THE USE OF ALGEBRA IN WRITING CHEMICAL EQUATIONS.

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A chemical equation may be regarded as a representation by means of special symbols of the material transformations that take place in a chemical reaction. We have the facts of the reaction established by experiment and measurement of weight or volume, the numbers called atomic weights, and the formulas of the compounds determined by analysis.

Our procedure then is (1) to form a tentative equation writing the formulas of the factors on the left and those of the products on the right and (2) to make the equation "balance" by writing in the proper coefficients.

How do we determine these coefficients? Various methods are in use as "by inspection," by the principles of valence, by the principles of the theory of electrolytic dissociation, successive reactions, or by mere memory. Perhaps many prefer to remember that in the reaction between copper and dilute nitric acid yielding nitric oxide as one of the products, the coefficient of the copper and nitric acid are, respectively, 3 and 8, or in the reaction in which potassium permanganate acts as an oxidizing agent in acid solution, two molecular weights of potassium permanganate yield five atomic weights of oxygen for oxidizing purposes.

There are cases, however, where the determination of the coefficient by any of the foregoing methods presents considerable difficulty. The problem is fundamentally algebraic. Why not then try the application of algebra for its solution? Leaving aside all considerations other than weight relations, the problem may be put thus: By what numbers shall the molecular weights be multiplied, so that the products so obtained shall stand in the ratio of the weights of the substances taking part in the reaction?

Let us suppose we have shown by experiment that kaolinite heated with concentrated sulphuric acid yields aluminun sulphate, metasilicic acid and water, and wish to represent the fact by an equation. We write:

$$x\ H_4Al_2Si_2O_9 + y\ H_2SO_4 = z\ Al_2(SO_4)_3 + w\ H_2SiO_3 + t\ H_2O$$

Now since the equations must balance, the hydrogen on one side, $4x+2y$ must equal the hydrogen on the other, $2w+2t$

$$\text{or, } 4x+2y = 2w+2t$$

$$(1) \qquad \text{or } 2x+y = w+t$$

The same is true for the aluminum, hence

$$2x = 2z$$

(2) $x = z$

Likewise for the other elements,

(3) $2x = w$

(4) $9x + 4y = 12z + 3w + t$

(5) $y = 3z$

Since the same value of x must satisfy all the relations the equations are simultaneous. Let us find an expression for the value of each unknown quantity in terms of some one chosen unknown quantity. We choose z

(6) In (2) $x = z$

(7) In (5) $y = 3z$

(8) From (3) and (6) $w = 2z$

From (1), (6), (7) and (8) $t = 3z$

Assigning for the value of z the smallest number that will make the values of the other unknown quantities integers, (the form is frequently fractional) namely, we have $x = 1$, $y = 3$, $z = 1$, $w = 2$, and $t = 3$, which values written as coefficients in the equation, it will be found to balance.

We did not make use of the equation (4) because we were able to obtain an expression of the value of each unknown quantity in terms of z without it. We are seeking to establish only relative values, for any multiples of the values found would make the chemical equation balance. The values found will, however, satisfy equation (4) also.

A few more examples are given to show the working of the method. Sulphuric acid and potassium mangnate yield potassium permanganate, potassium sulphate, manganous acid and water.

$$x\ H_2SO_4 + y\ K_2MnO_4 = z\ KMnO_4 + wK_2SO_4 + t\ H_2MnO_3 + s\ H_2O$$

$$2x = 2t + 2s$$

$$x = t + s$$

$$x = w$$

$$4x + 4y = 4z + 4w + 3t + s$$

$$2y = z + 2w$$

$$y = z + t$$

$$4y = 4z + 3t + s$$

$$4y = 4z + 4t$$

$$o = t - s$$

$$s = t$$

$$x = 2t$$

$$w = 2t$$

$$z+2t=4t$$
$$z=2t$$
$$y=z+t=3t$$

Let $t=1$, then $x=2$, $y=3$, $z=2$, $w=2$, $t=1$ and $s=1$.

Copper and nitric acid yield copper nitrate, nitric oxide and water.

$$x\,Cu+y\,HNO_3=z\,Cu(NO_3)_2+w\,NO+t\,H_2O$$

$$x=z$$
$$y=2t$$
$$y=2z+w$$
$$3y=6z+w+t$$
$$3y=6z+3w$$
$$o=t-2w$$
$$2w=t$$
$$w=\frac{t}{2}$$

$$2t=2z+\frac{t}{2}$$
$$2z=2t-\frac{t}{2}$$
$$z=\frac{3t}{4}$$
$$x=\frac{3t}{4}$$
$$y=2t$$

Let $t=4$, then $x=3$, $y=8$, $z=3$ and $w=2$.

The student of elementary chemistry is generally at the time well trained in algebraic manipulation and will readily handle the method. Lest he is led to put too much dependence on the mere balancing of an equation, his attention may be called to the fact that balancing is not a criterion of its chemical correctness, and illustrations such as:

$$Pt+H_2SO_4=Pt\,SO_4+H_2 \text{ or}$$
$$4HCl+SiO_2=SiCl_4+2H_2O \text{ may be given.}$$

The method may be outlined as follows: From the statement of the reaction write a tentative chemical equation using the symbols x, y, z, etc. in the place of coefficients. Form algebraic equations, involving these quantities, one equation for each element. Regarding these equations simultaneous, find an expression for the value of each unknown quantity in terms of one chosen unknown quantity. Assign a value to the chosen unknown quantity, which will render the values of the other unknown quantities integral. The intergers so obtained will be suitable for coefficients in the chemical equation.