



88136106

**CHEMISTRY**  
**STANDARD LEVEL**  
**PAPER 3**

Candidate session number

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Tuesday 19 November 2013 (morning)

Examination code

1 hour

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**INSTRUCTIONS TO CANDIDATES**

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the 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 [40 marks].

Option	Questions
Option A — Modern analytical chemistry	1 – 4
Option B — Human biochemistry	5 – 7
Option C — Chemistry in industry and technology	8 – 10
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Option E — Environmental chemistry	15 – 18
Option F — Food chemistry	19 – 21
Option G — Further organic chemistry	22 – 24



40EP01

**Option A — Modern analytical chemistry**

1. Magnetic resonance imaging (MRI) is a diagnostic technique in which protons, in water and other molecules inside a patient, interact with a magnetic field.

(a) State the property of protons that allows them to be detected by MRI. [1]

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(b) State **one** advantage, other than reducing health risks, of using MRI rather than X-ray radiography. [1]

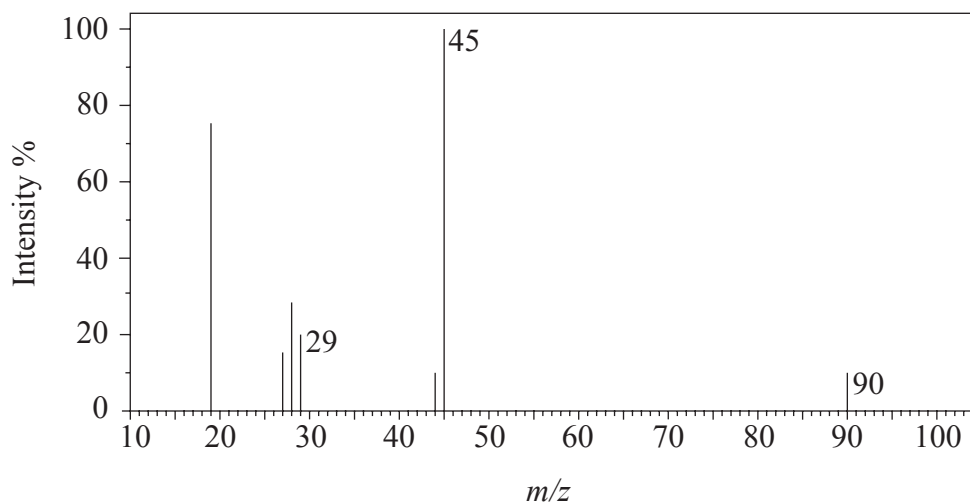
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*(Option A continues on the following page)*



(Option A continued)

2. (a) The mass spectrum of an unknown acidic compound, X, with empirical formula  $\text{CH}_2\text{O}$ , is shown below.



- (i) Determine the relative molecular mass, to the nearest integer, of the compound from the mass spectrum and deduce the formula of the molecular ion. [2]

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- (ii) Deduce the formula of the fragment responsible for the peak at 45. [1]

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- (iii) Deduce the formula of the fragment responsible for the peak at 29. [1]

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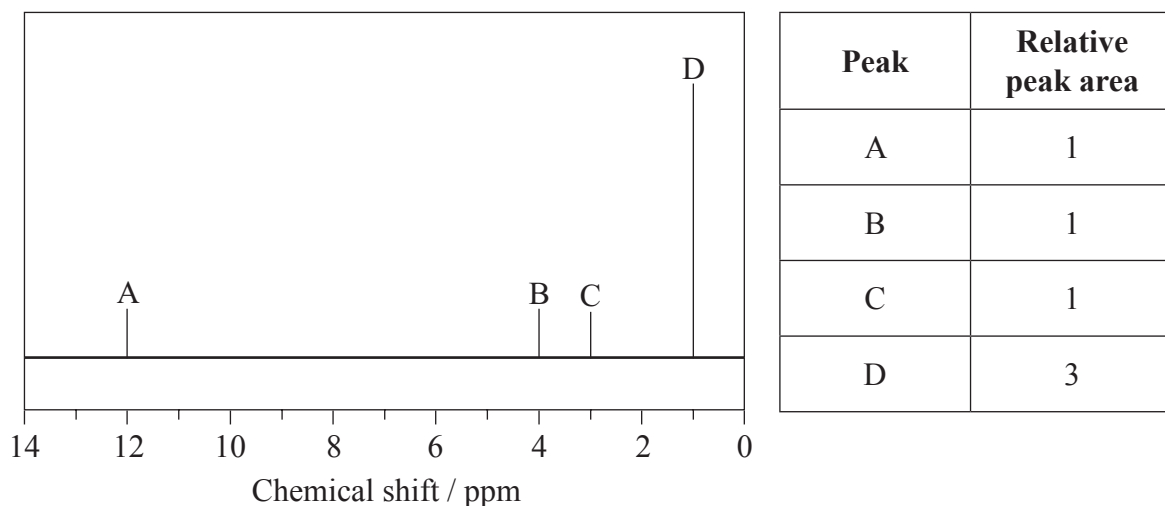
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(Option A continues on the following page)



(Option A, question 2 continued)

- (b) The low-resolution  $^1\text{H}$ NMR spectrum of **X** shows four peaks. A simplified representation is shown alongside a table with relative peak areas.



- (i) Identify the group responsible for the peak at **D**. [1]

.....

- (ii) Suggest a possible structure for **X**. [1]

(Option A continues on the following page)



(Option A, question 2 continued)

- (c) Infrared (IR) spectroscopy is widely used as a technique in analytical chemistry to show the presence of chemical bonds. Explain what happens at a molecular level during the absorption of IR radiation by the C–H bonds in an organic molecule. [2]

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3. Paper chromatography and thin-layer chromatography (TLC) can both be used to separate and analyse a mixture of amino acids.

- (a) Compare the two techniques by completing the following table. [3]

	Partition/adsorption	Mobile phase	Stationary phase
Paper			
TLC			

- (b) State **one** advantage of using TLC rather than paper chromatography. [1]

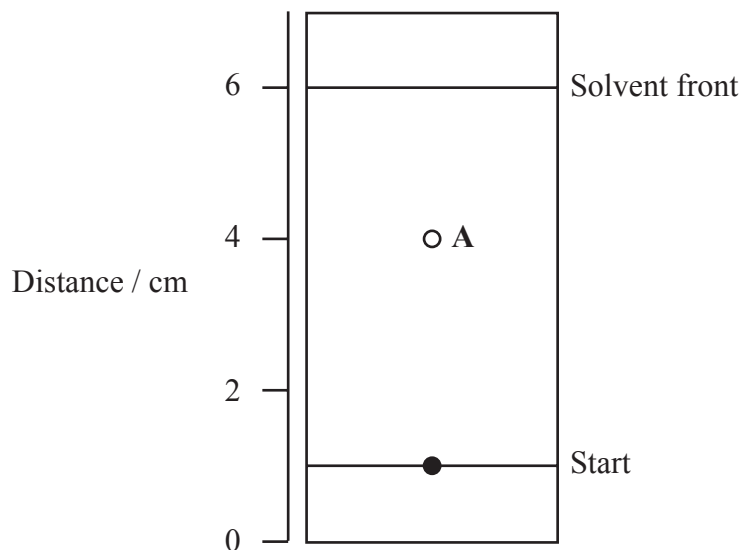
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(Option A continues on the following page)



(Option A, question 3 continued)

- (c) Amino acids can be identified by their retention factor ( $R_f$  value). Calculate the  $R_f$  value of the amino acid, **A**, from the chromatogram below. [1]



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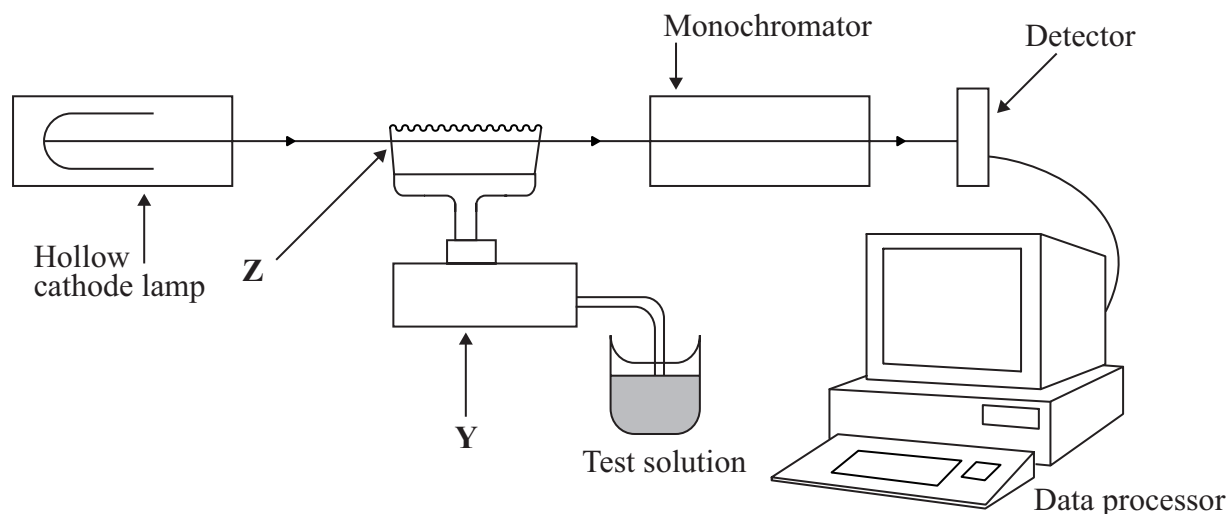
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(Option A continues on the following page)



(Option A continued)

4. Aluminium salts are widely used in water treatment, but levels need to be continually monitored because high exposure to  $Al^{3+}$  ions may increase the risk of Alzheimer's disease. A sample of drinking water was analysed using atomic absorption (AA) spectroscopy. A simplified diagram of the AA spectrometer is shown below.



- (a) Outline the essential characteristics of the hollow cathode lamp. [1]

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- (b) Describe the changes that the sample undergoes at Y and Z. [2]

**Y:** .....  
.....  
**Z:** .....  
.....

(Option A continues on the following page)

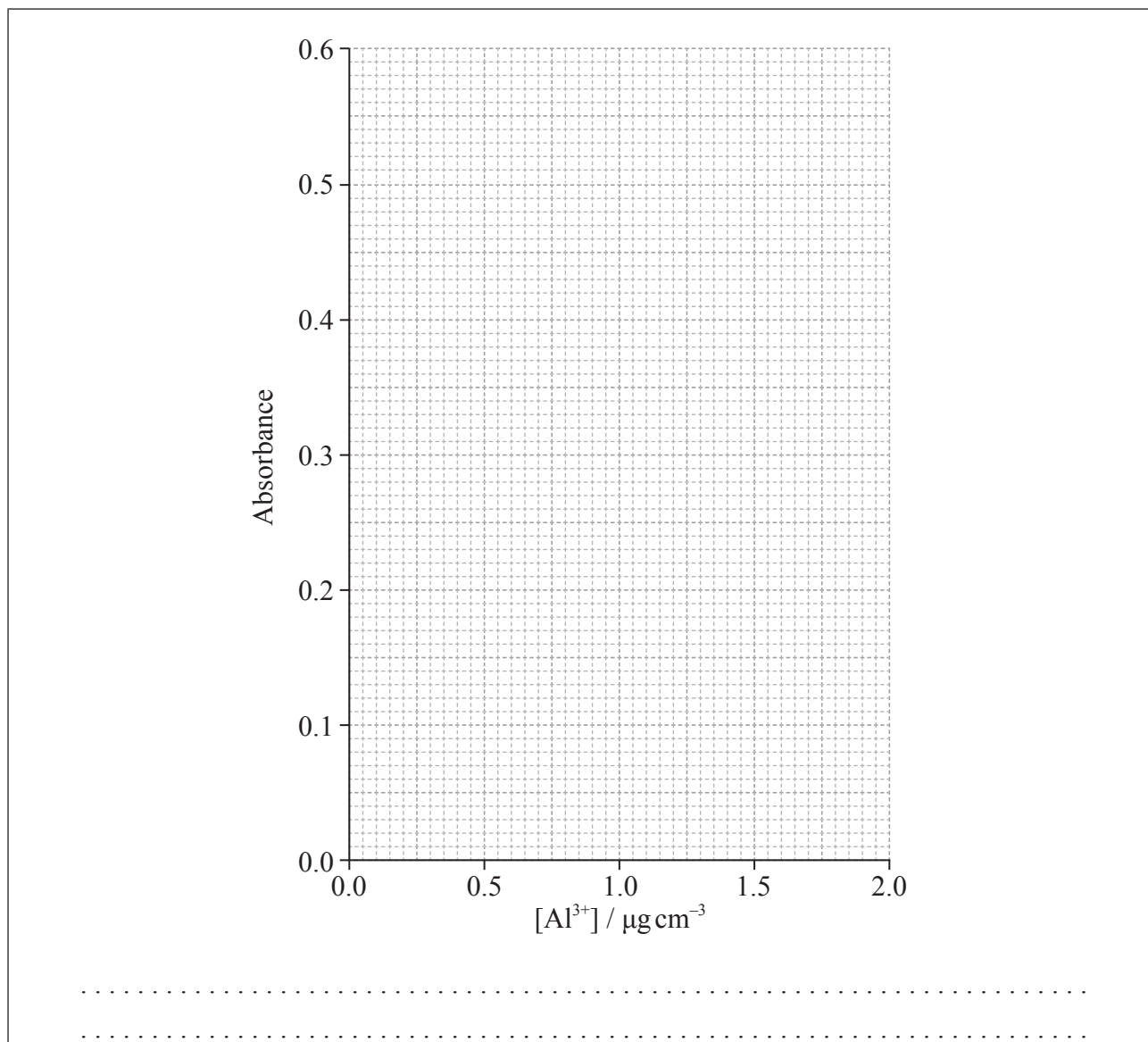


(Option A, question 4 continued)

(c) The AA spectrometer was calibrated and the following results were obtained.

$[\text{Al}^{3+}] / \mu\text{g cm}^{-3}$	Absorbance ( $\lambda_{\text{max}} = 535 \text{ nm}$ )
0.00	0.00
0.50	0.15
0.75	0.22
1.00	0.29
1.50	0.44
2.00	0.58
Unknown sample	0.49

Draw a calibration curve on the grid provided and determine the concentration, in  $\mu\text{g cm}^{-3}$ , of  $\text{Al}^{3+}$  ions in the unknown sample. [2]



**End of Option A**





**Option B — Human biochemistry**

5. Vitamins are organic micronutrients essential for good health. The structures of vitamins A, C and D are given in Table 21 of the Data Booklet.

(a) Identify by name **two** functional groups that are common to all three of these vitamins. [1]

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(b) Only one of these three vitamins is soluble in water.

(i) Identify this vitamin. [1]

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(ii) Explain why this vitamin is soluble in water. [2]

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*(Option B continues on the following page)*



*(Option B, question 5 continued)*

(c) Vitamin D is the only vitamin that can be synthesized in the body, by the action of sunlight on the skin.

(i) State **one** effect of vitamin D deficiency. [1]

.....

(ii) Suggest why vitamin D deficiency diseases are becoming increasingly common in young people. [1]

.....  
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6. Proteins are polymers of 2-amino acids. The structures of the common amino acids are given in Table 19 of the Data Booklet. This question refers to the two amino acids alanine and cysteine.

(a) State the structural formula of cysteine as a zwitterion. [1]

*(Option B continues on the following page)*



(Option B, question 6 continued)

(b) With reference to the isoelectric points of alanine and cysteine:

(i) identify a pH value where both amino acids would be positively charged. [1]

.....

(ii) describe with a reason what pH value would be suitable to use in an electrophoresis experiment designed to separate these two amino acids in solution. [2]

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(c) Cysteine is responsible for a specific type of intra-molecular bonding within a protein molecule. State the name of this type of interaction and outline how it is different from other interactions responsible for the tertiary structure. [2]

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(d) State **three** functions of proteins in the body and include a named example for each. [3]

	Function	Named example
1.		
2.		
3.		

(Option B continues on the following page)



(Option B continued)

7. The following products result from the hydrolysis of a triglyceride.



(a) Draw a possible structure for the triglyceride. [1]

(b) State the other reactant and one essential condition that would favour this hydrolysis reaction in the body. [1]

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(c) Identify which product is polyunsaturated, and outline why foods containing this type of fatty acid are important for health. [2]

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(d) People who live in very cold regions need a diet with a higher ratio of fat to carbohydrate than people who live in warmer climates. Suggest why this is the case. [1]

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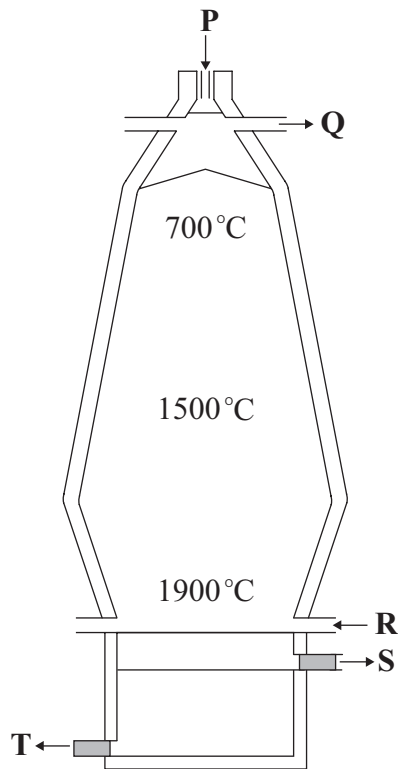
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**End of Option B**



**Option C — Chemistry in industry and technology**

8. Iron ore can be reduced in a blast furnace.



- (a) (i) State the name of an iron ore used and identify which letter, in the diagram above, shows where the iron ore is added. [1]

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- (ii) State the names of the other raw materials needed for the process. [1]

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*(Option C continues on the following page)*



**Turn over**

*(Option C, question 8 continued)*

- (b) The temperature in the furnace rises to 1900 °C. State the equation, including state symbols, for the reaction that causes this high temperature. [1]

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- (c) (i) State the name of substance S. [1]

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- (ii) Deduce an equation for the formation of S from the raw materials. [1]

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- (d) The iron produced in the blast furnace contains carbon impurities. State how the percentage of carbon is decreased by further treatment. [1]

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*(Option C continues on the following page)*



*(Option C, question 8 continued)*

(e) The properties of a metal can be altered by alloying or heat treatment.

(i) Explain why alloying can modify the structure and properties of a metal. [2]

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(ii) Describe the effect of the tempering process on steel. [1]

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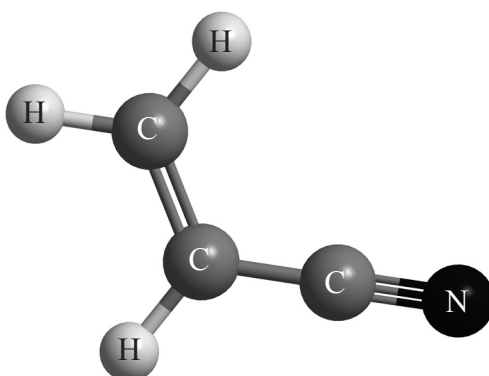
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*(Option C continues on the following page)*



(Option C continued)

9. Polyacrylonitrile is an important polymer used in the manufacture of carbon fibres. The monomer has the structure below.



- (a) Polyacrylonitrile is similar to polypropene and can exist in two forms.

- (i) Draw the structure of the isotactic form of polyacrylonitrile showing **three** repeating units. [2]

- (ii) Explain why the isotactic form is more suitable for the manufacture of strong fibres. [2]

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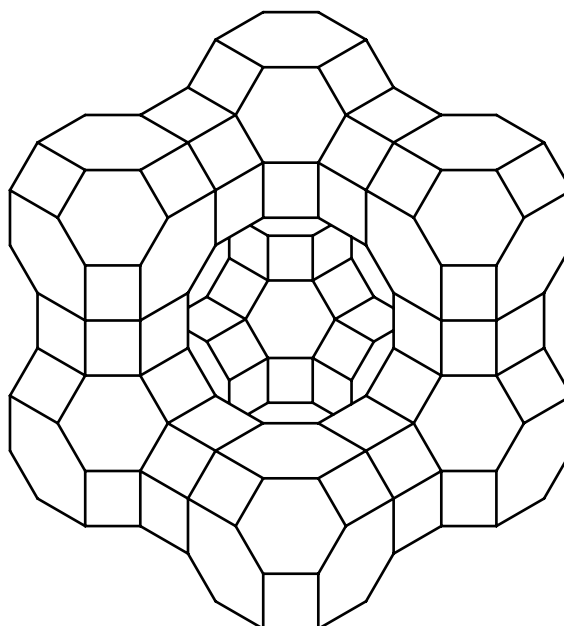
(Option C continues on the following page)





(Option C, question 9 continued)

- (b) The rate of the polymerization reaction from the gaseous monomer is increased in the presence of a zeolite with the cage structure shown.



- (i) Identify the role of the zeolite in the reaction. [1]

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- (ii) Suggest an explanation for its efficiency in favouring the production of the crystalline polymer. [1]

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(Option C continues on the following page)



(Option C, question 9 continued)

- (c) A new range of light batteries has been developed that uses open carbon nanotubes, covered with silicon, as electrodes.

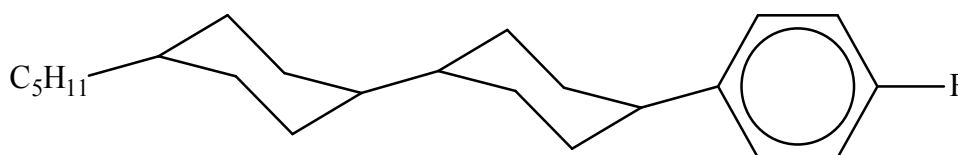
- (i) Outline the structure of the open carbon nanotubes. [1]

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- (ii) State a property of these nanotubes that makes them suitable for this use. [1]

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10. Liquid-crystal displays are used in many electronic appliances. The molecule below has liquid-crystal display properties.



- Suggest **three** reasons why the molecule is suitable for use in liquid-crystal display devices. [3]

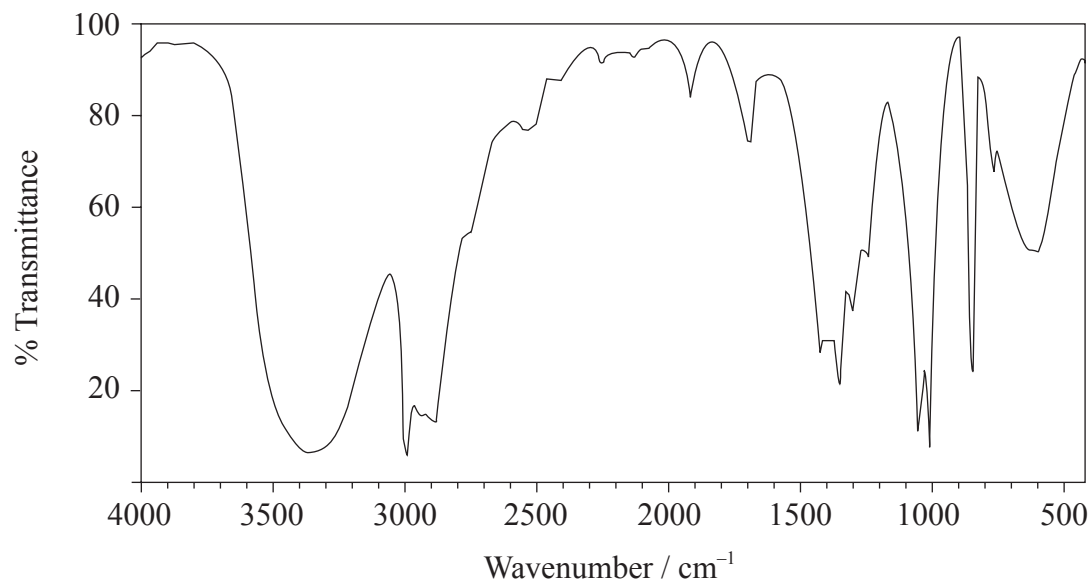
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**End of Option C**



**Option D — Medicines and drugs**

11. A modern method for accurately determining ethanol concentrations in the breath is based on the infrared (IR) spectrum of the molecule.



- (a) (i) Use Table 17 of the Data Booklet to identify the wavenumber range used in the determination. [1]

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- (ii) State why the absorption in the range 3200 to 3600  $\text{cm}^{-1}$  is not used. [1]

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*(Option D continues on the following page)*



*(Option D, question 11 continued)*

- (b) The concentration of ethanol is determined by passing IR radiation through a breath sample. Outline how the transmittance of IR radiation changes when increased levels of ethanol are present. [1]

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- (c) (i) Outline why it can be dangerous to drink ethanol when taking other drugs. [1]

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- (ii) State the name of a drug and the dangerous effect it can have when taken with ethanol. [1]

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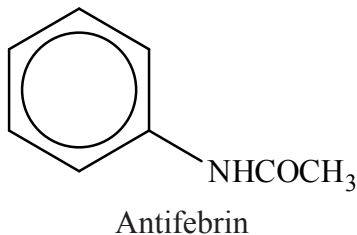
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*(Option D continues on the following page)*



(Option D continued)

12. The drug Antifebrin was first used as a medicine in 1886.



(a) The structures of some medicines and drugs are given in Table 20 of the Data Booklet.

(i) Identify the molecule which is most similar to Antifebrin in terms of size and structure. [1]

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(ii) State the names of the **two** functional groups that both molecules have in common. [1]

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(b) The action of a drug can depend on its polarity and shape, so similar molecules can have similar effects on the body. Suggest **one** physiological effect of taking Antifebrin. [1]

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(c) The therapeutic window is used as a measure of the safety of a drug. Define the term *therapeutic window*. [1]

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(Option D continues on the following page)



*(Option D continued)*

13. Aluminium hydroxide and calcium carbonate are both used as antacids.

- (a) State an equation for the reactions that occur in the stomach for both substances with hydrochloric acid. [2]

Aluminium hydroxide:

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Calcium carbonate:

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- (b) A typical antacid tablet has a mass of about 1 g. Determine which of the two antacids will neutralize the greater amount of hydrochloric acid if tablets of each are added to separate samples of acid. A detailed calculation is not required. [2]

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- (c) Potassium hydroxide also neutralizes hydrochloric acid. Suggest why it is not used as an antacid. [2]

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*(Option D continues on the following page)*



*(Option D, question 13 continued)*

- (d) Clinical tests have shown that patients can benefit from taking sugar pills if they believe they have medicinal properties. Studies have shown, for example, that four sugar pills are more effective in the treatment of gastric ulcers than two. Outline the importance of the placebo effect in drug development. [2]

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- 14. Acquired immune deficiency syndrome (AIDS), a disease caused by the HIV virus, has resulted in millions of deaths worldwide since it was first identified in 1981.

Explain why viral infections, such as AIDS, are generally more difficult to treat than bacterial infections. [3]

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**End of Option D**



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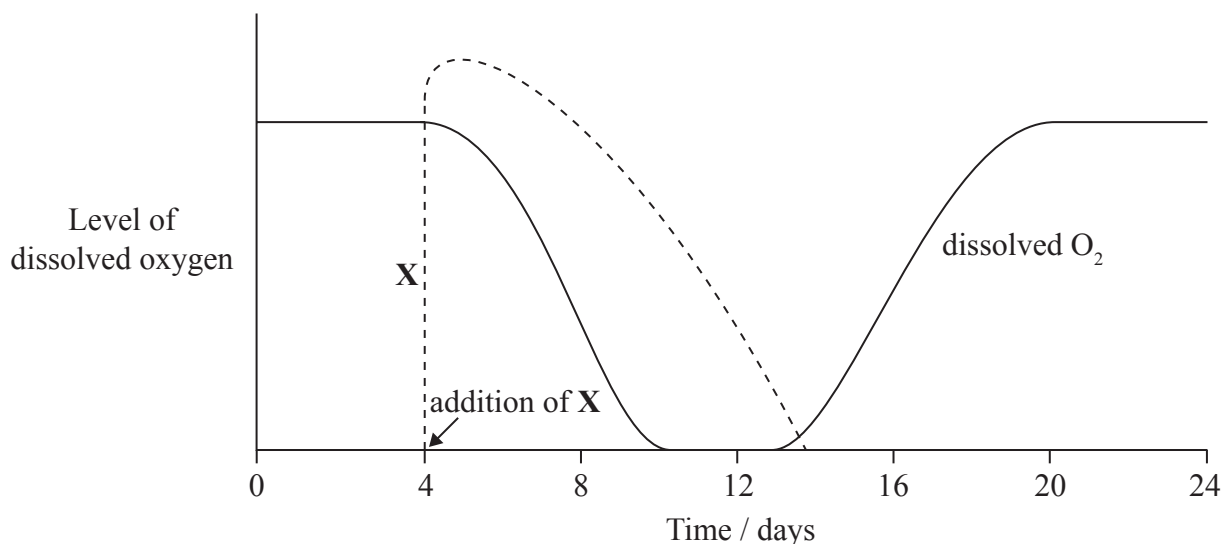
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**Option E — Environmental chemistry**

15. (a) Outline the meaning of the term *biochemical oxygen demand* (BOD). [2]

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(b) The graph below shows the level of dissolved oxygen measured in the same location in a stream over a period of 24 days. The dashed line represents the concentration of substance **X** in the stream, which was introduced after 4 days.



(i) State a possible identity for **X**. [1]

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*(Option E continues on the following page)*





(Option E, question 15 continued)

(ii) Outline why the concentration of dissolved oxygen falls between days 4 and 9. [1]

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(iii) Describe why the concentration of dissolved oxygen changes between days 12 and 18. [2]

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(iv) Identify the days during which the population of anaerobic bacteria will be highest. [1]

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(c) A student did an experiment using digital probes to measure the effect of temperature on the concentration of dissolved oxygen in the stream. Sketch a graph of her expected results using the axes below. [1]



(Option E continues on the following page)



40EP25

Turn over

*(Option E continued)*

16. Soil degradation is a global problem that can lead to a reduction in food production.

(a) One factor that contributes to soil degradation is salinization.

(i) Describe the cause of salinization.

[1]

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.....

(ii) Explain its effect on the fertility of the soil.

[2]

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(b) The extent of soil degradation can be reduced by increasing the soil organic matter (SOM). Describe how the physical and biological functions of SOM improve the quality of the soil.

[2]

Physical:  
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.....  
.....

Biological:  
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*(Option E continues on the following page)*



(Option E, question 16 continued)

- (c) From your answer to (b), suggest **one** specific change in agricultural practice that would be beneficial to soil. [1]

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17. The normal pH of rainwater is 5.6, but in some parts of the world rainwater has been recorded with a pH of several units lower than this. This is associated with harmful effects on living and non-living things.

- (a) The decrease in the pH of rainwater is mainly caused by oxides of non-metals, principally nitrogen and sulfur. State chemical equations that show how the primary pollutant nitrogen(II) oxide can produce **two** different acids containing nitrogen. [2]

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- (b) Explain, including an equation, the effect of the acid rain produced in (a) on certain stone buildings. [2]

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(Option E continues on the following page)



Turn over

*(Option E continued)*

- 18.** Many countries obtain at least some of their power from nuclear energy. This process results in the production of waste, which can be classified as low-level or high-level radioactive waste. State **one** source of low-level radioactive waste, and a suitable method for its storage and/or disposal. [2]

<p>Source:</p> <p>.....</p> <p>.....</p> <p>Storage/disposal method:</p> <p>.....</p> <p>.....</p>
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**End of Option E**



**Option F — Food chemistry**

19. (a) Define the term *antioxidant*. [1]

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(b) The structures of three synthetic antioxidants, 2-BHA, 3-BHA and BHT, are given in Table 22 of the Data Booklet.

(i) Identify by name **two** functional groups common to all **three** molecules. [1]

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(ii) Suggest why all three molecules contain *tert-* in the prefix of their name. [1]

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(iii) Deduce the molecular formula of BHT. [1]

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*(Option F continues on the following page)*



*(Option F, question 19 continued)*

(c) Many foods contain natural antioxidants, such as  $\beta$ -carotene.

(i) State **two** examples of foods which contain large amounts of  $\beta$ -carotene. [1]

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(ii) State the names of **two** other natural antioxidants, not including  $\alpha$ -carotene. [1]

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(d) Different countries have different guidelines on the use of synthetic antioxidants as food additives. Suggest **one** reason why synthetic antioxidants should **not** be added to foods. [1]

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*(Option F continues on the following page)*



(Option F continued)

20. Stearic acid, oleic acid and linolenic acid are all fatty acids that contain 18 carbon atoms. Their structures are given in Table 22 of the Data Booklet.

(a) Explain which acid has the highest melting point. [3]

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(b) State the equation for the complete hydrogenation of linolenic acid. Describe the conditions used for this reaction. [2]

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(c) Partial hydrogenation of linolenic acid may lead to a product known as a *trans* fatty acid.

(i) Draw the structure of a possible *trans* fatty acid product. [1]

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(Option F continues on the following page)



(Option F, question 20 continued)

- (ii) Discuss **two** potential problems or health concerns associated with *trans* fatty acids. [2]

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21. Many food substances involve different types of dispersed systems.

- (a) State the meaning of a *dispersed system*. [1]

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- (b) (i) Distinguish between an *emulsion* and a *foam*. [1]

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(Option F continues on the following page)





(Option F, question 21 continued)

(ii) Identify **one** emulsion and **one** foam from the following list of foods:

- |        |                   |               |
|--------|-------------------|---------------|
| BEER   | CREAM (UNWHIPPED) | UNCOOKED RICE |
| BUTTER | JAM               | WHIPPED CREAM |

[1]

Emulsion: ..... Foam: .....
--------------------------------------

(c) The preparation of some food substances involves the addition of chemicals to modify the texture of the food.

(i) Distinguish between the action of an *emulsifier* and a *stabilizer*.

[1]

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(ii) Outline the structural features you would expect an emulsifier to possess.

[1]

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**End of Option F**



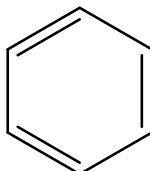
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Turn over

**Option G — Further organic chemistry**

22. The bonding in benzene is one of the most challenging problems for chemists interested in explaining the bonding and structure of covalent molecules.

- (a) The structure of benzene was originally represented by the German chemist August Kekulé as:



- (i) Explain why this structure is considered to be incorrect, using information from Table 9 of the Data Booklet. [2]


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- (ii) Cyclohexene reacts with hydrogen to form cyclohexane.



Estimate the enthalpy change, in  $\text{kJ mol}^{-1}$ , for the hydrogenation of benzene to cyclohexane, assuming it has the  structure. [1]

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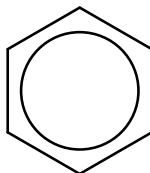
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*(Option G continues on the following page)*



(Option G, question 22 continued)

- (b) The experimental value for the hydrogenation of benzene to cyclohexane is  $-205 \text{ kJ mol}^{-1}$ , which is not consistent with the Kekulé structure. A different structure for benzene that accounts for this value is shown below.



- (i) Outline what the circle represents in the diagram. [1]

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- (ii) Describe how the structure accounts for the C–C bond length in Table 9 of the Data Booklet. [1]

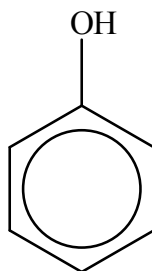
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(Option G continues on the following page)



(Option G, question 22 continued)

- (c) Phenol, which is also known as carboic acid, was one of the first antiseptics used in medical surgery.



- (i) Explain why phenol is a stronger acid than ethanol. [2]

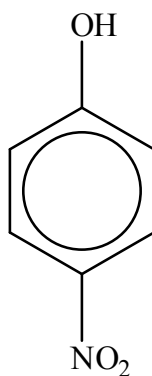
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- (ii) Explain how the presence of a nitro, NO<sub>2</sub>, group on the benzene ring increases the acidity of the OH group in the molecule below.



[2]

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(Option G continues on the following page)



*(Option G continued)*

23. 2-chloropropane is the major product of the reaction between propene and hydrogen chloride.

(a) State the mechanism by which this reaction occurs. [1]

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(b) Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. [4]

(c) Outline why 2-chloropropane is the major organic product of this reaction. [2]

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*(Option G continues on the following page)*



(Option G continued)

24. Victor Grignard was awarded the Nobel Prize in 1912 for the use of organomagnesium compounds in preparative organic chemistry.

- (a) (i) State the structural formula of the Grignard reagent formed when bromoethane and magnesium react together in a non-polar solvent. [1]

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.....

- (ii) Outline why water is not used as a solvent in this reaction. [1]

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.....

(b) Deduce the reagents required to convert the Grignard reagent in (a) (i) into:

- (i)  $\text{CH}_3\text{CH}_2\text{COOH}$  [1]

.....  
.....

- (ii)  $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{OH}$  [1]

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**End of Option G**



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40EP39

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