Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

11 May 2023

Zone A afternoon | **Zone B** morning | **Zone C** afternoon

Candidate session number

1 hour

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- 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 **[35 marks]**.

Section A	Questions
Answer all questions.	1 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 4
Option B — Biochemistry	5 – 10
Option C — Energy	11 – 13
Option D — Medicinal chemistry	14 – 21

2223 – 6118

27 pages

Section A

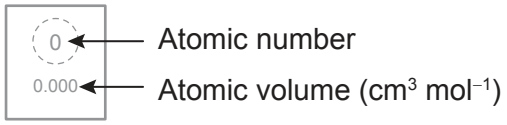
Answer **all** questions. Answers must be written within the answer boxes provided.

1. One definition of atomic volume is given by the formula:

$$\text{Atomic volume} = \frac{\text{atomic mass (g mol}^{-1})}{\text{density (g cm}^{-3})}$$

The table gives the atomic volumes of the first nineteen elements, in the form in which they occur at STP.

Key:



1 11 240							2 22 400
3 13.00	4 4.870	5 4.620	6 5.459 (3.419)	7 11 200	8 11 200 (7460)	9 11 200	10 22 420
11 23.70	12 13.97	13 9.993	14 12.06	15 16.99 (13.24)	16 15.49 (16.36)	17 11 080	18 22 390
19 43.93	20 ?						

(a) Outline why many elements have atomic volumes greater than 10 000 cm^3 mol^{-1}. [1]

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(b) Outline why some of those with larger atomic volumes have values ~11 000 cm^3 mol^{-1} and others ~22 000 cm^3 mol^{-1}. [1]

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(This question continues on the following page)

(Question 1 continued)

(c) Suggest why some elements, such as carbon and oxygen, have more than one value for their atomic volume. [1]

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(d) Explain why the atomic volumes of elements 11, 12 and 13 show a steady decrease. [2]

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(e) Estimate the atomic volume, in $cm^3\ mol^{-1}$, of element 20. [1]

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(f) Suggest, giving **one** reason, whether you could ever know the actual volume of a single atom. [1]

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2. To investigate how much kale would supply the daily recommended intake of iron a student:

1 weighed 79.6 g of kale leaves and blended with 500 cm^3 of water
2 boiled, filtered and cooled
3 pipetted 10.0 cm^3 of the filtrate into 20.0 cm^3 of 2.00 mol dm^{-3} sulfuric acid in a flask
4 titrated with 0.00100 mol dm^{-3} potassium manganate (VII).

The reaction taking place is:

$$5Fe^{2+}(aq) + MnO_4^-(aq) + 8H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(l)$$

(a) All species are almost colourless except for MnO_4^-, which has an intense purple colour, though the kale extract is coloured by the chlorophyll present.

(i) State the colour change at the end point. [1]

From: . . . . . .

To: . . . . . .

(ii) Outline how the addition of distilled water to the 10.0 cm^3 aliquot before titration will affect the titrant volume at the end point. [1]

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(b) State the class of errors that always affect results in a particular direction. [1]

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(This question continues on the following page)

(Question 2 continued)

(c) The end point occurred when $3.1 \pm 0.1\,cm^3$ of the titrant had been added.

(i) Calculate the percentage uncertainty associated with the titre. [1]

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(ii) Suggest **one** procedural modification which would reduce the percentage uncertainty for a single titration, other than using a burette with greater precision. [1]

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(iii) The solution in the titration flask contained 8.66×10^{-4} g of iron. Determine, to three significant figures, the percentage of iron, by mass, in the kale leaves. [2]

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(d) The value obtained is about 30 times greater than published values for the percentage of iron in kale. Suggest **one** reason, other than human error, why there might be such a large discrepancy. [1]

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Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Materials

3. Most metals have to be extracted from an ore. The way in which this is carried out depends on the reactivity of the metal.

(a) Identify a metal produced by reacting its oxide with carbon or carbon monoxide. Use section 25 of the data booklet. [1]

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(b) Aluminium is produced by electrolytic reduction of a solution of aluminium oxide, Al_2O_3, in molten cryolite, Na_3AlF_6.

(i) Write the half equation for the reaction at the electrode where aluminium is formed. [1]

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(ii) Calculate the atom economy for the production of aluminium from its oxide, assuming the products do not react with the electrodes. Use section 1 of the data booklet. [1]

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(iii) Suggest **one** factor, other than atom economy, that indicates the production of aluminium from its ore has a significant environmental impact. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(iv) Deduce why pure molten aluminium oxide is a poor conductor of electricity. Use sections 8 and 29 of the data booklet. [2]

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(c) Inductively coupled plasma (ICP) techniques can be used to estimate the concentration of other metals in the aluminium produced.

(i) Describe the plasma state. [1]

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(ii) Explain how different metals are identified, and their concentrations determined, if ICP is coupled with Optical Emission Spectroscopy (OES). [2]

Identification: . . . . . .

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Concentration: . . . . . .

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(Option A continues on page 9)

Please **do not** write on this page.

Answers written on this page
will not be marked.

(Option A, question 3 continued)

(d) An aluminium matrix can be reinforced with carbon nanotubes. Outline why carbon nanotubes are so strong and rigid. [1]

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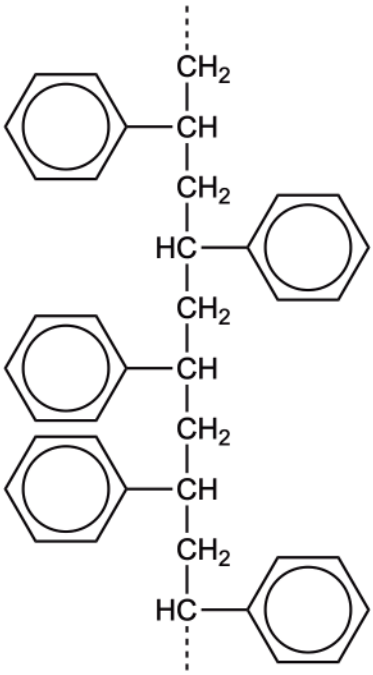
(Option A continues on the following page)

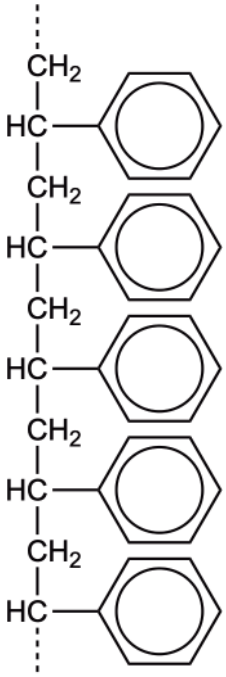
(Option A continued)

4. Sections of two forms of polystyrene are shown:

Polystyrene A



Polystyrene B



(a) (i) Draw the structural formula of the monomer from which they were formed. [1]

(Option A continues on the following page)

(Option A, question 4 continued)

(ii) Identify, giving **one** reason, the form with the higher melting point. [1]

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(b) Explain how a substance in the same phase as the reactants can reduce the activation energy and act as a catalyst. [2]

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(c) Solutions of substituted polystyrenes can form lyotropic liquid crystals. Outline how lyotropic liquid crystals differ from other liquid crystals. [1]

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(Option A continues on page 13)

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will not be marked.

(Option A, question 4 continued)

(d) Expanded polystyrene (EPS) is a useful material.

(i) Explain how polystyrene is converted to EPS. [2]

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(ii) State **one** property of EPS that makes it a useful material. [1]

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(e) Outline why plastics do not break down easily in the environment. [1]

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(f) State the RIC number for polyamide plastic (nylon). Use section 30 of the data booklet. [1]

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End of Option A

Option B — Biochemistry

5. State an equation for aerobic respiration. [1]

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6. Proteins are large polymers of 2-amino acids.

(a) Describe the interactions between amino acids occurring at the primary, secondary and tertiary levels within a protein. [3]

Structure Level	Interactions between amino acids
Primary	. . . . .
Secondary	. . . . .
Tertiary	. . . . .

(b) Explain how paper chromatography can separate and identify mixtures of amino acids. [2]

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(Option B continues on the following page)

(Option B continued)

7. Lipids are another group of biomolecules.

(a) Compare the hydrolytic and oxidative rancidity and contrast the site where the chemical changes occur. [2]

Compare rancidity: . . . . . .

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Contrast reaction site: . . . . . .

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(b) Calculate the iodine number for ozubondo acid, $C_{21}H_{33}COOH$. [2]

$M_r = 330.56$

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(c) Explain **two** ways in which carbohydrates and lipids differ as sources of energy. [2]

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(Option B continues on the following page)

(Option B, question 7 continued)

(d) Explain why stearic acid has a higher melting point than linoleic acid based on their structural differences. Use section 34 of the data booklet. [2]

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8. (a) Identify the type of bond and by-product when monosaccharides combine. [2]

Bond: . . . . . .

By-product: . . . . . .

(b) Calculate the energy produced from the combustion of 15.00 g of sucrose, $C_{12}H_{22}O_{11}$. [2]

$$\Delta H_c = -5640\,\text{kJ mol}^{-1}$$

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(Option B continues on the following page)

(Option B continued)

9. Outline why we need vitamins/micronutrients in our diets. [1]

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10. Outline how the toxicity of xenobiotics is reduced using host–guest chemistry. [1]

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End of Option B

Option C — Energy

11. (a) Photosynthesis enables green plants to store energy from sunlight as glucose.

(i) Write the equation for photosynthesis. [1]

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(ii) Identify the structural feature that allows chlorophyll to absorb light.
Use section 35 of the data booklet. [1]

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(iii) Explain how photosynthesis is being employed to control global warming. [2]

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(Option C continues on the following page)

(Option C, question 11 continued)

(b) Glucose can be converted to ethanol through fermentation:

$$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

(i) Determine the energy efficiency of this conversion in terms of the enthalpies of combustion of the reactants and products. Use section 13 of the data booklet. [1]

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(ii) Suggest **one** reason, other than energy density and specific energy, why ethanol may be considered a more useful fuel than glucose. [1]

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(Option C continues on the following page)

(Option C continued)

12. Geological transformations produce fossil fuels.

(a) Combustion of coal emits particulates into the atmosphere.

(i) Outline why this affects global warming. [1]

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(ii) State the major form of energy produced by the combustion of coal. [1]

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(b) Conversion of petroleum to petrol (gasoline) involves fractional distillation and cracking.

Distinguish between these processes. [2]

Fractional distillation: . . . . . .
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Cracking: . . . . . .
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(Option C continues on the following page)

(Option C, question 12 continued)

(c) The equation for the combustion of octane is:

$$C_8H_{18}(l) + 12\frac{1}{2}O_2 \rightarrow 8CO_2(g) + 9H_2O(l)$$

(i) Determine the mass of carbon dioxide, in g, produced when 1 kJ of energy is produced. Use section 13 of the data booklet. [3]

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(ii) Suggest a piece of evidence that leads some people to not accept a causal link between the industrial emission of greenhouse gases, such as CO_2, and global warming. [1]

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(Option C continues on the following page)

(Option C continued)

13. Both fission and fusion reactions are potential sources of nuclear energy.

(a) Compare and contrast the nuclear changes and products formed in these processes giving **one** similarity and **one** difference. [2]

Similarity: . . . . . .

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Difference: . . . . . .

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(b) Uranium is the most common fuel for fission reactors, but only ^{235}U undergoes fission.

State a process that could be used to determine the relative percentages of ^{235}U and ^{238}U in a sample of uranium. [1]

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(Option C continues on the following page)

(Option C, question 13 continued)

(c) Some reactors convert ^{238}U into another nucleus that can also undergo fission.

(i) Complete the equation for this process by identifying the reacting particle, **X**, and the isotope formed, **Y**. [2]

$$^{238}U + \mathbf{X} \rightarrow {}^{239}U \rightarrow \mathbf{Y} + 2\,{}^{0}\beta^{-}$$

X: . . . . . .

Y: . . . . . .

(ii) The intermediate, ^{239}U, has a half-life of 23 minutes. Outline what is meant by half-life. [1]

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End of Option C

Option D — Medicinal chemistry

14. Outline how these drug administration methods affect bioavailability. [2]

Oral: . . . . . .

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Intravenous: . . . . . .

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15. Aspirin is most commonly used as a mild analgesic. State **two** other common medical uses for aspirin. [2]

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16. Suggest **two** reasons why the penicillin side-chain is modified. [2]

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(Option D continues on the following page)

(Option D continued)

17. Opioids are a class of compounds that includes morphine and codeine.

(a) Explain how strong analgesics like morphine work. [2]

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(b) Outline why codeine is a weaker analgesic than morphine. [1]

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(Option D continues on the following page)

(Option D continued)

18. Aluminium hydroxide and ranitidine can be used to relieve indigestion.

(a) (i) Write an equation for the reaction of aluminium hydroxide with stomach acid. [1]

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(ii) Calculate the mass, in g, of aluminium hydroxide needed to neutralize 100.0 cm^3 of 5.00×10^{-3} mol dm^{-3} stomach acid. [2]

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(b) Explain how ranitidine (Zantac®) can also relieve excess stomach acid. [2]

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(Option D continues on the following page)

(Option D continued)

19. Explain **two** different ways antiviral medications work. [2]

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20. Distinguish between the hazards of high-level and low-level nuclear waste. [2]

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21. The production of many pharmaceutical drugs involves the use of solvents.

(a) State **one** problem associated with chlorinated organic solvents as chemical waste. [1]

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(b) Suggest how the principles of green chemistry can be used to overcome the environmental problems caused by organic solvents. [1]

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End of Option D

References: