UNIT 5: CHEMICAL EQUATIONS AND REACTIONS & STOICHIOMETRY

Chapter 8: Chemical Equations and Reactions

8.1: Describing Chemical Reactions

Physical Properties: - properties or characteristics that describe the look or feel (physical nature) of a substance.

Examples: colour, hardness, malleability (ability to bend), texture, phase at room temperature, boiling point and melting point ...etc.

Physical Change: - the change of a substance that alter its physical appearance but does **not** alter its chemical composition. (It is **easily reversible**.)

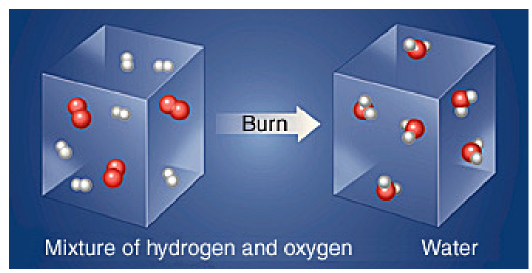
Examples: freezing water into ice (phase change – freezing), breaking a large clump of sugar into powder form using a mortar and pestle.

Chemical Properties: - properties or characteristics of a substance that describes how it reacts with other substances.

Examples: sodium reacts violently with water but iron rusts slowly when it places in water.

Chemical Change: - the change of a substance that alter its chemical composition, and a new substance(s) with different physical and chemical properties is/are formed. (It is **NOT** easily **reversible**.)
- sometimes refer to as a **Chemical Reaction**.

Five Evidences of a Chemical Change**:



1. **Precipitate (New Solid) ↓ is formed.**
2. **Colour Change.**
3. **Presence of Bubbles or New Odour to indicate a New Gas ↑.**
4. **Heat is suddenly Given off or Taken in.**
5. **Explosion!**

** New substances with different chemical compositions have to be formed in each case. Otherwise, it is only a physical change.

Example 1: Classify the following as a physical change or a chemical change and state the reason why.

a. plywood is cut up into smaller pieces

Physical. No new subtance is formed. The smaller pieces of plywood has the same physical properties as the original big piece.

b. plywood is burned.

Chemical. New subtance (ashes) is formed. The ashes cannot be turned back into the original plywood.

c. an egg is boiled in boiling water

Chemical. New substance (Hard-boiled egg) cannot be turned back to the original raw egg.

d. alcohol is distilled from an alcohol-water solution

Physical. The alcohol merely separated from the alcohol-water solution. The mixture can be reconstituted by mixing alcohol and water again.

Reactants: - chemicals that goes into a reaction. **Products**: - chemicals that are produced from a reaction.

Chemical Word Equation: - a chemical reaction written out in words.

Chemical Equation (Formula Equation): - uses chemical symbols to represent what happens in a reaction.

$$\textbf{Reactants} \xrightarrow{\text{"yields""}} \textbf{Products}$$

States of Chemicals: - (*s*) solid, (*l*) liquid, (*g*) gas, (*aq*) aqueous – dissolved in water

Other Chemical Symbols:

1. **Heat is Added**: - $\xrightarrow{\textit{heat}}$ or $\xrightarrow{\Delta}$
2. **Energy is absorbed (written on reactant side) or released (written on the product side).**

   Energy **+ Reactants** $\longrightarrow$ **Products**   **Reactants** $\longrightarrow$ **Products +** ***Energy***
3. **Catalyst is Added**: - $\xrightarrow{\textit{Name of Catalyst}}$

   (**Catalyst**: - a chemical that is used to speed up a reaction but does not get consumed)
4. **Reversible (Equilibrium) Reaction**: - Reactants $\rightleftharpoons$ Products

Example 2: Convert the following word equations into chemical equations without balancing.

a. Heating solid diphosphorous pentaoxide decomposes into phosphorous and oxygen.

$\textit{Energy} + P_2O_{5\,(s)} \rightarrow P_{4\,(s)} + O_{2\,(g)}$ **or** $P_2O_{5\,(s)} \xrightarrow{\Delta} P_{4\,(s)} + O_{2\,(g)}$	**Recall that phosphorus is a polyatomic element, and oxygen is a diatomic element.**

b. Hypochlorous acid ($HClO_{(aq)}$) is neutralized by barium hydroxide solution to form water and soluble barium hypochlorite.

$HClO_{(aq)} + Ba(OH)_{2\,(aq)} \rightarrow H_2O_{(l)} + Ba(ClO)_{2\,(aq)}$	**It is very important that the subscripts for these ionic compounds are correct.**

Assignment

8.1 pg. 266 #1 to 17

8.2 & 8.3: Balancing and Classifying Chemical Equations

Steps involve to Balance Chemical Equation

1. Write the chemical formulas of all reactants and products with their proper subscripts and state to form a skeletal equation.
2. Count the number of atoms / polyatomic ions (always view complex ion as a group) of each chemical formula. Balance the atoms / polyatomic ions by writing the coefficient in front of the reactant / product. Do NOT mess with any of the subscripts.
3. Always balance the atoms that appear in more than two chemicals last.
4. Verify that all atoms / polyatomic ions are balanced.

Example 1: Balance the following chemical equations

a. $N_{2\,(g)} + H_{2\,(g)} \rightarrow NH_{3\,(g)}$

$N_{2\,(g)} + \underline{3}\ H_{2\,(g)} \rightarrow \underline{2}\ NH_{3\,(g)}$

b. $Al_2O_{3\,(s)} \rightarrow Al_{(s)} + O_{2\,(g)}$

$\underline{2}\ Al_2O_{3\,(s)} \rightarrow \underline{4}\ Al_{(s)} + \underline{3}\ O_{2\,(g)}$

c. $Na_{(s)} + H_2O_{(l)} \rightarrow NaOH_{(aq)} + H_{2\,(g)}$

$Na_{(s)} + HOH_{(l)} \rightarrow NaOH_{(aq)} + H_{2\,(g)}$

$\underline{2}\ Na_{(s)} + \underline{2}\ HOH_{(l)} \rightarrow \underline{2}\ NaOH_{(aq)} + H_{2\,(g)}$

Sometimes, it is easier to rewrite H_2O as HOH. This is especially true when a OH^- is part of the products. The first H atom in the HOH becomes $H_{2\,(g)}$ and the remaining part, OH, becomes the polyatomic ion, OH^-.

d. $Fe(NO_3)_{3\,(aq)} + Ba(OH)_{2\,(aq)} \rightarrow Fe(OH)_{3\,(s)} + Ba(NO_3)_{2\,(aq)}$

$\underline{2}\ Fe(NO_3)_{3\,(aq)} + \underline{3}\ Ba(OH)_{2\,(aq)} \rightarrow \underline{2}\ Fe(OH)_{3\,(s)} + \underline{3}\ Ba(NO_3)_{2\,(aq)}$

Look at each polyatomic ion as one item. There were $(NO_3)_3$ on the left hand side and $(NO_3)_2$ on the right hand side. Hence, we need to use 2 and 3 as coefficients to balance them. Similarly, there were $(OH)_2$ on the reactant side and $(OH)_3$ on the product side. Therefore, we are required to use 3 and 2 to balance them. Note that once the coefficients are in place, the Fe and Ba atoms are also balanced.

e. $C_2H_{6\,(g)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + H_2O_{(l)}$

For burning (adding O_2) with hydrocarbons (compounds containing carbon and hydrogen), *we must balance C, H, O in that order*. This is because oxygen atoms exist in more than two compounds on the product side. After we balance carbon and hydrogen, we have the following number of oxygen atoms.

$C_2H_{6\,(g)}$ + __ $O_{2\,(g)}$ → $\underline{2}\ CO_{2\,(g)}$ + $3\ H_2O_{(l)}$

need 7 oxygen 4 oxygen 3 oxygen

$$C_2H_{6\,(g)} + \frac{7}{2}O_{2\,(g)} \rightarrow \underline{2}\ CO_{2\,(g)} + \underline{3}\ H_2O_{(l)}$$

Multiply all coefficients by 2:

$$2\ C_2H_{6\,(g)} + \underline{7}\ O_{2\,(g)} \rightarrow \underline{4}\ CO_{2\,(g)} + \underline{6}\ H_2O_{(l)}$$

Since elemental oxygen is diatomic, the 7 oxygen needed on the reactant side needs to have a coefficient of 7/2.

This can easily be converted to a whole number by multiplying all the coefficients by 2.

Example 2: Rewrite the following sentences into balanced chemical equations.

a. Sulfur is burned in the presence of oxygen to form sulfur dioxide gas.

First, we write the skeletal equation.
(Recall that sulfur is a polyatomic element, and oxygen is a diatomic element.)

$$S_{8\,(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}$$

Then, we balance the equation. $S_{8\,(s)} + \underline{8}\ O_{2\,(g)} \rightarrow \underline{8}\ SO_{2\,(g)}$

b. Hydrogen gas is added to propyne (C_3H_4) gas with the aid of a platinum catalyst to form propane gas.

First, we write the skeletal equation. **(Propane is C_3H_8 – a formula that should have been memorized.)**

$$C_3H_{4\,(g)} + H_{2\,(g)} \xrightarrow{Pt} C_3H_{8\,(g)}$$

Then, we balance the equation. $C_3H_{4\,(g)} + \underline{2}\ H_{2\,(g)} \xrightarrow{Pt} C_3H_{8\,(g)}$

$C_3H_{4\,(g)}$	+ $\underline{2}\ H_{2\,(g)}$	$\xrightarrow{Pt}$	$C_3H_{8\,(g)}$
4 hydrogen	***need 4 more hydrogen***		**8 hydrogen**

There are 5 basic types of chemical reactions:

1. **Formation, Composition or Synthesis**
   (Many Elements → Compound or Many Reactants → Single Product)

   Examples: $2\ Mg_{(s)} + O_{2\,(g)} \rightarrow 2\ MgO_{(s)}$ $\quad SO_{2\,(g)} + H_2O_{(l)} \rightarrow H_2SO_{3\,(aq)}$

2. **Deformation or Decomposition**
   (Compound → Many Elements or Single Reactant → Many Products)

   Examples: $2\ Al_2O_{3\,(s)} \rightarrow 4\ Al_{(s)} + 3\ O_{2\,(g)}$ $\quad H_2CO_{3\,(aq)} \rightarrow H_2O_{(l)} + CO_{2\,(g)}$

3. **Single Replacement (Displacement)** **(Element + Compound → Element + Compound)**

   Example: $2\ AgNO_{3\,(aq)} + Cu_{(s)} \rightarrow 2\ Ag_{(s)} + Cu(NO_3)_{2\,(aq)}$

4. **Double Replacement (Displacement)** **(Compound + Compound → Compound + Compound)**

   Example: $AgNO_{3\,(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3\,(aq)}$

5. **Hydrocarbon Combustion** **(Hydrocarbon + Oxygen → Carbon Dioxide + Water)**

   Example: $CH_{4\,(g)} + 2\ O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\ H_2O_{(g)}$

Balancing Chemical Equations: - both sides of the equations must have equal number of the same atoms.
(*Law of Conservation of Mass*)

Coefficient: - the number in front of the chemical formula that indicates the number of moles, atoms or molecules involve in a chemical reaction.
- the absence of number in front of chemical means the coefficient is 1.

Example: $\mathbf{2}\ H_{2\,(g)} + 1\ O_{2\,(g)} \rightarrow \mathbf{2}\ H_2O_{(g)}$

Activity Series: - elements are arranged in order of reactivity (with the most reactive near the top).
- a **metal that appears higher in the activity series** ***displaces*** a **cation of a metal lower in the series**.
- if and when a **metal reacts with water**, it will **produce $H_{2\,(g)}$ and metal hydroxide**.

Activity Series for some Common Metals

More Reactive

$Li_{(s)}$ $Rb_{(s)}$ $K_{(s)}$ $Ca_{(s)}$ $Ba_{(s)}$ $Sr_{(s)}$ $Na_{(s)}$	• React with Cold Water to produce $H_{2\,(g)}$ • React with Acids to produce $H_{2\,(g)}$ • React with Oxygen to form Oxides
$Mg_{(s)}$ $Al_{(s)}$ $Mn_{(s)}$ $Zn_{(s)}$ $Cr_{(s)}$ $Fe_{(s)}$ $Cd_{(s)}$	• React with Steam (but ***not*** with Cold Water) • React with Acids to produce $H_{2\,(g)}$ • React with Oxygen to form Oxides
$Co_{(s)}$ $Ni_{(s)}$ $Sn_{(s)}$ $Pb_{(s)}$	• Do ***not*** React with Water • React with Acids to produce $H_{2\,(g)}$ • React with Oxygen to form Oxides
$H_{2\,(g)}$ $Sb_{(s)}$ $Bi_{(s)}$ $Cu_{(s)}$ $Hg_{(l)}$	• Do ***not*** React with Water • Do ***not*** react with Acids to produce $H_{2\,(g)}$ • React with Oxygen to form Oxides
$Ag_{(s)}$ $Pt_{(s)}$ $Au_{(s)}$	• Fairly ***Unreactive*** • Forms Oxides ***only*** indirectly

Example 3: Write an unbalanced chemical equation if the following reactants produce any products. If there is no product form, write "No Reaction".

a. Tin metal is immersed in a silver nitrate solution.

$Sn_{(s)}$ is higher in the series than Ag^+ ion

$$Sn_{(s)} + AgNO_{3\,(aq)} \rightarrow Sn(NO_3)_{4\,(aq)} + Ag_{(s)}$$

Use the first (the most common) charge from the Periodic Table → Sn^{4+} Ag^+ NO_3^-

b. Solid magnesium is dropped in a solution of hydrochloric acid ($HCl_{(aq)}$).

$Mg_{(s)}$ reacts with Acids.

$$Mg_{(s)} + HCl_{(aq)} \rightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$$

Mg^{2+} H^+ Cl^-

c. A piece of gold nugget is placed in an oxygen chamber.

$Au_{(s)}$ does *not* react with Oxygen ***"No Reaction"***

d. Cold water is poured on to a piece of lithium metal.

$Li_{(s)}$ reacts with Cold Water. **Write H_2O as HOH**	$Li_{(s)} + HOH_{(aq)} \rightarrow LiOH_{(aq)} + H_{2\,(g)}$ Li^+ H^+ OH^-

Solubility Table: - indicates whether an ionic compound is soluble in water.

Solubility of Some Common Ionic Compounds in Water at 298.15 K (25°C)

Ion	**H_3O^+ (H^+), Na^+, NH_4^+, NO_3^-, ClO_3^-, ClO_4^-, CH_3COO^-**	**F^-**	**Cl^- Br^- I^-**	**SO_4^{2-}**	**CO_3^{2-} PO_4^{3-} SO_3^{2-}**	**IO_3^- $OOCCOO^{2-}$**	**S^{2-}**	**OH^-**
Solubility greater than or equal to 0.1 mol/L (very soluble)	Most	most	most	most	NH_4^+ H^+ Na^+ K^+	NH_4^+ H^+ Li^+ Na^+ K^+ Ni^{2+} Zn^{2+}	NH_4^+ H^+ Li^+ Na^+ K^+ Mg^{2+} Ca^{2+}	NH_4^+ H^+ Li^+ Na^+ K^+ Ca^{2+} Sr^{2+} Ba^{2+}
Solubility less than 0.1 mol/L (slightly soluble)	$RbClO_4$ $CsClO_4$ $AgCH_3COO$ $Hg_2(CH_3COO)_2$	Li^+ Mg^{2+} Ca^{2+} Sr^{2+} Ba^{2+} Fe^{2+} Hg_2^{2+} Pb^{2+}	Cu^+ Ag^+ Hg_2^{2+} Hg^{2+} Pb^{2+}	Ca^{2+} Sr^{2+} Ba^{2+} Hg_2^{2+} Pb^{2+} Ag^+	most **Exception:** Li_2CO_3 is soluble	most **Exceptions:** $Co(IO_3)_2$ $Fe_2(OOCCOO)_3$ are soluble	most	most

Example 4: Determine if the following ionic compounds are soluble in water.

a. silver chloride

Insoluble
Under the Cl^- column, Ag^+ is in the "slightly soluble" row.

b. ammonium hydroxide

Soluble
Under the NH_4^+ column, all cations combinations are soluble. *or* Under the OH^- column, NH_4^+ is listed in the "very soluble"

c. lead (IV) sulfate

Soluble
Under the SO_4^{2-} column, Pb^{4+} is NOT in the "slightly soluble" row.
(Pb^{4+} is NOT the same as Pb^{2+})

d. chromium (III) nitrate

Soluble
Under the NO_3^- column, all cations are combinations are soluble.

e. aluminum hydroxide

Insoluble
Under the OH^- column, Al^{3+} is NOT in the "very soluble" row.

f. copper (I) bromide

Insoluble
Under the Br^- column, Cu^+ is in the "slightly soluble" row.
(Cu^+ is NOT the same as Cu^{2+})

To Predict Products and Balance Chemical Equations:

1. Write the correct chemical formulas for all products and reactants with proper subscripts. The presence of metals or ionic compounds indicates that we will need to use ions and charges to form any products.
2. For hydrocarbon combustion, balance in the order of C, H, and then O. The product, H_2O, is always in gaseous form unless otherwise stated. (It's usually quite hot in combustion.)
3. For other type of reactions, balance the equation for each type of cations and anions. Do NOT break up the polyatomic ions. Water may be written as HOH (H^+ and OH^-) in single and double replacements.
4. Check with the Activity Series, Solubility Table (see above) and the Table of Elements for the states of chemicals.

Example 5: Predict the product(s) along with the states, indicate the type of reaction, and balance the following chemical reactions.

a. Sulfur trioxide gas is produced from its elements.

Formation: $S_{8\,(s)} + 12\ O_{2\,(g)} \rightarrow 8\ SO_{3\,(g)}$

b. A solid piece of zinc is immersed in an iron (III) chloride solution.

Single Replacement: $3\ Zn_{(s)} + 2\ FeCl_{3\,(aq)} \rightarrow 3\ ZnCl_{2\,(aq)} + 2\ Fe_{(s)}$

Zn^{2+} Fe^{3+} Cl^-

c. Propane ($C_3H_{8\,(g)}$) is burned in a gas barbecue.

Hydrocarbon Combustion: $C_3H_{8\,(g)} + 5\ O_{2\,(g)} \rightarrow 3\ CO_{2\,(g)} + 4\ H_2O_{(g)}$

d. Chlorine gas is bubbled through a copper (II) iodide solution.

Single Replacement: $Cl_{2\,(g)} + CuI_{2\,(aq)} \rightarrow CuCl_{2\,(aq)} + I_{2\,(s)}$

Cl^- Cu^{2+} I^-

e. Ammonia gas is decomposed into its elements.

Decomposition: $2\ NH_{3\,(g)} \rightarrow N_{2\,(g)} + 3\ H_{2\,(g)}$

f. Sulfuric acid ($H_2SO_{4\,(aq)}$) is neutralized by sodium hydroxide solution.

Double Replacement: $H_2SO_{4\,(aq)} + 2\ NaOH_{(aq)} \rightarrow 2\ HOH_{(l)} + Na_2SO_{4\,(aq)}$

H^+ SO_4^{2-} Na^+ OH^-

g. Propanol ($C_3H_7OH_{(l)}$) is accidentally ignited.

Hydrocarbon Combustion: $C_3H_7OH_{(l)} + 9/2\ O_{2\,(g)} \rightarrow 3\ CO_{2\,(g)} + 4\ H_2O_{(g)}$

(Multiply Coefficients by 2) $2\ C_3H_7OH_{(l)} + 9\ O_{2\,(g)} \rightarrow 6\ CO_{2\,(g)} + 8\ H_2O_{(g)}$

h. Lead (II) nitrate solution is reacted with chromium (III) sulfate solution.

Double Replacement: $3\ Pb(NO_3)_{2\,(aq)} + Cr_2(SO_4)_{3\,(aq)} \rightarrow 2\ Cr(NO_3)_{3\,(aq)} + 3\ PbSO_{4\,(s)}$

$Pb^{2+}\ NO_3^-$ $Cr^{3+}\ SO_4^{2-}$

i. Octane ($C_8H_{18\,(l)}$) is combusted in an automobile.

Hydrocarbon Combustion: $C_8H_{18\,(l)} + 25/2\ O_{2\,(g)} \rightarrow 8\ CO_{2\,(g)} + 9\ H_2O_{(g)}$

(Multiply Coefficients by 2) $2\ C_8H_{18\,(l)} + 25\ O_{2\,(g)} \rightarrow 16\ CO_{2\,(g)} + 18\ H_2O_{(g)}$

Assignment

8.2 pg. 269 #1 to 4 (Practice); pg. 271 #1 to 3 (Practice); pg. 273 #1 to 3 (Practice); pg. 274 # 1 to 10

8.3 pg. 279 #1 to 4 (Practice); pg. 282 #1 to 3 (Practice); pg. 285 #3 to 14

8.4: Writing Net-Ionic Equations

Molecular Equation: - a chemical equation where compounds are written in their chemical formulas.

Complete Ionic Equation: - a chemical equation where all compounds that are soluble are written in the ionic components (slightly soluble compounds are not separated into ions).

Net Ionic Equation: - an ionic equation that only shows the ions responsible in forming the precipitate.

Spectator Ions: - (ions that do not form the precipitate or pure liquid and gas) are omitted.

Example 1: Predict all products form when an ammonium phosphate solution reacts with a calcium chloride solution. Explain the reaction in a form of a balanced

a. Molecular Equation

$2\ (NH_4)_3PO_{4\,(aq)} + 3\ CaCl_{2\,(aq)} \rightarrow 6\ NH_4Cl_{(aq)} + Ca_3(PO_4)_{2\,(s)}\downarrow$ **(precipitate)**

$NH_4^+\ PO_4^{3-}$ $Ca^{2+}\ Cl^-$

b. Complete Ionic Equation (Identify the Spectator Ions)

$6\ NH_4^+{}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)} + 3\ Ca^{2+}{}_{(aq)} + 6\ Cl^-{}_{(aq)} \rightarrow 6\ NH_4^+{}_{(aq)} + 6\ Cl^-{}_{(aq)} + Ca_3(PO_4)_{2\,(s)}\downarrow$

Spectator Ions: NH_4^+ and Cl^- **(Precipitate does NOT separate into ions)**

c. Net Ionic Equation

$2\ PO_4^{3-}{}_{(aq)} + 3\ Ca^{2+}{}_{(aq)} \rightarrow Ca_3(PO_4)_{2\,(s)}$

(Only write the ions that contribute to the precipitated chemical species)

Example 2: Predict all products form when sulfuric acid reacts with a lithium hydroxide solution. Explain the reaction in a form of a balanced

a. Molecular Equation

$$H_2SO_{4\,(aq)} + 2\ LiOH_{(aq)} \rightarrow Li_2SO_{4\,(aq)} + 2\ HOH_{(l)}$$

(liquid water)

H^+ SO_4^{2-} Li^+ OH^-

b. Complete Ionic Equation (Identify the Spectator Ions)

$$2\ H^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ Li^+_{(aq)} + 2\ OH^-_{(aq)} \rightarrow 2\ Li^+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\ HOH_{(l)}$$

Spectator Ions: Li^+ and SO_4^{2-} **(Pure Liquid does NOT separate into ions)**

c. Net Ionic Equation

$$2\ H^+_{(aq)} + 2\ OH^-_{(aq)} \rightarrow 2\ HOH_{(l)}$$
$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

This is the main result of acid-base neutralization (the formation of water).

(Only write the ions that contribute to the pure liquid species)

Example 3: Predict all products form when solid aluminium reacts with a copper (II) nitrate solution. Explain the reaction in a form of a balanced

a. Molecular Equation

$$2\ Al_{(s)} + 3\ Cu(NO_3)_{2\,(aq)} \rightarrow 2\ Al(NO_3)_{3\,(aq)} + 3\ Cu_{(s)} \downarrow$$

(precipitate)

Al^{3+} Cu^{2+} NO_3^-

b. Complete Ionic Equation (Identify the Spectator Ion)

$$2\ Al_{(s)} + 3\ Cu^{2+}_{(aq)} + 6\ NO_3^-{}_{(aq)} \rightarrow 2\ Al^{3+}_{(aq)} + 6\ NO_3^-{}_{(aq)} + 3\ Cu_{(s)} \downarrow$$

Spectator Ion: NO_3^-

c. Net Ionic Equation

$$2\ Al_{(s)} + 3\ Cu^{2+}_{(aq)} \rightarrow 2\ Al^{3+}_{(aq)} + 3\ Cu_{(s)}$$

(Need to write all the ions on both sides that correspond to any solid used or formed)

Example 4: Predict all products form when a sodium nitrate solution is mixed with a copper (II) sulfate solution. Explain the reaction in a form of a balanced

a. Molecular Equation

$$2\ NaNO_{3\,(aq)} + CuSO_{4\,(aq)} \rightarrow Na_2SO_{4\,(aq)} + Cu(NO_3)_{2\,(aq)}$$

(No Precipitate)

Na^+ NO_3^- Cu^{2+} SO_4^{2-}

b. Complete Ionic Equation (Identify the Spectator Ions)

$$2\ Na^+_{(aq)} + 2\ NO_3^-{}_{(aq)} + Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow 2\ Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} + Cu^{2+}_{(aq)} + 2\ NO_3^-{}_{(aq)}$$

(No Precipitate)

Since *all ions are spectator ions* and they cancel out on both sides, *there is no net-ionic equation.*
(No reaction!)

Assignment

8.4 pg. 289 #1 to 12 and 15 **Chapter 8 Review pg. 293−295 #26 to 44**

Chapter 9: Stoichiometry

9.1: Calculating Quantities in Reactions

Avogadro's Number: - a group of (6.022×10^{23}) molecules = 1 mole

Stoichiometry: - the calculation of quantities in a chemical reaction.
- the coefficients of various reactants and /or products form **mole ratios**.
- these mole ratios hold for moles, molecules or atoms.

Mole Ratio: - a ratio form between the coefficient of the required chemical amount to the given chemical amount. $\left(\dfrac{\textbf{require coefficient}}{\textbf{given coefficient}}\right)$

Example 1: Interpret the chemical equation $4\ NH_{3\,(g)} + 7\ O_{2\,(g)} \rightarrow 4\ NO_{2\,(g)} + 6\ H_2O_{(g)}$ in terms of
a. moles. b. molecules. c. masses.

	$4\ NH_{3\,(g)}$	$7\ O_{2\,(g)}$	$4\ NO_{2\,(g)}$	$6\ H_2O_{(g)}$
a.	**4 moles of NH_3**	**7 moles of O_2**	**4 moles of NO_2**	**6 moles of H_2O**
b.	**4 molecules of NH_3**	**7 molecules of O_2**	**4 molecules of NO_2**	**6 molecules of H_2O**
c.	$m = nM$ $m = (4\ \cancel{\text{mol}})(17.04\ \text{g}/\cancel{\text{mol}})$ $\boldsymbol{m = 68.16\ \text{g}}$	$m = nM$ $m = (7\ \cancel{\text{mol}})(32.00\ \text{g}/\cancel{\text{mol}})$ $\boldsymbol{m = 224.0\ \text{g}}$	$m = nM$ $m = (4\ \cancel{\text{mol}})(46.01\ \text{g}/\cancel{\text{mol}})$ $\boldsymbol{m = 184.0\ \text{g}}$	$m = nM$ $m = (6\ \cancel{\text{mol}})(18.02\ \text{g}/\cancel{\text{mol}})$ $\boldsymbol{m = 108.1\ \text{g}}$

***Note the Law of Conservation of Mass holds after converting mole of each chemical to its mass.**

Example 2: 4.35 mol of $PCl_{5\,(g)}$ is decomposed into its elements. Write a balance equation and determined the amount of chlorine produced.

$$\underline{4}\ PCl_{5\,(g)} \rightarrow P_{4\,(s)} + \underline{10}\ Cl_{2\,(g)}$$
4.35 mol ? mol

$$n_{Cl_2} = 4.35\ \cancel{\text{mol PCl}_5} \times \frac{\textbf{10 mol Cl}_2}{\textbf{4}\ \cancel{\textbf{mol PCl}_5}} = 10.875\ \text{mol Cl}_2 \qquad \boldsymbol{n_{Cl_2} = 10.9\ \text{mol}}$$

Gravimetric Stoichiometry: - stoichiometry that involves quantities of masses.

Density-Volume Stoichiometry: - stoichiometry that involves quantities of volumes with densities given.

Particles Stoichiometry: - stoichiometry that involves quantities of particles such as atoms and molecules.

General Stoichiometry Procedure:

1. Predict the products and balance the chemical equation.
2. Put all the information given under the appropriate chemicals. If necessary, determine the molar mass of any chemical involved (i.e. if the chemical given or asked involves mass).
3. Find the moles of the given chemical by using the proper conversion factor. This can be $\left(mass \times \dfrac{1\,\text{mol}}{\text{Molar Mass (g)}}\right)$ if mass is given. It can be $\left(particles\ given \times \dfrac{1\,\text{mol}}{6.022\times10^{23}\,\text{particles}}\right)$ if number of atoms or molecules are given. If a Volume is given with Density, then it can be $\left(Volume\ given \times \dfrac{\text{Density (g)}}{1\,\text{mL or }1\,\text{L}} \times \dfrac{1\,\text{mol}}{\text{Molar Mass (g)}}\right)$
4. Continue to find the mole of the required chemical by using mole ratio. $\left(\times\dfrac{\text{require coefficient}}{\text{given coefficient}}\right)$
5. Convert mole of the required chemical to the type of quantity asks. If the question requires mass, then use conversion factor $\left(\times\dfrac{\text{Molar Mass (g)}}{1\,\text{mol}}\right)$. If the questions asks for the number of particles, then use conversion factor $\left(\times\dfrac{6.022\times10^{23}\,\text{particles}}{1\ \text{mol}}\right)$. If it wants the volume and density is given, then we can use $\left(\times\dfrac{\text{Molar Mass (g)}}{1\,\text{mol}}\times\dfrac{1\,\text{mL or }1\,\text{L}}{\text{Density (g)}}\right)$

Example 3: Determine the mass of carbon dioxide formed when 50.0 kg of butane ($C_4H_{10\,(l)}$) is burned.

$2\ C_4H_{10\,(g)}$	+	$13\ O_{2\,(g)}$	→	$8\ CO_{2\,(g)}$	+	$10\ H_2O_{\,(g)}$
50.0 kg				? g		
58.14 g/mol				M = 44.01 g/mol		

$$50.0\ \text{kg}\ \cancel{C_4H_{10}} \times \frac{1\ \cancel{\text{mol}\ C_4H_{10}}}{58.14\ \text{g}\ \cancel{C_4H_{10}}} \times \frac{8\ \cancel{\text{mol}\ CO_2}}{2\ \cancel{\text{mol}\ C_4H_{10}}} \times \frac{44.01\ \text{g}\ CO_2}{1\ \cancel{\text{mol}\ CO_2}} = 151.3931189\ \text{kg}\ CO_2$$

$$\boldsymbol{m_{CO_2} = 151\ \text{kg}}$$

Example 4: Barium bromide solution was mixed with an excess sodium phosphate solution. What was the mass of barium bromide solid needed in the original solution to form 3.21 g of precipitate?

$3\ BaBr_{2\,(aq)}$	+	$2\ Na_3PO_{4\,(aq)}$	→	$Ba_3(PO_4)_{2\,(s)}$	+	$6\ NaBr_{\,(aq)}$
? g				3.21 g		
297.13 g/mol				M = 601.93 g/mol		

$$3.21\ \cancel{\text{g}}\ \cancel{Ba_3(PO_4)_2} \times \frac{1\ \cancel{\text{mol}}\ Ba_3(PO_4)_2}{601.93\ \text{g}\ Ba_3(PO_4)_2} \times \frac{3\ \cancel{\text{mol}}\ BaCl_2}{1\ \cancel{\text{mol}}\ Ba_3(PO_4)_2} \times \frac{297.13\ \text{g}\ BaCl_2}{1\ \cancel{\text{mol}}\ BaCl_2} = 4.753645607\ \text{g}\ BaBr_2$$

$$\boldsymbol{m_{BaBr_2} = 4.75\ \text{g}}$$

Example 5: Aluminium metal combines with chlorine gas to form a white solid. What is the mass of this product when 3.46×10^{25} molecules of chlorine gas is used for this reaction?

$$2\,Al_{(s)} + 3\,Cl_{2\,(g)} \rightarrow 2\,AlCl_{3\,(g)}$$

Cl_2: 3.46×10^{25} molecules; 6.022×10^{23} molecules = 1 mol

$AlCl_3$: ? g; M = 133.33 g/mol

$$3.46 \times 10^{25}\ \cancel{\text{molecules } Cl_2} \times \frac{1\ \cancel{\text{mol } Cl_2}}{6.022\times 10^{23}\ \cancel{\text{molecules } Cl_2}} \times \frac{2\ \cancel{\text{mol } AlCl_3}}{3\ \cancel{\text{mol } Cl_2}} \times \frac{133.33\text{ g } AlCl_3}{1\ \cancel{\text{mol } AlCl_3}} = 5107.1\text{ g } AlCl_3$$

$$\boldsymbol{m_{AlCl_3} = 5.11 \times 10^3\text{ g or } 5.11\text{ kg}}$$

Example 6: At room temperature and normal pressure, nitrogen and ammonia have densities of 1.130 g/L and 0.687 g/L. Suppose 400. mL of nitrogen gas is reacted with excess hydrogen under the same conditions. What is the volume of ammonia gas formed from this reaction?

$$N_{2\,(g)} + 3\,H_{2\,(g)} \rightarrow 2\,NH_{3\,(g)}$$

N_2: 400 mL = 0.400 L; D = 1.130 g/L; M = 28.02 g/mol

NH_3: ? mL; D = 0.687 g/L; M = 17.04 g/mol

$$0.400\ \cancel{\text{L } N_2} \times \frac{1.130\ \cancel{\text{g } N_2}}{1\ \cancel{\text{L } N_2}} \times \frac{1\ \cancel{\text{mol } N_2}}{28.02\ \cancel{\text{g } N_2}} \times \frac{2\ \cancel{\text{mol } NH_3}}{1\ \cancel{\text{mol } N_2}} \times \frac{17.04\ \cancel{\text{g } NH_3}}{1\ \cancel{\text{mol } NH_3}} \times \frac{1\text{ L } NH_3}{0.697\ \cancel{\text{g } NH_3}} = 0.8007985028\text{ L } NH_3$$

$$\boldsymbol{V_{NH_3} = 0.801\text{ L or } 801\text{ mL}}$$

Assignment

9.1 pg. 304 #1 and 2 (Practice); pg. 307 #1 to 4 (Practice); pg. 309 #1 to 4 (Practice); pg. 311 #1 and 2 (Practice); pg. 311 # 1 to 7

9.2: Limiting Reactants and Percentage Yield

Excess Reactant: - the reactant that is not completely used up in the reaction.

Limiting Reactant: - the reactant with the smaller amount (accounting for the mole ratio of the two reactants).
- a limiting reactant will always be completely used up in the reaction.
- if the mass of the product is calculated using the excess reactant, it will always be more than the mass determined using the limiting reactant.
- ***just because the reactant has a smaller mass initially does not mean it is a limiting reactant***.
- the mass of the product calculated from the limiting reactant is referred to as the ***theoretical yield*** (because it is the amount that the reaction ***should*** produce).
- the theoretical yield can be determined by calculation without the need of experimentation.

Note: A limiting reagent question will always have enough information to find the moles of both reactants.

Actual Yield: - the mass of the product that was actually produced in the lab. It is also referred to as the ***Experimental Yield***.

Steps to deal with Limiting Reagent Problems: (the quantities of both reactants are given in the question)

1. Calculate the mass of the product using one reactant using the stoichiometric method.
2. Calculate the mass of the product using the other reactant using the stoichiometric method.
3. **The reactant that generates the smaller product mass is the limiting reactant**. That product mass calculated is the ***theoretical yield***.
4. The ***other reactant that gives a larger product mass*** is the ***excess reactant***.
5. If the question provides the actual yield, then determine the percentage yield and / or percentage error.

$$\textbf{\% Yield} = \frac{\textbf{Actual}}{\textbf{Theoretical}} \times \textbf{100\%} \qquad \textbf{\% Error} = \frac{\left|\textbf{Theoretical} - \textbf{Actual}\right|}{\textbf{Theoretical}} \times \textbf{100\%}$$

Example 1: 5.00 g of phosphorus is reacted with 15.00 g of chlorine gas to produce phosphorus trichloride.

a. Determine the theoretical yield of the product produced and identify the limiting and excess reactant.

$P_{4\,(s)}$	+	$6\,Cl_{2\,(g)}$	→	$4\,PCl_{3\,(s)}$
5.00 g		15.00 g		? g
M = 123.88 g/mol		M = 70.90 g/mol		M = 137.32 g/mol

Since there is enough information to determine the moles of two reactants (quantities of both reactants are given), we need to find the mass of the product from each of these reactant before labelling which reactant is limiting.

① $5.00\,\cancel{g}\,\cancel{P_4} \times \frac{1\,\cancel{mol}\,\cancel{P_4}}{123.88\,\cancel{g}\,\cancel{P_4}} \times \frac{4\,\cancel{mol}\,\cancel{PCl_3}}{1\,\cancel{mol}\,\cancel{P_4}} \times \frac{137.32\text{ g }PCl_3}{1\,\cancel{mol}\,\cancel{PCl_3}} = 22.2\text{ g }PCl_3$

② $15.00\text{ g }Cl_2 \times \frac{1\,\cancel{mol}\,\cancel{Cl_2}}{70.90\,\cancel{g}\,\cancel{Cl_2}} \times \frac{4\,\cancel{mol}\,\cancel{PCl_3}}{6\,\cancel{mol}\,\cancel{Cl_2}} \times \frac{137.32\text{ g }PCl_3}{1\,\cancel{mol}\,\cancel{PCl_3}} =$ **19.4 g PCl_3** (lesser product mass)

Since Cl_2 gives a smaller calculated product mass, **Cl_2 is the limiting reactant**; **P_4 is the excess reactant**.

b. The actual yield of the product was measured at 17.51 g in an experiment. What are the percentage yield and the percentage error from the lab?

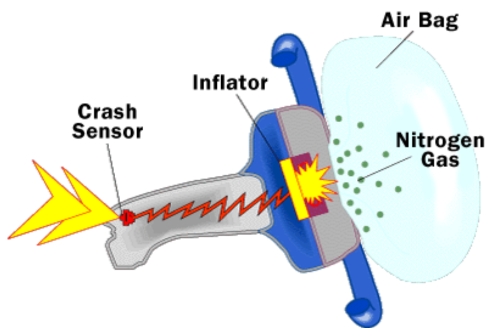
$$\%\text{ Yield} = \frac{17.51\text{ g}}{19.4\text{ g}} \times 100\% \qquad \%\text{ Error} = \frac{|19.4\text{ g} - 17.51\text{ g}|}{19.4\text{ g}} \times 100\%$$

% Yield = 90.3% **% Error = 9.74%**

Assignment

9.2 pg. 314 #1 to 3 (Practice); pg. 317 #1 to 3 (Practice); pg. 318 #1 to 3 (Practice); pg. 319 #1 and 14

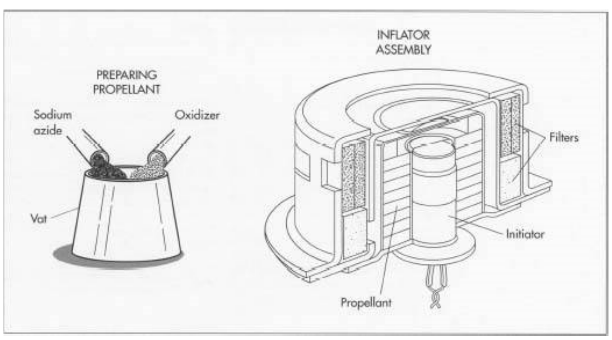
9.3: Stoichiometry of Cars

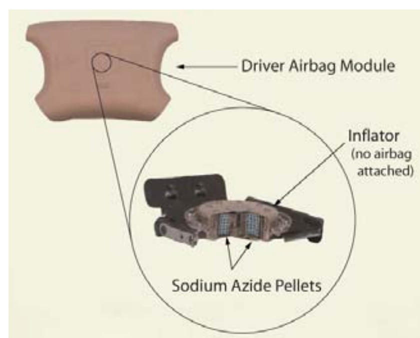


Air-Bag Chemistry:

- solid sodium azide (NaN_3), an unstable substance, can decompose given enough initial energy into sodium metal and nitrogen gas. Hence allowing the airbag to inflate quickly.

$$2\ NaN_{3\,(s)} \rightarrow 2\ Na_{(s)} + 3\ N_{2\,(g)}$$





Example 1: Suppose 55.8 L of nitrogen gas is needed to inflate an airbag. What mass of sodium azide must be placed inside the airbag column if the density of nitrogen is 0.92 g/L?

$2\ NaN_{3\,(s)}$	$\rightarrow$	$2\ Na_{(s)}$	+	$3\ N_{2\,(g)}$
? g				55.8 L and 0.92 g/L
M = 65.02 g/mol				M = 28.02 g/mol

$$55.85\ \cancel{\text{L N}_2} \times \frac{0.92\ \cancel{\text{g N}_2}}{1\ \cancel{\text{L N}_2}} \times \frac{1\ \cancel{\text{mol N}_2}}{28.02\ \cancel{\text{g N}_2}} \times \frac{2\ \cancel{\text{mol NaN}_3}}{3\ \cancel{\text{mol N}_2}} \times \frac{65.02\text{ g NaN}_3}{1\ \cancel{\text{mol NaN}_3}} = 79.44475584\text{ g NaN}_3$$

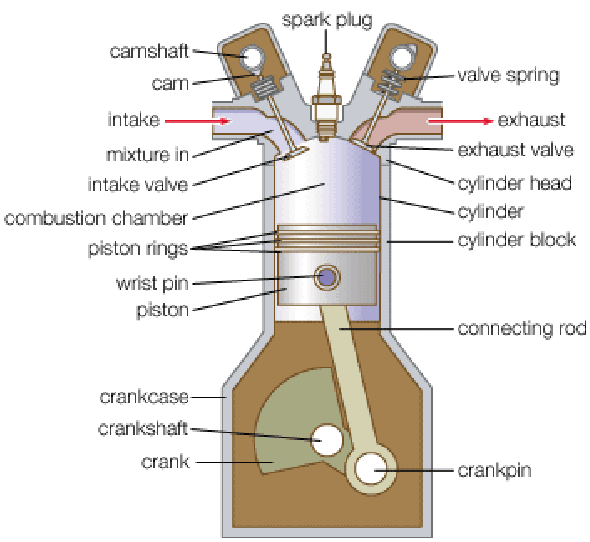
m_{NaN_3} **= 79 g**

Fuel-Oxygen Ratio: - the amount of fuel to amount of oxygen to ensure complete combustion in an engine.
- the optimal fuel ratio for a car engine depends on what the car is doing (see below).

Engine Activity	**Fuel Oxygen Mole Ratio**	**Results**
Starting	1: 1.7	Very low engine efficiency Most Harmful Pollutants (NO and CO) produce - incomplete combustion
Idling	1: 7.4	Still low efficiency and Some Other Pollutants (NO and CO) produce
Running at Normal Speed	1: 13.2	Optimal efficiency and Main Exhausts (NO_2, CO_2 and H_2O) produce

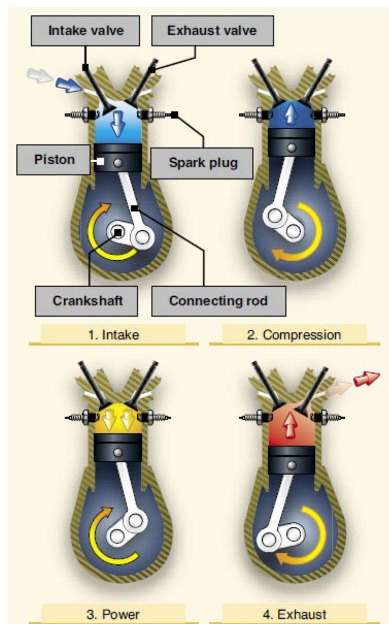
- automobile gasoline is a mixture; the main component of gasoline is isooctane – C_8H_{18} (the other component is heptane – C_7H_{16}).
- a rating of 87 octane means 87/13 isooctane to heptane ratio in the fuel. It also means how much the fuel can be compressed. High performance engine requires a higher compression and hence higher octane rating.
- assuming gasoline is pure octane, the equation for the hydrocarbon combustion is

$$2\ C_8H_{18\,(l)} + 25\ O_{2\,(g)} \rightarrow 16\ CO_{2\,(g)} + 18\ H_2O_{\,(g)}$$



(left) a typical automobile engine cylinder.

(right) the four-stroke cycle of igniting fuel and ejecting exhaust in a cylinder; the crankshaft turns in the direction of the arrow; the spark-plug ignites the fuel during the compression part of the cycle.



Engine Cycle: - a complete turn of events when the cylinder intakes the fuel, then compresses and ignites the fuel. This follows by the power output where the exhaust products (CO_2 and H_2O) push down on the piston. Finally, the exhaust gases are pushed out of the cylinder (see diagram above).
- each four-stroke cycle as described above ***uses up a volume of air equal to that of the size of a cylinder***.
- a typical automobile engine can come in four, six (V-6), or eight (V-8) cylinders. Some very high power engine has twelve cylinders (V-12).

Flooding the Engine: - when there is too much fuel in the cylinder and not enough engine – the engine will stop, and it will not start again until the air intake is reset. Need to open the carburetor and tip the air intake up).

Engine Stall: - when there is no enough fuel in the cylinder and too much air – the engine will act like it is out of gas.

Example 2: A V-8 (eight cylinder) engine burned for 30.0 cycles. Determine the volume of gasoline (isooactane) burned if each cylinder has a 600. mL air capacity.
(Density of isooctane = 0.692 g/mL; Density of oxygen = 1.33 g/L. Air is 21.0% oxygen)

$2\,C_8H_{18\,(l)}$	+	$25\,O_{2\,(g)}$	→	$16\,CO_{2\,(g)}$	+	$18\,H_2O_{(g)}$
? mL		30.0 cycles; 8 cylinders; 600 mL air/cylinder				
0.692 g/mL		1.33 g/L; air = 21.0% O_2				
M = 114.26 g/mol		M = 32.00 g/mol				

First, we have to calculate the volume of oxygen in the cylinder (Volume of Air ≠ Volume of Oxygen)
Note the density of oxygen is given in g/L → we need to convert the volume of oxygen to Litre.

$$30.0\,\cancel{\text{cycles}} \times \frac{8\,\cancel{\text{cylinders}}}{1\,\cancel{\text{cycle}}} \times \frac{600\,\cancel{\text{mL air}}}{1\,\cancel{\text{cylinder}}} \times \frac{21.0\,\text{mL } O_2}{100\,\cancel{\text{mL air}}} \times \frac{1\,\text{L } O_2}{1000\,\cancel{\text{mL } O_2}} = 30.24\text{ L } O_2 \text{ used}$$

Next, we can determine the volume of C_8H_{18} (gasoline) used with regular stoichiometry.

$$30.24\,\cancel{\text{L } O_2} \times \frac{1.33\,\cancel{\text{g } O_2}}{1\,\cancel{\text{L } O_2}} \times \frac{1\,\cancel{\text{mol } O_2}}{32.00\,\cancel{\text{g } O_2}} \times \frac{2\,\cancel{\text{mol } C_8H_{18}}}{25\,\cancel{\text{mol } O_2}} \times \frac{114.26\,\cancel{\text{g } C_8H_{18}}}{1\,\cancel{\text{mol } C_8H_{18}}} \times \frac{1\,\text{mL } C_8H_{18}}{0.692\,\cancel{\text{g } C_8H_{18}}} = 16.60204405\text{ mL}$$

$$V_{C_8H_{18}} = 16.6\text{ mL}$$

Example 3: A V-6 (six cylinder) engine has a individual cylinder air capacity of 500. mL. How many cycles are needed to burn 1.00 gal (3.75 L) of isooctane?
(Density of isooctane = 0.692 g/mL; Density of oxygen = 1.33 g/L. Air is 21.0% oxygen)

$2\,C_8H_{18\,(l)}$	+	$25\,O_{2\,(g)}$	→	$16\,CO_{2\,(g)}$	+	$18\,H_2O_{(g)}$
3.75 L = 3750 mL		?? cycles; 6 cylinders				
0.692 g/mL		500 mL air/cylinder; air = 21.0% O_2				
M = 114.26 g/mol		1.33 g/L; M = 32.00 g/mol				

First, we have to calculate the volume of oxygen used with regular stoichiometry. Density of C_8H_{18} was given in g/mL → need to convert 1.00 L C_8H_{18} to mL.

$$3750\,\cancel{\text{mL } C_8H_{18}} \times \frac{0.692\,\cancel{\text{g } C_8H_{18}}}{1\,\cancel{\text{mL } C_8H_{18}}} \times \frac{1\,\cancel{\text{mol } C_8H_{18}}}{114.26\,\cancel{\text{g } C_8H_{18}}} \times \frac{25\,\cancel{\text{mol } O_2}}{2\,\cancel{\text{mol } C_8H_{18}}} \times \frac{32.00\,\cancel{\text{g } O_2}}{1\,\cancel{\text{mol } O_2}} \times \frac{1\,\cancel{\text{L } O_2}}{1.33\,\cancel{\text{g } O_2}} = 6830.484227\text{ L } O_2$$

Next, we can determine the number of cycles after converting volume of oxygen to volume of air.
(Volume of Air ≠ Volume of Oxygen)

$$6830.484227\,\cancel{\text{L } O_2} \times \frac{100\,\cancel{\text{L air}}}{21.0\,\cancel{\text{L } O_2}} \times \frac{1000\,\cancel{\text{mL air}}}{1\,\cancel{\text{L air}}} \times \frac{1\,\cancel{\text{cylinder}}}{500\,\cancel{\text{mL air}}} \times \frac{1\,\text{cycle}}{6\,\cancel{\text{cylinders}}} = 10842.03846\text{ cycles}$$

1.08×10^4 cycles ≈ 11 thousands cycles

Incomplete Combustion: - when the fuel-oxygen ratio is low (oxygen is the limiting reactant), the product of the combustion can be a mixture $CO_{(g)}$, $C_{(s)}$ with $H_2O_{(g)}$. Carbon monoxide is a colourless and odourless gas. It is highly toxic because it inhibits haemoglobin in the blood to deliver oxygen to cells.

$$2\,C_8H_{18\,(l)} + 13\,O_{2\,(g)} \rightarrow 8\,CO_{(g)} + 8\,C_{(s)} + 18\,H_2O_{(g)}$$

Photochemical Smog: - under the high temperature in the engine, nitrogen in the air can combine with oxygen to form $NO_{(g)}$ and $NO_{2\,(g)}$ (photochemical smog).

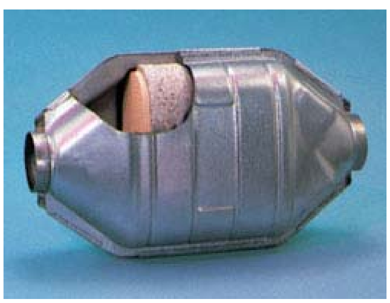
$$N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{(g)}$$
$$2\,NO_{(g)} + O_{2\,(g)} \rightarrow 2\,NO_{2\,(g)}$$

- nitrogen dioxide can further react with oxygen under sunlight to form ground-level ozone (when inhale, it can react with cholesterol to form plague, thereby increasing the chance of a heart-attack). Ozone is also considered as a constituent of photochemical smog.

$$NO_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{(g)} + O_{3\,(g)}$$

(above) Smog over the Los Angeles skyline

Catalytic Converter: - converts $NO_{(g)}$ (result of burning nitrogen at high temperature) to $N_{2\,(g)}$ and $O_{2\,(g)}$ in a relatively short amount of time. Oxygen gas along with the catalytic converter is also used to produce $CO_{2\,(g)}$ from $CO_{(g)}$.



$$2\,NO_{(g)} \xrightarrow{\text{catalytic converter}} N_{2\,(g)} + O_{2\,(g)}$$
$$2\,CO_{(g)} + O_{2\,(g)} \xrightarrow{\text{catalytic converter}} 2\,CO_{2\,(g)}$$

A catalytic converter for most modern vehicle. Leaded gasoline deactivates catalytic converter. Therefore, they are not legally used in vehicles

Example 4: Calculate the mass of carbon monoxide formed during an incomplete combustion of 1 gallon (3.75 L) of isooctane, $C_8H_{18\,(l)}$. (Density of isooctane = 0.692 g/mL)

$2\,C_8H_{18\,(l)}$	+	$13\,O_{2\,(g)}$	$\rightarrow$	$8\,CO_{(g)}$	+	$8\,C_{(s)}$	+	$18\,H_2O_{(g)}$
3.75 L; 0.692 g/mL				? g				
M = 114.18 g/mol				M = 28.01 g/mol				

$$3.75\ \cancel{L\ C_8H_{18}} \times \frac{1000\ \cancel{mL}\ \cancel{C_8H_{18}}}{1\ \cancel{L}\ \cancel{C_8H_{18}}} \times \frac{0.692\ \cancel{g}\ \cancel{C_8H_{18}}}{1\ \cancel{mL}\ \cancel{C_8H_{18}}} \times \frac{1\ \cancel{mol}\ \cancel{C_8H_{18}}}{114.26\ \cancel{g}\ \cancel{C_8H_{18}}} \times \frac{8\ \cancel{mol}\ \cancel{CO}}{2\ \cancel{mol}\ \cancel{C_8H_{18}}} \times \frac{28.01\ g\ CO}{1\ \cancel{mol}\ \cancel{CO}}$$
$$= 2544.580781\ g\ CO$$

$$m_{CO} = \mathbf{2.54 \times 10^3\ g\ or\ 2.54\ kg}$$

Assignment

9.3 pg. 322 #1 to 4 (Practice); pg. 324 #1 to 3 (Practice);
pg. 327 #1 (Practice); pg. 327 #1 and 9
Chapter 9 Review pg. 329−332 #21 to 49 (odd); Optional: #22 to 50 (even)