Chemistry 10123, **Exam 1** **Answer Key**
January 30, 2019

1. (3 points) At a pressure of 1025 torr, the solubility of O_2 gas in water is 0.00175 M. If the pressure is increased to 25 atm, the solubility of O_2 should be 0.0324 M.

2. (4 points) The heat of solution ($\Delta H°_{soln}$) of an ionic compound in water is approximately equal to the sum of the lattice energy of the crystalline solid and the hydration energy of the ions in solution.

3. (2 points) In the Transition State Theory of chemical kinetics, a type of graph called a "reaction coordinate diagram" is used to illustrate Energy of Activation.

4. (2 points) In water, soap molecules aggregate into small particles called micelles.

5. (2 points) Three common examples of colloidal dispersions are: paint, milk, soap, fog, etc.

6. (11 points) A kinetic study of the following gas-phase reaction gave the concentration *vs* initial rate data summarized below. $CH_3Cl + 3\ Cl_2 \longrightarrow CCl_4 + 3\ HCl$

Expt	**[CH_3Cl]**	**[Cl_2]**	**initial rate** (mole/L·sec)
(1)	0.250	0.150	0.0215
(2)	0.450	0.450	0.0670
(3)	1.350	0.150	0.1161
(4)	0.450	0.150	0.0387

Determine the **rate law** for this reaction. **Clearly SHOW how you arrive at your answer**. (It is not necessary to calculate the value of the rate constant.)

Compare expts 1 & 3 with constant $[Cl_2]$ to find rate ~ $[CH_3Cl]^x$

$0.1161 / 0.0215 = (1.35 / 0.25)^x$

$5.4 = (5.40)^x \quad \therefore\ x = 1$ (1st order in CH_3Cl)

Compare expts 2 and 4 with constant $[CH_3Cl]$ to find rate ~ $[Cl_2]^y$

$0.0670 / 0.0387 = (0.450 / 0.150)^y$

$1.73 = 3^y \quad \therefore\ y = 1/2$ (1/2 order in Cl_2)

Overall Rate Law: rate = $k[CH_3Cl][Cl_2]^{1/2}$

7. (10 points) **SHOW ALL WORK.** A 0.725 g sample of an unknown polymer was dissolved in a suitable solvent and diluted with the solvent to make 250 mL of solution. The osmotic pressure of the solution was found to equal 1.35 torr at 20° C. Determine the molar mass of the polymer.

$\Pi V = nRT$

$n = \Pi V/RT = (1.35 \text{ torr})(1 \text{ atm} / 760 \text{ torr})(0.250 \text{ L}) / (0.0821 \text{ L·atm/mole·K})(293 \text{ K})$

$n = 1.846 \times 10^{-5}$ moles

molar mass $= (0.725 \text{ g}) / (1.846 \times 10^{-5} \text{ moles}) = 3.93 \times 10^{4}$ g/mole

8. A concentrated solution of $MgCl_{2(aq)}$ is 25.0 % $MgCl_2$ by mass and has a density of 1.26 g/mL. The following problems all deal with this solution but they can be solved independently.
[Molar masses: $H_2O = 18.0$, $MgCl_2 = 95.2$]

(a) (6 points) **SHOW ALL WORK.** Determine the mole percent of $MgCl_2$ in the solution.

25.0 % by mass: 25.0 g $MgCl_2$ mixed with 75.0 g H_2O

$(25.0 \text{ g } MgCl_2)(1 \text{ mole} / 95.2 \text{ g}) = 0.263$ mole $MgCl_2$

$(75.0 \text{ g } H_2O)(1 \text{ mole} / 18.0 \text{ g}) = 4.167$ mole H_2O

mole % $= (0.263) / (0.263 + 4.167) \times 100\ \% = 5.94$ mole %

(b) (8 points) **SHOW ALL WORK.** Assuming complete dissociation, determine the freezing point (in °C) of this $MgCl_2$ solution. (***Note***: For water, $K_f = 1.86$ °C/m)

molality of $MgCl_2 = (0.263 \text{ mole } MgCl_2) / (0.075 \text{ kg } H_2O) = 3.51$ m

1 mole of $MgCl_2$ yields 3 moles of ions in solution

$\therefore$ effective molality is $3 \times 3.51 = 10.5$ m

$\Delta T = K_f m = (1{,}86 \text{ °C/m})(10.5 \text{ m}) = 19.5$ °C freezing point = - 19.5 °C

(c) (10 points) **SHOW ALL WORK.** Determine the volume (in mL) of this $MgCl_2$ solution that is required to react exactly with 1.50 L of 0.250 M $AgNO_{3(aq)}$ to precipitate all of the Ag^+ as $AgCl_{(s)}$.

Precipitation: $2\ AgNO_{3(aq)} + MgCl_{2(aq)} \longrightarrow 2\ AgCl_{(s)} + Mg(NO_3)_{2(aq)}$

0.263 moles $MgCl_2$ is contained in 100 g of solution

$(100 \text{ g})(1 \text{ mL} / 1.26 \text{ g}) = 79.37 \text{ mL} = 0.07937$ L

$(0.263 \text{ mole}) / (0.07937 \text{ L}) = 3.314$ M $MgCl_2$

$(1.50 \text{ L})(0.25 \text{ mole } Ag^+/\text{L}) = 0.375$ mole Ag^+

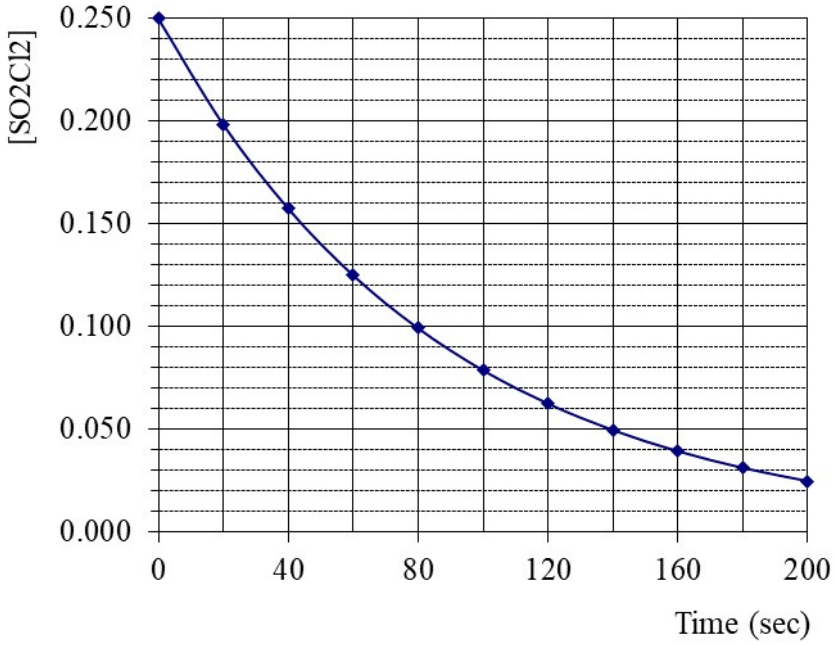
$(0.375 \text{ mole } Ag^+)(1 \text{ mole } MgCl_2 / 2 \text{ mole } Ag^+) = 0.1875$ mole $MgCl_2$

$(0.1875 \text{ mole } MgCl_2)(1000 \text{ mL} / 3.314 \text{ mole}) = 56.6$ mL

9. (3 points) The vapor pressure of pure hexane (C_6H_{14}) is 120 torr at 20 °C. If 1.0 mole of a non-volatile solute is dissolved in 5.0 moles of hexane at that temperature, the vapor pressure of the resulting solution should be 100 torr.

10 At a certain temperature, a kinetic study of the decomposition reaction of SO_2Cl_2 gave the following concentration *vs* time data. (***Do not assume the reaction is first order!***)

$$SO_2Cl_2 \longrightarrow SO_2 + Cl_2$$



(a) (2 points) The half-life for this reaction is 60 sec.

(b) (4 points) **SHOW ALL WORK.** Determine the ***initial rate*** of this reaction in units of mole/L·sec.

rate = Δconc / Δtime = (0.250 M - 0.200 M) / 20 sec = 2.5×10^{-3} M/sec

(c) (4 points) **SHOW ALL WORK.** Determine the ***instantaneous*** rate of this reaction when time = 120 sec.

rate = (0.080 M - 0.050 M) / 40 sec = 7.5×10^{-4} M/sec

(d) (5 points) ***In 50 words or less, describe*** how you would re-plot the above data in order to prove that this reaction is first order? Also, explain how to determine the rate constant (k) from your new graph.

For a first order process, the integrated rate law is: $\ln[SO_2Cl_2]_t = -kt + \ln[SO_2Cl_2]_0$

Therefore, a plot of $\ln[SO_2Cl_2]$ vs t should be a straight line with slope = -k.

11. (2 points) Two important factors that affect the rate of a reaction are: concentration, temperature, or nature of reactants. (Do ***not*** write "time" as one of your answers!)

12. A kinetic study of the gas-phase decomposition reaction of N_2O_5 shows it to be a first-order process. In one experiment at 25 °C, the reaction vessel initially contained pure N_2O_5 at a pressure of 250 torr. After the reaction occurred for 10.0 hours, the ***total*** pressure in the reaction vessel was 484 torr.

$$2\ N_2O_{5(g)} \longrightarrow 4\ NO_{2(g)} + O_{2(g)}$$

(a) (2 points) Write the rate law for this reaction.

rate = $k[N_2O_5]$

(b) (10 points) **SHOW ALL WORK.** Determine the rate constant (k) for this reaction at 25 °C in units of sec^{-1}.

Since the Rx is first order: $\ln P(N_2O_5)_t = -kt + \ln P(N_2O_5)_0$

As the reaction occurs, based on the balanced equation above, 2x torr of N_2O_5 reacts to form 4x torr of NO_2 and x torr of O_2.

$P(total) = P(N_2O_5) + P(NO_2) + P(O_2)$

484 torr = (250 torr - 2x) + 4x + x = 250 torr + 3x solve for x = 78 torr

After 10 hrs has elapsed: $P(N_2O_5)$ = 250 torr - 2 (78 torr) = 94 torr

$\ln(94) = -k\ (10.0\ hr)\ (3600\ sec/hr) + \ln(250)$

$k = 2.72 \times 10^{-5}\ sec^{-1}$

13. (10 points) **SHOW ALL WORK.** A certain chemical reaction has an Activation Energy of 105 kJ/mole. Determine the temperature (in °C) at which the reaction would occur 10^5 times faster than it does at 0 °C.

$\ln(k_2 / k_1) = - E_a/RT\ [1/T_2 - 1/T_1]$

$\ln(10^5) = (- 105\ kJ/mole)/(8.314 \times 10^{-3}\ kJ/mole{\cdot}K)\ [1/T_2 - 1/273\ K]$

$11.513 = - (12629)\ [1/T_2 - 1/273]$

$1/T_2 = 2.751 \times 10^{-3}$

$T_2 = 363\ K = 90.5\ °C$