CHMG-152 Exam #1 D Name (print): ______________________________________

SHOW ALL WORK PLEASE!!!!!!!

$c_{acetone,liq}$=1.9 J/gK

$c_{acetone,gas}$=1.2 J/gK

$c_{acetone,solid}$=1.5 J/gK

$c_{H2O,\ liq}$ = 4.18 J/gK, c_{ice} = 2.09 J/gK, c_{steam} = 2.01 J/gK

D_{H2O} = 0.97 g/mL at 25ºC

ΔH_{fus} (H_2O) = 6.02 kJ/mol ΔH_{vap}(H_2O) = 40.7 kJ/mol

1 lb = 453.6 g

ΔH_{fus} (ethanol) = 4.93 kJ/mol ΔH_{vap}(ethanol) = 38.56 kJ/mol

ΔH_{fus} (acetone) = 6.93 kJ/mol ΔH_{vap}(acetone) = 27.43 kJ/mol

$c_{ethanol,liq}$=2.4 J/gK

$c_{ethanol,\ gas}$ =1.4 J/gK

$c_{ethanol,\ solid}$ =1.3 J/gK

Normal boiling point of water =100ºC

Normal freezing point of water =0ºC

Normal boiling point of ethanol =78.3ºC

Normal freezing point of ethanol= - 114.5ºC

Normal boiling point of acetone =65.3ºC

Normal freezing point of acetone= - 96.5ºC

Density of acetone = 0.79 g/mL at 25 ºC

Density of ethanol = 0.87 g/mL at 25 ºC

Density of water = 0.97 g/mL at 25 ºC

K_f(ethanol)=0.86 K_f (water) = 1.86

K_b(ethanol)=0.43 K_b (water) = 0.51

1. (20 pt.) Rank the following compounds in order of increasing boiling point:

A) CH_4, CH_3Cl, CH_3CH_3, CH_3OH

Lowest b.p. Highest b.p.

CH_4, CH_3CH_3, CH_3Cl, CH_3OH

B) HCl, HF, HBr, H_2O

Lowest b.p. Highest b.p.

HCl, HBr, HF, H_2O

C) NH_3, NO_2, $LiNO_2$, N_2H_2

Lowest b.p. Highest b.p.
NO_2, N_2H_2, NH_3, $LiNO_2$

2. (20 pt.) I find a white crystalline substance on the floor of my office. I think it is either ice remover from the sidewalk (calcium chloride, $CaCl_2$) OR salt (sodium chloride, NaCl) from lunch. Calcium chloride and NaCl are both ionic compound that dissociate in water. The van't Hoff coefficient of $CaCl_2$ is 2.7. The van't Hoff coefficient of NaCl is 1.9

I take 2.5 g of the crystalline substance and dissolve it in 25.0 g of distilled water. What should the freezing point of the solution be if the crystalline substance is actually $CaCl_2$? What would the freezing point be if the substance is actually NaCl?

$$\Delta T_f = -iK_f m = -iK_f \frac{mol\ solute}{kg\ solvent}$$

$CaCl_2$

$$\Delta T_f = -(2.7)\left(1.86\ \frac{℃}{m}\right)\frac{2.5\ g\ \frac{1\ mol}{110.9\ g\ CaCl_2}}{0.025\ kg\ solvent} = -4.53℃$$

NaCl

$$\Delta T_f = -(1.9)\left(1.86\ \frac{℃}{m}\right)\frac{2.5\ g\ \frac{1\ mol}{58.453\ g\ NaCl}}{0.025\ kg\ solvent} = -6.0℃$$

3. (20 pt.) Consider the reaction:

$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$$

The following data was obtained at 298 K.

$[H_2(g)]_0$ (M)	$[O_2(g)]_0$ (M)	Initial Rate (M/s)	Temp (K)
1.50	1.50	0.160	298 K
1.50	0.75	0.170	298 K
3.00	1.50	0.640	298 K
3.00	1.50	0.720	325 K

What is the initial rate of reaction if 0.500 M of hydrogen and 0.500 M of oxygen are mixed together at 373 K?
How much hydrogen (H_2) is left after 1 hour [of the 0.500 M at 373 K from the previous question]?

Looking at the 1st 2 rows, must be 0 order in oxygen.

Looking at 1st and 3rd row, must be 2nd order in hydrogen

Rate=k$[H_2]^2$

So, at 298 K

$$0.160\frac{M}{s} = k(1.5)^2$$

$$k = 0.0711\ M^{-1}s^{-1}$$

If you do this for all 3 sets of data at 298 K, you get an average k =0.0726

At 325 K

$$0.720\frac{M}{s} = k(2.0)^2$$

$$k = 0.080\ M^{-1}s^{-1}$$

At 373 K

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln\left(\frac{0.0726}{0.080}\right) = -\frac{E_a}{8.314\frac{J}{molK}}\left(\frac{1}{298} - \frac{1}{325}\right)$$

$$E_a = 2895 \frac{J}{mol}$$

$$\ln\left(\frac{x}{0.080}\right) = -\frac{2895 \frac{J}{mol}}{8.314 \frac{J}{molK}} (\frac{1}{373} - \frac{1}{325})$$

$$x = 0.092\ M^{-1}s^{-1}$$

At 373:

$$Rate = (0.0918\ M^{-1}s^{-1})(0.5\ M)^2 = 0.023 \frac{M}{s}$$

$$\frac{1}{[H_2]_t} = kt + \frac{1}{[H_2]_{initial}}$$

$$\frac{1}{[H_2]_t} = (0.092\ M^{-1}s^{-1})(3600\ s) + \frac{1}{0.500}$$

$$[H_2]_t = 0.030\ M$$

4. (20 pt.) I have 250 g of ethanol (C_2H_5OH) at 150 ºC. How much energy would I need to remove for the ethanol to get down to -100 ºC ?

Freezing point is -114.5 C
Boiling point is 78.3C

So it condenses at 78.3

$$Q = mc\Delta T + n(-\Delta H_{vap}) + mc\Delta T$$

$$Q = (250\ g)\left(1.4\frac{J}{gK}\right)(78.3 - 150) + \left(250\ g\frac{1\ mol}{46.07\ g\ eth}\right)\left(38{,}560\frac{J}{mol}\right) + (250\ g)\left(2.4\frac{J}{gK}\right)(-100 - 78.3) = -341{,}300\ J$$

5. (20 pt) Consider the following reaction:

$N_2 (aq) + O_2(aq) \rightarrow 2 NO (aq)$

$[N_2]$ M	$[O_2]$ M	Rate of reaction M/sec	Temp (K)
0.0040	1.00	0.192	325
0.0020	1.00	0.048	325
0.0020	0.50	0.012	325

What is the rate law for the reaction?
What is the rate constant for the reaction? [Appropriate units included.]

Looking at 1st and 2nd rows: doubling nitrogen quadruples the rate. It's 2nd order in nitrogen.

Looking at the 2nd and 3rd rows: doubling oxygen quadruples the rate. It's 2nd order in oxygen.

$$Rate = k[N_2]^2[O_2]^2$$

The data is perfect, so if you do all 3 data sets, you get the same result for k:

$$0.192\frac{M}{s} = k(0.0040\ M)^2(1.00\ M)^2$$
$$0.192\frac{M}{s} = k(1.6 \times 10^{-5}\ M^4)$$
$$k = \frac{0.192\frac{M}{s}}{1.6 \times 10^{-5} M^4} = 12{,}000\ M^{-3}s^{-1}$$