Chemistry
Standard level
Paper 3

11 May 2023

Zone A afternoon | **Zone B** morning | **Zone C** afternoon

1 hour

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answers must be written within the answer 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 **[35 marks].**

Section A	Questions
Answer all questions.	1 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 4
Option B — Biochemistry	5 – 8
Option C — Energy	9 – 11
Option D — Medicinal chemistry	12 – 15

32EP01

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Answers written on this page
will not be marked.

Section A

Answer **all** questions. Answers must be written within the answer boxes provided.

1. Graphs showing the first ionization energy and first electron affinity of the elements in period 2 of the periodic table are shown.

First ionization energy
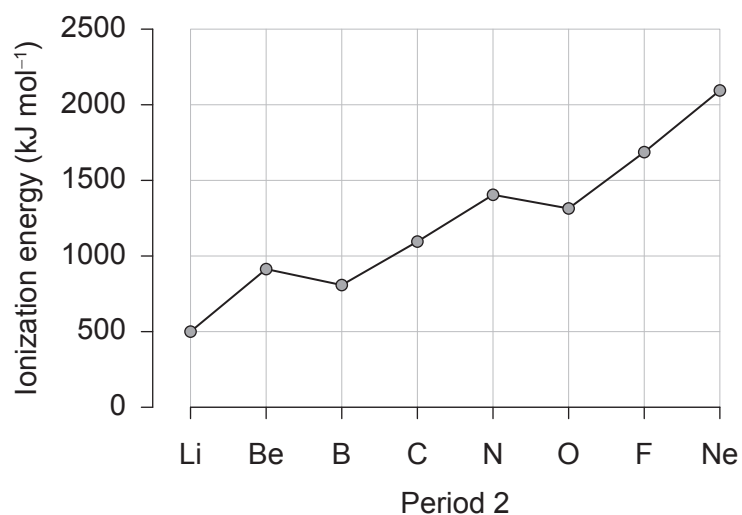
First electron affinity
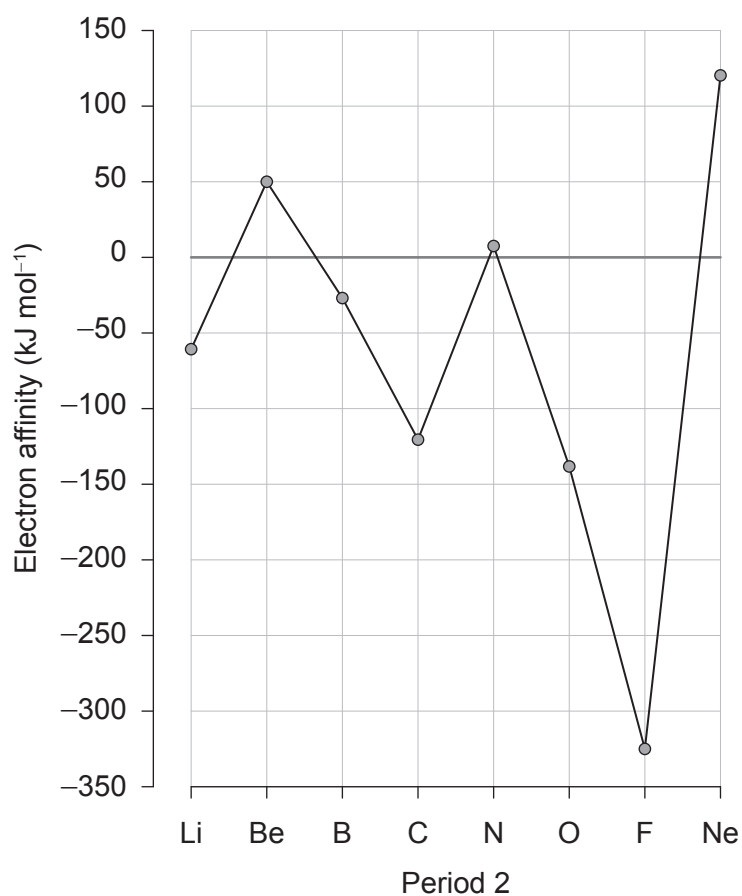
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Turn over

(Question 1 continued)

(a)   Outline why ionization energies have positive values but most electron affinities have
       negative values.   [1]

       . . . .

       . . . .

(b)   First ionization energy tends to increase across the period. Explain the decrease in first
       ionization energy from beryllium to boron.   [2]

       . . . .

       . . . .

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       . . . .

(c)   The electron affinity of nitrogen is $6.8 \, \text{kJ mol}^{-1}$. Sketch the 2s and 2p orbital filling
       diagram that represents the electron arrangement of the species produced.   [1]

       2s   2p
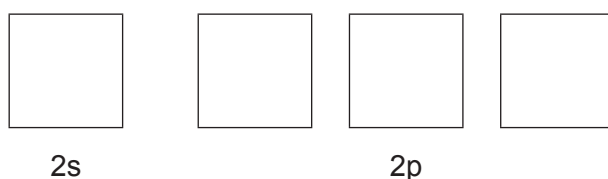
(d)   Suggest **one** reason for a positive value for the first electron affinity for nitrogen.   [1]

       . . . .

       . . . .

(This question continues on the following page)

(Question 1 continued)

(e) Suggest reasons why noble gases have the largest first ionization energy and largest positive first electron affinity in their period. [2]

Largest first ionization energy: . . . .

. . . .

Largest positive first electron affinity: . . . .

. . . .

(f) Suggest, giving **one** reason, how the first electron affinity of xenon compares with that of neon. [1]

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2. Metals A, B, C, D, and E were placed in sulfate solutions.

(a) The results are given where ✓ = reaction occurred and ✗ = no reaction.

Metal	ASO_4 (aq)	BSO_4 (aq)	CSO_4 (aq)	DSO_4 (aq)	ESO_4 (aq)
A	—	✓	✗	✓	✓
B	✗	—	✗	✓	✓
C	✓	✓	—	✓	✓
D	✗	✗	✗	—	✓
E	✗	✗	✗	✗	—

(i) Identify the oxidation state of metal A in ASO_4. [1]

....

....

(ii) Deduce the activity series of the metals. [1]

....

....

(This question continues on the following page)

(Question 2 continued)

    (b)   Sketch the voltaic cell that produces the greatest electromotive force, EMF, using the information in part (a). Label the direction of electron flow, salt bridge, anode, cathode, the metals (A–E) and solutions used in each half-cell.   [4]

    (c)   Deduce the products formed at the electrodes during the electrolysis of molten zinc bromide.   [1]

Anode (positive electrode): . . . .

Cathode (negative electrode): . . . .

Section B

Answer **all** of the questions from **one** of the options. Answers must be written within the answer boxes provided.

Option A — Materials

3. New materials have brought many benefits to society but come with associated risks.

   (a) High-pressure carbon monoxide disproportionation (HiPco) produces carbon atoms that react with nano catalysts to produce carbon nanotubes.

   (i) Write the equation for the disproportionation of carbon monoxide to produce carbon atoms. [1]

   ....
   ....

   (ii) Calculate the percent atom economy of producing carbon using this method. Use section 1 of the data booklet. [1]

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

   (iii) Outline how a metal functions as a heterogeneous catalyst. [2]

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

   (iv) Explain whether the production of carbon nanotubes using HiPco is a bottom up or top down nanotechnology technique. [1]

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

(Option A continues on the following page)

(Option A, question 3 continued)

(v) Suggest **one** health risk of using nanoparticles. [1]

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....

(b) Kevlar® is a recyclable polyamide polymer and a liquid crystal. One repeating unit of the polyamide is shown.
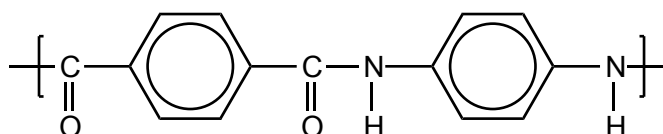
(i) Outline what is meant by a *liquid crystal*. [1]

....

....

(ii) Some liquid crystal displays (LCD) use liquid crystals between two polarizing filters. The display appears black until a small voltage is applied. Outline how the liquid crystals allow polarized light to pass through the filters. [2]

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(iii) Identify the resin identification code (RIC) that applies to Kevlar®. Use section 30 of the data booklet. [1]

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....

(Option A continues on the following page)

(Option A, question 3 continued)

The IR spectrum of Kevlar® is shown.

IR spectrum of Kevlar®
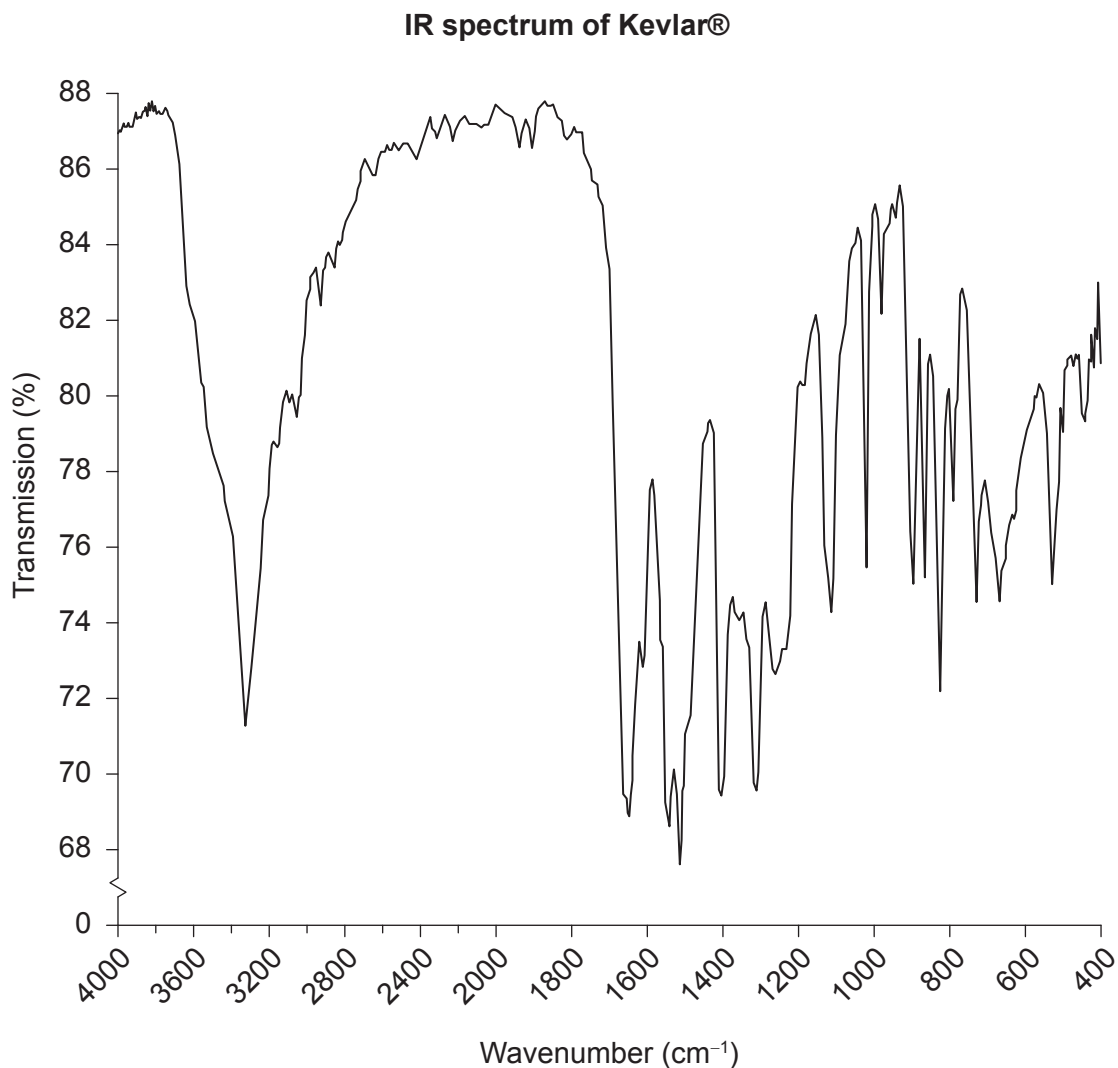
(iv) Deduce the peak in the Kevlar® IR spectrum which would not be found in compounds with any other RIC code. Use Sections 26 and 30 of the data booklet. [1]

. . . .

. . . .

(Option A continues on the following page)

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(Option A, question 3 continued)

    (v)   Discuss **one** environmental advantage **and one** disadvantage of using plastics.   [2]

Advantage: . . . .

. . . .

. . . .

Disadvantage: . . . .

. . . .

. . . .

Turn over

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will not be marked.

(Option A continued)

4. Metals are often alloyed for desired characteristics.

   (a) Explain why metals alloyed with another metal are usually harder and stronger but poorer conductors than the pure metal. [3]

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   (b) Bronze is one of the oldest known alloys. Inductively coupled plasma spectroscopy can be combined with mass spectrometry (ICP–MS) or optical emission spectroscopy (ICP–OES) to analyse the structure and composition of alloys.

   Sketch a typical calibration curve for ICP–OES. [1]
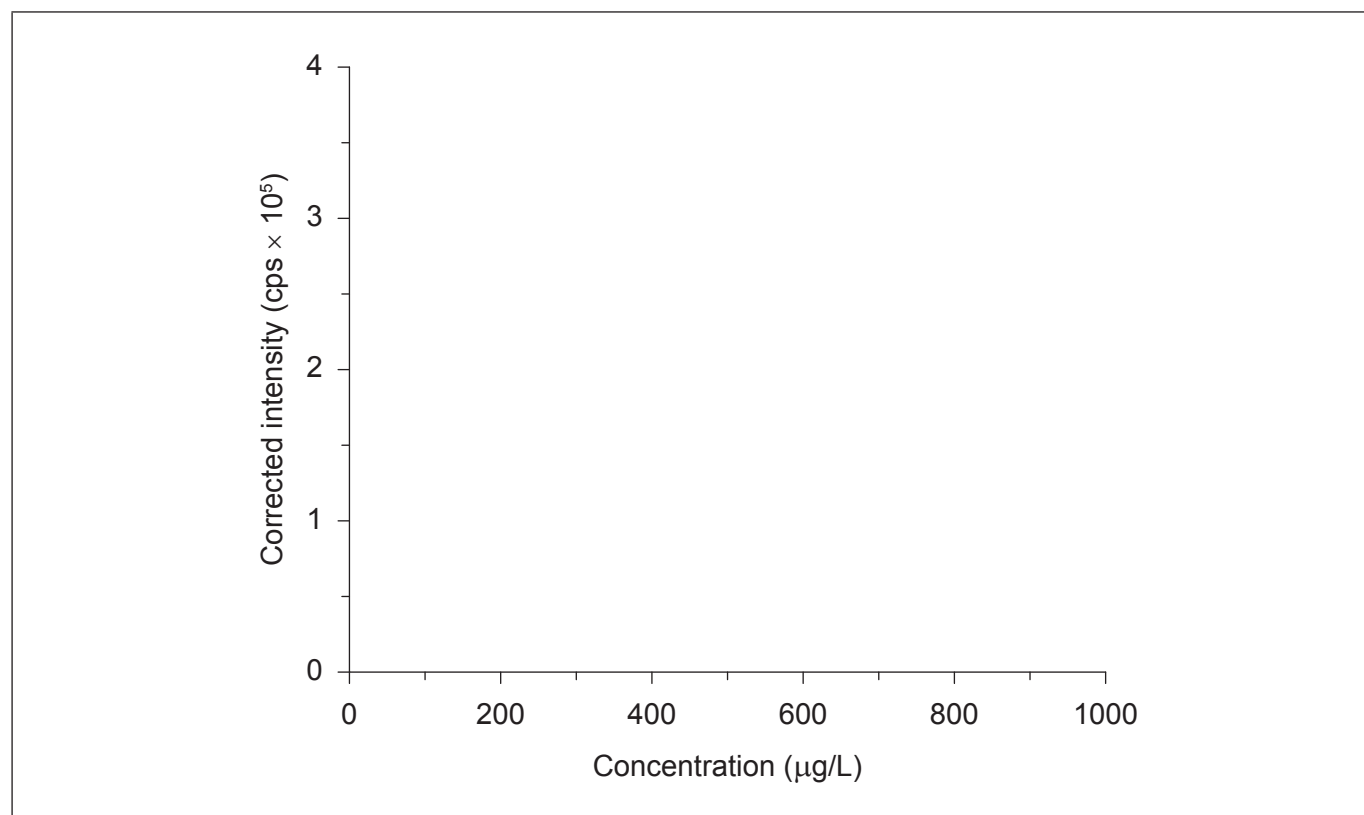
(Option A continues on the following page)

(Option A, question 4 continued)

(c) Various bronze shields from Ayanis fortress in Turkey, dated 670 BCE, were analysed using ICP–MS.

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(i) Draw the expected mass spectrum produced by shield EHR for the range given on the graph. Use relative atomic mass, ignoring isotopes. [1]

Mass spectrum for elements in shield EHR
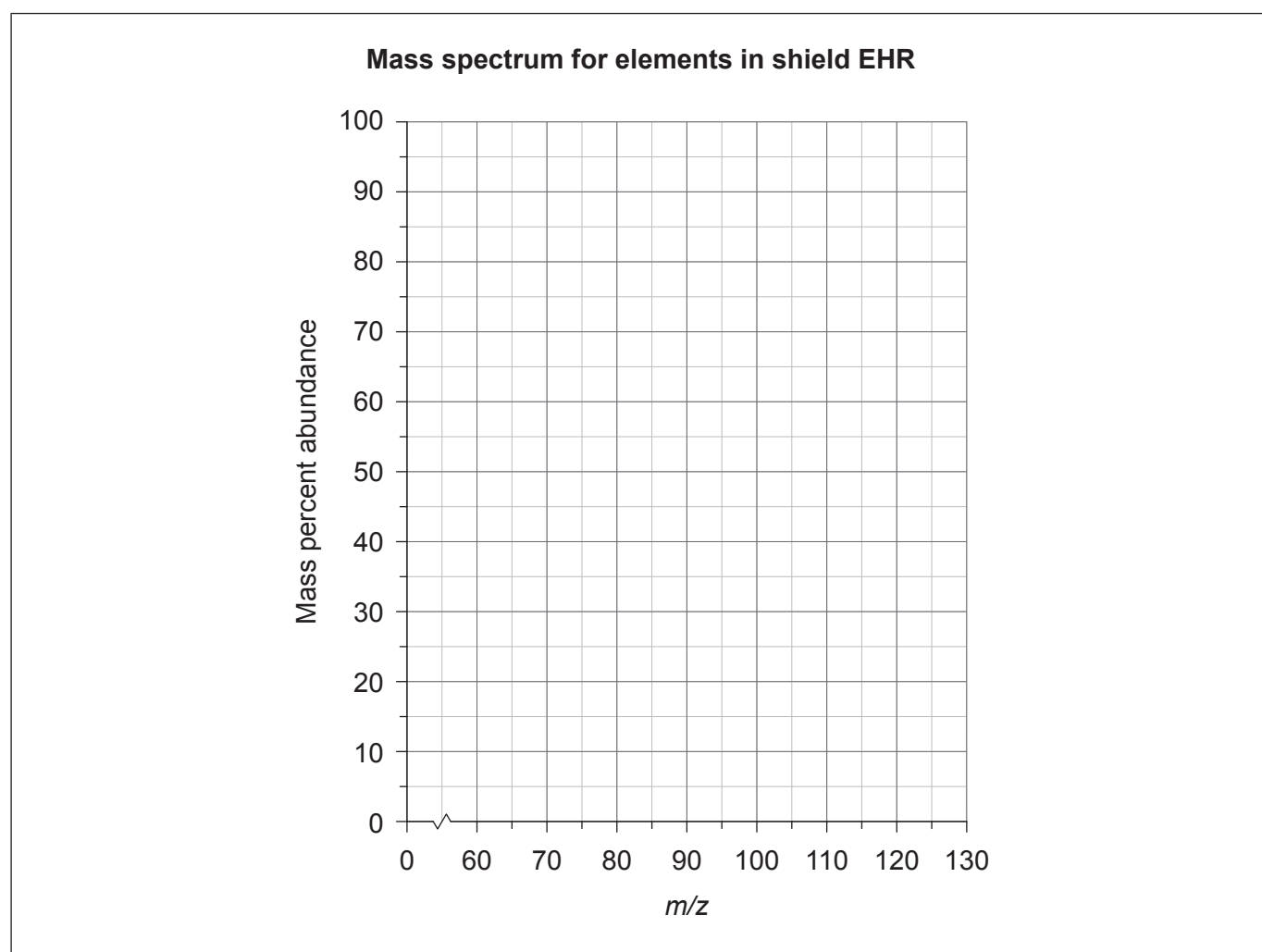
(Option A continues on the following page)

(Option A, question 4 continued)

(ii) Explain the role of the inductively coupled plasma (ICP) torch in allowing the sample to be injected into the mass spectrometer for analysis. [2]

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End of Option A

Option B — Biochemistry

5.   Vitamins are micronutrients necessary for the correct functioning of the body.

(a)   Outline why vitamins usually need to be obtained from food sources.   [1]

....

....

(b)   The structures of three vitamins are given in section 35 of the data booklet.

(i)   Identify **one** functional group present in all three vitamins.   [1]

....

(ii)   Identify **one** functional group only present in vitamin C.   [1]

....

(c)   (i)   State **two** factors, other than concentration, that must be controlled for correct metabolic functioning in the cytoplasm of a cell.   [1]

....

....

(ii)   Suggest **one** reason why it is necessary for cells to have a high water content.   [1]

....

....

(Option B continues on the following page)

(Option B continued)

6. Lipids and carbohydrates play an essential role in the body.

(a) (i) State the general formula of a carbohydrate. [1]

....

(ii) Fructose is a carbohydrate. Determine the energy, in kJ, released by the respiration of 10.5 g of fructose, $C_6H_{12}O_6$. [2]

Enthalpy of $(\Delta H_c^\ominus)$ of fructose $= -2810\,\text{kJ mol}^{-1}$

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(b) Lipids and carbohydrates both release energy in the body.

(i) Write balanced equations for the complete oxidation of fructose, $C_6H_{12}O_6$, and the triglyceride tristearin, $C_{57}H_{110}O_6$. [2]

$C_6H_{12}O_6$: ....

....

$C_{57}H_{110}O_6$: ....

....

(ii) Predict, giving **one** reason, whether 10.5 g of the triglyceride tristearin would release more or less energy than 10.5 g of fructose when completely oxidized. [1]

....

....

....

(Option B continues on the following page)

(Option B, question 6 continued)

    (c)   Describe the chemical composition of phospholipids and their function in the body, other than as energy storage.   [2]

Chemical composition: . . . .

. . . .

Function: . . . .

. . . .

7.   The amino acids in a protein can be separated using paper chromatography. The R_f values using a solvent of butanol and ethanoic acid are given.

Amino acid	R_f value
Lysine	0.14
Glutamic acid	0.30
Threonine	0.35
Tyrosine	0.45
Asparagine	0.5
Methionine	0.55
Valine	0.61
Tryptophan	0.66
Leucine	0.73

(Option B continues on the following page)

(Option B, question 7 continued)

(a) The following diagram shows a chromatogram.

Solvent butanol / ethanoic acid
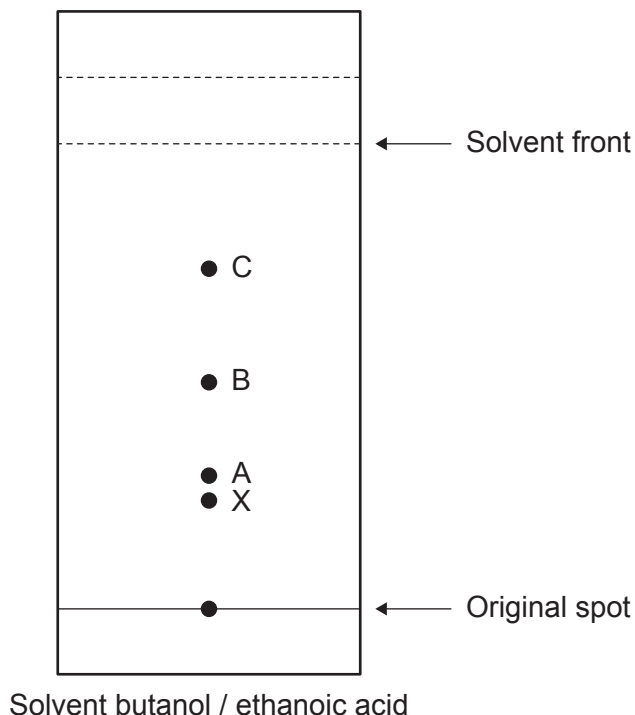
(i) Determine the identity of the amino acid creating spot C by calculating the R_f value from the chromatogram. [1]

Identity of spot C: . . . .

(ii) Predict, referring to the structure of the amino acids, whether spot X on the chromatogram in part (a)(i) is more likely to be serine or phenylalanine. Use the table of R_f values and section 33 of the data booklet. [2]

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(Option B continues on page 21)

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(Option B, question 7 continued)

    (b)   One role of proteins in the body is to catalyse reactions. Describe how enzymes catalyse reactions in the body. [2]

    (c)   State **one** industrial use of enzymes. [1]

8.   Outline the meaning of the term *xenobiotic*. [1]

End of Option B

Option C — Energy

9.   Energy is often converted into more usable forms.

   (a)   The efficiency of a nuclear power plant is approximately 33 %.

      (i)   Outline the meaning of the above statement in terms of energy conversion.   [1]

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....

      (ii)   The fusion of two deuterium nuclei, $_1^2H$, can occur in two ways:

$$_1^2H + _1^2H \rightarrow \mathbf{X} + _0^1n$$

$$_1^2H + _1^2H \rightarrow \mathbf{Y} + _1^1p$$
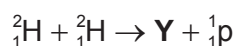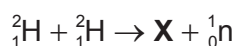
Deduce the nuclear symbols for **X** and **Y** using the correct notation.   [1]

X: ....

....

Y: ....

....

      (iii)   Explain which fusion reaction of deuterium releases more energy. Use section 36 of the data booklet.   [1]

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(Option C continues on the following page)

(Option C, question 9 continued)

(iv) Suggest why the specific energy of deuterium in fusion is higher than that of uranium-235 in fission, yet the energy density of uranium is significantly greater than that of deuterium. Use section 1 of the data booklet. [4]

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(b) Catalytic reforming and cracking can produce more efficient fuel.

(i) Deduce the equation for the conversion of heptane to methylbenzene. [1]

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(ii) Identify **two** products that can be formed from cracking heptane. [1]

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(Option C continues on page 25)

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(Option C continued)

10. Biofuels can be synthesized or converted to make them more usable.

(a) Write the equation for the fermentation of glucose, $C_6H_{12}O_6$, to produce ethanol. [1]

. . . .

. . . .

(b) Deduce the equation for the reaction of the triglyceride shown with methanol. [2]
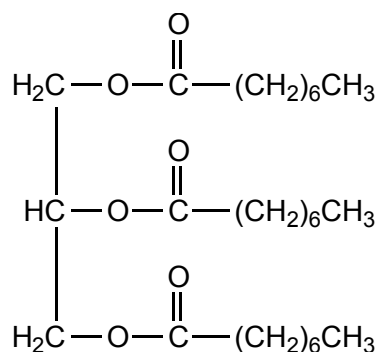
(c) Outline the essential feature needed for a molecule to convert light energy into chemical energy. [1]

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(Option C continues on the following page)

(Option C continued)

11. Energy production often has associated costs.

(a) Calculate the mass of CO_2 produced per 1000 kJ of heat obtained from the combustion of ethanol. Use section 13 of the data booklet. [2]

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(b) Global warming potential (GWP) is a measure of heat absorbed by a greenhouse gas relative to the heat absorbed by the same mass of carbon dioxide.

(i) Suggest **one** piece of evidence, other than temperature rise, that shows correlation between greenhouse gas emission and global warming. [1]

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. . . .

(ii) Outline how greenhouse gas molecules absorb infrared radiation. [1]

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(iii) The GWP of methane is approximately 21. Estimate the heat absorbed by one mole of methane relative to a mole of carbon dioxide. [2]

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(Option C continues on the following page)

(Option C, question 11 continued)

    (c)   Suggest, giving **one** reason, whether the use of biofuels or nuclear power has a lower carbon footprint. [1]

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End of Option C

Option D — Medicinal chemistry

12. Drugs are commonly prescribed by medical professionals to treat illness.

(a) State **two** different drug administration methods. [1]

....

....

(b) Describe **one** similarity **and one** difference between the therapeutic index in animal
and human studies. [2]

Similarity: ....

....

Difference: ....

....

(c) Explain how aspirin works as a mild analgesic. [2]

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....

....

(Option D continues on the following page)

(Option D, question 12 continued)

(d) Deduce the structural formulae of the missing reactant **A** and product **B** in the synthesis of aspirin from salicylic acid. [2]

Salicylic acid

CO₂H

OH

+ (A) →

Aspirin

+ (B)
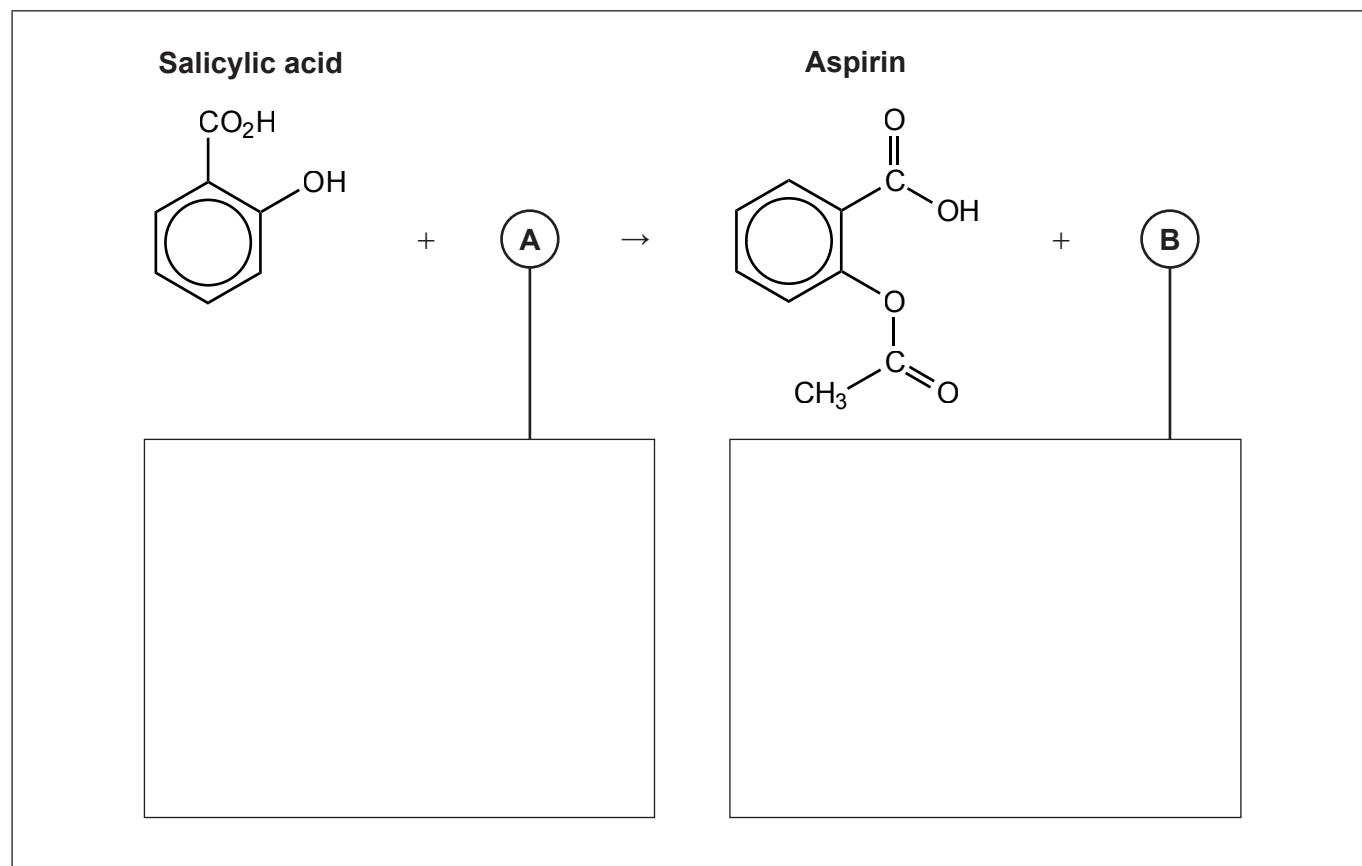
(e) Opiates are another class of drug found in nature. Identify the naturally occurring source of opiates. [1]

....

(f) State **one** advantage **and one** disadvantage of prescribing opiates to patients. [2]

Advantage: ....

....

Disadvantage: ....

....

(Option D continues on the following page)

(Option D continued)

13. Magnesium carbonate and aluminium hydroxide are two antacids.

(a) Write **two** equations showing how these antacids neutralize excess hydrochloric acid. [1]

Magnesium carbonate: ....

....

Aluminium hydroxide: ....

....

(b) Show by calculation that a 2.00 g tablet of aluminium hydroxide would neutralize more hydrochloric acid than a 2.00 g tablet of magnesium carbonate. [2]

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14. Many illnesses are caused by bacteria and viruses.

(a) Describe how viruses differ from bacteria. [1]

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(Option D continues on the following page)

(Option D, question 14 continued)

(b)　Explain **two** ways antiviral medications prevent the replication of viruses. [2]

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(c)　Bacterial infections are treated using antibiotics such as penicillin. Suggest how penicillin can be modified and the reasons for the modification. [2]

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15.　State **two** principles of green (sustainable) chemistry in drug manufacturing, other than using less hazardous or toxic reactants. [2]

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End of Option D

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References:

1. Wikipedia, n.d. *Electron affinity*. [online] Available at: https://en.wikipedia.org/wiki/Electron_affinity [Accessed 22 June 2021]. Source adapted.

3.(b)(iv) A. Campopiano, A. Cannizzaro, A. Olori, S. Boccanera. Study of a selection of man-made organic fibres. *Prevention Today*, vol.5, n.1/2, 33–49. Editorial Office: ISPESL-Department of Organization Processes. (The law of 30 July 2010, n. 122 attributed to INAIL the functions performed in the past by ISPESL).

7. BioTopics. n.d. *Chromatography of amino acids*. [online] Available at: https://www.biotopics.co.uk/as/amino_acid_chromatography.html [Accessed 20 May 2021]. Source adapted.