Some Interesting Methods of Balancing Oxidation-reduction Equations

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During the past few years the writer has made a sort of hobby of the subject of balancing equations. During the years 1931-1934 there was a continuous series of correspondence on the merits of the various methods in the Journal of Chemical Education. Nothing was settled as to the best method of balancing equations, but it is the opinion of the writer that the valence-change method (1) is the most rapid and dependable while the ion-electron (2) method is the most in keeping with our modern knowledge and the most instructive, but a little tedious. A third method which is always interesting to students and teacher alike is the algebraic method (3). The latter method is hardly suitable for use but has in it an element of surprise because few people realize that complex equations may be accurately balanced by mere algebra without recourse to valence considerations of some kind.

Let us select a sample equation such as: $Cu + HNO_3 \rightarrow Cu(NO_3)_2 + NO + H_2O$ and balance it by each of the methods.

Algebraic method.—This method is based on the assumption that there is a certain number of Cu atoms which we may designate as a; then b HNO_3, etc. Our equation becomes: $a\ Cu + b\ HNO_3 \rightarrow c\ Cu(NO_3)_2 + d\ NO + e\ H_2O$ now for:

Cu	$a = c$
H	$b = 2e$
N	$b = 2c + d$
O	$3b = 6c + d + e$

Since $b = 2e$, for the N equation, we have: $2e = 2c + d$ and for the O equation $6e = 2c + d + e$ or $5e = 6c + d$. Subtracting the first equation from the last, we have: $3e = 4c$, whence $e = 4/3c$.

Let $c = 1$, then: $a = 1$, $e = 4/3$, $b = 8/3$, and $d = 2/3$.

To remove fractions multiply all coefficients by 3. Then: $a = 3$, $b = 8$, $c = 3$, $d = 2$, and $e = 4$, resulting in the orthodox equation:

$$3\ Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$$

As H. G. Deming (4) points out much time can be saved by eliminating two of the unknowns at the start since $a = c$ and $b = 2e$.

Valence-change method.—The valence-change method is so commonly used that there is little need to go into detail beyond the statement that a mutually consistent set of valences is assigned to the elements and from these and the change these valences undergo, a relationship can be set up between the number of molecules of oxidant and reductant. These valences, while not always consistent with our modern knowledge, do lead to rapid, accurate results. In our chosen equation the valence of Cu changes from 0 to 2 in $Cu(NO_3)_2$, a gain of 2, while that of N changes from 5 in HNO_3 to 2 in NO, a loss of 3. To equalize this gain and loss, 3 coppers and 2 nitrogens which change valence are needed. The remainder of the equation is quickly balanced by inspection.

Ion-electron method.—The ion-electron method, while very complicated, has great teaching value. The equation is divided into two partial equations, one for the oxidant, and one for the reductant, using only the ions which are really concerned in the equation. These must be balanced first atomically and then electrically:

$$\text{oxidant } 4H^+ + NO_3^- \rightarrow NO + 2H_2O$$

There are now 4 pluses and 1 minus on the left, making an excess of 3 pluses which may be balanced electrically by the addition of 3 electrons:

$$3e + 4H^+ + NO_3^- \rightarrow NO + 2H_2O$$

Similarly for the reductant:

$$\overset{0}{Cu} \rightarrow Cu^{++} + 2e$$

Since we have 2e and 3e, we must reach the lowest common multiple 6 by multiplying the oxidant equation by 2 and the reductant equation by 3 and then add:

$$\begin{array}{l} 6e + 8H^+ + 2NO_3^- \rightarrow 2NO + 4H_2O \\ 3Cu \rightarrow 3Cu^{++} + 6e \\ \hline 3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{++} + 2NO + 4H_2O \end{array}$$

The equation is now balanced but to be orthodox it should have 6 more nitrate ions on each side. It is seen by the example that the ion-electron method makes no arbitrary assumptions of valence and stands the test of our modern thinking. It may fail to achieve the popularity it deserves due to the fact that it is cumbersome.

BIBLIOGRAPHY

1. Bennett, J. Chem. Education *12,* 189 (1935).
2. Jette and La Mer, J. Chem. Education *4,* 1021 (1927).
3. Endslow, J. Chem. Education *8,* 2453 (1931).
4. Deming, J. Chem. Education *11,* 125 (1934).