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The opposition of sign is apparent only, and relates to the different methods of measurement adopted in the two cases. In (65) the primary and secondary disturbances are represented by h/K , but in (67) by the magnetic function c . If we express the solution in the second case in terms of the electric function g , we shall find (see 13) that the ratio of c to g changes sign when we pass from the primary light propagated along $-x$ to the secondary light propagated along $+x$. The actual ratio of amplitudes in the two cases is thus $(k'^2 + k^2)/2k^2$, or $(K' + K)/2K$. Unless the difference between K' and K be neglected, the two components of unpolarized light are scattered along this direction in different proportions, that component preponderating in which the electric displacement is parallel to the axis of the cylinder. The secondary light is therefore partially polarized in the plane perpendicular to the axis.

June 1881.

XI. *An Abstract of the Results obtained in a Recalculation of the Atomic Weights.* By FRANK WIGGLESWORTH CLARKE, S.B., Professor of Chemistry in the University of Cincinnati*.

DURING the past three years I have been engaged upon a recalculation of all the atomic-weight determinations which have been published from the time of Berzelius's earlier investigations down to the present date. My purpose has been to reduce all similar series of experiments to common standards, to calculate the probable error of each series, to combine the results into general means, and then to deduce the atomic weights in such a way that each value should represent a fair average of all the trustworthy estimations. In other words, I have sought to bring together all the vast number of scattered details, and to derive from them a more consistent table of atomic weights than has hitherto been found in chemical literature. My complete work will appear in due time as a separate volume; my present intention is to give merely a summary of my methods, and my conclusions.

Taking hydrogen as unity, I necessarily began with the ratio between it and oxygen. This ratio has been determined accurately in only two ways:—first, by the synthesis of water over copper oxide; and secondly, from the relative density of the two gases. Ignoring earlier inexact experiments, we may consider only the data furnished by Dumas, by Erdmann and Marchand, and by Regnault. From Dumas's nineteen syntheses of water we get for oxygen values ranging

* Communicated by the Author.

from $O=15.892$ to $O=16.024$. The mean of all is 15.9607 , with a probable error of $\pm .007$. Erdmann and Marchand give eight results, which average $O=15.9733 \pm .0113$. The general mean from both investigations is

$$O=15.9642 \pm .006.$$

The density of hydrogen, referred to air as unity, was determined by Regnault in three experiments. The mean was $.069263$; $\pm .000019$. For oxygen four determinations were made by Regnault, and one of them was rejected. The three remaining figures give a density of 1.105633 ; $\pm .000008$. The ratio between these two density-estimations gives an atomic weight of $O=15.9628$; $\pm .0044$. Combining this with the value found from the synthesis of water, we get a general mean of

$$O=15.9633 ; \pm .0035.$$

This is the most probable value which can be deduced from the published data, and it forms the corner-stone upon which our entire system of atomic weights must rest. I need not discuss here the methods employed in the calculation of probable errors; for they are given in all treatises upon least squares. Suffice it to say, that I assign no arbitrary weights to the values under examination; each series of experiments receives the weight to which the probable error of its mean entitles it.

Having found a value for oxygen, I next discussed in a group the atomic weights of the elements chlorine, bromine, iodine, silver, potassium, sodium, and sulphur. The data to be considered were determined by Berzelius, Penny, Pelouze, Marignac, Maumené, Gerhardt, Millon, Struve, Svanberg and Struve, Turner, Dumas, Cooke, and Stas, and represented twenty distinct ratios. For example, one of the most important ratios was that between potassium-chloride and potassium-chlorate, for which there were nine series of determinations. The mean of each series was calculated, together with its probable error; and then all nine means were combined into one general mean. Thus all the available data were reduced to the twenty compact ratios above referred to. Two of these may be cited, to illustrate the methods of calculation.

1. Percentage of O in $KClO_3$, 39.154 ; $\pm .0004$.
2. Ag: $KCl :: 100 : 69.1032$; $\pm .0002$.

From the first of these ratios the molecular weight of KCl is easily calculated by the usual proportion $39.154 : 60.846 :: O_3 : x$.

Using the value for oxygen previously found, x , or KCl , became 74.4217 ; and as the probable errors are known for

the three known terms of the proportion, we easily deduce that of the fourth term, and write

$$\text{KCl} = 74.4217 ; \pm .0164.$$

Here the probable error is a function of the probable errors of the experiments upon potassium-chlorate, and the probable error of the atomic weight of oxygen. We may now use this value KCl in connexion with the second of the ratios above cited, and deduce for the atomic weight of silver the figure $\text{Ag} = 107.696 ; \pm .024$. In every proportion used there are known probable errors for three terms, and they are involved in the probable error of the fourth term. From the twenty ratios above referred to, eight entirely independent values for the atomic weight of silver can be found. Each value has a definitely ascertained probable error, and each receives the weight which that error indicates. The general mean of all is

$$\text{Ag} = 107.675 \pm .0096.$$

This is the final result from the discussion of over two hundred experiments ; and it gives us the key to the atomic weights of the other elements in the group under consideration. These are as follows, when $\text{O} = 15.9633 \pm .0035$:—

$$\begin{aligned} \text{Cl} &= 35.370 ; \pm .014. \\ \text{Br} &= 79.768 ; \pm .019. \\ \text{I} &= 126.557 ; \pm .022. \\ \text{K} &= 39.019 ; \pm .012. \\ \text{Na} &= 22.998 ; \pm .011. \\ \text{S} &= 31.984 ; \pm .012. \end{aligned}$$

The values which Stas assigns to these elements are all based upon the standard of $\text{O} = 16$. If we adapt the above figures to the same standard, we may compare them side by side with those of Stas. As the latter chemist also determined the atomic weights of nitrogen, lithium, and lead, I will include the values found in this recalculation for these substances also.

Atomic Weights with $\text{O} = 16$.

	New values.	Stas's values.	Difference.
Ag.....	107.923	107.930	— .007
Cl	35.451	35.457	— .006
Br	79.951	79.952	— .001
I	126.848	126.850	— .002
Na.....	23.051	23.043	+ .008
K	39.109	39.137	— .028
S	32.058	32.074	— .016
N	14.029	14.044	— .015
Li	7.0235	7.022	+ .0015
Pb	206.946	206.926	+ .020

The magnificent accuracy of Stas's manipulations could hardly receive more striking confirmation than is afforded by these figures.

The atomic weights of the remaining elements I give below in the order of their calculation. I also give the authorities whose experiments are combined in the values presented. Elaborate details there is, of course, no room for. They must be sought in the complete monograph when the latter is published.

Nitrogen.—Data by Regnault, Pelouze, Marignac, Turner, Penny, and Stas. General mean of all, $N=14.0210$; ± 0.0035 . This value involved the values previously found for O, K, Na, Ag, and Cl.

Carbon.—Data by Liebig and Redtenbacher, Maumené, Dumas and Stas, Erdmann and Marchand, and Stas. General mean of all, $C=12.0021$; ± 0.0019 . Rejecting the series by Liebig and Redtenbacher, and by Maumené, which involve constant errors, we get from the remaining series a value of $C=11.9736$; ± 0.0028 . If $O=16$, this becomes $C=12.0011$. The ratio between oxygen and carbon, therefore, is a ratio between two whole numbers, 16 and 12.

Barium.—Determined by Berzelius, Turner, Struve, Pelouze, Marignac, Dumas, and Stas. General mean, $Ba=136.763$; ± 0.031 . If $O=16$, $Ba=137.007$.

Strontium.—Data by Pelouze, Dumas, and Marignac. General mean, $Sr=87.374$; ± 0.032 .

Calcium.—Experiments by Berzelius, Erdmann and Marchand, and Dumas. $Ca=39.990$; ± 0.010 . The best single result by Erdmann and Marchand gives $Ca=39.905$; or, if $O=16$, $Ca=39.997$.

Lead.—Berzelius, Turner, Marignac, Dumas, Anderson, and Stas. Some data were rejected. The final, most probable value is $Pb=206.471$; ± 0.021 .

Fluorine.—Berzelius, Louyet, Dumas, and De Luca. General mean, $F=18.984$; ± 0.007 .

Phosphorus.—The only good determinations for this element are those by Schrötter and by Dumas. General mean of both series, $P=30.958$; ± 0.007 .

Boron.—Berzelius, Laurent, Dumas, and Deville. In mean, $B=10.941$; ± 0.023 . Not well determined.

Silicon.—Pelouze, Dumas, and Schiel. $Si=28.195$; ± 0.031 . This constant needs thorough experimental revision.

Lithium.—Mellet, Diehl, Troost, and Stas. General mean, $Li=7.0073$; ± 0.007 .

Rubidium.—Bunsen, Piccard, Godeffroy. $Rb=85.251$; ± 0.0045 .

Cæsium.—Johnson and Allen, Bunsen, and Godeffroy.
Cs=132·583 ; \pm ·024.

Thallium.—Although I have recalculated the results obtained by Lamy, Hebberling, and Werther, I need consider here only the experiments of Crookes. His weighings, calculated with the values for O and N given above, make Tl=203·715 ; \pm ·037. Crookes himself, using the value NO₃=61·889, found Tl=203·642 and regards his results as evidence against Prout's hypothesis. His experiments, however, really fix only the ratio between NO₃ and Tl. If NO₃=62, then Tl=204·008 ; that is, the ratio which Crookes has rigorously established is a ratio between two whole numbers, and is confirmatory of Prout's idea.

Glucinum.—The results of Awdejew, Klatzo, Weeren, and Debray have high probable errors, and practically vanish from the mean when combined with those of Nilson and Pettersson. The weighings published by the latter chemists give me Gl=9·085 \pm ·0055, or Gl=13·628 \pm ·008, according to whether the oxide is GlO or Gl₂O₃.

Magnesium.—Scheerer, Svanberg, and Nordenfeldt, Bahr, Jacquelain, Marchand and Scheerer, and Dumas. General mean of all, Mg=24·103 ; \pm ·004. Some of the series are vitiated by constant errors. The best value is to be deduced from Marchand and Scheerer's work alone, and is Mg=23·959 ; \pm ·005.

Zinc.—Jacquelain, Favre, and Axel Erdmann. General mean, Zn=65·557 ; \pm ·011. Erdmann's results alone, however, give a more probable value (considered chemically) of Zn=64·9045 ; \pm ·019.

Cadmium.—Von Hauer, Lenssen, and Dumas. General mean, Cd=111·770 ; \pm ·030.

Mercury.—Part of Turner's data are to be considered, together with results by Erdmann and Marchand, Millon, and Svanberg. General mean, Hg=199·712 ; \pm ·042. New determinations are much needed.

Chromium.—Peligot's work was not available for discussion. The data studied were by Berlin, Moberg, Lefort, Wildenstein, Kessler, and Siewert. General mean from all, Cr=52·453 ; \pm ·015. Berlin's work, considered by itself, gives Cr=52·389 ; \pm ·019. Siewert's results give Cr=52·009 ; \pm ·025. I regard the last value as freest from constant errors, and use it in subsequent calculations.

Manganese.—Turner, Berzelius, Dumas, v. Hauer, Schneider, Rawack. General mean, Mn=54·128 ; \pm ·011. Schneider's and Rawack's results give a better value of Mn=53·906 ; \pm ·012.

Iron.—Berzelius, Svanberg, and Norlin, Erdmann and Marchand, Maumené, Rivot, and Dumas. General mean, $\text{Fe}=55.913$; $\pm .012$.

Copper.—Berzelius, Erdmann and Marchand, Millon and Commaille, and Hampe. $\text{Cu}=63.173$; $\pm .011$.

Molybdenum.—Debray, Dumas, Rammelsberg, and analyses by Liechti and Kemp. $\text{Mo}=95.527$; $\pm .051$.

Tungsten.—Berzelius, Schneider, Marchand, v. Borch, Dumas, Bernoulli, Persoz, Roscoe, Scheibler, and Zettnow. General mean of all, $\text{W}=183.610$; $\pm .032$.

Uranium.—Peligot, Ebelmen, and Wertheim. General mean, $\text{U}=238.481$; $\pm .082$.

Aluminum.—Berzelius, Tissier, Isnard, Dumas, Terreil, and Mallet. General mean, $\text{Al}=27.0092$; $\pm .0028$. All the data except Mallet's might be rejected without essentially affecting this value.

Gold.—Berzelius and Levol. $\text{Au}=196.155$; $\pm .095$. A thorough redetermination is much needed.

Nickel.—Several early series of nickel and cobalt were rejected. The data taken were by Schneider, Dumas, Russell, Sommaruga, Winkler, and Lee. General mean, $\text{Ni}=58.547$; $\pm .009$. I attach more importance to the concordant results of Schneider, Sommaruga, and Lee, whose figures give a general mean of $\text{Ni}=57.928$; $\pm .022$. Lee's investigation was of all the least susceptible to constant errors.

Cobalt.—Schneider, Dumas, Russell, Sommaruga, Winkler, Weselsky, and Lee. $\text{Co}=58.887$; $\pm .008$.

Selenium.—Berzelius, Sacc, Erdmann, and Marchand, Dumas, and Ekman and Pettersson. $\text{Se}=78.797$; $\pm .011$.

Tellurium.—Berzelius, v. Hauer, and Wills. General mean, $\text{Te}=127.960$; $\pm .034$. The results of v. Hauer and Wills upon K_2TeBr_6 give $\text{Te}=127.170$; $\pm .173$. Wills's minimum figures give me $\text{Te}=126.07$. In all of these results certain constant errors are possible; so that the question raised by Mendelejeff as to whether tellurium is above or below iodine, cannot be regarded as settled.

Vanadium.—Roscoe's weighings, recalculated with the new values for O, Ag, and Cl, give $\text{V}=51.256$; $\pm .024$.

Arsenic.—Pelouze, Dumas, Wallace, and Kessler. General mean, $\text{As}=74.918$; $\pm .016$. Wallace's analyses of AsBr_3 were made to establish the atomic weight of bromine; but they serve a better purpose here.

Antimony.—For this element there have been the two rival figures 120 and 122. The general mean from data by Kessler, Dumas, and Dexter is $\text{Sb}=122.092$; $\pm .035$. The general mean from the experiments of Schneider and of Cooke is

Sb=119.955 ; ± 0.036 . In view of the recent discussions upon the subject, we may regard the lower figure as established.

Bismuth.—General mean from Schneider's experiments Bi=207.523 ; ± 0.082 . If O=16, this becomes 208.001. All of Dumas's results on bismuth chloride give a mean of Bi=210.464 ; the figures which he considers best give Bi=209.78. Schneider's work is probably nearest correct, his method being less liable to constant errors than that of Dumas.

Tin.—Berzelius, Mulder and Vlaanderen, Dumas, and Vlaanderen. General mean, Sn=117.698 ; ± 0.040 .

Titanium.—Rose's weighings give Ti = 48.710 ± 0.105 . Mosander's figures give Ti=47.045. Pierre's give Ti=49.889 ± 0.096 ; and Demoly's, Ti=52.191 ± 0.153 . A general mean of the results of Pierre, Rose, and Demoly is 49.846 ± 0.064 . Mosander's work must be rejected for want of sufficient details. An experimental revision is wanted.

Zirconium.—From Berzelius's figures, Zr=89.255 ; ± 0.039 . From Marignac's data Zr=90.328 ; ± 0.113 . The general mean of both sets is Zr=89.367 ; ± 0.037 . New determinations are evidently needed.

Thorium.—Berzelius, Chydenius, Berlin, Delafontaine, Hermann, and Cleve. General mean, Th=233.414 ; ± 0.073 .

Gallium.—From Boisbaudran's results, in mean, Ga=68.854.

Indium.—Reich and Richter, Winkler, and Bunsen. General mean, In=113.398 ; ± 0.047 .

Cerium.—Berlinger, Hermann, Marignac, Bunsen and Jegel, Rammelsberg, Wolf, Wing, and Buehrig. General mean of all, Ce=140.424 ; ± 0.017 . Buehrig's analyses of the oxalate give Ce=141.198 ; ± 0.020 . The figures by Wolf and by Wing give Ce=137.724. Wolf and Wing had a white ceroso-ceric oxide ; and Wolf suspects the ordinary yellowish compound to contain a fourth metal of the cerium group. Buehrig's work is the best ; but the possible presence of a fourth metal is not considered by this chemist. Therefore new experiments are needed.

Lanthanum.—Hermann, Rammelsberg, Marignac, Czudnowicz, Holzmann, Zschiesche, Erk, and Cleve. General mean, La=138.526 ; ± 0.030 .

Didymium.—Marignac, Hermann, Zschiesche, Erk, and Cleve. General mean, Di=144.573 ; ± 0.031 . Cleve's work alone, which is doubtless the best, gives Di=146.804.

Scandium.—Nilson's results, recalculated, give Sc=43.980 ; ± 0.015 .

Yttrium.—Popp, Delafontaine, Bahr and Bunsen, and Cleve,

General mean, $Yt=97.616$. Excluding Popp's work as worthless, the general mean becomes $Yt=89.816$; ± 0.067 .

Ytterbium.—Nilson. $Yb=172.761$; ± 0.038 .

Erbium.—For this metal the most probable results are those of Cleve, which give, recalculated, $Er=165.891$. Previous workers undoubtedly studied material rich in ytterbium and other metals of the group.

For terbium, samarium, phillipium, decipium, thulium, &c. there are no satisfactory data. Cleve gives 170.7 for thulium, while Delafontaine puts $Ph=123$ to 125 , and $Dp=171$. These figures assume that all the earths of the group are sesquioxides.

*Columbium**.—Marignac's results give approximately $Cb=94$; Blomstrand regards 95 as the most probable value. New estimations are needed.

Tantalum.—All of Marignac's figures give a general mean of $Ta=182.144$; ± 0.166 . Probably 182 may be safely used as the true value.

Platinum.—By a recalculation of the results lately published by Seubert, I get $Pt=194.415$; ± 0.049 .

Osmium.—Berzelius's figures give me $Os=198.494$.

Iridium.—The general mean calculated from Seubert's weighings is $Ir=192.651$; ± 0.033 .

Palladium.—Berzelius's last results are the only ones worth considering. They give $Pd=105.737$.

Rhodium.—Data by Berzelius. $Rh=104.055$.

Ruthenium.—A single analysis of potassium ruthenio-chloride by Claus gives $Ru=104.217$. Plainly the values for Ru , Rh , Pd , and Os need scrupulous redetermination.

Conclusions.

A careful scrutiny of all the data upon which the foregoing atomic-weight calculations depend will reveal various sources of error. Of course, each series of results must be considered by itself and weighed on its own merits; but a few general errors are important enough to warrant mention here.

First, every value after oxygen, with one or two partial exceptions, involves whatever error may attach to the atomic weight of oxygen. If the latter is 16 instead of 15.9633, this error in some instances becomes multiplied to a serious extent, as a glance at the tabulated results will show. Other similar errors are repeated continually. The value assigned to any element is necessarily affected by whatever errors may attach to the atomic weights of those other elements through whose medium it is referred to the standard, hydrogen.

* This name has priority over the generally accepted "niobium," and therefore is entitled to preference.

Secondly, confusion arises from the fact that many of the weighings under discussion were not reduced to the standard of a vacuum; while others had been subjected to such a correction. The errors thus introduced into the calculations are small, but still they cannot be lost sight of.

Another set of errors of unknown magnitude are produced as follows:—Many series of experiments, notably in the work of Stas, Marignac, and other eminent investigators, involve the titration of chlorides, bromides, or iodides with solutions containing known weights of metallic silver. But Dumas has lately shown that silver, purified after the usual methods, occludes weighable quantities of oxygen. In other words, the silver hitherto employed in atomic-weight investigations has not been pure silver. One exception is found in Mallet's research upon aluminum. Since the atomic weights of nearly all the elements depend directly or indirectly upon silver, this source of error becomes of the gravest importance. Analogous errors may possibly occur with metals other than silver, and should be carefully looked for. For example, the atomic weights of both copper and oxygen depend upon the reduction of copper-oxide in hydrogen. If the residual copper, which is weighed, occludes any hydrogen, then the atomic weight of copper will come out too high, and that of oxygen a trifle too low. Such an error might account for the difference of between 15.9633 and 16 in the case of oxygen.

In connexion with the data discussed in this investigation, it is perhaps worth while to consider the bearing of the results upon Prout's famous hypothesis. In order to simplify matters I tabulate the new atomic-weight values in two columns, one containing numbers referred to hydrogen as unity, the other with figures comparable with oxygen as equal to 16.

Table of Atomic Weights.

	H=1.	O=16.		H=1.	O=16.
Hydrogen ...	1.0000	1.0023	Cæsium	132.583	132.918
Fluorine ...	18.984	19.027	Silver.....	197.675	197.023
Chlorine ...	35.370	35.451	Thallium ...	203.715	204.183
Bromine ...	79.768	79.951	Phosphorus ...	30.958	31.029
Iodine	126.557	126.848	Vanadium...	51.256	51.373
Lithium.....	7.0073	7.0235	Arsenic	74.918	75.090
Glucinum ...	9.085	9.106	Cadmium ...	111.770	112.027
Magnesium ...	23.959	24.014	Mercury ...	199.712	200.171
Zinc	64.905	65.054	Calcium ...	39.990	40.082
Sodium	22.998	23.051	Strontium...	87.374	87.575
Potassium ...	39.019	39.109	Barium	136.763	137.007
Rubidium ...	85.251	85.529	Lead	206.471	206.946

Table of Atomic Weights (*continued*).

	H=1.	O=16.		H=1.	O=16.
Oxygen	15.9633	16.0000	Tantalum ...	182.144	182.562
Sulphur.....	31.984	32.074	Scandium ...	43.980	44.081
Selenium ...	78.797	78.978	Yttrium.....	89.816	90.023
Tellurium ...	127.960	128.254	Erbium	165.891	166.273
Chromium ...	52.009	52.129	Ytterbium ...	172.761	173.158
Molybdenum	95.527	95.747	Cerium	140.424	140.747
Tungsten ...	183.610	184.032	Lanthanum	138.526	138.844
Uranium ...	238.482	239.030	Didymium	144.573	144.906
Manganese..	53.906	54.029	Carbon	11.9736	12.0011
Iron	55.913	56.042	Silicon	28.195	28.260
Nickel	57.928	58.062	Titanium ...	49.846	49.961
Cobalt	58.887	59.023	Zirconium...	89.367	89.573
Copper	63.173	63.318	Tin.....	117.698	117.968
Boron	10.941	10.966	Thorium ...	233.414	233.951
Aluminum ..	27.009	27.075	Platinum ...	194.415	194.867
Gallium.....	68.854	68.963	Iridium	192.651	193.094
Indium	113.398	113.659	Osmium.....	198.494	198.951
Nitrogen ...	14.021	14.029	Palladium...	105.737	105.981
Antimony ...	119.955	120.231	Rhodium ...	104.055	104.285
Bismuth ...	207.523	208.001	Euthenium	104.217	104.457
Columbium	about 94	about 94	Gold	196.155	196.606

Here we have sixty-six elements, or, rejecting columbium as too vaguely determined, sixty-five. Such elements as phillipium, decipium, thulium, samarium, &c. are not yet sufficiently well known to be considered in this connexion.

In his recent superb investigation of the atomic weight of aluminum, Mallet makes substantially the following argument in favour of Prout's hypothesis. Considering the atomic weights of eighteen elements only as well determined, he finds that ten of them have values varying less than 0.1 from whole numbers. In other words, these ten elements have atomic weights varying from even multiples of that of hydrogen by insignificant amounts. What is the probability that this agreement with Prout's hypothesis in ten cases out of eighteen is purely accidental, as those hold who agree with the views of Stas? Working this problem out, he finds the probability of mere coincidence to be 1:1097.8; and he concludes that Prout's hypothesis is still worthy of careful consideration.

Applying Mallet's reasoning to the Table of atomic weights now before us, we find that in the first column, when $H=1$, twenty-five out of sixty-five elements have atomic weights falling within one tenth of a unit of whole numbers; but many of the figures which fall outside this limit of variation involve the variation of oxygen multiplied many times over. We must therefore study the second column, which assumes $O=16$. Here we have thirty-nine elements falling within the limit of variation assigned by Mallet and twenty-six falling

without. The latter are chlorine, iodine, potassium, thallium, glucinum, mercury, strontium, tellurium, chromium, molybdenum, rubidium, copper, indium, vanadium, antimony, tantalum, erbium, ytterbium, cerium, lanthanum, silicon, zirconium, platinum, rhodium, ruthenium, and gold. Of these, chlorine, rubidium, and strontium agree closely with half multiples of hydrogen; while tellurium, molybdenum, iridium, tantalum, erbium, cerium, silicon, zirconium, lanthanum, rhodium, and ruthenium may be dismissed from consideration as not sufficiently well determined to bear upon the problem before us. The exceptions in the cases of potassium, iodine, thallium, glucinum, mercury, chromium, vanadium, antimony, ytterbium, platinum, and gold remain to be considered.

For potassium and iodine, we must remember that both of these elements involve the constant error due to the occlusion of oxygen by silver. This error is probably great enough to throw the values for both elements outside the limit of variation above assigned. For thallium it has already been shown that when its atomic weight is calculated with $\text{NO}_3=62$, Crookes's data give $\text{Tl}=204\cdot008$. The atomic weights of glucinum and ytterbium, as given in the Tables, are calculated from analyses of the sulphates. If $\text{SO}_3=80$, then $\text{Gl}=9\cdot096$; and $\text{Yb}=173\cdot016$. Both fall within, and one *narrowly* within the limit of one tenth of a unit variation. In the case of platinum, I need only say that Seubert's figures give values ranging both above and below the even number 195; while as for antimony, although the general mean is $\text{Sb}=120\cdot231$, Crookes's analyses of the bromide, reckoned with $\text{Br}=80$, give almost exactly 120 for the value. For mercury, chromium, vanadium, and gold, new determinations are desirable.

Enough has been said to show that none of the apparent exceptions to Prout's hypothesis are absolutely inexplicable. As the figures actually stand, thirty-nine out of sixty-five elements vary less than a tenth of a unit each from even multiples of the atomic weights of hydrogen. Of the remaining twenty-six, three conform to half multiples, three more are legitimately recalculable so as to fall within bounds, and eleven have been so defectively determined that the assigned values can carry scarcely any weight. The remaining nine are still subject to slight revision. In short, the many agreements, which include three fourths of the *well*-determined atomic weights, renders Prout's hypothesis very highly probable. It is more likely that the seeming exceptions are due to undetected constant errors, than that the great number of coincidences should be accidental. The mathematical probability in favour of Prout's hypothesis I have not yet calculated;

but a glance at Mallet's figures will show that it must be enormous.

As I said at the beginning, this paper is but a summary of methods and conclusions. Within its scope elaborate discussions would not be admissible. I hope that my complete memoir will soon be published; and it is my intention to discuss, in an appendix to it, both the bearing of the results upon Prout's hypothesis, and the distribution of the variations therefrom. I ought to say, that at the beginning of my investigation I was strongly prejudiced against Prout's hypothesis, and fully believed that it had been for ever overthrown. My results have forced me to give it very respectful consideration.

XII. *On the Opacity of Tourmaline Crystals.*

By PROFESSOR SILVANUS P. THOMPSON, *B.A., D.Sc.**

Introduction.

1. **T**OURMALINE is distinguished amongst crystals for its remarkable optical properties, particularly its power of polarizing light. It is distinguished moreover by possessing characteristic electric properties. It possesses also a crystallographic interest as furnishing an eminent example of non-superposable hemihedry. There can be little doubt that these remarkable and characteristic qualities are closely related to one another, though as yet very little is known of the nature of this probable connexion. In the present paper an attempt is made to connect the optical and electrical properties of the crystal, by showing that the opacity of the crystal to light polarized in a principal plane of section can be deduced from its electric conductivity.

2. In a paper read before Section A of the British Association at Dublin in 1878, by Dr. O. J. Lodge and myself†, we suggested, as a possible explanation of the phenomena of pyroelectricity in tourmaline, that it might be found to possess unilateral conductivity for electricity—and if for electricity, for heat also. Our experiments on the electric conductivity, however, led to negative results; and in the case of heat-conductivity, the only differences observed of a unilateral kind were such as occurred while the temperature was either rising or falling—not whilst it was constant. Our original suggestion, therefore, was not confirmed, though I obtained instead

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† Report Brit. Assoc. (Dublin) 1878, p. 495; and Phil. Mag. July 1879.