



XXVIII. On a great regularity in the physical properties of analogous organic compounds

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bining with another in several proportions, does not always retain the same atomic volume, although these cases appear to be of less frequent occurrence than those in which it always retains one and the same atomic volume.

The above is a short abstract of Dr. Kopp's most important researches on the specific weight of chemical compounds; at the same time he published another work on the specific gravities of arbitrary mixtures, in which there are some important considerations with regard to the hydracid theory. Should the above abstract meet with the favour of British chemists, I may perhaps be induced to attempt something similar with the last-mentioned work.

January 11th, 1842.

HENRY CROFT.

35 Upper Gower Street, London.

XXVIII. *On a great Regularity in the Physical Properties of analogous Organic Compounds.* By Dr. HERMANN KOPP, *Lecturer at the University of Giessen**.

IN a recent publication on the Specific Weights of Chemical Compounds†, I endeavoured to show how the atomic volumes of analogous groups of such combinations might be very simply explained by means of certain general admissions, and how the specific weight of any compound belonging to such a group might be determined *à priori* with considerable accuracy. This work was confined to inorganic compounds: I have since then extended my researches to the organic combinations, and have likewise arrived at very simple results.

In organic chemistry there are proportionally more liquid compounds than in the inorganic, and the existence of dimorphism, which frequently renders the discovery of the laws for the specific weight difficult in this latter branch, is of rarer occurrence. The determinations of the densities of fluids are in general easier, and the statements respecting them more accurate than is the case with solid bodies. On the other hand, fluids have a greater expansibility by heat than solids, and as long as it remains unascertained at what temperature a comparison of the specific volumes of various bodies can properly be made, this stronger expansibility, which varies in different compounds, appears to lay great difficulties in the way of our arriving at correct results from a comparison of specific volumes. I have not hitherto been able to devote any special attention to this subject, on account of the several

* Communicated by the Author.

† Vide preceding abstract by Mr. H. Croft.

statements respecting the specific weight of one and the same compound frequently differing very considerably, and the uncertainty which this gives rise to is greater than that resulting from our ignorance of the temperature which should be taken as basis when determining the density of any body.

Let us imagine a great number of organic compounds, which may be considered as analogous, arranged under the following scheme :—

A + α	B + α	C + α	D + α
A + β	B + β	C + β	D + β
A + γ	B + γ	C + γ	D + γ
A + δ	B + δ	C + δ	D + δ

where A, B, C, D, α , β , γ , δ express certain bodies or constant combinations of elements.

A, for instance, may represent hypothetical anhydrous acetic acid, B formic acid, C benzoic acid, &c.; α water, β oxide of æthyl, γ oxide of methyl, &c. Or we may conceive by A chlorine, by B iodine, by C sulphur, &c.; and by α hydrogen, by β æthyl, by γ methyl, &c.

It is only necessary to become acquainted with one horizontal and one vertical series, to know the most important physical properties of all the combinations contained in such a table. If the properties of the compounds contained in one horizontal or in one vertical series are known, the mere knowledge of one of these compounds is sufficient in order to ascertain the properties of all the compounds arranged in any other horizontal or vertical series.

The specific weight is given by the specific volume, since the atomic weights* of the compounds are taken as known. If the specific volumes and the boiling points of the compounds A + α , A + β , A + γ , &c. are known, and we are also acquainted with the specific gravity and boiling point of B + α , we ascertain directly the specific gravities and boiling points of the bodies B + β , B + γ , B + δ . For between the specific volumes and the boiling points of

A + α and B + α	B + α and D + α	A + α and A + δ
A + β and B + β	B + β and D + β	B + α and B + δ
A + γ and B + γ	B + γ and D + γ	C + α and C + δ
.....
.....

the differences are always the same.

* The atomic weight of carbon is taken at 75.854 as found by Liebig and Redtenbacher. [See our last volume, p. 210. EDIT.]

This law is confirmed by all known observations. The following specific volumes of the combinations of acetic acid (A.), formic acid (B.), and benzoic acid (C.) with water (α .), oxide of æthyl (β .), and oxide of methyl (γ .), result from the observations which follow:—

	A.	B.	C.
α	709 Mollerat.	467 Liebig.	?
β	1243 Liebig.	1020 ...	1794 Dumas.
γ	1012 Dumas.	? ...	1558 ...

and the observations give the boiling points in centesimal degrees for the same compounds:—

	A.	B.	C.
α	120° Liebig.	99° Liebig.	239° Liebig.
β	74 ...	53 ...	209 Dumas.
γ	58 Dumas.	? ...	198 ...

If we designate the specific volumes or the boiling points of the compounds $A + \alpha$, $A + \beta$, $A + \gamma$. . . by $(A + \alpha)$ $(A + \beta)$ $(A + \gamma)$. . . , we find that within the limits of the errors of experiment,

$$\begin{aligned}(A + \alpha) - (A + \beta) &= (B + \alpha) - (B + \beta) \\(A + \beta) - (A + \gamma) &= (C + \beta) - (C + \gamma) \\(A + \alpha) - (B + \alpha) &= (A + \beta) - (B + \beta) \\(A + \beta) - (C + \beta) &= (A + \gamma) - (C + \gamma), \text{ \&c.}\end{aligned}$$

This law may be specially applied to single cases and rules advanced for certain compounds which could be proved by numerous observations. I will here enumerate some few cases which frequently occur.

I. “The specific volume of a hydrated acid ($\overline{A} + H^2 O$) is 534 smaller than that of the corresponding æthyl compound ($\overline{A} + Ae O$).” To prove this and the following laws, I will give a table of the compounds, containing the formulæ, the atomic weights, the observed specific volumes and densities, and those calculated after the above laws.

In the following table therefore the observations of the hydrated acid have always been placed first, and from the specific volume of the hydrated acid resulting from the observed specific weight, the specific volume of the æthyl compound is obtained by the addition of 534. If the atomic weight of the æthyl compound be divided by this calculated specific volume, we obtain the calculated specific weight, and the agreement between the latter and that observed shows the correctness of the law.

Formula.	Atomic weight.	Specific volume.		Density.		
		Observed.	Calculated.	Calculated.	Observed.	
Hydrate and Æther of Acetic Acid.						
$\overline{A} + H^2 O$	753	709	...	...	1.062	Mollerat.
$\overline{A} + Ae O$	1107	...	1243	0.8906	0.89	Liebig 15° C.
Hydrate and Æther of Formic Acid.						
$\overline{F} + H^2 O$	577	467	...	...	1.2353	Liebig 12°.
$\overline{F} + Ae O$	930	...	1001	0.9293	0.912	...
Hydrate and Æther of Succinic Acid.						
$\overline{Su} + H^2 O$	741	478	...	...	1.55	Richter.
$\overline{Su} + Ae O$	1094	...	1012	1.0812	1.036	D'Arcet.

II. "The specific volume of a hydrated acid ($\overline{A} + H^2 O$) is 300 smaller than that of the corresponding methyl compound ($\overline{A} + Me O$)."

To test the correctness of this law, let us, as above, calculate the density of the methyl compound from the observed density of the hydrated acid, by adding 300 to the specific volume of the hydrated acid as resulting from observation, and dividing the atomic weight of the methyl compound by this sum, which is the calculated specific volume. The quotient which is the calculated density of the methyl compound may then be compared with that obtained by experiment.

Formula.	Atomic weight.	Specific volume.		Density.		
		Observed.	Calculated.	Calculated.	Observed.	
Sulphate of Water and of Oxide of Methyl.						
SO ³ +H ² O	614	332	...	...	1.85	Dalton.
SO ³ +Me O	790	...	632	1.2511	1.324	Dumas 22°.
Nitrate of Water and of Oxide of Methyl.						
N ² O ⁵ +H ² O	790	519	...	...	1.522	Mitscherlich.
N ² O ⁵ +MeO	966	...	819	1.1800	1.182	Dumas 22°.
Acetate of Water and of Oxide of Methyl.						
A+H ² O ...	753	709	...	...	1.063	Mollerat.
A+Me O...	930	...	1009	0.9220	0.919	Dumas 22°.

III. "The specific volume of each æthyl compound is 234 greater than that of the corresponding methyl compound."

Formula.	Atomic weight.	Specific volume.		Density.		
		Observed.	Calculated.	Calculated.	Observed.	
Alcohol and Pyroligneous Spirit (Wood-spirit).						
Ae + H ² O	578	730	...	...	0.792	Gay-Lus. 18°.
Me + H ² O	402	...	496	0.8098	0.798	Dumas 20°.
Sulphurets of Æthyl and Methyl.						
Ae + S.....	567	687	...	...	0.825	Regnault 20°.
Me + S.....	390	...	453	0.8610	0.845	... 21°.
Iodides of Æthyl and Methyl.						
Ae + I ² ...	1944	1012	...	...	1.9206	Gay-Lus. 22°.
Me + I ² ...	1767	...	778	2.2712	2.237	Dumas 22°.
Acetates of the Oxides of Æthyl and Methyl.						
\overline{A} + Ae O...	1107	1244	...	...	0.89	Liebig 15°.
\overline{A} + Me O...	930	...	1010	0.9213	0.919	Dumas 22°.
Benzoates of the Oxides of Æthyl and Methyl.						
\overline{Bz} + Ae O	1890	1793	...	...	1.0539	Dumas 10°.
\overline{Bz} + Me O	1713	...	1559	1.0987	1.1	... 17°.
Suberates of the Oxides of Æthyl and Methyl.						
\overline{Su} + Ae O	1348	1329	...	...	1.014	Laurent 18°C.
\overline{Su} + Me O	1171	...	1095	1.0694	1.003	... 18 C.
Mucates of the Oxides of Æthyl and Methyl.						
\overline{Mu} + Ae O	1671	1266	...	...	1.32	Malaguti.
\overline{Mu} + Me O	1494	...	1032	1.4480	1.48	...
Hydrates of Acetic and Formic Acids.						
Ae + O ⁴ —H ²	753	709	...	...	1.063	Mollerat.
Me + O ⁴ —H ²	577	...	475	1.2148	1.2353	Liebig 12°.

In this manner a number of laws which are confirmed by experience, may be advanced for numerous compounds, indeed for all analogous combinations. Thus the specific volumes of all acetates are 234 greater than those of the corresponding formates; the specific volumes of the benzoates are 548 greater than those of the corresponding acetates; the specific volumes of all the succinates are 34 greater than those of the corresponding formates; the specific volumes of all the mucates are 538 greater than those of the corresponding benzoates, &c.

Let us compare the compounds of valerianic acid with the corresponding ones of acetic acid. The specific volume of the

hydrated acetic acid is 709; the specific volume of the hydrated valerianic acid (spec. weight = 0.944 Trommsdorff, atomic weight = 1738) is 1842, that is, 1133 greater than that of the hydrated acetic acid. If we have studied the compounds of acetic acid we may then deduce the specific volumes and densities of the corresponding valerianates; the specific volume of any compound of valerianic acid is 1133 greater than that of acetic acid. The specific volume of acetic æther is 1243, that of valerianic æther must therefore be $1243 + 1133 = 2376$. The density therefore is equal to the atomic weight 2098 divided by $2376 = 0.833$. Otto found it to be 0.894.

Similar laws might be adduced with reference to the boiling points, *e. g.* if we neglect the small differences resulting from the varying states of the barometer, the boiling points of all the compounds of æthyl are 18° C. higher than those of the corresponding methyl compounds within the limits of the errors of experiment.

Formulae.	Observed boiling point C.		Differences.
Ae O + H ² O	78°·4	Gay-Lussac.	} 18°·4
Me O + H ² O	60	Kane.	
Ae + I ²	64·8	Mitscherlich.	} 24·8—14·8
Me + I ²	40—50	Dumas.	
Ae S + H ² S	36·2	Liebig.	} 15·2
Me S + H ² S	21	Gregory.	
$\overline{\text{C}}$ + Ae O	184	Dumas.	} 23
$\overline{\text{C}}$ + Me O	161	Dumas.	
$\overline{\text{A}}$ + Ae O	74	Liebig.	} 16
$\overline{\text{A}}$ + Me O	58	Dumas.	
$\overline{\text{Bz}}$ + Ae O	209	Dumas.	} 11
$\overline{\text{Bz}}$ + Me O	198	Dumas.	
Ae + O ⁴ —H ²	120	Liebig.	} 21·5
Me + O ⁴ —H ²	98·5	Liebig.	

Moreover, the boiling points of all the hydrated acids are 45° C. higher than those of the corresponding æthers, and 63° C. higher than the corresponding compounds of methyl; the boiling points of all the oxalates are 106° higher than those of the acetates; the boiling points of the benzoates 148° C. higher than those of the formates; the boiling points of the succinates

128° C. higher than those of the acetates; the boiling points of the acetates 18° higher than those of the corresponding formates, &c.

The accurate study of the physical properties of all the compounds of one body and of any single compound of another, enables us to form a conclusion with respect to all other compounds of the latter, and affords a control for the observations in general.

A similar regularity occurs in the physical properties in such cases where substitutions occur. Many organic compounds may be so arranged in a series that the amount of hydrogen decreases successively, while that of chlorine increases, which is explained by the supposition of the substitution of chlorine in the place of hydrogen. Let A represent, for instance, a combination of oxygen and carbon which remains unaltered, α hydrogen, β chlorine, m , n , x , y numbers, we then have the following scheme:—

$$\begin{array}{rcl} A + m\alpha & + & n\beta \\ A + (m-x)\alpha & + & (n+x)\beta \\ A + (m-y)\alpha & + & (m+y)\beta. \end{array}$$

The number of atoms α and β taken together remains the same in each compound.

Compounds belonging to such a group or scheme may be arranged in the table given at the commencement of this paper, and the laws which have there been communicated may also be applied to them. But we may also consider independently a whole series of such compounds where chlorine and hydrogen replace each other, and prove specially for them a peculiar regularity in their physical properties.

With reference to the specific volumes of such compounds, the following law holds good:—

“If in any compound x atoms of hydrogen are replaced by (x atoms of chlorine), the specific volume of the new compound is greater than that of the former by the number $x \cdot 80$.”

[The number 80 is merely approximate, inasmuch as no attention has been paid to the temperature at which the specific volumes should be considered.]

In proof of this law I will arrange together a large number of substitutions, and always calculate by the above law from the observed density of the preceding compound the density of that which has been formed from it by substitution, and compare the calculations with the observations.

Formula.	Atomic weight.	Specific volume.		Density.		
		Obs.	Calculated.	Observed.	Calcul.	
Substitution of Chlorine in Hyduret of Benzoyl.						
C ¹⁴ H ¹² O ²	1337	1282	...	...	1.043	Liebig & Wöhler.
C ¹⁴ H ¹⁰ O ² Cl ²	1767	...	1282+2.80=1442	1.225	1.196	... 18° C.
Substitution of Chlorine in Oxide of Methyl.						
C ² H ⁴ Cl ² O	719	547	...	...	1.315	Regnault 20°.
C ² H ² Cl ⁴ O	1149	...	547+2.80=707	1.626	1.606	... ..
Substitution of Chlorine in Acetate of the Oxide of Methyl.						
C ⁶ H ¹² O ⁴ ...	930	1012	...	...	0.919	{ Dumas & Peli- got 22°.
C ⁶ H ⁸ Cl ⁴ O ⁴	1790	...	1012+4.80=1332	1.344	1.261	
Substitution of Chlorine in Oxide of Æthyl.						
C ⁴ H ¹⁰ O.....	466	643	...	...	0.724	Gay-Lussac 12°.
C ⁴ H ⁶ Cl ⁴ O	1326	...	643+4.80=963	1.377	1.501	Malaguti.
Substitution of Chlorine in Acetic Æther.						
C ⁸ H ¹⁶ O ⁴ ...	1107	1244	...	...	0.89	Liebig 15°.
C ⁸ H ¹² Cl ⁴ O ⁴	1967	...	1244+4.80=1564	1.258	1.301	Malaguti 12°.
Substitution of Chlorine in Formic Æther.						
C ⁶ H ¹² O ⁴ ...	930	1020	...	...	0.912	Liebig.
C ⁶ H ⁸ Cl ⁴ O ⁴	1790	...	1020+4.80=1340	1.336	1.261	Malaguti 16°.
Substitution of Chlorine in Camphoric Æther.						
C ¹⁴ H ²⁴ O ⁴ ..	1612	1566	...	...	1.029	Malaguti 16°.
C ¹⁴ H ²⁰ Cl ⁴ O ⁴	2472	...	1566+4.80=1886	1.311	1.386	... 14°.
Substitution of Chlorine in Benzol (Benzin).						
C ¹² H ¹²	985	1159	...	...	0.85	Mitscherlich.
C ¹² H ⁶ Cl ⁶ ...	2276	...	1159+6.80=1639	1.389	1.457	... 7°.
Substitution of Chlorine in Aldehyd.						
C ⁴ H ⁸ O ²	553	700	...	...	0.79	Liebig 18°.
C ⁴ H ² Cl ⁶ O ²	1844	...	700+6.80=1180	1.563	1.502	... ..
Substitution of Chlorine in Hydrated Acetic Acid.						
C ⁴ H ⁸ O ⁴	753	709	...	...	1.063	Mollérat.
C ⁴ H ² Cl ⁶ O ⁴	2044	...	709+6.80=1189	1.719	1.617	Dumas 64°.
Substitution of Chlorine in Cœnanthic Æther.						
C ¹⁸ H ³⁶ O ³ ...	1890	2193	...	...	0.862	Liebig & Pelouze.
C ¹⁸ H ²⁸ Cl ⁸ O ³	3612	...	2193+8.80=2833	1.275	1.291	Malaguti 16°.
Substitution of Chlorine in Sulphuret of Æthyl.						
C ⁴ H ¹⁰ S.....	567	687	...	...	0.825	Regnault 20°.
C ⁴ H ² Cl ⁸ S...	2288	...	687+8.80=1327	1.724	1.673	... 24°.
Substitution of Chlorine in Chloride of Methyl.						
C ² H ⁴ Cl ⁴ ...	1062	790	...	...	1.344	Regnault 18°.
C ² H ² Cl ⁶	1492	...	790+2.80=950	1.571	1.480	Liebig 18°.
C ² Cl ⁸	1922	...	790+4.80=1110	1.731	1.599	Regnault 1°.

Where several substitutions occur successively, it is requisite to calculate from each of the compounds examined the density of the other, so that any accidental error of experiment may not be allowed to have too great an influence. To be as precise as possible, I will here take for calculation two of the best-examined compounds, one containing the greatest number of atoms of hydrogen, and the other the greatest number of atoms of chlorine.

Substitution of Chlorine in Chloride of Æthyl.						
If we calculate from the combination $C^4 H^{10} Cl^2$,						
Formula.	Atomic weight.	Specific volume.		Density.		
		Obs.	Calculated.	Observed.	Calcul.	
$C^4 H^{10} Cl^2$	808	925	...	...	0.874	Thenard 5°.
$C^4 H^8 Cl^4$	1239	...	$925 + 2.80 = 1085$	1.142	1.174	Regnault 17°.
$C^4 H^6 Cl^6$	1669	...	$925 + 4.80 = 1245$	1.341	1.372	... 16°.
$C^4 H^4 Cl^8$	2099	...	$925 + 6.80 = 1405$	1.494	1.530	... 17°.
$C^4 H^2 Cl^{10}$	2529	...	$925 + 8.80 = 1565$	1.616	1.644	... 17°.
$C^4 Cl^{12}$	2959	...	$925 + 10.80 = 1725$	1.715	nearly 2	Faraday.
If we calculate from the compound $C^4 H^2 Cl^{10}$,						
$C^4 H^2 Cl^{10}$	2529	1538	...	...	1.644	Regnault.
$C^4 H^{10} Cl^2$	808	...	$1538 - 8.80 = 898$	0.900	0.874	Thenard 5°.
$C^4 H^8 Cl^4$	1239	...	$1538 - 6.80 = 1058$	1.171	1.174	Regnault 17°.
$C^4 H^6 Cl^6$	1669	...	$1538 - 4.80 = 1218$	1.370	1.372	... 16°.
$C^4 H^4 Cl^8$	2099	...	$1538 - 2.80 = 1378$	1.523	1.530	... 17°.
$C^4 Cl^{12}$	2959	...	$1538 + 2.80 = 1698$	1.743	nearly 2	Faraday.

From this table it becomes evident that the law above advanced is generally confirmed by experiment. However, the calculated densities frequently differ more from those observed than was the case for the other laws. This arises from various circumstances.

It is very difficult to obtain by substitution a pure compound, one which is not rendered impure by the presence of another preceding or following degree of substitution. This uncertainty in the preparation of the compounds, to which Berzelius has drawn particular attention, is the cause that the statement of various observers are often in contradiction. In the 41st volume of the *Annalen der Chemie und Pharmacie*, I have treated at length of the uncertainty and contradiction of the observations on such compounds, and have shown that the differences between the observations are not smaller than those between the calculated and the observed magnitudes.

Another reason why the calculation does not always agree accurately with the experiment, is that the temperatures at

which the comparison between the specific volumes should properly be made, have always been neglected. Without doubt such a comparison is, strictly speaking, only then admissible when the temperatures are equidistant from the boiling points; but all observations have been made at mean temperature, and this accounts for the differences between the results of calculation and those of observation. On this account all the numbers in the above laws must be regarded as being merely approximative.

The less the boiling points of the corresponding compounds differ from each other, the greater will be the agreement of the calculated results with those of observation. Since the corresponding compounds of æthyl and methyl differ only by 18° C. in their boiling points, the neglecting the circumstance of at what temperature the specific weights should be compared, has very slight influence in the consideration of these compounds; but where it is a question of replacement of hydrogen by chlorine it is totally different, as the boiling point rises rapidly with the increase of chlorine.

Unfortunately, the observations on the boiling points of substitution compounds are far more contradictory than those on their specific weights, and the uncertainty is too great to allow us at present to state with accuracy how many degrees the boiling point rises when x atoms of chlorine take the place of x atoms of hydrogen.

The best observations seem however to indicate, that for substitution compounds, which can be compared with regard to their condensation or specific weight in the gaseous form, the boiling point is raised $x \cdot 12^{\circ}$ C. by the substitution of x atoms of chlorine for x atoms of hydrogen. Let D be the number of degrees the boiling point is raised by the substitution of one atom of chlorine for one of hydrogen, we have from the best observations,—

Hydrated acetic acid and chloro-acetic acid,

$$\left. \begin{array}{ll} \text{C}^4 \text{H}^8 \text{O}^4 & 120 \text{ Liebig} \\ \text{C}^4 \text{H}^2 \text{O}^4 \text{Cl}^6 & 195 \text{ Dumas} \end{array} \right\} 6 D = 75^{\circ}; D = 12^{\circ} \cdot 5.$$

Aldehyd and chloral,

$$\left. \begin{array}{ll} \text{C}^4 \text{H}^8 \text{O}^2 & 21 \cdot 8 \text{ Liebig} \\ \text{C}^4 \text{H}^2 \text{Cl}^6 \text{O}^2 & 94 \quad \dots \end{array} \right\} 6 D = 72 \cdot 2; D = 12^{\circ} \cdot 0.$$

Several other observations, which however I do not regard as perfectly admissible, and do not consider as fit for the establishment of the law, agree in this respect. If we calculate for several substitution compounds the boiling points of all the other compounds from that which has the lowest boiling

point, and compare them with those afforded by observation, we obtain the following table:—

Boiling point C.			
	Calculated.	Observed.	
$C^4 H^{10} S$	.....	73	Regnault.
$C^4 H^2 Cl^8 S$	$73 + 8 \cdot 12 = 169$	160	...
$C^2 H^4 Cl^4$	.....	30.5	...
$C^2 H^2 Cl^6$	$30.5 + 2 \cdot 12 = 54.5$	60.8	...
$C^2 Cl^8$	$30.5 + 4 \cdot 12 = 78.5$	78.0	...

But, as I have already stated, too much uncertainty prevails respecting the boiling points to allow of our determining the numbers in a law with absolute accuracy: the existence of a law of the form which has been proposed is beyond doubt.

When the specific volumes of a body are known for all temperatures, those of an analogous compound always differ by a constant magnitude, and the knowledge of the specific weight, and of the expansion of the first and of the specific weight of the latter for any temperature, consequently gives the expansion of the latter.

It is scarcely necessary to call attention to the importance of these laws; they are for the determination of the physical properties of chemical compounds what the law of definite proportions is for the knowledge of their constitution.

XXIX. *On the Constitution of the Atmosphere.* By JAMES IVORY, K.H., M.A., Hon. M.R.I.A., Instit. Reg. Sc. Paris, et Reg. Soc. Götting. Corresp.*

IT is known that atmospheric air is a mixture of several gases and of aqueous vapour. The quantity of aqueous vapour amounts, at a maximum, only to an inconsiderable proportion of the whole volume, and often to so small a proportion as to be insensible in its effect. We may therefore, for the sake of simplicity, suppose, in the first place, that the air of the atmosphere contains no vapour of water, or is in a dry state. The constituent gases of air, as far as they have been estimated, are three, oxygen, azote, and carbonic acid, but as this last never exceeds $\frac{1}{1000}$ th of the mixture, we may neglect it and consider air as containing only oxygen and azote.

Let us now take a portion of oxygen, one of azote, and one of atmospheric air; p and θ representing the pressure and temperature common to all the three fluids; and their densities and volumes being respectively ρ, v ; ρ', v' ; and R, V . We shall have, by the law of Mariotte,

* Communicated by the Author.