Chemical Reactions 2

The Chemical Equation

INFORMATION

Chemical equations are symbolic devices used to represent actual chemical reactions. The left side of the equation, called the **reactants**, is separated with an arrow (→) from the right side of the equation, called the **products**.

A generic chemical equation is shown below:

$$A + B \rightarrow C + D$$

A and B represent reactants; C and D represent products.

Consider the following equation, which represents a real reaction:

$$\mathbf{Pb(NO_3)_{2\,(aq)} + 2KI_{\,(aq)} \rightarrow 2KNO_{3\,(aq)} + PbI_{2\,(\downarrow)}}$$

Chemical equations can also be written verbally. For example, the above equation in verbal form would look like this:

Lead(II) nitrate and potassium iodide react to form potassium nitrate and lead(II) iodide

Of course, before any meaningful work can be done using this reaction, it must be converted to its chemical formula version. This requires a thorough understanding of chemical nomenclature[1].

There are several components of this equation:

1. **Chemical formulas** – the reactants and products are represented by their chemical formulas. A reactant is sometimes referred to as a **reagent**.
2. **States of matter** – each chemical formula is followed by a parenthesized code that indicates the state of matter of the substance it follows: (s) represents a *solid*, (l) represents a *liquid*, (g) represents a *gas*, (aq) represents *aqueous* (dissolved in water), and (↓) represents a *precipitate*.
3. **"Yields" arrow** – the arrow (→) indicates that a reaction has occurred and that the reactants have been converted to the products. In reversible reactions, the arrow is replaced by a two-headed arrow (↔) to show that the reaction proceeds in both directions. A "Δ" or the word "heat" over the arrow indicates that heat is supplied to the reaction. A chemical formula above or below the arrow indicates its use as a catalyst in the reaction.
4. **"+" signs** – this symbol does not indicate mathematical addition in the strictest sense; it is a convention for separating species in an equation.
5. **Molar coefficients** – these integers that precede a reactant or product represent the number of moles present for the compound to which they are attached (see *Balancing Equations*, below).

[1] See the series **POGIL 01 – Nomenclature and Formula Writing** for a comprehensive tutorial on inorganic nomenclature.

Balancing Equations

Balanced equations represent the core of understanding and working with all chemical reactions. The purpose of using coefficients on some compounds (if any) is to ensure that the equation is properly **balanced**; that is, that the same total number of atoms (or ions) of each element can be found on both sides of the equation.

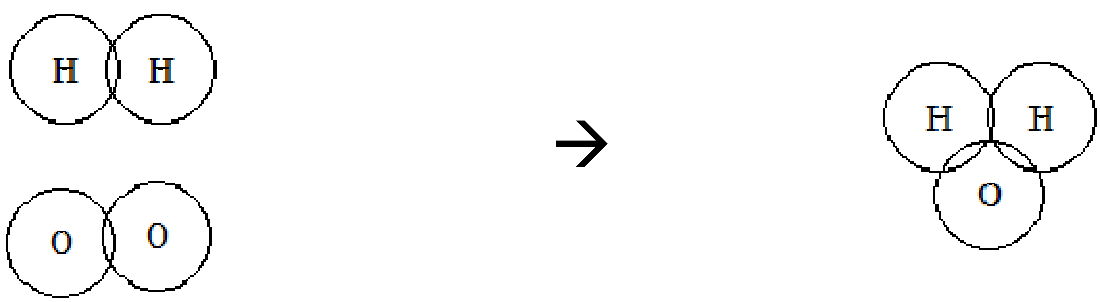
Balancing an equation guarantees that there an equal number of all atoms on the reactants side and products side of the reaction. Also, when calculations are performed to determine specific quantities consumed or produced in reactions, only a balanced equation can provide the information necessary for accurate results.

The procedure for balancing equations is simple: count the number of each atom on each side of the equation, and use coefficients to *multiply* the number of atoms on one side of the equation in an effort to balance the other side. Remember, *if you multiply a formula to change the number of one atom present in the formula, all of the atoms in the compound must be multiplied by that same factor.* For example, multiplying H_2O by 2 results in 4 H atoms (coefficient of 2 times the subscript of 2) and 2 oxygen atoms (coefficient of 2 times the subscript of 1).

Look at the simple reaction of hydrogen gas and oxygen gas combining to form water:

$$H_{2\,(g)} + O_{2\,(g)} \rightarrow H_2O_{\,(l)}$$

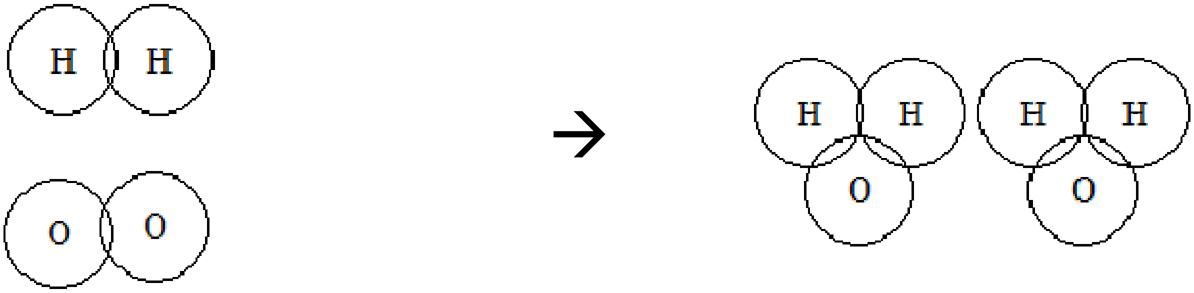
In this equation, we begin 2 hydrogen atoms and 2 oxygen atoms on the left (reactants), and 1 H_2O molecule (which is 2 hydrogen atoms and 1 oxygen atom) on the right (products):



As shown by the diagram, there is one more oxygen atom on the reactants side of the equation than on the products side. To resolve this, we can multiply the H_2O molecule by 2 to get the necessary two oxygen atoms required:

$$H_{2\,(g)} + O_{2\,(g)} \rightarrow \mathbf{2}H_2O_{\,(l)}$$

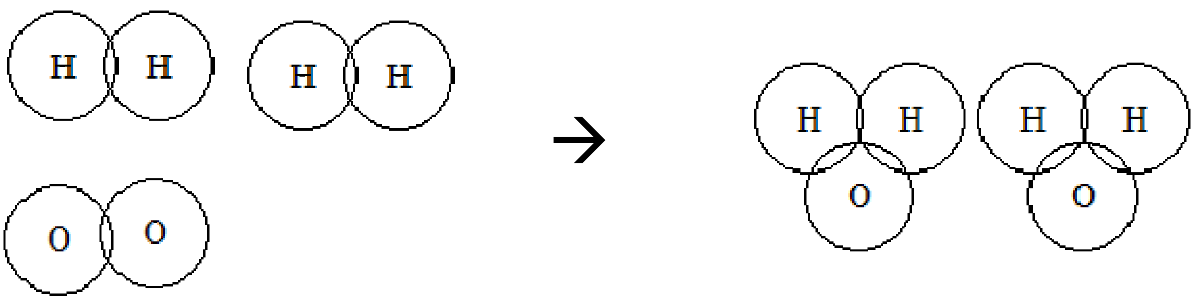
And our diagram now looks like this:



The two requisite oxygen atoms are now present on the right. However, because the H_2O molecules cannot be broken apart to simply add an oxygen atom to products, the number of hydrogen atoms is *also* doubled. There are now 4 hydrogen atoms in the products, but only 2 in the reactants. This is remedied by adding coefficient of 2 to the H_2 molecule on the reactants side of the equation:

$$\mathbf{2}H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(l)}$$

And our diagram now looks like this:



Both sides of the equation now have 4 hydrogen atoms and 2 oxygen atoms. This equation is balanced, and looks like this:

$$\mathbf{2H_{2\,(g)} + O_{2\,(g)} \rightarrow 2H_2O_{(l)}}$$

For now, equations will only be balanced using integers. If all of the coefficients share a common factor, they must be simplified to their smallest integer values.

Key Questions

1. Use a few grammatically correct sentences to explain the procedure for obtaining a balanced chemical equation.

2. Why do you think it is a good practice to balance using integer coefficients, rather than allowing decimals?

3. A precipitate is a solid product that forms as the result of the reaction of two aqueous (dissolved in water) reactants. Why do think precipitates are represented by a (↓) rather than (s)?

4. How many oxygen atoms are present in $Al_2(Cr_2O_7)_3$? Explain how you determined this.

Student Name: ____ Pd. ______ Date: ____________

Supplementary Exercises
Balancing Chemical Equations

1. _____ H_2 + _____ O_2 => _____ H_2O
2. _____ H_3PO_4 + _____ KOH => _____ K_3PO_4 + _____ H_2O
3. _____ K + _____ B_2O_3 => _____ K_2O + _____ B
4. _____ HCl + _____ NaOH => _____ NaCl + _____ H_2O
5. _____ Na + _____ $NaNO_3$ => _____ Na_2O + _____ N_2
6. _____ C + _____ S_8 => _____ CS_2
7. _____ Na + _____ O_2 => _____ Na_2O_2
8. _____ N_2 + _____ O_2 => _____ N_2O_5
9. _____ H_3PO_4 + _____ $Mg(OH)_2$ => _____ $Mg_3(PO_4)_2$ + _____ H_2O
10. _____ NaOH + _____ H_2CO_3 => _____ Na_2CO_3 + _____ H_2O
11. _____ KOH + _____ HBr => _____ KBr + _____ H_2O
12. _____ H_2 + _____ O_2 => _____ H_2O_2
13. _____ Na + _____ O_2 => _____ Na_2O
14. _____ $Al(OH)_3$ + _____ H_2CO_3 => _____ $Al_2(CO_3)_3$ + _____ H_2O
15. _____ Al + _____ S_8 => _____ Al_2S_3
16. _____ Cs + _____ N_2 => _____ Cs_3N
17. _____ Mg + _____ Cl_2 => _____ $MgCl_2$
18. _____ Rb + _____ $RbNO_3$ => _____ Rb_2O + _____ N_2
19. _____ C_6H_6 + _____ O_2 => _____ CO_2 + _____ H_2O
20. _____ N_2 + _____ H_2 => _____ NH_3
21. _____ $C_{10}H_{22}$ + _____ O_2 => _____ CO_2 + _____ H_2O
22. _____ $Al(OH)_3$ + _____ HBr => _____ $AlBr_3$ + _____ H_2O
23. _____ C_4H_{10} + _____ O_2 => _____ CO_2 + _____ H_2O
24. _____ C + _____ O_2 => _____ CO_2
25. _____ C_3H_8 + _____ O_2 => _____ CO_2 + _____ H_2O