CHE / Ass. 3 / 26-27

Chemistry Exam Paper

Duration: 2 hours

Total Marks: 70

Instructions to Candidates

- Answer all questions.
- Section A multiple-choice questions come first. Record the selected option in the separate answer booklet.
- Write all extended responses in the separate answer booklet and identify each question clearly.
- A scientific, non-programmable, non-graphing calculator may be used.
- Use the supplied Chemistry Data and Formulae Booklet.
- Show all working where relevant.
- No AI is permitted.

- The mark allocation is shown beside each question.

Section A · Multiple-choice questions

Answer all 20 multiple-choice questions. 20 marks.

Question A1: Which change does a catalyst make to a reaction pathway? 1
A. It raises the energy of all reactants.
B. It lowers the activation energy.
C. It changes the equilibrium constant at fixed temperature.
D. It makes every collision successful.

Question A2: Which statement describes a dynamic equilibrium in a closed system? 1
A. Both reactions have stopped.
B. Reactant and product concentrations must be equal.
C. Forward and reverse rates are equal.
D. All reactants have become products.

Question A3: What is the IUPAC name of $CH_3CH(CH_3)CH_2OH$? 1
A. 2-Methylpropan-1-ol
B. 2-Methylpropan-2-ol
C. Butan-1-ol
D. Propan-2-ol

Question A4: Which equation is the initiation step in the free-radical chlorination of methane? 1
A. $CH_4 + Cl\bullet \rightarrow CH_3\bullet + HCl$
B. $CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$
C. $CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$
D. $Cl_2 \rightarrow 2Cl$

Question A5: What is the main organic product when propene reacts with HBr in the absence of peroxides? 1
A. Propane
B. 1-Bromopropane
C. 1,2-Dibromopropane
D. 2-Bromopropane

Question A6: A reaction has rate = $k[X]^2[Y]$. What is its overall order? 1
A. 2
B. 3
C. 1
D. 4

Question A7: A reactant concentration falls from 0.080 to 0.040 mol dm^{-3} in 40 s and from 0.040 to 0.020 mol dm^{-3} in the next 40 s. Which order is consistent with these data? 1

A. First order
B. Second order
C. Zero order
D. Third order

Question A8: At constant temperature and pressure, what does a negative reaction Gibbs energy indicate? 1

A. The reaction must be rapid.
B. No activation barrier exists.
C. The forward change is thermodynamically feasible under those conditions.
D. The reaction cannot be reversed.

Question A9: What is the pH of 1.00×10^{-3} mol dm^{-3} HCl, assuming complete dissociation and negligible water contribution? 1

A. 3.00
B. 11.00
C. 1.00
D. 0.00100

Question A10: Which mixture can form an acidic buffer? 1

A. HCl and NaCl
B. NaOH and NaCl
C. Ethanoic acid and sodium ethanoate
D. HNO_3 and KNO_3

Question A11: Which description defines a ligand? 1

A. A species that always accepts a proton
B. A metal atom with a full d subshell
C. A species that contains only ionic bonds
D. A species that donates an electron pair to a central metal atom or ion

Question A12: Which alcohol forms a ketone on oxidation with acidified potassium dichromate(VI)? 1

A. Propan-1-ol
B. Propan-2-ol
C. 2-Methylpropan-2-ol
D. Ethanol

Question A13: What is the electrophile in the nitration of benzene? 1

A. NO_2^-
B. NO_2^+
C. NH_4^+
D. NO_3^-

Question A14: Which observation supports the delocalised model of benzene? 1
A. Three distinct short and three distinct long carbon–carbon bonds
B. Benzene readily adds bromine water without a catalyst
C. The molecule has no π electrons
D. All six carbon–carbon bond lengths are equal

Question A15: Which reagent reduces propanone to propan-2-ol? 1
A. Sodium borohydride
B. Tollens' reagent
C. Acidified potassium dichromate(VI)
D. Sodium hydrogencarbonate

Question A16: What is the name of $CH_3COOCH_2CH_3$? 1
A. Methyl propanoate
B. Propyl methanoate
C. Ethyl ethanoate
D. Ethanoic acid

Question A17: Which reagent gives effervescence of carbon dioxide with a carboxylic acid? 1
A. Aqueous sodium chloride
B. Bromine water
C. Aqueous sodium hydrogencarbonate
D. Sodium borohydride

Question A18: An organic molecular ion has charge +1 and m/z 74. What is the relative molecular mass of the molecule? 1
A. 37
B. 75
C. 148
D. 74

Question A19: In a simple high-resolution proton NMR spectrum, a CH_3 group has two equivalent neighbouring hydrogen atoms. Ignoring other coupling, what splitting is expected? 1
A. Triplet
B. Doublet
C. Singlet
D. Quartet

Question A20: Why are deuterated solvents commonly used in proton NMR spectroscopy? 1
A. They remove all proton signals from the sample.
B. They greatly reduce the solvent proton signal.
C. They increase the number of carbon atoms in the analyte.
D. They always react with the analyte.

Section B · Extended-response questions

Answer all 5 extended-response questions. 50 marks.

Question B1: Rate measurements and catalysis 10

Initial rates for A + B → products are measured at a fixed temperature. Concentrations are in mol dm^{-3} and rates in mol dm^{-3} s^{-1}.
Experiment 1: [A] = 0.100; [B] = 0.100; rate = 2.00×10^{-3}.
Experiment 2: [A] = 0.200; [B] = 0.100; rate = 8.00×10^{-3}.
Experiment 3: [A] = 0.100; [B] = 0.200; rate = 4.00×10^{-3}.

(a) Determine the order with respect to A and the order with respect to B. Refer to the rate changes. [2]

(b) Calculate the rate constant k and state its units. [2]

(c) Explain why raising the temperature increases the rate constant, using the energy distribution and activation energy. [2]

(d) Explain why a catalyst increases the rate at the same temperature without increasing the mean kinetic energy of the particles. [2]

(e) A learner says these three experiments prove that the reaction occurs in one step involving two A particles and one B particle. Evaluate this claim. [2]

Question B2: Equilibrium and acid–base calculations 10

At a fixed temperature, a 2.00 dm^3 vessel contains an equilibrium mixture for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$: 0.200 mol H_2, 0.200 mol I_2 and 1.20 mol HI. In a separate acid–base calculation at 25 °C, use $K_w = 1.00 \times 10^{-14}$ mol^2 dm^{-6}.

(a) Calculate Kc for the gas equilibrium. [3]

(b) Predict the effect on the equilibrium composition of compressing this ideal-gas mixture at unchanged temperature, and explain your answer. [2]

(c) Calculate the pH of 0.0200 mol dm^{-3} NaOH at 25 °C. Assume complete dissociation. [3]

(d) Explain how an ethanoic acid/ethanoate buffer resists a small addition of strong acid. [2]

Question B3: Thermodynamics and transition-metal complexes 10

For a hypothetical reaction, $\Delta H^\circ = +40.0$ kJ mol^{-1} and $\Delta S^\circ = +150$ J mol^{-1} K^{-1}. Treat these values as constant over the temperature range considered. A separate solution contains the octahedral complex ion $[Cu(H_2O)_6]^{2+}$.

(a) Calculate ΔG° for the reaction at 298 K, including its sign and units. [3]

(b) A learner claims that this value proves the reaction will finish quickly at 298 K. Evaluate the claim. [2]

(c) State the coordination number of $[Cu(H_2O)_6]^{2+}$ and identify the atom in each ligand that bonds to copper. [2]

(d) Explain the origin of colour in this transition-metal complex. [3]

Question B4: Organic reactions and synthesis 10

Ethene can be converted to bromoethane by reaction with HBr. Ethanol can also be converted to ethanal or to an ester using suitable reagents and conditions.

(a) Draw the electrophilic addition mechanism for ethene reacting with HBr. Show the relevant dipole, curly arrows, intermediate and organic product. [4]

(b) Describe reagents and conditions for converting ethanol to ethanal while limiting further oxidation. [3]

(c) Write a balanced structural equation for ethanol reacting with ethanoic acid to form an ester. Name the ester. [3]

Question B5: Identifying an organic compound 10

Compound X is known to be either propanal or propanone. Its singly charged molecular ion has m/z 58. Its IR spectrum has a strong absorption near 1720 cm^{-1}. Its high-resolution proton NMR spectrum shows a singlet integrating to six hydrogen atoms. Ignore trace impurities.

(a) State the relative molecular mass of X. [1]

(b) Identify the bond responsible for the IR absorption and explain why that absorption alone does not distinguish these two candidates. [2]

(c) Identify X and explain the integration and splitting of its proton NMR signal in terms of its structure. [3]

(d) Describe a chemical test and the contrasting observations that would distinguish propanal from propanone. [2]

(e) A learner claims that a molecular-ion peak at m/z 58 proves that any unknown is propanone. Evaluate this claim and identify how the supplied NMR evidence improves the identification here. [2]