

Chemistry

Standard level

Paper 3

Friday 12 May 2017 (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.
- 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 – 5

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	6 – 10
Option B — Biochemistry	11 – 13
Option C — Energy	14 – 17
Option D — Medicinal chemistry	18 – 21



Section A

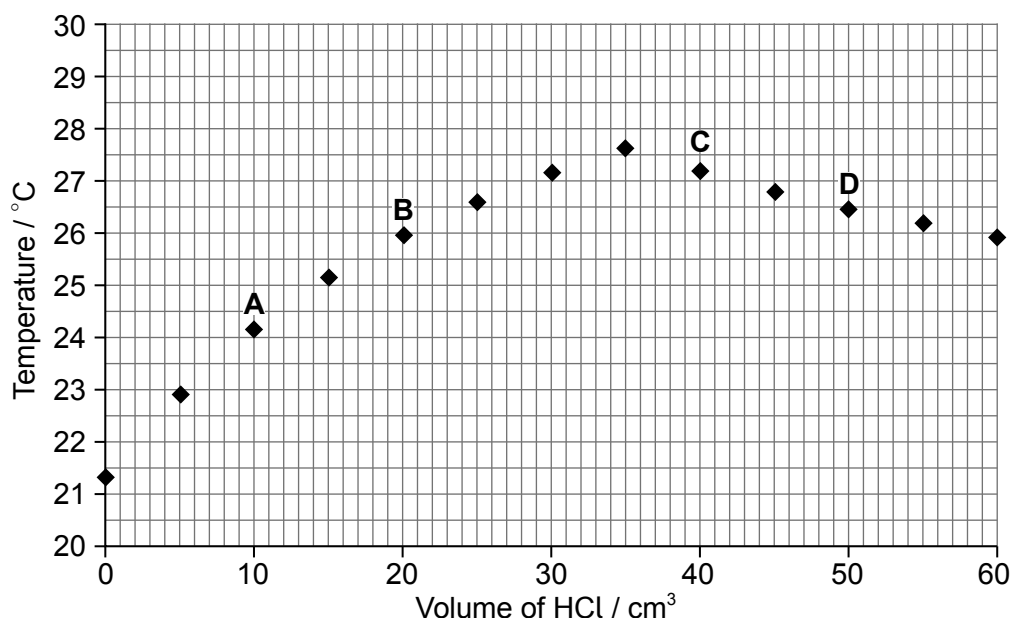
Answer **all** questions. Write your answers in the boxes provided.

A class was determining the concentration of aqueous sodium hydroxide by titrating it with hydrochloric acid, whilst monitoring the pH of the solution. The sodium hydroxide solution was added into a glass beaker from a measuring cylinder and the hydrochloric acid added using a burette. One group of students accidentally used a temperature probe rather than a pH probe. Their results are given below.

Volume of aqueous NaOH = $25.0 \pm 0.5 \text{ cm}^3$

Concentration of HCl = $1.00 \pm 0.01 \text{ mol dm}^{-3}$

Volume HCl $\pm 0.1 / \text{cm}^3$	0.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
Temperature $\pm 0.1 / ^\circ\text{C}$	21.3	22.9	24.2	25.1	25.9	26.6	27.2	27.6	27.2	26.8	26.5	26.2	25.9



1. (a) Calculate the percentage uncertainty of the volume of the aqueous sodium hydroxide. [1]

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- (b) Suggest how the precision of this measurement could be improved. [1]

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2. (a) Deduce why more heat was produced in mixture **B** than in mixture **A**. [1]

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(b) Deduce why the temperature is higher in mixture **C** than in mixture **D**. [1]

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3. Suggest how the end point of the titration might be estimated from the graph. [1]

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4. State and explain how the graph would differ if 1 mol dm^{-3} sulfuric acid had been used instead of 1 mol dm^{-3} hydrochloric acid. [2]

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5. The graph of temperature against titre can be used to calculate the concentration of alkali without knowing the concentration of the hydrochloric acid, using the enthalpy of neutralization.

(a) Explain how the concentration may be calculated in this way. [2]

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(b) Heat losses would make this method less accurate than the pH probe method. Outline why the thermometric method would always give a lower, not a higher, concentration. [2]

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(c) Suggest how heat loss could be reduced. [1]

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(d) State **one** other assumption that is usually made in the calculation of the heat produced. [1]

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(This question continues on the following page)



(Question 5 continued)

(e) Suggest why scientists often make assumptions that do not correspond to reality. [1]

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(f) Outline why the thermochemical method would not be appropriate for $0.001 \text{ mol dm}^{-3}$ hydrochloric acid and aqueous sodium hydroxide of a similar concentration. [1]

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Section B

Answer **all** of the questions from **one** of the options. Write your answers in the boxes provided.

Option A — Materials

6. Lanthanum, La, and antimony, Sb, form compounds with bromine that have similar formulas, LaBr_3 and SbBr_3 .

(a) Determine the type of bond present in SbBr_3 , showing your method. Use sections 8 and 29 of the data booklet. [2]

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(b) Lanthanum has a similar electronegativity to group 2 metals. Explain, in terms of bonding and structure, why crystalline lanthanum bromide is brittle. [2]

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7. Lanthanum metal may be produced by the electrolysis of molten LaBr_3 .

(a) State why lanthanum cannot be produced by reducing its oxide with carbon. [1]

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(Option A continues on the following page)



(Option A, question 7 continued)

- (b) Calculate the current (I), in A, required to produce 1.00 kg of lanthanum metal per hour. Use the formula $Q(C) = I(A) \times t(s)$ and sections 2 and 6 of the data booklet. [3]

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8. Lanthanum nanoparticles are incorporated into certain catalysts and the electrodes of some fuel cells.

- (a) State the major advantage that nanoparticles have in these applications. [1]

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- (b) Suggest why nanoparticles need to be handled with care. [1]

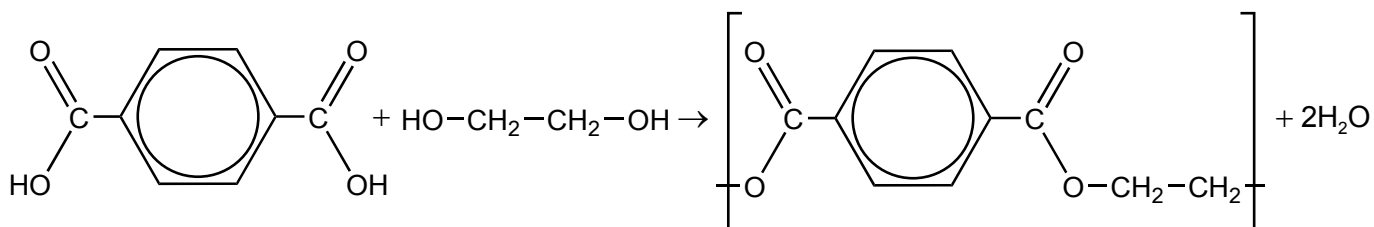
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(Option A continues on the following page)



(Option A continued)

9. Antimony oxide is widely used as a homogeneous catalyst in the reaction of benzene-1,4-dicarboxylic acid with ethane-1,2-diol in the production of polyethylene terephthalate (PETE) shown below.



- (a) Catalysts reduce the activation energy. Outline how homogeneous catalysts are involved in the reaction mechanism. [1]

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- (b) Suggest why it is important to know how catalysts function. [1]

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- (c) Antimony and its compounds are toxic, so it is important to check that the catalyst is removed from the final product. One technique to detect antimony is Inductively Coupled Plasma Mass Spectroscopy (ICP-MS).

Outline the nature of the plasma state and how it is produced in ICP-MS. [2]

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(Option A continues on page 10)



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Answers written on this page
will not be marked.



28EP09

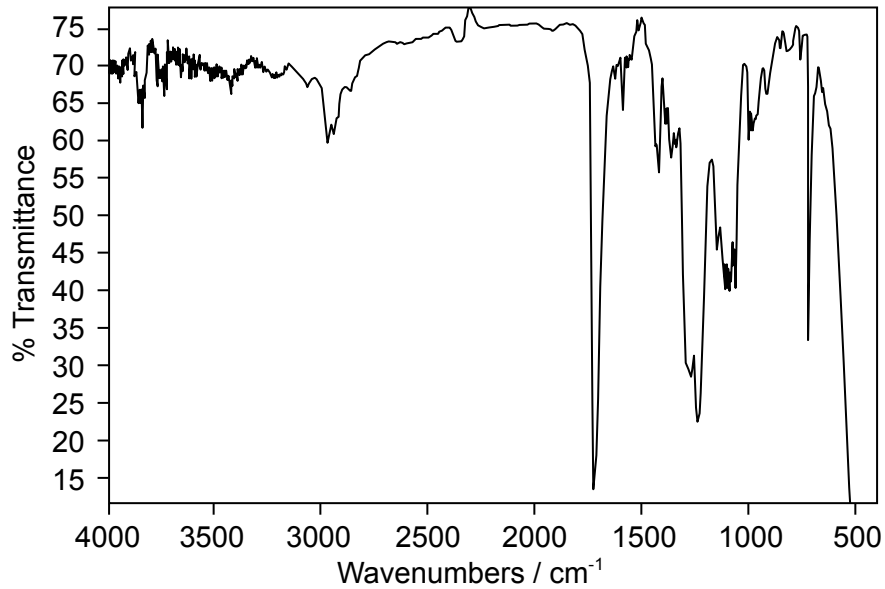
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(Option A continued)

10. Infrared (IR) spectroscopy is often used for the identification of polymers, such as PETE, for recycling.

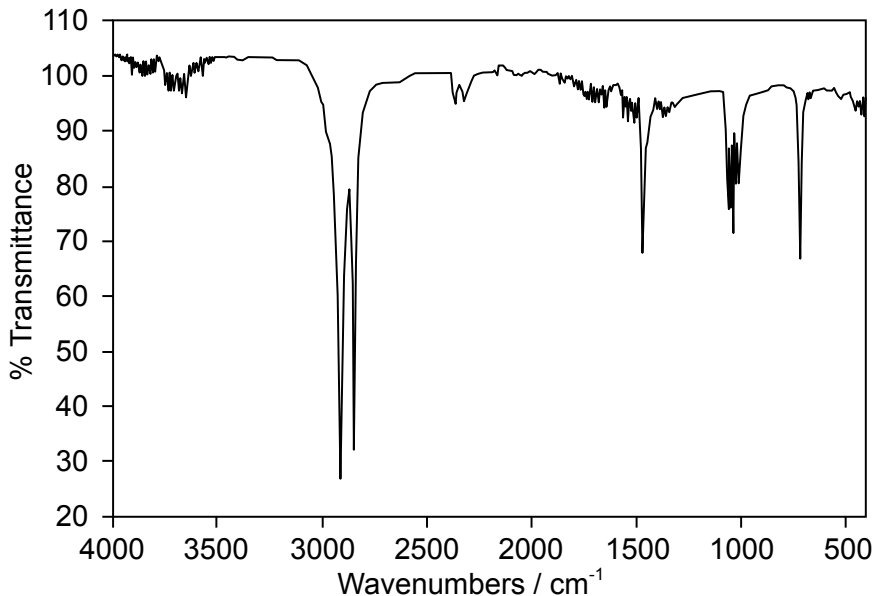
(a) Below are the IR spectra of two plastics (**A** and **B**); one is PETE, the other is low density polyethene (LDPE).

A



[Source: www.intechopen.com]

B



[Source: www.andersonmaterials.com]

(Option A continues on the following page)



28EP10

(Option A, question 10(a) continued)

Deduce, giving your reasons, the identity and resin identification code (RIC) of **A** and **B** using sections 26 and 30 of the data booklet.

[3]

A RIC:

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B RIC:

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(b) LDPE and high density polyethene (HDPE) have very similar IR spectra even though they have rather different structures and physical properties.

(i) Describe the difference in their structures.

[1]

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(ii) Explain why the difference in their structures affects their melting points.

[2]

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End of Option A



Option B — Biochemistry

11. Lipids and carbohydrates contain the same elements but have different properties.

(a) List the building blocks of triglycerides and carbohydrates.

[1]

Triglycerides:

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Carbohydrates:

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(b) (i) The drain pipe of a kitchen sink can become clogged by fatty acids, such as linoleic acid, $C_{18}H_{32}O_2$, but not by the trisaccharide, raffinose, $C_{18}H_{32}O_{16}$, containing the same number of carbon atoms.

Explain why raffinose is far more water soluble than linoleic acid.

[2]

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(ii) Solid fat triglycerides can also clog kitchen sink drains.

Explain how sodium hydroxide unblocks the drain.

[2]

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(Option B continues on the following page)



(Option B, question 11 continued)

- (c) The amount of proteins, fats and carbohydrates determine the energy content of foods.

Explain why linoleic acid, $C_{18}H_{32}O_2$, is a more efficient energy storage molecule than raffinose, $C_{18}H_{32}O_{16}$.

[2]

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12. Sugars exist in both straight chain and ring forms.

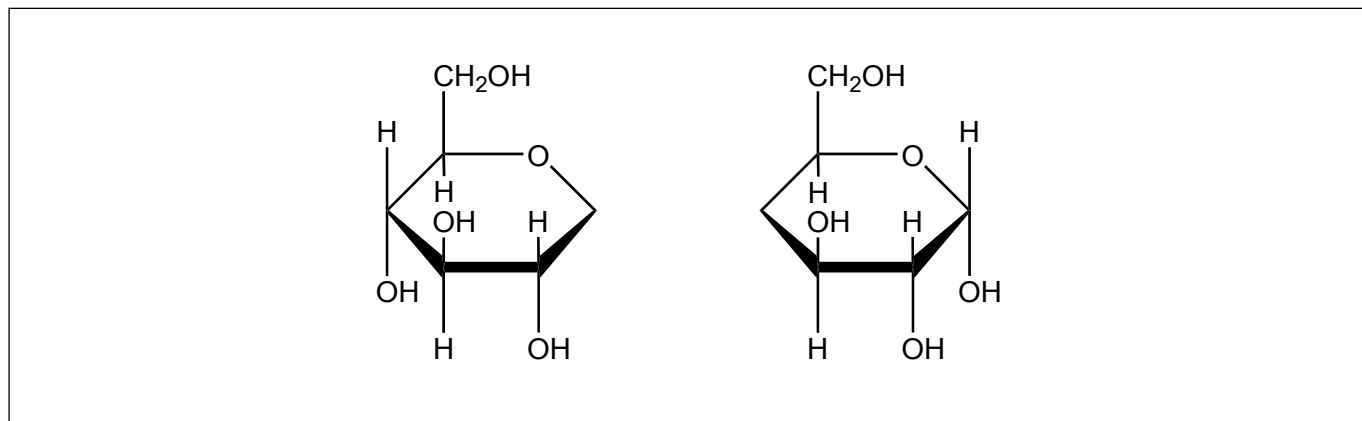
- (a) (i) Deduce the straight chain structure of ribose from its ring structure drawn in section 34 of the data booklet.

[1]

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- (ii) Using the **partial** structure given, complete the structural formula of the molecule formed from the condensation of two cyclic α -glucose molecules.

[1]



(Option B continues on the following page)



28EP13

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(Option B, question 12 continued)

- (b) Constructing models that allow visualizations of the stereochemistry of carbohydrates is essential to understand their structural roles in cells.

Describe how Haworth projections help focus on the position of attached groups. [1]

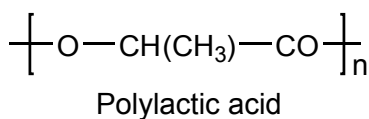
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- (c) Biodegradable plastics produced from starch present one solution to the environmental problem created by the use of large quantities of plastics.

- (i) State **one** advantage of starch based polymers besides being biodegradable. [1]

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- (ii) Biodegradable boxes made from polylactic acid, PLA, disintegrate when exposed to water.



State the formula of the product formed when water reacts with PLA. [1]

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(Option B continues on the following page)



(Option B continued)

13. Peptidase enzyme in the digestive system hydrolyses peptide bonds.

- (a) Identify the type of metabolic process that occurs in the hydrolysis of the peptide during digestion. [1]

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(b) A tripeptide Ala-Asp-Lys was hydrolysed and electrophoresis of the mixture of the amino acids was carried out at a pH of 6.0. Refer to section 33 of the data booklet.

- (i) Identify the **name** of the amino acid that does not move under the influence of the applied voltage. [1]

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- (ii) Deduce, giving a reason, which amino acid will develop closest to the negative electrode. [2]

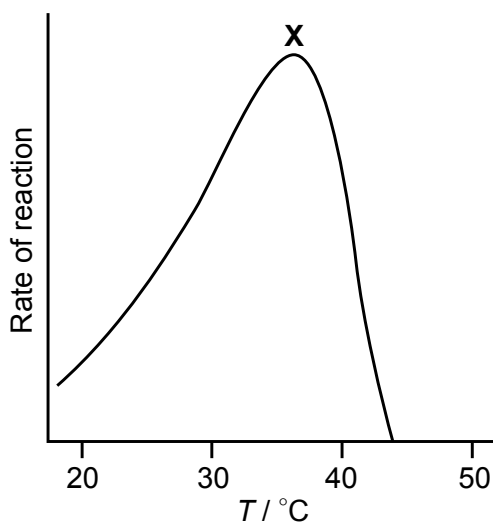
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(Option B continues on the following page)



(Option B, question 13 continued)

- (c) The breakdown of a dipeptide in the presence of peptidase was investigated between 18°C and 43°C. The results are shown below.



Comment on the rate of reaction at temperature X in terms of the enzyme's active site. [1]

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- (d) The solubility of a vitamin depends on its structure.

Identify the vitamin given in section 35 of the data booklet that is the most soluble in water. [1]

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- (e) Pollution from heavy metal ions has become a health concern.

Outline how the presence of heavy metal ions decreases the action of enzymes. [1]

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(Option B continues on the following page)



(Option B, question 13 continued)

- (f) Outline how lead ions could be removed from an individual suffering from lead poisoning. [1]

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End of Option B



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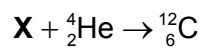
Option C — Energy

14. Carbon is produced by fusion reactions in stars.

(a) Outline how the spectra of light from stars can be used to detect the presence of carbon. [1]

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(b) The main fusion reaction responsible for the production of carbon is:



(i) Deduce the identity of X. [1]

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(ii) Outline why this reaction results in a release of energy. [1]

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(c) Nuclear fusion reactors are predicted to become an important source of electrical energy in the future. State **two** advantages of nuclear fusion over nuclear fission. [2]

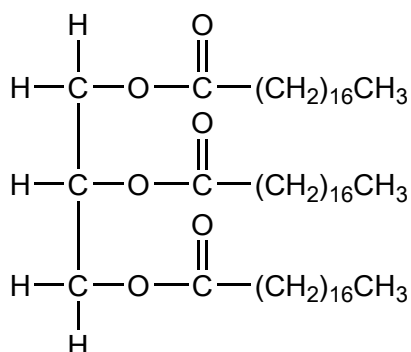
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(Option C continues on the following page)



(Option C continued)

15. Vegetable oils, such as that shown, require conversion to biodiesel for use in current internal combustion engines.



- (a) State **two** reagents required to convert vegetable oil to biodiesel. [2]

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- (b) Deduce the formula of the biodiesel formed when the vegetable oil shown is reacted with the reagents in (a). [1]

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- (c) Explain, in terms of the molecular structure, the critical difference in properties that makes biodiesel a more suitable liquid fuel than vegetable oil. [2]

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(Option C continues on the following page)



(Option C, question 15 continued)

- (d) Determine the specific energy, in kJ g^{-1} , and energy density, in kJ cm^{-3} , of a particular biodiesel using the following data and section 1 of the data booklet.

Density = 0.850 g cm^{-3} ; Molar mass = 299 g mol^{-1} ;
Enthalpy of combustion = 12.0 MJ mol^{-1} .

[2]

Specific energy:

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Energy density:

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16. Coal is often converted to liquid hydrocarbon fuels through initial conversion to carbon monoxide and hydrogen.

- (a) State how these gases are produced, giving the appropriate equation(s).

[2]

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- (b) Outline how the carbon monoxide is then converted to a hydrocarbon fuel.

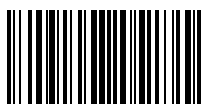
[1]

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(Option C continues on the following page)



(Option C continued)

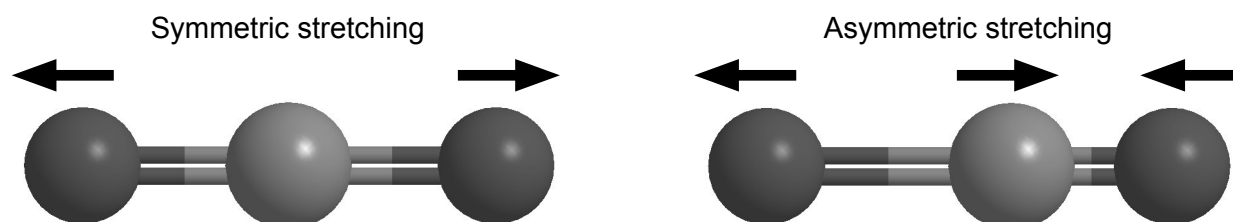
17. A link between the combustion of fossil fuels and an increase in the temperature of the Earth's atmosphere was proposed over a century ago.

(a) Suggest why it is only in recent years that specific predictions of the future effects of fossil fuel combustion have been made.

[1]

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(b) Carbon dioxide has two different bond stretching modes illustrated below.



Predict, with an explanation, whether these stretching modes will absorb infrared radiation.

[2]

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(c) Outline, giving the appropriate equation(s), how increasing levels of carbon dioxide will affect the pH of the oceans.

[1]

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(Option C continues on the following page)



(Option C, question 17 continued)

- (d) Many combustion processes also release particulate matter into the atmosphere. Suggest, giving your reason, how this might affect the temperature of the Earth's surface.

[1]

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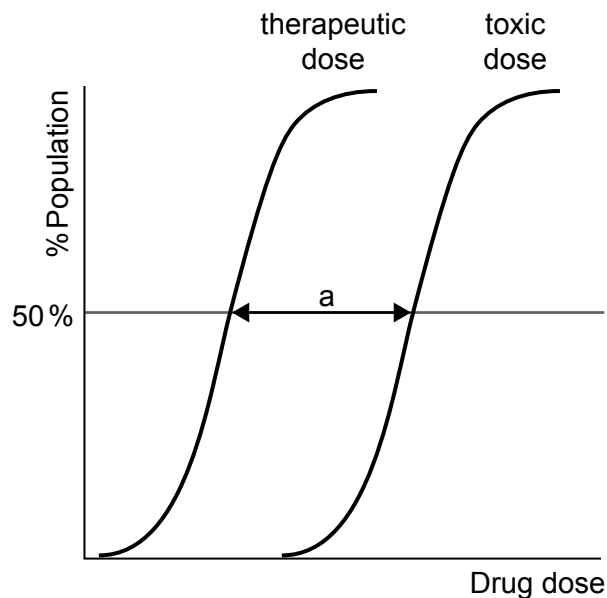
End of Option C



Option D — Medicinal chemistry

18. Medicines have a variety of different effects on the body and act at the molecular level.

(a) Dose response curves are determined for each drug.



Outline the significance of range "a".

[1]

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(b) Morphine and codeine are strong analgesics. Their structures are given in section 37 of the data booklet.

(i) Suggest the type of reaction used to convert morphine to codeine.

[1]

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(Option D continues on the following page)



(Option D, question 18 continued)

(ii) State and explain the action of opiates as painkillers. [2]

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19. Solubility plays an important role in the bioavailability of drugs in the body.

(a) Suggest why aspirin is **slightly** soluble in water. Refer to section 37 of the data booklet. [2]

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(b) Formulate an equation for the conversion of aspirin to a more water soluble derivative. [1]

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(Option D continues on the following page)



(Option D, question 19 continued)

- (c) A student prepares aspirin from salicylic acid in the laboratory, extracts it from the reaction mixture, ensures the sample is dry and determines its melting point.

Substance	Melting point / °C
Student's aspirin sample	120–126
Pure aspirin	136

Suggest why the melting point of the student's sample is lower and not sharp compared to that of pure aspirin.

[2]

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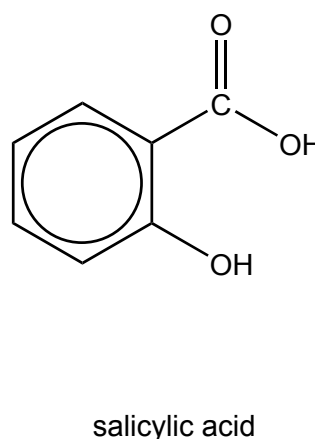
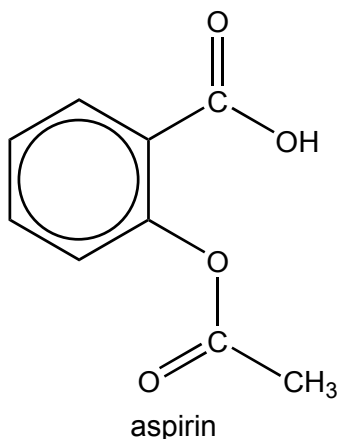
(Option D continues on the following page)



(Option D, question 19 continued)

- (d) Organic molecules can be characterized using infrared (IR) spectroscopy.

Compare and contrast the infrared peaks above 1500 cm^{-1} in pure samples of aspirin and salicylic acid using section 26 of the data booklet. [2]



One similarity:

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One difference:

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- (e) The pharmaceutical industry is one of the largest producers of waste solvents.

State a green solution to the problem of organic solvent waste. [1]

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(Option D continues on the following page)



(Option D continued)

20. The buffer formed by carbon dioxide, $\text{CO}_2(\text{aq})$ and hydrogen carbonate ion, $\text{HCO}_3^-(\text{aq})$, plays an important role in maintaining the pH of blood.

(a) Calculate the pH of the buffer from the following data and section 1 of the data booklet.

$\text{p}K_a(\text{CO}_2) = 6.34$ [1]
 $[\text{HCO}_3^-(\text{aq})] = 1.40 \times 10^{-2} \text{ mol dm}^{-3}$
 $[\text{CO}_2(\text{aq})] = 1.25 \times 10^{-3} \text{ mol dm}^{-3}$

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(b) Explain the effect of a large amount of aspirin on the pH of blood. [2]

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(Option D continues on the following page)



(Option D continued)

21. Antiviral drugs are designed to take different approaches to fighting viruses.

(a) Outline how oseltamivir (Tamiflu®) works.

[2]

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(b) Oseltamivir was commercially produced from shikimic acid, a precursor which is a metabolite in micro-organisms and plants.

Outline how green chemistry was used to develop the precursor for oseltamivir in order to overcome a shortage of the drug during the flu season.

[2]

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(c) Suggest why the administration of antibiotics to humans and animals can affect the environment.

[1]

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End of Option D

