100	58·3	13·214	73·10	·9661
7893	10·276	10·331	77	95				
			—6	82				
			—9	70	59·5			
			78	68				
8141	10·357	10·362	—1	64				
			—6	50	59·8	13·613	73·459	1·0000
			79	45	59·9			
			—2	40				
8388	10·355	10·392	—6	32	60·5			
			80	21	60·6			
			—5	9				
			81	zero	60·7	14·015		
			—4	10				
			—7	21				
			82	28				
			—3	31				
8635	10·427	10·423	—5	32				
			—5	37				
			—6	45				
			—7	48				
8645	10·428	10·424	—8	50		14·417		
8665	10·427	10·427	—9	52		14·433		
			83	54	59·9			
			83·1	56		14·465		
					60			
8854					60·1			
					60·3			
					60·7			
					60·8			
				76	61	14·485		

This temperature supposed at M

K 4

T₀

To recapitulate the foregoing Experiments—

Observe,

At A, mercury is of the specific gravity 13·613 at the temperature 50.

At B, alcohol is of the specific gravity ·8141 at the temperature 50.

At C, silver is of the specific gravity 10·362 at the temperature 50.

At C and D there is error shown to exist in estimating the specific gravity of bodies in the usual mode, without having regard to a fixed point of temperature, at which the medium chosen to compare other bodies with should be estimated at 1·000; and without having regard to the ratio of contraction in the body weighed, and the medium in which it is weighed.

At E, a variation of contraction between mercury and alcohol expressed by 22 in weighing 5276 of mercury.

At F, the error of common practice noted at D is confirmed, the increased loss of weight showing the contraction of water to be greater than that of mercury of equal volume; it is expressed by 4·7 in 150° on the quantity 3024.

At G, mercury in its frozen state weighed by the hydrostatic balance lost 59·9 to 61 on the quantity of 100. For the calculations from these facts, see L and the annexed table. The mercurial thermometer fell below 270° on the scale below zero.

At H, silver, going down 150 degrees of Fahrenheit's scale, contracts $\frac{3}{4}$ th part of its dimensions, which is called its *visible contraction*.

The silver at 117 above zero is 10·321

—	50	—	10·362
—	56 below zero		10·426

The increase of silver in its specific gravity is ·0006114 each degree.

At I, the error of general practice observed at D and F is confirmed. A rule is given for finding the specific gravity of the alcohol. When ·8141 at 50 above zero it appears to be ·8665 at 56 below zero.

At

At I, the increased specific gravity of alcohol each degree is $\cdot 0004934$.

For the further variations of gravity see the annexed table.

At K, a rule for finding the specific gravity of silver from loss of weight at C, and the specific gravity of alcohol at I.

If silver at 50 above zero be $10\cdot 362$, it will be

at 56 below zero $10\cdot 427$.

At L, a rule is shown for finding the specific gravity of mercury.—At 200 above zero it is found to be $12\cdot 407$

50 ————— $13\cdot 613$

56 below ————— $14\cdot 465$

The increase each degree is $\cdot 00804$

A comparison of C and G as it relates to alcohol; and by the rule at I it appears they accord in the number $\cdot 8665$, the specific gravity at 56 below zero.

At M, the contraction of mercury in its solid state, supposed to be near twice that of silver, or $\cdot 001$ each degree, because near the point of fluidity.

Alcohol of the specific gravity $\cdot 8854$ at 76 below zero.

Mercury in a solid form of the specific gravity $14\cdot 485$ at 76 below zero.

The mode of calculating this is shown.

The increase of specific gravity of alcohol in each degree not shown by the hydrostatic balance, when mercury is weighed in it in a solid form, is $\cdot 000061$.

At N, rule for finding the increase of water of equal bulk to that of mercury. It appears from F to be $\cdot 00072$ each degree.

Rule for finding the *ratio of contraction* of mercury, alcohol, water, and silver, *of equal volume*; mercury being supposed 100.

A ratio of contraction also of water, mercury, alcohol, and silver; water being supposed 1 $\cdot$ 000.

Rule also given to find the ratio of contraction of alcohol, water, silver, and mercury, *of equal weight*.