CHE / Ass. 2 / 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: What amount of sodium hydroxide is present in 4.00 g of NaOH? Use M(NaOH) = 40.0 g mol^{-1}. 1
A. 0.0100 mol
B. 160 mol
C. 10.0 mol
D. 0.100 mol

Question A2: A gas has a molar volume of 24.0 dm^3 mol^{-1} at the stated conditions. What volume does 0.250 mol occupy at these conditions? 1
A. 96.0 dm^3
B. 6.00 dm^3
C. 0.0104 dm^3
D. 24.3 dm^3

Question A3: Each burette reading has an absolute uncertainty of ±0.05 cm^3. Using addition of absolute uncertainties, what is the percentage uncertainty in a titre of 25.00 cm^3? 1
A. 0.40%
B. 0.20%
C. 2.0%
D. 4.0%

Question A4: Which statement describes accuracy? 1
A. Agreement between repeated measurements only
B. The number of decimal places displayed
C. Closeness of a measured value to the accepted or true value
D. The size of a sample

Question A5: Which quantities are the same for neutral atoms of two isotopes of one element? 1
A. Proton number and electron number
B. Neutron number and mass number
C. Mass number and electron number
D. Proton number and neutron number

Question A6: An element has isotopes of mass 24, 25 and 26 with abundances of 80.0%, 10.0% and 10.0%. What is its relative atomic mass? 1
A. 25.0
B. 24.0
C. 24.3
D. 75.0

Question A7: What is the ground-state electron configuration of a neutral aluminium atom, atomic number 13? 1
A. $1s^2\ 2s^2\ 2p^6\ 3d^3$
B. $1s^2\ 2s^2\ 2p^6\ 3s^1$
C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

Question A8: Why is the first ionisation energy of aluminium lower than that of magnesium? 1
A. Aluminium has a smaller nuclear charge.
B. The electron removed from aluminium is in a higher-energy 3p subshell.
C. Aluminium has no shielding electrons.
D. An electron is removed from an inner shell in aluminium.

Question A9: When NH_3 reacts with H^+ to form NH_4^+, where do the electrons in the new coordinate bond initially come from? 1
A. One electron from each species
B. Both electrons from nitrogen
C. Both electrons from H^+
D. Both electrons from a neutron

Question A10: What is the shape of SF_6? 1
A. Octahedral
B. Tetrahedral
C. Trigonal planar
D. Bent

Question A11: Which interaction helps explain the unusually high boiling point of water compared with hydrogen sulfide? 1
A. Ionic bonding between neutral water molecules
B. Covalent bonds between different water molecules
C. Metallic bonding in liquid water
D. Hydrogen bonding between water molecules

Question A12: Carbon dioxide has polar C=O bonds but is a non-polar molecule. Which explanation is correct? 1
A. Carbon and oxygen have equal electronegativity.
B. Its bonds contain no electrons.
C. Its equal bond dipoles cancel in a linear molecule.
D. Its molecules are bent.

Question A13: What is the oxidation number of sulfur in SO_4^{2-}? 1
A. −2
B. +4
C. +6
D. +8

Question A14: Why does the reactivity of Group 1 metals generally increase down the group? 1
A. Their outer electrons are in lower principal shells.
B. Their atoms lose fewer electrons in each reaction.
C. Their nuclei contain fewer protons.
D. Increased distance and shielding make the outer electron easier to remove.

Question A15: Which products form when magnesium reacts with steam? 1
A. Magnesium oxide and hydrogen
B. Magnesium chloride and oxygen
C. Magnesium hydroxide and oxygen
D. Magnesium sulfate and hydrogen

Question A16: In $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$, which species is oxidised? 1
A. Cl_2
B. Br^-
C. Br_2
D. Cl^-

Question A17: Which observation is consistent with an endothermic reaction in an insulated cup? 1
A. The surroundings gain heat from the reaction.
B. No energy is transferred.
C. The reaction enthalpy is negative.
D. The solution temperature falls.

Question A18: A 100 g solution warms by 5.0 °C. Using $c = 4.18\ J\ g^{-1}\ K^{-1}$, how much heat does it gain? 1
A. 2090 J
B. 209 J
C. 20.9 J
D. 20 900 J

Question A19: What does Hess’s law state? 1
A. Every reaction has a positive enthalpy change.
B. The enthalpy change depends only on initial and final states, not the route.
C. A catalyst changes the reaction enthalpy.
D. All bonds have equal dissociation enthalpies.

Question A20: What is a mean bond enthalpy? 1
A. The energy released when one molecule boils
B. The enthalpy change of forming an ionic lattice
C. An average enthalpy needed to break one mole of a specified bond in gaseous species
D. The energy needed to remove an electron from an atom

Section B · Extended-response questions

Answer all 5 extended-response questions. 50 marks.

Question B1: Quantitative analysis of sodium carbonate — 10

A learner dissolves 2.65 g of pure anhydrous Na_2CO_3 and makes the solution up to 250.0 cm^3. A 25.00 cm^3 aliquot requires a mean titre of 20.00 cm^3 hydrochloric acid for complete neutralisation. Use $M(Na_2CO_3) = 106.0$ g mol^{-1}.

(a) Write the balanced equation for the complete reaction of sodium carbonate with hydrochloric acid. [2]

(b) Calculate the concentration of the sodium carbonate solution in mol dm^{-3}. [3]

(c) Calculate the concentration of the hydrochloric acid in mol dm^{-3}. [3]

(d) The learner records three closely agreeing titres and concludes that the acid concentration must be accurate. Explain why agreement alone does not establish accuracy, and suggest one additional check. [2]

Question B2: Atomic structure and evidence — 10

An element X has atomic number 17. A simplified mass spectrum contains singly charged ions with m/z 35 at relative abundance 75.0% and m/z 37 at relative abundance 25.0%. A separate element Y has successive ionisation energies 590, 1150, 4940 and 6480 kJ mol^{-1}.

(a) State the number of protons and neutrons in an atom of X with mass number 37. [2]

(b) Calculate the relative atomic mass of X from these data. [2]

(c) State the most likely number of outer-shell electrons in Y and explain your answer using the ionisation-energy data. [2]

(d) Explain why an atomic emission spectrum contains discrete lines rather than a continuous range of wavelengths. [4]

Question B3: Bonding and physical properties 10

Substances P and Q have the following properties. P has a high melting point and conducts electricity when molten but not when solid. Q has a low boiling point and does not conduct in either liquid or solid form. Water and hydrogen sulfide are also considered.

(a) Define an ionic bond. [2]

(b) Suggest the structure type of P and explain its high melting point and change in conductivity on melting. [4]

(c) Describe the conditions needed for hydrogen bonding between molecules. [2]

(d) A learner identifies Q as a particular named covalent compound from the two properties given. Explain one limitation of this identification and suggest one further type of evidence that could distinguish Q. [2]

Question B4: Periodicity and halogen reactions 10

Chlorine water is added to an aqueous potassium bromide solution. Bromine forms. In a separate comparison, magnesium carbonate decomposes more readily on heating than barium carbonate.

(a) Write the oxidation and reduction half-equations for the chlorine/bromide reaction. [4]

(b) Explain why chlorine displaces bromine from bromide ions, but bromine does not displace chlorine from chloride ions under comparable conditions. [2]

(c) Use the relative sizes of Mg^{2+} and Ba^{2+} to explain the difference in carbonate thermal stability. [2]

(d) A learner heats unequal masses of the two carbonates in different vessels and compares the time before gas is detected. Identify one weakness in this comparison and explain its effect on the conclusion. [2]

Question B5: Enthalpy changes and experimental estimates 10

The standard enthalpy of combustion of ethanol is −1367 kJ mol^{-1}. Use M(ethanol) = 46.0 g mol^{-1}. In a separate calculation, use these mean bond enthalpies: H–H 436, Cl–Cl 243 and H–Cl 432 kJ mol^{-1}.

(a) Define the standard enthalpy change of combustion. [2]

(b) Calculate the energy released when 2.30 g of ethanol undergoes complete combustion. [3]

(c) Use the mean bond enthalpies to estimate ΔH for $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$. [3]

(d) A flame calorimetry experiment gives an ethanol combustion enthalpy much less negative than the reference value. Suggest one experimental cause and explain how it produces this difference. [2]