Balancing Chemical Equations

Unit: Chemical Reactions

MA Curriculum Frameworks (2016): HS-PS1-7

Mastery Objective(s): (Students will be able to…)

- Apply the law of definite proportions to balance chemical equations.

Success Criteria:

- Equation is balanced such that there are the same number of atoms (moles) of each element on each side of the equation.

Tier 2 Vocabulary: balance

Language Objectives:

- Explain the law of definite proportions and conservation of mass and relate them to chemical equations.

Notes:

A chemical equation needs to describe the chemical formulas and relative number of molecules involved of each molecule that reacts, and each molecule that is produced.

Remember from Dalton's theory of the atom:

"Atoms are neither created nor destroyed in any chemical reaction."

Therefore, not only must we have the same kinds of atoms (same elements) on both sides of a chemical reaction, we need to have the *same number* of each kind of atom before and after the reaction..

Use this space for summary and/or additional notes:

For example, consider the chemical equation:

$$S + O_2 \rightarrow SO_3$$

There are 2 oxygen atoms on the left, but 3 on the right. We can't change the formulas of the molecules that take part in the reaction, so we need to specify different numbers of each molecule to "balance" the equation.

The easiest solution would be to split an O_2 molecule in half:

$$S + 1\tfrac{1}{2}\,O_2 \rightarrow SO_3$$

But we can't have ½ of a molecule of O_2. Therefore, the smallest set of integers that give us the same number of each atom on both sides would be:

$$2\,S + 3\,O_2 \rightarrow 2\,SO_3$$

This works because there are 2 atoms of S and 6 atoms of O on each side of the equation ("before" and "after").

We balanced this equation by inspection, but for more complicated equations, it helps to have a system.

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To balance an equation, start with one element. Put coëfficients in front of the molecules that contain the element so that you have the same number on each side. Then do the same for every other element. For example, to balance the equation:

$$\_N_2 + \_H_2 \rightarrow \_NH_3$$

we need to figure out the coëfficients that go in the blanks. We can start by balancing any element we want, so let's start with nitrogen (N). The smallest numbers that we can use to balance atoms of N are a "1" in front of N_2 and a 2 in front of NH_3. This gives us:

$$\underline{1}\,N_2 + \_H_2 \rightarrow \underline{2}\,NH_3$$

Now we have 2 atoms of N on each side, so N is balanced. Next, we move on to H. We already have a "2" in front of NH_3, which means we have 6 atoms of H on the right side. To get 6 atoms of H on the left side, we need a "3" in front of H_2. This gives us the equation:

$$\underline{1}\,N_2 + \underline{3}\,H_2 \rightarrow \underline{2}\,NH_3$$

We have coefficients in front of all of the products and reactants, so the equation is balanced. For the final form of the equation, we leave out any coëfficient that is "1". (This is just like algebra—we would write "x" instead of "1x".) This gives us:

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

This equation was equally easy to balance regardless of whether we started with N or H, but for more complicated equations, making good decisions about what order to balance the elements in can make a huge difference.

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Strategy for Balancing Equations

1. Figure out which elements to balance First, Middle, and Last. We will refer to this method as the "FML" method.* Always start by deciding which elements to save for last:
    - Last: any element that appears by itself (anywhere in the equation)
    - First: elements that appear in only one molecule on each side (if you haven't already saved them for last).
    - Middle: every element that's not already last or first.
2. Start with any element on the "First" list. Add coëfficients to make it balance.
3. Pick another element. (Work your way through the "First," then "Middle," then "Last" lists.) Start with elements that already have at least one coëfficient, but still need at least one.
4. Repeat step #3 until everything is balanced.

Notes:

- Polyatomic ions usually stay together.
- If you end up with a fraction, write it in temporarily, then multiply *all* of your coëfficients by the denominator of the fraction to get back to whole numbers.

* Now you can say to yourself, "I have to balance this equation? FML."

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Example:

$$H_2SO_4 + HI \rightarrow H_2S + I_2 + H_2O$$

1. Make lists:
   1. Last: I — I appears by itself as I_2 (on the right)
   2. First: S, O — S only appears in H_2SO_4 on the left and H_2S on the right; O only appears in H_2SO_4 on the left and H_2O on the right.
   3. Middle: H appears in two places each on the left and right.

2. Balance "First" elements (S & O; the order doesn't matter):
   a. Let's start with S. Neither H_2SO_4 nor H_2S has a coëfficient, so we choose the smallest pair that works for both: 1 of each:

   $$1\ H_2SO_4 + \_HI \rightarrow 1\ H_2S + \_I_2 + \_H_2O$$

   b. Next balance O. We already have a "1" in front of H_2SO_4, which means we have 4 atoms of O on the left. This means we need a "4" in front of H_2O to have 4 atoms of O on the right.

   $$1\ H_2SO_4 + \_HI \rightarrow 1\ H_2S + \_I_2 + 4\ H_2O$$

3. Balance "Middle" elements (H). We have a total of 10 H atoms on the right (2 in the 1 H_2S and 8 more in the 4 H_2O), and our coëfficients only show 2 H atoms so far on the left. This means we need an "8" in front of HI for the remaining 8 atoms of H.

   $$1\ H_2SO_4 + 8\ HI \rightarrow 1\ H_2S + \_I_2 + 4\ H_2O$$

4. Balance "Last" elements (I). We have 8 atoms of I on the left, which is 4 molecules of I_2.:

   $$1\ H_2SO_4 + 8\ HI \rightarrow 1\ H_2S + 4\ I_2 + 4\ H_2O$$

5. For the final answer, leave out any coëfficient of 1:

   $$H_2SO_4 + 8\ HI \rightarrow H_2S + 4\ I_2 + 4\ H_2O$$

Use this space for summary and/or additional notes:

Homework Problems

Set #1 (Easier)

Balance the following chemical equations.

1. $H_2 + \quad O_2 \rightarrow \quad H_2O$

2. $S_8 + \quad O_2 \rightarrow \quad SO_3$

3. $HgO \rightarrow \quad Hg + \quad O_2$

4. $Zn + \quad HCl \rightarrow \quad ZnCl_2 + \quad H_2$

5. $Na + \quad H_2O \rightarrow \quad NaOH + \quad H_2$

6. $C_{10}H_{16} + \quad Cl_2 \rightarrow \quad C + \quad HCl$

7. $Si_2H_3 + \quad O_2 \rightarrow \quad SiO_2 + \quad H_2O$

8. $Fe + \quad O_2 \rightarrow \quad Fe_2O_3$

9. $C_7H_6O_2 + \quad O_2 \rightarrow \quad CO_2 + \quad H_2O$

Use this space for summary and/or additional notes:

10. FeS_2 + O_2 → Fe_2O_3 + SO_2

11. Fe_2O_3 + H_2 → Fe + H_2O

12. K + Br_2 → KBr

13. C_2H_2 + O_2 → CO_2 + H_2O

14. H_2O_2 → H_2O + O_2

15. C_7H_{16} + O_2 → CO_2 + H_2O

16. SiO_2 + HF → SiF_4 + H_2O

17. $KClO_3$ → KCl + O_2

18. $KClO_3$ → $KClO_4$ + KCl

19. P_4O_{10} + H_2O → H_3PO_4

20. Sb + O_2 → Sb_4O_6

Use this space for summary and/or additional notes:

Homework Problems

Set #2 (More Challenging)

Balance the following chemical equations.

1. $Pb(NO_3)_2 \rightarrow$ PbO + NO_2 + O_2

2. Ca_3P_2 + $H_2O \rightarrow$ $Ca(OH)_2$ + PH_3

3. Ca + $AlCl_3 \rightarrow$ $CaCl_2$ + Al

4. $H_3PO_3 \rightarrow$ H_3PO_4 + PH_3

5. C_6H_6 + $O_2 \rightarrow$ CO_2 + H_2O

6. Al_4C_3 + $H_2O \rightarrow$ CH_4 + $Al(OH)_3$

7. Ag_2S + $KCN \rightarrow$ $KAg(CN)_2$ + K_2S

8. $MgNH_4PO_4 \rightarrow$ $Mg_2P_2O_7$ + NH_3 + H_2O

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