Chem 103 Summer 2024
Professor Goldsmith

Key Name

# EXAM 1 – June 11, 2024

#1 (/15)_____

#2 (/20)_____

#3 (/15)_____

#4 (/15)_____

#5 (/15)_____

#6 (/15)_____

#7 (/5)_____

Bonus (/3)_____

Total (/100)_____

1. (15 points) Meteorites are rocks that fall from outer space. They are typically made of iron and as they fall through the atmosphere they get very very hot (2000 °C). You have a bucket of water in your back yard that contains 1.0 gallons of water at a temperature of 27.3 °C. An iron meteorite weighing 92.3 grams falls from outer space and lands in your bucket. What will the temperature of the water in the bucket be when thermal equilibrium is reached? The specific heat capacity of iron is 0.45 J/gK.

$$1.0\ \text{gallon water} \times \frac{3.7\ \text{L}}{1\ \text{gal}} \times \frac{1000\ \text{mL}}{\text{L}} \times \frac{1\ \text{g } H_2O}{1\ \text{mL}} = 3700\ \text{g}$$

$$q_{water} = (3700\text{g})\left(4.184\ \frac{\text{J}}{\text{g°C}}\right)(T_f - 27.3\text{°C})$$

$$q_{met} = (92.3\text{g})\left(0.45\ \frac{\text{J}}{\text{g°C}}\right)(T_f - 2000\text{°C})$$

$$q_{water} + q_{met} = 0$$

$$15480.85T_f - 422626\text{J} + 41.55T_f - 83070\text{J} = 0$$

$$15522.35T_f = 505696\text{J}$$

$$T_f = 32.58\text{°C} \rightarrow 32.6\text{°C}$$

or 305.7 K

2. (20 points)

a) If you want a sample of magnesium sulfate that contains $9.71 \times 10^{24}$ atoms of O, how many grams of magnesium sulfate do you need?

$9.71 \times 10^{24}$ O atoms $\times \frac{1\ MgSO_4}{4\ O\ atoms} \times \frac{1\ mol\ MgSO_4}{6.02 \times 10^{23}\ MgSO_4} \times \frac{120.38\ g}{1\ mol\ MgSO_4} = 485.4\ g\ MgSO_4$

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

$0.328\ L \times \frac{0.81\ mol\ K_3PO_4}{1\ L} \times \frac{3\ mol\ K^+}{1\ mol\ K_3PO_4} \times \frac{6.02 \times 10^{23}}{mole}$

$= 0.797$ moles $K^+$ or $4.8 \times 10^{23}$ $K^+$ ions

c) How many moles of hydrogen atoms are there in a 25 pound bag of sugar ($C_{12}H_{22}O_{11}$)

$25\ lb \times \frac{1\ kg}{2.2\ lb} \times \frac{1000\ g}{1\ kg} \times \frac{1\ mol\ C_{12}H_{22}O_{11}}{342\ g} \times \frac{22\ mol\ H}{1\ mol\ C_{12}H_{22}O_{11}} = 731$ moles H atoms

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

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

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

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

| | | | |
|---|---|---|---|
| gains $H^+$ | loses $H^+$ | loses $H^+$ | gains $H^+$ |
| base | acid | acid | base |

3. (15 points) 35.00 g of an unknown molecule (that may contain C, H and O) is burned (i.e. reacts with molecular oxygen), producing 66.47 g of $CO_2$ and 27.22 g of $H_2O$. The molecular weight of this unknown is 162.2 g/mol. What is its molecular formula? **You must show all work to receive credit.**

$66.47\ g\ CO_2 \times \frac{1\ mol}{44.01\ g} = 1.51\ mol\ CO_2 = 1.51\ mol\ C$

$= 18.14\ g\ C$

$27.22\ g\ H_2O \times \frac{1\ mol}{18.02\ g} : 1.51\ mol\ H_2O \rightarrow 3.02$ mole H

$= 3.05\ g\ C$

$35.00\ g - 18.14\ g - 3.05\ g = 13.81\ g\ O$

$\downarrow$

0.86 moles O

C : H : O $\rightarrow$ 1.51 : 3.02 : 0.86

$\rightarrow$ 1.75 : 3.50 : 1

$\rightarrow$ 3.50 : 7 : 2

$\rightarrow$ 7 : 14 : 4

$C_7H_{14}O_4 \rightarrow 162.2\ g/mol$

4. (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.

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

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 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?

10 inch = 25.4 cm  Volume of cube $= (25.4\,cm)^3 = 1.64\times10^4\,cm^3$

$1.64\times10^4\,cm^3 \times 0.917\,\frac{g}{cm^3} = 15027$ grams ice

$15027\,g$ ice $\times 333\,\frac{J}{g}$ to melt $\rightarrow$ 5004 kJ of energy

$100\,g\,C_2H_2 \times \frac{1\,mol}{26.04\,g} = 3.84\,mol\,C_2H_2$

Burning 3.84 mol $C_2H_2$ gave off 5004 kJ so burning 1 mole would give off 1303 kJ

$$-\frac{1303\,kJ}{mol} = \left(2\times\frac{-393.5\,kJ}{mol} + \frac{-285.8\,kJ}{mol}\right) - \Delta_f H^o\,C_2H_2$$

$$-230\,\frac{kJ}{mol} = -\Delta_f H^o$$

$$\Delta_f H^o = +230\,\frac{kJ}{mol}$$

5. (15 points)

a) Write the **net** ionic equation for the reaction of aqueous potassium phosphate ($K_3PO_4$) with aqueous silver nitrate ($AgNO_3$) Hint: a precipitate forms.

$$3\,Ag^+_{(aq)} + PO_4^{-3}{}_{(aq)} \rightarrow Ag_3PO_4\,(s)$$

b) If you combine 375 mL of a 0.32M potassium phosphate solution with 250 mL of a 0.38M silver nitrate solution, how many grams of precipitate will be formed?

$$0.375\,L\ K_3PO_4 \times \frac{0.32\ mol\ PO_4^{-3}}{L} = 0.12\ mol\ PO_4^{-3}$$

$$0.250\,L\ AgNO_3 \times \frac{0.38\ mol\ Ag^+}{L} = 0.095\ mol\ Ag^+ \leftarrow LR$$

$$0.095\ mol\ Ag^+ \times \frac{1\ mol\ Ag_3PO_4}{3\ mol\ Ag^+} \times \frac{418.6\,g}{mol} = 13.26\,g\ Ag_3PO_4$$

c) After the precipitate forms, what is the molarity of phosphate ions in solution?

$$0.095\ mol\ Ag^+ \times \frac{1\ mol\ PO_4^{-3}}{3\ mol\ Ag^+} = 0.0317\ mol\ PO_4^{-3}\ \text{in ppt}$$

$$0.12 - 0.0317 = 0.0883\ mole\ PO_4^{-3}\ \text{in } 0.625\,L\ \text{soln}$$

$$[PO_4^{-3}] = \frac{0.0883\ mol}{0.625\,L} = 0.141\,M$$

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.

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

I 0 → −1

S 2 → 2.5 – weird but it happens

each I oxidizes 2 S

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

$0.1436\ L\ I_2 \times \frac{0.055\ mol}{L} = 0.007898\ mol\ I_2$

$0.007898\ mol\ I_2 \times \frac{2\ mol\ S_2O_3^{-2}}{1\ mol\ I_2} = 0.0158\ mol$

$S_2O_3^{-2}$ initially present

$\frac{2.5\ g}{0.0158\ mol} = 158.2\ g/mol$

$Li_2S_2O_3 \rightarrow 126\ g/mol$

$Na_2S_2O_3 \rightarrow 158.3\ g/mol$

$K_2S_2O_3 \rightarrow 190.3\ g/mol$

7. (5 points) There are 4 pecks in every bushel (both bushel and peck are units of volume). One peck of apples weights 5.0 kg. An apple tree can produce 5 bushels of apples. You need 13 apples to make an apple pie and each pie can be cut into 8 pieces. 5 apples weigh 3 pounds. You have 2 apple trees in your yard. How many pies can you make with all the apples from all the trees in your yard?

$$2\ \text{trees} \times \frac{5\ \text{bushels}}{\text{tree}} \times \frac{4\ \text{pecks}}{\text{bushel}} \times \frac{5\ \text{kg}}{\text{peck}} \times \frac{2.2\ \text{lb}}{\text{kg}} \times \frac{5\ \text{apples}}{3\ \text{lb}} \times \frac{1\ \text{pie}}{13\ \text{apples}}$$

$$= 56.4\ \text{pies}$$

but no such thing as .4 pies

so 56 pies

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

**LAST NAME** _____

**FIRST NAME** _____