CHEM110 – Chapter 3
Chemical Reactions and Stoichiometry

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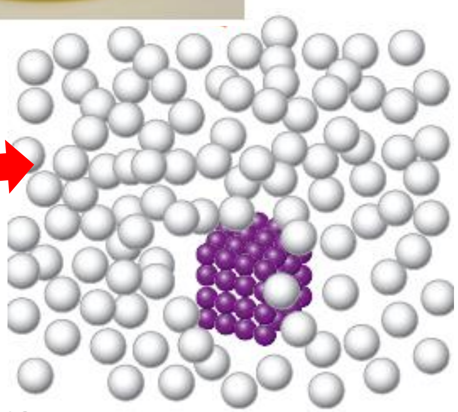
3.6 Solution Stoichiometry

SOLUTION
homogeneous mixture

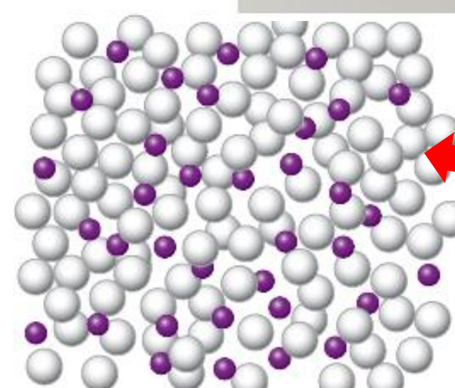
SOLUTE | **SOLVENT**



A crystal of solute is placed in the solvent.

solvent molecule (ethanol)

solute molecule (iodine)



A solution. Solute molecules are dispersed throughout the solvent.

3.6 Solution Stoichiometry

- **Solution concentration is the ratio of the amount of solute to the volume of solution [X]**

The units of c are mol L^{-1}

$$C = \frac{n}{V}$$

n is the number of moles (recall M = m/n)

V is the volume (in Litres)

Molarity (or molar concentration) has the units mol L^{-1} (abbreviated M)

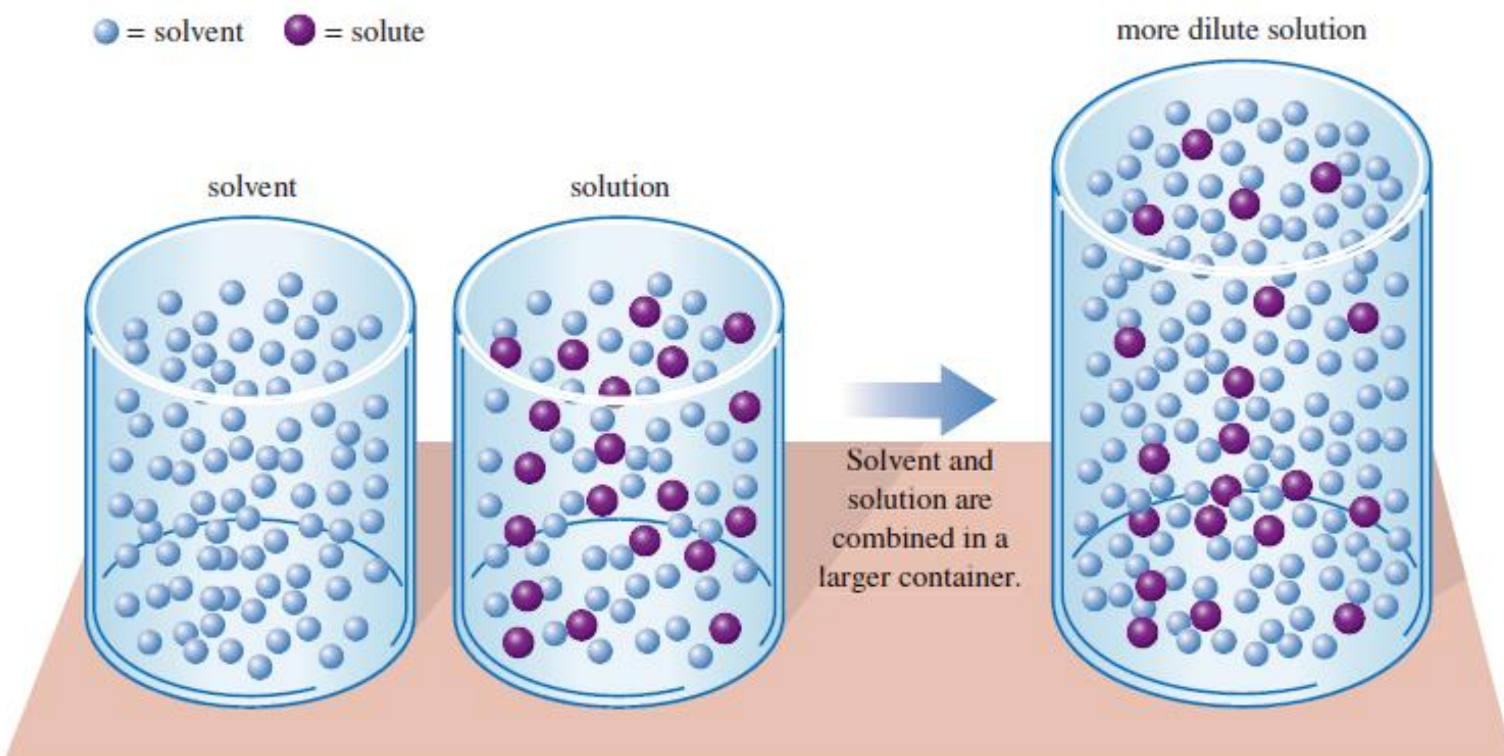
Worked Example 3.12 – page 91

A student prepared a solution of NaCl by dissolving 1.461 g of NaCl in water and making up to the final volume of 250.0 mL in a volumetric flask to study the effect of dissolved salt on the rusting of an iron sample. What is the concentration of this solution?

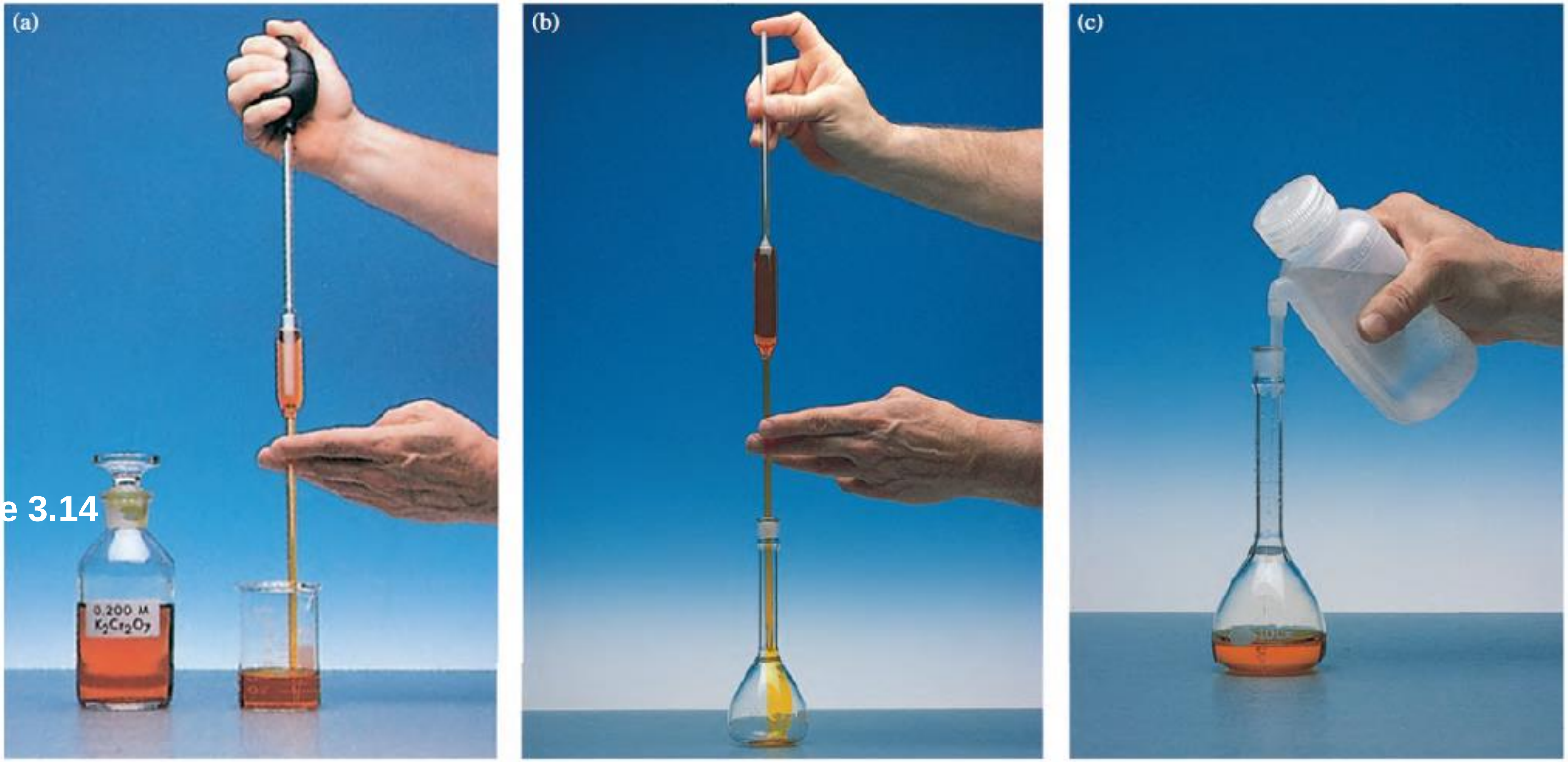
Worked Example 3.13 – page 92

Strontium nitrate, $Sr(NO_3)_3$, is used in fireworks to produce brilliant red colours. What mass of strontium nitrate would a chemist need to prepare 250.0 mL of a 0.100 M $Sr(NO_3)_3$ solution?

3.6 Diluting a Solution



3.6 Diluting a Solution



Worked Example 3.14 – page 94

How could we prepare 100.0 mL of 0.0400 M $K_2Cr_2O_7$ from a solution of 0.200 M $K_2Cr_2O_7$?

Worked Example 3.15 – page 95

Before the advent of digital cameras, silver bromide, AgBr, was used extensively in photographic film. This compound is essentially insoluble in water, and one way to prepare it is to mix solutions of the water-soluble compounds, silver nitrate and calcium bromide. Suppose we wished to prepare AgBr by the following precipitation reaction:

$$2AgNO_3(aq) + CaBr_2(aq) \rightarrow 2AgBr(s) + Ca(NO_3)_2(aq)$$

What volume of 0.125 M $CaBr_2$ solution would be required to react completely with 50.0 mL of 0.115 M $AgNO_3$?

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3.6 Solution Stoichiometry

- **Ionic compounds dissociate into their constituent ions when dissolved in water**
- **An aqueous solution of 0.10M $CaBr_2$ means that each litre of solution is dissociated into ions:**

$$CaBr_2(s) \rightarrow Ca^{2+}(aq) + 2Br^{-}(aq)$$

Worked Example 3.16 – page 97

What are the concentrations of the ions in a 0.20 M solution of $Al_2(SO_4)_3(aq)$?

3.6 Solution Stoichiometry

$2AgNO_3(aq) + CaBr_2(aq) \rightarrow 2AgBr(s) + Ca(NO_3)_2(aq)$

- **We can write this chemical equation in terms of the ions present**

- **IONIC EQUATION**

3.6 Solution Stoichiometry

TABLE 3.1 Solubility of common binary ionic compounds in water.

If the anion is	the compound is usually	except for
F^-	soluble	Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+} and Pb^{2+} (Al^{3+})
Cl^-	soluble	Ag^+ and $Hg_2{}^{2+}$ (Pb^{2+})
Br^-	soluble	Ag^+ and $Hg_2{}^{2+}$ (Hg^{2+} and Pb^{2+})
I^-	soluble	Ag^+, Hg^{2+}, $Hg_2{}^{2+}$ and Pb^{2+}
$NO_3{}^-$	soluble	none
$SO_4{}^{2-}$	soluble	Sr^{2+}, Ba^{2+}, $Hg_2{}^{2+}$ and Pb^{2+} (Ag^+ and Ca^{2+})
CH_3COO^-	soluble	none (Ag^+ and $Hg_2{}^{2+}$)
OH^-	insoluble	Li^+, Na^+, K^+ and Ba^{2+} (Ca^{2+} and Sr^{2+})
$SO_3{}^{2-}$	insoluble	Li^+, Na^+, K^+, $NH_4{}^+$ and Mg^{2+}
$PO_4{}^{3-}$	insoluble	Na^+, K^+ and $NH_4{}^+$
$CO_3{}^{2-}$	insoluble	Li^+, Na^+, K^+ and $NH_4{}^+$
$C_2O_4{}^{2-}$	insoluble	Li^+, Na^+, K^+ and $NH_4{}^+$

Note: For the purposes of this table, insoluble compounds are arbitrarily deemed to have molar solubilities of less than 1×10^{-2} M in water, slightly soluble compounds have molar solubilities in water between 1×10^{-1} M and 1×10^{-2} M, while soluble compounds have molar solubilities greater than 1×10^{-1} M in water. Cations in parentheses form slightly soluble compounds with the specified anion. Most oxides and sulfides are insoluble in water; apparent exceptions to this rule (e.g. Li_2O and MgS) are generally complicated by hydrolysis reactions and are therefore not listed.

3.6 Solution Stoichiometry

- **SPECTATOR IONS** are aqueous ions that don't participate in reactions

$$2AgNO_3(aq) + CaBr_2(aq) \rightarrow 2AgBr(s) + Ca(NO_3)_2(aq)$$

- The NO_3^- and Ca^{2+} ions **don't take part** in the reaction

Q. What is the net ionic equation?

A. $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

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Worked Example 3.17 – page 97

When aqueous solutions of $AgNO_3$ and $CaCl_2$ are mixed, a white precipitate of AgCl(s) is formed. The net ionic equation for the formation of this precipitate is:

$$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$$

What volume of 0.100 M $AgNO^3$ solution is needed to react completely with 25.0 mL of 0.400 M $CaCl_2$ solution to form AgCl(s)?

Worked Example 3.18 – page 98

A suspension of $Mg(OH)_2$ in water is sometimes used as an antacid. It can be made be adding NaOH to a solution containing Mg^{2+} ions. Suppose that 40.0 mL of a 0.200 M NaOH solution is added to 25.0 mL of a 0.300 M $MgCl_2$ solution. The net ionic equation for the reaction is:

$$Mg^{2+}(aq) + 2OH^{-}(aq) \rightarrow Mg(OH)_2(s)$$

What mass of $Mg(OH)_2$ will be formed, and what will the concentrations of the ions in the solution be after the reaction is complete?

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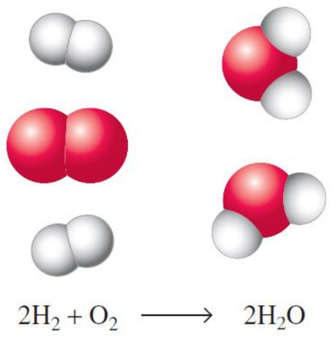
Worked Example 3.19 – page 99

A compound used as an insecticide contains carbon, hydrogen and chlorine. Reactions were carried out on a 1.340 g sample of the compound that converted all of its chlorine to chloride ions dissolved in water. This aqueous solution was treated with an excess of $AgNO_3$ solution, and the AgCl precipitate was collected and then weighed. It's mass was 2.709 g. What was the percentage by mass of Cl in the original insecticide sample?

Chapter 3 Summary

- A chemical reaction is the formation of new substances (products) upon mixing two or more chemical species (reactants)



- Stoichiometry is concerned with relative amounts of products and reactants
- A balanced chemical equation has the same number of entities of each kind in the products and reactants and should show the physical states of the reactants and products

Chapter Summary

- The mole is the unit of substance
- Avogadro's constant is 6.022×10^{23} mol^{-1} and gives the number of specified entities in 1 mole of a substance
- The molar mass is the mass of 1 mole of a substance
- The actual composition of a molecule is given by its molecular formula

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Chapter 3 Summary

- An empirical formula gives the smallest whole-number ratio of atoms
- Percentage composition is used to describe the relative amount of each element in a compound
- A reactant present in the smallest quantity is called the limiting reactant → the other reactant is called the excess reactant

Chapter 3 Summary

- The **percentage yield** is the actual yield calculated as a percentage of the theoretical yield
- When a **solution** forms, at least two substances are involved
- **Concentration** is the ratio of the amount of solute to the volume of solution
- Ionic compounds **dissociate** into their constituent ions when dissolved in water
- **Spectator ions** don't take part in reactions

Chapter 3 - LEARNING OBJECTIVES

- Understand chemical equations
- Learn how to balance equations
- Understand the mole concept
- Determine empirical formulae
- Understand solution stoichiometry
- Use stoichiometry rules to determine
  - Limiting reagents
  - % Yield

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Chapter 3 – Wrap up

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