Chem 103 Summer 2022
Professor Goldsmith

Key Name

EXAM 1 – June 15, 2022

#1 (/20)_____

#2 (/15)_____

#3 (/15)_____

#4 (/15)_____

#5 (/20)_____

#6 (/15)_____

Bonus (/3)_____

Total (/100)_____

1. (20 points)

a) If you want a sample of $Al_2(SO_4)_3$ that contains 3.86×10^{25} atoms of O, how many grams of $Al_2(SO_4)_3$ do you need?

3.86×10^{25} atoms O $\times \frac{1 \text{ mol O}}{6.02 \times 10^{23} \text{ atoms O}} \times \frac{1 \text{ mol } Al_2(SO_4)_3}{12 \text{ mol O}} = 5.34 \text{ moles } Al_2(SO_4)_3$

or $5.34 \text{ mol} \times \frac{342 \text{ g}}{\text{mol}} = 1826 \text{ g } Al_2(SO_4)_3$

b) How many potassium ions are there in 785 mL of a 0.47M potassium phosphate solution?

$0.785 \text{ L} \times \frac{0.47 \text{ mol } K_3PO_4}{1 \text{ L}} \times \frac{3 \text{ mol } K^+}{1 \text{ mol } K_3PO_4} \times \frac{6.02 \times 10^{23} K^+}{1 \text{ mol } K^+} = 6.66 \times 10^{23} K^+ \text{ ions}$

c) Balance this equation: $(NH_4)_2MoS_4 + H_2 \rightarrow MoS_2 + NH_3 + H_2S$

$(NH_4)_2MoS_4 + H_2 \rightarrow MoS_2 + 2NH_3 + 2H_2S$

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? How do you know?

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

base — acid — acid — base

accepts H^+

donates H^+

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 126.3 g of CO_2 and 22.1 g of H_2O.
a) How many moles of C atoms were in the original unknown?

$126.3\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44.01\text{ g}} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} = 2.87\text{ mol C}$

b) How many moles of H atoms were in the original unknown?

$22.1\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.02\text{ g}} \times \frac{2\text{ mol H}}{1\text{ mol } H_2O} = 2.45\text{ mol H}$

c) If the molecular weight of this unknown is 122.1 g/mole, what is its formula?

$2.87\text{ mol C} \times \frac{12.01\text{ g}}{\text{mol}} = 34.47\text{ g C}$

$2.45\text{ mol H} \times \frac{1.01\text{ g}}{\text{mol}} = 2.47\text{ g C}$

} 36.94 g total

So 50 − 36.94 g must be oxygen → 13.06 g O

$13.06\text{ g O} \times \frac{1\text{ mol}}{16\text{ g}} = 0.82\text{ mol O}$

C : H : O = 2.87 : 2.45 : 0.82 or 3.5 : 3 : 1 or 7 : 6 : 2

$C_7H_6O_2$ → 122 g/mol

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

$C_7H_6O_2 + \frac{15}{2}O_2 \rightarrow 7CO_2 + 3H_2O$

3. (15 points) It is a hot day and you are getting ready to get into your tiny backyard swimming pool. The pool has 22.0 gallons of water in it (it is really one of those plastic kiddie pools) and the pool thermometer reads 28.3 °C. All of a sudden a red hot chunk of rock falls from the sky and lands in the pool; you were almost hit by a meteorite!! After recovering from your surprise, you reach into the pool to remove it and notice that the water is a lot warmer – the thermometer now reads 35.1 °C. You inspect the meteorite, which had equilibrated to the temperature of the water and note that it appears to be made of pure iron. You then weigh it and find that its mass is 3885 grams. When you look up the specific heat capacity of iron you find it to be 0.444 J/g•K What was the temperature of the meteorite just before it hit your pool?

$22.0\ \text{gallons} \times \frac{3.7\ \text{L}}{\text{gal}} \times \frac{1000\ \text{mL}}{\text{L}} \times \frac{1\ \text{g}\ H_2O}{\text{mL}\ H_2O} = 81400\ \text{grams}\ H_2O$

$q_{H_2O} = (81400\ \text{g})\left(4.184 \frac{\text{J}}{\text{g K}}\right)(6.8\ \text{K}) = 2.32 \times 10^6\ \text{J}$

$q_{rock} = (3885\ \text{g})\left(0.444 \frac{\text{J}}{\text{g K}}\right)(308.25\ \text{K} - T_i)$

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

$(2.32 \times 10^6\ \text{J}) + (5.32 \times 10^5\ \text{J} - 1724.94\ \text{J}\ T_i) = 0$

$2.85 \times 10^6\ \text{J} = 1724.94\ \text{J}\ T_i$

$T_i = 1653.4\ \text{K}$

or $1380.2\ ^\circ\text{C}$

4. (15 points)

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

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

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

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

c) If you combine 575 mL of a 0.37M potassium chromate solution with 450 mL of a 0.28M iron (III) chloride solution, how many grams of precipitate will be formed?

$0.575\,L \times 0.37\,\frac{mol\ CrO_4^{-2}}{L} = 0.213\ mol\ CrO_4^{-2}$

$0.450\,L \times 0.28\,\frac{mol\ FeCl_3}{L} = 0.126\ mol\ Fe^{3+}$

$0.126\ mol\ Fe^{3+}$ requires $\frac{3\ mol\ CrO_4^{-2}}{2\ mol\ Fe^{3+}} = 0.189\ mol\ CrO_4^{-2}$

So Fe^{3+} is LR and CrO_4^{-2} is in excess

$0.126\ mol\ Fe^{3+} \times \frac{1\ mol\ Fe_2(CrO_4)_3}{2\ mol\ Fe} \times \frac{459.7\,g}{mol} = 28.96\,g$ precipitate

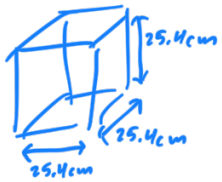
5. (20 points) C_2H_2 is acetylene and is very combustible (it is used in welding torches).

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

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

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 melt 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) What is the $\Delta_f H^o$ of acetylene?

Ice cube mass → $10 \text{ inches} \times \frac{2.54 \text{ cm}}{\text{inch}} = 25.4 \text{ cm}$



cube volume $= (25.4 \text{ cm})^3 = 16387 \text{ cm}^3$

$16387 \text{ cm}^3 \times \frac{0.917 \text{ g}}{\text{cm}^3} = 15027 \text{ g ice}$

$q_{ice} = 15027 \text{ g} \times \frac{333 \text{ J}}{\text{g}} = 5.00 \times 10^6 \text{ J}$ into ice, from combustion

$100 \text{ g } C_2H_2 \times \frac{1 \text{ mol}}{26.04 \text{ g}} = 3.84 \text{ mol } C_2H_2$ so burning of 1 mol C_2H_2 gives $\frac{5 \times 10^6}{3.84} = 1.302 \times 10^6 \text{ J}$ or 1302 kJ

$$\Delta_f H^o = [2 \times \Delta_f H^o_{CO_2} + 1 \times \Delta_f H^o_{H_2O\,l\,q}] - \Delta_f H^o_{C_2H_2}$$

$$-1302 \text{ kJ} = [2 \times -393.5 \text{ kJ} + -285.8 \text{ kJ}] - \Delta_f H^o_{C_2H_2}$$

$$-1302 \text{ kJ} = -1073 \text{ kJ} - \Delta_f H^o_{C_2H_2} \quad \Delta_f H^o_{C_2H_2} = +229 \text{ kJ/mol}$$

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. For each atom, assign the oxidation number and indicate what, if anything, is being oxidized/reduced. Remember that the oxidation number is just book-keeping and isn't actually the number of electrons.

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

0   2x+2   3x-2   -1   4x+2.5   6x-2

each S went from +2 → +2.5 oxidized
each I went from 0 → -1 reduced

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

$0.1436\ L\ I_2 \times \frac{0.055\ mol}{L} = 7.9\times10^{-3}\ mol\ I_2 \times \frac{2\ mol\ S_2O_3^{-2}}{1\ mol\ I_2} = 0.0158\ mol\ S_2O_3^{-2}$ in original sample

$\frac{2.5g\ X_2S_2O_3}{0.0158\ mol} \rightarrow 158.3\ g/mol$

$Li_2S_2O_3 \rightarrow 125.9\ g/mol$

$Na_2S_2O_3 \rightarrow 158\ g/mol$

$K_2S_2O_4 \rightarrow 190.2\ g/mol$

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

LAST NAME _____

FIRST NAME _____