V. *On the measurement of high temperatures.* *By* James Prinsep, *Esq. Assay Master of the Mint at Benares. Communicated by* Peter Mark Roget, *M.D. Secretary of the Royal Society.*

Read December 13, 1827.

If all the experiments had been recorded, which at different times must undoubtedly have been made on the subject of Pyrometry, by those engaged in operations requiring the accurate management of fire, the catalogue would consist principally of abortive attempts, if not of decided failures. The efforts to obtain exact measurements of high temperatures have probably been abandoned, partly from the occurrence of unforeseen difficulties, partly from the uncertainty of the results obtained: such, at least, appears to be the only way of accounting for the blank presented in this interesting and practically important branch of chemical knowledge.

In the admeasurement of the lower portions of the scale of temperature, and the determination of the proper methods of graduation, and the laws of expansion, gaseous tension, &c. a great degree of accuracy has been introduced. To the extent of the boiling point of mercury, indeed, we have tolerably exact values of the dilatation of metals and fluids; and by Messrs. Dulong and Petit's experiments, the table has been extended to the irregularities of the thermometric indications of several substances, compared with the supposed uniform expansion of air, or of any other gas in a dry state.

But with respect to the measure of heat produced by furnaces, until Mr. Daniell recently took up the subject, we only find upon record the invention of Mr. Wedgwood's pyrometer; an instrument the indications of which are assumed in every chemical work as authority for some doctrines relative to the scale of temperature, which savour of the marvellous; and for others, which a slight practical acquaintance with metals and crucibles must at all times have proved to be fallacious. As an example of the latter, I will only adduce the instance of the fusing point of copper, which, in Mr. Wedgwood's table, is placed, on the authority of Mr. ALCHORNE, considerably below that of silver; whereas if a crucible containing the two metals in a state of purity be carefully heated, the silver may be seen to flow round the copper some little time before the latter yields to the fire.

When I assert that so little progress has been made in pyrometry, however, I must be understood to refer only to the absolute measurement of high temperatures; for which purpose Mr. WEDGWOOD himself never considered his instrument qualified, although it was well adapted to the practical purpose of ascertaining deviations from a regulated heat required in any process of the arts. In this branch of the subject we may no doubt find numerous contrivances on record, which the ingenuity of different artists has at different times suggested. Most igneous operations, however, such as enamelling, assaying, foundry, &c. furnish tests of themselves on which the workman can generally place all the confidence he requires.

It is needless to describe the devices invented to indicate the mere comparative heat of fires: the principle of most of them consists in making a bar of some metal traverse the middle of the furnace, and act, by its elongation or otherwise, upon a convenient piece of mechanism outside. I have myself long made use of such a bar, carrying at one extremity an index on the compensation principle, made of silver and gold: and I only advert to it here that I may take the opportunity of noticing a curious circumstance brought to light by its constant use during five years.

The heat communicated to this compound index can never have much exceeded the melting point of lead, or about 700° FAHR., and yet the surface of the gold has gradually become perfectly discoloured, and apparently penetrated by the silver, in the same manner as would have been produced by mercury at a common temperature. This effect commenced on the edges of the slip of metal, and has now advanced nearly over the whole surface of the gold, giving it the appearance, under the microscope, of being studded over with hard tubercles of a leaden colour. The golden yellow, where it is not yet thoroughly changed, has become green like that of an alloy of gold and silver. The impregnation has extended to a considerable depth in the gold, and consequently the index has become less and less sensible to changes of temperature. But I should remark, that at the fixed end of the plate, where a piece of platina foil had been joined, to strengthen and support the index, no discoloration has taken effect, the platina covering seeming to shelter the gold from the argentine vapours. I should also remark, that the two metals were originally quite pure, and were united without any alloy, by simply laying an ingot of silver over one of gold, and heating the two until the former just began to melt; the compound ingot was then laminated.

Mr. Faraday has shown that mercury emits vapour capable of amalgamating with gold at very low temperatures. The circumstance just described tends to prove that silver does the same while yet in a solid state, and below the lowest red heat visible in the dark. I unfortunately omitted to keep any note of the original weight of the bar, and am therefore unable to say whether any sensible diminution has taken place.

To return from this digression.—In the Journal of the Royal Institution, vol. xi. Mr. Daniell has described an ingenious instrument, with which he measured the fusing points of many metals, and which has served to remove many of the anomalies of our so long undisputed catalogues. It may, however, be urged against his pyrometer, that platina has a smaller dilatation than every other metal, which is again diminished by the expansibility of the inclosing case of black-lead; and, moreover, that plumbago is acknowledged to be a very bad conductor of heat, and is liable to lose its shape. There does not appear by Mr. Daniell's account, to have been a desirable accordance in the result of different trials, excepting in the two experiments upon the fusing point of silver.

In the present day such a laudable jealousy of invention exists among scientific men, that it would be dangerous, even in this remote part of the world, to pass over any thing connected with my subject, lest I should be suspected of plagiarism in what I may hereafter offer as my own. I should therefore notice that Dr. Ure has recommended an air thermometer made of platina; but I cannot learn whether his plan has ever been carried into effect*. Sir James Hall has also announced that he has found a means of measuring furnace heat; and the world will no doubt receive it with the confidence due to the ingenuity of the illustrious inventor.

* I find since, that the instruments have been made for sale; but I have seen no statements of experiments made with them.

The mind often speculates upon such subjects without bringing its crude ideas into practical form. I have at one time thought that the light, and consequently heat, of a fire might be admirably measured by the eye, with the intervention of a series of thin plates of coloured glass or talc; the number necessary to obscure the light being the indication of the heat.

It would be difficult, without actual trial, to estimate the objections to a photometer of this kind, from which doubtless some useful observations might arise: the intense heat of the oxy-hydrogen blowpipe, the fusion of platina, and other refractory metals, might thus be roughly estimated. The dark brown mica is well adapted for the construction of such an instrument, which might be made of one or two hundred thin laminæ pasted on card frames. The eye should be protected from extraneous light by means of a dark tube during observation.

After trying various plans, I have at last fixed upon one which appears to have superior claims to accuracy; and possesses the great advantage of being identifiable at any time and in any part of the world.

The fusing points of pure metals are determinate and unchangeable; they also comprehend nearly the whole scale of temperature: the unoxidable, or noble metals, alone embrace a range from the low melting point of silver to the high ignition of platina. There are, it is true, only three fixed points in this scale; but as many intermediate links may be made as are required, by alloying the three metals together in different proportions. When such a series has been once prepared, the heat of any furnace may be expressed by the alloy of least fusibility which it is capable of melting. Besides the unity of determinations which such a pyrometer would give, several other advantages might be enumerated:—the smallness of the apparatus; nothing more being necessary than a little cupel, containing in separate cells eight or ten pyrometric alloys, each of the size of a pin's head:—the indestructibility of the specimens; since those melted in one experiment would need only to be flattened under the hammer to be again ready for action:—and the facility of notation; since three letters with the decimal of the alloy would express the maximum heat: thus, pyrom. S .3 G might be used for an alloy of 0.7 silver with 0.3 gold, and G .23 P would express gold containing 23 per cent of platina.

Having thus explained the principles of my proposed pyrometer, I proceed to describe the circumstances worthy of notice which occurred in the preparation of the alloys.

As gold melts at a heat not very much above silver, I assumed only ten degrees between them, measuring each by a successive addition in the alloy of 10 per cent of gold to the pure silver; the tenth degree being, of course, measured by pure gold. These alloys are easily made, and require no comment: in accurate researches they may be further subdivided, using always the decimal notation.

From the fusion of pure gold to that of pure platina, I assumed 100 degrees, adding one per cent of the latter metal to the alloy which measured each successive degree. Now, it is hardly to be supposed that the progress of these hypothetical degrees represent equable increments of heat; they will however, as I before observed, always indicate the same intensity; and their absolute value, as a matter rather of speculative than of practical interest, is to be sought by other expedients, such as the expansion of a platina bar, &c. in co-operation with the pyrometric cupel. I shall hereafter have to show how this has been practised in measuring the melting point of silver.

It was as long ago as the year 1821 when I made up the first twenty alloys of platina and gold; the metals were in a state of purity, and the proportions were adjusted to less than the thousandth part of the unit of each specimen, which weighed precisely 15 grains troy. The metals were fused in a powerful forge, supported on a small bone-ash cupel, and inclosed in an earthern crucible. The access of air was prevented as far as possible, and in some cases the metal was wrapped in paper to prevent the separation of small particles. I am thus particular in describing minutely the process of fusion, because some unexpected circumstances presented themselves in the fused buttons, which I believe have not hitherto been observed. Upon examining the specimens on their return from the fire, some were found to have gained considerably in weight; these were always more or less brittle under the hammer: others returned of the same weight as at first; and some few had even lost slightly in weight, and these, especially the latter, proved perfectly malleable. They were also of a brighter colour, and more deeply crystallized on the surface with the curiously knotted retiform indentations so peculiar to the alloys of platina.

I cannot here refrain from indulging in a few remarks upon the cause of this phænomenon. Neither gold nor platina, alone, were known to have the faculty of absorbing oxygen at high temperatures; and yet I could attribute the increase to nothing else, as carbon in many cases was not present, and the cupel exhibited no trace of being acted upon; excepting now and then where a paper covering had been employed, when the phosphate of lime had assumed, under the metallic button, a beautiful bright blue colour, resembling that of phosphate of iron. I soon satisfied myself that no carbon had been absorbed, by submitting a portion of the suspected metal to solution in nitro-muriatic acid. Neither could I obtain traces of silex, nor of any other earth; although M. Boussingault has observed that platina may even be readily fused by combining it with silex, which is effected by heating the metal in a crucible lined with wood charcoal: the metal in such case becomes brittle, and gains about one per cent in weight; but the silex is regularly discoverable by its forming a jelly on solution in aqua regia, which was by no means the case in my experiments. I am rather inclined therefore to believe, although unable to confirm the supposition for want of due examination, that the increase of weight must be attributed to oxygen, as has been proved by Mr. Lucas to be the case with regard to silver and copper. But the former of these metals gives out, at the moment of its becoming solid, the oxygen absorbed while it was in a liquid state: and copper, when quite brittle from the presence (as is supposed) of oxygen, may be restored to its malleable state by what is technically called poling; that is, by bringing carbon in contact with the melted metal: whereas when I remelted one of the platina alloys in an envelope of leather, it gained additional weight, and became more brittle than before.—The subject must be left for future examination.

The following Table will explain more fully the effect to which I have alluded. I have continued the series of alloys up to 70 per cent of platina, but that and the previous specimen were not fused in the highest forge heat. G .55 P. was only half melted by the intense heat capable of fusing the cupel of Gualior clay in which it was supported.

Alloys of Platina and Gold.

No.	Proportions of		Heat employed.	Colour of the Alloy.	Specific Gravity.	Weight of fused bead.	Malleability.
	Gold.	Platina.					
0	100	0	hottest part of assay furnace.	Bright orange, a cast redder; inclining to a buff or yellow ochre; then growing paler; cream-yellow and wood-brown; then acquiring a dingy-purplish tint like tarnished silver, and gradually losing the buff tint until it has nearly the bright steel-colour of platina.	19·36	1000	Perfectly malleable.
1	99	1			18·4	1001·4	Rather brittle.
2	98	2			19·0	1001	Ditto.
3	97	3			19·0	1000	Ditto.
4	96	4	ditto remelted.		19·8	1004	Not very perfectly fused.
5	95	5	forge.		19·1	1008·5	Brittle.
6	94	6	,,		18·6	1001	Rather so on edges.
7	93	7	,,		18·7	1014·5	Very brittle.
8	92	8	,,		19·5	1000	Quite malleable.
9	91	9	,,		19·4	1000	Quite malleable.
10	90	10	,,		18·7	1005	Brittle.
11	89	11	,,		19·0	1003	Brittle.
12	88	12	,,		19·4	1000	Quite malleable.
13	87	13	,,		18·8	1013	Very brittle.
14	86	14	,,		18·6	1000	Malleable.
15	85	15	,,		20·0	1000	Quite malleable.
16	84	16	,,		19·1	1004	Brittle on edges.
17	83	17	,,		19·2	1003	Ditto.
18	82	18	,,		20·5	990?	Perfectly malleable.
19	81	19	,,		20·9	996	Ditto.
20	80	20	bone-ash cupel		18·9	1000·2	Not entirely.
21	75	25	melted.		20·9	992	Malleable.
22	70	30	,,		20·0	994	Not quite malleable.
23	65	35	,,		19·9	990	Perfectly malleable.
24	60	40	,,		19·0	1000·2	Cracks on edges and blisters.
25	55	45	,,		18·9	1000·3	Ditto, ditto, and brittle.
26	50	50	,,		20·0	1000	Rather brittle.
27	45	55	Gualior clay.		..	1000·3	Brittle, but not fused.
28	40	60	crucible melted.		..	991	Not fused.
29	30	70			..	1000	Platina wires only agglutinated or soldered together by the gold.

Note 1.—The first four specimens were melted under an assay muffle: they were wrapped in paper, and the bone ash cupels were all stained under the metallic beads of a fine azure blue (query, phosphate of iron?).

2.—The beads melted in a forge, when suffered to cool gradually, were all crystallized deeply: the colour of the brittle beads was duller than that of the malleable ones.

3.—No. 7 was remelted inclosed in leather: it gained an additional six-tenths per cent, and was more brittle than before. This is unfavourable to the oxygen hypothesis.

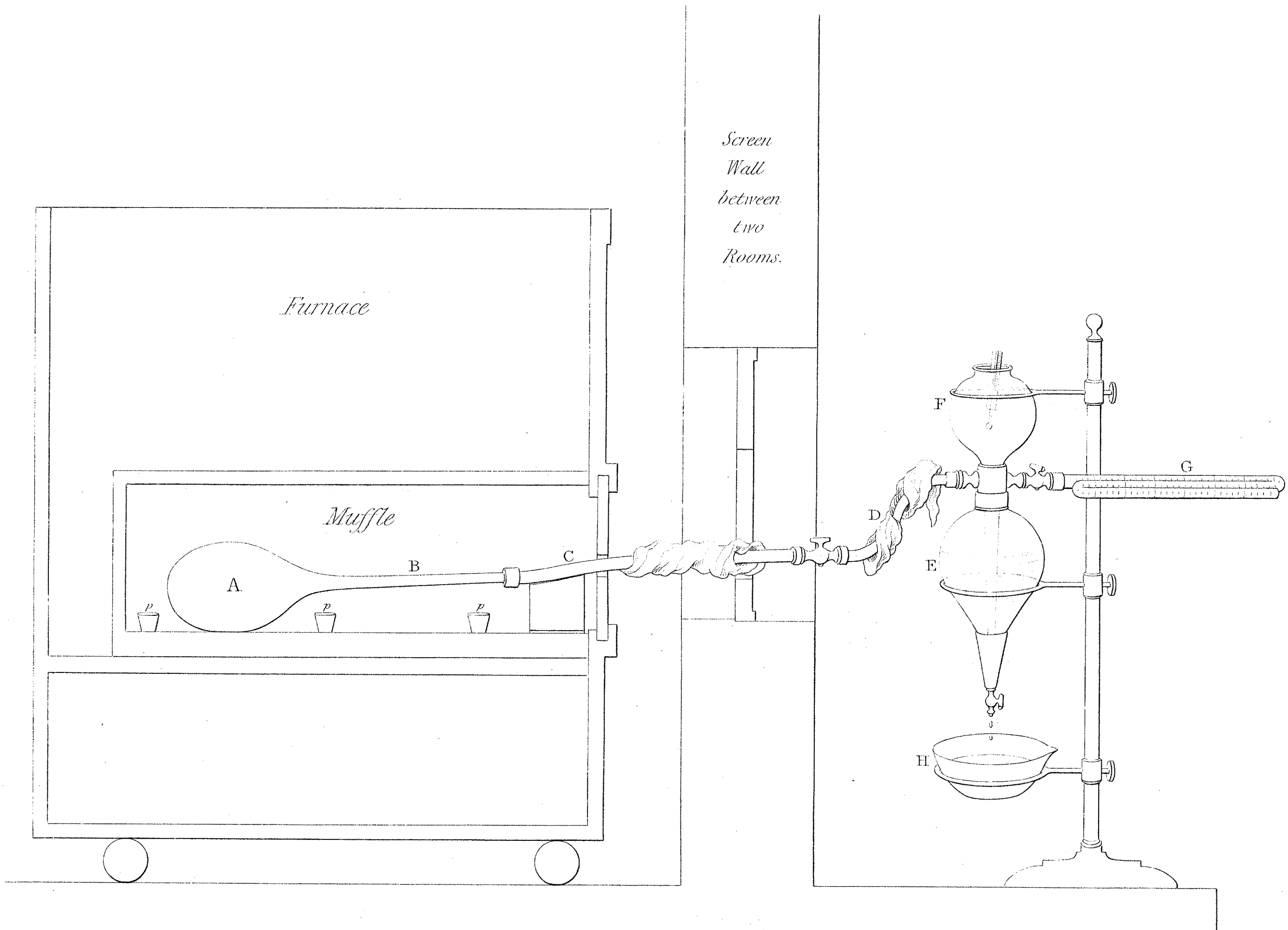
4.—The specific gravities were taken after hammering and annealing; but they cannot be depended upon, on account of the small bulk of the specimens, and the cracks on their edges: they are, however, the mean of two separate experiments made at distant periods; and prove, in a general way, that the brittle were of less specific weight than the malleable beads.

I shall now proceed to mention a few trials made with my pyrometric alloys in different furnaces and in different parts of the same furnace. The disparity of heat is greater than might have been supposed: and where, as in assaying the precious metals, so much depends upon the temperature at which the operation is performed, it would be useful to know every difference in this respect obtaining in various countries, and its effect upon the quality or standard of bullion.

	Maximum alloy melted.
Muffle of an assay furnace; front;	S .0 G
Muffle of an assay furnace; middle; average	S .3 G
Muffle of an assay furnace; behind; average	S .5 G
The Calcutta charcoal is better than that of Benares, and frequently heats the muffle to	G .04 P
Calcutta silver-melting furnaces of the English construction (specimens inclosed in an iron melting-pot)	G .075 P
Calcutta open native furnace	G .06 P
Calcutta blast furnace for melting musters	G .20 P
Black lead table furnace without chimney	G .08 P
Apex of condensed air blowpipe flame	G .20 P
Melting point of copper by two trials under a muffle	G .03 P
Melting of cast iron, about	G .30 P
Highest heat of a forge with the charcoal of Benares	G .55 P

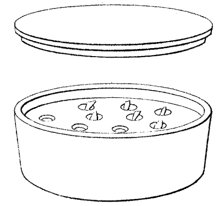
The above examples are sufficient to show the use of this simple instrument as an indicator of heat. I lay no stress upon the melting points of copper or iron, because I have no opportunity of trying them on a large scale. The instrument is well adapted for measuring the relative force of different fuel;—of pit-coal, charcoal, wood, &c.; a point, in this country especially, where woods vary so much in texture, of no inconsiderable interest. In conclusion, I may notice that some ingenuity is necessary in the contrivance of a box to hold and pre-

Fig. 1.



Section of the Golden Bulb Thermometer. Scale 1½ inch to a foot.

Fig. 2.



Pyrometer Cupel.

J. Basire, sc.

serve the specimens separate; and that the alloys of silver and gold lose in weight by long exposure to heat: they are however easily replaced; and the little musters need never be thrown away, as the gold may always be again purified. The platina alloys are very durable.

Having explained the means which I had provided for ascertaining the relative heat of a furnace, I turn to the more interesting portion of my experiments on pyrometric subjects; namely, the determination by means of an air thermometer of the absolute temperature at which pure silver enters into fusion. And here I pass over many fruitless endeavours made with cast iron retorts *, filled with azote to prevent oxidation, and proceed at once to the description of the apparatus which at last satisfied my expectations, and furnished the results presently to be enumerated.

In Plate II. fig. 1. the complete apparatus is displayed at the moment of an experiment. A, represents a retort or bulb of pure gold, weighing about 6500 grains troy, and containing nearly ten cubic inches of air. B, is a tube also of pure gold, which at its outer end is firmly united by a small gold collar to a similar tube, C, of pure silver; the bore of the latter tube is larger than that of the gold; but to prevent any undue influence from the unequal heating of the air contained in them both, and to confine the operation entirely to the gold bulb, the two tubes are plugged by wires of the same metals, so as to leave a very minute crevice for the air to pass. The outer part of the tube C is kept cool with a wet towel, to protect the stopcocks and flexible tube D. The tube D completes the communication of the air bulb with the glass reservoir E, which is intended as a substitute for an inconvenient length of

* These experiments only furnished me with one fact new to myself; namely, that cast iron acquires a permanent increase of bulk by each successive heating: for the cubic contents of the retort used, as determined by the weight of pure mercury contained at the temperature of 80°, were as follows:

Before the first experiment.	9.13 cubic inches.
After the first fire	9.64
After three fires	10.16

And the augmentation, which is more remarkable, exceeds the dilatation due to the temperature to which it was exposed; for as iron expands .0105 in 180 degrees, the increase of bulk upon 10 cubic inches should be $.105 \times 3 = .315$ at 1800° Fahr., or near the melting point of silver: whence it may be concluded that the dilatation of iron is not equable, as has been also proved by Messrs. Dulong and Petit.

graduated tube. This reservoir is nearly filled with olive oil, and is furnished with a safety tube and bulb F into which the oil rises when the air of A begins to flow, and a stopcock below, for the purpose of restoring the equilibrium of pressure by drawing out a portion of the oil. In the collar of the reservoir E, however, there is another stopcock aperture, leading into a graduated glass tube, G, in which a small bubble of oil is made to traverse. As this tube was very accurately divided into two-hundredths of a cubic inch, and may be read off to a tenth of that quantity, the equilibrium is capable of very delicate adjustment.

The furnace, as the figure exhibits, was situated in an adjoining apartment, so as to screen the exterior apparatus entirely from the heat. A small thermometer in F, however, serves to note any small change of temperature in the reservoir.

The furnace and muffle need no description, being of the ordinary assay construction. *p*, *p*, *p*, are little pyrometer cupels containing alloys of silver and gold, as mentioned in the former part of this paper.

Fig. 2. represents one of these pyrometer cupels with the lid raised, showing three of the alloys melted, and the rest retaining their form.

Every part of the instrument was ultimately rendered perfectly air-tight. But the first twelve experiments were rejected on account of minute leakage, which was at length entirely overcome; and several more were excluded on the suspicion of the air within the bulb not being thoroughly deprived of moisture, which desideratum was at last considered to be attained after frequently replenishing it with fresh air from a mercurial gasometer, where it had been exposed for days and even weeks to the drying action of concentrated sulphuric acid.

The absolute temperature, as must be evident from the construction of the instrument, is to be deduced from the measured volume of air expelled from the heated gold bulb; which volume again is to be found by the weight of the oil drawn from the reservoir, together with the adjustment of the bubble of oil in the graduated glass tube. The necessary calculation, however, embraces several corrections: some of them of minor effect and of known and certain influence,—as the formulæ for barometric and thermometric change; specific gravity of the oil, &c.;—others, which affect materially the results, and are by no means so certain in their power: these are the dilatation of gold at high temperatures, and the absolute law of gaseous expansion. The close agreement of M. Gay-Lussac's and Mr. Dalton's expressions for the expansion of gas between the fusing and the boiling point of water (0.375 and 0.376 in 180° Fahr.) leaves, it is true, but little room for hesitation in the adoption of the term 0.375 for 180 degrees. But as the tables of the dilatation of metals only give that of gold up to the boiling point of water, I may be wrong in assuming an equable rate of increase for greater heat: and it is therefore as much to provide against alterations in these points by future experimentalists, as from an earnest desire to conceal nothing which may affect my general conclusions, that I venture to trouble the Society with a detail of the data on which the several calculations are made. By this means, too, the following tables will speak for themselves, without the necessity of continual explanation.

First Series.

1. The tubes of silver and gold not plugged.
2. The contents, or interior volume of the gold bulb and tube, were found equal to 9.989 cubic inches, at the rate of 252.397 grains of pure water to the cubic inch at 80° Fahr.: but as the minus expansion of the portion of air in the gold tube, due to its not being heated to the full heat of the bulb, was rather more than balanced by the plus expansion of the air in the silver tube, the volume is estimated at 10 cubic inches.
3. The specific gravity of the oil found to be .91 at 80° Fahr.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
May 29	1744·1	29·55	·48	90·	97·	+·005	1	Small square muffle furnace.—Silver not melted.
30	1726·0	29·40	·40	95·	93·6	+·028	2	Ditto. About the same heat, or rather hotter; —silver not melted.
June 1	1611·0	29·36	·35	94·5	100·5	—·043	3	Black's table furnace with muffle; bright-red heat, or orange.—Silver not at all affected.
4	1757·5	29·43	·40	93·3	94·5	+·010	4	Ditto.—Could not raise sufficient heat to fuse silver with the large muffle in.
5	1786·2	29·46	·43	87·	87·	—·011	5	Same furnace with narrower muffle.—A silver wire held over the bulb barely melted.
6	1753·5	29·31	·33	91·	94·8	—·023	6	Same furnace—heat not full. (Several subsequent experiments were rendered imperfect by a minute leakage where the gold and silver tubes were joined: this was remedied by adding solder.)
10	1810·0	29·315	·31	94·2	96·	+·025	7	Large assay furnace. Heat = S.4 G. (The next experiments were faulty from leakage, and it became necessary to cut off and replace the tip of the gold tube. The contents were now 10·062; or, allowing roughly for the portion less influenced by the heat, 10·03.)
July 1	1814·0	29·36	·43	90·	90·	+·040	8	Large assay furnace; bright orange heat: expansion continuing,—doubtful whether moisture was not present.
9	518·5	29·29	·29	84·1	86·	+·055	9	In boiling water.
10	1829·5	29·275	·27	86·5	84·5	+·062	10	Large furnace. Full melting heat.

Second Series.

1. The silver tube was now plugged with a wire whose cubic measure was 0·611 inch. This, projecting a little way into the gold tube, diminished the latter about 0·03 inch.
2. The volume of the gold tube being 0·415 inch, requires, now that there is no counterbalancing effect produced by the air of the silver tube, a correction to be introduced for its not sharing the full heat of the bulb itself in the furnace. I have thus experimentally estimated this correction, dividing the tube into four compartments:

the first containing	0·185 ;	heated, say to	1200°,	yields expansion 0·647
the second —	·120	— —	1100	— — ·394
the third —	·080	— —	1000	— — ·246
the fourth —	·030	— —	900	— — ·086
				Sum.... 1·373
	·415	heated all to	1600°	would yield.... 1·785

The quantity of cold air expelled from the tube proportionate to 1·785 is 0·319
and for 1·373 is 0·290
leaving a difference 0·029

which is to be deducted from the residual gas in every experiment; or, as it comes to the same thing, may be deducted from the contents of the bulb and tube at once. 10·062 — ·03 + ·029 =10·003. Therefore 10,000 may be safely used as the volume of air during the present series.
3. The specific gravity at the beginning and end of these experiments was
24th of September at 88°....·9111. 11th of July at 82°....·9125

And the latter estimation is used for the temperature of 80°; to which, in the following series, the weight of the oil expelled is always reduced.

Date.	Oil expelled.	Barometer before.	Barometer after.	Thermometer before.	Thermometer after.	Adjustment of the Index.	No. of Exper.	Notes made at the time.
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
July 14 15	1789·	29·25	·35	83·3	89·	+·012	11	Large furnace always used. Full melting heat. —Apparatus placed in the cold muffle the preceding evening.
	1590·	29·25	·35	83·8	87·	....	12	Same experiment. At a full red heat.
16	1738·2	29·28	·38	91·	89·7	—·030	13	Oil allowed to remain in the safety tube under a pressure of three inches during the night; so that a small portion of air might have been absorbed by it.
17	1805·	29·38	·375	89·8	92·5	+·068	14	Good experiment. When cooled down, the index returned almost precisely to the original point.
19	1801·	29·28	·39	90·	89·9	+·033	15	Fresh air from the gasometer. Hot fire.
20	489·	29·37	·37	90·	91·	—·021	16	In boiling water—whole tube submerged.
21	1808·7	29·32	·34	88·5	88·	+·035	17	Hot fire. Henceforward the instrument was put suddenly into the muffle when heated to the necessary pitch.
24	1809·6	29·27	·282	91·	88·2	+·005	18	Moderate fire.
24	1816·2	29·28	·27	91·8	94·9	+·018	19	Second fire—rather hotter than the last.
25	1821·9	29·28	·32	88·2	90·9	—·060	20	
27	1814·	29·24	·27	85·4	88·2	—·012	21	
28	1836·2	29·29	·285	85·7	88·8	+·019	22	Hot fire.
29	1843·4	29·26	·28	83·8	83·9	+·069	23	Before this experiment the gold bulb had been inadvertently filled with the damp air of the room.—hygr. 91°.
29	1787·2	29·29	·27	86·6	91·	+·033	24	Dry air from the gasometer—low heat.
31	1813·4	29·20	·21	82·9	83·6	·000	25	Silver-melting heat.
Aug. 2	1816·7	29·436	·442	82·	85·	+·025	26	Full heat.
3	1795·7	29·405	·43	83·7	86·5	+·010	27	Silver not melted close to the bulb.
5	1820·	29·41	·44	83·	85·5	—·008	28	A hotter fire.
7	1823·3	29·45	·455	83·	84·3	+·028	29	Ditto.
9	1821·6	29·475	·474	89·	91·4	·000	30	Fully the melting point of silver—air fresh from the gasometer.

Although the foregoing series of experiments exhibits as much uniformity as could possibly be expected in a subject so liable to unavoidable irregularities, still I felt anxious to get rid altogether of the small correction allowed for the imperfect heating of the tube. With this view I re-opened the tubes, and fitted in the thick gold wire mentioned on a former occasion. The interior volume was now reduced to 9.7615 cubic inches: and by the trial in boiling water, this appears to be most correctly the influential volume.

THIRD SERIES.

Date.	Oil expelled.	Barometer		Thermometer		Adjustment of the Index.	No. of Exper.	Notes made at the time.
		before.	after.	before.	after.			
Aug.	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
17	455·9	29·40	·402	87·8	87·5	·000	31	In boiling water. Instrument in a very perfect state.
18	1736·3	29·43	·451	84·3	85·1	+·025	32	Large furnace; a little hotter than silver fusion.
20	1735·6	29·472	·480	83·	86·1	+·051	33	A minute portion of atmospheric air had previously been admitted to the dry air of the oil reservoir. Good experiment.
21	1786·8	29·486	·500	81·9	86·	—·170	34	Full muffle heat.
23	1695·5	29·43	·44	82·	86·3	—·012	35	Small furnace. Bright orange heat; silver not melted.
25	..	..	..	..	..	....	36	Back of the gold bulb melted at a temperature of about S.9 G. There had been a little silver solder applied to the part which gave way.

After this accident I endeavoured to render the bulb again serviceable by patching on a new bottom with as little solder as possible. In effecting the junction, I had reason to fear that a small portion of borax got into the interior of the instrument, and injured the subsequent experiments; and, as accidents seldom come singly, I was also perplexed by a few drops of oil having oozed down the tubes into the bulb, and, being suddenly converted into permanent gas, producing an excess in the quantity of oil driven from the reservoir. In four experiments the excess was about 150 grains, and the cause was evident during the process of cooling; but it was difficult to estimate the exact amount of new gas generated.

The contents of the repaired bulb were 7.666.

FOURTH SERIES.

Date.	Oil expelled.	Barometer before.	Barometer after.	Thermometer before.	Thermometer after.	Adjustment of the Index.	No. of Exper.	Notes made at the time.
	troy grs.	in. dec.	dec.	deg.	deg.	cub. in.		
Sept. 6	1841·1	29·575	·580	86·3	88·7	—·002	37	A hot fire.
7	1813·5	29·55	·56	86·9	91·1	+·035	38	Moderate and regular.
7	1923·3	29·592	·58	91·	94·8	+·072	39	Very hot fire. The solder on the bottom of the bulb had evidently run, but no leakage ensued.
8	1848·4	29·54	·54	88·	91·6	+·028	40	A regular fire.
9	1842·7	29·58	·59	87·	89·7	+·037	41	Below the ordinary heat.
11	1900·8	29·49	·49	87·	91·	+·040	42	Hot fire—Quere, any air generated.
13	1867·8	29·38	·398	87·	88·5	·000	43	Solder had partially fused. No leakage.
14	1859·5	29·47	·47	88·2	91·1	+·015	44	A good experiment.
14	1852·5	29·48	·48	89·2	92·9	+·065	45	Fresh air from the gasometer. No leakage; fire rather hot.
17	859·2	29·41	·40	87·	89·	+·024?	46	In boiling water.—This extraordinary anomaly seemed to be caused by an exceedingly minute infiltration of aqueous vapour, through the new joint; but on examination with a condensing air syringe, there did not appear any leakage. The longer the bulb remained in the water, the more gas came over; and when the instrument was again submitted to the furnace, the oil expelled amounted only to 1200 and 1300 grains, proving that some leakage existed which was not perceptible at a low temperature. With this experiment the whole series was brought to a conclusion.

It now remains to convert the data afforded by the foregoing table into degrees of the common thermometer. A single example will suffice to explain the process of this simple though somewhat lengthy calculation: and the table No. II. which follows, will set forth the fundamental data whence the results of each experiment are deduced.

One or two corrections,—for the expansion of the glass reservoir, and for the minute quantity of air contained in the exterior part of the apparatus,—are omitted in the calculation, as hardly appreciable: the temperature of the air in E (fig. 1.) may not always have been given with accuracy, as the thermometer was unavoidably suspended in F. No error on this head could exceed a single degree, as the screen wall effectually kept off the influence of the furnace, or equalized it on all objects connected with the apparatus outside.

Table II.

No. of experiment.	Volume of air expelled after all corrections.	Dimensions of heated gold bulb.	Expansion converted into degrees at ·375 per 180°.	Temperature of air.	Heat of the furnace.	Heat by Pyrometric cupels.	Notes.
	cubic inch.	cubic inch.	deg.	deg.	deg.		
1	7·472	10·410	1492	90	1582	none	Orange heat.
2	7·559	10·430	1578	95	1673	none	Bright orange.
3	7·106	10·370	1239	95	1334	none	Bright red heat, rather orange.
4	7·643	10·442	1644	94	1738	none	Bright orange—not quite melting silver.
5	7·775	10·465	1771	90	1861	S	Silver wire melted.
6	7·620	10·440	1627	91	1718	S	Perhaps a little less.
7	7·901	10·480	1917	94	2011	S .4 G	
8	7·978	10·470	2011	90	2101	none?	Damp air } (These three rejected.)
9	2·300	10·032	144	84	228	....	Ditto
10	8·057	10·499	2112	86	2198	S .2 G	Ditto
11	7·717	10·460	1727	84	1811	S	
12	6·876	10·350	1110	84	1194	....	Full red heat.
13	7·566	10·430	1579	91	1670	S .1 G	Rejected.—Some air oozed out in night?
14	7·859	10·475	1863	90	1953	S .2 G?	Pyrometer cupel not employed, but put down [by estimation.
15	7·851	10·475	1863	90	1953	S .3 G	Fresh air.
16	2·100	10·030	128	88	216	....	Doubtful to what the excess can be attributed.
17	7·911	10·480	1930	88	2018	S .2 G?	
18	7·915	10·480	1934	90	2024	S .2 G	Pyrometer cupel at back of bulb S .3 G.
19	7·830	10·470	1835	92	1927	S .1 G?	
20	7·810	10·470	1812	88	1900	S .1 G?	
21	7·836	10·470	1845	85	1930	S .1 G	
22	7·936	10·490	1959	86	2045	S .3 G	Pyrometer; behind S .4 G, in front S .2 G.
23	8·094	10·500	2166	84	2250	S .2 G	Damp air.—Rejected.
24	7·712	10·460	1713	87	1800	S	Dry air. Fire proved dull.
25	7·864	10·475	1875	83	1958	S	Behind, S 0.15 G.
26	7·838	10·470	1792	82	1874	S .1 G	
27	7·769	10·465	1773	84	1857	S	Hardly so high.
28	7·863	10·475	1875	83	1958	S .2 G	
29	7·923	10·490	1945	83	2028	S .2 G	
30	7·866	10·475	1877	89	1966	S .1 G	
31	1·979	9·792	124·3	87·7	212	....	The whole bulb and tube submerged in boiling [water.
32	7·518	10·190	1701	88	1789	S	Perhaps these three are all a little too low; for the part of the bulb next the tube must have been less heated than the rest, and no allowance is made: the difference however must be very small.
33	7·538	10·190	1721	86	1807	S	
34	7·524	10·190	1708	86	1794	none	
38	7·819	10·121	2015	89	2104	S	From the uncertainty attending this series of experiments, it is better at once to reject the resulting temperatures. In Nos. 39 and 42 gas was evidently generated: and upon breaking up the instrument the interior of the tubes was found coated with oil, and the glaze of borax.
39	8·360	10·172	2993	95	3088	S	
40	7·989	10·150	2261	91	2352	S	
41	7·993	10·150	2268	90	2358	S	
42	8·218	10·170	2674	91	2765	S .4 G	
43	8·088	10·158	2426	88	2514	S .7 G	
44	8·037	10·154	2339	88	2427	S .2 G	
45	8·042	10·156	2348	89	2437	S .25 G	

The average results may be thus expressed:

Full red heat . . .	1200	
Orange heat . . .	1650	
Silver melts	1830	DANIELL . . 2233°. WEDGWOOD 4717°.
Silver with $\frac{1}{10}$ gold .	1920	
Silver with $\frac{1}{4}$ gold, say	2050	

Example of the calculation of temperature from TABLE I.

On the 27th July 1826—twenty-first experiment.

	Weight of oil at temperature 80°, 1814·0 grains . . . . log.		3·2586373
	Correction for barometer {29°·24, 29 ·27} . . . . difference of logarithms	+	·0004453
	Correction for thermometer {85°·4, 88 ·2} log. vol. air {·9763879, ·9737043} diff.	−	·0026836
	Constant for specific gravity of oil = ·9125 . . . . $\bar{1}$·9602329; Constant for grains of water per cubic inch = 252·397 . . 2·4020842 . . .	−	2·3623171
Results,	Correct volume of air expelled at 85°·4 = 7·8358 cub. in.		0·8940819
	Volume of bulb . . . . 10·0000		
	Residual gas in the heated bulb . . . . . . 2·1642		0·3352974
	Correction for change of barometric pressure	−	·0004453
	Correct residual gas . . . . 2·1620		0·3348521
	Expansion of gold at 1950° on 10 cub. in. = ·470		1·0199467
			1·
	Therefore as 2·1620 : 10·47 : : 10 : volume of gas, if all were heated = 48·428		1·6850946
	deduct 10·000		
Results,	Quantity of expansion, cubic inches 38·428		1·5846478
	Constant for gaseous expansion 0·375 . . . . $\bar{1}$·5740313; Constant for 180° FAHR. . . . . 2·2552725	+	1·6812412
	1844·6		3·2658890
	+ 85·4		
	Temperature of the furnace in degrees of FAHR. 1930·0°		

I have now brought these experiments to a conclusion, and believe that they are sufficiently trustworthy to warrant a reduction in the tabular melting point of pure silver of at least 400 degrees below the determination of Mr. DANIELL, while they indisputably prove the superiority of that gentleman's thermometric table as contrasted with that of Mr. WEDGWOOD.

That the air thermometer cannot be expected to give indications perfectly accordant, those who have kept registers of the manometer of the sympiesometer will be ready to grant. At high temperatures, also, a very small difference in the quantity of air ejected produces a considerable change in the corresponding heat; and the air thermometer has the disadvantage of becoming less sensible with every increase of heat; for the portion which is expelled from the hot bulb must necessarily be cooled to a known point before it can be measured. The substitution of a reservoir of oil or mercury in the place of a mere graduated tube is essential, where the instrument is to be suddenly thrust into the fire, as the rapid motion of a bubble of liquid in a tube would either, if oil, leave it as a film lining the tube, or if mercury, break a passage for the air by the side of it. The reservoir employed by me was equal to a tube fifty feet long, and of the same bore as the adjusting tube G.

To obviate the uncertainty of the increase of the bulb A, I constructed an apparatus for submitting the dilatation of gold and other metals to actual measurement: but as I have not yet concluded my experiments, I shall reserve them for a separate communication.