KATHMANDU UNIVERSITY
End Semester Examination
March, 2025

Marks Scored:

Level : B.E./B.Sc./B.Tech.
Year : I

Course : CHEM 101
Semester : I

Exam Roll No. :

Time: 30 mins.

F. M. : 20

Registration No.:

Date : 09 MAR 2025

SECTION "A"
[20Q. × 1 = 20 marks]

Choose and Mark [X] in the most appropriate answer.

1. Two liquid components of an ideal solution can mix in any proportion, because.....
   [ ] the system attains minimum energy [ ] the entropy of the system increases
   [ ] the system attains maximum energy [ ] the entropy of the system decreases

2. Given the information shown below, how many millimoles of K_2HPO_4 must be added to 100 ml of a 0.10 M KH_2PO_4 solution to obtain a solution with a pH of 7.0?

   $H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{-2} + H_3O^+ \quad K_a = 5.0 \times 10^{-8}$

   [ ] 20 mmol [ ] 10 mmol [ ] 5 mmol [ ] 1.0 mmol

3. The molecular weight of nicotine, a colorless oil, is 162.1 and it contains 74.0 % carbon, 8.7 % hydrogen and 17.3 % nitrogen. Calculate the molecular formula of nicotine
   [ ] $C_4H_{14}N$ [ ] C_5H_7N [ ] $C_8H_{28}N_2$ [ ] $C_{10}H_{14}N_2$

4. A $2.0g$ sample containing calcium is treated appropriately to precipitate 3.0 g of $Ca_3(PO_4)_2$ (MW = 310). The mass percent of calcium in the original sample is closest to
   [ ] 19 % [ ] 26 % [ ] 39% [ ] 58%

5. The reaction shown below is not balanced, if the reaction is balanced using the smallest whole number coefficients possible, the coefficient for I^- will be

   $\ldots\ldots H^+ + \ldots\ldots IO_3^- + \ldots\ldots I^- \longrightarrow \ldots\ldots I_2 + \ldots\ldots H_2O$

   [ ] 3 [ ] 5 [ ] 8 [ ] 10

6. Given the cell potentials: $Hg^{2+} + 2e^- \rightarrow Hg;\ E^\circ = 0.85\,V$ *and* $Zn^{2+} + 2e^- \rightarrow Zn;\ E^\circ = -0.76\,V;$
   the equilibrium constant at $298K$ for the reaction: $Zn + Hg^{2+} \rightarrow Zn^{2+} + Hg$; is closest to which of the following?
   [ ] 3.7×10^{54} [ ] 54 [ ] 1.6 [ ] 1.8×10^{-2}

7. According to the Brønsted-Lowry Theory, an acid is
   [ ] a proton donor [ ] a proton acceptor
   [ ] an electron donor [ ] an electron acceptor

8. Which of the following represents unit for the second order rate constant?
   [ ] $mol\,L^{-1}Sec^{-1}$ [ ] $L\,mol^{-1}Sec^{-1}$
   [ ] Sec^{-1} [ ] $L^2\,mol^{-2}\,Sec^{-1}$

9. In this equilibrium reaction: $A + B \rightarrow AB + heat$ (in a closed container), how could the forward reaction rate be increased?

I. By increasing the concentration of AB
II. By increasing the concentration of A
III. By removing some of product AB

[ ] I only [ ] III only [ ] I and III only [ ] II and III only

10. Which of the following process can cause branching in the chain reaction?

[ ] $O_2 + M \longrightarrow 2O^{\bullet}$
[ ] $H_2 + O \longrightarrow OH^{\bullet} + H^{\bullet}$
[ ] $H_2 + OH^{\bullet} \longrightarrow H_2O + H^{\bullet}$
[ ] $H^{\bullet} + OH^{\bullet} \longrightarrow H_2O$

Fill in the blanks with most appropriate value or words

11. Based on LeChatelier's principle, the equilibrium constant value for the reaction, $2NO_2(g) \rightarrow N_2O_4(g);\ \Delta H = -13.9\ kcal$, will _____ with decrease in temperature.

12. At constant pressure, when n moles of a substance is heated from T_1 to T_2, the associated entropy change is given by ΔS =_____.

13. The $[H_3O^+]$ when 0.100 mol of $NaHSO_4$ ($K_a = 1.0 \times 10^{-2}$) and 0.100 mol of Na_2SO_4 were dissolved in 1L H_2O will be_____ M.

14. For the reaction $A \rightarrow Products$, the experimental rate law is $rate = k[A]$. The integrated rate law for this reaction is _____.

15. New reactive intermediates are continuously regenerated in a _____ step of a chain reaction.

16. For a reaction relationship among equilibrium constant (K), $\Delta H°$ and $\Delta S°$ can be expressed as _____.

17. The time required for a $500A$ current used for the electrolysis of $AlCl_3$ in order to deposit 2.7 g of aluminum metal at the cathode ($AW\ of\ Al = 27$, Faraday constant = 96,485 $coulombs\ mol^{-1}$) _____ seconds.

18. The amount of heat required to raise 1 mole of material by 1°C is known is _____.

19. In the reaction shown below, Cl^- (aq) behaves as _____.

$3Cl^-(aq) + 4CrO_4^{2-}(aq) + 23H^+(aq) \longrightarrow 3HClO_2(aq) + 4Cr^{3+}(aq) + 10H_2O(l)$

20. The Michaelis-Menten equation for enzyme-catalyzed reactions predicts that the reaction will exhibit _____ order kinetics **at low substrate concentrations.**

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09 MAR 2025

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Semester : I
F. M. : 55

SECTION "B"
[5Q × 6 = 30 marks]

Attempt ANY FIVE questions.

1.
a. Define azeotrope mixture. Show that $\Delta T = K_f m$. [3]
b. The freezing point depression constant for mercuric chloride, $HgCl_2$, is 34.3. for a solution of 0.849 gm of mercurous chloride, (empirical formula $HgCl$) in 50 gm of $HgCl_2$, the freezing point depression is 1.24°C. What is the molecular weight of mercurous chloride in this solution? What is its molecular formula? [3]

2.
a. State first law of thermodynamics. Show that $w_{irrev} > w_{rev}$. [3]
b. Calculate the change in entropy that occurs when a sample containing 2.0 moles of water is heated from 50.0°C to 150.0°C at 1 atm pressure. The molar heat capacities for $H_2O(l)$and $H_2O(g)$ are $18.0\ Cal\ K^{-1}\ mol^{-1}$ and $8.7\ Cal\ K^{-1}\ mol^{-1}$, respectively, and the enthalpy of vaporization for water is 9.7 $kCal/mol$ at 100°C. [3]

3.
a. Define reaction rate. Derive integrated rate law for the reaction that follows second order kinetics. [3]
b. A mixture of KBr and $NaBr$ weighing 0.560 gm was treated with aqueous Ag^+ and all the bromide ion was recovered as 0.970 gm of pure $AgBr$. What was the fraction by weight of KBr in the original sample?

4.
a. Differentiate between reversible and irreversible process. Show that entropy of the universe for an irreversible process always increases. [3]
b. For the reaction: $C_2H_5I + OH^- \rightarrow C_2H_5OH + I^-, k = 5.03 \times 10^{-2} M^{-1} sec^{-1}$ at 289K and $k = 6.71\ M^{-1} sec^{-1}$ at 333K. What is the activation energy of the reaction? What is its rate constant at 305K? [3]

5.
a. State LeChatelier's principle and explain the effect of temperature for the following reaction.
$N_2(g) + O_2(g) \rightleftharpoons 2NO \quad \Delta H = 43.5\ kcal$ [3]
b. Hydrogen and iodine react at 699°K according to
$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
If 1.00 mole of H_2 and 1.00 mole of I_2 are placed in a 1.00-liter vessel and allowed to react, what weight of hydrogen iodide will be present at equilibrium? (*At 699°K, K = 55.3, Atomic weight of Iodine = 126.9*) [3]

P.T.O.

6. Give reasonable explanations for the following. [2+2+2 = 6]
   a. Acid base indicators respond to the change in pH of a solution.
   b. Aqueous solution of a nonvolatile solute boils at greater than 100°C at 1 atm pressure.
   c. Differential rate law is helpful to predict reaction mechanism.

7. Balance the following redox reactions using half-reaction method. [3+3 = 6]
   i. $Zn + NO_3^- \longrightarrow Zn^{++} + NH_4^+$ *(in basic medium)*
   ii. $CuS + NO_3^- \longrightarrow Cu^{++} + SO_4^{2-} + NO$ *(in acidic medium)*

SECTION "C"
[25 marks]

Attempt *ANY THREE* questions. **(Q. N. 8 is compulsory)**

8. Explain briefly on (***ANY THREE***) of the following [3+3+3=9]
   a. Electrochemical theory of rusting of iron
   b. Solution that displays positive deviation from Raoult's law
   c. Collision theory of gaseous reactions
   d. Characteristics of chemical equilibria
   e. Fuel cell and its benefits.

9.
   a. Evidences support that decomposition of di-nitrogen pentoxide (N_2O_5) follows the following mechanism. Based on steady state approximation derive rate law for this reaction. [4]

$$N_2O_5 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} NO_2 + NO_3$$

$$NO_2 + NO_3 \xrightarrow{k_2} NO + NO_2 + O_2$$

$$NO + NO_3 \xrightarrow{k_3} 2NO_2$$

   b. A sample of iron (At. Wt. 55.85) weighing 15.0 g was heated with $KClO_3$ in an evacuated container. The O_2 generated from the decomposition of $KClO_3$ converted some of the Fe to Fe_2O_3. If the combined mass of Fe and Fe_2O_3 was 17.9 g, calculate the mass of Fe_2O_3 formed and the mass of $KClO_3$ decomposed. [4]

10.
   a. Give an example of acidic buffer solution. Derive a Henderson-Hassel Balch equation for this buffer. Explain how does this buffer resist change in pH on addition of i. strong acid, ii. Strong base.

   b. Consider that a solution of hydrogen sulfide is added slowly to a mixture containing 0.1 M each of Zn^{2+} and Fe^{2+} in order to carry out selective precipitation. Which salt precipitates out first and why? Find the concentration of cation of first precipitate when the second salt just starts to precipitate? (Given K_{sp} of FeS, is 1.0×10^{-19} and ZnS is 4.5×10^{-24}). [4]

11.

a. What is Nernst equation? Write its application. [1+3]

b. Calculate ΔH for the reaction: $N_2H_4\ (l) + O_2\ (g) \longrightarrow N_2\ (g) + 2H_2O\ (l)$ using the following data: [4]

$2NH_3\ (g) + 3N_2O(g) \longrightarrow 4N_2\ (g) + 3H_2O(l)$ $\quad \Delta H = -1010\ kJ$

$N_2O(g) + 3H_2\ (g) \longrightarrow N_2H_4\ (l) + H_2O(l)$ $\quad \Delta H = -317\ kJ$

$2NH_3(g) + 1/2\ O_2(g) \longrightarrow N_2H_4\ (l) + H_2O(l)$ $\quad \Delta H = -143\ kJ$

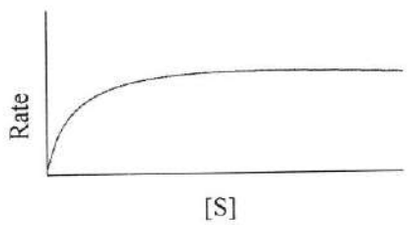
$H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l)$ $\quad \Delta H = -286\ kJ$

12.

a. For enzyme-catalyzed reactions that follow the mechanism, a graph of the rate as a function of [S] has the appearance as provided. Note that at higher substrate concentrations the rate no longer changes with

$$E + S \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} ES \xrightarrow{k_2} E + P$$

[S]. Suggest a reason for this. [4]



b. Consider the reaction: $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$; carried out at 25°C, and 1 atm. Calculate $\Delta H°$, $\Delta S°$, $\Delta G°$ and equilibrium constant (K), using the following data:[4]

Substance	$\Delta H_f^{\circ} kCal\ mol^{-1}$	$S^{\circ}(Cal\ K^{-1}mol^{-1})$
$SO_2(g)$	−70.98	59.27
$SO_3(g)$	−94.64	61.42
$O_2(g)$	0	48.99