CHEM110 – Chapter 3 Chemical Reactions and Stoichiometry

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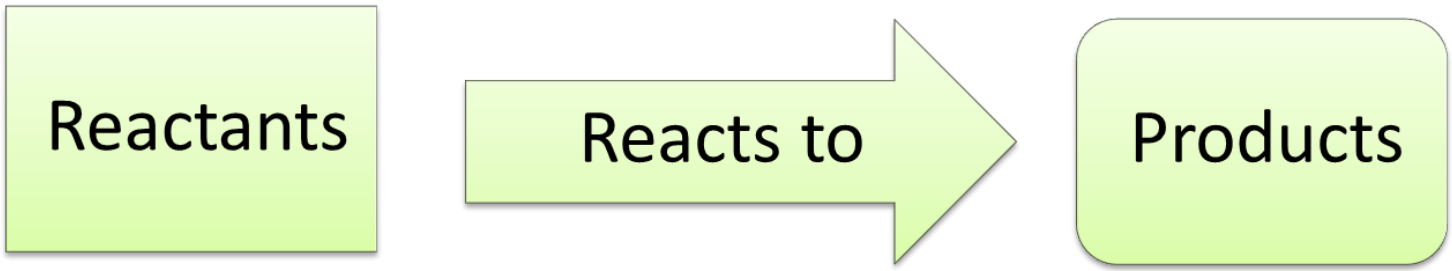
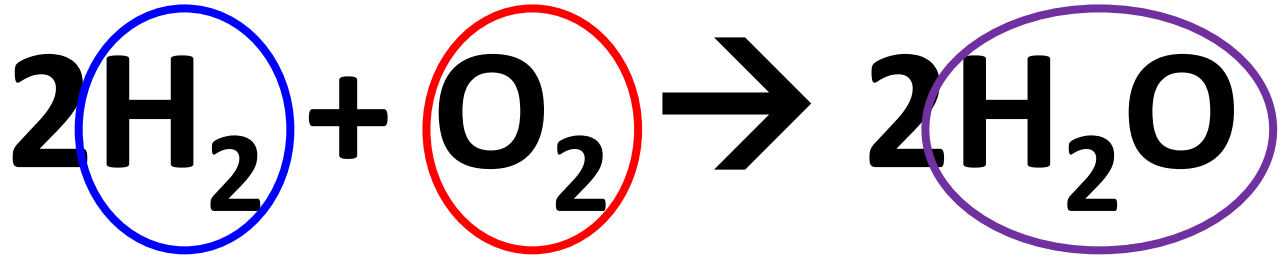
3.1 Chemical Equations

- Summarize information about chemical reactions
- A chemical reaction is the mixing of two or more species (reactants) to produce new substances (products)

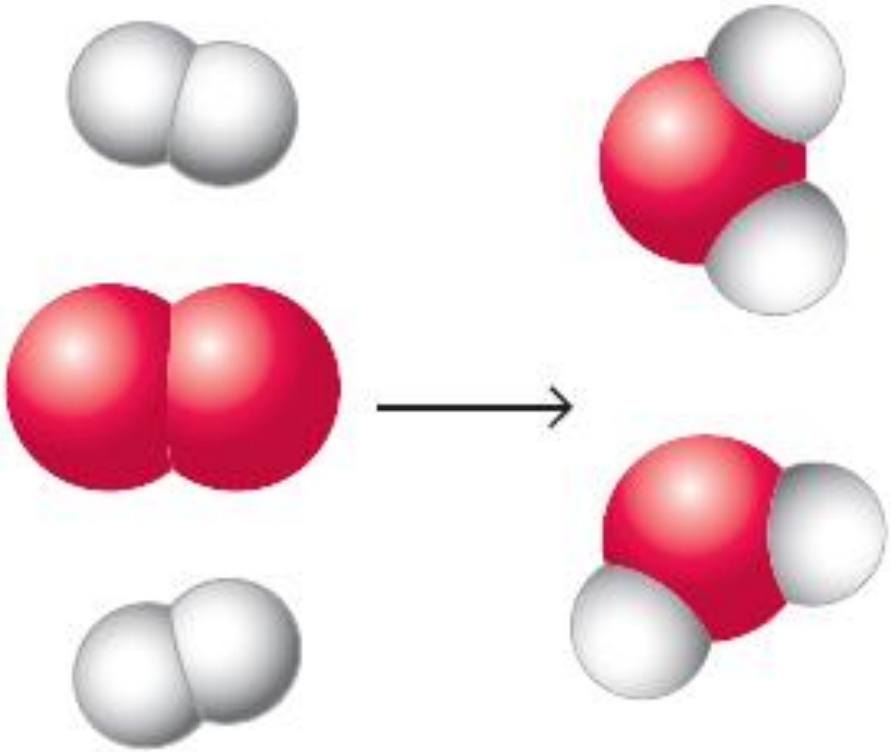


3.1 Chemical Equations



This reaction tells us that hydrogen and oxygen react together to form water

3.1 Chemical Equations



$$2H_2 + O_2 \longrightarrow 2H_2O$$

FIGURE 3.1 The reaction between 2 molecules of hydrogen and 1 molecule of oxygen gives 2 molecules of water as depicted by the space-filling models and chemical equation shown here.

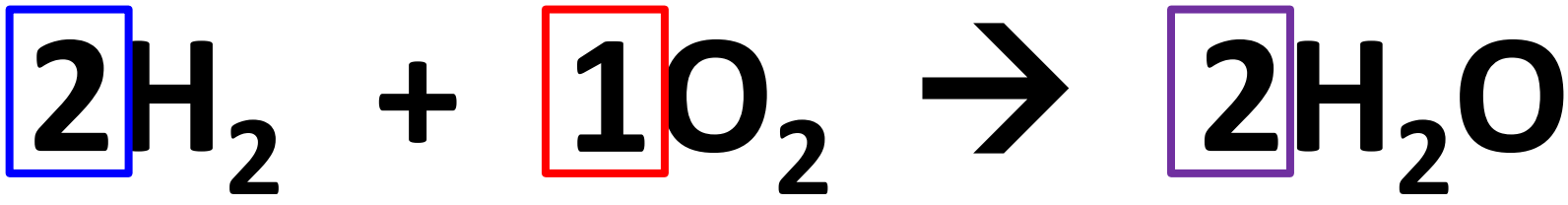
3.1 Chemical Equations

- What you start with → REACTANTS
- What you finish with → PRODUCTS
- Relative amounts → STOICHIOMETRY

3.1 Chemical Equations

$$2H_2 + 1O_2 \rightarrow 2H_2O$$

3.1 Chemical Equations



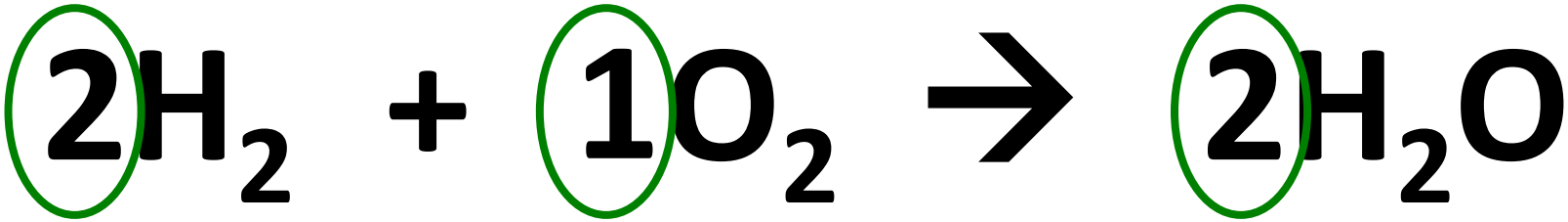
This chemical equation tells us that …

two (2) hydrogens react with

one (1) oxygen to form

two (2) waters

3.1 Chemical Equations

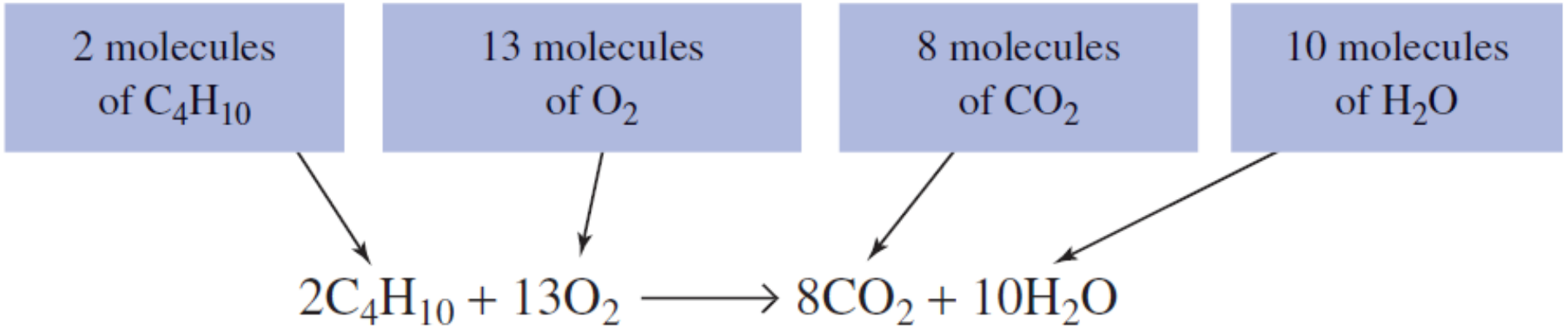


STOICHIOMETRIC COEFFICIENTS

Required to ensure conformation to the law of conservation of mass → no atoms created or destroyed!

3.1 Chemical Equations

Figure 3.2



Law of Conservation of Mass → Stoichiometric coefficients are used to balance an equation to meet this condition

3.1 Chemical Equations

- **Specify the physical states of matter**
  - **(s) for solid**
  - **(l) for liquid**
  - **(g) for gas**
  - **(aq) meaning 'aqueous solution'**

$$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Practice Question 3.1 – page 73

How many atoms of each element appear on each side of the arrow in the following equation?

$$Mg(OH)_2 + HCl \rightarrow MgCl_2 + 2H_2O$$

Practice Question 3.2 – page 73

Rewrite the following equation to show that $Mg(OH)_2$ is a solid, HCl and $MgCl_2$ are dissolved in water, and H_2O is a liquid.

$$Mg(OH)_2 + HCl \rightarrow MgCl_2 + 2H_2O$$

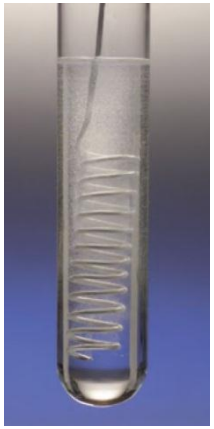
3.2 Balancing Chemical Equations

- A chemical equation is balanced when the number and type of atoms present in the reactants are equal to the number and type of atoms present in the products

- Arrangement of atoms is not relevant in balancing → only number and type

3.2 Balancing Chemical Equations

1. **Write the unbalanced 'equation' → organize the formulae in the pattern of an equation with plus signs and arrows**



$$Al(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2(g)$$

Count the number of each element present.

Is the equation balanced?

3.2 Balancing Chemical Equations

2. **Adjust the coefficients so that the equation is balanced**

   a) **Balance elements other than H and O**
   b) **Balance polyatomic ions as a group**
   c) **Balance ions to balance charge**
   d) **Balance lone elements or ions**
   e) **Balance H and O by adding H_2O or OH^-**

Most Common Polyatomic Ions

OH^- → hydroxide	$(OH)^-$
NO_3^- → nitrate	$(NO_3)^-$
SO_4^{2-} → sulphate	$(SO_4)^{2-}$
PO_4^{3-} → phosphate	$(PO_4)^{3-}$
CO_3^{2-} → carbonate	$(CO_3)^{2-}$
CH_3COO^- → acetate	$(CH_3COO)^-$
ClO_3^- → chlorate	$(ClO_3)^-$
NH_4^+ → ammonium	$(NH_4)^+$

You must know these as well as you know your own name!

3.2 Balancing Chemical Equations

$Al(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2(g)$

1 x Al	1 x Al
1 x H	2 x H
1 x Cl	3 x Cl

Not Balanced

$2Al(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2(g)$

2 x Al	2 x Al
6 x H	6 x H
6 x Cl	6 x Cl

Balanced

3.2 Balancing Chemical Equations

DO NOT CHANGE THE CHEMICAL FORMULAE!!!!!!

→When balancing chemical equations you can only change the stoichiometric coefficients (the "big" number out the front of each reactant or product)

→You CANNOT change the subscripts as this changes the substance!!!!

Worked Example 3.1 – page 74

Aqueous solutions of calcium hydroxide, $Ca(OH)_2$, and phosphoric acid, H_3PO_4, react to give calcium phosphate, $Ca_3(PO_4)_2$, and water. The calcium phosphate precipitates from solution. Write the balanced equation for this reaction.

3.3 The Mole

$$A + 2B \rightarrow AB_2$$

- What if you wanted to actually do this in the lab?
- Can we count out how many atoms we need?
- What would they do in a bearing shop if you ordered 500 000 o-rings?

3.3 The Mole

- How do we know how much of each reactant to weigh out?

$$A + 2B \rightarrow AB_2$$

- Should I weigh out twice as much of B as A?

- No … A and B have different weights!

3.3 The Mole

- **Some of the information we need to work out how much reactant to weigh out is in the balanced chemical equation!**

- **First we must meet (or get reaquainted with) the MOLE!**

- **1 mole = 6.022×10^{23}**

3.3 The Mole

- 1 mole = 6.022×10^{23}
- 1 dozen = 12
- A mole of C atoms = 6.022×10^{23} ^{12}C atoms
- We know how much each atom weighs (it is on the periodic table)
- 1 x C atom = 12.01 u

3.3 The Mole

$$12.01\,\text{u}\left(\frac{1.66054\times10^{-24}\ \text{g}}{1\,\text{u}}\right)=1.9943\times10^{-23}\,\text{g}$$

Therefore 1 x C atom weighs 1.9926 x 10^{-23} g

$$1.9943\times10^{-23}\,\text{g}\ \times\ (6.022\times10^{23})=12.01\,\text{g}$$

Therefore 1 mol of C weighs 12.01 g

More formally → the molar mass of C is 12.01 g mol^{-1}

3.3 The Mole

IMPORTANT → The atomic masses given on the periodic table are:

- **The mass of one atom in units of 'u'**
- **The mass of one mole in units of 'g mol^{-1}'**

3.3 The Mole

- **What is the molar mass of water (H_2O)?**

– **The chemical formula tells us it is made up of 2 hydrogen atoms and 1 oxygen atom**

– **Hence the molar mass is:**

$$M_{H_2O} = (2 \text{ x H}) + (1 \text{ x O})$$
$$= (2 \times 1.008 \text{ g mol}^{-1}) + 16.00 \text{ g mol}^{-1}$$
$$= 18.02 \text{ g mol}^{-1}$$

3.3 The Mole

- The number of specified entities in a mole is constant
- The mass of 1 mole depends on the mass of the individual entities

Figure 3.5

3.3 The Mole

$$A + 2B \rightarrow AB_2$$

- Chemical equation tells us 1 x A for every 2 x B
- Same as saying we need 1 mol of A for every 2 mol of B
- We know the weights of molar amounts in grams → much easier to weigh than atomic mass units!

3.3 The Mole

$$M = \frac{m}{n}$$

Figure 3.5

M → molar mass (g mol^{-1})

m → mass (g)

n → number of moles (mol)

Worked Example 3.2 – page 76

The *Golden Jubilee* diamond is the largest faceted diamond in the world. It has a mass of 109.13 g. If the stone consists of pure carbon, what amount of carbon does the stone contain, given the molar mass of C is 12.01 g mol^{-1}.

Worked Example 3.3 – page 77

Calcium phosphate, $Ca_3(PO_4)_2$, is often used to coat some of the surfaces of bone or dental implants to permit bone to bond with the implant surface. If a coating procedure can deposit 0.115 mol of pure $Ca_3(PO_4)_2$ on an implant, what is the mass of the coating? The molar mass of Ca is 40.08 g mol^{-1}, of P is 30.97 g mol^{-1}, and of O is 16.00 g mol^{-1}.