

LAST NAME: \_\_\_\_\_

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Student Number: \_\_\_\_\_

**CHM 1311 D**  
**Prof. Goto**  
**Midterm #2**  
**Fall 2018**

*Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.*

**There are 7 pages in this test, for a total of 35 marks. An equation sheet is provided at the end that may be removed from the exam and used to cover your work during the test. Any scratch work should be done on the back of the equation sheet.**

**Please show all work to receive partial credit.**

**Make sure that units are included in your final answer.**

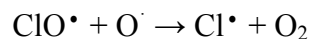
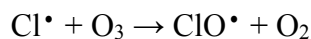
**You have 90 minutes to complete the test.**

**Warning:**

Cellular phones, unauthorized electronic devices or course notes are not allowed during this exam. Phones and devices must be turned off and stored in your bag. Do not keep them in your possession, such as in your pockets. If caught with such a device or document, academic fraud allegations will be filed which may result in your obtaining a **0** (zero) for the midterm.

**Question 1.** Short answer questions (7 marks)

a) What is the catalyst in the 2-step reaction mechanism given below?



b) Suppose that for the elementary reaction  $\text{A} + \text{B} \rightarrow \text{P}$ , a product is formed every time that  $\text{A} + \text{B}$  collide. What is the activation energy of this reaction?

c) Suppose that under a given set of conditions the reaction proceeds towards the reactants. Is  $Q$  greater than or less than  $K$  for this reaction?

d) What is the conjugate base that will be produced by the reaction of  $\text{HPO}_4^-$  with  $\text{NH}_3$ ?

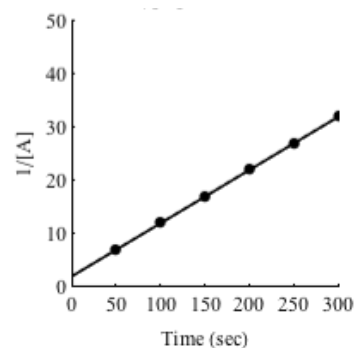
e) What is the rate of the second order reaction:



if the rate constant for the reaction is  $1.1 \times 10^{-3} \text{ M}^{-1} \text{ s}^{-1}$  and the concentration of the reactant is 0.020 M.

f) For a one step reaction, the activation energy for the forward reaction is  $55.0 \text{ kJ mol}^{-1}$ , and the enthalpy of reaction is  $15.0 \text{ kJ mol}^{-1}$ . What is the activation energy for the reverse reaction?

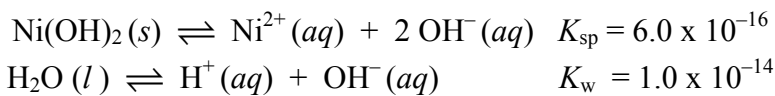
g) What is the order of the reaction plotted on the right?



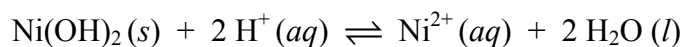
**Question 2.** Short questions (2 marks each)

a) If a solution of  $\text{HONH}_3\text{NO}_3$  is dissolved in water, will the solution be acidic, basic or neutral? Write the balanced chemical equation that explains your answer.

b) Given that:



Calculate the equilibrium constant for:



c) What is the pH of water at 50 °C, given that  $K_{\text{w}}$  at this temperature is  $5.48 \times 10^{-14}$ ?

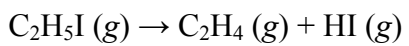
d) Write the reaction between hydroxylamine ( $\text{HONH}_2$ ,  $\text{p}K_{\text{b}} = 8.06$ ) and hydrocyanic acid ( $\text{HCN}$ ,  $\text{p}K_{\text{a}} = 9.21$ ). Will the equilibrium favor the reactants or products? Briefly justify your answer.

**Question 3** (7 marks)

What will be the pH of a 0.651 M solution of  $(\text{C}_2\text{H}_5)_3\text{NHCl}$ , given that the  $\text{p}K_b$  of triethylamine is 3.25? Show your justification for any assumption(s) that were made to solve this problem.

**Question 4.**

For the first order reaction,



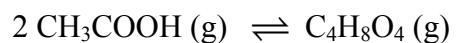
The half-life was found to be 29.0 min at 660 K and rate constant was found to be  $0.158 \text{ s}^{-1}$  at 775 K.

a) Calculate the activation energy (in kJ/mol) for this reaction. (5 marks)

b) How long will it take for 95% of 0.250 M  $\text{C}_2\text{H}_5\text{I}$  to react at 660 K? (2 marks)

**Question 5.**

2 molecules of acetic acid in the gas phase can hydrogen bond to form a dimer in the reaction:



a) What is  $K_{eq}$  at 100.0°C if  $1.000 \times 10^{-3}$  mol of acetic acid gas is introduced to an empty 100.0 mL reaction flask, and the total pressure of gas in the flask at equilibrium at 100.0°C is 0.229 bar? (4 marks)

b) Given that energy is required to break hydrogen bonds, will the equilibrium constant go up or go down if the temperature is raised? Justify your answer with one sentence. (1 mark)

c) What will happen to the yield of the reaction if it is run in a smaller reaction vessel? Justify your answer with one sentence. (1 mark)

## Selected Constants and Conversion Factors

$$1 \text{ mmHg} = 1 \text{ torr} \quad 760 \text{ mmHg} = 1 \text{ atm} \quad 1 \text{ atm} = 101.325 \text{ kPa} \quad 1 \text{ atm} = 1.013125 \text{ bar}$$

$$1 \text{ bar} = 10^5 \text{ Pa} \quad 1 \text{ cm}^3 = 1 \text{ mL} \quad 1 \text{ dm}^3 = 1000 \text{ mL} = 1 \text{ L} \quad 1 \text{ m}^3 = 1000 \text{ L} \quad 1 \text{ cal} = 4.184 \text{ J}$$

Avogadro's Number	$N_A$	$6.022 \times 10^{23} \text{ mol}^{-1}$
Gas constant	$R$	$8.31451 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	$R$	$0.08206 \text{ atm} \cdot \text{L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	$R$	$8.31451 \text{ L} \cdot \text{kPa} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$
	$R$	$0.0831451 \text{ bar} \cdot \text{L} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$

## Equations Covered Since Midterm 1

$$\text{Rate} = \frac{1}{\nu_X} \frac{\Delta[X]}{\Delta t} \quad \text{Rate} = k[A]^y[B]^z \dots \quad \frac{\text{Initial Rate 1}}{\text{Initial Rate 2}} = \frac{k[A]_1^y[B]_2^z \dots}{k[A]_2^y[B]_2^z \dots} \quad k = Ae^{-\frac{E_a}{RT}}$$

$$[A]_t = [A]_o - akt \quad \ln \frac{[A]_o}{[A]_t} = akt \quad \frac{1}{[A]_t} - \frac{1}{[A]_o} = 2kt \quad \ln \left( \frac{k_2}{k_1} \right) = -\frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$$

$$t_{\frac{1}{2}} = \frac{[A]_o}{2ak} \quad t_{\frac{1}{2}} = \frac{\ln 2}{ak} \quad t_{\frac{1}{2}} = \frac{1}{2k[A]_o} \quad K_{eq} = \frac{[C]_{eq}^c [D]_{eq}^d}{[A]_{eq}^a [B]_{eq}^b} \quad K_{eq} = \frac{p_{C,eq}^c p_{D,eq}^d}{p_{A,eq}^a p_{B,eq}^b}$$

$$Q = \frac{p_C^c p_D^d}{p_A^a p_B^b} \quad Q = \frac{[C]^c [D]^d}{[A]^a [B]^b} \quad K_{eq} = K_1 \times K_2 \times K_3 \times \dots \quad K_{eq,reverse} = \frac{1}{K_{eq,forward}} \quad K_{eq,new} = (K_{eq,old})^n$$

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \quad \text{pOH} = -\log[\text{OH}^-] \quad \text{pH} + \text{pOH} = 14 \quad K_a \times K_b = K_w = 10^{-14} = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$pK_b = -\log K_b \quad pK_a = -\log K_a \quad ax^2 + bx + c = 0 \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\% \text{ error} = 100\% \times \frac{\text{difference from assumed value}}{\text{actual value}} \quad \% \text{ HA hydrolyzed} = 100\% \times \frac{[\text{H}_3\text{O}^+]_{eq}}{[\text{HA}]_{initial}}$$

## Midterm 1 Equations

$$T(\text{in K}) = T(\text{in } ^\circ\text{C}) + 273.15 \text{ K} \quad n = \frac{m}{M} = \frac{N}{N_A} \quad \% \text{ Yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% \quad c(\text{mol/L}) = \frac{n}{V}$$

$$c_1 V_1 = c_2 V_2 = n \quad p = \frac{mg}{A} \quad p = dgh \quad pV = nRT \quad \frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \quad p_T = p_1 + p_2 + p_3 + \dots$$

$$p_A = X_A \times p_T \quad X_A = \frac{n_A}{n_T} \quad d = \frac{m}{V} = \frac{p \cdot M}{RT} \quad E_K = \frac{1}{2} mv^2 \quad \bar{E} = \frac{3RT}{2N_A} \quad \bar{v} = \sqrt{\frac{3RT}{M}}$$

$$\frac{\text{Rate A}}{\text{Rate B}} = \sqrt{\frac{M_B}{M_A}} \quad p = \frac{nRT}{(V - nb)} - a \frac{n^2}{V^2} \quad \Delta E = w + q \quad w = F \times d = -p\Delta V$$

$$q_{\text{calorimeter}} = C_{cal} \Delta T \quad q = mC\Delta T \quad \Delta E_{\text{reaction}} = \sum BE_{\text{reactant bonds broken}} - \sum BE_{\text{product bonds formed}} \quad \Delta E_{\text{molar}} = \frac{\Delta E}{n}$$

$$\Delta H_{\text{reaction}}^{\circ} = \sum \nu_p \Delta H_{f,p}^{\circ} - \sum \nu_r \Delta H_{f,r}^{\circ} \quad \Delta H_{\text{reaction}} = \Delta E_{\text{reaction}} + RT\Delta n_{\text{gas}} \quad H = E + pV$$