General Chemistry I
PLI Sheet 3

1. **The combustion of 1.38 g of a compound which contains C, H, O, and N yields 1.72 g of CO_2 and 1.18 g of H_2O. Another sample of the compound with a mass of 22.34 g is found to contain 6.75 g of O. What is the empirical formula of the compound?**

   Equation: $\boldsymbol{C_wH_xN_yO_z + O_2 \rightarrow CO_2 + H_2O + NO_2}$

   When asked for empirical formula, think about what information you need to eventually take mole ratios. This problem is very similar to yesterday's problem, just with another element to deal with. The approach however, is essentially the same.

$$1.18\ g\ H_2O * \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} * \frac{2\ mol\ H}{1\ mol\ H_2O} = 0.13097\ mol\ H * \frac{1.008\ g\ H}{1\ mol\ H} = 0.1320\ g\ H$$

$$1.72\ g\ CO_2 * \frac{1\ mol\ CO_2}{44.01\ g\ CO_2} * \frac{1\ mol\ C}{1\ mol\ CO_2} = 0.03908\ mol\ C * \frac{12.011\ g\ C}{1\ mol\ C} = 0.4694\ g\ C$$

$$Mass\ \%\ of\ O = \frac{6.75\ g}{22.34\ g} * 100\% = 30.21\%$$

Now, let's find the amount of O in the sample that was combusted.

$$Mass\ O = Mass\ \%\ O * sample\ mass = 0.3021 * 1.38\ g = 0.4170\ g\ O$$

Find the moles of O:

$$0.4170\ g\ O * \frac{1\ mol\ O}{15.9994\ g\ O} = 0.02606\ mol\ O$$

Use the calculated masses to find the mass of N in the sample, and subsequently moles of N.

$$\begin{aligned} Mass\ N &= Mass\ sample - Mass\ C - Mass\ H - Mass\ O \\ &= 1.38\ g - 0.4694\ g - 0.1320\ g - 0.4170\ g = 0.3616\ g\ N \end{aligned}$$

$$0.3616\ g\ N * \frac{1\ mol\ N}{14.0067\ g\ N} = 0.02582\ mol\ N$$

Take mole ratios to find empirical formula!

$$Mass\ \%\ of\ O = \frac{6.75\ g}{22.34\ g} * 100\% = 30.21\%$$

Now, let's find the amount of O in the sample that was combusted.

$$Mass\ O = Mass\ \%\ O * sample\ mass = 0.3021 * 1.38\ g = 0.4170\ g\ O$$

$$C: \frac{0.03908}{0.02582} = 1.5$$

$$H: \frac{0.13097}{0.02582} = 5.07 \sim 5$$

$$O: \frac{0.02606}{0.02582} = 1$$

$$N: \frac{0.02582}{0.02582} = 1$$

Resulting formula: $C_{1.5}H_5NO$
Remember empirical formulas must contain whole number coefficients! The final answer is: $C_3H_{10}N_2O_2$

2. **Write balanced equations corresponding to the following descriptions.**
   a. **When hydrogen sulfide gas is passed over solid hot iron(III) hydroxide, the resultant reaction produces solid iron(III) sulfide and gaseous water.**

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

   b. **When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphorous acid, H_3PO_3 (aq), and aqueous hydrochloric acid.**

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

   c. **The complete combustion of acetic acid (CH_3COOH), the main active ingredient in vinegar.**

   $$CH_3COOH(l) + 2O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

3. **Washing soda, a compound used to prepare hard water for washing laundry. Its formula is represented as $Na_2CO_3 \cdot xH_2O$, where x is the number of moles of H_2O per mole of Na_2CO_3. When a 2.558---g sample of washing soda is heated, all of the water of hydration is lost, leaving 0.948 g of anhydrous Na_2CO_3 left. What is x?**

$$Mass\ H_2O = Mass\ hydrate - Mass\ anhydrate$$
$$= 2.558\ g\ Na_2CO_3 \cdot H_2O - 0.948\ g\ Na_2CO_3 = 1.61\ g\ H_2O$$

$$1.61\ g\ H_2O * \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} = 0.0894\ mol\ H_2O$$

$$0.948\ g\ Na_2CO_3 * \frac{1\ mol\ Na_2CO_3}{105.988\ g\ Na_2CO_3} = 0.00894\ mol\ Na_2CO_3$$

Take mole ratios! Just like finding empirical formula.

$$\frac{mol\ H_2O}{mol\ Na_2CO_3} = \frac{0.0894}{0.00894} = 10$$

For every mole of Na_2CO_3, there are 10 moles of H_2O. Thus, x = 10.

4. **Determine the oxidation number of each element in each of the following substances:**
   a. **SO_2** S: +4; O: -2
   b. **$COCl_2$** C: +4; O: -2; Cl: -1
   c. **HBrO** H: +1; Br: +1; O: -2
   d. **$BaCrO_4$** Ba: +2; Cr: +6; O: -2
   e. **$HClO_4$** H: +1; Cl: +7; O: -2

5. **Which of the following are redox reactions? For those that are, indicate which elements are being oxidized and reduced. For those that are not, indicate whether they are neutralization or precipitation reactions.**

   a. $\boldsymbol{P_4(s) + 10HClO(aq) + 6H_2O(l) \rightarrow 4H_3PO_4(aq) + 10HCl(aq)}$

   Redox reaction. P is oxidized (O to +5) and Cl is reduced (+1 to -1)

   b. $\boldsymbol{Br_2(l) + 2K(s) \rightarrow 2KBr(s)}$

   Redox reaction. K is oxidized (0 to +1) and Br is reduced (0 to -1)

   c. $\boldsymbol{CH_3CH_2OH(l) + 3O_2(g) \rightarrow 3H_2O(l) + 2CO_2(g)}$

   It may help to rewrite the first reactant as C_2H_6O. Redox reaction.
   C is oxidized (-2 to +4), O_2 is reduced (0 to -2)

   d. $\boldsymbol{ZnCl_2(aq) + 2NaOH(aq) \rightarrow Zn(OH)_2(s) + 2NaCl(aq)}$

   Precipitation reaction (check ox #s to make sure they don't change from reactants to products

6. **Write the overall balanced equation, total ionic equation, and net ionic equations for each of the following cases. Identify the spectator ions.**
   a. **$Cr_2(SO_4)_3(aq) + (NH_4)_2CO_3(aq) \rightarrow$**

   Overall balanced equation:

$$Cr_2(SO_4)_3(aq) + 3(NH_4)_2CO_3(aq) \rightarrow Cr_2(CO_3)_3(s) + 3(NH_4)_2SO_4(aq)$$

   Total ionic equation:

$$2Cr^{3+}(aq) + 3SO_4^{2-}(aq) + 6NH_4^{1+}(aq) + 3CO_3^{2-}(aq) \rightarrow Cr_2(CO_3)_3(s) + 6NH_4^{1+}(aq) + 3SO_4^{2-}(aq)$$

   Net ionic equation:

$$2Cr^{3+}(aq) + 3CO_3^{2-}(aq) \rightarrow Cr_2(CO_3)_3(s)$$

   Spectator ions: SO_3^{2-}, NH_4^{1+}

   b. **$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow$**

   Overall balanced equation:

$$Ba(NO_3)_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KNO_3(aq)$$

   Total ionic equation:

$$Ba^{2+}(aq) + 2NO_3^{1-}(aq) + 2K^{1+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2K^{1+}(aq) + 2NO_3^{1-}(aq)$$

   Net ionic equation:

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

   Spectator ions: NO_3^{1-}, K^{1+}

   c. **$Fe(NO_3)_2(aq) + KOH(aq) \rightarrow$**

Overall balanced equation:

$$Fe(NO_3)_2(aq) + 2KOH(aq) \rightarrow Fe(OH)_2(s) + 2KNO_3(aq)$$

Total ionic equation:

$$Fe^{2+}(aq) + 2NO_3^{1-}(aq) + 2K^{1+}(aq) + 2OH^{1-}(aq) \\ \rightarrow Fe(OH)_2(s) + 2K^{1+}(aq) + 2NO_3^{1-}(aq)$$

Net ionic equation:

$$Fe^{2+}(aq) + 2OH^{1-}(aq) \rightarrow Fe(OH)_2(s)$$

Spectator ions: NO_3^{1-}, K^{1+}

7. **Write the balanced chemical and net ionic equations for the following situations.**
   a. **Reaction of acetic acid (CH_3COOH) with water**

$$CH_3COOH(aq) + H_2O \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$

The equation above is the overall equation and the net ionic one since acetic acid is a weak acid.

   b. **HCl(aq) + NaOH(aq) →**

Overall equation:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

Net ionic equation:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

c. **$HCN(aq) + KOH(aq) \rightarrow$** **(hint: HCN is a weak acid)**

Overall equation:

$$HCN(aq) + KOH(aq) \rightarrow KCN(aq) + H_2O(l)$$

Net ionic equation:

$$HCN(aq) + OH^-(aq) \rightarrow CN^-(aq) + H_2O(l)$$

8.

a. **How many grams of PF_5 can be formed from 9.46 g of PF_3 and 9.42 g of XeF_4 in the following unbalanced reaction.**

$$\mathbf{2PF_3 + XeF_4 \rightarrow 2PF_5 + Xe}$$

Make sure to balance the chemical equation!

$$9.46\ g\ PF_3 * \frac{1\ mol\ PF_3}{87.97\ g\ PF_3} * \frac{2\ mol\ PF_5}{2\ mol\ PF_3} = 0.108\ mol\ PF_5$$

$$9.42\ g\ XeF_4 * \frac{1\ mol\ XeF_4}{207.28\ g\ XeF_4} * \frac{2\ mol\ PF_5}{1\ mol\ XeF_4} = 0.0909\ mol\ PF_5$$

Since 0.0909 moles is less than 0.108 moles of PF_5, XeF_4 is the limiting reactant.

$$0.0909\ mol\ PF_5 * \frac{125.97\ g\ PF_5}{1\ mol\ PF_5} = 11.45\ g\ PF_5$$

b. **Identify the species being oxidized and the one being reduced.**
What is the oxidizing agent, reducing agent?

P is oxidized (+3 to +5), Xe is reduced (+4 to 0). Oxidizing agent: XeF_4, reducing agent: PF_3

Note that oxidizing and reducing agents are the entire compounds themselves, not just the element

9. **You combine 0.871 moles of sodium phosphate with 1.23 L of water. What is the molarity of the solution, of sodium ions, and phosphate ions?**

$$Molarity\ of\ solution = \frac{0.871\ mol\ Na_3PO_4}{1.23\ L\ H_2O} = 0.708\ M$$

$$[Na^+] = \frac{0.871\ mol\ Na_3PO_4}{1.23\ L\ H_2O} * \frac{3\ mol\ Na^+}{1\ mol\ Na_3PO_4} = 2.12\ M$$

$$[PO_4^{3-}] = \frac{0.871\ mol\ Na_3PO_4}{1.23\ L\ H_2O} * \frac{1\ mol\ PO_4^{3-}}{1\ mol\ Na_3PO_4} = 0.708\ M$$