Chapter 3.5

# Determining Formulas – Composition Analysis

# Look at your periodic table

- Do any elements share the same **molar mass** (atomic mass)?
- No – so you can identify an element from its molar mass
- You can also identify a **compound** from its mass
- This is what a mass spectrometer does (as seen on CSI)

# Percentage Composition

- Percent of a compound's **mass** contributed by each type of atom in the compound.
- You can find it from its formula

# Percentage Composition of $H_2O$

- Calculate the **molar mass**:
  - 2H + O = 2(1.01) + 16.0 = **18.02 g/mol**
  - Thus there is 2.01 g H and 16.0 g O
- Find the percentage of each part $\frac{\text{mass of one}}{mass\ of\ total}$
  - %H = $\frac{2.02g}{18.02\ g}$ x100 = **11.2%**
  - % O = $\frac{16.0\ g}{18.02\ g}$ x100 = **88.8%**

# Workbook p. 143

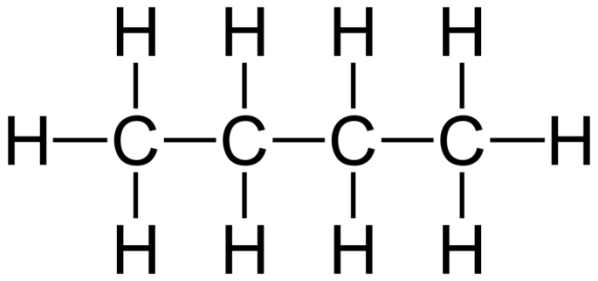
- Please complete the practice problems 1-3
  - Look at the sample problem for help

# Answers p. 143

| | | | | |
|---|---|---|---|---|
| 1. | 13 C | (13 × 12.0 g)/mol | = 156.0 g/mol | = 75.7% |
| | 18 H | (18 × 1.0 g)/mol | = 18.0 g/mol | = 8.7% |
| | 2 O | ( 2 × 16.0 g)/mol | = 32.0 g/mol | = 15.5% |
| | | | 206.0 g/mol | 99.9% |
| 2. | 2 N | (2 × 14.0 g)/mol | = 28.0 g/mol | = 21.2% |
| | 8 H | (8 × 1.0 g)/mol | = 18.0 g/mol | = 6.1% |
| | 1 S | (1 × 32.0 g)/mol | = 32.1 g/mol | = 24.3% |
| | 4 O | (4 × 16.0 g)/mol | = 64.0 g/mol | = 48.4% |
| | | | 132.1 g/mol | 100.0% |
| 3. | 1 Mg | (1 × 24.3 g)/mol | = 24.3 g/mol | |
| | 1 S | (1 × 32.0 g)/mol | = 32.1 g/mol | |
| | 4 O | (4 × 16.0 g)/mol | = 64.0 g/mol | |
| | | | 120.4 g/mol | |
| | 7 $H_2O$ | (7 × 18.0 g)/mol | = 126.0 g/mol | = 51.1% |
| | | | 246.4 g/mol | |

# Types of Formulas: Example Butane

- Every compound has **three** formulas
  - **Molecular** formula- how the compound actually exists
    - Butane is $C_4H_{10}$
  - **Empirica**l formula – the simplest ratio
    - Butane simplifies to $C_2H_5$
  - **Structural** formula – a diagram showing the arrangement of molecules



# Finding Empirical Formulas from %

- Step 1- change % to **grams**
  - Assume there are a 100g of the substance so the conversion is easy
- Step 2 - Convert grams to **moles**
  - Use molar masses from the periodic table
- Step 3- Find the **ratio** of the elements
  - Divide by the **smallest** value
- Step 4- Make sure the ratios are whole numbers
  - Write formula- $C_{1.5}O_2$ would become $C_3O_4$

# Determine the empirical formula for a compound composed of 80.0% C and 20.0% H.

- Step one: Change to grams
  - 80.0% C and 20.0% H becomes **80.0**g C and 20.0 g H
- Step 2: Convert to moles
  - 80.0 g H x $\frac{1\ mol}{12.0\ g\ H}$ = **6.67 mol C**
  - 20.0 g H x $\frac{1\ mol}{1.0\ g\ H}$ = **20.0 mol H**

# Determine the empirical formula for a compound composed of 80.0% C and 20.0% H. Continued…

- Step 3: Find the ratio of elements
  - ÷ by smallest which is Carbon with **6.67** moles
  - $\frac{6.67}{6.67} = 1$ C
  - $\frac{20.0}{6.67} =$ **3 H**
- Step 4: Make sure the ratios are **whole** numbers
  - 1C: 3H – yup whole numbers
  - $CH_3$

# Workbook p. 145

- Complete Practice Problems 1-3

# Answers p. 145

1. $Li_2CO_3$
2. $CCl_2F_2$
3. $Ag_2SO_4$

1. $18.7\ g\ Li \times \frac{1\ mol\ Li}{6.9\ g\ Li} = 2.7101\ mol\ Li$

$16.3\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} = 1.3583\ mol\ C$

$65.5\ g\ O \times \frac{1\ mol\ O}{16.0\ g\ O} = 4.0938\ mol\ O$

$Li_2CO_3$

2. $9.93\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} = 0.8275\ mol\ C$

$58.6\ g\ Cl \times \frac{1\ mol\ Cl}{35.5\ g\ Cl} = 1.6507\ mol\ Cl$

$31.4\ g\ F \times \frac{1\ mol\ F}{19.0\ g\ F} = 1.6526\ mol\ F$

$CCl_2F_2$

3. $5.723\ g\ Ag \times \frac{1\ mol\ Ag}{107.9\ g\ Ag} = 0.8275\ mol\ C$

$0.852\ g\ S \times \frac{1\ mol\ S}{32.1\ g\ S} = 1.6507\ mol\ Cl$

$1.695\ g\ O \times \frac{1\ mol\ O}{16.0\ g\ O} = 0.1059\ mol\ O$

$Ag_2SO_4$

# Determining the Molecular Formula

- Recall that the molecular formula is the actual number of each type of atom in a molecule

$$\text{molecular formula} = \text{empirical formula} \times \frac{\text{compound's molar mass}}{\text{molar mass of empirical formula}}$$

# Determining Molecular Formula

- Step one: calculate the **molar** mass of the empirical formula
- Step two: divide molar mass of molecular formula (usually given in question) by the molar mass of the **empirical** formula
- Step three: **multiply** the empirical formula by this factor $(\text{empirical formula})_{\text{factor}}$

$$\text{molecular formula} = \text{empirical formula} \times \frac{\text{compound's molar mass}}{\text{molar mass of empirical formula}}$$

# The empirical formula of glucose is $CH_2O$ and its molar mass is 180.0g . Determine the molecular formula.

- Step one- molar mass of $CH_2O$
  - $\mathbf{12.0\ g} + 2(1.01)g + 16.0g = 30.0g$
- Step two- divide molar mass by empirical molar mass to get the factor
  - $\frac{180.0g}{30.0g} = \mathbf{6}$
  - We need 6 times as much of everything!!
- $(CH_2O)_6 = \mathbf{C_6H_{12}O_6}$

# Workbook p. 147

- Practice Problems 1-3

# Answers p. 147

1. $C_2H_4O_2$
2. 80 or 120 g/m
3. $C_2H_6O_2$

1. 1C $(1 \times 12.0\ g)/mol = 12.0\ g/mol$
   2H $(2 \times 1.0\ g)/mol = 2.0\ g/mol$
   1O $(1 \times 16.0\ g)/mol = 16.0\ g/mol$
   $30.0\ g/mol$

   $\frac{60.0\ g/mol}{30.0\ g/mol} = 2$

   $2\ (CH_2O) = C_2H_4O_2$

2. 3 C $(1 \times 12.0\ g)/mol = 36.0\ g/mol$
   4 H $(4 \times 1.0\ g)/mol = 4.0\ g/mol$
   $40.0\ g/mol$

   80.0 g/mol, 120.0 g/mol because they are both multiples of 40 g/mo

3. $4.51\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} = 0.3758\ mol\ C$

   $1.13\ g\ H \times \frac{1\ mol\ H}{1.0\ g\ H} = 1.13\ mol\ H$

   $6.01\ g\ O \times \frac{1\ mol\ O}{16.0\ g\ O} = 0.3756\ mol\ O$

   $CH_3O$

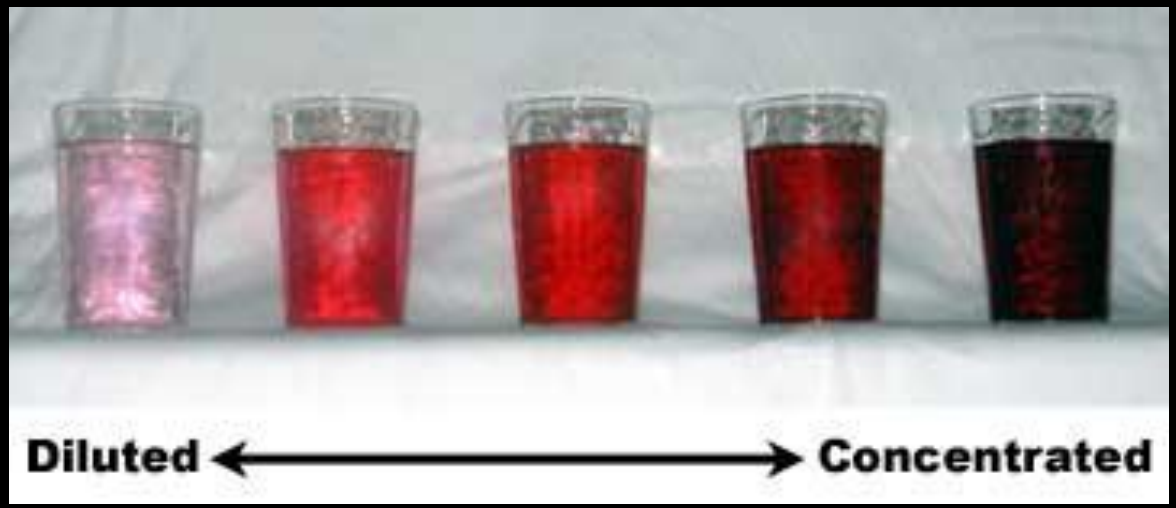
   1 C $(1 \times 12.0\ g)/mol = 12.0\ g/mol$
   3 H $(3 \times 1.0\ g)/mol = 3.0\ g/mol$
   1 O $(1 \times 16.0\ g)/mol = 16.0\ g/mol$
   $31.0\ g/mol$

   $\frac{62.0\ g/mol}{31.0\ g/mol} = 2$

   $2\ (CH_3O) = C_2H_6O_2$

# Homework

- Workbook
  - 3.5 all practice problems
  - 3.5 Review Questions p.149
    - 1-7, 9, 11
- Optional practice problems on moodle site
- Check white board for additional homework

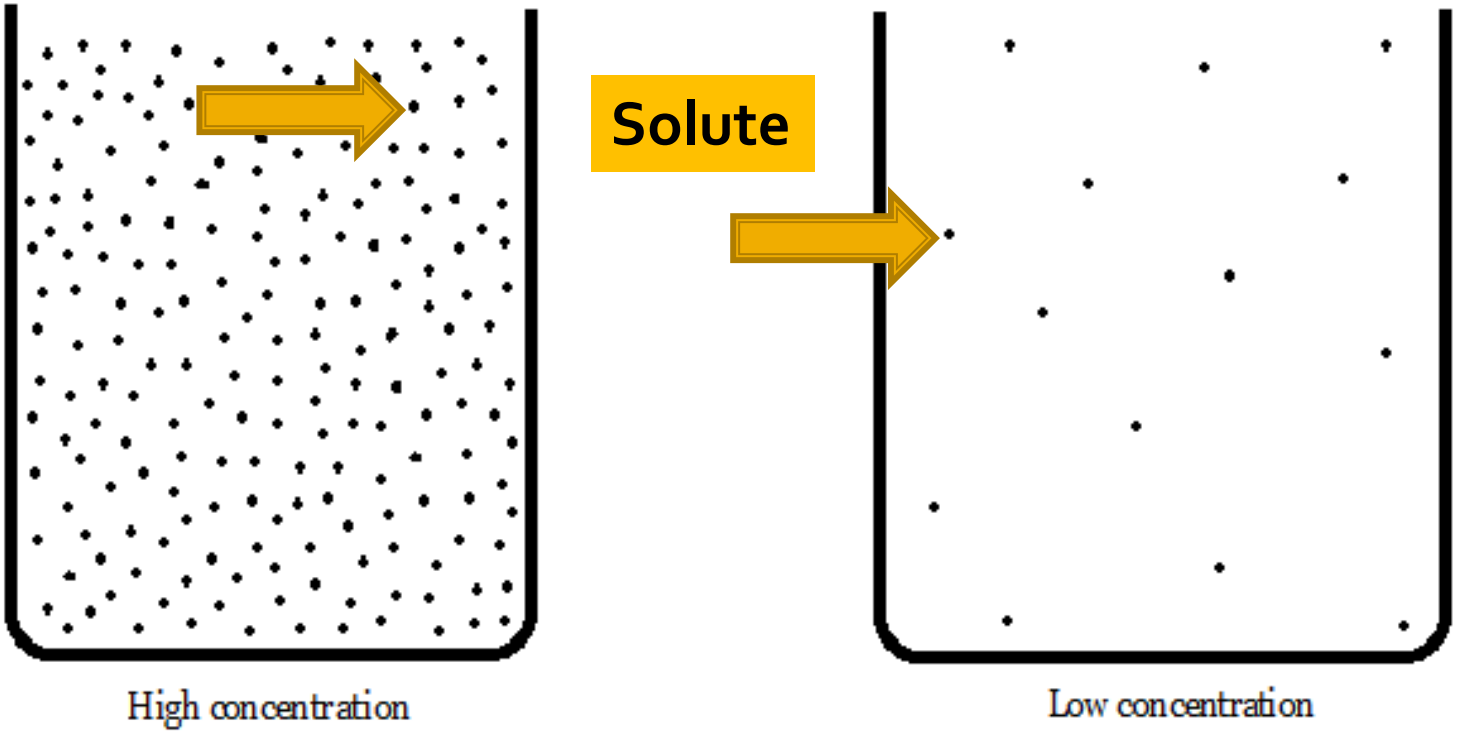



Chapter 3.6

# Molar Concentration

# Concentration

- The **proportion** of a chemical in a solution or the amount of solute per volume of a solution
- g/mL , mg/L , or parts per million



# Molarity M

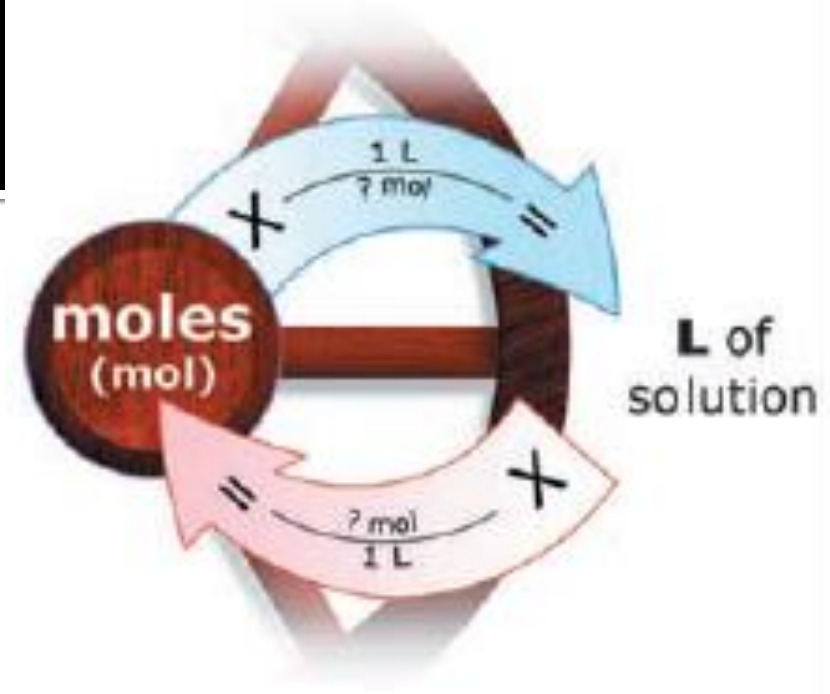
- It is a measure of the amount of **moles** of solute in solution per **litre** of solvent
- Allows us to compare number of **particles** in the same volume of different solutions
- Units are **mol/L** which is called M
- Also called **molar** concentration
- Square brackets [ ] are used to indicate it

# Examples

I. 1 M $HNO_3$ means **1 mol** of $HNO_3$ per liter of solution
   - $6.02 \times 10^{23}$ molecules per liter
II. 2M $HNO_3$ means **2 mol** of $HNO_3$ per liter
   - $2(6.02 \times 10^{23})$ molecules
III. So one liter of 2M $HNO_3$ has **twice** as many molecules as one liter of 1m $HNO_3$

# To convert

- Multiply or divide by




| Name | Equivalence Statement | Conversion Factors | |
|---|---|---|---|
| Molar concentration | 1 L solution = ? mol solute | $\frac{\text{? mol solute}}{\text{1 L solution}}$ | $\frac{\text{1 L solution}}{\text{? mol solute}}$ |
| Example: 3 M HCN | 1 L solution = 3 mol HCN | $\frac{\text{3 mol HCN}}{\text{1 L solution}}$ | $\frac{\text{1 L solution}}{\text{3 mol HCN}}$ |

# 1.23 L of 3.00 M KCl = _____ mol KCl

- 1.23L
- 1.23L x $\frac{\mathbf{3.00\ mol}}{1\ L}$ =
- 1.23L x $\frac{3.00\ mol}{1\ L}$ = **3.69** mol KCl

# Workbook p.153

- Try practice problems 1-4

# Answers p.153

1. $$0.72\ \text{L soln} \times \frac{2.5\ \text{mol NaOH}}{1\ \text{L soln}} = 1.8\ \text{mol NaOH}$$

2. $$0.500\ \text{L soln} \times \frac{0.154\ \text{mol NaCl}}{1\ \text{L soln}} = 0.0770\ \text{mol NaCl}$$

3. $$3.0\ \text{mol HCl} \times \frac{1\ \text{L soln}}{0.60\ \text{mol HCl}} = 5.0\ \text{L soln}$$

4. $$1.0 \times 10^{-3}\ \text{mol methanethiol} \times \frac{1\ \text{L urine}}{4.0 \times 10^{-8}\ \text{mol methanethiol}} = 25000\ \text{L urin}$$

# Preparing solutions

- A **standard** solution is a term for a solution with a known concentration
- To prepare it you mix a mass of **solute** and a volume of water

- Prepare **1M** $CaCl_2(aq)$
  - Measure out 1 mol of CaCl2 which is 110.94 g and add water until the solution **totals** one liter

# Try it! Describe how to prepare 0.055L of 0.20 M KCL from the solid.

- 0.055L
- 0.055L x $\frac{0.20\ mol\ KCl}{1\ L}$
- 0.055L x $\frac{0.20\ mol\ KCl}{1\ L}$ x $\frac{74.6g\ KCl}{1\ mol\ KCl}$
- 0.055L x $\frac{0.20\ mol\ KCl}{1\ L}$ x $\frac{74.6g\ KCl}{1\ mol\ KCl}$ =0.82 g KCl
- You would measure out 0.82g KCl and add water up to 55 ml (0.055L) of solution.

# What molar concentration (M) of KCl is produced by measuring out 1.0 g KCL and adding water up to 0.350L of solution?

- First we need to convert grams to moles
- 1.0 g KCl x $\frac{1\ mol\ KCl}{74.6\ g\ KCl}$ = **0.013 mol KCl**
- Now find molar concentration (mol/L)
- $\frac{0.013\ mol\ KCl}{0.350\ L\ of\ solution}$ = **0.038 M KCl**

# Workbook p. 154

- Practice problems 1-3

# Answers p. 154

1. $0.500\ \text{L soln} \times \frac{1.5\ \text{mol}\ CaCl_2}{1\ \text{L soln}} \times \frac{111.1\ \text{g}\ CaCl_2}{1\ \text{mol}\ CaCl_2} = 83\ \text{g}\ CaCl_2$

   Measure out 83 g $CaCl_2$ and add water up to 0.500 L soln.

2. $0.055\ \text{L soln} \times \frac{0.20\ \text{mol KCl}}{1\ \text{L soln}} \times \frac{74.6\ \text{g KCl}}{1\ \text{mol KCl}} = 0.82\ \text{g KCl}$

3. $1.8\ \text{g}\ AgNO_3 \times \frac{1\ \text{mol}\ AgNO_3}{169.0\ \text{g}\ AgNO_3} = 0.01059\ \text{mol}\ AgNO_3$

   $\frac{0.01059\ \text{mol}\ AgNO_3}{0.075\ \text{L soln}} = 0.14\ \text{M}\ AgNO_3$

# Multi- step Conversions

- We know how to use molarity (M) to convert from a volume of solution to **moles** now we will determine the number of atoms or vice versa
- 1 mol = **$6.02 \times 10^{23}$** atoms or molecules

# How many chlorine ions are in 0.025L of 0.30 M $AlCl_3$?

- 0.025 L
- 0.025 L x $\frac{\mathbf{0.30\ mol}}{\mathbf{1\ L}}$
- 0.025 L x $\frac{0.30\ mol AlCl_3}{1\ L}$ x $\frac{\mathbf{3\ mol\ Cl-}}{\mathbf{1\ mol\ AlCl_3}}$
- 0.025 L x $\frac{0.30\ mol AlCl_3}{1\ L}$ x $\frac{3\ mol\ Cl-}{1\ mol\ AlCl_3}$ x $\frac{\mathbf{6.02x1023\ ions\ Cl-}}{\mathbf{1\ mol\ Cl-}}$

**= 1.4x10$^{22}$ ions Cl-**

# Workbook p. 157

- practice problems 1-5

# Answers p. 157

1. $CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$ 1.5 M $Ca^{2+}$ and 3.0 M $Cl^-$

2. $Na_3PO_4(s) \rightarrow 3Na^+(aq) + PO_4^{3-}(aq)$ 0.20 M $Na_3PO_4$

3. $Li_3PO_4(s) \rightarrow 3Li^+(aq) + PO_4^{3-}(aq)$ $[Li^+] = 3[PO_4^{3-}]$

4. $$0.75 \text{ L soln} \times \frac{2.8 \text{ mol } K^+}{1 \text{ L soln}} \times \frac{39.1 \text{ g } K^+}{1 \text{ mol } K^+} = 82 \text{ g } K^+$$

5. $$0.525 \text{ L soln} \times \frac{3.0 \text{ mol } Fe(NO_3)_3}{1 \text{ L soln}} \times \frac{3 \text{ mol } NO_3^-}{1 \text{ mol } Fe(NO_3)_3} \times \frac{6.02 \times 10^{23} \text{ ions } NO_3^-}{1 \text{ mol } NO_3^-}$$

$= 2.8 \times 10^{24}$ ions $NO_3^-$

# Homework

- Review Questions
  - 1-9, 12,13,17