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CHEM 111 – Dr. McCorkle – Exam #1

While you wait, please complete the following information:

Name: _____

Student ID: _____

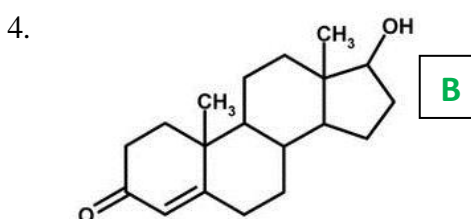
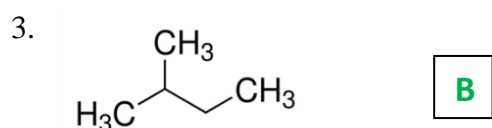
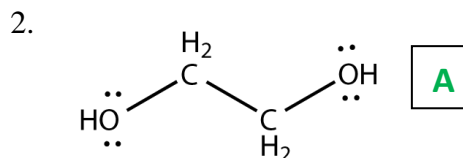
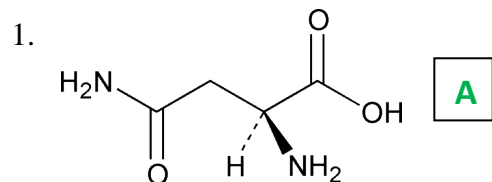
Turn off cellphones and stow them away. No headphones, mp3 players, hats, sunglasses, food, drinks, restroom breaks, graphing calculators, programmable calculators, or sharing calculators.

Multiple Choice – Choose the answer that best completes the question. Use an 815-E Scantron to record your response. [2 points each]

For the molecules 1-4, would you expect greater solubility in:

A) water

B) benzene (C_6H_6)?



5. Which substance would you expect to be the most soluble in water?

A) $CH_3CH_2CH_3$

B) $CH_3CH(OH)CH_3$

C) **$HOCH_2CH_2OH$**

D) $HOCH_2CH_2CH_2OH$

E) $CH_3CH_2CH_2COOH$

6. Which aqueous solution would you expect to produce the lowest freezing point? Assume all are ideal, non-volatile, 1.0 L solutions.

A) 0.750 *m* KCl

B) 1.200 *m* $CH_3CH_2CH_3$

C) **0.600 *m* Li_2SO_4**

D) 0.400 *m* Na_3PO_4

E) 0.800 *m* $HOCH_2CH_2OH$

7. When lithium iodide dissolves in water the solution becomes hotter. Which of the following is NOT true about the solution?

A) The solution is exothermic.

B) The lattice energy is smaller in magnitude than the heat of hydration.

C) The solution forms because the system tends towards greater entropy.

D) **The solution forms because the system tends towards greater energy.**

E) The ΔH_{mix} must be larger in magnitude than the sum of $\Delta H_{\text{solvent}}$ and ΔH_{solute} .

8. Solutions having osmotic pressure less than those of bodily fluids are called _____.

- A) isosmotic B) **hyposmotic** C) hyperosmotic
D) hemosmotic E) perosmotic

9. The Tyndall effect is due to:

- A) blockage of a beam of light an aerosol
B) bending of light by an emulsion
C) light passing through a solution
D) **scattering of a beam of light by a colloid**
E) light refracting through a suspension

10. Consider the reaction: $2 \text{C}_4\text{H}_{10}(\text{g}) + 13 \text{O}_2(\text{g}) \rightarrow 8 \text{CO}_2(\text{g}) + 10 \text{H}_2\text{O}(\text{g})$

If the rate of loss of O_2 is 0.32 M/s , what is rate of formation of CO_2 ?

- A) 2.6 M/s B) **0.20 M/s** C) 0.52 M/s
D) 0.025 M/s E) 0.32 M/s

Calculations – Write your initials in the upper-right corner of every page that contains work. For full credit show all work and write neatly; give answers with correct significant figures and units. Place a box around your final answer.

11. Ascorbic acid (vitamin C, $C_6H_8O_6$) is a water-soluble vitamin. A solution containing 80.5 g of ascorbic acid dissolved in 210.0 g of water has a density of 1.22 g/mL at 55°C. Calculate the following quantities for ascorbic acid in this solution: [3 points each]

a. mass percentage

$$\text{mass \%} = \frac{80.5 \text{ g}}{80.5 \text{ g} + 210.0 \text{ g}} \times 100 = 27.7\%$$

b. mole fraction

$$n_{\text{ascorbic acid}} = 80.5 \text{ g} \times \frac{1 \text{ mol}}{176.14 \text{ g}} = 0.4570 \text{ mol}$$

$$n_{\text{water}} = 210.0 \text{ g} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 11.653 \text{ mol}$$

$$X_{\text{ascorbic acid}} = \frac{0.4570 \text{ mol}}{0.4570 \text{ mol} + 11.653 \text{ mol}} = 0.0377$$

c. molality

$$210.0 \text{ g} \times \frac{1 \text{ kg}}{10^3 \text{ g}} = 0.2100 \text{ kg}$$

$$\text{molality} = \frac{0.4570 \text{ mol}}{0.2100 \text{ kg}} = 2.18 \text{ m}$$

d. molarity

$$80.5 \text{ g} + 210.0 \text{ g} = 290.5 \text{ g} \times \frac{1 \text{ mL}}{1.22 \text{ g}} \times \frac{10^{-3} \text{ L}}{1 \text{ mL}} = 0.2381 \text{ L}$$

$$\text{molarity} = \frac{0.4570 \text{ mol}}{0.2381 \text{ L}} = 1.92 \text{ M}$$

12. Nitric acid is usually purchased in a concentrated form that is 70.3% HNO_3 by mass and has a density of 1.41 g/mL. How many mL of concentrated solution would you take to prepare 1.50 L of 0.125 M HNO_3 by mixing with water? [4]

$$1.50 \text{ L} \times \frac{0.125 \text{ mol HNO}_3}{1 \text{ L}} \times \frac{63.02 \text{ g HNO}_3}{1 \text{ mol HNO}_3} \times \frac{100 \text{ g solution}}{70.3 \text{ g HNO}_3} \times \frac{1 \text{ mL}}{1.41 \text{ g}} = 11.9 \text{ mL}$$

13. Calculate the vapor pressure in atm of a solution containing 25.1 g of glycerin ($\text{C}_3\text{H}_8\text{O}_3$) in 115 mL of water at 30.0 °C. The vapor pressure of pure water at this temperature is 31.8 torr. Assume that glycerin is not volatile and dissolves molecularly (i.e., it is not ionic); use a density of 1.00 g/mL for the water. [5]

$$n_{\text{glycerin}} = 25.1 \text{ g} \times \frac{1 \text{ mol}}{92.11 \text{ g}} = 0.2725 \text{ mol}$$

$$n_{\text{water}} = 115 \text{ mL} \times \frac{1.00 \text{ g}}{1 \text{ mL}} \times \frac{1 \text{ mol}}{18.02 \text{ g}} = 6.381 \text{ mol}$$

$$\chi_{\text{water}} = \frac{6.381 \text{ mol}}{6.381 \text{ mol} + 0.2725 \text{ mol}} = 0.9590$$

$$P_{\text{water}} = \chi_{\text{water}} \cdot P_{\text{water}}^o = 0.9590 \times 31.8 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}}$$

$$P_{\text{water}} = 0.0401 \text{ atm}$$

14. An aqueous solution containing 15.6 g of an unknown molecular (nonelectrolyte) compound in 109.5 g of water was found to have a freezing point of -1.6 °C. Calculate the molar mass of the unknown compound. ($K_f = 1.86 \text{ }^\circ\text{C}/m$) [3]

$$\Delta T_f = m \times K_f \quad m = \frac{\Delta T_f}{K_f} = \frac{-1.6 \text{ }^\circ\text{C}}{1.86 \frac{^\circ\text{C}}{m}} = 0.860 m$$

$$109.5 \text{ g H}_2\text{O} \times \frac{1 \text{ kg}}{10^3 \text{ g}} \times \frac{0.860 \text{ mol}}{1 \text{ kg H}_2\text{O}} = 0.09417 \text{ mol}$$

$$\text{MM} = \frac{15.6 \text{ g}}{0.09417 \text{ mol}} = 170 \text{ g/mol}$$

15. The decomposition of dinitrogen pentoxide ($\text{N}_2\text{O}_5 \rightarrow \text{N}_2\text{O}_3 + \text{O}_2$) obeys the rate-law expression, $\text{Rate} = 0.080 \text{ min}^{-1}[\text{N}_2\text{O}_5]$. If the initial concentration of N_2O_5 is 0.30 M , what is the concentration after 2.6 minutes? [3]

$$\ln[\text{A}]_t = -kt + \ln[\text{A}]_0$$

$$\ln[\text{A}]_t = -0.080 \text{ min}^{-1} \times 2.6 \text{ min} + \ln(0.30)$$

$$\ln[\text{A}]_t = -1.41$$

$$[\text{A}]_t = e^{-1.41} = 0.24 \text{ M}$$

16. Consider the reaction: $2\text{B} \rightarrow \text{C} + 3\text{D}$. In one experiment it was found that at 27°C the rate constant is $0.134 \text{ M}^{-1}\cdot\text{s}^{-1}$. A second experiment showed that at 177°C , the rate constant was $0.569 \text{ M}^{-1}\cdot\text{s}^{-1}$. Determine the activation energy for the reaction in joules. [3]

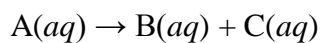
$$\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln \left(\frac{0.569 \text{ M}^{-1} \cdot \text{s}^{-1}}{0.134 \text{ M}^{-1} \cdot \text{s}^{-1}} \right) = \frac{E_a}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} \left(\frac{1}{300.\text{K}} - \frac{1}{450.\text{K}} \right)$$

$$1.446 = \frac{E_a}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} (0.001111 \text{ K}^{-1})$$

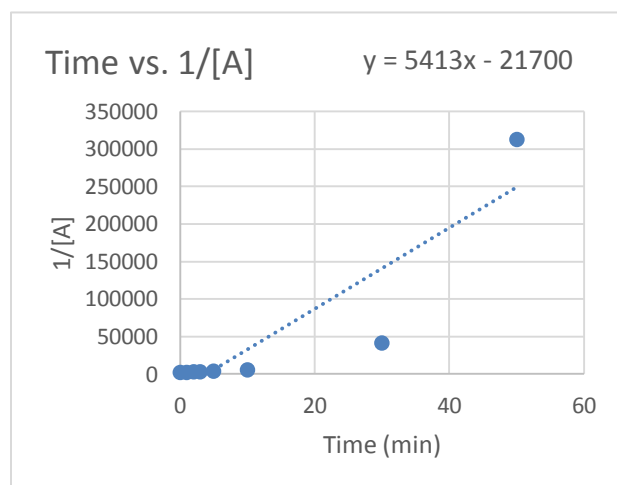
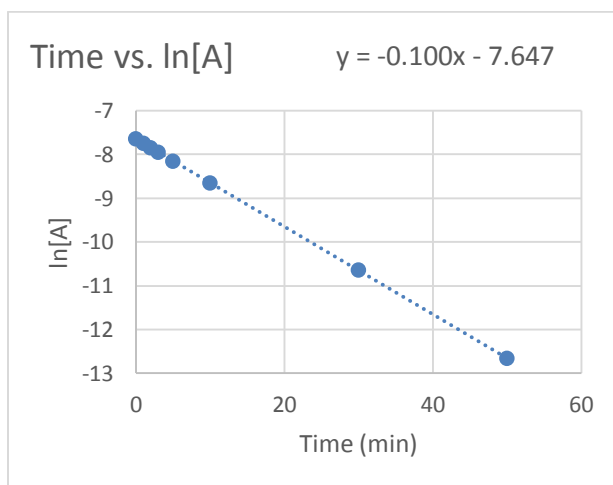
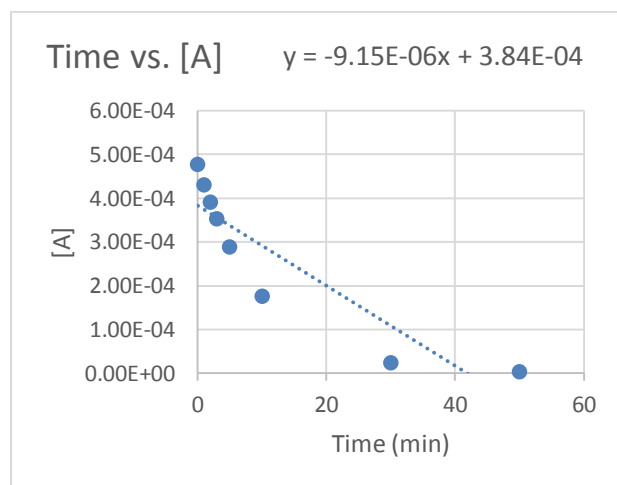
$$E_a = 1.08 \times 10^4 \text{ J}$$

17. Consider the following reaction:



The concentration of A was measured over time and the following data collected.

Time (min)	0.00	1.00	2.00	3.00	5.00	10.00	30.00	50.00
[A] (M)	4.77×10^{-4}	4.31×10^{-4}	3.91×10^{-4}	3.53×10^{-4}	2.89×10^{-4}	1.76×10^{-4}	2.40×10^{-5}	3.20×10^{-6}



a. Determine the rate constant: [2]

**time vs. $\ln[A]$ gives a straight line
so reaction is first – order in A**

slope = $-k$

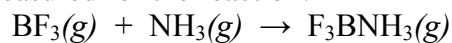
slope = $-(-0.100 \text{ min}^{-1})$

slope = 0.100 min^{-1}

b. Write the rate law: [2]

Rate = $k[A]^1$ or $0.100 \text{ min}^{-1}[A]^1$

18. The following data were measured for the reaction:



Experiment	[BF ₃] (M)	[NH ₃] (M)	Initial rate (M·s ⁻¹)
1	0.250	0.250	0.2130
2	0.250	0.125	0.1065
3	0.200	0.100	0.0682
4	0.350	0.100	0.1193
5	0.175	0.100	0.0596

a. Determine the rate law for the reaction. [4]

$$\left(\frac{\text{Rate}_1}{\text{Rate}_2}\right) = \left(\frac{k_1[\text{BF}_3]^m[\text{NH}_3]^n}{k_2[\text{BF}_3]^m[\text{NH}_3]^n}\right) \qquad \left(\frac{\text{Rate}_4}{\text{Rate}_3}\right) = \left(\frac{k_4[\text{BF}_3]^m[\text{NH}_3]^n}{k_3[\text{BF}_3]^m[\text{NH}_3]^n}\right)$$

$$\left(\frac{0.2130 \text{ M}\cdot\text{s}^{-1}}{0.1065 \text{ M}\cdot\text{s}^{-1}}\right) = \left(\frac{0.250 \text{ M}}{0.125 \text{ M}}\right)^m \qquad \left(\frac{0.1193 \text{ M}\cdot\text{s}^{-1}}{0.0682 \text{ M}\cdot\text{s}^{-1}}\right) = \left(\frac{0.350 \text{ M}}{0.200 \text{ M}}\right)^n$$

$$(2) = (2)^m$$

$$(1.75) = (1.75)^n$$

$$m = 1$$

$$n = 1$$

$$\text{Rate} = k[\text{BF}_3]^1[\text{NH}_3]^1$$

b. What is the overall order of the reaction? [2]

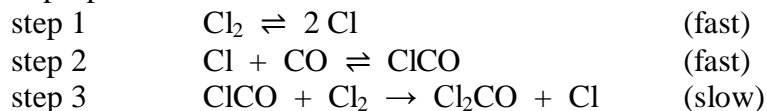
$$\text{overall order} = 1 + 1 = 2$$

c. Determine the rate constant. [3]

$$\text{Rate} = k[\text{BF}_3]^1[\text{NH}_3]^1$$

$$k = \frac{\text{Rate}}{[\text{BF}_3]^1[\text{NH}_3]^1} = \frac{0.2130 \text{ M}\cdot\text{s}^{-1}}{(0.250 \text{ M})^1(0.250 \text{ M})^1} = 3.41 \text{ M}^{-1} \cdot \text{s}^{-1}$$

19. **Challenge Question:** For the reaction $\text{Cl}_2 + \text{CO} \rightleftharpoons \text{Cl}_2\text{CO}$, the following three-step mechanism has been proposed:



(Hint: Remember that orders do not have to be whole numbers.)

a) Identify the intermediates, if any, in the mechanism. [2]

**Both Cl and ClCO could be considered intermediates
(although technically Cl is catalyst)**

b) What is the rate law expression for the overall reaction? [5]

Start with the slow step: $\text{Rate}_3 = k_3[\text{ClCO}]^1[\text{Cl}_2]^1$

Have to substitute for the intermediate, ClCO

$$\text{Rate}_2 = \text{Rate}_{-2}$$

$$k_2[\text{Cl}]^1[\text{CO}]^1 = k_{-2}[\text{ClCO}]^1 \quad \frac{k_2}{k_{-2}}[\text{Cl}]^1[\text{CO}]^1 = [\text{ClCO}]^1$$

$$\text{Rate}_3 = \frac{k_3 \cdot k_2}{k_{-2}}[\text{Cl}]^1[\text{CO}]^1[\text{Cl}_2]^1$$

$$\text{Rate}_1 = \text{Rate}_{-1}$$

$$k_1[\text{Cl}_2]^1 = k_{-1}[\text{Cl}]^2 \quad \frac{k_1}{k_{-1}}[\text{Cl}_2]^{1/2} = [\text{Cl}]$$

$$\text{Rate}_3 = \frac{k_3 \cdot k_2 \cdot k_1}{k_{-2} \cdot k_{-1}}[\text{Cl}_2]^{1/2}[\text{CO}]^1[\text{Cl}_2]^1$$

$$\text{Rate} = k[\text{Cl}_2]^{3/2}[\text{CO}]^1$$

Extra Credit: When molecules with hydrophilic heads and long hydrophobic tails are placed in water they often cluster together in spheres. What are these spheres called? [2 points]

micelles

Formulas & Constants

$$M = \frac{\text{mol solute}}{\text{liters solution}}$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}}$$

$$\chi_A = \frac{\text{mol A}}{\text{total moles}}$$

$$P_A = \chi_A \cdot P_A^o$$

$$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

$$R = 8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

$$\Delta T_f = \underline{m} \cdot K_f$$

$$\Delta T_b = \underline{m} \cdot K_b$$

$$\Pi = \underline{M}RT$$

$$\Delta T_f = i \cdot \underline{m} \cdot K_f$$

$$\Delta T_b = i \cdot \underline{m} \cdot K_b$$

$$\Pi = i \cdot \underline{M}RT$$

$$K = ^\circ\text{C} + 273.15$$

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mmHg}$$

$$S_{\text{gas}} = k_H \cdot P_{\text{gas}}$$

$$\Delta H_{\text{sol'n}} = \Delta H_{\text{hydration}} - \Delta H_{\text{lattice}}$$

$$f = e^{-E_a/RT}$$

$$k = Ae^{-E_a/RT}$$

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

$$\ln k = -\frac{E_a}{R} \left(\frac{1}{T} \right) + \ln A$$

$$K_p = K_c(RT)^{\Delta n}$$

$$K_w = 1.0 \times 10^{-14}$$

$$K_a \times K_b = K_w$$

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$\text{pH} = \text{p}K_a + \log \frac{[\text{base}]}{[\text{acid}]}$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$K = e^{-\Delta G^\circ/RT}$$

$$\Delta G^\circ = -nFE^\circ$$

$$F = 96,485 \text{ J/V} \cdot \text{mol}$$

$$E^\circ_{\text{cell}} = E^\circ(\text{cathode}) - E^\circ(\text{anode}) \quad E = E^\circ - (0.0592/n) \log Q$$

$$E = E^\circ - (RT/nF) \ln Q$$

$$1 \text{ V} = 1 \text{ J/C}$$

Order in [A]	Rate Law	Integrated Form, $y = mx + b$	Straight Line Plot	Half-Life $t_{1/2}$
zero-order (n = 0)	rate = $k [A]^0 = k$	$[A]_t = -kt + [A]_0$	$[A]_t$ vs. t	$t_{1/2} = \frac{[A]_0}{2k}$
first-order (n = 1)	rate = $k [A]^1$	$\ln[A]_t = -kt + \ln[A]_0$	$\ln[A]_t$ vs. t	$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$
second-order (n = 2)	rate = $k [A]^2$	$\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}$	$\frac{1}{[A]_t}$ vs. t	$t_{1/2} = \frac{1}{k[A]_0}$

Scratch Page
(to be handed in)