#1. (10 points) Short Answer Questions

$\frac{1}{2}\,N_2(g) + 2\,H_2(g) + \frac{1}{2}\,Cl_2(g) \rightarrow NH_4Cl(s)$

a) The standard heat of formation of solid ammonium chloride is –314.4 kJ. Write the chemical equation for the reaction to which this value applies (include phases).

b) Name the following compounds:

$Co(ClO)_2$ _____cobalt (II) hypochlorite_________________

$CaSO_4 \cdot 7\,H_2O$ _____calcium sulphate heptahydrate_________________

c) Complete the following table:

Element	Mass Number	Number of protons	Number of electrons	Number of neutrons	Charge
Se	79	34	36	45	–2

d) Breaking chemical bonds is always an endothermic process. TRUE FALSE

e) If the molar mass of a gas is doubled, the root-mean-squared speed of the molecules will increase by a factor of _____$\sqrt{\frac{1}{2}}$ __________.

f) You take a 4.0 L volume of gas at 600 K. You expand the gas to an 8.0 L volume and simultaneously heat the vessel to 1200 K. The pressure of the gas:

DOUBLES HALVES QUADRUPLES STAYS CONSTANT

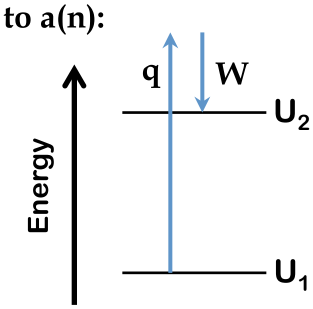
g) Which compound has the highest oxidation state of nitrogen?

NO^+ N_2 NH_3 NO_2 N_2O NO_3^-

h) When the power was turned off to a 125 L water heater, the temperature of the water dropped from 75.0°C to 22.5°C. The amount of heat, in kilojoules, transferred to the surroundings was: _______2.75×10^4 kJ (note that the – sign isn't necessary in this case, since it says "transferred to…."_______.

BONUS: The energy change shown in the diagram at right corresponds to a(n):

- ☐ EXOTHERMIC CONTRACTION
- ☐ ENDOTHERMIC CONTRACTION
- ☐ EXOTHERMIC EXPANSION
- ☐ ENDOTHERMIC EXPANSION



#2. 45.0 g of solid calcium carbonate is added to 1.25 L of an aqueous hydrochloric acid solution. The hydrochloric acid solution has a density of 1.13 g/mL and is 25.7% acid by mass. The solid calcium carbonate reacts with the acid to yield liquid water, aqueous calcium chloride, and carbon dioxide gas.

This question is Petrucci Ch. 4 #110 and was covered in DGD #3

a) **(2 pts) Write a balanced chemical equation for the described reaction, *including phases*.**

$CaCO_3 (s) + 2 HCl (aq) \rightarrow H_2O (l) + CaCl_2 (aq) + CO_2 (g)$

b) **(3 pts) What is the initial molarity of the acid solution?**

$$\frac{?\text{ mol HCl}}{\text{L}} = \frac{25.7\text{ g HCl}}{100\text{ g soln}} \times \frac{1.13\text{ g soln}}{\text{mL soln}} \times \frac{1000\text{ mL}}{\text{L}} \times \frac{\text{mol HCl}}{36.45\text{ g HCl}}$$
$$= 7.97\text{ mol/L}$$

Answer: ________7.97 M______________

c) **(5 pts) What is the molarity of the acid solution after the reaction is complete? You may assume no volume changes.**

The question implies that there is excess HCl (i.e. $CaCO_3$ is the limiting reagent).

$$?\text{ initial mol HCl} = 1.25\text{ L soln} \times \frac{7.97\text{ mol HCl}}{\text{L}}$$
$$= 9.96\text{ mol}$$

$$?\text{ mol HCl reacted} = 45.0\text{ g CaCO}_3 \times \frac{\text{mol CaCO}_3}{100.1\text{ g CaCO}_3} \times \frac{2\text{ mol HCl}}{1\text{ mol CaCO}_3}$$
$$= 0.899\text{ mol}$$

$$?\text{ mol HCl leftover} = 9.96\text{ mol} - 0.899\text{ mol}$$
$$= 9.06\text{ mol}$$

$$\frac{?\text{ mol HCl leftover}}{\text{L}} = \frac{9.06\text{ mol}}{1.25\text{ L}}$$
$$= 7.25\text{ mol/L}$$

Answer: ________7.25 M_________________

#3. A 3.902 g sample of an unknown compound containing only C, H, and O is combusted in an oxygen-rich environment.

This is a slightly changed version of the Sample Midterm Problem on Sapling

a) **(3 pts) The CO_2 gas produced in the reaction is collected over water at 20.00°C in a 5.000 L flask. The pressure in the flask is measured to be 100.52 kPa. What is the number of moles of carbon dioxide gas produced in the combustion?**

$$P_{H_2O} = 2.3393 \text{ kPa } (\textit{from Table on data sheets})$$
$$P_{total} = P_{CO_2} + P_{H_2O}$$
$$P_{CO_2} = P_{total} - P_{H_2O} = 100.52\text{kPa}-2.3393\text{kPa} = 98.18\text{kPa}$$
$$? \text{ mol } CO_2 = \frac{P_{CO_2} \cdot V}{RT} = \frac{(98.18 \text{ kPa})(5.000 \text{ L})}{(8.3145 \text{ kPa} \cdot \text{L/mol} \cdot \text{K})(293.15 \text{ K})} = 0.2014 \text{ mol}$$

Answer : ________0.2014 mol________________

b) **(5 pts) The reaction was found to also produce 3.633 g of liquid H_2O. What is the empirical formula of the unknown compound?**

$$? \text{ mol C} = 0.2014 \text{ mol } CO_2 \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} = 0.2014 \text{ mol C}$$
$$? \text{ mol H} = 3.633 \text{ g } H_2O \times \frac{\text{mol } H_2O}{18.02 \text{ g } H_2O} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} = 0.4032 \text{ mol H}$$
$$? \text{ g C} = 0.2014 \text{ mol C} \times \frac{12.011 \text{ g C}}{1 \text{ mol C}} = 2.42 \text{ g C}$$
$$? \text{ g H} = 0.4031 \text{ mol H} \times \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 0.406 \text{ g H}$$
$$\therefore ? \text{ g O} = 3.902 \text{ g sample} - 2.42 \text{ g C} - 0.406 \text{ g H} = 1.07 \text{ g O}$$
$$? \text{ mol O} = 1.07 \text{ g O} \times \frac{1 \text{ mol O}}{15.999 \text{ g O}} = 0.0669 \text{ mol O}$$
$$\therefore C_{\frac{0.2014}{0.0669}} H_{\frac{0.4032}{0.0669}} O_{\frac{0.0669}{0.0669}} = C_3H_6O$$

Answer : _________C_3H_6O________________

c) **(2 pts) If the molecular mass of the unknown compound is found to be 116.2 u, what is its molecular formula?**

$$\frac{\text{MF mass}}{\text{EF mass}} = \frac{116 \text{ u}}{58 \text{ u}} = 2$$
$$\therefore \text{MF} = 2 \times \text{EF} = C_6H_{12}O_2$$

Answer : _______$C_6H_{12}O_2$___________

#4. This past summer, Dr. Fox went scuba diving in False Bay, South Africa, where the water temperature was a chilly 13.5°C. Despite wearing two 5 mm thick neoprene wetsuits, Dr. Fox still lost body heat at a rate of 38.0 J per second.

NEW QUESTION: I actually thought up this question during the dive!

a) **(2 pts) How much body heat, in kJ, was lost over the course of a 45.0 min dive?**

$$? \text{ kJ} = 45.0 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} \times \frac{38.0 \text{ J}}{\text{s}} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 102.6 \text{ kJ}$$

Technically, the sign here would be negative (to show heat leaving the system), but since this is already acknowledged in the question, it's not necessary.

Answer : ____102.6 kJ____________

b) **(3 pts) To recuperate this energy loss, Dr. Fox decides to eat a candy bar, which contains glucose, $C_6H_{12}O_6$. Using the data tables, determine the enthalpy of combustion of glucose, in kJ/mol.**

$$C_6H_{12}O_6 \text{ (s)} + 6\ O_2 \text{ (g)} \rightarrow 6\ CO_2 \text{ (g)} + 6\ H_2O \text{ (l)}$$

$$\begin{aligned}\Delta H^\circ_{comb} &= \{(6 \times \Delta H^\circ_f\ CO_2) + (6 \times \Delta H^\circ_f\ H_2O)\} - \{(1 \times \Delta H^\circ_f\ C_6H_{12}O_6) + (6 \times \Delta H^\circ_f\ O_2)\} \\ &= \{(6 \times -393.5) + (6 \times -285.8)\} - \{(1 \times -1273.3) + (6 \times 0)\} \\ &= -2802.5 \text{ kJ/mol}\end{aligned}$$

Answer : ______–2802.5 kJ/mol ___________

c) **(5 pts) If the candy bar contains 8.55% glucose by mass, how many grams of it will Dr. Fox need to eat to balance out the heat lost in part (a)?**

$$\begin{aligned}? \text{ g candy} &= 102.6 \text{ kJ} \times \frac{\text{mol } C_6H_{12}O_6}{2802.5 \text{ kJ}} \times \frac{180 \text{ g } C_6H_{12}O_6}{\text{mol } C_6H_{12}O_6} \times \frac{100 \text{ g candy}}{8.55 \text{ g } C_6H_{12}O_6} \\ &= 77.1 \text{ g candy}\end{aligned}$$

Answer : ______77.1 g__________

#5. Cyanide ion, CN^-, is the conjugate base of a highly poisonous substance, hydrogen cyanide (and if you saw the movie *Skyfall* you saw its effects). In an environmental test for cyanide, the ion is treated in a redox reaction in basic solution with permanganate.

$$CN^-(aq) + MnO_4^-(aq) \rightarrow CNO^-(aq) + MnO_2(s)$$ ***(basic conditions)***

a) (5 pts) Determine the overall balanced redox reaction equation.

This is taken directly from the course notes

oxidation:

$$CN^- \rightarrow CNO^-$$
$$H_2O + CN^- \rightarrow CNO^-$$
$$H_2O + CN^- \rightarrow CNO^- + 2\,H^+$$
$$2\,OH^- + H_2O + CN^- \rightarrow CNO^- + 2\,H^+ + 2\,OH^-$$
$$2\,OH^- + H_2O + CN^- \rightarrow CNO^- + 2\,H_2O$$
$$2\,OH^- + CN^- \rightarrow CNO^- + H_2O$$
$$2\,OH^- + CN^- \rightarrow CNO^- + H_2O + 2\,e^-$$
$$6\,OH^- + 3\,CN^- \rightarrow 3\,CNO^- + 3\,H_2O + 6\,e^-$$

reduction:

$$MnO_4^- \rightarrow MnO_2$$
$$MnO_4^- \rightarrow MnO_2 + 2\,H_2O$$
$$4\,H^+ + MnO_4^- \rightarrow MnO_2 + 2\,H_2O$$
$$4\,OH^- + 4\,H^+ + MnO_4^- \rightarrow MnO_2 + 2\,H_2O + 4\,OH^-$$
$$4\,H_2O + MnO_4^- \rightarrow MnO_2 + 2\,H_2O + 4\,OH^-$$
$$2\,H_2O + MnO_4^- \rightarrow MnO_2 + 4\,OH^-$$
$$3\,e^- + 2\,H_2O + MnO_4^- \rightarrow MnO_2 + 4\,OH^-$$
$$6\,e^- + 4\,H_2O + 2\,MnO_4^- \rightarrow 2\,MnO_2 + 8\,OH^-$$

Adding the two together and simplifying gives the overall balanced redox reaction:

$$H_2O + 2\,MnO_4^- + 3\,CN^- \rightarrow 3\,CNO^- + 2\,MnO_2 + 2\,OH^-$$

b) (5 pts) 450.0 mL of a 0.02270 M $Ca(CN)_2$ solution are added to 725.0 mL of a 0.01055 M $KMnO_4$ solution. If the above reaction has a percent yield of 78.3%, what is the expected mass of solid manganese dioxide?

$$?\text{ mol MnO}_2\text{ from CN}^- = 0.4500\text{ L} \times \frac{0.02270\text{ mol Ca(CN)}_2}{\text{L}} \times \frac{2\text{ mol CN}^-}{1\text{ mol Ca(CN)}_2} \times \frac{2\text{ mol MnO}_2}{3\text{ mol CN}^-}$$
$$= 0.01362\text{ mol}$$

$$?\text{ mol MnO}_2\text{ from MnO}_4^- = 0.7250\text{ L} \times \frac{0.01055\text{ mol KMnO}_4}{\text{L}} \times \frac{1\text{ mol MnO}_4^-}{1\text{ mol KMnO}_4} \times \frac{2\text{ mol MnO}_2}{2\text{ mol MnO}_4^-}$$
$$= 0.007649\text{ mol}$$

Therefore, permanganate is the limiting reagent.

$$?\text{ actual g MnO}_2 = \left(0.007649\text{ mol MnO}_2 \times \frac{86.94\text{ g MnO}_2}{\text{mol MnO}_2}\right) \times 78.3\%$$
$$= 0.52\text{ g}$$

Answer: ________0.52 g____________