#1. (10 points) Short Answer Questions

a) Provide the name or formula for the following:

$CuNO_3$ copper (I) nitrate (1)

calcium sulfate tetrahydrate $CaSO_4 \cdot 4H_2O$ (1)

b) The molar 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: 4.22 kJ. (1)

c) You take a 4.0 L volume of gas at 600 K. You compress the gas to a 1.0 L volume and simultaneously cool the vessel to 300 K. The pressure of the gas:

(DOUBLES) HALVES QUADRUPLES STAYS CONSTANT (1)

d) The standard heat of formation of solid sodium carbonate is –1131 kJ. Write the chemical equation for the reaction to which this value applies (include phases).

$$2\,Na(s) + C(s, graphite) + \frac{3}{2}O_2(g) \rightarrow Na_2CO_3(s)$$ (1)

e) The root-mean-square-speed of xenon is 237 m/s. A molecule of chlorine gas would beat a molecule of xenon gas in a race. (TRUE) FALSE (1)

Xe 131
Cl_2 71

f) Write the equilibrium constant expression for the following reaction, and choose the best means by which you could encourage the formation of hydrogen gas.

$C(s) + H_2O(g) \leftrightarrows CO(g) + H_2(g)$ $\Delta H^\circ = 211$ kJ

i) Add steam and remove heat
ii) Remove carbon monoxide and decrease volume
(iii) Increase volume and add heat (1)
iv) Add hydrogen gas and increase volume

$K = \dfrac{P_{CO} \cdot P_{H_2}}{P_{H_2O}}$ (1)

g) Which of the following isotopes has the greatest number of neutrons?

$^{35}_{17}Cl$ (${}^{40}_{19}K$) $^{37}_{17}Cl$ $^{40}_{20}Ca$ (1)

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

NaOCl, HCl, Cl_2 HCl, Cl_2, NaOCl (1)

#2. (10 points) The following reaction, occurring in a sealed vessel, has a percent yield of 94.9%:

$$2NaN_3\,(s) \rightarrow 2\,Na\,(l) + 3\,N_2(g)$$

a) What volume of N_2, measured at 735 mmHg and 26.0°C, is produced when 75.0 g of sodium azide decomposes?

$$?\,\text{theo. mol } N_2 = 75.0\,g\,NaN_3 \cdot \frac{\text{mol } NaN_3}{65.011\,g\,NaN_3} \cdot \frac{3\,\text{mol } N_2}{2\,\text{mol } NaN_3} = 1.730\,\text{mol}$$ (2)

$$?\,\text{actual mol } N_2 = 1.730\,\text{mol} \cdot 0.949 = 1.642\,\text{mol}$$ (2)

$$P = 735\,\text{mmHg} \cdot \frac{1\,\text{atm}}{760\,\text{mmHg}} = 0.967\,\text{atm}$$

$$T = (26.0 + 273.15) = 299\,K$$ (2)

$$V = \frac{nRT}{P} = \frac{1.642\,\text{mol} \cdot 0.08206\,L \cdot \text{atm/mol} \cdot K \cdot 299\,K}{0.967\,\text{atm}}$$

$$= 41.7\,L$$ (2)

Answer: 41.7 L

b) After the reaction is complete, argon gas is added to the vessel until the final total pressure is 1000 mmHg. What is the mole fraction of nitrogen in the gas mixture?

$$P_T = 1000\,\text{mmHg} \qquad P_{N_2} = 735\,\text{mmHg}$$

$$\chi_{N_2} = \frac{P_{N_2}}{P_T} = \frac{735\,\text{mmHg}}{1000\,\text{mmHg}} = 0.735$$ (2)

Answer: 0.735

#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.

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.

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

$= (2.20\,g + 24.0\,g)(4.184\,J/g°C)(28.0°C - 13.0°C)$ (4)

$= +1644\,J$

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

$n = 2.20\,g \cdot \frac{mol}{47.0\,g} = 0.0468\,mol$

$\Delta H° = \frac{q_{rxn}}{n} = \frac{-1644\,J}{0.0468\,mol}$

$= -35.1\,kJ/mol$

Answer: $-35.1\,kJ/mol$

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

$\Delta U = q + w$ (2)

BUT: since there are no gases, $w \approx 0$ $\therefore \Delta U \approx q$

$\Delta U = -35.1\,kJ/mol$

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

$X(s) \rightarrow X(aq)$ $-35.1\,kJ/mol$ (1)

$X(aq) \rightarrow 2Y(aq)$ $+1.44\,kJ/mol$ (1)

$2Y(aq) \rightarrow 2Y(s)$ $-49.4\,kJ/mol$ (1)

$X(s) \rightarrow 2Y(s)$ $-83.1\,kJ/mol$ (1)

Answer: $-83.1\,kJ/mol$

#4. (10 points) In a reaction chamber, 0.1000 mol of H_2S is mixed with 0.0500 mol of methane and is brought to equilibrium at 700°C and a total pressure of 1.000 bar.

$$2\ H_2S(g) + CH_4(g) \leftrightarrows CS_2(g) + 4\ H_2(g)$$

Upon analysis, the equilibrium mixture was found to contain 3.34×10^{-2} mol carbon disulfide.

a) Determine the number of moles of each of the other species present at equilibrium.

	$2H_2S$	+ CH_4	⇄ CS_2	+ $4H_2$
I	0.1000	0.0500	0	0
C	$-2(0.0334)$	-0.0334	$+0.0334$	$+4(0.0334)$
E	0.0332	0.0166	0.0334	0.1336

(3)

$H_2S =$ 0.0332 mol $CH_4 =$ 0.0166 mol $H_2 =$ 0.1336 mol

b) Calculate K_P at 700°C.

$$n_T = n_{H_2S} + n_{CH_4} + n_{CS_2} + n_{H_2} = 0.2168\ mol$$

(5)

$$P_{H_2S} = \chi_{H_2S} P_T = \frac{0.0332}{0.2168} \cdot 1.000\ bar = 0.153\ bar$$

$P_{CH_4} = 0.0766$ bar

$P_{CS_2} = 0.154$ bar

$P_{H_2} = 0.616$ bar

$$K_p = \frac{P_{CS_2} \cdot P_{H_2}^4}{P_{H_2S}^2 \cdot P_{CH_4}} = \frac{(0.154)(0.616)^4}{(0.153)^2(0.0766)}$$

$K_p = 12.4$

c) Calculate K_C at 700°C.

$$K_c = \frac{K_P}{(RT)^{\Delta n}} = \frac{12.4}{(0.083145 \cdot 973)^{(5-3)}} = 1.89 \times 10^{-3}$$

(2)

#5. (10 points) In an environmental analysis for lead in soils, the lead must first be oxidized to lead ions using permanganate ions in acidic solution, with the following half-reactions.

$$MnO_4^- \rightarrow Mn^{2+}$$

$$Pb \rightarrow Pb^{2+}$$

a) Determine the overall balanced redox reaction equation.

① $5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$

② $Pb \rightarrow Pb^{2+} + 2e^-$

$2 \times ① = 10e^- + 16H^+ + 2MnO_4^- \rightarrow 2Mn^{2+} + 8H_2O$

$5 \times ② = 5Pb \rightarrow 5Pb^{2+} + 10e^-$

$$5Pb + 2MnO_4^- + 16H^+ \rightarrow 5Pb^{2+} + 2Mn^{2+} + 8H_2O$$

(5)

b) A 25.0 g sample of soil was found to react with 14.92 mL of a 0.150 M $KMnO_4$ solution. What was the percent composition by mass of lead in the soil sample?

$$?\,g\ Pb = 0.01492\ L\ KMnO_4 \cdot \frac{0.150\ mol\ KMnO_4}{L\ KMnO_4} \cdot \frac{5\ mol\ Pb}{2\ mol\ KMnO_4} \cdot \frac{207.2\ g\ Pb}{mol\ Pb}$$

$= 1.16\ g$

$$\%\ Pb = \frac{1.16\ g}{25.0\ g} \times 100\% = 4.64\%$$

(5)

Answer: 4.64%