

SHOW ALL WORK PLEASE!!!!!!

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

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

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

$$c_{\text{H}_2\text{O, liq}} = 4.18 \text{ J/gK}, c_{\text{ice}} = 2.09 \text{ J/gK}, c_{\text{steam}} = 2.01 \text{ J/gK}$$

$$D_{\text{H}_2\text{O}} = 0.97 \text{ g/mL at } 25^\circ\text{C}$$

$$\Delta H_{\text{fus}}(\text{H}_2\text{O}) = 6.02 \text{ kJ/mol} \quad \Delta H_{\text{vap}}(\text{H}_2\text{O}) = 40.7 \text{ kJ/mol}$$

$$1 \text{ lb} = 453.6 \text{ g}$$

$$\Delta H_{\text{fus}}(\text{ethanol}) = 4.93 \text{ kJ/mol} \quad \Delta H_{\text{vap}}(\text{ethanol}) = 38.56 \text{ kJ/mol}$$

$$\Delta H_{\text{fus}}(\text{acetone}) = 6.93 \text{ kJ/mol} \quad \Delta H_{\text{vap}}(\text{acetone}) = 27.43 \text{ kJ/mol}$$

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

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

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

Normal boiling point of water = 100°C

Normal freezing point of water = 0°C

Normal boiling point of ethanol = 78.3°C

Normal freezing point of ethanol = - 114.5°C

Normal boiling point of acetone = 65.3°C

Normal freezing point of acetone = - 96.5°C

Density of acetone = 0.79 g/mL at 25 °C

Density of ethanol = 0.87 g/mL at 25 °C

Density of water = 0.97 g/mL at 25 °C

$$K_f(\text{ethanol})=0.86 \quad K_f(\text{water}) = 1.86$$

$$K_b(\text{ethanol})=0.43 \quad K_b(\text{water}) = 0.51$$

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

A)  $\text{CH}_4$ ,  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_3\text{CH}_3$ ,  $\text{CH}_3\text{OH}$

Lowest b.p.

Highest b.p.

$\text{CH}_4$ ,  $\text{CH}_3\text{CH}_3$ ,  $\text{CH}_3\text{Cl}$ ,  $\text{CH}_3\text{OH}$

B)  $\text{HCl}$ ,  $\text{HF}$ ,  $\text{HBr}$ ,  $\text{H}_2\text{O}$

Lowest b.p.

Highest b.p.

$\text{HCl}$ ,  $\text{HBr}$ ,  $\text{HF}$ ,  $\text{H}_2\text{O}$

C)  $\text{NH}_3$ ,  $\text{NO}_2$ ,  $\text{LiNO}_2$ ,  $\text{N}_2\text{H}_2$

Lowest b.p.

Highest b.p.

$\text{NO}_2$ ,  $\text{N}_2\text{H}_2$ ,  $\text{NH}_3$ ,  $\text{LiNO}_2$

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,  $\text{CaCl}_2$ ) OR salt (sodium chloride,  $\text{NaCl}$ ) from lunch. Calcium chloride and  $\text{NaCl}$  are both ionic compounds that dissociate in water. The van't Hoff coefficient of  $\text{CaCl}_2$  is 2.7. The van't Hoff coefficient of  $\text{NaCl}$  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  $\text{CaCl}_2$ ? What would the freezing point be if the substance is actually  $\text{NaCl}$ ?

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

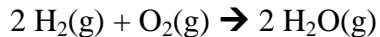
$\text{CaCl}_2$

$$\Delta T_f = -(2.7) \left( 1.86 \frac{^\circ\text{C}}{m} \right) \frac{2.5 \text{ g} \frac{1 \text{ mol}}{110.9 \text{ g CaCl}_2}}{0.025 \text{ kg solvent}} = -4.53^\circ\text{C}$$

$\text{NaCl}$

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

3. (20 pt.) Consider the reaction:



The following data was obtained at 298 K.

$[\text{H}_2(\text{g})]_0$ (M)	$[\text{O}_2(\text{g})]_0$ (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 ( $\text{H}_2$ ) is left after 1 hour [of the 0.500 M at 373 K from the previous question]?

Looking at the 1<sup>st</sup> 2 rows, must be 0 order in oxygen.

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

$$\text{Rate} = k[\text{H}_2]^2$$

So, at 298 K

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

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

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

At 325 K

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

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

At 373 K

$$\ln\left(\frac{k_2}{k_1}\right) = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$
$$\ln\left(\frac{0.0726}{0.080}\right) = -\frac{E_a}{8.314 \frac{\text{J}}{\text{molK}}}\left(\frac{1}{298} - \frac{1}{325}\right)$$

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

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

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

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  $150\text{ }^\circ\text{C}$ . How much energy would I need to remove for the ethanol to get down to  $-100\text{ }^\circ\text{C}$  ?

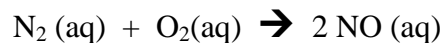
Freezing point is  $-114.5\text{ }^\circ\text{C}$

Boiling point is  $78.3\text{ }^\circ\text{C}$

So it condenses at  $78.3$

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

5. (20 pt) Consider the following reaction:



[N <sub>2</sub> ] M	[O <sub>2</sub> ] 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 1<sup>st</sup> and 2<sup>nd</sup> rows: doubling nitrogen quadruples the rate. It's 2<sup>nd</sup> order in nitrogen.

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

$$\text{Rate} = k[\text{N}_2]^2[\text{O}_2]^2$$

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

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

