

22146112

**CHEMISTRY
STANDARD LEVEL
PAPER 3**

Candidate session number

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Tuesday 20 May 2014 (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
Option D — Medicines and drugs	11 – 13
Option E — Environmental chemistry	14 – 17
Option F — Food chemistry	18 – 21
Option G — Further organic chemistry	22 – 24



40EP01

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

Answers written on this page
will not be marked.



Option A — Modern analytical chemistry

1. (a) Describe the essential difference between the **emission** spectrum of sodium and the **absorption** spectrum of sodium. [1]

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- (b) Identify the five missing components in the following table.

Type of spectroscopy	Type of atomic or molecular process	Region of electromagnetic spectrum
¹ H NMR		
IR		infrared
	electronic transitions	

[4]

- (c) Other than to identify the presence of a particular element, state **one** use of atomic absorption spectroscopy. [1]

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.....

(Option A continues on the following page)



(Option A continued)

2. (a) The mass spectrum of iodoethane, C_2H_5I , shows three prominent peaks with m/z values of 156, 127 and 29. Identify the ions responsible for each of these three prominent peaks. [2]

156:
127:
29:

- (b) Bromine contains two isotopes, ^{79}Br and ^{81}Br , in approximately equal amounts. Predict the m/z values of the prominent peaks in the mass spectrum of bromoethane, C_2H_5Br . [3]

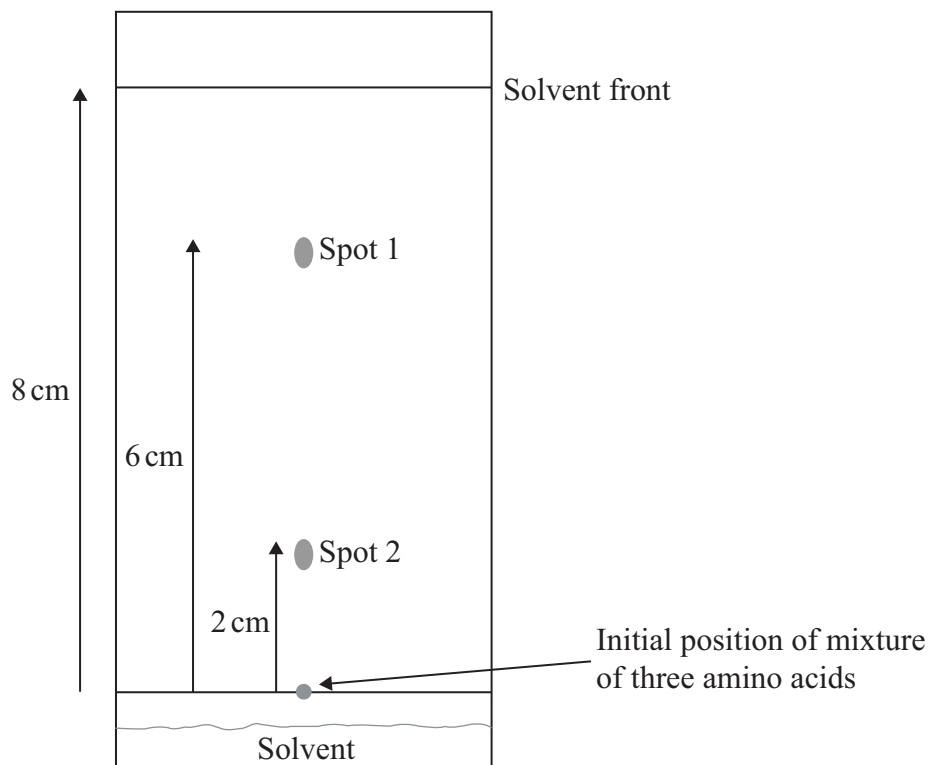
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(Option A continues on the following page)



(Option A continued)

3. A sample is known to contain three different amino acids. After carrying out paper chromatography using a solvent made up of propan-1-ol, water and ammonia, the following chromatogram was obtained once the spots had been developed with ninhydrin.



- (a) Calculate the R_f values for the two spots. [1]

Spot 1:
.....

Spot 2:
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- (b) Suggest a reason why only two spots are present. [1]

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(Option A continues on the following page)



(Option A, question 3 continued)

- (c) Suggest how the chromatography experiment with the same sample could be altered in order to obtain three spots. [1]

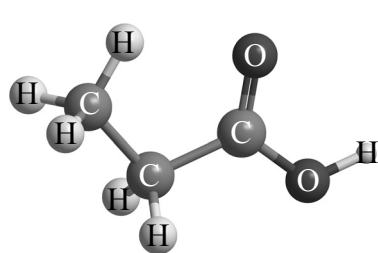
<p>.....</p> <p>.....</p>

(Option A continues on the following page)

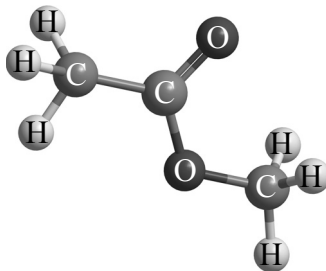


(Option A continued)

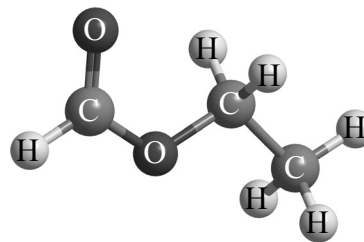
4. Two students were provided with three different isomers of $C_3H_6O_2$.



Propanoic acid



Methyl ethanoate



Ethyl methanoate

They were asked to suggest how the isomers could be distinguished and positively identified from each other using spectroscopic techniques. Student **A** said that they could be positively identified just from their infrared spectra. Student **B** said that they could be positively identified just from the number of peaks and the areas under each peak in their 1H NMR spectra.

Evaluate these two claims and suggest how any possible limitations could be overcome using the same spectroscopic technique.

[6]

Student **A** / Infrared:

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Student **B** / 1H NMR:

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End of Option A



40EP07

Turn over

Option B — Human biochemistry

5. Granola bars are a source of dietary fibre.

- (a) When 1.13 g of a granola bar was combusted in a bomb calorimeter, the temperature of 500 cm³ of water increased from 18.5 °C to 28.0 °C. Calculate the energy value, in kJ per 100 g, of the granola bar to the correct number of significant figures. [3]

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- (b) (i) State what is meant by the term dietary fibre. [1]

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- (ii) State **two** health problems that can be associated with a diet that is low in dietary fibre. [2]

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(Option B continues on the following page)



(Option B continued)

6. Lipids are a group of molecules which includes fats, fat-soluble vitamins and triglycerides.

(a) State **two** examples of saturated fatty acids using Table 22 of the Data Booklet. [1]

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.....

(b) Iodine can be used to determine the degree of unsaturation in fatty acids.

(i) Deduce the chemical equation for the reaction of oleic acid with iodine. [1]

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.....

(ii) Calculate the volume, in cm^3 , of a 1.00 mol dm^{-3} iodine solution needed to react exactly with 1.00 g of oleic acid (molar mass = $282.52 \text{ g mol}^{-1}$). [2]

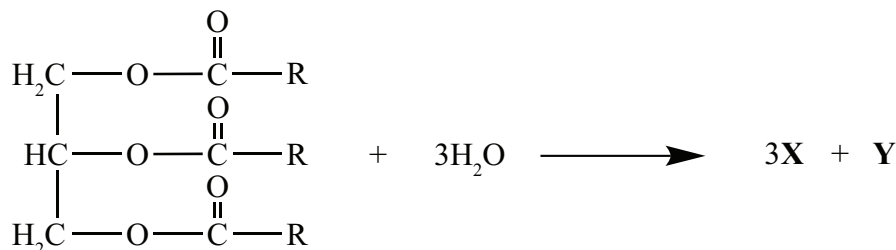
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(Option B continues on the following page)



(Option B, question 6 continued)

- (c) The partial equation for the enzyme-catalysed hydrolysis of a triglyceride is represented below.



- (i) Deduce the named functional groups present in the two products **X** and **Y**. [2]

X:

Y:

- (ii) Outline the factors which determine whether **X** obtained in part (i) will have a higher or lower melting point than oleic acid. [2]

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- (d) Suggest why fats have a higher energy value than carbohydrates. [1]

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(Option B continues on the following page)



(Option B, question 6 continued)

- (e) The two fatty acids linoleic acid and linolenic acid both have the same number of carbon atoms. Compare the structures of the two acids. [2]

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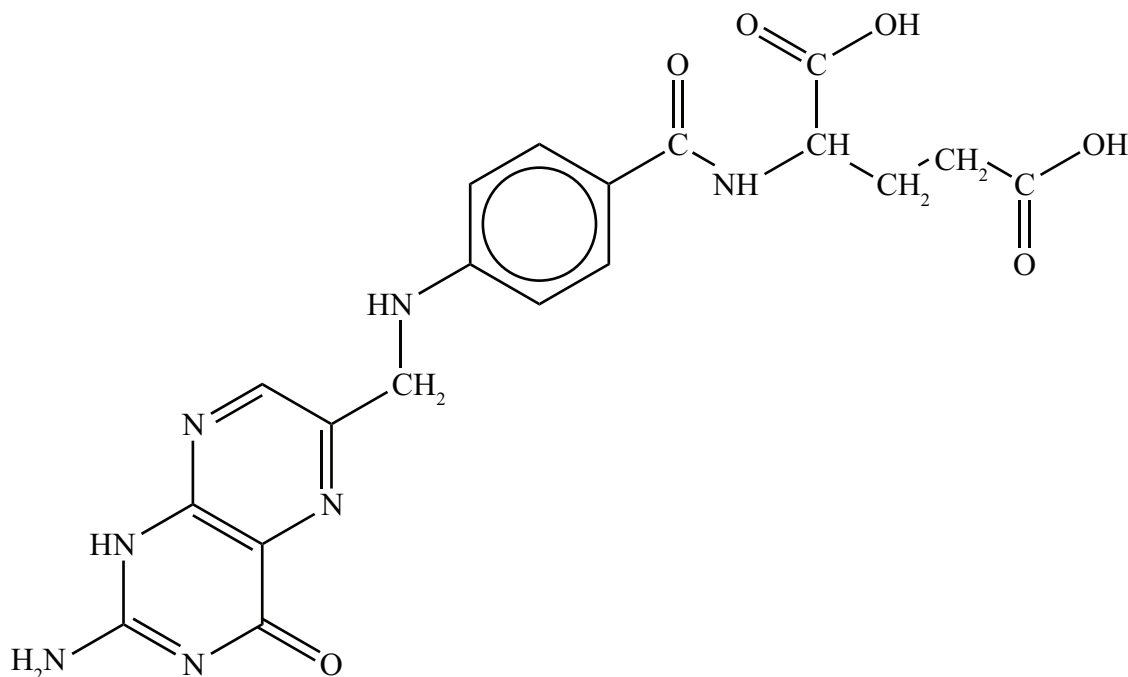
(Option B continues on the following page)



(Option B continued)

7. Vitamins are organic compounds needed in small amounts for normal metabolism in the body. Vitamins can be classified as water-soluble or fat-soluble.

(a) Vitamin B₉ is water-soluble and is important in the repair of DNA. The structure of vitamin B₉ is given below.



Suggest why this vitamin is water-soluble.

[1]

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(Option B continues on the following page)



(Option B, question 7 continued)

(b) Vitamin A (retinol) is important for maintaining healthy skin. The structure of vitamin A (retinol) is given in Table 21 of the Data Booklet.

(i) State **one** disease caused by a deficiency of vitamin A in the body. [1]

.....

(ii) The livers of polar bears and seals contain a very large amount of vitamin A. Some early explorers in the Arctic died from consuming too many livers.

Suggest an explanation for this even though males require at least 0.9 mg of the vitamin per day (females require at least 0.7 mg per day). [1]

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End of Option B



Option C — Chemistry in industry and technology

8. Although crude oil is considered an extremely important energy source, it cannot be used directly as a resource.

(a) Suggest why crude oil needs to be refined before it can be used. [1]

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(b) Discuss the use of crude oil as an energy source and as a chemical feedstock, stating **two** examples of the use of crude oil as a chemical feedstock. [2]

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(c) Thermal cracking, catalytic cracking and steam cracking can all be used to convert molecules of alkanes into alkenes.

(i) State the type of cracking which can be used to crack ethane into ethene, the chemical equation for the process and **one** reaction condition required. [2]

Type of cracking:
.....

Chemical equation:
.....

Reaction condition:
.....

(Option C continues on the following page)



(Option C, question 8 continued)

- (ii) Suggest **one** use for the other product formed in this reaction in addition to ethene. [1]

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9. Although fossil fuels are considered significant sources of energy, the energy conversion associated with the production of electricity is a very inefficient process, often in the region of only 40 % of total possible energy conversion.

Fuel cells provide a much more efficient process, often with a 70 % conversion factor.

- (a) State the energy change conversion involved in a fuel cell. [1]

.....

- (b) (i) Identify the two half-equations that take place at the positive electrode (cathode) and negative electrode (anode) in a hydrogen-oxygen fuel cell with an **alkaline** electrolyte. [2]

Positive electrode (cathode) half-equation:
.....
Negative electrode (anode) half-equation:
.....

(Option C continues on the following page)



(Option C, question 9 continued)

(ii) State the overall reaction, identifying the states of all species involved. [1]

.....

(iii) Outline the function of the thin polymer membrane used in the corresponding hydrogen-oxygen fuel cell with an **acidic** electrolyte. [1]

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(iv) Other than cost, state **one** disadvantage of a fuel cell. [1]

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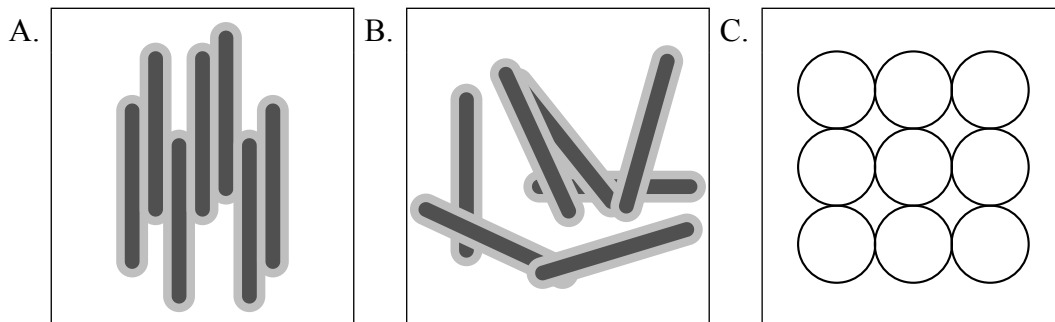
(Option C continues on the following page)



(Option C continued)

10. Liquid crystals are widely used in devices such as calculators, laptop computers and advanced optical materials.

- (a) (i) Describe the meaning of the term liquid crystals and state which of the representations below (A, B or C) best describes molecules present in the liquid-crystalline phase. [1]



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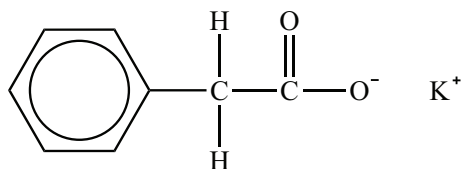
(Option C continues on the following page)



(Option C, question 10 continued)

- (ii) Deduce, with reasoning, which of the following substance(s) is/are most likely to show liquid-crystalline behaviour. [4]

Substance I:



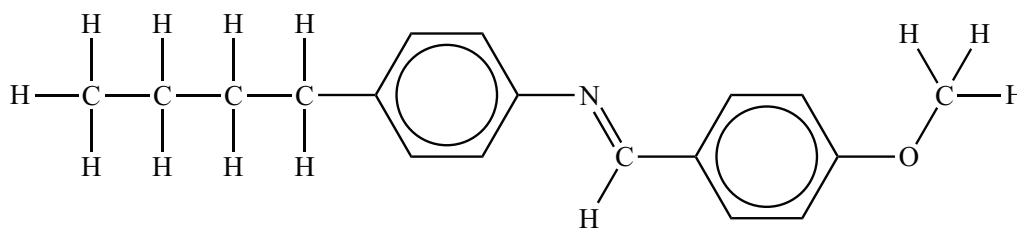
Liquid-crystalline behaviour (yes/no):

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Reasoning:

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Substance II:



Liquid-crystalline behaviour (yes/no):

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Reasoning:

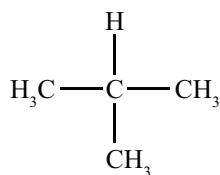
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(Option C continues on the following page)



(Option C, question 10 continued)

Substance III:



Liquid-crystalline behaviour (yes/no):

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Reasoning:

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(iii) Suggest why octane does not show liquid-crystalline behaviour. [1]

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(b) (i) State **one** difference between thermotropic and lyotropic liquid crystals. [1]

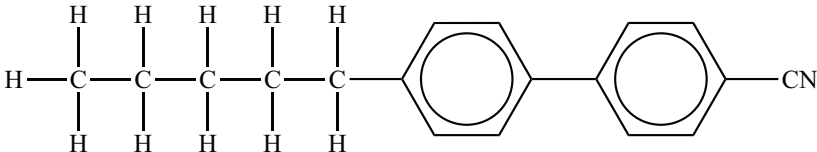
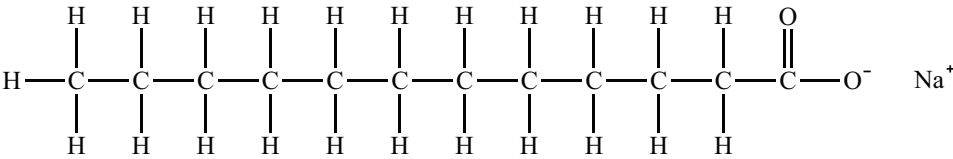
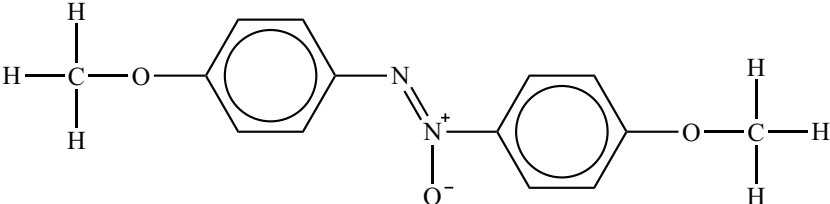
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(Option C continues on the following page)



(Option C, question 10 continued)

- (ii) Identify, by stating yes or no, the substance(s) which show(s) thermotropic liquid-crystalline behaviour. [1]

Substance	Thermotropic liquid-crystalline behaviour
X: 	
Y: 	
Z: 	

End of Option C



Option D — Medicines and drugs

11. Each capsule of Solpadol[®], a commercial analgesic, contains 500 mg of paracetamol (acetaminophen) and 30 mg of codeine (in the form of codeine phosphate hemihydrate).

(a) Discuss the different modes of action of paracetamol (acetaminophen) and codeine in relieving pain. [2]

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(b) Diamorphine (heroin) is an even stronger painkiller than codeine. The structures of codeine and diamorphine are given in Table 20 of the Data Booklet. Discuss, in terms of named functional groups, how the structure of diamorphine differs from the structure of codeine. [3]

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(c) State **one** specific reason why many doctors recommend paracetamol rather than aspirin as a mild analgesic. [1]

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(Option D continues on the following page)



(Option D, question 11 continued)

- (d) A normal aspirin tablet taken to relieve pain contains about 300 mg of aspirin. Certain adults who are not in pain are recommended by doctors to take a smaller 75 mg dose of aspirin each day. State **one** reason for this recommendation. [1]

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.....

- (e) Suggest a reason why aspirin and paracetamol are “over the counter” drugs but in many countries Solpadol[®] must be prescribed by a doctor. [1]

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(Option D continues on the following page)



(Option D continued)

12. Maalox[®] manufactures several different types of antacid. Maalox[®] Extra Strength is a suspension. One teaspoon (5.00 cm³) contains 400 mg of magnesium hydroxide, Mg(OH)₂, 306 mg of aluminium hydroxide, Al(OH)₃, and 40.0 mg of simethicone. Maalox[®] Extra Strength with Anti-gas comes in tablet form. Each tablet contains 1000 mg of calcium carbonate, CaCO₃, and 60.0 mg of simethicone.

- (a) State the equations for the reactions of magnesium hydroxide, aluminium hydroxide and calcium carbonate with hydrochloric acid. [3]

<p>Magnesium hydroxide:</p> <p>.....</p> <p>.....</p> <p>Aluminium hydroxide:</p> <p>.....</p> <p>.....</p> <p>Calcium carbonate:</p> <p>.....</p> <p>.....</p>

(Option D continues on the following page)



(Option D, question 12 continued)

(b) Stomach acid approximates to $1.00 \times 10^{-2} \text{ mol dm}^{-3}$ hydrochloric acid. Assuming that simethicone does not react with acid, determine the volume, in dm^3 , of stomach acid neutralized by:

(i) one teaspoon (5.00 cm^3) of Maalox[®] Extra Strength. [2]

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(ii) one tablet of Maalox[®] Extra Strength with Anti-gas. [2]

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(c) Suggest the function of the simethicone present in both antacids. [1]

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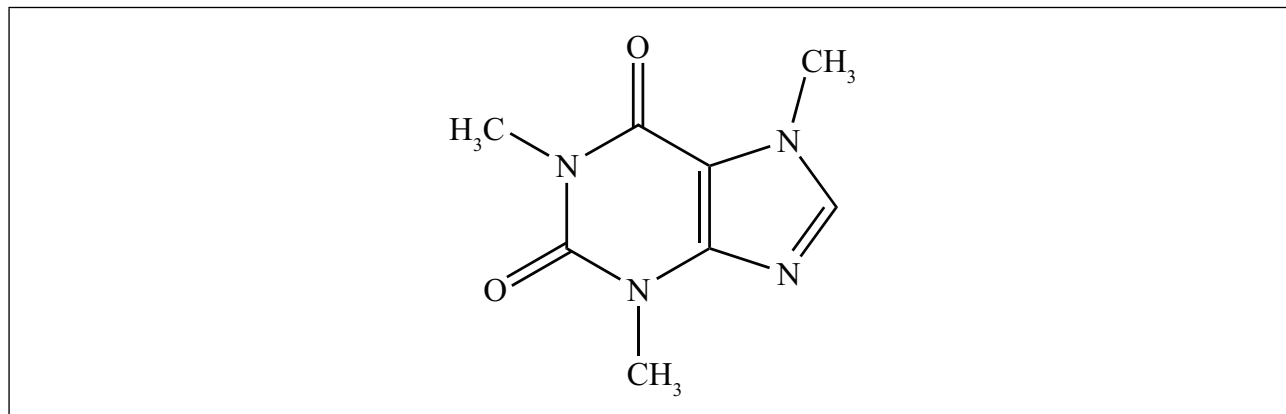
(Option D continues on the following page)



(Option D continued)

13. Caffeine contains both amide and amine functional groups.

(a) Identify the amine group in caffeine by drawing a circle around it. [1]



(b) Caffeine is a stimulant and also a diuretic. State the meaning of the term diuretic. [1]

.....

(c) Nicotine is also a stimulant. Both caffeine and nicotine contain a tertiary amine group. Distinguish between the terms *primary* and *tertiary* when applied to amines. [1]

.....

(d) Another type of stimulant is amphetamine. Its structure can be found in Table 20 of the Data Booklet. Amphetamine and related stimulants, such as methamphetamine and adrenaline, are derived from the phenylethylamine structure. Draw the structural formula of phenylethylamine. [1]

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End of Option D



Option E — Environmental chemistry

14. Carbon dioxide, methane, ozone, chlorofluorocarbons (CFCs) and water are examples of greenhouse gases.

(a) Describe how these gases contribute to the greenhouse effect. [3]

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(b) (i) Identify by chemical formula **one** other greenhouse gas not mentioned above. [1]

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(ii) State the source of this gas. [1]

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(Option E continues on the following page)



(Option E, question 14 continued)

- (c) Many scientists claim that global warming is associated with the increasing concentration of greenhouse gases in the atmosphere. Other than temperature change, state **two** effects of global warming. [1]

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15. Although methane is a greenhouse gas produced by anaerobic decomposition of organic matter, methane produced from landfill is now being used in New Jersey, USA, to generate electricity for homes in New York City.

- (a) Evaluate the advantages and disadvantages of landfill and incineration as methods of waste disposal. [4]

One advantage of landfill:

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One disadvantage of landfill:

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One advantage of incineration:

.....

.....

One disadvantage of incineration:

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.....

(Option E continues on the following page)



(Option E, question 15 continued)

- (b) (i) Other than landfill, state one other source of methane produced from the decomposition of organic material. [1]

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- (ii) State the equation, including state symbols, for the oxidation of methane in the atmosphere to produce a primary pollutant which is toxic to humans. [1]

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(Option E continues on the following page)



(Option E continued)

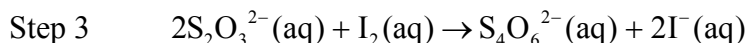
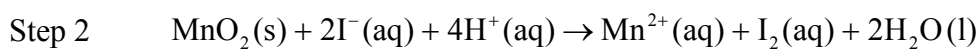
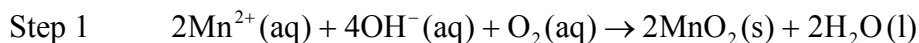
16. Dissolved oxygen is used up when organic matter is decomposed aerobically in water.

- (a) Distinguish between *aerobic* and *anaerobic* decomposition of organic material in water in terms of redox processes. [1]

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- (b) The Winkler method, which is based on redox reactions, can be used to determine the concentration of dissolved oxygen in water.

A 200 cm³ sample of water was taken from a river and analysed using this method. The redox reactions are shown below.



- (i) 1.50×10^{-4} mol of $\text{I}^{-}(\text{aq})$ was formed in step 3. Determine the amount, in mol, of oxygen, $\text{O}_2(\text{aq})$, dissolved in the water. [1]

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.....

- (ii) Determine the solubility, in g dm^{-3} , of the oxygen in the water. [1]

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(Option E continues on the following page)



(Option E continued)

17. Ozone prevents UV radiation emitted from the Sun reaching the surface of the Earth.

- (a) Describe, using chemical equations, the two-step mechanism of photochemical decomposition of ozone in the Earth's stratosphere. [2]

Step 1:
.....
Step 2:
.....

- (b) The ozone layer in the stratosphere has been progressively depleted by pollutants such as chlorofluorocarbons (CFCs), which have been used as refrigerants. Compare CFCs with the alternative refrigerant hexafluoroethane, C₂F₆. [3]

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End of Option E



Option F — Food chemistry

18. The formula of linoleic acid is given in Table 22 of the Data Booklet.

- (a) Identify the structural formula of the triglyceride formed when three molecules of linoleic acid react with one molecule of glycerol (propane-1,2,3-triol), $\text{CH}_2\text{OHCHOHCH}_2\text{OH}$. [1]

- (b) State the other product formed during this reaction. [1]

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- (c) Explain why the triglyceride formed from linoleic acid and glycerol is a liquid and not a solid at room temperature. [2]

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(Option F continues on the following page)



(Option F, question 18 continued)

- (d) Describe how the triglyceride formed from linoleic acid and glycerol could be converted into a saturated fat and give any necessary conditions. [2]

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- (e) Other than the fact that it is a solid at room temperature, discuss **two** advantages and **two** disadvantages of a saturated fat compared to an unsaturated fat or oil. [4]

Advantages:

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Disadvantages:

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(Option F continues on the following page)



(Option F continued)

19. (a) Describe how the following additives can prolong the shelf life of food:

(i) sodium benzoate and benzoic acid.

[1]

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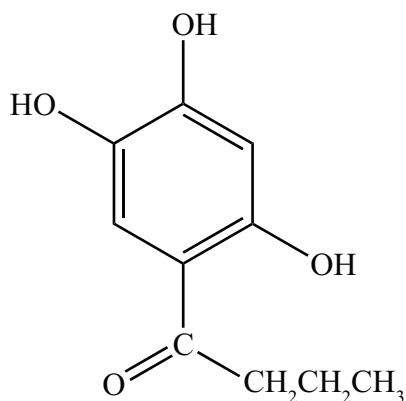
(ii) potassium nitrite and potassium nitrate.

[1]

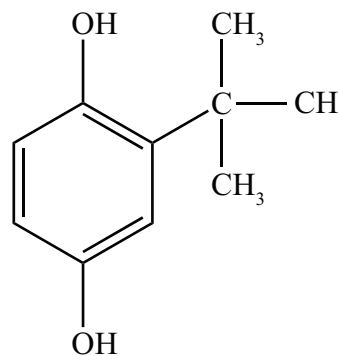
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(b) Two synthetic preservatives added to food are THBP and TBHQ.



THBP



TBHQ

State the name of the functional group present in THBP but absent in TBHQ.

[1]

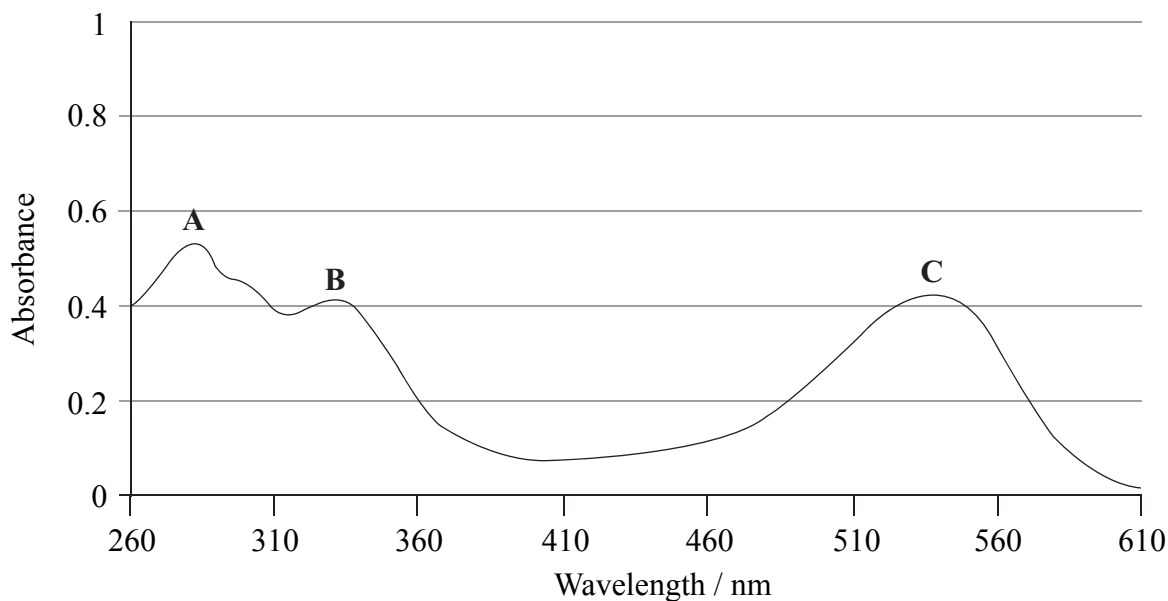
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(Option F continues on the following page)



(Option F continued)

20. The diagram below shows the absorbance spectrum of anthocyanins found in blueberries.



[Source: Adapted from <http://www.biomedsearch.com/nih/Change-Total-Anthocyanins-in-Blueberries/15577185.html>]

(a) State and explain which of the absorbances, **A**, **B** or **C**, is responsible for the colour of blueberries. [2]

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(b) State **two** factors which affect either the actual colour or the intensity of the colour when blueberries are stored. [2]

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(Option F continues on the following page)



(Option F continued)

- 21.** Your school is holding a debate on the benefits and concerns of genetically modified (GM) food. Several speakers have argued the benefits of GM foods and included such factors as enhanced taste, resistance to disease and increase in crop yields. Discuss three arguments you would use to highlight the concerns of using GM foods. [3]

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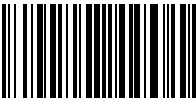
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End of Option F



Option G — Further organic chemistry

22. (a) Pentanal, C_4H_9CHO , can react with hydrogen cyanide, HCN.

(i) State the equation for this reaction. [1]

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(ii) State the name of the mechanism for this reaction. [1]

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(iii) Describe the mechanism for this reaction using curly arrows to represent the movement of electron pairs. [3]

(Option G continues on the following page)



(Option G, question 22 continued)

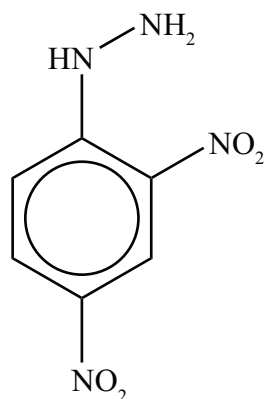
- (iv) The organic product from the reaction of pentanal with hydrogen cyanide can be hydrolysed in the presence of dilute acid. Draw the structural formula and state the name of the organic product formed. [2]

Structure:

Name:

.....

- (b) State the equation for the reaction of pentan-3-one with 2,4-dinitrophenylhydrazine. [2]



2,4-dinitrophenylhydrazine

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(Option G continues on the following page)



(Option G continued)

23. Deduce the two-step reaction pathways for the following two syntheses. In each case state the reagents and conditions and the name of the intermediate.

(a) The formation of but-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$, from ethylmagnesium bromide, $\text{C}_2\text{H}_5\text{MgBr}$. [3]

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(b) The formation of butanoic acid, $\text{C}_3\text{H}_7\text{COOH}$, from bromopropane, $\text{C}_3\text{H}_7\text{Br}$. [3]

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24. Ethylamine, $\text{C}_2\text{H}_5\text{NH}_2$, is a weak base.

(a) State the equation for the reaction of ethylamine with water. [1]

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(Option G continues on the following page)



(Option G, question 24 continued)

(b) Explain why ethylamine has basic properties. [1]

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(c) Explain why diethylamine is a stronger base than ethylamine. [1]

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(d) State the formula and deduce the shape of the positive ion (cation) formed when triethylamine, $(C_2H_5)_3N$, reacts with hydrochloric acid. [2]

Formula:
.....
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Name of shape:
.....
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End of Option G



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Answers written on this page
will not be marked.



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