IB DEMYSTIFIED

Examiners • Moderators • Mentors

Chemistry

Standard Level

Paper 2 — Mock Examination

Mock Exam 1

Calculator required

Time allowed: **1 hour 30 minutes**

Maximum mark: **50 marks**

Candidate information

Candidate name: .....

Session number: .....

Date: .....

Topic emphasis: models of the particulate nature of matter, models of bonding and structure, classification of matter, what drives chemical reactions, how much / how fast / how far, and what are the mechanisms of chemical change.

Instructions to candidates

- Write your session number in the box on the cover.
- Do not open this examination paper until you are told to do so.
- Answer **all** questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks]**.

The mark allocation is shown in square brackets at the end of each question or part question. Where a numerical answer is required, values of constants, molar masses, electronegativities and bond enthalpies should be taken from the chemistry data booklet unless they are given in the question. Show your working for all calculations; marks are available for correct method even where the final answer is incorrect.

Take the molar volume of an ideal gas at STP to be 22.7 $\mathrm{dm^3\,mol^{-1}}$, Avogadro's constant to be 6.02×10^{23} $\mathrm{mol^{-1}}$ and the ideal gas constant to be $R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$. All questions refer to standard conditions and to a temperature of 298 K unless otherwise stated.

Mark allocation

Question	**Marks**
Question 1 — Sulfur and its compounds	[17]
Question 2 — Organic reactions and mechanisms	[18]
Question 3 — Energetics, equilibrium and kinetics	[15]
Total	**[50]**

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Sulfur is a group 16 element that occurs naturally as the element and in a wide range of minerals and fossil fuels.

(a) (i) Draw the orbital diagram of the sulfur atom in the ground state by adding, filling and labelling the orbitals. Use section 7 of the data booklet. **[2]**

(ii) The first ionization energy of sulfur is lower than that of phosphorus, even though sulfur has a greater nuclear charge.

Explain this observation. **[2]**

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(Question 1 continued)

(b) 3.21 g of sulfur reacted completely with chlorine gas. The mass of the chloride produced was 6.76 g.

(i) Calculate the number of atoms in 3.21 g of sulfur. Use sections 2 and 7 of the data booklet. **[1]**

(ii) Determine the empirical formula of the chloride formed, showing your working. Use section 7 of the data booklet. **[3]**

(iii) The M_r of the chloride formed in (b)(ii) was found to be 135.04 $g\,mol^{-1}$.

Determine its molecular formula, showing your working. **[1]**

(Question 1 continued)

(iv) This chloride of sulfur has a boiling point of 411 K.

Outline, with reference to structure and bonding, the reasons why the boiling point of this compound is low. **[2]**

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(c) Sulfur also forms the compound sulfur dichloride, SCl_2.

(i) Deduce the Lewis formula of SCl_2. **[1]**

(ii) State the molecular geometry of SCl_2 and predict the Cl−S−Cl bond angle. **[2]**

Molecular geometry: .....

Bond angle: .....

(Question 1 continued)

(d) Sulfur dioxide, SO_2, is released when fossil fuels containing sulfur are burned. It dissolves in atmospheric water to form sulfurous acid, H_2SO_3, a weak acid.

(i) Write an equation for the reaction of sulfur dioxide with water. **[1]**

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(ii) State the oxidation state of sulfur in sulfurous acid, H_2SO_3. **[1]**

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(iii) Write an equation for the reaction of sulfurous acid with an excess of aqueous sodium hydroxide. **[1]**

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(iv) A 0.010 mol dm^{-3} solution of sulfurous acid has a pH of 2.10, while a 0.010 mol dm^{-3} solution of hydrochloric acid has a pH of 2.00.

Explain the difference in pH. **[2]**

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2. Bromomethane, CH_3Br, can be prepared from methane in a chain reaction.

$$CH_4(g) + Br_2(g) \longrightarrow CH_3Br(g) + HBr(g)$$

The first step in this reaction, initiation, is given by the following equation.

$$Br_2 \longrightarrow 2\,Br^{\bullet}$$

(a) (i) State an essential condition for this step. **[1]**

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(ii) Deduce **two** propagation steps and **one** termination step for this reaction. **[3]**

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(iii) Explain why a small amount of ethane, C_2H_6, is detected among the products. **[1]**

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(Question 2 continued)

(b) 1-bromopropane reacts with warm aqueous sodium hydroxide to produce propan-1-ol.

$$CH_3CH_2CH_2Br(l) + OH^-(aq) \longrightarrow CH_3CH_2CH_2OH(aq) + Br^-(aq)$$

(i) State the type of reaction. **[1]**

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(ii) Sketch the mechanism of the reaction, showing structural formulas and using curly arrows to represent the movement of electron pairs. **[3]**

(Question 2 continued)

(c) Propanoic acid, CH_3CH_2COOH, reacts with ethanol in the presence of a few drops of concentrated sulfuric acid to form an ester.

(i) Deduce the structural formula and the name of the ester produced. **[2]**

Name of ester: .....

(ii) Explain the action of the sulfuric acid catalyst in this reaction. **[2]**

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(iii) Calculate the atom economy for the formation of the ester. Use sections 1 and 7 of the data booklet. **[2]**

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(Question 2 continued)

(d) Propanoic acid has the molecular formula $C_3H_6O_2$.

Deduce the structure and name of a functional group isomer of propanoic acid, and state the homologous series to which it belongs. **[2]**

Name of isomer: .....

Homologous series: .....

(e) Propanoic acid is still widely known by the trivial name propionic acid.

Outline **two** advantages of using systematic (IUPAC) names rather than trivial names when communicating chemical information internationally. **[2]**

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3. Ammonia is manufactured from nitrogen and hydrogen in a homogeneous, reversible, gas-phase reaction.

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g)$$

(a) Calculate the enthalpy change of the forward reaction, ΔH, using average bond enthalpies. Use section 12 of the data booklet. **[3]**

(b) (i) Deduce the expression for the equilibrium constant, K, for this reaction. **[1]**

(ii) 2.00 mol of nitrogen and 6.00 mol of hydrogen were placed in a sealed 1.00 dm^3 container and allowed to reach equilibrium. At equilibrium the mixture contained 3.00 mol of ammonia.

Calculate the amounts, in mol, of nitrogen and hydrogen at equilibrium, and determine the value of K. **[3]**

(Question 3 continued)

(iii) Explain the effect of increasing the temperature on the value of K and on the equilibrium yield of ammonia. **[2]**

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(iv) Suggest, with a reason, the effect of increasing the pressure on the position of equilibrium. **[1]**

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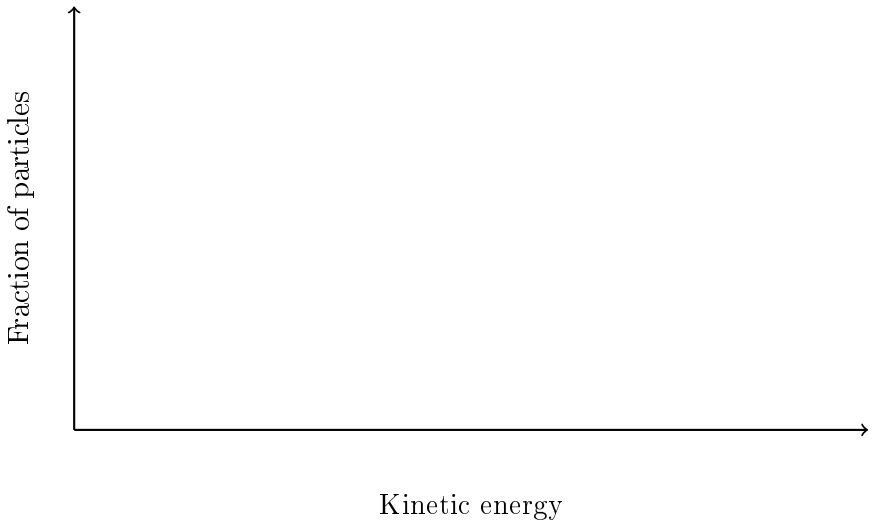
(c) (i) Sketch the Maxwell–Boltzmann energy distribution curve for the reaction mixture at 500 K on the axes below. On the same axes, sketch and label a second curve for the same mixture at 700 K. **[2]**



(Question 3 continued)

(ii) Annotate the graph in part (c)(i) to show the activation energy, E_a, of the forward reaction. **[1]**

(iii) Explain, referring to your graph, why increasing the temperature increases the rate of reaction. **[2]**

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End of examination.

Total: **50 marks**