[Braille page 1] X813/76/01 PRINT COPY BRAILLE

H

National Qualifications

2026

Chemistry

Paper 2

Tuesday, 12 May

Instructions to Candidates

Candidates should enter their surname, forename(s), date of birth, Scottish candidate number and the name and level of the subject at the top of their first answer sheet.

Total marks — 95

Attempt ALL questions.

You may use a calculator.

You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.

An ow in the margin indicates a new question.

Questions marked with an asterisk differ in some respect from those in the printed paper.

You must clearly identify the question number you are attempting on your answer sheet.

Any rough work must be written on your answer sheet.

Tactile diagrams are produced in a separately bound booklet.

Marks are shown in square brackets at **[Braille page 2]** the end of each question or part question.

[Braille page 3] Total marks — 95

Attempt ALL questions

ow 1. (a) Refer to the diagram for Question 1. Sodium chloride is an ionic compound and has the structure shown.

(i) State the term used to describe the structure of sodium chloride. [1 mark]

(ii) An ionic bond is a type of electrostatic attraction.

(A) Describe what is meant by the term electrostatic attraction. [1 mark]

(B) Explain why sodium and chlorine form an ionic compound using electronegativity values from the data booklet. [1 mark]

(b) The boiling point of pure water is 100 °C. Dissolving an ionic solute in water raises the boiling point.

The increase in boiling point depends on the total number of solute particles.

The increase in boiling point (ΔT_b), in °C, can be calculated using the formula shown.

$\Delta T_b = 0.51 \times c \times i$

c = the concentration of the solution in mol l^{-1}

i = the number of particles in solution when one formula unit of solute dissolves

[Braille page 4] The values of i for some ionic solutes are shown in the table.

Ionic solute	Value of i
::::::::::::::::	::::::::::::
KCl	2
$CaBr_2$	3
$(NH_4)_3PO_4$	4

(i) State the value of i for lithium sulfate. [1 mark]

(ii) Calculate the boiling point, in °C, of an aqueous solution of 0.35 mol l^{-1} of ammonium phosphate. [2 marks]

ow 2. Water, H_2O, and methane, CH_4, are covalent molecules.

The table shows the van der Waals forces present and boiling points for these molecules.

In the table below, Molecule is followed by: Van der Waals forces present; Boiling point (°C).

CH_4: London dispersion forces; −162.

H_2O: London dispersion forces Hydrogen bonds; 100.

[Braille page 5] (a) Explain fully how London dispersion forces are formed. [2 marks]

(b) The boiling points of these two molecules, H_2O and CH_4, can be used to compare the strength of van der Waals forces.

Explain why H_2O and CH_4 are suitable for this comparison. [1 mark]

(c) Explain fully why water is a polar molecule. [2 marks]

ow 3. Trends in melting points, ionisation energy, covalent radius and electronegativity can be related to the position of an element in the periodic table.

Using your knowledge of chemistry, comment on how the position of an element in the periodic table can be used to predict its physical and chemical properties. [3 marks]

[Braille page 6] ow 4. Refer to the diagram for Question 4. Hydrogen peroxide, H_2O_2, decomposes very slowly to produce water and oxygen.

$$2H_2O_2\,(aq) \rightarrow 2H_2O(l) + O_2\,(g)$$

(a) The activation energy, E_a, for this reaction is 75 kJ mol^{-1} and the enthalpy change, ΔH, is −98 kJ mol^{-1}.

(i) Describe the activation energy and enthalpy change given above to complete the potential energy diagram for the reaction. [1 mark]

(ii) Calculate the activation energy, in kJ mol^{-1}, for the reverse reaction. [1 mark]

(b) Manganese dioxide catalyses the decomposition of hydrogen peroxide solution.

When a catalyst is used in a reaction more successful collisions occur and the rate of reaction increases.

Explain fully the way in which catalysts increase the number of successful collisions. [2 marks]

[Braille page 7] (c) The balanced equation for the decomposition of hydrogen peroxide, H_2O_2, is shown.

$$2H_2O_2\,(aq) \rightarrow 2H_2O(l) + O_2\,(g)$$

GFM = 34 g

Calculate the mass, in g, of hydrogen peroxide required to produce 60 cm^3 of oxygen gas. [2 marks]

Take the volume of one mole of oxygen gas to be 24 litres.

(d) Hydrogen peroxide, H_2O_2, should be stored in the dark as sunlight can provide sufficient energy to break the weak oxygen to oxygen single bond in the molecule creating free radicals.

(i) State the meaning of the term free radicals. [1 mark]

(ii) Identify the free radical formed from hydrogen peroxide. [1 mark]

(e) Refer to the diagram for Question 4 (e). Increasing the temperature will increase the rate of a reaction.

The diagram shows the distribution of **[Braille page 8]** kinetic energies of molecules in a sample of a gas.

(i) Suggest what is represented by the shaded area in the diagram. [1 mark]

(ii) Describe a second curve that could be added to the diagram to show the distribution of kinetic energies at a higher temperature. [1 mark]

ow 5. The peel of citrus fruits contains essential oils.

(a) Essential oils in citrus fruits have aromas. State another property of an essential oil. [1 mark]

(b) Refer to the diagram for Question 5 (b). Limonene is an essential oil found in citrus peel.

A structure for limonene is shown.

(i) When limonene is heated, it can undergo decomposition to form isoprene units.

Describe a structural formula for isoprene. [1 mark]

(ii) State the number of isoprene units that would be produced when one molecule of limonene decomposes. [1 mark]

(c) Citrus peel has been investigated as a possible source of biofuel for cars.

[Braille page 9] (i) The first step in producing the fuel is to extract essential oils, including limonene, from citrus peel.

One method uses hexane to dissolve the essential oils.

Explain why hexane is a suitable solvent for essential oils. [1 mark]

(ii) An experiment was carried out to determine the enthalpy of combustion for limonene.

3.5 g of limonene (GFM = 136 g) was burned and the temperature rise in 500 cm^3 of water was 56 °C.

Calculate the enthalpy of combustion, in kJ mol^{-1}, of limonene using these experimental results. [3 marks]

(d) Refer to the diagram for Question 5 (d). Limonene can undergo oxidation to produce carveol.

A structure for carveol is shown.

(i) Explain why carveol can be classified as a secondary alcohol. [1 mark]

(ii) Carveol can be further oxidised to produce a ketone.

Describe a structural formula for the ketone produced when carveol is oxidised. [1 mark]

[Braille page 10] ow 6. Refer to the diagram for Question 6 (a). Bananas contain a range of compounds.

(a) An ester responsible for the flavour of bananas is shown.

(i) Name the alcohol used to make this ester. [1 mark]

(ii) This alcohol was passed over heated black copper(II) oxide. Suggest what would be seen at the end of the reaction. [1 mark]

(b) Bananas produce the gas ethene, C_2H_4, (GFM = 28 g) which causes them to ripen.

To speed up the ripening of bananas, they are stored in a gas mixture containing 4% ethene and 96% nitrogen.

A gas mixture has a volume of 27 000 litres.

Calculate the mass of ethene required, in g, for this gas mixture. [2 marks]

Take the volume of one mole of ethene gas to be 23 litres.

(c) When bananas are cut, the colour changes from yellow to brown.

Enzymes cause the breakdown of chemicals in the banana, resulting in this colour change.

[Braille page 11] (i) Name the class of compounds to which enzymes belong. [1 mark]

(ii) To stop cut bananas turning brown, they can be treated with lemon juice, denaturing the enzymes.

Explain fully what is meant by denaturing. [2 marks]

ow * 7. Refer to the diagram for Question 7. Ethanol is an important industrial chemical.

(a) The flow diagram of an industrial process to produce ethanol is shown.

(i) Using the flow diagram explain where you would add an arrow to suggest one way to maximise profit in this industrial process. [1 mark]

(ii) Name the process used in separator 2 to separate ethanol from water. [1 mark]

(iii) In the reactor ethene reacts with water to form ethanol.

$$C_2H_4(g) \quad + \quad H_2O(g) \quad \rightleftharpoons \quad C_2H_5OH(g)$$

[Braille page 12] (A) The reaction taking place is called hydration.

State another name for this type of reaction. [1 mark]

(B) Increasing the pressure in the reactor improves the yield of ethanol.

Explain fully why increasing pressure would shift the equilibrium to the right producing more ethanol. [2 marks]

(C) Using mean bond enthalpies from the data booklet, calculate the enthalpy change, in kJ mol^{-1}, for this reaction. [2 marks]

$$C_2H_4(g) \quad + \quad H_2O(g) \quad \rightleftharpoons \quad C_2H_5OH(g)$$

(D) The atom economy for this reaction is 100%.

Explain what this means. [1 mark]

[Braille page 13] (b) Ethanol can be oxidised to compound X.

$$\underset{\text{ethanol}}{CH_3CH_2OH} \xrightarrow{\text{Step 1}} \underset{\text{ethanal}}{CH_3CHO} \xrightarrow{\text{Step 2}} \underset{\text{compound X}}{CH_3COOH}$$

(i) State why steps 1 and 2 can be described as oxidation. [1 mark]

(ii) Name compound X. [1 mark]

(iii) Refer to the diagram for Question 7 (b) (iii). In the laboratory, acidified dichromate solution can be used to convert ethanol to compound X.

(A) Suggest why a water bath is a suitable method of heating the reaction mixture. [1 mark]

(B) Describe the colour change that would be observed. [1 mark]

[Braille page 14] (C) Complete the ion electron equation for the reaction shown below. [1 mark]

$C_2H_5OH \rightarrow CH_3COOH$

(D) The other reaction taking place is shown.

$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$

Explain why the dichromate solution needs to be acidified. [1 mark]

(E) State the classification of alcohols that do not react with acidified dichromate solution. [1 mark]

(iv) Name another oxidising agent that could be used to convert ethanal to compound X in step 2. [1 mark]

(c) Ethanol can be converted to ethene in the laboratory using a catalyst.

In this experiment, aluminium oxide powder is heated. This heat also causes the ethanol to turn to vapour.

The ethanol vapour passes over the hot aluminium oxide powder and forms ethene. The **[Braille page 15]** ethene gas is collected over water.

(i) Describe how the test tube would be heated. [1 mark]

(ii) Describe the apparatus used to collect gas over water. [1 mark]

(iii) When bromine solution is added to the collected gas it rapidly decolourises.

State the term given to a chemical that rapidly decolourises bromine solution. [1 mark]

ow 8. Snake venom contains proteins.

(a) Proteins are formed by joining together amino acids.

(i) Name the type of reaction that takes place when amino acids are joined. [1 mark]

(ii) Refer to the diagram for Question 8 (a) (ii). Two amino acids can join to form a dipeptide.

Two of the amino acids found in snake venom are shown.

Describe a structural formula to show a dipeptide formed when these two amino acids join. [1 mark]

(b) Refer to the diagram for Question 8 (b). Amino acids can be classified according to their side chains.

[Braille page 16] (i) Four types of side chain are acidic, basic, hydrophobic and polar.

(A) Refer to the diagram for Question 8 (b) (i) (A). The structure of the amino acid isoleucine is shown.

Identify the class of amino acid to which isoleucine belongs. [1 mark]

(B) Refer to the diagram for Question 8 (b) (i) (B). The structure of the amino acid aspartic acid is shown.

Suggest why aspartic acid can be classified as acidic. [1 mark]

(ii) When amino acids form proteins, the proteins are stabilised by intermolecular forces that form between the side chains.

Refer to the diagram for Question 8 (b) (ii). The structure of the amino acid threonine is shown.

Identify the strongest intermolecular force that would form between molecules of threonine. [1 mark]

(c) Refer to the diagram for Question 8 (c). Proteins that contain the amino acid cysteine can form disulfide bonds (—S—S—) between cysteine side chains. This makes the protein resistant **[Braille page 17]** to being broken down when heated.

Suggest why proteins forming disulfide bonds are resistant to heat. [1 mark]

ow 9. Liquids and powders that remove dirt and stains from clothes contain a variety of chemicals.

The chemicals in the liquids and powders include soaps, detergents, bleaching agents and enzymes.

Using your knowledge of chemistry, explain the action of the chemicals used to remove dirt and stains from clothes. [3 marks]

ow 10. Ammonia, NH_3, can be made using the Haber process.

(a) In the Haber process, nitrogen and hydrogen react together in the presence of an iron catalyst.

$$N_2(g) \quad + \quad 3H_2(g) \quad \rightleftharpoons \quad 2NH_3(g) \qquad\qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

[Braille page 18] (i) Complete the table to show the change in conditions required to increase the yield of ammonia. [1 mark]

Condition	Increase/ Decrease
::::::::::::	::::::::::::
Pressure	increase
Temperature	_
Concentration of ammonia in the reaction mixture	_

(ii) State the effect of the catalyst on the equilibrium position of this reaction. [1 mark]

(iii) Under certain conditions, 500 kg of nitrogen reacts with excess hydrogen to produce 405 kg of ammonia.

$$\begin{array}{ccccc} N_2(g) & + & 3H_2(g) & \rightleftharpoons & 2NH_3(g) \\ GFM = 28 \text{ g} & & & & GFM = 17 \text{ g} \end{array}$$

[Braille page 19] Calculate the percentage yield of ammonia under these conditions. [2 marks]

(b) The hydrogen needed for ammonia production by the Haber process can be made by reacting methane with steam.

$CH_4\ (g) + H_2O\ (g) \rightarrow CO\ (g) + 3H_2\ (g)$

Calculate the enthalpy change, in kJ mol^{-1}, for this reaction using the following information. [2 marks]

$$CO(g) + \tfrac{1}{2}O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -283\ \text{kJ mol}^{-1}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad \Delta H = -242\ \text{kJ mol}^{-1}$$
$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -803\ \text{kJ mol}^{-1}$$

(c) A new method for producing ammonia has recently been developed.

Lithium oxide is reduced to lithium using a laser. Lithium then reacts with **[Braille page 20]** nitrogen in the air to form lithium nitride.

(i) Lithium nitride, Li_3N, then reacts with water.

$Li_3N(s)$	+	$3H_2O(\ell)$	$\rightarrow$	$NH_3(g)$	+	$3LiOH(aq)$
$GFM = 34.7$ g		$GFM = 18.0$ g		$GFM = 17.0$ g		$GFM = 23.9$ g

Calculate the atom economy for the production of ammonia. [2 marks]

(ii) Using this method, 0.0013 g of ammonia (GFM = 17.0 g) was produced in 78 seconds.

Calculate the time, in hours, required to produce 1 mole of ammonia. [2 marks]

ow 11. The concentration of a sodium hydroxide solution can be determined by titration with oxalic acid.

(a) A student made an oxalic acid solution of accurately known concentration.

(i) State the term used to describe a solution of accurately known **[Braille page 21]** concentration. [1 mark]

(ii) Calculate the mass, in g, of oxalic acid (GFM = 90 g) needed to make 250 cm^3 of 0.050 mol l^{-1} oxalic acid solution. [1 mark]

(iii) A section of the student's notebook is shown with the experimental procedure they used to make the solution.

1. The sample of oxalic acid was dissolved in 25 cm^3 of deionised water in the beaker.

2. The solution was poured into the 250 cm^3 volumetric flask using a funnel.

3. The solution was made up to the graduated mark with tap water so that the top of the meniscus meets the line.

4. The flask was stoppered and then inverted several times to mix the solution.

The solution prepared by the student did not have an accurately known concentration.

Suggest two improvements the student could make to the procedure. [2 marks]

(b) The student titrated the sodium hydroxide solution with a new oxalic acid solution using an indicator.

(i) State why it was necessary to add an indicator to this titration. [1 mark]

(ii) The burette was clamped **[Braille page 22]** vertically, rinsed with the new oxalic acid solution and filled up to above 0.0 cm^3 of the scale.

Suggest one other step required before the burette is ready to begin the titration. [1 mark]

(iii) Three 25.0 cm^3 samples of sodium hydroxide, NaOH, were titrated with a solution of 0.0517 mol l^{-1} oxalic acid, $(COOH)_2$.

The results are shown in the table.

Sample	Volume of oxalic acid used (cm^3)
:::::::::::	:::::::::::::::::::::::
1	27.4
2	27.0
3	26.9

(A) State why the volume of oxalic acid used in the calculation was taken to be 26.95 cm^3, although this is not the average of the three titre volumes in the table. [1 mark]

(B) Calculate the concentration, in mol l^{-1}, of the sodium hydroxide solution. [3 arks]

[Braille page 23]

$(COOH)_2\ (aq) + 2NaOH\ (aq) \rightarrow 2H_2O(l) + (COONa)_2\ (aq)$

(C) The sodium salt of oxalic acid produced in the reaction has the formula $(COONa)_2$.

Describe a structural formula for the sodium salt of oxalic acid. [1 mark]

ow * 12. Flame emission spectroscopy is a method of chemical analysis used to identify the elements present in a sample and determine their concentrations.

The sample is vaporised in a flame. Heat energy from the flame excites electrons in atoms to higher energy levels. When the excited electrons fall back to lower energy levels, light is emitted which is detected by the spectrometer.

Each element emits light as a pattern of characteristic wavelengths called an emission spectrum.

(a) Refer to the diagram for Question 12 (a). The emission spectra for some **[Braille page 24]** elements are shown.

(i) Refer to the diagram for Question 12 (a) (i). A sample of water was analysed and the following emission spectrum was observed.

Name the elements present in this water sample. [1 mark]

(ii) Thallium, Tl, shows only one line in this emission spectrum at 535 nm.

Use the colour wheel in the data booklet to suggest what colour flame thallium would produce. [1 mark]

(b) The concentration of barium ions in a water sample can be determined using flame emission spectroscopy.

(i) Refer to the diagram for Question 12 (b) (i). The emission intensity was measured for a range of solutions with known concentrations of barium ions and a graph was produced.

Using the same procedure, the emission intensity of a sample was measured as 40.

Determine the concentration of barium ions, in mg l^{-1}, in the sample. [1 mark]

(ii) State the term used to describe water containing high levels of dissolved metal ions. [1 mark]

(c) The temperature of the flame **[Braille page 25]** is important. If it is too high, the element will ionise.

(i) Write the equation for the first ionisation energy of helium. [1 mark]

(ii) There is no third ionisation energy value listed for helium in the data booklet.

Explain why this is the case. [1 mark]

[END OF QUESTION PAPER]