22126109

International Baccalaureate®
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**CHEMISTRY**
**HIGHER LEVEL**
**PAPER 3**

Candidate session number

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Wednesday 9 May 2012 (morning)

1 hour 15 minutes

Examination code

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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 *[50 marks]*.

0140

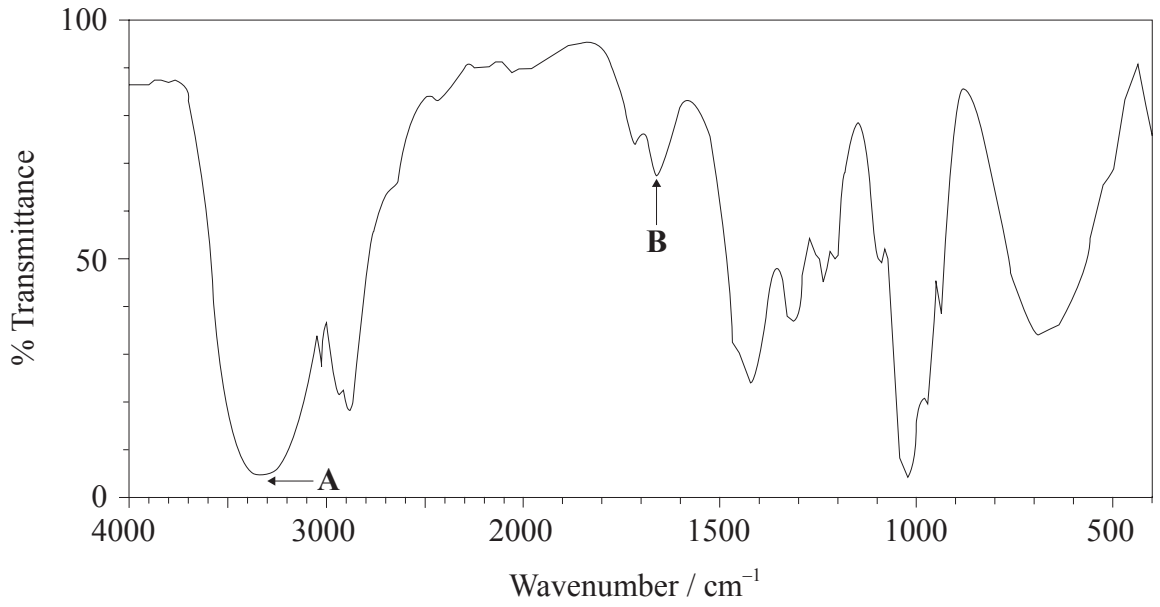
**Option A — Modern analytical chemistry**

**A1.** Analytical techniques are very useful in determining molecular structures. A compound, **X**, has the empirical formula $C_2H_4O$.

(a) Identify the analytical technique that would most readily provide the additional data required to calculate the molecular formula of **X**. *[1]*

. . . . . .

(b) The molecular formula of **X** is $C_4H_8O_2$. The information in the IR spectrum below can be used to help determine the structure of **X**.




(i) Deduce the information obtained from absorptions **A** and **B**. *[2]*

**A**: . . . . . .

**B**: . . . . . .

*(This question continues on the following page)*

*(Question A1 continued)*

(ii) Comment on the absence of any major absorption in the region 1700–1750 $cm^{-1}$. *[1]*

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(c) The $^1H$ NMR spectrum of **X** shows three peaks with relative areas of 2:1:1.

(i) Deduce what information can be obtained from these data. *[2]*

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(ii) Deduce the structure of **X**. *[2]*

(d) Peaks in a $^1H$ NMR spectrum are measured relative to a reference standard. State the name of a substance used and identify **one** property that makes it particularly suitable for this application. *[2]*

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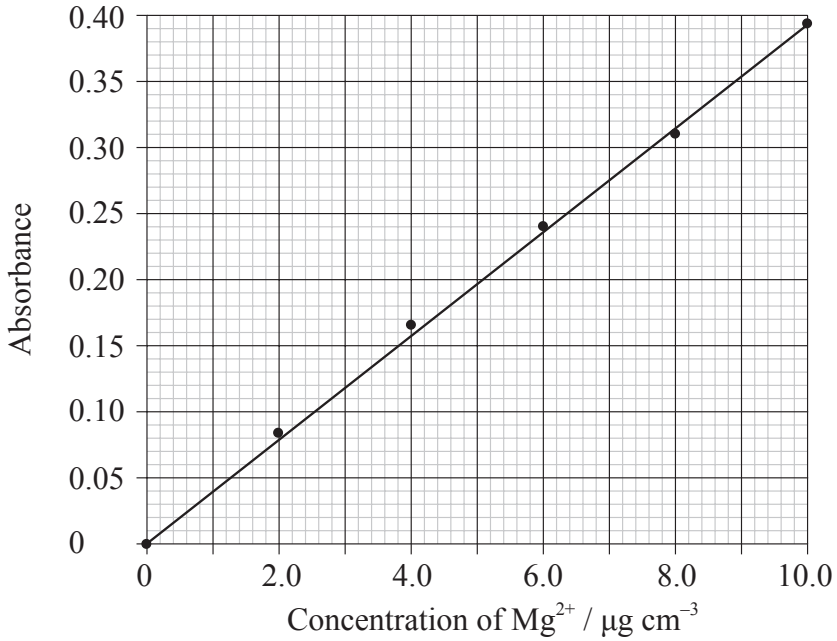
**A2.** Atomic absorption spectroscopy is frequently used to determine the concentration of metal ions in aqueous solution.

(a) Atomic absorption spectroscopy was used to determine the concentration of magnesium in cast iron. Solutions of known concentration were used for calibration.




When a 0.200 g sample of cast iron was dissolved in acid to produce 100 $cm^3$ of solution, the absorbance of the resulting solution was 0.131. Calculate the percentage by mass of magnesium in the sample. *[3]*

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(b) The same sample is also analysed for calcium. Identify the change to the instrument that is required. *[1]*

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**A3.** Chromatography is a technique frequently used to separate mixtures of substances.

(a) Describe how you would show that a sugar solution was a mixture of two substances using the technique of thin-layer chromatography (TLC). *[3]*

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(b) Given solutions of glucose and fructose, explain how you would show that these were the two sugars present in the mixture. *[2]*

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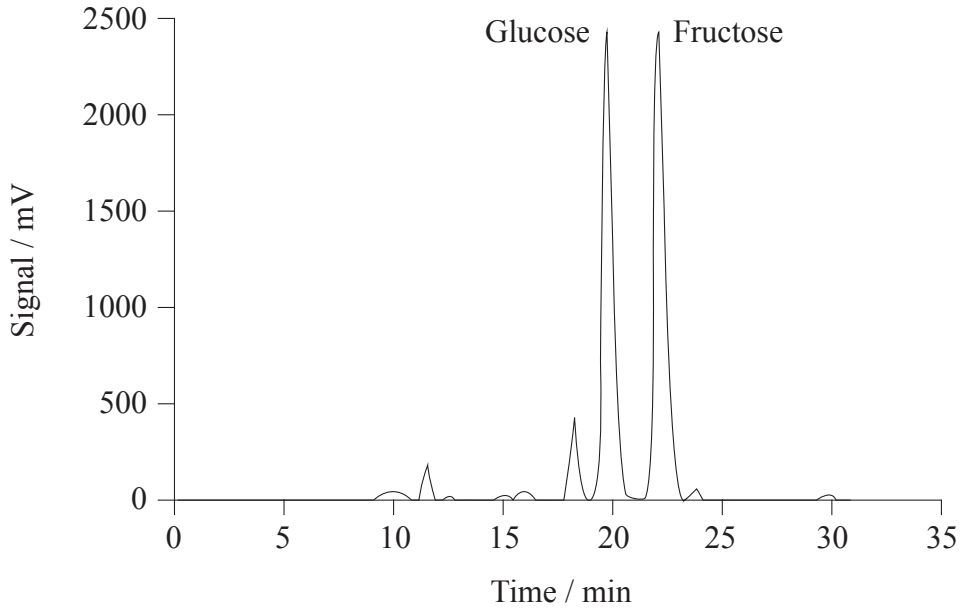
*(This question continues on the following page)*

*(Question A3 continued)*

(c) The relative amounts of these two sugars can also be determined by high-performance liquid chromatography (HPLC). The chromatogram below was produced when a sample of apple juice was analysed.




(i) State what happened to the sample at time zero. *[1]*

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. . . . . .

(ii) Glucose elutes from the column before fructose. State what this shows about the bonding of these sugars in the phases present. *[1]*

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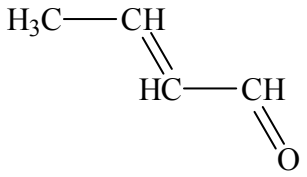
**A4.** The molecule **Y**, shown below, absorbs ultraviolet (UV) radiation.



(a) (i) Identify the structural feature of **Y** that causes the molecule to absorb UV radiation. *[1]*

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. . . . . .

(ii) Describe the changes that occur in the molecule as a result of this absorption. *[1]*

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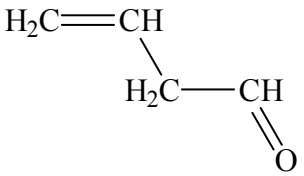
(b) **Z** is an isomer of **Y**.



Predict how the UV spectrum of **Z** differs from that of **Y** and explain your reasoning. *[2]*

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**Option B — Human biochemistry**

**B1.** A large proportion of the food we eat provides energy through the process of respiration. Carbohydrates and triglycerides are the food groups mainly responsible for providing this energy.

(a) When the diet contains too much carbohydrate the body stores it. State the name of the carbohydrate that the body uses as a reserve store of energy. *[1]*

. . . . . .

(b) The major function of triglycerides is the provision of energy. State the name of **one** other type of lipid found in the body and **one** role, other than energy storage, of this type of lipid. *[2]*

Name:

. . . . . .

. . . . . .

Role:

. . . . . .

. . . . . .

(c) Explain why lipids have a higher energy content than carbohydrates. *[1]*

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*(This question continues on the following page)*

*(Question B1 continued)*

(d) Metal complexes are involved in respiration. State the names of **two** such complexes and the metals they contain. Explain the role of these complexes in respiration. *[4]*

Complex 1:

. . . . . .

Metal:

. . . . . .

Role:

. . . . . .
. . . . . .
. . . . . .

Complex 2:

. . . . . .

Metal:

. . . . . .

Role:

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. . . . . .

(e) In humans, if the supply of oxygen to the cells is limited, anaerobic respiration occurs. State the final product of anaerobic respiration in humans. *[1]*

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*(This question continues on the following page)*

*(Question B1 continued)*

(f) Compare the behaviour of enzymes and inorganic catalysts, including reference to the mechanism of enzyme action and the ways in which this can be inhibited. *[5]*

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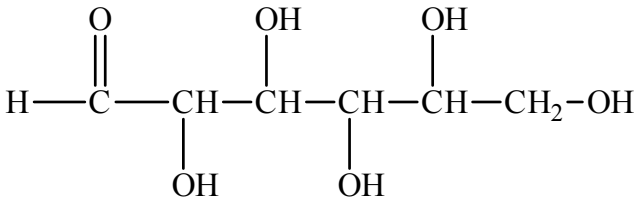
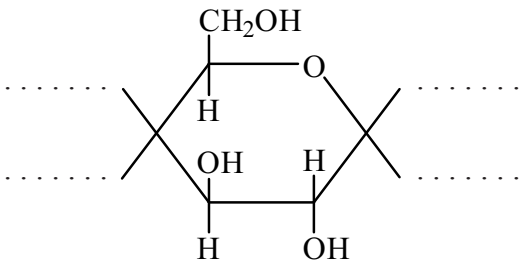
**B2.** The straight chain form of glucose is represented below.

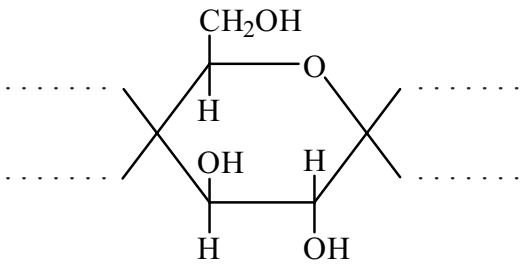


(a) Glucose is mainly present in one of two cyclic forms: α-glucose and β-glucose. Distinguish between the two cyclic forms by completing the diagrams below. *[2]*

α-glucose



β-glucose



*(This question continues on the following page)*

*(Question B2 continued)*

(b) Fructose is an isomer of glucose, but they differ with regard to one functional group and hence in their redox properties.

(i) Identify the functional group present in glucose, but not fructose. *[1]*

. . . . . .

(ii) Identify the functional group present in fructose, but not glucose. *[1]*

. . . . . .

(iii) Identify the sugar that acts as a reducing agent. *[1]*

. . . . . .

(c) Outline how the structure of cellulose is related to that of glucose. *[2]*

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**B3.** Macronutrients and micronutrients are essential components of a balanced diet.

(a) State the difference between macronutrients and micronutrients. *[1]*

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(b) State **one** consequence of a deficiency of thiamin (vitamin $B_1$). *[1]*

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(c) Suggest **two** ways in which vitamin deficiencies can be avoided. *[2]*

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

**C1.** Aluminium and iron are both widely used in modern society.

(a) Almost all iron is used in the form of an alloy. State the name of the most common type of iron alloy and the other element that is an essential component of these alloys. *[1]*

Name:

. . . . . .

Other element:

. . . . . .

(b) An early alloy of aluminium was Duralumin which contained small quantities of copper and magnesium. This is stronger and more rigid than pure aluminium. Explain on an atomic level why the addition of other elements has this effect. *[2]*

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**C2.** Fuel cells and rechargeable batteries are both convenient ways of providing portable electric power.

(a) Compare fuel cells and rechargeable batteries giving **one** similarity and **one** difference. *[2]*

Similarity:

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Difference:

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(b) One common type of rechargeable cell is the nickel–cadmium (NiCad) battery. For each terminal of this battery state the initial and final oxidation number of the element when the cell is delivering a current. Hence deduce which electrode is acting as the anode and which the cathode. *[3]*

| | **Positive terminal (when delivering a current)** | **Negative terminal (when delivering a current)** |
|---|---|---|
| **Initial oxidation number** | | |
| **Final oxidation number** | | |
| **Anode / cathode** | | |

(c) A common type of fuel cell uses hydrogen and oxygen with an acidic electrolyte. State the half-equations for the reactions at the two electrodes. *[2]*

Positive electrode:

. . . . . .

Negative electrode:

. . . . . .

*(This question continues on the following page)*

*(Question C2 continued)*

(d) The electrodes of fuel cells and rechargeable batteries have a feature in common with heterogeneous catalysts. Identify this feature and state why it is important for them to work efficiently. *[2]*

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**C3.** Polymers can be classified as addition polymers or condensation polymers.

(a) Outline the difference in the way in which polymerization occurs, stating a specific example of a polymer produced by each process. *[5]*

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(b) Polymers can either soften when heated or remain rigid until they decompose or combust. Other than Kevlar, state the names of **one** polymer that softens and **one** that does not. Explain this difference on a molecular level. *[3]*

Softening polymer:

. . . . . .

Non-softening polymer:

. . . . . .

Explanation:

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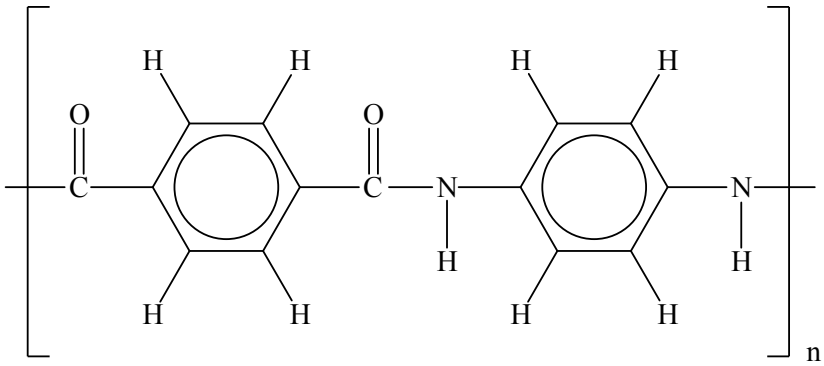
**C4.** Kevlar behaves as a lyotropic liquid crystal when dissolved in suitable solvents. Its structure is shown below.




(a) State the properties that a molecule, such as Kevlar, must have in order to enable it to behave as a liquid crystal. *[2]*

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(b) Discuss the additional properties that a substance must have to make it suitable for commercial liquid-crystal displays. *[2]*

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(c) Explain what is meant by the term *lyotropic*. *[1]*

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**Option D — Medicines and drugs**

**D1.** Alcohol abuse is a major problem in many countries, especially when associated with driving. Many police forces now use instruments that detect the presence of ethanol on a person's breath by its absorption of electromagnetic radiation.

(a) Identify the region of the electromagnetic spectrum used to detect the presence of ethanol. *[1]*

. . . . . .

(b) A number of other depressants that are frequently prescribed for stress relief are shown in Table 20 of the Data Booklet. State the names of **two** drugs of this type that have very similar structures. *[1]*

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(c) There is a third type of depressant, also shown in Table 20 of the Data Booklet, which is much more water-soluble than the two depressants in (b). Explain, in terms of its structure, why this is. *[2]*

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*(This question continues on the following page)*

*(Question D1 continued)*

(d) These drugs are most commonly taken orally. State **one** advantage and **one** disadvantage of this. *[2]*

Advantage:

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Disadvantage:

. . . . . .

. . . . . .

**D2.** Many diseases are the result of infection of the body by either bacteria or viruses.

(a) (i) State the name of **one** disease caused by each. *[2]*

Bacteria:

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Viruses:

. . . . . .

(ii) Discuss the differences between bacteria and viruses. *[3]*

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(b) Describe **two** misuses of antibiotics that have led to some bacteria becoming resistant. *[2]*

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*(This question continues on the following page)*

*(Question D2 continued)*

(c) Identify the particular structural feature of penicillins that is responsible for their action and explain how this prevents bacteria multiplying. *[4]*

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(d) It is much more difficult to produce effective antiviral drugs than drugs that kill bacteria. Describe **two** ways in which antiviral drugs work. *[2]*

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**D3.** (a) Describe how computers can be used to predict how changes to the structure of a drug might affect its activity. *[2]*

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(b) The action of a drug molecule often depends on its shape. Discuss a specific example of a drug where one stereoisomer has a different physiological activity to the other. *[2]*

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(c) Combinatorial chemistry is being increasingly used to produce compounds that may have physiological activity. Explain what is meant by *combinatorial chemistry* and how it is used to increase the efficiency of drug synthesis. *[2]*

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**Option E — Environmental chemistry**

**E1.** Ozone is a gas present in both the stratosphere and the troposphere.

(a) Oxygen absorbs much of the ultraviolet (UV) radiation from the sun, but ozone is important because it absorbs UV radiation not absorbed by oxygen. Explain, referring to the bonding in the two molecules, why this is the case. *[3]*

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(b) Nitrogen monoxide, NO, produced by jet engines catalyses the decomposition of the ozone in the stratosphere. Write equations for this catalytic decomposition. *[2]*

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*(This question continues on the following page)*

*(Question E1 continued)*

(c) Near ground level, in the troposphere, ozone is involved in the formation of toxic secondary air pollutants such as peroxyacylnitrates (PANs) from car exhaust gases. Outline the source of this ozone and how it can form these other pollutants; include appropriate equations. *[5]*

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**E2.** One major environmental problem that affects many countries is acid rain.

(a) Explain, writing an appropriate equation, why, even in an unpolluted environment, rainwater is still slightly acidic. *[2]*

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(b) Nitrogen monoxide pollution is a major contributor of acid rain.

(i) Outline the major source of this gas, including an equation. *[2]*

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(ii) Describe, including an equation, a chemical method used to control the emission of this pollutant. *[2]*

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(iii) Identify a compound, to which nitrogen monoxide is eventually converted, that is responsible for acidity in lakes and rivers. *[1]*

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**E3.** Many current environmental problems result from the intensive production of cereal crops.

(a) Intensive methods deplete soil organic matter (SOM). State **two** important components of SOM and describe **one** biological/physical and **one** chemical function of this material. *[4]*

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(b) Explain what natural nutrient cycles are, why intensive crop production interferes with these and how farmers compensate for this. *[3]*

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(c) State the name of a class of compounds, other than that referred to in (b), that is frequently used in intensive agriculture. *[1]*

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**Option F — Food chemistry**

**F1.** Most foods are complex mixtures and many components of them are nutrients.

(a) State an example of a *food* that is not a *nutrient* and use this to explain the difference between these two terms. *[3]*

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(b) Anthocyanins, carotenes and porphyrins are coloured substances found in foods. Their structures are shown in Table 22 of the Data Booklet.

(i) Identify the common feature in their structures that results in these compounds all being coloured and explain this on a molecular level. *[3]*

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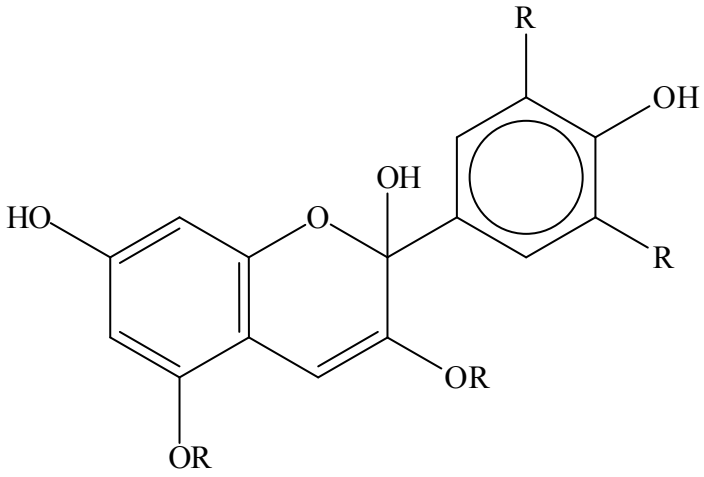
*(This question continues on the following page)*

*(Question F1 continued)*

(ii) Under certain conditions, anthocyanins are converted into a colourless carbinol pseudobase, an example of which is shown below.




In terms of its structure, explain why the pseudobase is colourless even though the anthocyanin is coloured. *[1]*

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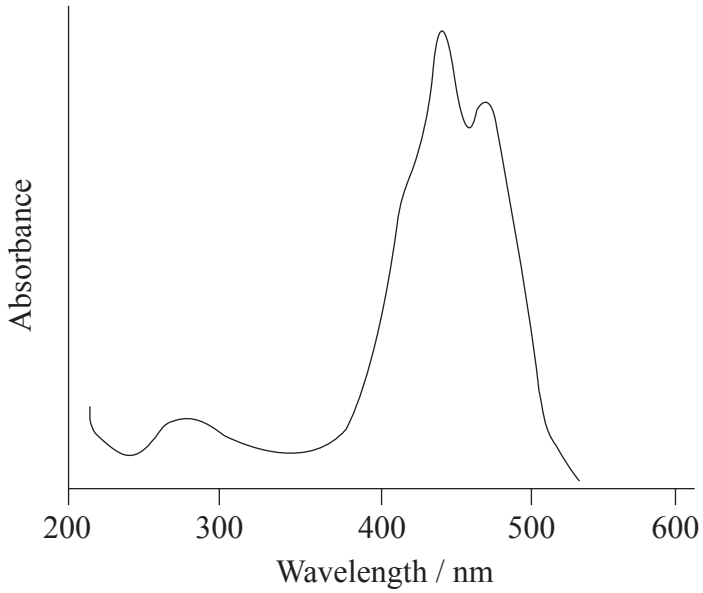
*(This question continues on the following page)*

*(Question F1 continued)*

(c) The absorption spectrum of β-carotene is shown below.




In terms of this spectrum, explain why carotenes have their typical colour. *[2]*

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(d) There are distinct differences between the solubilities of anthocyanins and carotenes. Describe these and explain the differences in terms of their structures. *[3]*

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**F2.** Rancidity limits the shelf life of foods containing oils and fats.

(a) Rancidity can occur as a result of two separate processes. State these processes and explain the difference between them. *[3]*

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(b) Substances such as THBP (2,4,5-trihydroxybutyrophenone) and TBHQ (*tert*-butylhydroquinone) are often added to slow down rancidity. Explain how additives such as THBP and TBHQ delay rancidity. *[2]*

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*(This question continues on the following page)*

*(Question F2 continued)*

(c) State the name of **one** naturally occurring substance which has a similar effect in slowing down rancidity. Identify a food that is rich in this and state an additional health benefit thought to arise from its regular consumption. *[3]*

Compound:

. . . . . .

Food:

. . . . . .

Benefit:

. . . . . .

. . . . . .

**F3.** Texture is an important feature of food. Various dispersed systems have distinctive textures.

(a) Describe what is meant by the term *dispersed system*. *[1]*

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. . . . . .

(b) Identify the phases of the two components of an emulsion. *[1]*

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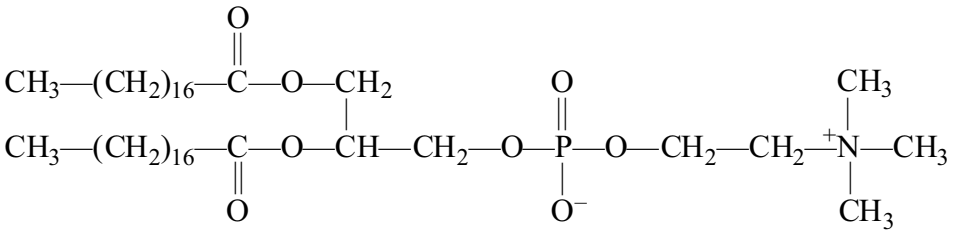
. . . . . .

(c) Emulsifiers such as lecithin are frequently used to prevent the separation of emulsions. One component of lecithin has the structure shown below.



Explain how emulsifiers, such as this, stabilize emulsions. *[3]*

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**Option G — Further organic chemistry**

**G1.** Consider the two-stage reaction pathways below.

$$CH_3CH_2I \xrightarrow{\mathbf{I}} \mathbf{W} \xrightarrow{\mathbf{II}} CH_3CH_2COOH$$

$$CH_3CHO \xrightarrow{\mathbf{III}} CH_3CH(OH)CN \xrightarrow{\mathbf{IV}} CH_3CH(OH)COOH$$

(a) Other than altering the functional groups, identify the fundamental structural change that these two pathways achieve. *[1]*

. . . . . .
. . . . . .

(b) Given that **W** does not contain nitrogen, deduce its structural formula. *[1]*

(c) State the reagent(s) required for reaction **I** and for reaction **II**. *[3]*

Reaction **I**:

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. . . . . .

Reaction **II**:

. . . . . .
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*(This question continues on the following page)*

*(Question G1 continued)*

(d) The products of both reaction pathways are carboxylic acids. Suggest which is the stronger acid and explain your answer. *[3]*

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**G2.** The base strength of amines depends on their structure.

(a) Draw the structure of a primary amine, a secondary amine and a tertiary amine of molecular formula $C_3H_9N$. *[3]*

| Primary | Secondary | Tertiary |
|---|---|---|
| | | |

(b) Explain why the secondary amine is a stronger base than the primary amine. *[2]*

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(c) Amines can also react with acid anhydrides and acyl chlorides. State the balanced equation for the reaction between ethylamine and ethanoyl chloride. *[1]*

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. . . . . .

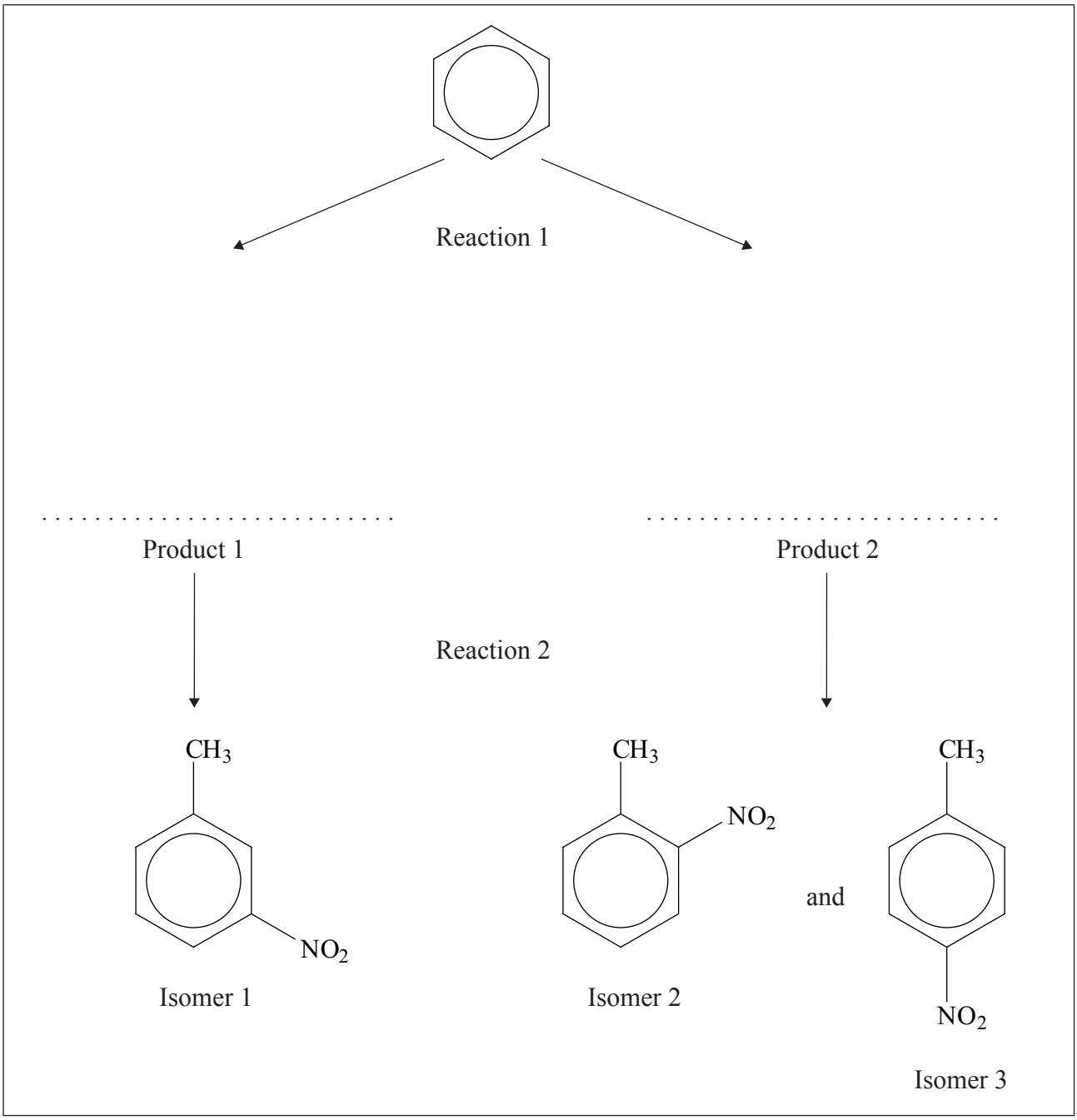
*(This question continues on the following page)*

*(Question G2 continued)*

(d) Explain the mechanism of this reaction, using curly arrows to represent the movement of electron pairs. *[4]*

**G3.** There are three possible structural isomers of methylnitrobenzene (nitrotoluene). They all can be synthesized starting with benzene, but use different reagents and conditions and are based essentially on the different orientation effects of the initial group that is substituted in benzene.

(a) Using the abbreviated scheme below, draw the structure of the products of the first stage (Reaction 1) that will lead to the different structural isomers in the second stage (Reaction 2). *[2]*




*(This question continues on the following page)*

*(Question G3 continued)*

(b) For the formation of Isomer 1:

(i) State an equation for the formation of the electrophile in Reaction 1 leading to Isomer 1. *[1]*

. . . . . .

. . . . . .

(ii) Explain the mechanism for the first stage of the synthesis (of Isomer 1), using curly arrows to represent the movement of electron pairs. *[4]*

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

Answers written on this page
will not be marked.