Chem 103 Summer 2023
Professor Goldsmith

Key Name

EXAM 1 – June 14, 2023

#1 (/20)____________

#2 (/15)____________

#3 (/15)____________

#4 (/20)____________

#5 (/15)____________

#6 (/15)____________

Bonus (/3)____________

Total (/100)____________

1. (20 points)

a) If you want a sample of $Al_2(SO_4)_3$ that contains $9.71x10^{24}$ atoms of O, how many grams of $Al_2(SO_4)_3$ do you need?

$$9.71 \times 10^{24} \text{ atoms O} \times \frac{1 \text{ mol O}}{6.02 \times 10^{23} \text{ O atoms}} \times \frac{1 \text{ mol } Al_2(SO_4)_3}{12 \text{ mol O}} \times \frac{342 g}{1 \text{ mol } Al_2(SO_4)_3}$$

$$= 459.6 g \; Al_2(SO_4)_3$$

b) How many sodium ions are there in 328 mL of a 0.81M sodium phosphate solution?

$$0.328 L \times \frac{0.81 \text{ mol } Na_3PO_4}{L} \times \frac{3 \text{ mol } Na^+}{1 \text{ mol } Na_3PO_4} \times \frac{6.02 \times 10^{23}}{1 \text{ mol}}$$

$= 0.797$ mol Na^+

or 4.80×10^{23} Na^+ ions

c) How many moles of carbon atoms are there in a 5 pound bag of sugar ($C_{12}H_{22}O_{11}$)

$$5 \text{ pounds} \times \frac{1 kg}{2.2 lb} \times \frac{1000 g}{kg} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{342 g} \times \frac{12 \text{ mol C}}{1 \text{ mol } C_{12}H_{22}O_{11}} = 79.7 \text{ mol C}$$

d) Balance this equation: $Na_2B_4O_7 + HCl + H_2O \rightarrow NaCl + H_3BO_3$

$$Na_2B_4O_7 + 2HCl + 5H_2O \rightarrow 2NaCl + 4H_3BO_3$$

e) In the following reaction which species are acting as acids and which are acting as bases? **You must explain for full credit**

$$HCO_3^-(aq) + HSO_4^-(aq) \leftrightarrow H_2CO_3(aq) + SO_4^{-2}(aq)$$

HCO_3^- gains H^+ so base

HSO_4^- loses H^+ so acid

H_2CO_3 loses H^+ so acid

SO_4^{-2} gains H^+ so base

2. (15 points) 50.0 g of an unknown molecule (that may contain C, H and O) is burned (i.e. reacts with molecular oxygen), producing 73.3 g of CO_2 and 30.2 g of H_2O.
a) What is the empirical formula of this molecule?

$$73.3\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44\text{ g}} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} = 1.67\text{ mol C in sample}$$

$$30.2\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18\text{ g}} \times \frac{2\text{ mol H}}{1\text{ mol } H_2O} = 3.36\text{ mol H in sample}$$

$$1.67\text{ mol C} \times \frac{12\text{ g}}{\text{mol}} = 20.0\text{ g C}$$

$$3.36\text{ mol H} \times \frac{1\text{ g}}{\text{mol}} = 3.36\text{ g C}$$

doesn't add to 50.0 g
so $50.0\text{ g} - [20.0\text{ g} + 3.36\text{ g}] = 26.64\text{ g O}$

$$26.64\text{ g O} \times \frac{1\text{ mol O}}{16\text{ g}} = 1.67\text{ mol O}$$

C:H:O is 1.67:3.36:1.67

or $\boxed{CH_2O}$

b) If the molecular weight of this unknown is 180.1 g/mole, what is its formula?

$CH_2O \rightarrow 12+2+16 = 30\text{ g/mol } CH_2O$

so $6\times CH_2O$ is 180 g/mol

$$\boxed{C_6H_{12}O_6}$$

c) Write the balanced equation for the combustion of this compound (i.e. the reaction that occurred when it was burned)

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$$

3. (15 points) You work in a jewelry shop and you come across a cube of silvery metal whose sides are each 1.00 inches long. You can't tell if it is platinum (specific heat capacity = 0.126 J/gK) or palladium (specific heat capacity = 0.239 J/gK) and you are very curious to find out which it is. You have a scale and you measure the mass of the cube to be 351.5 grams. You heat the cube in a furnace to a temperature of 800.0 °C and then drop it into a bucket that contains 2.75 gallons of water initially at 22.40 °C. When the water and the metal cube have reached thermal equilibrium, you measure the temperature of the water to be 23.21 °C. Is the cube platinum or palladium? **You must show your work to receive credit. Guessing is not an option.**

$$q_{metal} = (351.5\,g)(C_{metal})[296.36\,K - 1073.15\,K]$$

$$q_{H_2O} = \left(2.75\,gal \times \frac{3700\,g}{gal}\right)\left(4.184\,\frac{J}{gK}\right)[296.36\,K - 295.55\,K]$$

$$q_{metal} = -273041\,gK \times C_{metal}$$

$$q_{H_2O} = 34483\,J$$

$$q_{metal} + q_{H_2O} = 0$$

$$-273041\,gK\,C_{metal} + 34483\,J = 0$$

$$C_{metal} = \frac{-34483\,J}{-273041\,gK} = 0.126\,\frac{J}{gK} \rightarrow \underline{\text{platinum}}$$

4. (20 points)

a) Write the total ionic equation for the reaction of aqueous potassium chromate (K_2CrO_4) with aqueous iron (III) chloride ($FeCl_3$). Hint: a precipitate forms.

$$6K^+_{(aq)} + 6Cl^-_{(aq)} + 2Fe^{3+}_{(aq)} + 3CrO_{4\,(aq)}^{-2} \rightarrow 6K^+_{(aq)} + 6Cl^-_{(aq)} + Fe_2(CrO_4)_{3(s)}$$

b) Write the net ionic equation for the process in a)

$$2Fe^{3+}_{(aq)} + 3CrO_{4\,(aq)}^{-2} \rightarrow Fe_2(CrO_4)_3\,(s)$$

c) If you combine 375 mL of a 0.32M potassium chromate solution with 250 mL of a 0.38M iron (III) chloride solution, how many grams of precipitate will be formed?

$$0.375\,L \times \frac{0.32\,mol\,K_2CrO_4}{L} \times \frac{1\,mol\,CrO_4^{2-}}{1\,mol\,K_2CrO_4} = 0.12\,mol\,CrO_4^{2-}$$

$$0.250\,L \times \frac{0.38\,mol\,FeCl_3}{L} \times \frac{1\,mol\,Fe^{3+}}{1\,mol\,FeCl_3} = 0.095\,mol\,Fe^{3+}$$

How much CrO_4^{-2} needed to react w/all Fe^{3+}? $0.095\,mol\,Fe^{3+} \times \frac{3\,mol\,CrO_4^{-2}}{2\,mol\,Fe^{3+}}$

$= 0.1475\,mol\,CrO_4^{-2}$ needed

so CrO_4^{-2} is LR

$$0.12\,mol\,CrO_4^{-2} \times \frac{1\,mol\,Fe_2(CrO_4)_3}{3\,mol\,CrO_4^{2-}} \times \frac{459.7\,g}{1\,mol\,Fe_2(CrO_4)_3}$$

$= 18.4\,g$ precip

d) After the precipitate forms, what is the molarity of Fe^{3+} in solution?

$$0.12\,mol\,CrO_4^{2-} \times \frac{2\,mol\,Fe^{3+}}{3\,mol\,CrO_4^{2-}} = 0.08\,mol\,Fe^{3+} \text{ in precip}$$

so $0.015\,mol\,Fe^{3+}$ still in solution

$$[Fe^{3+}] = \frac{0.015\,mol}{(0.375\,L + 0.25\,L)} = 0.024\,M$$

5. (15 points) C_2H_2 is acetylene and is very combustible (it is used in welding torches).

a) Write the balanced equation for the combustion of acetylene in the presence of oxygen gas. Assume that the products are liquid water and gaseous carbon dioxide

$$C_2H_2 + \frac{5}{2} O_{2(g)} \rightarrow 2CO_{2(g)} + 1\,H_2O_{(l)}$$

b) The $\Delta_f H^o$ of liquid water is -285.8 kJ/mol. The $\Delta_f H^o$ of gaseous carbon dioxide is -393.5 kJ/mol. If you combust 100 grams of acetylene with excess oxygen, enough heat is given off to turn a cube of ice 10.0 inches on a side originally at 0.0 °C (the density of ice is 0.917 g/cm^3) into a puddle of water at 0.0°C. What is the $\Delta_f H^o$ of acetylene?

q to melt ice? $10.0 \text{ inches} \times \frac{2.54 \text{ cm}}{\text{inch}} = 25.4$ cm on a side

$$(25.4 \text{ cm})^3 \times \frac{0.917 \text{ g}}{\text{cm}^3} \times \frac{333 \text{ J}}{\text{g}} = 5.00 \times 10^6 \text{ J to melt ice -or } 5000 \text{ kJ}$$

5000 kJ given off by 100g C_2H_2 reacting

$$\times \frac{1 \text{ mol}}{26 \text{ g}} \rightarrow 3.85 \text{ mol } C_2H_2$$

IF 1 mol C_2H_2

$$\frac{5000 \text{ kJ}}{3.85 \text{ mol}} \rightarrow 1300 \text{ kJ given off} \rightarrow \Delta_r H^0 = -\frac{1300 \text{ kJ}}{\text{mol rxn}}$$

note sign

$$so\left[\left(-285.8 \frac{\text{kJ}}{\text{mol}}\right) + \left(2 \times -393.5 \frac{\text{kJ}}{\text{mol}}\right)\right] - \Delta_f H^0_{C_2H_2} = -1300 \frac{\text{kJ}}{\text{mol}}$$

$$-1073 \frac{\text{kJ}}{\text{mol}} - \Delta_f H^0_{C_2H_2} = -1300 \frac{\text{kJ}}{\text{mol}}$$

$$\Delta_f H^0_{C_2H_2} = +227 \frac{\text{kJ}}{\text{mol}}$$

6. (15 points) You come across an unmarked bottle on the shelf in the chemistry stockroom. By a process of elimination you narrow down the identity of the chemical to three possibilities: $Li_2S_2O_3$, $Na_2S_2O_3$ or $K_2S_2O_3$. You take 2.50 grams of the unknown, dissolve it in water to make 50 mL of solution and titrate it with a 0.055 M solution of iodine (I_2). The iodine solution is brown, but when it reacts with thiosulfate ($S_2O_3^{2-}$) ions it becomes colorless. After the addition of 143.6 mL of the iodine solution, the brown color persists, meaning that the endpoint of the titration has been reached.

a) The chemistry that occurs can be described by the equation below. Is anything being oxidized or reduced? You must fully explain your answer for credit.

$$I_{2\,(aq)} + 2\ S_2O_3^{-2}{}_{(aq)} \rightarrow 2\ I^-{}_{(aq)} + S_4O_6^{-2}{}_{(aq)}$$

OX numbers: I_2: 0; $S_2O_3^{-2}$: +2, -2; I^-: -1; $S_4O_6^{-2}$: +2.5, -2

I reduced (ON went from $0 \rightarrow -1$)
S oxidized (ON went from $+2 \rightarrow +2.5$)

b) What is the chemical formula of the unknown material? You can't just guess, you need to prove that your answer is correct.

$$0.1436\ L \times \frac{0.055\ mol\ I_2}{L} \times \frac{2\ S_2O_3^{-2}}{1\ I_2} = 0.0158\ mol\ S_2O_3^{-2}$$

originally present

$$\frac{2.5g}{0.0158\ mol} \rightarrow 158\ g/mol$$

$Li_2S_2O_3 \rightarrow 126\ g/mol$
$\boxed{Na_2S_2O_3 \rightarrow 158\ g/mol}$
$K_2S_2O_3 \rightarrow 190\ g/mol$

Bonus (3 points) Write a haiku (5/7/5 syllables) describing your first 2 weeks of the post-bacc program

LAST NAME ______________________

FIRST NAME ______________________