



22146118

**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 – 3
Option B — Human biochemistry	4 – 6
Option C — Chemistry in industry and technology	7 – 9
Option D — Medicines and drugs	10 – 12
Option E — Environmental chemistry	13 – 16
Option F — Food chemistry	17 – 19
Option G — Further organic chemistry	20 – 22



44EP01

**Option A — Modern analytical chemistry**

1. Modern analytical techniques are used widely for different purposes in everyday life.

(a) State which analytical technique or combination of techniques would be most suitable for the following purposes. [2]

Purpose	Analytical technique(s)
Determining the level of ethanol in the breath of a driver of a vehicle	.....
Determining the concentration of chromium in seawater	.....
Body scanning to diagnose the autoimmune disease, multiple sclerosis	.....
Testing for the presence of volatile compounds	.....

(b) Two types of spectroscopy are absorption and emission. Distinguish between each type of spectra, including how each is produced. [4]

<p>Absorption spectra:</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>Emission spectra:</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p> <p>.....</p>
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*(Option A continues on the following page)*



*(Option A continued)*

2. Thin-layer chromatography (TLC) is an example of adsorption chromatography.

(a) Identify a stationary phase and a **specific** mobile phase often used in TLC. [2]

<p>Stationary phase:</p> <p>.....</p> <p>.....</p> <p>Specific mobile phase:</p> <p>.....</p> <p>.....</p>
------------------------------------------------------------------------------------------------------------

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

<p>.....</p> <p>.....</p> <p>.....</p>
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*(Option A continues on the following page)*



(Option A, question 2 continued)

- (c) A mixture of two organic compounds was separated by TLC using a non-polar solvent.

Compound	Distance travelled / mm
A	22
B	65
Solvent	80

- (i) Calculate the  $R_f$  values of A and B.

[1]

Compound	$R_f$ value
A	
B	

- (ii) Outline why compound B has travelled the greater distance.

[1]

..... .....
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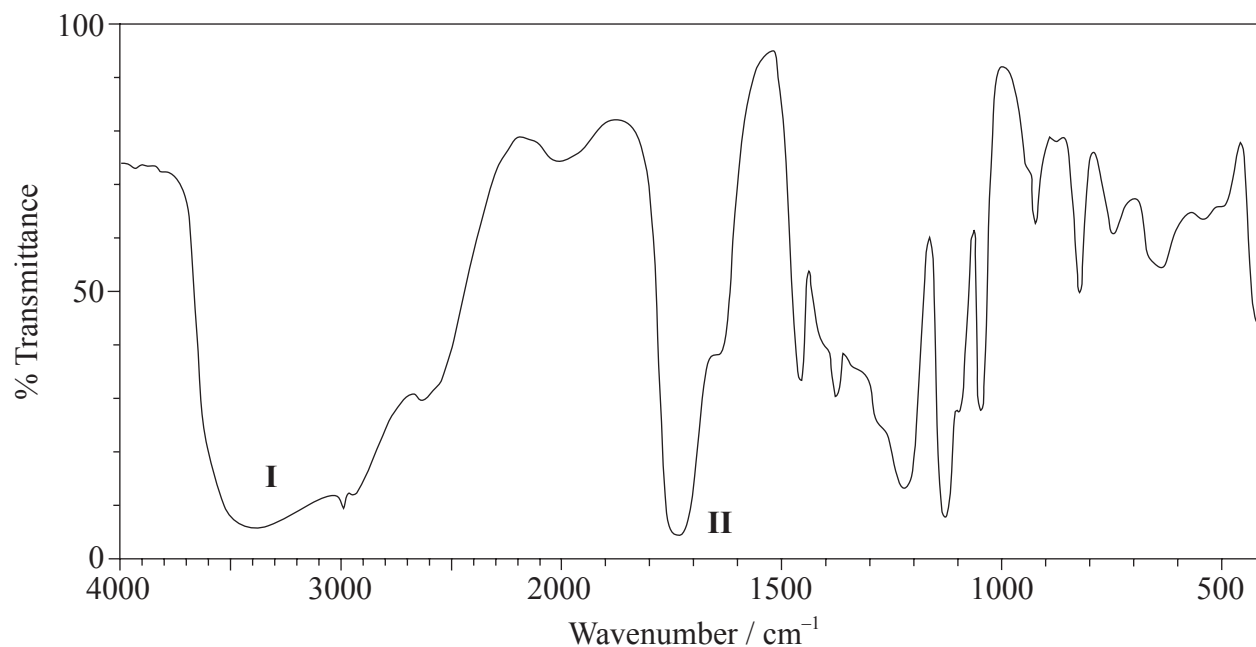
(Option A continues on the following page)



(Option A continued)

3. Compound **X** has the molecular formula  $C_3H_6O_3$  and is found in human perspiration.

(a) Its infrared (IR) spectrum is represented below.



[Source: SDBS web: [www.sdb.s.riodb.aist.go.jp](http://www.sdb.s.riodb.aist.go.jp) (National Institute of Advanced Industrial Science and Technology, 2013)]

Deduce the bonds responsible for the absorptions labelled **I** and **II**.

[1]

<p><b>I:</b></p> <p>.....</p> <p><b>II:</b></p> <p>.....</p>
--------------------------------------------------------------

(Option A continues on the following page)



(Option A, question 3 continued)

- (b) The  $^1\text{H}$ NMR spectrum recorded showed four peaks with the following chemical shift values (in ppm):

Peaks	Chemical shift / ppm
A	12.4
B	4.0
C	3.4
D	1.2

The integration trace for A:B:C:D was found to be 1:1:1:3.

Deduce what information can be obtained about the hydrogen atoms responsible for peak D at 1.2 ppm from the integration trace in the  $^1\text{H}$ NMR spectrum of X. [1]

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

- (c) Deduce the fragments in the mass spectrum which correspond to the following  $m/z$  values. [2]

$m/z = 45$ :  
.....

$m/z = 17$  :  
.....

$m/z = 15$ :  
.....

(Option A continues on the following page)



(Option A, question 3 continued)

- (d) Deduce the structural formula of **X**. [1]

- (e) **Y** is an isomer of **X**, which contains the same functional groups.

- (i) Deduce the structural formula of **Y**. [1]

- (ii) Predict **one** difference between the  $^1\text{H}$ NMR spectrum of **Y** and **X**. [1]

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.....

(Option A continues on the following page)



(Option A, question 3 continued)

- (f) (i) Like X, 3-methylbutanoic acid is also a source of body odour. Deduce the  $m/z$  value for the molecular ion peak on the mass spectrum of this compound. [1]

.....  
.....

- (ii) Deduce the number of different chemical environments of the hydrogen atoms in the  $^1\text{H}$ NMR spectrum of 3-methylbutanoic acid. [1]

.....  
.....

**End of Option A**





**Option B — Human biochemistry**

4. Foods such as pasta are rich in carbohydrates.

(a) State why a professional cyclist would eat pasta before a race.

[1]

.....  
.....

(b) Monosaccharides are a type of carbohydrate.

(i) Fructose, a monosaccharide, is found in honey. Draw the straight-chain structure of fructose.

[1]

(ii) Draw the five-membered ring structure of  $\beta$ -fructose.

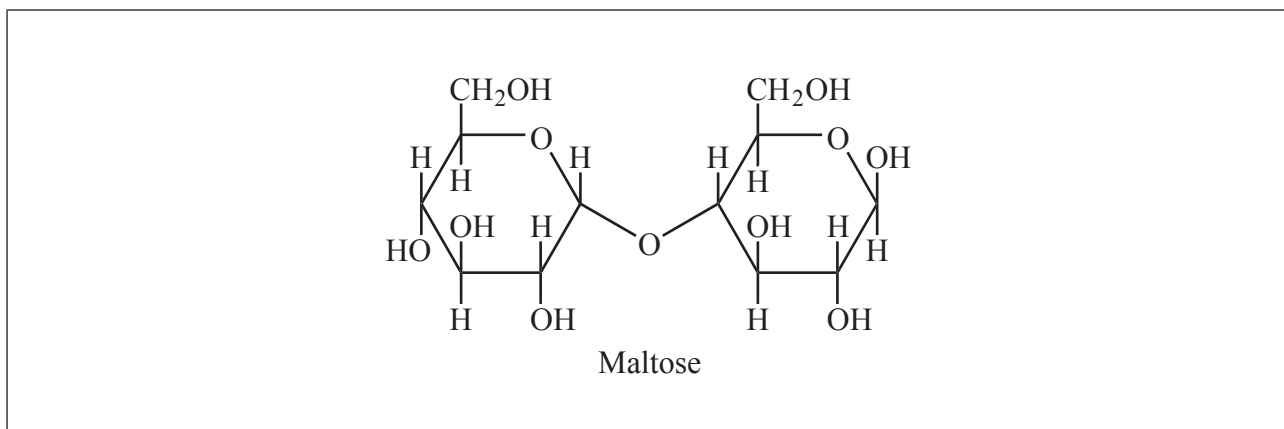
[1]

*(Option B continues on the following page)*



(Option B, question 4 continued)

- (c) The structure of maltose is shown below. The structure of sucrose is given in Table 21 of the Data Booklet.



- (i) Draw a circle around the 1,4 glycosidic link in maltose. [1]
- (ii) Identify which sugar other than fructose is involved in these two structures. [1]

.....

.....

- (iii) The structure of lactose is also given in Table 21 of the Data Booklet. Outline how the structure of lactose differs from that of maltose. [2]

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(Option B continues on the following page)



(Option B continued)

5. Lipids are a group of naturally occurring largely non-polar biomolecules. The term *iodine number* is often used to characterize particular lipids.

(a) (i) Define the term *iodine number*. [1]

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

(ii) A sample containing  $1.12 \times 10^{-2}$  mol of fatty acid was found to react with 8.50 g of iodine,  $I_2$ . Calculate the number of carbon-carbon double bonds present in the fatty acid, showing your working. [2]

.....  
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.....

(Option B continues on the following page)



*(Option B, question 5 continued)*

- (b) (i) Draw the structure of glycerol (propane-1,2,3-triol). [1]

- (ii) Glycerol can react with three molecules of lauric acid to form a triglyceride. The structure of lauric acid is given in Table 22 of the Data Booklet. State the name of the functional group of the triglyceride and identify the other product formed. [1]

Name of functional group of triglyceride:

.....

Other product formed:

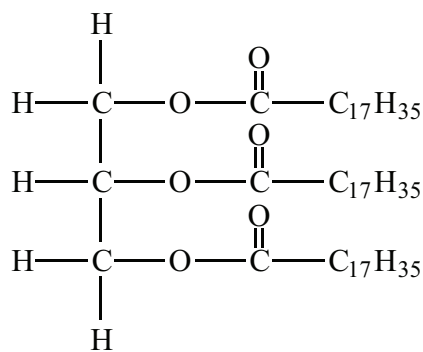
.....

*(Option B continues on the following page)*



(Option B, question 5 continued)

- (c) The hydrolysis of tristearin, whose structure is shown below, can be catalysed by the enzyme lipase.



Tristearin

Successive hydrolysis of tristearin results in the formation of distearin and monostearin. Deduce the structure of the diglyceride, distearin, and state the name of the other product formed from this reaction.

[2]

Structure of diglyceride, distearin:

Name of other product:

.....

(Option B continues on the following page)



*(Option B, question 5 continued)*

- (d) Explain why the metabolism of fats produces much more energy per gram than that of carbohydrates. [2]

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*(Option B continues on the following page)*



(Option B continued)

6. Anabolic androgenic steroids mimic the effect of testosterone in the body. The structures of testosterone and other hormones are given in Table 21 of the Data Booklet.

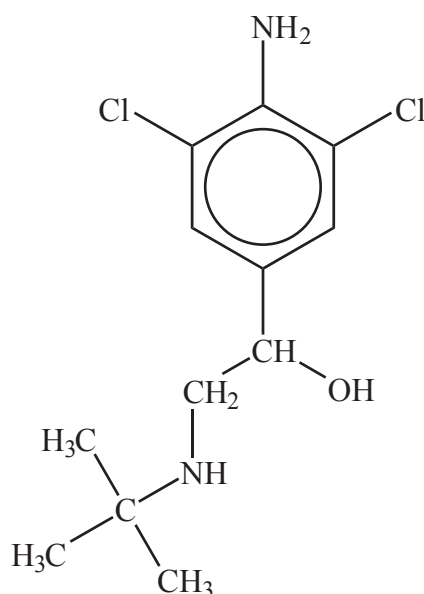
(a) State **one** side-effect **specific to males** of taking anabolic steroids in large doses. [1]

.....

.....

(b) The use of anabolic steroids is prohibited by UCI (*Union Cycliste Internationale*) – the governing body of world cycling, based in Switzerland.

Since 2010, a number of professional cyclists have tested positive to traces of the substance clenbuterol, known to enhance the aerobic capacity of high-performance cyclists. The structure of clenbuterol is given below.



Some sections of the media have described clenbuterol as an anabolic steroid. Suggest why this is incorrect. [1]

.....

.....

(Option B continues on the following page)



*(Option B, question 6 continued)*

- (c) Compare the functional groups present in the structures of the male sex hormone, testosterone, and the female sex hormone, progesterone. [2]

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**End of Option B**





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

7. Aluminium is an important metal to modern society.

- (a) (i) Describe the production of aluminium from its purified ore. Explain the role of cryolite and deduce the equations for the reactions occurring at the two electrodes. [4]

Production of aluminium:

.....

.....

.....

Role of cryolite:

.....

.....

Negative electrode (cathode):

.....

Positive electrode (anode):

.....

- (ii) Outline why aluminium was not available in large quantities before 1900. [1]

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.....

*(Option C continues on the following page)*



(Option C, question 7 continued)

(b) Aluminium is often used to produce lightweight alloys for use in the aerospace industry.

(i) State **one** advantage of using an alloy rather than the pure metal. [1]

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.....

(ii) Outline why the range of metals alloyed with aluminium for this use is very limited. [1]

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(c) Suggest **one** possible environmental impact that can result from the large-scale production of aluminium. [1]

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.....

(Option C continues on the following page)



*(Option C continued)*

8. Modern society is very dependent on electrical power for portable devices.

(a) Two common rechargeable batteries are lead-acid and nickel-cadmium (NiCad) batteries.

(i) State equations for the reactions that occur at each electrode in a **lead-acid battery** when it delivers a current. [2]

Positive electrode (cathode):  
.....  
Negative electrode (anode):  
.....

(ii) State equations for the reactions that occur at each electrode in a **nickel-cadmium (NiCad) battery** when it delivers a current. [2]

Positive electrode (cathode):  
.....  
Negative electrode (anode):  
.....

*(Option C continues on the following page)*



*(Option C, question 8 continued)*

- (b) Another source of power for portable devices is the fuel cell. Compare fuel cells with **lead-acid** rechargeable batteries, stating **one** similarity and **two** differences. [3]

Similarity:

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Differences:

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*(Option C continues on the following page)*



*(Option C continued)*

9. Crude oil (petroleum) is initially separated into its components by fractional distillation, but subsequent cracking of the heavier fractions is usually required.

(a) State a balanced equation for the thermal cracking of  $C_{20}H_{42}$  in which octane and ethene are products. [2]

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(b) Ethene can be polymerized to form poly(ethene) and, depending on the conditions used, either high-density poly(ethene) (HDPE) or low-density poly(ethene) (LDPE) is formed.

(i) Other than density, state **two** differences in the physical properties of HDPE and LDPE. [1]

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.....  
.....

(ii) Outline how the differences in (b)(i) relate to differences in their chemical structure. [1]

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.....  
.....

*(Option C continues on the following page)*



*(Option C, question 9 continued)*

- (c) It has been said that bitumen and heavy fuel oils are too valuable a resource to use for road surfacing and electricity generation. Comment on this statement. [1]

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**End of Option C**



**Option D — Medicines and drugs**

**10.** Adults can produce approximately  $2 \text{ dm}^3$  of gastric juice daily in the stomach.

- (a) The pH of gastric juice is 1.5. Identify the compound responsible for its acidity and state whether it is a strong or weak acid. [2]

Compound: ..... Strong or weak acid: .....
-----------------------------------------------------

- (b) Antacid tablets are often taken for an upset stomach. Identify the reaction involved in this treatment and state the general ionic equation for this reaction type. [2]

Type of reaction: ..... Ionic equation: .....
--------------------------------------------------------

*(Option D continues on the following page)*



**Turn over**

(Option D, question 10 continued)

- (c) One active ingredient in a commercial brand of antacid tablets is a complex of aluminium hydroxide and sodium carbonate, dihydroxyaluminium sodium carbonate,  $\text{Al}(\text{OH})_2\text{NaCO}_3(\text{s})$ .

Deduce the balanced equation, including state symbols, for the reaction of  $\text{Al}(\text{OH})_2\text{NaCO}_3(\text{s})$  with the acid present in gastric juice. [2]

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- (d) (i) Explain why anti-foaming agents are often added to the formulation in antacids. [1]

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- (ii) State the name of **one** such agent. [1]

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(Option D continues on the following page)





*(Option D continued)*

11. A commonly used mild analgesic is aspirin, 2-acetoxybenzoic acid, whose structure is given in Table 20 of the Data Booklet.

(a) Describe how mild analgesics function. [1]

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.....

(b) One form of soluble aspirin is  $\text{Ca}(\text{C}_9\text{H}_7\text{O}_4)_2$ .

(i) Outline why this substance is more soluble than standard aspirin in water. [1]

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(ii) Deduce the balanced ionic equation for the reaction that occurs between soluble aspirin and the acid in the stomach. [1]

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*(Option D continues on the following page)*



(Option D, question 11 continued)

(c) Morphine, codeine and diamorphine (heroin) are examples of strong analgesics. Their structures are given in Table 20 of the Data Booklet.

(i) Deduce **two** named functional groups present in both aspirin and diamorphine. [2]

.....  
.....

(ii) Deduce **one** named functional group present in morphine but not in diamorphine. [1]

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(iii) State **two** short-term advantages and **two** long-term disadvantages of using codeine as a strong analgesic. [2]

Short-term advantages:  
.....  
.....  
.....  
.....

Long-term disadvantages:  
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.....  
.....  
.....

(Option D continues on the following page)



(Option D continued)

12. Some drugs, such as aspirin, can be taken orally whereas others, such as nicotine, a socially used stimulant, are usually taken by inhalation.

(a) State the name of **two** other methods of administering drugs including **one** example of their use in each case. [2]

Method	Example
.....	.....
.....	.....

(b) State **two** long-term effects of nicotine consumption. [1]

.....  
.....  
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(c) Caffeine is also a stimulant. The structures of both caffeine and nicotine are given in Table 20 of the Data Booklet. Based on structural features, suggest a reason why caffeine is more soluble in water than nicotine. [1]

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**End of Option D**



Turn over

**Option E — Environmental chemistry**

13. Motor vehicles are very convenient but can be a major source of air pollution.

- (a) In some countries there has been a recent shift from petrol (gasoline) to diesel as a fuel for motor vehicles. State **one** primary pollutant produced by both of these fuels. [1]

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- (b) Outline **one** method that has been developed for each fuel to reduce polluting emissions. [2]

Fuel	Method to decrease emissions
Diesel	.....
Petrol (gasoline)	.....

- (c) Sulfur dioxide is generated from the sulfur present in diesel fuel. State **two** other manufactured (anthropogenic or sometimes termed man-made) sources of sulfur dioxide. [2]

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.....

*(Option E continues on the following page)*



*(Option E continued)*

14. Suggest why the temperature decrease of the Earth's surface after sunset is less when the weather is cloudy than when there are no clouds. [2]

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15. Acid deposition is a consequence of industrial processes.

- (a) State what is meant by the term acid deposition. [1]

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.....  
.....

- (b) Industrial processes, such as the burning of coal, generate non-metallic oxides of carbon and nitrogen into the atmosphere. State balanced equations for the reactions by which these oxides are produced and then removed from the atmosphere. [4]

Oxide of carbon:  
Produced: .....  
Removed: .....  
Oxide of nitrogen:  
Produced: .....  
Removed: .....

*(Option E continues on the following page)*



(Option E, question 15 continued)

- (c) All shellfish have a calcium carbonate shell. Discuss, including a balanced equation, the long-term effect of acid deposition on these organisms. [2]

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Balanced equation:

.....

16. The health of soils is important for feeding the world's population.

- (a) (i) Describe how nutrient depletion occurs. [1]

.....

.....

- (ii) State **one** way of minimizing nutrient depletion. [1]

.....

.....

(Option E continues on the following page)



*(Option E, question 16 continued)*

- (b) Explain why the soil becomes salty in areas where soil is constantly irrigated. [2]

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

- (c) Describe **two** ways in which soil organic matter (SOM) contributes to preventing soil degradation. [2]

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**End of Option E**



**Option F — Food chemistry**

17. Food chemistry and nutritional science are two important scientific fields to which the general public relate.

(a) Distinguish between a *food* and a *nutrient*. [2]

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.....
.....

(b) State **two** named functional groups present in each of the following molecules found in two different food products (honey and sardines). Identify each molecule as a protein, a carbohydrate or a fatty acid. [3]

<b>Molecule</b>	$  \begin{array}{ccccccc}  & \text{OH} & \text{H} & \text{OH} & \text{OH} & & \\  &   &   &   &   & & \\  \text{OHC} & - \text{C} & - \text{C} & - \text{C} & - \text{C} & - \text{CH}_2\text{OH} & \\  &   &   &   &   & & \\  & \text{H} & \text{OH} & \text{H} & \text{H} & &   \end{array}  $	$\text{CH}_3\text{CH}_2(\text{CH}=\text{CHCH}_2)_3(\text{CH}_2)_6\text{COOH}$
<b>Present in food</b>	honey	sardines
<b>Two named functional groups</b>	..... .....	..... .....
<b>Protein, carbohydrate or fatty acid</b>	.....	.....

(Option F continues on the following page)





(Option F, question 17 continued)

- (c) Butter is an example of a saturated fat and olive oil is an example of an unsaturated fat. Describe the main structural difference between these two types of fat. [1]

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

- (d) (i) Linoleic acid, whose structure is given in Table 22 of the Data Booklet, is present in peanut oil. The oil can be converted to a semi-solid using hydrogen gas. Predict the structural formula of the compound formed from the **partial** hydrogenation reaction of linoleic acid, and state a suitable catalyst for this reaction. [2]

Structural formula:

Catalyst:

.....

- (ii) State **one** food product that may be obtained by careful control of the extent of the reaction in (d)(i). [1]

.....

(Option F continues on the following page)



(Option F, question 17 continued)

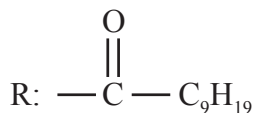
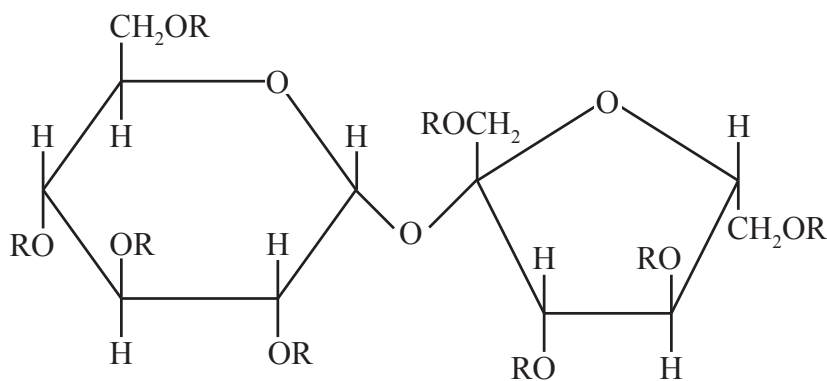
- (iii) Partial hydrogenation can sometimes produce *trans* fats. Suggest why *trans* fats are considered unhealthy. [1]

.....

.....

.....

- (iv) Olestra, with one of its structures shown below, has been used to prepare snacks such as crisps (potato chips). Deduce the type of compound that can undergo an esterification reaction involving carboxylic acid to produce olestra. [1]



Olestra

.....

(Option F continues on the following page)



(Option F continued)

18. Antioxidants are a type of food additive.

(a) Define the term *antioxidant*.

[1]

..... .....
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(b) (i) State **one** example of a source of food for each of the two naturally occurring antioxidants.

[1]

Antioxidant	Food source
Selenium	.....
$\beta$ -carotene	.....

(ii) Identify **one** named functional group present in both of the preservatives BHT and 3-BHA, whose structures are given in Table 22 of the Data Booklet.

[1]

.....
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(iii) Antioxidants such as BHT and 3-BHA prevent the unwanted reactions of free radicals. State what a free radical is.

[1]

..... .....
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(Option F continues on the following page)



Turn over

(Option F, question 18 continued)

- (iv) Antioxidants can also prevent rancidity in foods such as butter. Describe what is meant by rancidity. [1]

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19. Food can be coloured by natural or artificial means.

- (a) Distinguish between a *dye* and a *pigment* in terms of their solubility. [1]

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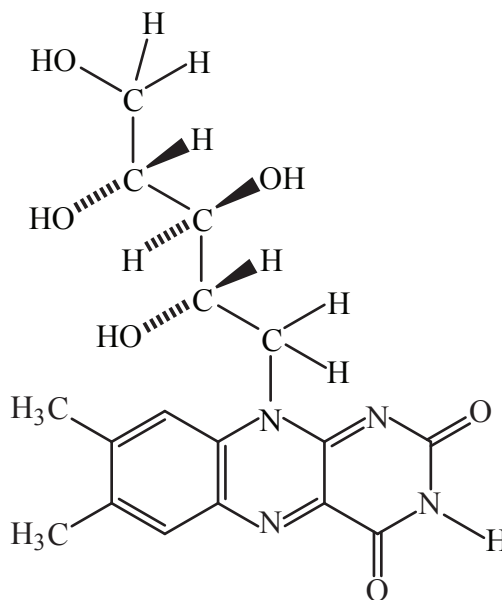
(Option F continues on the following page)



(Option F, question 19 continued)

- (b) (i) Many vegetables contain the pigment  $\beta$ -carotene. After ingestion,  $\beta$ -carotene is oxidized by enzymes forming vitamin A (retinol), whose structure is given in Table 21 of the Data Booklet.

Suggest why taking large doses of vitamin B<sub>2</sub> (riboflavin), which is found in eggs, can be safer than taking large doses of vitamin A (retinol). [1]



Vitamin B<sub>2</sub> (riboflavin)

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.....

(Option F continues on the following page)

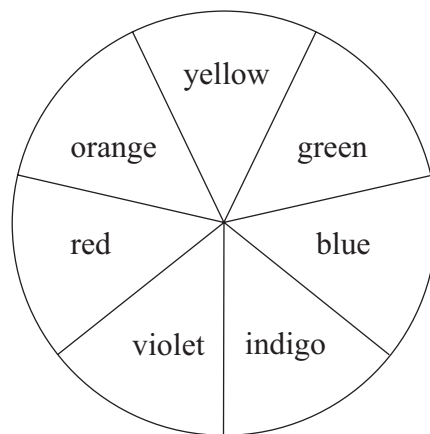


(Option F, question 19 continued)

- (ii) Extraction of the vegetable spinach produces  $\beta$ -carotene and chlorophyll, which have different colours due to their different ultraviolet-visible (UV-Vis) absorption spectra. The  $\lambda_{\text{max}}$  values for  $\beta$ -carotene and chlorophyll are 425 nm and 662 nm respectively.

Using the  $\lambda_{\text{max}}$  values corresponding to the colours of the visible region of the electromagnetic spectrum, explain the colours of the two compounds. [2]

Colour	$\lambda$ / nm
Violet	380–450
Indigo	450–475
Blue	475–495
Green	495–570
Yellow	570–590
Orange	590–620
Red	620–750



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**End of Option F**

**Option G — Further organic chemistry**

20. Following the initial discovery of benzene by Michael Faraday in 1825, it took many years before the structure was determined.

(a) Describe the structure of benzene.

[3]

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

(b) State **one** piece of **chemical** evidence proving benzene does not contain alternate single and double bonds.

[1]

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

*(Option G continues on the following page)*



(Option G continued)

21. Both phenol,  $C_6H_5OH$ , and butan-1-ol,  $CH_3CH_2CH_2CH_2OH$ , contain the hydroxyl group.

- (a) (i) State the structural formula of the organic product formed by heating butan-1-ol with concentrated phosphoric acid,  $H_3PO_4$ . [1]

- (ii) Identify the type of reaction in (a)(i). [1]

.....

- (iii) Suggest why concentrated phosphoric acid is a more effective reagent than concentrated sulfuric acid,  $H_2SO_4$ , for the reaction in (a)(i). [1]

.....  
.....

- (b) State whether phenol is a stronger or a weaker acid than butan-1-ol and explain your answer. [2]

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

(Option G continues on the following page)





(Option G continued)

22. Consider the following reaction pathway starting with the reaction of hex-1-ene with hydrogen iodide.



- (a) (i) In Stage 1 two isomers form. Deduce the **full** structural formula of each isomer, showing all the bonds. [2]

**X (Major):**

**Y (Minor):**

- (ii) Explain the mechanism of the reaction of hex-1-ene with hydrogen iodide to form **X**, using curly arrows to represent the movement of electron pairs. [3]

(Option G continues on the following page)



(Option G, question 22 continued)

- (iii) Suggest why the intermediate involved in forming isomer **X** is more stable than the one required to form **Y**. [1]

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

- (b) **Z** is a Grignard reagent.

- (i) State the structural formula of **Z**. [1]

- (ii) State an important condition for the Stage 2 reaction to occur. [1]

.....  
.....

(Option G continues on the following page)



(Option G, question 22 continued)

- (iii) Deduce the structural formula of the organic product formed from the reaction of **Z** with propanone,  $(\text{CH}_3)_2\text{CO}$ , and subsequent hydrolysis with dilute aqueous acid,  $\text{H}_3\text{O}^+$ . Identify the class of compound to which the organic product formed belongs. [2]

Structural formula:

Class of compound:

.....

- (iv) Identify the reagent that would be required to react with **Z** to produce a carboxylic acid. [1]

.....

**End of Option G**



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

Answers written on this page  
will not be marked.



44EP44