

## Chemistry

### Standard level

### Paper 3

Friday 15 May 2015 (morning)

Candidate session number

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 – 10
Option D — Medicines and drugs	11 – 13
Option E — Environmental chemistry	14 – 16
Option F — Food chemistry	17 – 19
Option G — Further organic chemistry	20 – 22



**Option A — Modern analytical chemistry**

1. Electromagnetic waves can transfer energy and carry information.

(a) State the relationship between the energy of a wave and its wavelength. [1]

.....  
.....

(b) Identify the region of the electromagnetic spectrum that can be used to obtain the concentration of Cr<sup>3+</sup> ions in industrial waste waters. [1]

.....  
.....

(c) (i) Magnetic resonance imaging (MRI) is a technique in which radio waves are used to obtain an image of part or the whole of the human body.  
Explain, on a molecular level, why this technique can be used to obtain information about the body. [2]

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.....  
.....

(ii) Outline the information that MRI scans provide about the body. [1]

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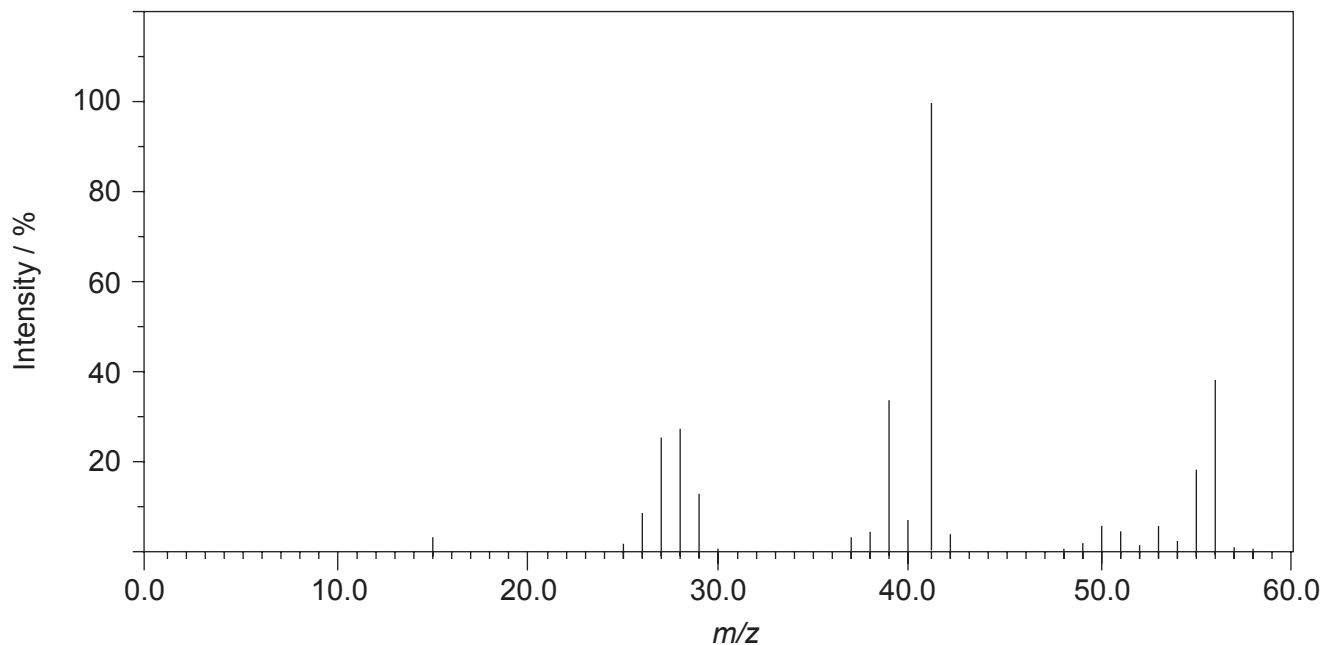
(Option A continues on the following page)



**(Option A continued)**

2. The structure of an unknown compound **A** with empirical formula  $\text{CH}_2$  can be determined using information from a variety of analytical techniques.

(a) The mass spectrum of **A** is shown below.



[Source: <http://webbook.nist.gov> (2013)]

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

.....  
.....

(ii) Deduce the formulas of the fragments which give rise to peaks at  $m/z = 27$  and 29. [1]

$m/z = 27$ :  
.....  
 $m/z = 29$ :  
.....

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

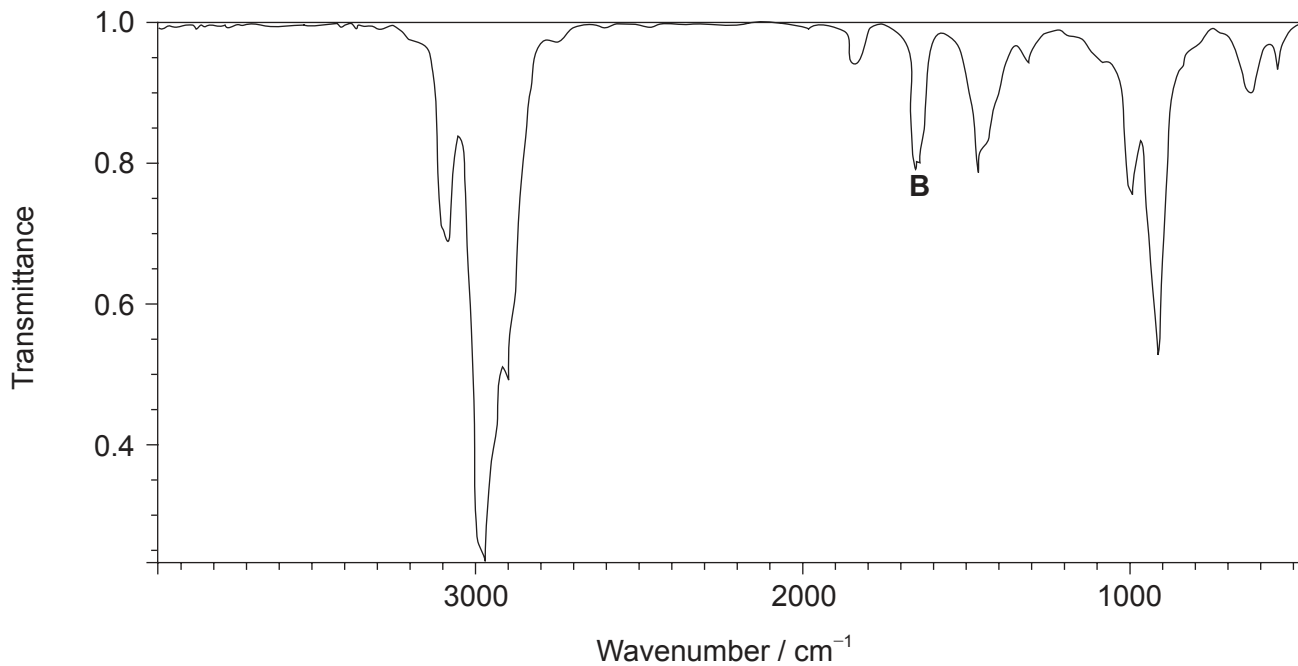


40EP03

Turn over

(Option A, question 2 continued)

(b) The infrared (IR) spectrum of **A** is shown below.



[Source: <http://webbook.nist.gov> (2013)]

(i) Explain what occurs at a molecular level during the absorption of IR radiation by molecule **A**. [2]

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

(ii) Identify the bond responsible for the IR absorption at **B**. [1]

.....  
.....

(iii) Deduce a structural formula consistent with the data. [1]

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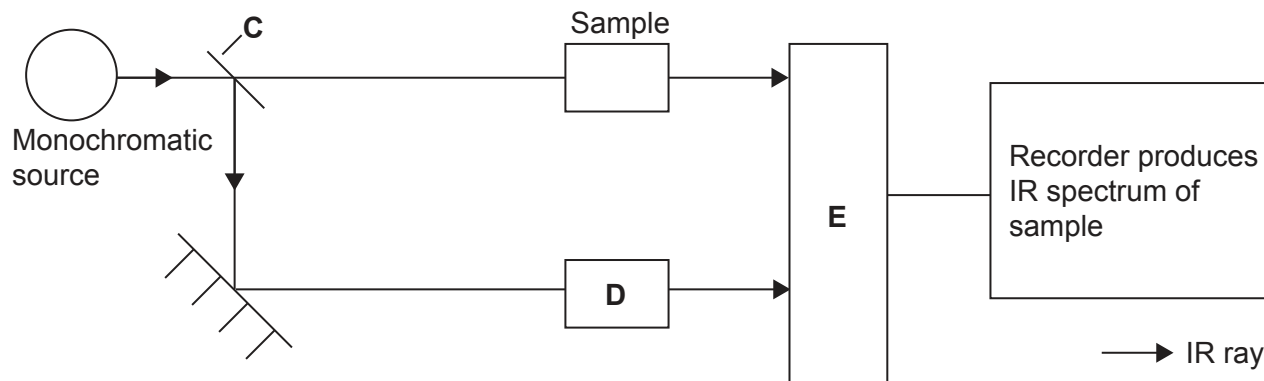
(Option A continues on the following page)



40EP04

(Option A, question 2 continued)

- (c) (i) The IR spectrum was obtained using a double-beam spectrometer. The principal components of the instrument are shown below.



Describe the functions of **C**, **D** and **E**.

[3]

C:  
.....  
.....

D:  
.....  
.....

E:  
.....  
.....

- (ii) The range of absorbances between  $1500\text{--}500\text{ cm}^{-1}$  is generally called the fingerprint region. Outline what happens on a molecular level when radiation in this region is absorbed, and suggest how the region is used in chemical analysis. [2]

.....  
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.....

(Option A continues on the following page)



40EP05

Turn over

**(Option A continued)**

3. Paper chromatography and column chromatography can both be used to separate and analyse mixtures. Distinguish between the two techniques by completing the table below. [3]

	<b>Partition or adsorption?</b>	<b>Mobile phase</b>	<b>Stationary phase</b>
<b>Paper</b>	.....	.....	.....
<b>Column</b>	.....	.....	.....

**End of Option A**



40EP06

**Option B — Human biochemistry**

4. The building blocks of human proteins are the 2-amino acids with the general formula  $H_2N-CHR-COOH$ , where R represents a side-chain specific to each amino acid. A list of these amino acids and their isoelectric points is given in table 19 of the data booklet.

(a) (i) State why they are called 2-amino acids. [1]

.....  
.....

(ii) Identify the amino acid with the empirical formula  $C_3H_7ON_2$ . [1]

.....

(iii) Hydrophobic groups do not like to reside in an aqueous environment and are non-polar. Identify **two** amino acids with a hydrophobic side-chain. [1]

.....  
.....

(iv) Deduce the structure of valine in a solution with a pH of 4.0. [1]

(Option B continues on the following page)



**(Option B, question 4 continued)**

- (b) Deduce the primary structures of the tripeptides formed by reacting together one molecule of each of the amino acids aspartic acid (Asp), glutamine (Gln) and histidine (His), using three-letter abbreviations to represent the amino acids. [2]

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- (c) Proteins carry out a number of important functions in the body. State the function of collagen. [1]

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.....

**(Option B continues on the following page)**





**(Option B continued)**

5. Lipids are a diverse group of compounds found in the body.

(a) Compare the structures and polarities of fats and phospholipids, giving **one** similarity and **one** difference in structure and **one** difference in polarity. [3]

Similarity in structure: ..... .....
Difference in structure: ..... .....
Difference in polarity: ..... .....

(b) Cholesterol is one of the most important steroids. It plays an essential role in metabolism and is the starting point for the synthesis of many important chemicals in the body.

(i) Vitamin D is produced from cholesterol. The structures of both molecules are given in table 21 of the data booklet. Outline **one** structural difference between the molecules. [1]

..... ..... .....
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**(Option B continues on the following page)**



40EP09

Turn over

**(Option B, question 5 continued)**

- (ii) Distinguish between **HDL** and **LDL** cholesterol in terms of their composition and their effect on health. [2]

Composition: ..... .....  One effect on health: ..... .....
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- (iii) Rickets is a softening of the bones in immature mammals due to a deficiency of vitamin D, which is involved in the uptake of two key elements in the diet. Suggest the identity of **one** of these two elements. [1]

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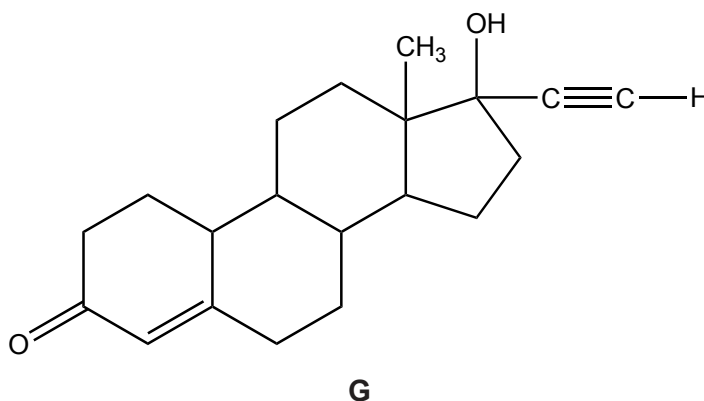
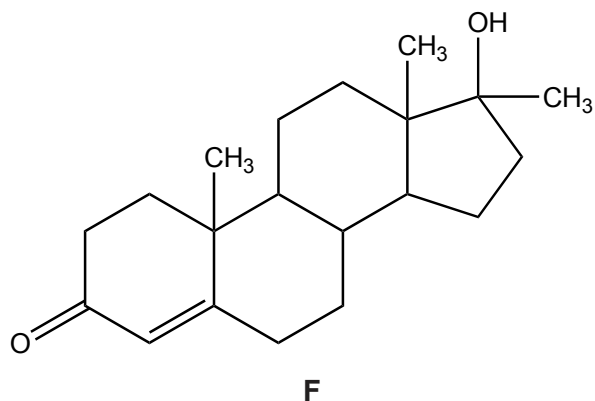
**(Option B continues on the following page)**



40EP10

(Option B continued)

6. **F** and **G** are two synthetic hormones. The structures of some natural hormones are given in table 21 of the data booklet.



- (a) A number of famous athletes have been banned from competition for using hormone **F**. Explain, with reference to its structure, why hormone **F** improves performance. [2]

.....

.....

.....

.....

- (b) (i) **G** was first patented as a drug in 1956.

Compare the structure of **G** with that of progesterone, in terms of functional groups, by stating **one** similarity and **one** difference. [2]

Similarity in structure:

.....

.....

Difference in structure:

.....

.....

(Option B continues on the following page)



**(Option B, question 6 continued)**

- (ii) **G** can be used as an oral contraceptive. Describe its likely action in the female body.

[2]

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.....

**End of Option B**



40EP12

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

7. The large-scale production of iron is important for the industrial development of many countries.

- (a) (i) Magnetite,  $\text{Fe}_3\text{O}_4$ , is a common ore of iron. Calculate the average oxidation state of iron in the compound and comment on your answer. [2]

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.....

- (ii) State the equation for the reduction of this ore to iron with carbon monoxide. [1]

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.....

- (iii) Outline why iron is obtained from its ores using chemical reducing agents but aluminium is obtained using electrolysis. [1]

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.....

- (b) Much of the iron produced in a blast furnace is converted into steel. The properties of the steel can be adapted for use by heat treatment. Describe the annealing process and its effect on the steel. [2]

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(Option C continues on the following page)

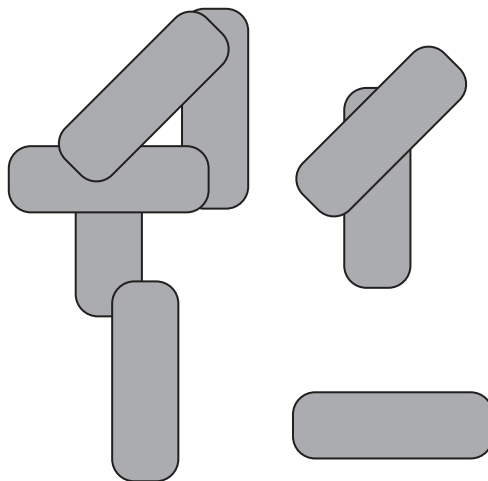


**(Option C continued)**

8. Thermotropic liquid crystals are widely used in display devices and sensors.

(a) The diagram below shows eight molecules in the liquid state. Suggest, with a diagram, a possible arrangement that these rod-shaped molecules could adopt in the nematic liquid-crystal phase.

[2]

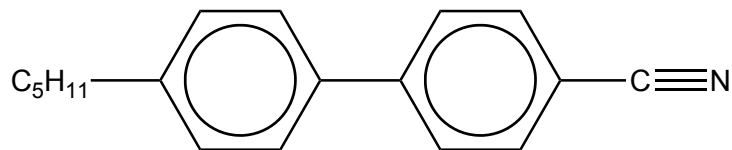


**(Option C continues on the following page)**



(Option C, question 8 continued)

(b) The structure of a material used in electrical display devices is shown below.



(i) Suggest, with reference to the structure, why the molecule is able to change orientation in an electric field. [1]

.....  
.....

(ii) Suggest how the C<sub>5</sub>H<sub>11</sub> chain contributes to the liquid-crystal properties of the compound. [1]

.....  
.....

(iii) Explain why a liquid-crystal device may be unreliable at low temperatures. [1]

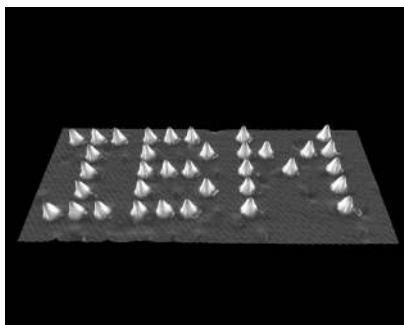
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(Option C continues on the following page)



**(Option C continued)**

9. In 1989 Don Eigler and his team carried out one of the first experiments in nanotechnology. They spelled out the IBM logo with 35 xenon atoms.



[Source: <http://www-03.ibm.com> (2013)]

- (a) Outline the technique used to manipulate the atoms in this way. [2]

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.....

- (b) The atomic radius of xenon is  $1.36 \times 10^{-10}$  m. Estimate the approximate length, in m, of the "I" in the original IBM image. [1]

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**(Option C continues on the following page)**



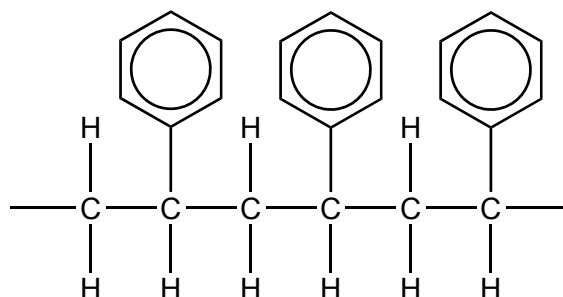
40EP16



(Option C continued)

10. The development and application of plastics was one of the most important technological developments of the last century.

The diagram below represents a section of a polymer.



- (a) (i) Identify the **two** functional groups in the monomer from which this polymer is manufactured. [1]

.....  
.....

- (ii) An expanded form of the plastic is often used in packaging. Describe how this is manufactured. [2]

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

(Option C continues on the following page)



(Option C, question 10 continued)

- (b) Discuss **two** advantages and **one** disadvantage of using the expanded form as a packaging material.

[3]

Two advantages:

.....

.....

.....

.....

One disadvantage:

.....

.....

**End of Option C**



40EP18

**Option D — Medicines and drugs**

11. Nicotine has led to over two billion people being addicted to smoking. Its structure is shown in table 20 of the data booklet.

(a) (i) Outline **two** short-term effects of nicotine consumption. [2]

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.....  
.....

(ii) Discuss **one** life-threatening effect of smoking tobacco that is not directly caused by nicotine consumption. [2]

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

(b) (i) Explain, with reference to its molecular structure, why nicotine is basic. [2]

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

(ii) Outline how nicotine passes into the bloodstream within seconds of a cigarette being smoked. [1]

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.....

(Option D continues on the following page)



(Option D, question 11 continued)

- (c) (i) Long-term smokers develop tolerance to the effects of nicotine. State what is meant by the term tolerance. [1]

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.....

- (ii) Nicotine replacement therapy involves administering the drug in ways other than smoking. Describe **two** other methods of administering nicotine. [2]

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12. Many common illnesses are caused by viral infections.

- (a) State the chemical composition of a virus. [2]

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.....  
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- (b) Acyclovir is an antiviral drug used to treat herpes infections. Outline **two** ways in which antiviral drugs work. [2]

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.....

(Option D continues on the following page)



(Option D, question 12 continued)

- (c) Discuss **two** difficulties associated with the development of drugs for the effective treatment of AIDS.

[2]

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.....

13. The properties of four analgesics are summarized below.

Drug	Strength	Acts	Addictive
A	mild	at site of pain	no
B	mild	on brain	no
C	mild	on brain	mildly addictive
D	strong	on brain	very addictive

- (a) Deduce which drugs could be morphine, aspirin and codeine.

[2]

Morphine:

.....

Aspirin:

.....

Codeine:

.....

(Option D continues on the following page)



40EP21

Turn over

**(Option D, question 13 continued)**

- (b) Compare the structures of diamorphine (heroin) and morphine. Their structures are given in table 20 of the data booklet.

[2]

Two similarities:

.....

.....

One difference:

.....

.....

**End of Option D**

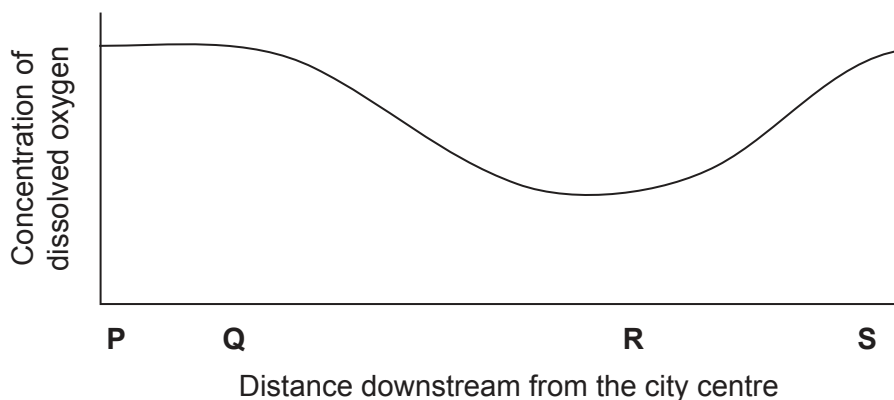


40EP22

**Option E — Environmental chemistry**

14. The oxygen levels in water can change for a number of reasons.

- (a) Some organic matter is added to a river from a food processing factory near a city centre. The graph represents the variation in the concentration of dissolved oxygen along the river as it flows away from the city.



Identify which letter is the most likely location for the food processing factory, giving a reason for your choice.

[2]

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

- (b) (i) State the names of the **two** pollutant negative ions added to a river by the excessive use of fertilizers.

[1]

.....

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



40EP23

Turn over

**(Option E, question 14 continued)**

(ii) Describe how these pollutants cause a decrease in the oxygen concentration in a river. [2]

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.....  
.....

(c) State a non-chemical reason for the decrease in oxygen concentration. [1]

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.....

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

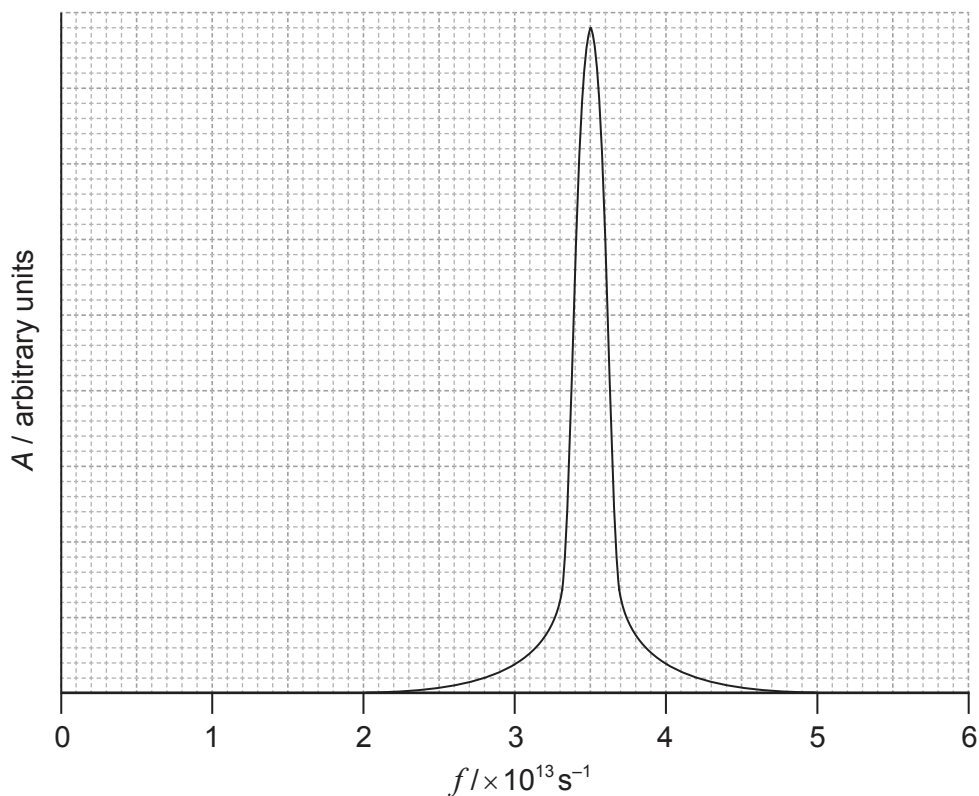




(Option E continued)

15. The atmospheric greenhouse effect is caused by several gases.

(a) The graph shows part of the absorption spectrum of an oxide of nitrogen in which the intensity of absorbed radiation  $A$  is plotted against frequency  $f$ .



(i) Determine the wavelength of the radiation absorbed, in m, using table 1 of the data booklet. (The speed of light,  $c$ , is  $3.0 \times 10^8$ .)

[1]

.....  
.....

(ii) Deduce the region of the electromagnetic spectrum to which this belongs.

[1]

.....

(Option E continues on the following page)



40EP25

Turn over

(Option E, question 15 continued)

- (b) State the chemical formula of this oxide of nitrogen. [1]

.....

- (c) Discuss the relative contributions of carbon dioxide and this oxide of nitrogen to global warming. [2]

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

- (d) Suggest **two** possible reasons why the climate change which results from global warming could result in a decrease in global food production. [2]

1. ....  
.....  
2. ....  
.....

16. Intensive farming changes the composition of soils and may lead to soil degradation.

- (a) Explain how agriculture removes soil nutrients and how they can be replaced. [2]

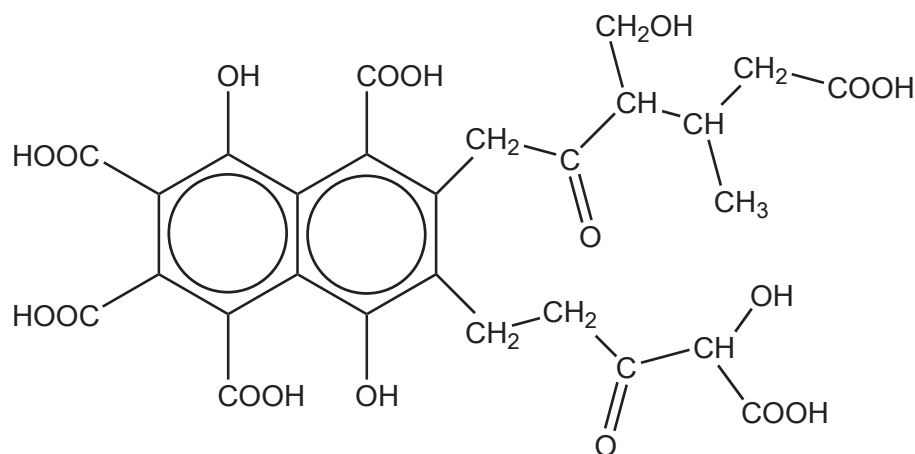
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(Option E continues on the following page)



**(Option E, question 16 continued)**

- (b) Fulvic acid is an important constituent of soil organic matter (SOM). A representation of its structure is shown below.

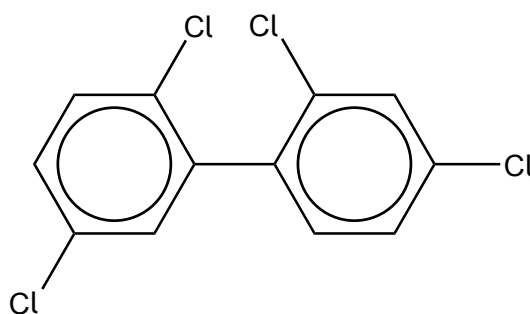


Outline how this structure of fulvic acid is able to retain water in soil.

[2]

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

- (c) Polychlorinated biphenyls (PCBs) are oils that do not catch fire under conditions of extreme pressure or temperature. The structure of a polychlorobiphenyl is shown below.



This chemical has now been banned from use in many countries. State a possible source of these organic soil pollutants.

[1]

.....

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



40EP27

Turn over

**(Option E, question 16 continued)**

- (d) Outline how the use of pesticides and fertilizers can cause soil degradation. [2]

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

**End of Option E**



**Option F — Food chemistry**

17. Although people may consume a large amount of food, they may still not consume sufficient nutrients.

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

Food: ..... ..... .....
Nutrient: ..... ..... .....

(b) (i) Describe **one** similarity and **one** difference between the structure of a saturated and an unsaturated fat. [2]

Similarity: ..... .....
Difference: ..... .....

(ii) Outline **one** factor that increases the melting point of oils and fats other than degree of saturation. [1]

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



Turn over

**(Option F, question 17 continued)**

- (c) State the names of **two** types of nutrient, other than lipids and water, and the purpose each serves in the body. [2]

Nutrient	Purpose
..... .....	..... .....
..... .....	..... .....

18. Many food labels now include a “best-before” expiry date to ensure that good-quality food is on sale.

- (a) Explain the meaning of the term shelf life and how it relates to the “best-before” date. [2]

<p>Shelf life:</p> <p>..... .....</p> <p>“Best-before” date:</p> <p>..... .....</p>
---

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



40EP30

**(Option F, question 18 continued)**

- (b) Explain, giving their names, the two types of reaction by which foods may become rancid.

[2]

Reaction 1:

.....

.....

.....

Reaction 2:

.....

.....

.....

- (c) The shelf life of many foodstuffs is extended by the addition of antioxidants; these may be natural or synthetic.

- (i) Suggest **one** advantage of using vitamin C and **one** different advantage of using  $\beta$ -carotene.

[2]

Vitamin C:

.....

.....

.....

.....

$\beta$ -carotene:

.....

.....

.....

.....

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



40EP31

Turn over

(Option F, question 18 continued)

- (ii) Suggest **two** disadvantages of using synthetic antioxidants. [2]

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

19. Mayonnaise is a thick creamy sauce made by blending oil, egg yolk and either lemon juice or vinegar.

- (a) Oil and vinegar are immiscible. Describe what you would expect to happen when oil and vinegar are shaken together and then left standing for a period of time. [2]

When shaken together:  
.....  
.....

After standing:  
.....  
.....

- (b) (i) The egg yolk binds the oil and aqueous component together in mayonnaise using an emulsifier. Outline the action of an emulsifier. [1]

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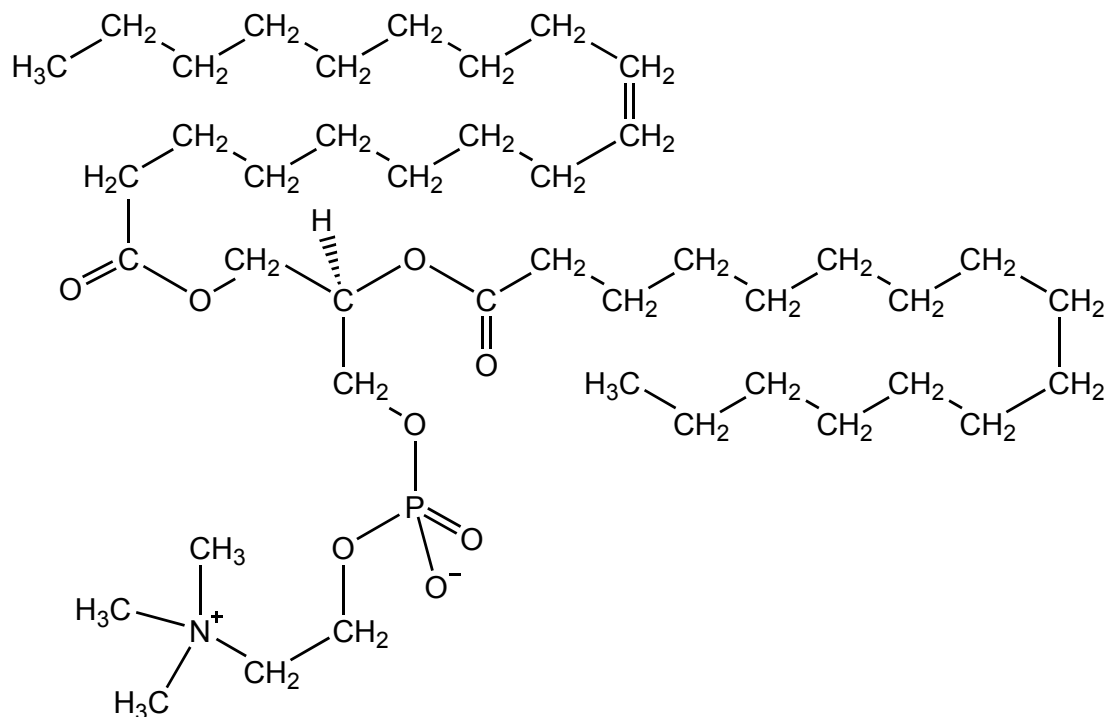
(Option F continues on the following page)





(Option F, question 19 continued)

(ii) Lecithin, found in egg yolk, contains this compound:



Explain, with reference to the structure, how lecithin acts as an emulsifier.

[2]

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**End of Option F**



40EP33

Turn over



**(Option G, question 20 continued)**

- (ii) Explain why 2-bromobutane is the major product and 1-bromobutane is the minor product. [2]

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

- (c) State the equation and associated conditions for the reaction by which an alkene can be synthesized from butan-1-ol. [2]

Equation:  
.....  
.....  
Conditions:  
.....  
.....

- (d) Deduce the structural formulas of the **two** possible products formed when butan-2-ol is dehydrated and then reacted with iodine. [2]

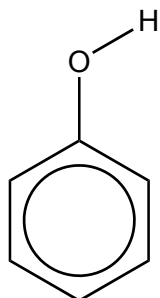
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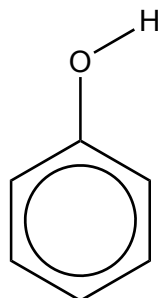


(Option G continued)

21. Phenol and 4-nitrophenol are weak acids. Their structures are given below.



Phenol



4-nitrophenol

(a) Outline, using an equation, why phenol is more acidic than ethanol.

[3]

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

(b) Explain which compound, phenol or 4-nitrophenol, is more acidic.

[3]

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(Option G continues on the following page)



**(Option G continued)**

**22.** Grignard reagents are common organometallic reactants.

(a) State the reagent and condition to form a Grignard reagent from 1-bromopropane. [2]

Reagent: ..... Condition: .....
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(b) Identify the reagents needed to make pentan-2-ol from the Grignard reagent formed in part (a). [1]

.....
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**End of Option G**



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40EP40