

YORK UNIVERSITY

SC/CHEM 1001M

Quiz #1 February 2, 2012

NAME: _____

STUDENT NO.: _____

50 min

30 marks

Use blue pen. The final answers should be in ink

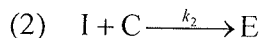
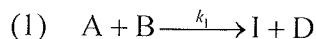
Marks	No	Problem
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- (1) 1 Reaction $A + 2B \longrightarrow C$ has an experimentally determined rate law of $k[A][B]$. Is this reaction an elementary process? Justify your answer in 1 sentence.

NO.

The stoichiometry coefficient for B is equal to 2 and is different from the reaction order for B which is equal to 1.

- 2 Reaction $A + B + C \longrightarrow D + E$ is hypothesized to proceed through the following mechanism:



- (4) a) What rate of reaction does this mechanism suggest for the steady state?

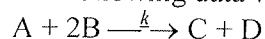
$$\text{Rate} = k_1 [A][B]$$

- (1) b) The rate of elementary process (2) at time t_1 in the steady state is equal to R_1 . What is the rate of the overall reaction at the same time? Justify your answer in a single sentence.

$$\text{Rate of overall reaction} = R_1$$

The rate of overall reaction is equal to those of the elementary steps in the steady state.

- 3 The following data were obtained for the following reaction



in three consecutive experiments

Experiment No	Initial [A], M	Initial [B], M	Initial Reaction Rate, M/s
1	2.0×10^{-4}	1.0×10^{-4}	3.0×10^{-5}
2	2.0×10^{-4}	2.0×10^{-4}	6.0×10^{-5}
3	0.5×10^{-4}	2.0×10^{-4}	1.5×10^{-5}

- (2) a) By doing simple analysis of the data in the table determine the reaction order with respect to reactant A. Explain your reasoning in no more than 2 sentences.

$$\text{order} = 1$$

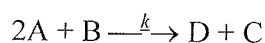
- (2) b) By doing simple analysis of the data in the table determine the reaction order with respect to reactant B. Explain your reasoning in no more than 2 sentences.

$$\text{order} = 1$$

- (2) c) What is the value of k ? Do not forget to provide the units.

$$1.5 \times 10^3 \text{ M}^{-1} \text{ s}^{-1}$$

- 4 In a reaction



the concentration of A (expressed in M) depends on time (expressed in seconds) as:

$$[A] = 1.5 \times 10^{-3} - 4.4 \times 10^{-5} t$$

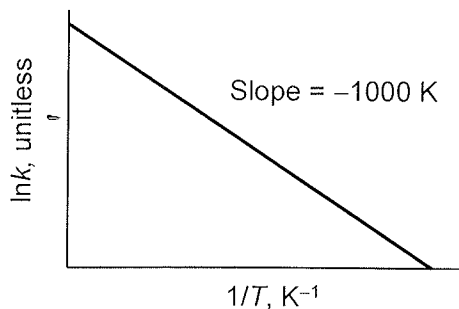
- (1) a) What is the order of this reaction with respect to [A]? Justify your answer in a single sentence.

Zero

- (2) b) What is the value of rate constant, k , of this reaction? Do not forget to indicate the units.

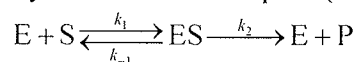
$$2.2 \times 10^{-5} \text{ M s}^{-1}$$

- (4) 5 The slope of straight line in a graph $\ln k$ versus $1/T$ is equal to -1000 K . What is the activation energy, E_a , of the reaction described by this graph (do not forget to indicate the units)? Assume that $R = 8.31 \text{ J/(mol K)}$.



$$8.31 \text{ kJ/mol}$$

- (4) 6 Enzyme E catalyzes the conversion of substrate S into product P. The reaction mechanism involves the formation of the enzyme-substrate complex (ES):



Use the rate law for this reaction to briefly explain how this reaction can be of the first and zero orders with respect to S.

$$\text{Rate} = k_2 [\text{E}]_0 [\text{S}] / (k_m + [\text{S}])$$

1) when $k_m \ll [\text{S}]$,

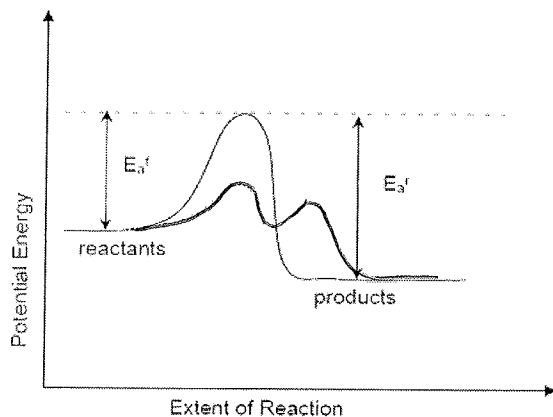
$$\text{Rate} \approx k_2 \frac{[\text{E}]_0 [\text{S}]}{[\text{S}]} = k_2 [\text{E}]_0, \text{ zero order wrt S}$$

2) when $k_m \gg [\text{S}]$,

$$\text{Rate} = k_2 \frac{[\text{E}]_0 [\text{S}]}{k_m}, \text{ rate} = k' [\text{S}]^1,$$

\therefore reaction 1st order wrt S

(2) 7 The graph below shows the reaction energy profile in the absence of a catalyst.

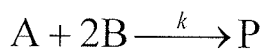


Unique features:

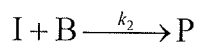
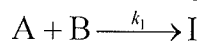
- 1) E_a decreases
- 2) ΔH unchanged
- 3) More than 1 transition states appear.

Draw schematically the energy profile of the same reaction in the presence of a catalyst. Make sure to depict two unique features of the new profile.

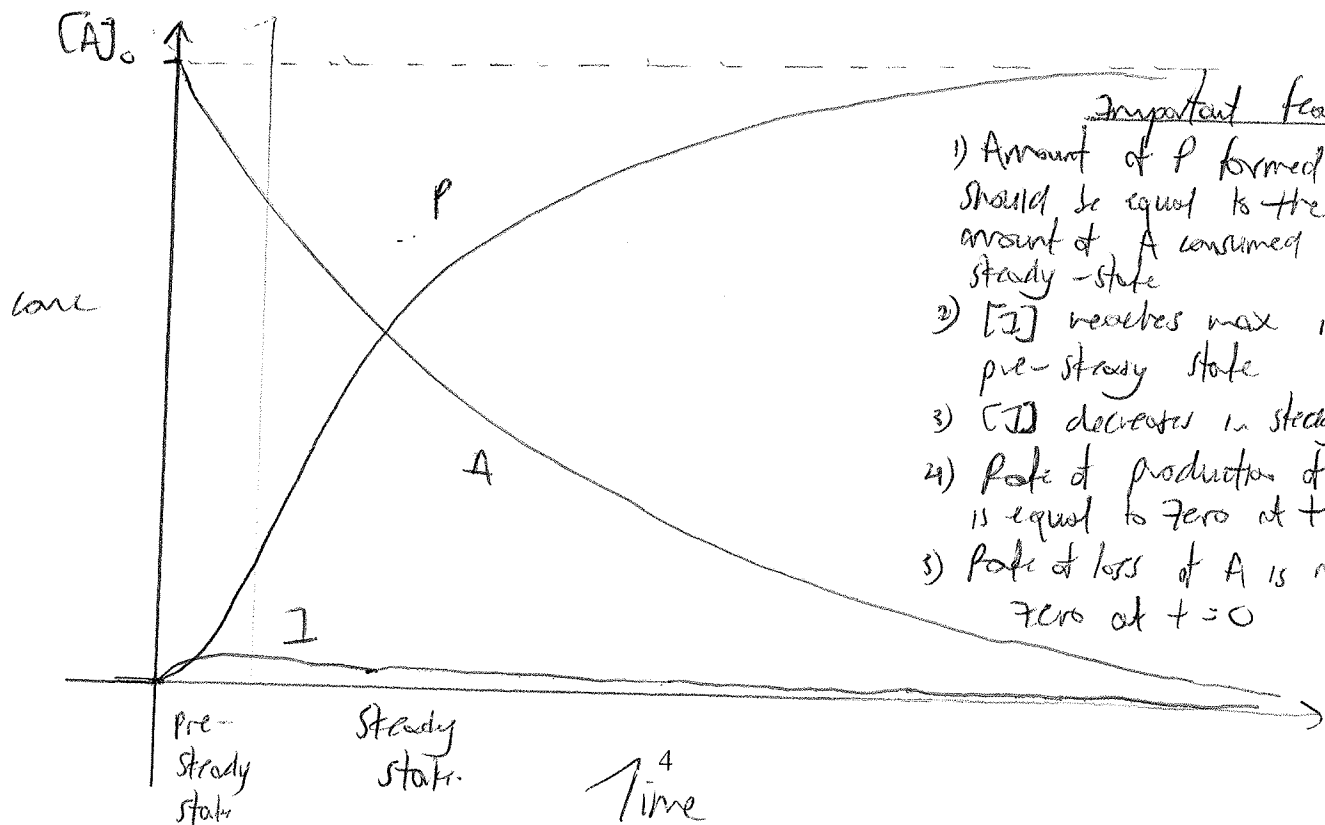
(4) 8 Reaction



proceeds through the following mechanism:



Draw **schematically** time-dependencies of $[A]$, $[I]$, and $[P]$ in the **pre-steady state** and **steady state** periods. Make sure to show all essential features of these dependencies. Use the whole width of the page for the **time** axis. Use the whole vertical space provided for the **concentration** axis.



Important features

- 1) Amount of P formed should be equal to the amount of A consumed in steady-state
- 2) $[I]$ reaches max in pre-steady state
- 3) $[I]$ decreases in steady state
- 4) Rate of production of P is equal to zero at $t=0$
- 5) Rate of loss of A is not zero at $t=0$

- (1) 9 The half life time for the first order reaction is:

$$t_{1/2} = \frac{\ln 2}{ak}$$

What is the precision (number of significant digits) of "2" in this expression? Justify your answer in no more than 3 sentences.

Infinite number of significant digits

"2" appears from definition of half-life, which is an integer and therefore has ultimate precision or infinite number of significant digits

In 2 thus also has infinite number of significant digits.

THE USE OF ANY REFERENCE MATERIAL OR ELECTRONIC GADGET IS PROHIBITED**Use blue pen. The final answers must be in ink. Write "No answer" if you do not know the answer.**

Marks	No	Problem
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- (4) 1. A liquid phase reaction $A + B \rightleftharpoons C$ reached equilibrium in volume V_1 (the equilibrium constant is known and equal to K_c). This equilibrium mixture is diluted with the same solvent to a total volume of V_2 .

What will be the reaction quotient Q_c immediately after the dilution, before the reaction started shifting to the new equilibrium? Derive an expression for Q_c as a function of K_c , V_1 , and V_2 .

$$Q_c = K_c \frac{V_2}{V_1}$$

- (6) 2. A weak base B is dissolved in water at a known concentration C_B . The base ionization constant is known and equal to K_b . The ion product of water is known and equal to K_w ($K_w = [H_3O^+][OH^-]$).

What is pH of this solution? Derive an expression for pH as a function of K_w , C_B , and K_b . Do not make any assumption about the degree of ionization. To simplify your solution, do not consider the contribution of water self-ionization.

$$pH = pK_w + \log \frac{-K_b + \sqrt{K_b^2 + 4K_b C_B}}{2}$$

3. Reaction $A(g) + B(g) \rightleftharpoons C(g)$, $\Delta H < 0$

is at equilibrium. Will the equilibrium shift and which way will it shift if one of the following actions is taken? Explain each of your answers using the Le Chatelier's Principle in no more than 4 sentences.

- (3) a) The reaction mixture is cooled down with pressure kept constant

Shifts to the right

- (3) b) A spectator gas is added when the volume and the temperature are kept constant

Does not shift

- (3) c) A spectator gas is added under a constant pressure and a constant temperature

Shifts to the left

- (4) 4. Equimolar amounts of aqueous solutions of NaOH and HF are mixed and allowed to react and reach equilibrium.

Will pH of the resulting solution be acidic, neutral, or basic? Justify your answer by showing relevant reactions and explaining how they affect pH.

basic

- (7) 5. A buffer is prepared by titrating an aqueous solution of sodium hydroxide of a concentration $C_{\text{NaOH}} = 10.0 \text{ M}$ into an aqueous solution of acetic acid of a concentration $C_{\text{HA}} = 0.100 \text{ M}$ ($\text{p}K_{\text{a}} = 4.77$). The initial volume of the acid solution is $V = 1.00 \text{ L}$. Calculate the volume of NaOH, V_{NaOH} that is needed to make a buffer with $\text{pH} 5.77$. If your final answer is expressed in letters, no number substitution is required.

0.009 L

THE USE OF ANY REFERENCE MATERIAL OR ELECTRONIC GADGET IS PROHIBITED**Use blue pen. The final answers must be in ink. Write "No answer" if you do not know the answer.**

Marks	No	Problem
(6)	1.	<p>MgF₂ is a poorly soluble salt with $K_{sp} = 4 \times 10^{-8}$. What is its solubility (S) in a buffered solution with $\text{pH} = 1$ if K_a of HF is equal to 10^{-3}?</p> <p>You can solve either for a number (complete all calculations) or for a formula (express S as a function of K_{sp}, K_a, and pH).</p>

$$S = 5 \times 10^{-2} \text{ M}$$

or

$$S = \sqrt[3]{\frac{10^{-2 \text{ pH}} K_{sp}}{4K_a^2}}$$

- (2) 2. Define the 2nd Law of Thermodynamics for spontaneous and reversible processes

$$\text{spontaneous: } \Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{sur}} > 0$$
$$\text{reversible: } \Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{sur}} = 0$$

-
- (1) 3. Define the 1st Law of Thermodynamics for change of enthalpy:

$$\Delta H_{\text{sys}} = -\Delta H_{\text{sur}}$$

-
- (1) 4. Relate standard molar entropies for the same amount of the same substance in different phases by properly placing the < or > signs:

$$S^{\circ}(\text{s}) < S^{\circ}(\text{l}) < S^{\circ}(\text{g})$$

-
- (4) 5. Characterize the following processes by a single word as spontaneous, non-spontaneous, or reversible:

- Gas condensation at melting temperature: *spontaneous*
- Liquid freezing at melting temperature: *reversible*
- Solid melting at melting temperature: *reversible*
- Solid melting at boiling temperature: *spontaneous*

-
6. Reaction $2\text{N}_2\text{O}(\text{g}) \rightleftharpoons 2\text{N}_2(\text{g}) + \text{O}_2(\text{g})$ is characterized by $\Delta H^{\circ} \approx -150 \text{ kJ/mol}$ and $\Delta S^{\circ} \approx 0.150 \text{ kJ/(mol K)}$ at $T \approx 300 \text{ K}$. Answer the following 2 questions (do calculations if required).

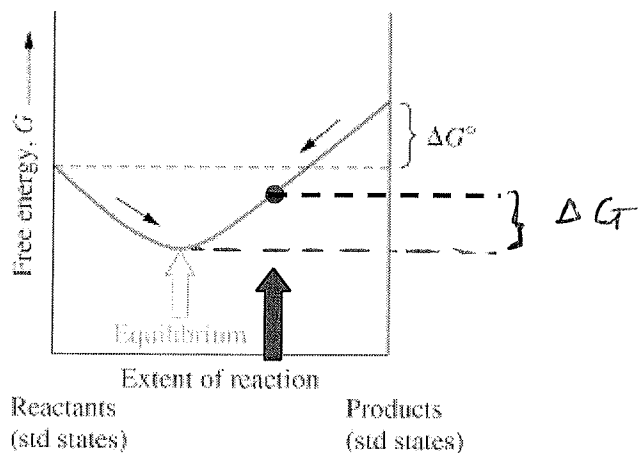
- (2) a) Is this reaction spontaneous at 300 K under standard conditions?

Yes

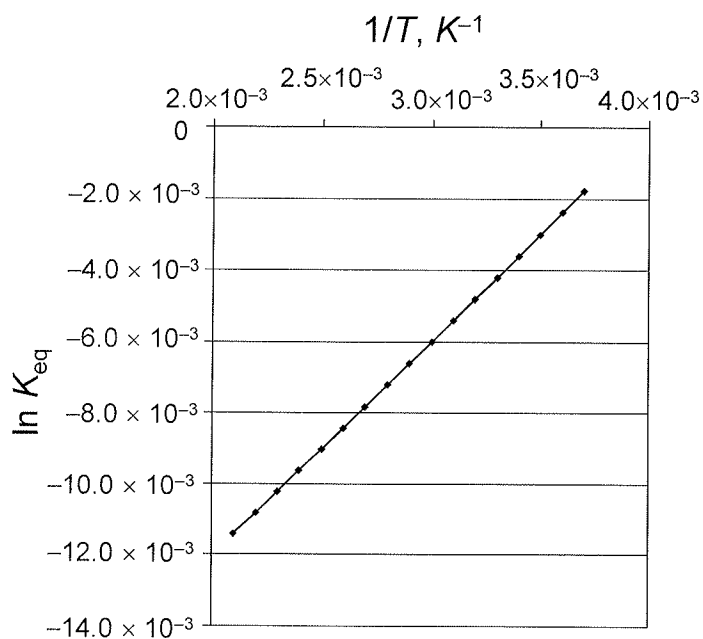
- (2) b) Is this reaction spontaneous at 300 K under non-standard conditions characterized by $Q = (P_{\text{N}_2}^2 P_{\text{O}_2}) / P_{\text{N}_2\text{O}}^2 \approx 2.73$?

Reaction is non-spontaneous

- (2) 7. A figure below illustrates a graphical definition of ΔG° . Define in a similar way ΔG for conditions illustrated by the solid arrow



- (6) 8. A graph below relates the thermodynamic equilibrium constant of a reaction with temperature. Do rough estimates of values of ΔH° and ΔS° from the graph.



$$\Delta H^\circ = -50 \text{ J/mol}$$

$$\Delta S^\circ = 0.2 \text{ J/mol K}$$

- (4) 9. Cu(s) dissolves in HNO₃ producing Cu²⁺ and NO₂(g). Write a balanced equation for this redox process.



Last Name _____

Student Number _____

First Name _____

Quiz 1 – 2 February 2012

Chemical Dynamics
Chem 1001N
Department of Chemistry
York University

Notes: All final answers must be in ink. All questions are to be answered.
Calculators are allowed.

Time allowed: 50 minutes; Total marks: 30

$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}.$$

$$t_{1/2} = \frac{\ln 2}{k}, [A] = [A]_0 - akt, [A] = [A]_0 e^{-akt}, PV = nRT, \ln\left(\frac{P_{A,0}}{P_A}\right) = akt$$

$$\frac{1}{[A]_t} = akt + \frac{1}{[A]_0}, k = Ae^{-\frac{E_a}{RT}}, \ln \frac{k_2}{k_1} = -\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

Marks

[5] 1

a. If the half-life of a reaction depends on the concentration of the reactant, can the reaction be first order? (answer yes or no)

Answer: NO

b. What is the overall order of reaction for the following: $\text{Rate} = k[A]^{-1/2} [B]^{1/2}$?

Answer: 0

c. Does a catalyst in a reaction increase the activation energy? (answer yes or no)

Answer: NO

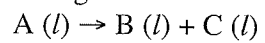
d. For the reaction $A \rightarrow \text{products}$, if a plot of $[A]$ vs. time is a straight line what is the order of the reaction?

Answer: 0

d. Are all enzymes proteins? (answer yes or no)

Answer: YES

[3] 2. The activation energy of the following reaction:



is 30 kJ/mol. Determine the factor by which the rate constant changes when the temperature increases from 0°C to 25°C?

3

[6] 3. Data for the reaction $G(l) + H(l) \rightarrow J(l)$ are given below.

Experiment	[G] (M)	[H] (M)	Initial rate (M/s)
1	0.030	0.060	2.5×10^{-5}
2	0.030	0.020	2.5×10^{-5}
3	0.060	0.060	10.0×10^{-5}

a. What is the rate of reaction?

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

b. What is the value of k ?

$$0.028 \text{ M}^{-1} \text{ s}^{-1}$$

[8] 4. For the second order reaction $A \rightarrow \text{products}$, the following data are obtained:

$$[A] = 1.512 \text{ M}, t = 0 \text{ min}$$

$$[A] = 1.490 \text{ M}, t = 1.0 \text{ min}$$

$$[A] = 1.469 \text{ M}, t = 2.0 \text{ min}$$

a. What is the average reaction rate over the first 2 min?

$$0.0215 \text{ M/min}$$

b. What is the rate constant, k , for this reaction?

$$9.68 \times 10^{-3} \text{ M}^{-1} \text{ min}^{-1}$$

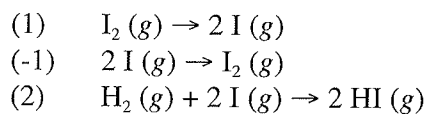
c. What is the instantaneous reaction rate at 2 min?

$$0.0209 \text{ M min}^{-1}$$

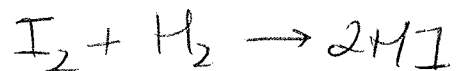
d. How long will it take for the concentration of A to drop by half the initial concentration?

$$68.3 \text{ min}$$

[8] 5. Hydrogen iodide is thought to form via the following mechanism:



a. What is the overall reaction corresponding to this mechanism?



b. If you assume that reactions (1) and (-1) are in rapid equilibrium and reaction 2 is rate determining, what is the rate equation corresponding to this mechanism?

$$\text{rate} = \frac{k_1}{k_{-1}} [\text{I}_2] [\text{H}_2]$$

c. What is a potential problem with this mechanism?

step 2 is trimolecular

Last Name _____

Student Number _____

First Name _____

Quiz 2 – 1 March 2012

Chemical Dynamics
Chem 1001N
Department of Chemistry
York University

Notes: All final answers must be in ink. All questions are to be answered.
Calculators are allowed.

Time allowed: 50 minutes; Total marks: 30

$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} = 0.08315 \text{ L bar mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}.$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}, \quad PV = nRT, \quad K_p = K_c (RT)^{\Delta n_{\text{gas}}}, \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Marks

[5] 1 N_2O_3 (g) decomposes to NO (g) and NO_2 (g) with a $\Delta H^\circ = 40.5 \text{ kJ mol}^{-1}$ according to the equilibrium:



What effect will the following changes have on the position of the equilibrium? Circle the correct answer

(a) more N_2O_3 (g) is added, volume stays fixed:

shift left

shift right

stay the same

(b) more NO_2 (g) is added, volume stays fixed:

shift left

shift right

stay the same

(c) the volume of the reaction flask is increased:

shift left

shift right

stay the same

(d) the temperature is lowered:

shift left

shift right

stay the same

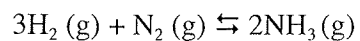
(e) add He (g) while keeping the volume fixed:

shift left

shift right

stay the same

[2] 2 Consider the following reaction:



For this reaction the value of K_p is 6.5×10^{-3} at 723 K. For the following mixture indicate if the system is at equilibrium, and if it is not, indicate the direction in which the reaction will proceed to achieve equilibrium.

Pressure of $\text{NH}_3 = 60$ atm, pressure of $\text{H}_2 = 150$ atm, pressure of $\text{N}_2 = 80$ atm

Rxn goes to right

[5] 3 Calculate the pH and concentration of the benzoate ion in a 50 mM solution of benzoic acid ($K_a = 6.3 \times 10^{-5}$).

$$\text{pH} = 2.7$$

$$\text{concentration} = 1.8 \times 10^{-3} \text{ M}$$

[9] 4 For the reaction $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$, K_p is 1.8 at 523 K.

a) What is the value of K_c for this reaction?

$$K_c = 0.041$$

b) If 0.10 moles of PCl_3 and 0.10 moles of Cl_2 were introduced into a 1.0 L flask, how many moles of PCl_5 would be produced?

$$0.053 \text{ moles of } \text{PCl}_5$$

- c) Calculate the concentrations of PCl_3 , Cl_2 and PCl_5 present at equilibrium if 0.10 moles of PCl_3 , 0.10 moles of Cl_2 and 0.10 moles of PCl_5 were introduced into a 1.0 L flask.

$$[\text{PCl}_3] = [\text{Cl}_2] = 0.073 \text{ M}$$

$$[\text{PCl}_5] = 0.127 \text{ M}$$

- [5] 5 The pK_a of formic acid is 3.74. A buffer is made by mixing 1.10 L of 10.0 mM formic acid with 100 mL of 20.0 mM NaOH. What is the pH of this buffer?

$$\text{pH} = 3.09$$

[4] 6 The pK_b value of ammonia is 4.74. The pH value of the buffer made of ammonia and ammonium chloride is equal to 9.26.

a) Calculate the ratio of conjugate base to conjugate acid for this buffer.

1

b) Is this solution a good buffer? Briefly explain your answer.

Yes

Last Name _____

Student Number _____

First Name _____

Quiz 3 – 22 March 2012

Chemical Dynamics
Chem 1001N
Department of Chemistry
York University

Notes: All final answers must be in ink. All questions are to be answered.
Calculators are allowed.

Time allowed: 50 minutes; Total marks: 30

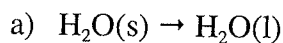
$$R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} = 0.08315 \text{ L bar mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} \quad k = 1.38 \cdot 10^{-23} \text{ J K}^{-1} \quad N_a = 6.022 \cdot 10^{23}$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}, \quad \Delta G = \Delta H - T\Delta S, \quad S = k \ln W, \quad \Delta S = \frac{q_{\text{rev}}}{T}, \quad x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\Delta G = \Delta G^\circ + RT \ln Q_{\text{eq}}, \quad \ln K_{\text{eq}} = -\frac{\Delta H^\circ}{R} \frac{1}{T} + \frac{\Delta S^\circ}{R}, \quad \Delta G^\circ = -RT \ln K_{\text{eq}}, \quad \text{pH} = \text{pK}_a + \log \frac{[\text{A}^-]}{[\text{HA}]}$$

Marks

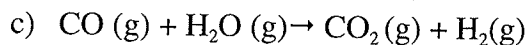
[4] 1. For each reaction indicate the whether sign of ΔS is positive, negative or not possible to determine from the information given. Briefly justify your answers (use less than 12 words).



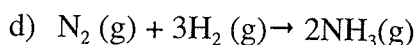
positive



positive



not possible to determine



negative

[6] 2 a. What is the solubility of AgCl if its solubility product is 1.8×10^{-10} ?

$$S = 1.3 \times 10^{-5} \text{ M}$$

b. Calculate the molar solubility of AgCl in 0.04 M NaCl.

$$S = 4.5 \times 10^{-9} \text{ M}$$

- [5] 3. Will AgCl precipitate after adding 10 mL of 1×10^{-6} M NaCl to 1 L of 0.1 M AgNO₃ (K_{sp} of AgCl = 1.8×10^{-10})? Support your answer with a calculation.

ppt will form

- [4] 4. For a given reaction if a plot of $\ln K_{eq}$ versus $1/T$ has a slope of 0 K what is the value of ΔH° ? If in the same plot the y intercept has a value of 4.0 is the reaction spontaneous? Briefly explain your answer.

$$\Delta H^\circ = \underline{0 \text{ kJ/mol}}$$

Spontaneous

- [4] 5. For the decomposition of calcium carbonate into calcium oxide and carbon dioxide the values of ΔH° and ΔS° for this reaction are 178 kJ and 161 J K⁻¹, respectively. Above which temperature is this reaction spontaneous?

$$\text{At } T > 1106 \text{ K}$$

- [7] 6 (a) Use the data below to determine ΔH° , ΔS° , ΔG° and K_{eq} for the following reaction at 25°C.



	ΔH_f° (kJ mol ⁻¹)	S° (J mol ⁻¹)
PCl ₅ (g)	-375.0	364.5
PCl ₃ (g)	-287.0	311.7
Cl ₂ (g)	0.000	223.0

$$\Delta H^\circ = \underline{88 \text{ kJ mol}^{-1}} \quad \Delta S^\circ = \underline{170.2 \text{ J mol}^{-1} \text{ K}^{-1}}$$
$$\Delta G^\circ = \underline{37.3 \text{ kJ/mol}} \quad K_{eq} = \underline{2.92 \times 10^{-7}}$$

- (b) For the reaction above (part a) is this reaction spontaneous under the conditions stated?

NO

- (c) Calculate the equilibrium constant (K_{eq}) for this reaction at 400° C. Briefly state the assumption(s) you are making when doing this.

$$K_{eq} = \underline{1.27 \times 10^{-3}}$$

Assumptions:

ΔG° independent of temperature.

Quiz No. 1 – January 31st

50 minutes

30 Marks

NOTE: ALL FINALS ANSWERS MUST BE WRITTEN IN INK

Calculators are permitted; sharing calculators is not permitted

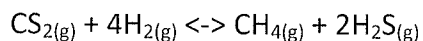
All cell phones must be turned off and out of reach. They cannot be used as clocks or calculators.

$$R = 8.314472 \text{ J K}^{-1} \text{ mol}^{-1} = 0.08205 \text{ L atm K mol}^{-1} ; 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa} = 760 \text{ torr (mmHg)}$$

$$\text{Avogadro's number } N_A = 6.022 \times 10^{23} \text{ molecules mol}^{-1} ; k = 1.38066 \times 10^{-23} \text{ J K}^{-1}$$

$$0^\circ\text{C} = 273 \text{ K} ; \ln k = \ln A - (E_a/RT) ; [A]_t = [A]_0 - akt ; \ln[A]_t = \ln[A]_0 - akt ; 1/[A]_t = 1/[A]_0 + akt$$

1. Predict the effect each of the following changes will have on the position of the equilibrium (shifts to the left, shifts to the right, or stays the same) for the reaction:



[1] a) Remove half of H_2S .

left right same

[1] b) Double the volume of the reactor.

left right same

[1] c) Add 10 bar of $\text{He}(g)$ at constant temperature and pressure

left right same

2. The first-order decomposition of hydrogen peroxide, $\text{H}_2\text{O}_2 \rightarrow \text{products}$, has a rate constant equal to $2.25 \times 10^{-6} \text{ s}^{-1}$ at a certain temperature. In a given solution $[\text{H}_2\text{O}_2] = 0.800 \text{ M}$.

[2] a) Write the differential and integrated rate laws for this reaction.

$$-\frac{d[\text{H}_2\text{O}_2]}{dt} = k[\text{H}_2\text{O}_2]$$

$$\ln [\text{H}_2\text{O}_2] = \ln [\text{H}_2\text{O}_2]_0 - kt$$

[3] a) What will the H_2O_2 concentration be after 01 day?

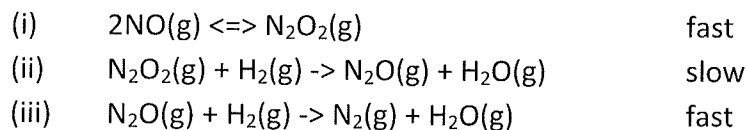
$$0.659 \text{ M}$$

[3] b) How long will it take the H_2O_2 concentration to decrease to 0.750M?

$$28,684 \text{ s}$$

3. Nitrogen monoxide, NO, reacts with hydrogen, H₂, to produce nitrogen, N₂, and water, H₂O,
$$2\text{NO}(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{N}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$$

The rate law was experimentally determined as $\text{Rate} = k[\text{NO}]^2[\text{H}_2]$ and the following mechanism of reaction proposed:



[1] a) Identify the intermediate(s). N_2O_2 and N_2O

[5] b) Is this mechanism plausible? Explain.

Step (ii) is rate-determining

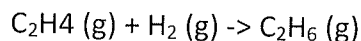
$$R = k_2 [\text{N}_2\text{O}_2] [\text{H}_2]$$

using SSA,

$$\text{Rate} = \frac{k_2 k_1 [\text{NO}]^2 [\text{H}_2]}{k_{-1}} = k [\text{NO}]^2 [\text{H}_2]$$

Yes, mechanism satisfies both the stoichiometry and rate law.

4. Consider the hydrogenation of ethylene, C_2H_4 , using the catalyst platinum oxide, PtO_2 , to produce ethane, C_2H_6 :



This is an example of heterogeneous catalysis which often involves gaseous reactants being adsorbed on the surface of a solid catalyst (i.e., PtO_2). The rate of hydrogenation of ethylene on the surface of the PtO_2 catalyst follows first-order kinetics for low concentrations of ethylene. However, as the concentration of ethylene is increased, the hydrogenation reaction becomes zero-order.

[2] a) Define "catalyst" in less than 20 words.

It is a substance that increases the rate of a chemical reaction without being consumed by the reaction.

[2] b) What is the difference between heterogeneous and homogeneous catalysis?

Homogeneous \rightarrow catalyst and reactants same phase

Heterogeneous \rightarrow catalyst and reactants in different phases.

[3] c) Explain why the hydrogenation reaction in the presence of the heterogeneous catalyst PtO_2 should be zero-order at high concentrations of ethylene.

low $[Ethylene] \rightarrow k$ depends on $[C]$, $\therefore 1^{st}$ order

high $[Ethylene] \rightarrow k$ does not depend on $[C]$, \therefore zero order

Reaction occurs at surface,

After saturation of surface,

additional ethylene will have no effect

\therefore , zero order reaction.

[6] 5. One mole of NOCl gas is added to a 4.0-liter container at 25°C. The NOCl undergoes slight decomposition to form NO and Cl₂ gases ($K = 2.00 \times 10^{-10}$). What are the concentration of all species at equilibrium at this temperature?

$$\begin{aligned}[\text{NOCl}] &= 0.25 \text{ M} \\[\text{NO}] &= 3.0 \times 10^{-4} \text{ M} \\[\text{Cl}_2] &= 1.5 \times 10^{-4} \text{ M}\end{aligned}$$

NOTE: ALL FINALS ANSWERS MUST BE WRITTEN IN INK

Calculators are permitted: sharing calculators is not permitted

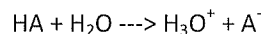
All cell phones must be turned off and out of reach. They cannot be used as clocks or calculators.

Table I - Acid/Base Ionization Constants at 25°C

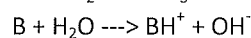
Acid	Formula	K _{a1}	K _{a2}
Acetic acid	CH ₃ CO ₂ H	1.8x10 ⁻⁵	
Ascorbic acid	H ₂ C ₆ H ₆ O ₆	7.9x10 ⁻⁵	1.6x10 ⁻¹²
Formic acid	HCO ₂ H	1.8x10 ⁻⁴	
Hydrocyanic acid	HCN	4.0x10 ⁻¹⁰	
Hydrofluoric acid	HF	7.2x10 ⁻⁴	
Hydrosulfuric acid	H ₂ S	1.0x10 ⁻⁷	1.0x10 ⁻¹⁹
Nitrous acid	HNO ₂	4.5x10 ⁻⁴	
Base	Formula	K _b	
Caffeine	C ₈ H ₁₀ N ₄ O ₂	4.1x10 ⁻⁴	
Codeine	C ₁₈ H ₂₁ O ₃ N	8.9x10 ⁻⁷	
Diethylamine	(C ₂ H ₅) ₂ NH	6.9x10 ⁻⁴	
Hydroxylamine	NH ₂ OH	9.1x10 ⁻⁹	

Table II – Solubility Product Constants at 25°C

Compound	Formula	K _{sp}
Nickel (II) hydroxide	Ni(OH) ₂	2.0x10 ⁻¹⁵
Calcium carbonate	CaCO ₃	2.8x10 ⁻⁹
Calcium sulfite	CaSO ₃	6.8x10 ⁻⁸
Silver bromide	AgBr	5.0x10 ⁻¹³
Silver chloride	AgCl	1.8x10 ⁻¹⁰
Tin (II) hydroxide	Sn(OH) ₂	1.4x10 ⁻²⁸



$$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$$



$$pOH = pK_b + \log\left(\frac{[BH^+]}{[B]}\right)$$

$$[H_3O^+].[OH^-] = 10^{-14} = K_w$$

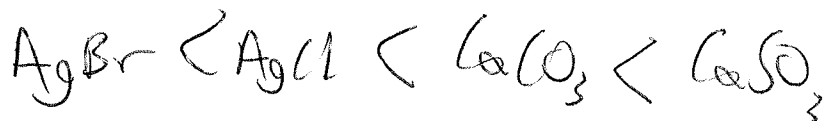
$$K_a \cdot K_b = K_w$$

1.

[2] a) Write the monoprotic acids listed in Table I in order of increasing strength.



[2] c) Write the salts listed in Table II in order of increasing solubility.



2. Calculate the pH (to two decimal places) of the following aqueous solutions:

[1] a) 1.50×10^{-2} M potassium hydroxide.

12.18

[1] b) 3.33×10^{-9} M hydrochloric acid.

7.00

[1] c) 1.00×10^{-1} M formic acid.

2.37

- [2] d) A solution with final concentrations of 2.50×10^{-2} M hydrobromic acid and 2.50×10^{-2} M hydrocyanic acid.

1.60

- [2] f) A solution with final concentrations of 5.00×10^{-1} M hydrofluoric acid and 4.50×10^{-1} M sodium fluoride.

3.10

- [2] e) A saturated solution of nickel (II) hydroxide.

9.20

[2] f) 25.0 mL of 0.1 M acetic acid + 12.5 mL 0.1M KOH (titration half-equivalence point).

4.74

[2] g) 25.0 mL of 0.1 M acetic acid + 25.0 mL of 0.1M KOH (titration equivalence point).

8.22

3.

[3] a) What is a buffer and what is it used for?

A buffer is a solution which contains a weak acid and its conjugate base or a weak base and its conjugate acid in approximately equal concentrations.

It is used to maintain the pH within narrow limits, avoiding drastic changes in the pH when H^+ or OH^- is added.

[1] b) For a given system buffered at a certain pH what determines the buffer capacity?

The amount of acid (or base) and its conjugate base (or acid) present in the system.
(Not the ratio!)

[3] c) For each base listed on Table I, calculate the ratio between the base and its conjugate acid, $[B]/[BH^+]$, required to yield a buffer of pH 8.75. Which base will work best? Explain.

CAF	0.014
COB	6.32
DEA	0.008
MOA	618

Codeine works best
as ratio is closest to 1.

4.

- [2] a) Calculate the solubility of silver chloride (in g/L) in a 6.5×10^{-3} M silver nitrate solution (AgCl molecular mass = 143.3g).

$$3.97 \times 10^{-6} \text{ g/L}$$

- [4] b) 0.80g of impure chalk was reacted with 100 mL of 1M hydrochloric acid (an excess) to produce calcium chloride. The mixture was filtered into a volumetric flask and made-up to 250mL. A 25.0mL portion of the solution required 8.5mL of 1M sodium hydroxide solution for neutralization. What is the percentage of calcium carbonate in the impure chalk? (CaCO_3 molecular mass = 100.1g).

$$93.8\%$$

YORK UNIVERSITY

NAME (in ink): _____

SC/CHEM 1001 3.0 Section P W2012

STUDENT NUMBER: _____

Quiz No. 3 – March 20th

50 minutes

30 Marks

NOTE: ALL FINALS ANSWERS MUST BE WRITTEN IN INK

Calculators are permitted: sharing calculators is not permitted. All cell phones must be turned off and out of reach. They cannot be used as clocks or calculators.

Equations

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

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

$$\Delta G^\circ = -RT \ln K_{eq}$$

$$\Delta G = -nFE_{cell}$$

$$\ln \left(\frac{K_2}{K_1} \right) = \frac{\Delta H^\circ}{R} \left(\frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln K_{eq} = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T} \right) + \frac{\Delta S^\circ}{R}$$

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln Q$$

$$E^\circ_{cell} = \frac{RT}{nF} \ln K_{eq}$$

Constants and Conversion Factors

$$0.00 \text{ }^\circ\text{C} = 273.15 \text{ K}$$

$$1.000 \text{ bar} = 1.000 \times 10^5 \text{ Pa} \approx 1.0 \text{ atm}$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

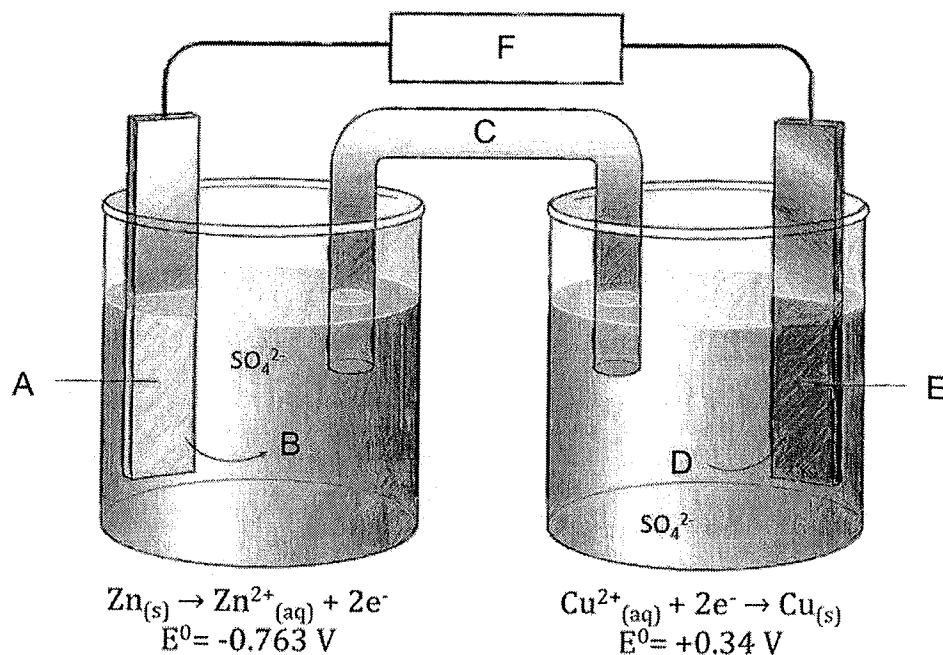
$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$K_w = 1.00 \times 10^{-14} \text{ at } 25^\circ \text{ C}$$

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

$$F = 96485 \text{ J V}^{-1} \text{ mol}^{-1} = 96485 \text{ C mol}^{-1}$$

[6] 1. Daniell cell is the name given to any galvanic cell that uses zinc and copper electrodes immersed in solutions of zinc sulfate and copper(II) sulfate, respectively.



Fill the gaps below using the letters (A-F) from the scheme above.

Electrode A is the Anode.

Oxidation takes place at A.

Reduction takes place at E.

C is a salt bridge.

B represents Zn^{2+} ions in solution.

Electrode E is the Cathode.

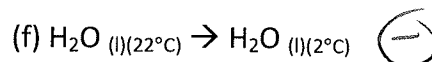
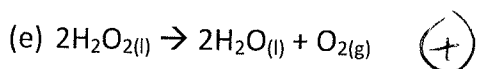
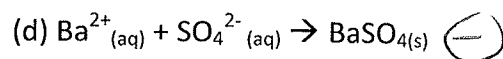
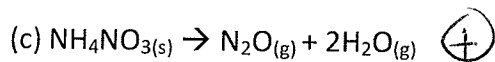
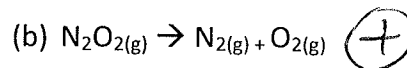
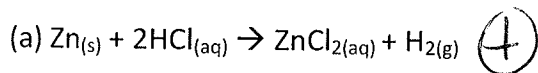
The cell potential (the potential difference between the two half-cells, E_{cell}) can be read on

F (the voltmeter).

The electrons flow from the electrode A to the electrode E.

The cell potential is 1.10 Volts (Numerical answer here).

[6] 2. Predict whether the entropy change is positive or negative (write a sign + or -) for each of the following physical or chemical processes (Assume constant temperature except for item f).



[3] 3. Water gas is a fuel made by exposing steam to red-hot coke (coke is the product of coal distillation; it contains carbon):

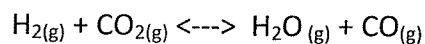
$$\text{H}_2\text{O}_{(g)} + \text{C}_{(s)} \rightarrow \text{CO}_{(g)} + \text{H}_{2(g)}$$

	H ₂ O	C	CO	H ₂
ΔH° (kJ/mol)	-241.8	0	-110.5	0
ΔS° (J/K)	188.7	5.69	197.9	131.0

Calculate the temperature (in Celsius) at which the reaction becomes favorable (or spontaneous). Assume that both ΔH° and ΔS° are independent of the temperature.

703°C

4. The equilibrium constant (K_p) for the reaction below is 4.40 at 2000K.



[3] a) Calculate ΔG° for the reaction.

$$-24.64 \text{ kJ}$$

[3] b) Calculate ΔG for the reaction when the partial pressures are $P_{\text{H}_2} = 0.25 \text{ atm}$, $P_{\text{CO}_2} = 0.78 \text{ atm}$, $P_{\text{H}_2\text{O}} = 0.66 \text{ atm}$, and $P_{\text{CO}} = 1.20 \text{ atm}$.

$$-1.33 \text{ kJ}$$

[3] c) Explain in a few lines or in a table the relationship between ΔG° , $\ln K_p$, K_p and the proportions between reactants and products at equilibrium. Consider $\Delta G^\circ > 0$, $\Delta G^\circ = 0$, $\Delta G^\circ < 0$, $\ln K_p > 0$, $\ln K_p < 0$, etc...

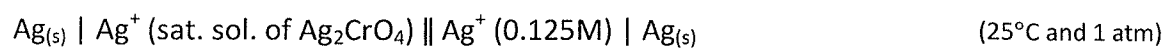
$$\Delta G^\circ = -RT \ln k_p$$

$$\Delta G^\circ < 0 \rightarrow \ln k_p > 0 \rightarrow k_p > 1$$

$$\Delta G^\circ = 0 \rightarrow \ln k_p = 0 \rightarrow k_p = 1$$

$$\Delta G^\circ > 0 \rightarrow \ln k_p < 0 \rightarrow k_p < 1$$

5. A voltaic cell is constructed as follows:



[3] a) Calculate $[\text{Ag}^+]$ in the saturated solution. $K_{\text{sp}} \text{Ag}_2\text{CrO}_4 = 1.1 \times 10^{-12}$

$$13.0 \times 10^{-5}$$

[3] b) What is the E_{cell} for this voltaic cell?

$$+0.176 \text{ V}$$

York University
Department of Chemistry
Final Examination
Chem 1001 Chemical Dynamics
Winter 2012
9 April 2012, 9:00 to 11:00 am

Last Name _____

Student Number _____

First Name _____

Instructors: D. Ifa, P. Johnson, & S. Krylov

Notes: This exam consists of 11 pages, including this one. There is a table of useful equations and constants and a periodic table that is provided following the last page of this examination. You may detach the additional pages.

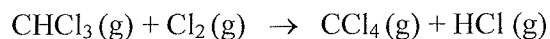
You have two hours to complete this exam. There are a total of 100 marks. All questions are to be answered. Answer all questions in the space provided. Additional paper for rough work is not permitted.

Calculators are allowed, but may not be shared. All other electronic devices (such as cell phones) are not permitted

page	marks
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
total	

Marks

1. Consider the gas-phase reaction of chlorine with trichloromethane:



The initial rate of reaction was determined for several initial concentrations of the reactants:

Experiment Number	$[\text{CHCl}_3]$, mol/L	$[\text{Cl}_2]$, mol/L	Initial Rate, mol L ⁻¹ s ⁻¹
1	0.010	0.010	0.0035
2	0.020	0.010	0.0069
3	0.020	0.020	0.0098
4	0.040	0.040	0.027

Based on the data above, derive:

[3] a) Reaction order for CHCl_3

Answer: Reaction order for CHCl_3 is 1

[3] b) Reaction order for Cl_2

Answer: Reaction order for Cl_2 is 0.5

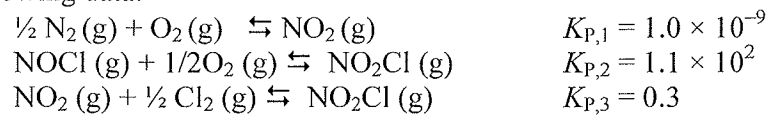
[3] c) The value of the rate constant, k (with units)

Answer: $k = 3.5 \text{ M}^{-1/2} \text{ s}^{-1}$

[1] d) The resulting rate law for the reaction

Answer: $R = 3.5 \times [\text{CHCl}_3][\text{Cl}_2]^{1/2}$

- [8] 2. Determine K_c for the reaction $\text{N}_2(\text{g}) + \text{O}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2 \text{NOCl}(\text{g})$ at 298 K, given the following data:



Solution:

Answer: $K_c \approx \underline{2 \times 10^{-22}}$

3. The conversion of cyclopropane to propene in the gas phase



is a first order reaction with a rate constant of $6.71 \times 10^{-4} \text{ s}^{-1}$ at 250°C .

- [3] a) If the initial concentration of cyclopropane was 0.25 M, what is the concentration after 4.5 min?

Solution:

Answer: The concentration is 0.21 M

- [3] b) How long it will take for the concentration of cyclopropane to decrease from 0.25 M to 0.15 M?

Solution:

Answer: Required time is 12.7 min

- [3] c) How long will it take to convert 72% of the starting material?

Solution:

Answer: Required time is 31.6 min

- [9] 4. Nitrous acid, HNO_2 , has a $\text{p}K_a$ of 3.14. Calculate the pH of a 0.175 M aqueous solution of the salt NaNO_2 .

Solution:

Answer: pH = 8.2

5. Pentachlorophenol (C_6Cl_5OH) is a toxic compound used in preserving wood and has a K_a of 3.5×10^{-9} . A 50 mL aqueous solution of 0.075 M pentachlorophenol was titrated with 0.125 M KOH.

[3] a) What volume of the KOH solution is needed to reach the equivalence point?

Solution:

Answer: $V_{KOH} = \underline{30 \text{ ml}}$

[4] b) What is the pH at the half-equivalence point (when half the acid has been neutralized)?

Solution:

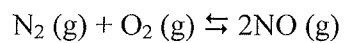
Answer: $pH = \underline{8.5}$

[3] c) What is the highest pH that can be reached during this titration?

Solution:

Answer: $pH = \underline{13.1}$

[10] 6. The value of K_{eq} for the following reaction is 5×10^{-4} .

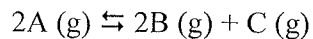


What is the partial pressure of NO at equilibrium if the initial pressures are 0.0 atm for NO, 0.1 atm for N_2 , and 0.1 atm for O_2 ?

Solution:

Answer: $P_{\text{NO}} = \underline{2.2 \times 10^{-3} \text{ atm}}$

7. The reaction



is characterized by:

$$\Delta H^\circ_{300\text{K}} = 100 \text{ kJ/mol}$$

$$\Delta S^\circ_{300\text{K}} = 350 \text{ J/(mol K)}$$

- [5] a) Estimate the thermodynamic equilibrium constant of this reaction at 300 K

Solution:

Answer: $K_{\text{eq}} \approx \underline{7.3}$

- [3] b) Is this reaction spontaneous under standard-state conditions? Justify your answer.

Circle the correct answer:

spontaneous

non-spontaneous

Justification:

- [3] c) How does the equilibrium constant change with increasing temperature? Justify your answer.

Answer: The equilibrium constant increases with increasing temperature.

Explanation:

[2] 8. A spontaneous process is carried out in an isolated universe. What is the sign of ΔS_{univ} ?

Answer: the sign of ΔS_{univ} is positive

[2] 9. A reversible process is carried out in an isolated universe. How are ΔS_{sys} and ΔS_{sur} related?

Answer: ΔS_{sys} = ΔS_{sur}

10. Heat of $q = 5 \text{ kJ}$ is removed from a cold system (a refrigerator) maintained at $T_{\text{sys}} = 250 \text{ }^\circ\text{K}$ and dissipated to the hot surroundings maintained at $T_{\text{sur}} = 300 \text{ }^\circ\text{K}$ in a reversible process ($\Delta S_{\text{univ}} = 0$).

[3] a) What is the change of entropy in the system?

Solution:

Answer: $\Delta S_{\text{sys}} =$ -20 J/K

[3] b) What is the change of entropy in the surroundings?

Solution:

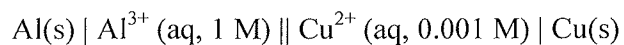
Answer: $\Delta S_{\text{univ}} =$ $+20 \text{ J/K}$

[3] c) What is total amount of heat, Q , that is received by the surroundings?

Solution:

Answer: $Q =$ 6 kJ

- [6] 11. Accurately calculate the voltage of a galvanic cell described by the following compressed diagram at 25 °C?



Solution:

Answer: $E_{\text{cell}} = \underline{1.927}$

- [4] 12. Identify metals from the following list as “soluble” or “insoluble in HBr

Zn is soluble in HBr

Mg is soluble in HBr

Al is soluble in HBr

Ag is insoluble in HBr

13. A silver-zinc galvanic cell converts Zn(s) into ZnO(s) and Ag₂O(s) into Ag(s) in the presence of concentrated aqueous solution of NaOH

- [5] a) Derive balanced chemical equations for the oxidation and reduction half cells and for the overall process:

Oxidation ½ reaction:



Reduction ½ reaction:



Overall reaction:



- [5] b) Roughly estimate the time required for reduction of $m = 1$ g of Ag₂O(s) if the current generated by the cell is $i = 10^{-5}$ A. The molecular weight of Ag₂O is $M \approx 230$ g/mol.

Solution:

Answer: The required time is 2.2×10^7 s

Equations

$$k = A e^{-E_a/RT}$$

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

$$[A]_t = [A]_0 - akt$$

$$[A]_t = [A]_0 \exp(-akt)$$

$$[A]_t^{-1} = [A]_0^{-1} + akt$$

$$\text{pH}_{\text{buffer}} = \text{p}K_a + \log\left(\frac{[A^-]}{[HA]}\right)$$

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

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

$$\Delta G^\circ = -RT \ln K_{eq}$$

$$\Delta G = -zFE_{\text{cell}}$$

$$\ln\left(\frac{K_2}{K_1}\right) = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\ln K_{eq} = \frac{-\Delta H^\circ}{R}\left(\frac{1}{T}\right) + \frac{\Delta S^\circ}{R}$$

$$E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{RT}{zF} \ln Q$$

$$E_{\text{cell}}^\circ = \frac{RT}{zF} \ln K_{eq}$$

Constants and Conversion Factors

$$0.00 \text{ }^\circ\text{C} = 273.15 \text{ K}$$

$$1.000 \text{ bar} = 1.000 \times 10^5 \text{ Pa} \approx 1.0 \text{ atm}$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$K_w = 1.00 \times 10^{-14} \text{ at } 25 \text{ }^\circ\text{C}$$

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

$$F = 96485 \text{ J V}^{-1} \text{ mol}^{-1} = 96485 \text{ C mol}^{-1}$$

TABLE 20.1 Some Selected Standard Electrode (Reduction) Potentials at 25 °C

Reduction Half-Reaction	E°, V
Acidic solution	
$F_2(g) + 2 e^- \longrightarrow 2 F^-(aq)$	+2.866
$O_3(g) + 2 H^+(aq) + 2 e^- \longrightarrow O_2(g) + H_2O(l)$	+2.075
$S_2O_8^{2-}(aq) + 2 e^- \longrightarrow 2 SO_4^{2-}(aq)$	+2.01
$H_2O_2(aq) + 2 H^+(aq) + 2 e^- \longrightarrow 2 H_2O(l)$	+1.763
$MnO_4^-(aq) + 8 H^+(aq) + 5 e^- \longrightarrow Mn^{2+}(aq) + 4 H_2O(l)$	+1.51
$PbO_2(s) + 4 H^+(aq) + 2 e^- \longrightarrow Pb^{2+}(aq) + 2 H_2O(l)$	+1.455
$Cl_2(g) + 2 e^- \longrightarrow 2 Cl^-(aq)$	+1.358
$Cr_2O_7^{2-}(aq) + 14 H^+(aq) + 6 e^- \longrightarrow 2 Cr^{3+}(aq) + 7 H_2O(l)$	+1.33
$MnO_2(s) + 4 H^+(aq) + 2 e^- \longrightarrow Mn^{2+}(aq) + 2 H_2O(l)$	+1.23
$O_2(g) + 4 H^+(aq) + 4 e^- \longrightarrow 2 H_2O(l)$	+1.229
$2 IO_3^-(aq) + 12 H^+(aq) + 10 e^- \longrightarrow I_2(s) + 6 H_2O(l)$	+1.20
$Br_2(l) + 2 e^- \longrightarrow 2 Br^-(aq)$	+1.065
$NO_3^-(aq) + 4 H^+(aq) + 3 e^- \longrightarrow NO(g) + 2 H_2O(l)$	+0.956
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.800
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.771
$O_2(g) + 2 H^+(aq) + 2 e^- \longrightarrow H_2O_2(aq)$	+0.695
$I_2(s) + 2 e^- \longrightarrow 2 I^-(aq)$	+0.535
$Cu^{2+}(aq) + 2 e^- \longrightarrow Cu(s)$	+0.340
$SO_4^{2-}(aq) + 4 H^+(aq) + 2 e^- \longrightarrow 2 H_2O(l) + SO_2(g)$	+0.17
$Sn^{4+}(aq) + 2 e^- \longrightarrow Sn^{2+}(aq)$	+0.154
$S(s) + 2 H^+(aq) + 2 e^- \longrightarrow H_2S(g)$	+0.14
$2 H^+(aq) + 2 e^- \longrightarrow H_2(g)$	0
$Pb^{2+}(aq) + 2 e^- \longrightarrow Pb(s)$	-0.125
$Sn^{2+}(aq) + 2 e^- \longrightarrow Sn(s)$	-0.137
$Fe^{2+}(aq) + 2 e^- \longrightarrow Fe(s)$	-0.440
$Zn^{2+}(aq) + 2 e^- \longrightarrow Zn(s)$	-0.763
$Al^{3+}(aq) + 3 e^- \longrightarrow Al(s)$	-1.676
$Mg^{2+}(aq) + 2 e^- \longrightarrow Mg(s)$	-2.356
$Na^+(aq) + e^- \longrightarrow Na(s)$	-2.713
$Ca^{2+}(aq) + 2 e^- \longrightarrow Ca(s)$	-2.84
$K^+(aq) + e^- \longrightarrow K(s)$	-2.924
$Li^+(aq) + e^- \longrightarrow Li(s)$	-3.040
Basic solution	
$O_3(g) + H_2O(l) + 2 e^- \longrightarrow O_2(g) + 2 OH^-(aq)$	+1.246
$OCl^-(aq) + H_2O(l) + 2 e^- \longrightarrow Cl^-(aq) + 2 OH^-(aq)$	+0.890
$O_2(g) + 2 H_2O(l) + 4 e^- \longrightarrow 4 OH^-(aq)$	+0.401
$2 H_2O(l) + 2 e^- \longrightarrow H_2(g) + 2 OH^-(aq)$	-0.828

hydrogen	1	H
lithium	3	Li
beryllium	4	Be
sodium	11	Na
magnesium	12	Mg
potassium	19	K
calcium	20	Ca
rubidium	37	Rb
strontium	38	Sr
cesium	55	Cs
barium	56	Ba
francium	87	Fr
radium	88	Ra

scandium	21	Sc
titanium	22	Ti
vanadium	23	V
chromium	24	Cr
manganese	25	Mn
iron	26	Fe
cobalt	27	Co
nickel	28	Ni
copper	29	Cu
zinc	30	Zn
gallium	31	Ga
germanium	32	Ge
arsenic	33	As
selenium	34	Se
bromine	35	Br
krypton	36	Kr
rubidium	37	Rb
strontium	38	Sr
yttrium	39	Y
zirconium	40	Zr
niobium	41	Nb
molybdenum	42	Mo
technetium	43	Tc
ruthenium	44	Ru
rhodium	45	Rh
palladium	46	Pd
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tin	50	Sn
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tellurium	52	Te
iodine	53	I
xenon	54	Xe
barium	56	Ba
cesium	55	Cs
francium	87	Fr
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lanthanum	57	La
cerium	58	Ce
praseodymium	59	Pr
neodymium	60	Nd
promethium	61	Pm
samarium	62	Sm
europtium	63	Eu
gadolinium	64	Gd
terbium	65	Tb
dysprosium	66	Dy
holmium	67	Ho
erbium	68	Er
thulium	69	Tm
ytterbium	70	Yb
lutetium	71	Lu
actinium	89	Ac
thorium	90	Th
protactinium	91	Pa
uranium	92	U
neptunium	93	Np
plutonium	94	Pu
americium	95	Am
curium	96	Cm
berkelium	97	Bk
californium	98	Cf
einsteinium	99	Es
fermium	100	Fm
mendelevium	101	Md
nobelium	102	No

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ruthenium	44	Ru
rhodium	4	