AP Chemistry – Unit 2 (Chapter 3) Review Key

1. Write and balance the following equations.

   a. Solid calcium carbide, CaC_2, reacts with water to form an aqueous solution of calcium hydroxide and acetylene gas, C_2H_2.

   $$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$$

   b. When solid potassium chlorate is heated, it decomposes to form solid potassium chloride and oxygen gas.

   $$2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g)$$

   c. Solid zinc metal reacts with sulfuric acid to form hydrogen gas and an aqueous solution of zinc sulfate.

   $$Zn(s) + H_2SO_4(aq) \rightarrow H_2(g) + ZnSO_4(aq)$$

   d. When liquid phosphorous trichloride is added to water, it reacts to form aqueous phosphorous acid and aqueous hydrochloric acid.

   $$PCl_3(l) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HCl(aq)$$

   e. When hydrogen sulfide gas is passed over hot iron (III) hydroxide, the resultant reaction produces solid iron (III) sulfide and steam.

   $$3H_2S(g) + 2Fe(OH)_3(s) \rightarrow Fe_2S_3(s) + 6H_2O(g)$$

2. Write a balanced chemical equation for the reaction that occurs when…

   a. Mg (s) reacts with Cl_2 (g).

   $$Mg(s) + Cl_2(g) \rightarrow MgCl_2(g)$$

   b. Barium carbonate decomposes into barium oxide and carbon dioxide gas when heated.

   $$BaCO_3(s) \xrightarrow{\Delta} BaO(s) + CO_2(g)$$

c. The hydrocarbon, styrene, C_8H_8 (l) completely combusts.

$$C_8H_8(l) + 10\,O_2(g) \rightarrow 8\,CO_2(g) + 4\,H_2O(g)$$

d. Dimethylether, CH_3OCH_3 (g), completely combusts.

$$CH_3OCH_3(g) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 3\,H_2O(g)$$

3. The molecular formula for allicin, the compound responsible for the characteristic of smell of garlic, is $C_6H_{10}OS_2$.

a. What is the molar mass of allicin?

C 6×12 g/mol $= 72$ g/mol
H 10×1 g/mol $= 10$ g/mol
O 1×16 g/mol $= 16$ g/mol
S 2×32 g/mol $= 64$ g/mol

$= \boxed{162 \text{ g/mol}}$

b. How many moles of allicin are present in 3.00 mg of this substance?

$$3.00\,\text{mg}\left(\frac{1\,\text{g}}{1000\,\text{mg}}\right)\left(\frac{1\,\text{mol}}{162\,\text{g}}\right) = \boxed{1.85 \times 10^{-5}\,\text{mol}}$$

c. How many S atoms are present in 5.00 mg of allicin?

$$5.00\,\text{mg}\,C_6H_{10}OS_2\left(\frac{1\,\text{g}\,C_6H_{10}OS_2}{1000\,\text{mg}\,C_6H_{10}OS_2}\right)\left(\frac{1\,\text{mol}\,C_6H_{10}OS_2}{162\,\text{g}\,C_6H_{10}OS_2}\right)\left(\frac{2\,\text{mol}\,S}{1\,\text{mol}\,C_6H_{10}OS_2}\right)$$

$$= 6.17 \times 10^{-5}\,\text{mol S}\left(\frac{6.02 \times 10^{23}\,\text{atoms S}}{1\,\text{mol S}}\right) = \boxed{3.72 \times 10^{19}\,\text{atoms S}}$$

4. The allowable concentration level of vinyl chloride. C_2H_3Cl, in the atmosphere in a chemical plant is 2.0×10^{-6} g/L. How many moles of vinyl chloride in each liter does this represent? How many molecules per liter?

moles of C_2H_3Cl

$$\frac{2.0 \times 10^{-6}\,\text{g}}{\text{L}}\left(\frac{1\,\text{mol}}{62.5\,\text{g}}\right) = \boxed{3.2 \times 10^{-8}\,\frac{\text{mol}}{\text{L}}}$$

molecules of C_2H_3Cl

$$\frac{3.2 \times 10^{-8}\,\text{mol}}{\text{L}}\left(\frac{6.02 \times 10^{23}\,\text{molecules}}{1\,\text{mol}}\right) = \boxed{1.9 \times 10^{16}\,\frac{\text{molecules}}{\text{L}}}$$

5. What is the molecular formula of each of the following compounds?

a. Empirical formula CH_2, molar mass = 84 g/mol.

$\frac{CH_2}{14 \text{ g/mol}}$ $\frac{84}{14} = 6$ $\frac{\text{M.F.}}{6(CH_2)} =$ **C_6H_{12}**

b. Empirical formula, NH_2Cl, molar mass = 51.5 g/mol.

$\frac{NH_2Cl}{51.5 \text{ g/mol}}$ $\frac{51.5}{51.5} = 1$ $\frac{\text{M.F.}}{1(NH_2Cl)} =$ **NH_2Cl**

6. A component of protein called serine has the percent composition is as follows, what is the empirical of serine? C = 34.95 % H= 6.844 % O = 46.56 % N= 13.59 %

C	H	O	N
$\frac{34.95 \text{ g}}{12 \text{ g/mol}}$	$\frac{6.844 \text{ g}}{1.0 \text{ g/mol}}$	$\frac{46.56 \text{ g}}{16 \text{ g/mol}}$	$\frac{13.59 \text{ g}}{14 \text{ g/mol}}$
$= \frac{2.9125 \text{ mol}}{.9707 \text{ mol}}$	$\frac{6.844 \text{ mol}}{.9707 \text{ mol}}$	$\frac{2.91 \text{ mol}}{.9707 \text{ mol}}$	$\frac{.9707 \text{ mol}}{.9707 \text{ mol}}$
= 3	= 7	= 3	= 1

$\frac{\text{EF}}{C_3H_7O_3N}$

7. Combustion of 3.903 g of a compound containing C, H, and O yields 9.848 g of CO_2 and 1.728 g of H_2O. What is the empirical formula?

$$9.848 \text{ g } CO_2 \left(\frac{1 \text{ mol } CO_2}{44 \text{ g } CO_2}\right)\left(\frac{1 \text{ mol C}}{1 \text{ mol } CO_2}\right)\left(\frac{12 \text{ g C}}{1 \text{ mol C}}\right) = 2.686 \text{ g C}$$

$$1.728 \text{ g } H_2O \left(\frac{1 \text{ mol } H_2O}{18 \text{ g } H_2O}\right)\left(\frac{2 \text{ mol H}}{1 \text{ mol } H_2O}\right)\left(\frac{1 \text{ g H}}{1 \text{ mol H}}\right) = .192 \text{ g H}$$

mass of O

$$3.903 \text{ g} - 2.686 \text{ g} - .192 \text{ g} = 1.025 \text{ g O}$$

$\frac{2.686 \text{ g C}}{12 \text{ g/mol}}$	$\frac{.192 \text{ g H}}{1 \text{ g/mol}}$	$\frac{1.025 \text{ g O}}{16 \text{ g/mol}}$
$= \frac{.2238 \text{ mol}}{.0641 \text{ mol}}$	$\frac{.192 \text{ mol}}{.0641 \text{ mol}}$	$\frac{.0641 \text{ mol}}{.0641 \text{ mol}}$
$= (3.5)2$	$= (3)2$	$= (1)2$

$\frac{\text{EF}}{C_7H_6O_2}$

8. Caffeine has C, H, O, and N. 1.00 mg of caffeine is combusted to form 1.813 mg of CO_2, 0.4639 mg of H_2O, and .2885 mg of N_2. Find the empirical formula.

$$1.813 mg\ CO_2 \left(\frac{1 g\ CO_2}{1000 mg\ CO_2}\right)\left(\frac{1 mol\ CO_2}{44 g\ CO_2}\right)\left(\frac{1 mol\ C}{1 mol\ CO_2}\right)\left(\frac{12 g\ C}{1 mol\ C}\right) = .0004945 g\ C$$

$$.4639 mg\ H_2O\left(\frac{1 g\ H_2O}{1000 mg\ H_2O}\right)\left(\frac{1 mol\ H_2O}{18 g\ H_2O}\right)\left(\frac{2 mol\ H}{1 mol\ H_2O}\right)\left(\frac{1 g\ H}{1 mol\ H}\right) = .00005154 g\ H$$

$$.2885 mg\ N_2\left(\frac{1 g\ N_2}{1000 mg\ N_2}\right)\left(\frac{1 mol\ N_2}{28 g\ N_2}\right)\left(\frac{2 mol\ N}{1 mol\ N_2}\right)\left(\frac{14 g\ N}{1 mol\ N}\right) = .0002885 g\ N$$

mass of O $= 1.00 mg\left(\frac{1 g}{1000 mg}\right) - .001 g - .0004945 g - .00005154 g - .0002885 g$

$= .0001655 g\ O$

$\frac{.0004945 g\ C}{12\ g/mol} = .0000412\ mol$; $\frac{.0000412\ mol}{.0000103\ mol} = 4$

$\frac{.0000515 g\ H}{1\ g/mol} = .0000515\ mol$; $\frac{.0000515\ mol}{.0000103\ mol} = 5$

$\frac{.0002885 g\ N}{14\ g/mol} = .0000206\ mol$; $\frac{.0000206\ mol}{.0000103\ mol} = 2$

$\frac{.0001655 g\ O}{16\ g/mol} = .0000103\ mol$; $\frac{.0000103\ mol}{.0000103\ mol} = 1$

EF: $C_4H_5N_2O$

9. Hydrofluoric acid, HF (aq), cannot be stored in glass bottles because compounds called silicates in the glass are attacked by the HF (aq). Sodium silicate (Na_2SiO_3), for example, reacts as follows:

$$\mathbf{Na_2SiO_3\ (s)\ +\ 8HF\ (aq)\ \rightarrow\ H_2SiF_6\ (aq)\ +\ 2NaF\ (aq)\ +\ 3H_2O\ (l)}$$

a. How many moles of HF are needed to react with 0.300 mol of Na_2SiO_3?

$$.300\ mol\ Na_2SiO_3\left(\frac{8\ mol\ HF}{1\ mol\ Na_2SiO_3}\right) = \boxed{2.40\ mol\ HF}$$

b. How many grams of NaF form when 0.500 mol of HF reacts with excess Na_2SiO_3?

$$.500\ mol\ HF\left(\frac{2\ mol\ NaF}{8\ mol\ HF}\right)\left(\frac{42 g\ NaF}{1\ mol\ NaF}\right) = \boxed{5.25 g\ NaF}$$

c. What mass of Na_2SiO_3 can react with 0.800 g of HF?

$$.800 g\ HF\left(\frac{1\ mol\ HF}{20 g\ HF}\right)\left(\frac{1\ mol\ Na_2SiO_3}{8\ mol\ HF}\right)\left(\frac{122 g\ Na_2SiO_3}{1\ mol\ Na_2SiO_3}\right) = \boxed{.61 g\ Na_2SiO_3}$$

10. Several brands of antacids use $Al(OH)_3$ to react with stomach acid, which contains primarily HCl:

$$2\ \mathbf{Al(OH)_3\ (s)} + 6\ \mathbf{HCl\ (aq)} \rightarrow 2\ \mathbf{AlCl_3\ (aq)} + 6\ \mathbf{H_2O\ (l)}$$

a. Balance the equation.

b. Calculate the number of grams of HCl that can react with 0.500 g of $Al(OH)_3$.

$$.500\text{g } Al(OH)_3 \left(\frac{1\text{ mol } Al(OH)_3}{78\text{g } Al(OH)_3}\right)\left(\frac{6\text{ mol HCl}}{2\text{ mol } Al(OH)_3}\right)\left(\frac{36.5\text{g HCl}}{1\text{ mol HCl}}\right) = \boxed{.702\text{g HCl}}$$

c. Calculate the masses of $AlCl_3$ and H_2O produced when 0.500 g of $Al(OH)_3$ reacts.

$$.500\text{g } Al(OH)_3 \left(\frac{1\text{ mol } Al(OH)_3}{78\text{g } Al(OH)_3}\right)\left(\frac{2\text{ mol } AlCl_3}{2\text{ mol } Al(OH)_3}\right)\left(\frac{133.5\text{g } AlCl_3}{1\text{ mol } AlCl_3}\right) = \boxed{.856\text{g } AlCl_3}$$

$$.500\text{g } Al(OH)_3 \left(\frac{1\text{ mol } Al(OH)_3}{78\text{g } Al(OH)_3}\right)\left(\frac{6\text{ mol } H_2O}{2\text{ mol } Al(OH)_3}\right)\left(\frac{18\text{g } H_2O}{1\text{ mol } H_2O}\right) = \boxed{.346\text{g } H_2O}$$

11. When benzene (C_6H_6) reacts with bromine (Br_2), bromobenzene (C_6H_5Br) is obtained:

$$\mathbf{C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr}$$

a. What is the theoretical yield of bromobenzene in this reaction when 30.0 g of benzene reacts with 65.0 of bromine?

Find limiting reactant.

$$30.0\text{g } C_6H_6 \left(\frac{1\text{ mol } C_6H_6}{78\text{g } C_6H_6}\right)\left(\frac{1\text{ mol } C_6H_5Br}{1\text{ mol } C_6H_6}\right) = .385\text{ mol } C_6H_5Br$$

$$65.0\text{g } Br_2 \left(\frac{1\text{ mol } Br_2}{160\text{g } Br_2}\right)\left(\frac{1\text{ mol } C_6H_5Br}{1\text{ mol } C_6H_6}\right) = .406\text{ mol } C_6H_5Br$$

Limiting Reactant is C_6H_6

$$.385\text{ mol } C_6H_5Br \left(\frac{157\text{ g } C_6H_5Br}{1\text{ mol } C_6H_5Br}\right) = \boxed{60.4\text{g } C_6H_5Br}$$

b. If the actual yield of bromobenzene was 42.3 g, what is the % yield?

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 = \frac{42.3\,g}{60.4\,g} \times 100$$

$$= \boxed{70.0\%}$$

12. Dimethylhydrazine, $(CH_3)_2NNH_2$, was used as a fuel for the Apollo Lunar Descent Module, with N_2O_4 being used as the oxidant. The products of the reaction are H_2O, N_2, and CO_2.

a. Write a balanced equation for the reaction?

$$(CH_3)_2NNH_2 + 2N_2O_4 \rightarrow 4H_2O + 6N_2 + 2CO_2$$

b. If 150. kg of $(CH_3)_2NNH_2$ react with 460. kg of N_2O_4, what is the theoretical yield of N_2?

$$150.\,kg\,(CH_3)_2NNH_2 \left(\frac{1000\,g\,(CH_3)_2NNH_2}{1\,kg\,(CH_3)_2NNH_2}\right)\left(\frac{6\,mol\,N_2}{1\,mol\,(CH_3)_2NNH_2}\right) = 900000\,mol\,N_2$$

$$460.\,kg\,N_2O_4 \left(\frac{1000\,g\,N_2O_4}{1\,kg\,N_2O_4}\right)\left(\frac{6\,mol\,N_2}{2\,mol\,N_2O_4}\right) = 1380000\,mol\,N_2$$

Limiting Reactant is $(CH_3)_2NNH_2$

$$900000\,mol\,N_2 \left(\frac{28\,g\,N_2}{1\,mol\,N_2}\right) = \boxed{25\,200\,000\,g\,N_2}$$

c. If a 30.0 kg yield of N_2 gas represents a 68% yield, what mass of N_2O_4 would have been used up in the reaction?

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}}$$

$$.68 = \frac{30\,kg}{x}$$

$$x = \frac{30\,kg}{.68}$$

$$x = 44.1\,kg$$

(theoretical yield)

$$44.1\,kg\,N_2 \left(\frac{1000\,g\,N_2}{1\,kg\,N_2}\right)\left(\frac{2\,mol\,N_2O_4}{6\,mol\,N_2}\right)\left(\frac{92\,g\,N_2O_4}{1\,mol\,N_2O_4}\right)$$

$$= 1\,352\,400\,g\,N_2O_4$$