#1. (10 points) Short Answer Questions

a) Provide the name or formula for the following:

magnesium sulphate pentahydrate _____$MgSO_4 \cdot 5H_2O$_______________________

$Fe(BrO_4)_3$ __iron (III) perbromate or ferric perbromate__

b) Four balloons are filled to the same volume with the following gases. If a small hole is made in each balloon, which will deflate the fastest?

According to Graham's Law, the lightest gas = fastest effusion. Therefore:

$SO_3$ $H_2S$ $N_2$ $CO_2$

c) The enthalpy of vaporization of sodium is 96.96 kJ/mol at 1156 K. The amount of heat (in kJ) needed to vaporize 1.00 g of sodium is: __________________.

$$? \text{ kJ} = 1.00 \text{ g Na} \times \frac{\text{mol Na}}{22.99 \text{ g}} \times \frac{96.96 \text{ kJ}}{\text{mol Na}} = +4.22 \text{ kJ}$$

d) A sample of a gas is slowly compressed from 8.0 L to 4.0 L. In order for the internal energy of the gas to remain constant, the gas must also be simultaneously cooled.

$\Delta U = q + W$

If the internal energy is constant, then $\Delta U = 0$ (no change).

Compression of a gas means that W is positive. Therefore, to keep $\Delta U = 0$, q must be negative. In other words, heat must be emitted from the system (it must cool down).

TRUE FALSE

e) Give the full, precise chemical symbol for the following:

| Number of protons | Number of neutrons | Number of electrons | Chemical Symbol |
|---|---|---|---|
| 17 | 20 | 18 | $^{37}_{17}Cl^{-}$ |

f) The standard heat of formation of solid sodium bicarbonate is –654 kJ. Write the chemical equation for the reaction to which this value applies (include phases).

$Na(s) + \frac{1}{2} H_2(g) + C(s, \text{graphite}) + \frac{3}{2} O_2(g) \rightarrow NaHCO_3(s)$

g) Two sets of successive reactions, A → B and B → C, have respective percent yields of 48% and 73%. The overall percent yield for the conversion of A to C is: __35%__.

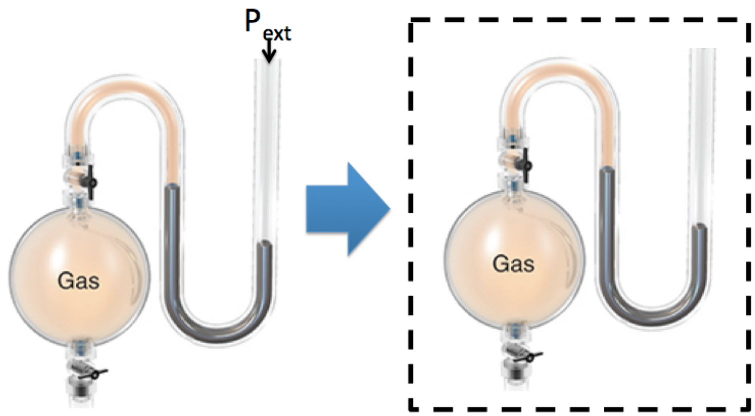
h) Rank the following compounds in *increasing* order of oxidation state of iodine:

NaOI, HI, $I_2$ ___ HI, $I_2$, NaOI ________________________

+1 –1 0

BONUS:

**The figure on the left shows 1 mol of gas in an open-end manometer. The external pressure is 1.0 bar and the temperature is 300K. In the box, sketch the manometer and qualitatively show the effect on the gas if the external pressure increases to 2.0 bar and the temperature is increased to 600K.**




**External pressure increases by a factor of 2. According to Boyle's law, this means the volume of the gas should be compressed to half its original volume. However, the temperature is raised by a factor of 2. According to Charles' Law, this means the volume of the gas should be double its original volume. Putting these two effects together means there is NO OVERALL CHANGE in the volume of the sample gas!**

**#2. (10 points) 15.0 kg of ammonium nitrate decomposes to nitrogen, oxygen, and water vapour.**

**NOTE: This question (Silberberg 4.102) was covered in DGD#3**

**a) What is the total volume of gas (in L) that will form at 307°C and 1.01 bar?**

Balanced equation: $2NH_4NO_3(s) \rightarrow 2N_2(g) + O_2(g) + 4H_2O(g)$

$$? \text{ mol gas} = 15.0 \text{ kg } NH_4NO_3 \times \frac{1000 \text{ g}}{\text{kg}} \times \frac{\text{mol } NH_4NO_3}{80.05 \text{ g } NH_4NO_3} \times \frac{7 \text{ mol gas}}{2 \text{ mol } NH_4NO_3}$$

$$= 655.8 \text{ mol}$$

$$? \text{ L gas} = \frac{(655.8 \text{ mol})(0.083145 \text{ L} \cdot \text{bar/mol} \cdot \text{K})(580 \text{ K})}{1.01 \text{ bar}} = 3.13x10^4 \text{L}$$

**Answer: ____3.13x10⁴ L______**

**b) What is the partial pressure of nitrogen in the product mixture?**

$$P_{N_2} = \chi_{N_2} P_{TOTAL}$$

$$= \frac{2 \text{ mol } N_2}{7 \text{ mol gas}} \times 1.01 \text{ bar}$$

$$= 0.289 \text{ bar}$$

**Answer: _____0.289 bar________**

**#3. (10 points) A calorimeter contains 24.0 mL of water at 13.0°C. When 2.20 g of X (molar mass 47.0 g/mol) is added, it dissolves via the reaction: X(s) → X(aq) and the temperature of the solution increases to 28.0°C.**

NOTE: This question is from the 2011 Midterm #1

a) **Calculate the enthalpy change for the dissolution, in kJ/mol. You may assume the specific heat capacity and density of the solution are equal to those of pure water; however, you may NOT assume that the mass of the solution is equal to the mass of the water.**

$$q_{soln} = m_{soln} c_{soln} \Delta T_{soln}$$

$$= (2.20\text{g} + 24.0\text{g})(4.184 \frac{\text{J}}{\text{g}^\circ\text{C}})(28.0^\circ\text{C} - 13.0^\circ\text{C})$$

$$= +\ 1644\ \text{J}$$

$$\therefore q_{rxn} = -\ 1644\ \text{J}$$

$$\Delta H^\circ_{rxn} = \frac{?\ \text{kJ}}{\text{mol}} = \frac{-1644\ \text{J}}{2.20\ \text{g}} \times \frac{47.0\ \text{g}}{\text{mol}} \times \frac{1\ \text{kJ}}{1000\ \text{J}} = -35.1\ \text{kJ/mol}$$

**Answer: ____–35.1 kJ/mol_________**

b) **Calculate the internal energy change for the dissolution, in kJ/mol.**

ΔU = q + W = ΔH + W
But: there are no gases involved. Therefore W ~ 0 and thus:
ΔU ~ ΔH = –35.1 kJ/mol

**Answer: _____–35.1 kJ/mol _________**

c) **Determine the enthalpy change for the following reaction, using the provided data.**

**X (s) → 2Y (s) ΔH° = ?**

| | |
|---|---|
| Y(s) → Y(aq) | ΔH° = +24.7 kJ |
| 2 Y(aq) → X(aq) | ΔH° = -1.44 kJ |

Using the value from part (a):

| | | |
|---|---|---|
| ① (same) | X(s) → X(aq) | ΔH° = –35.1 kJ |
| ③ reversed | X(aq) → 2 Y(aq) | ΔH° = +1.44 kJ |
| ② reversed, x2 | 2 Y(aq) → 2 Y(s) | ΔH° = -49.4 kJ |
| SUM | X (s) → 2Y (s) | ΔH° = –83.2 kJ |

**Answer: ____–83.1 kJ____________**

**#4. (10 points) Dr. Fox's favourite single malt scotch whisky is *Lagavulin*, which is 43% ethanol ($C_2H_5OH$) by volume. While marking midterms, Dr. Fox drinks 30 mL of the scotch, of which 22% of the ethanol by mass is absorbed into her blood.**

**NOTE: This question is a reworded version of Suggested Silberberg problem 12.152**

**a) If Dr. Fox has 6.5 L of blood, what concentration (in g/mL) of ethanol is in her blood? (*d* of ethanol = 0.789 g/mL)**

**Let "EtOH" represent ethanol.**

$$? \text{ g EtOH absorbed} = 30 \text{ mL scotch} \times \frac{43 \text{ mL EtOH}}{100 \text{ mL scotch}} \times \frac{0.789 \text{ g EtOH}}{\text{mL EtOH}} \times \frac{22 \text{ g EtOH absorbed}}{100 \text{ g EtOH consumed}}$$

$$= 2.24 \text{ g}$$

$$\frac{? \text{ g EtOH absorbed}}{\text{mL blood}} = \frac{2.24 \text{ g EtOH absorbed}}{6.5 \text{ L blood}} \times \frac{1 \text{ L}}{1000 \text{ mL}}$$

$$= 3.4x10^{-4} \text{ g/mL}$$

**Answer: ______3.4x10$^{-4}$ g/mL___________**

**b) What volume (mL) of scotch would raise Dr. Fox's blood alcohol level to 8.0x10$^{-4}$ g/mL, the level at which she would be considered intoxicated and no longer able to mark midterms?**

$$? \text{ g EtOH absorbed} = 6.5 \text{ L blood} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{8.0x10^{-4} \text{ g EtOH absorbed}}{\text{mL blood}}$$

$$= 5.20 \text{ g}$$

$$? \text{ mL scotch} = 5.20 \text{ g EtOH absorbed} \times \frac{100 \text{ g EtOH consumed}}{22 \text{ g EtOH absorbed}} \times \frac{\text{mL EtOH}}{0.789 \text{ g EtOH}} \times \frac{100 \text{ mL scotch}}{43 \text{ mL EtOH}}$$

$$= 70 \text{ mL scotch}$$

**Answer: _____70 mL______________**

**#5. (10 points) The following reaction is one route to solid copper metal.**

$$N_2H_4(aq) + Cu^{2+}(aq) \rightarrow N_2(g) + Cu(s)$$

**NOTE: This question was modified from Sapling Assignment #2 + an in-class question from Chapter 3**

**a) Determine the overall balanced redox equation in basic solution.**

| | OXIDATION | REDUCTION |
|---|---|---|
| Balance all except O/H. | $N_2H_4 \rightarrow N_2$ | $Cu^{2+} \rightarrow Cu$ |
| Balance O with $H_2O$ | $N_2H_4 \rightarrow N_2$ | $Cu^{2+} \rightarrow Cu$ |
| Balance H with $H^+$ | $N_2H_4 \rightarrow N_2 + 4H^+$ | $Cu^{2+} \rightarrow Cu$ |
| Neutralize $H^+$ with $OH^-$ | $4OH^- + N_2H_4 \rightarrow N_2 + 4H^+ + 4OH^-$ | $Cu^{2+} \rightarrow Cu$ |
| Simplify | $4OH^- + N_2H_4 \rightarrow N_2 + 4H_2O$ | $Cu^{2+} \rightarrow Cu$ |
| Balance charge with $e^-$ | $4OH^- + N_2H_4 \rightarrow N_2 + 4H_2O + 4e^-$ | $Cu^{2+} + 2e^- \rightarrow Cu$ |
| Equalize the # of $e^-$ | $4OH^- + N_2H_4 \rightarrow N_2 + 4H_2O + 4e^-$ | $2Cu^{2+} + 4e^- \rightarrow 2Cu$ |

Adding the 2 half-reactions gives:

$$N_2H_4 + 2Cu^{2+} + 4OH^- \rightarrow N_2 + 2Cu + 4H_2O$$

reducing agent ($N_2H_4$) oxidizing agent ($Cu^{2+}$)

**b) Label the oxidizing agent and reducing agent.**

**c) 1.54 g of $N_2H_4$ (MM = 32.05 g/mol) are added to 50.0 mL of a 1.55 M copper (II) hydroxide solution. What is the volume of nitrogen gas produced, at 1.01 bar and 20.0°C?**

$$? \text{ mol } N_2 \text{ from } N_2H_4 = 1.54 \text{ g } N_2H_4 \times \frac{\text{mol } N_2H_4}{32.05 \text{ g}} \times \frac{1 \text{ mol } N_2}{1 \text{ mol } N_2H_4} = 0.0480 \text{ mol}$$

$$? \text{ mol } N_2 \text{ from } Cu^{2+} = 0.0500 \text{ L} \times \frac{1.55 \text{ mol } Cu(OH)_2}{\text{L}} \times \frac{1 \text{ mol } Cu^{2+}}{1 \text{ mol } Cu(OH)_2} \times \frac{1 \text{ mol } N_2}{2 \text{ mol } Cu^{2+}} = 0.0388 \text{ mol}$$

Therefore, $Cu^{2+}$ is the limiting reagent and 0.0388 mol of nitrogen gas are formed.

$$V = \frac{nRT}{P} = \frac{(0.0388 \text{ mol})(0.083145 \text{ L}\cdot\text{bar/mol}\cdot\text{K})(293 \text{ K})}{1.01 \text{ bar}} = 0.936 \text{ L}$$

**Answer:** _____0.936 L______________