Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

8 May 2024

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

Candidate session number

1 hour

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 – 9
Option C — Energy	10 – 12
Option D — Medicinal chemistry	13 – 17

2224 – 6206

27 pages

Section A

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

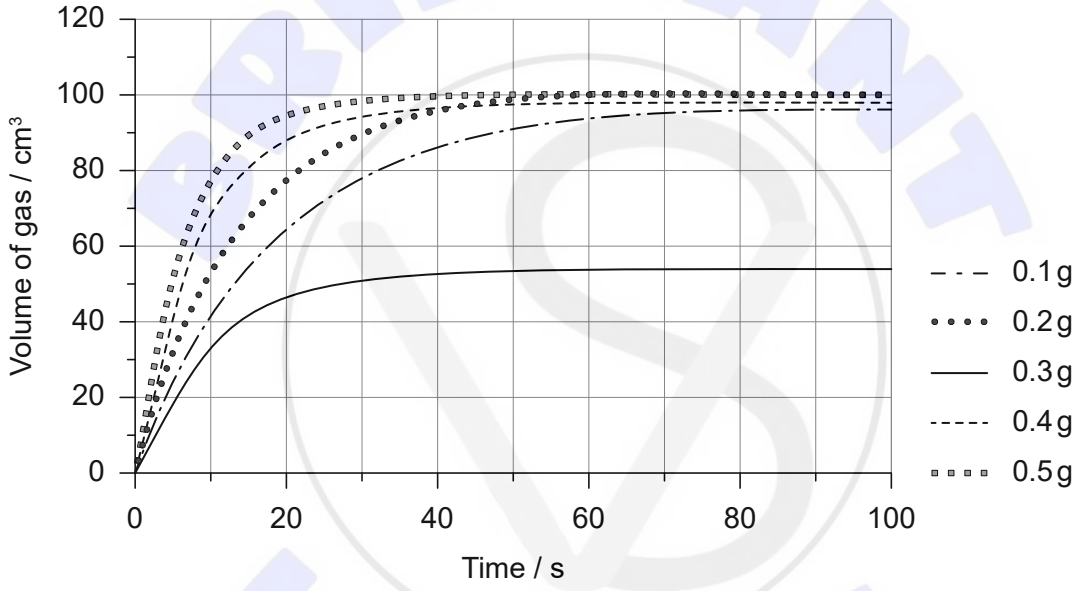
1. Hydrogen peroxide decomposes to form water and oxygen.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

The reaction is catalysed by solid manganese(IV) oxide, $MnO_2(s)$.

A student carried out a series of experiments to determine how the rate of decomposition depends on the mass of catalyst. Each time a different mass of MnO_2 was added to 25.0 cm^3 of hydrogen peroxide solution. The oxygen was collected in a graduated gas syringe and the volume recorded at regular intervals.

Figure 1



(a) The 0.3 g data seems to be anomalous. Suggest a possible cause for this. [1]

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(This question continues on the following page)

(Question 1 continued)

(b) The student hypothesized, based on underlying theory, that doubling the mass of MnO_2 would double the rate of the catalysed reaction.

(i) Suggest why it is important to have hypotheses on the outcome of experiments. [1]

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(ii) Explain how the student's hypothesis might be supported by collision theory. [2]

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(iii) Identify the critical controlled variable that is not specified in the description of the method. [1]

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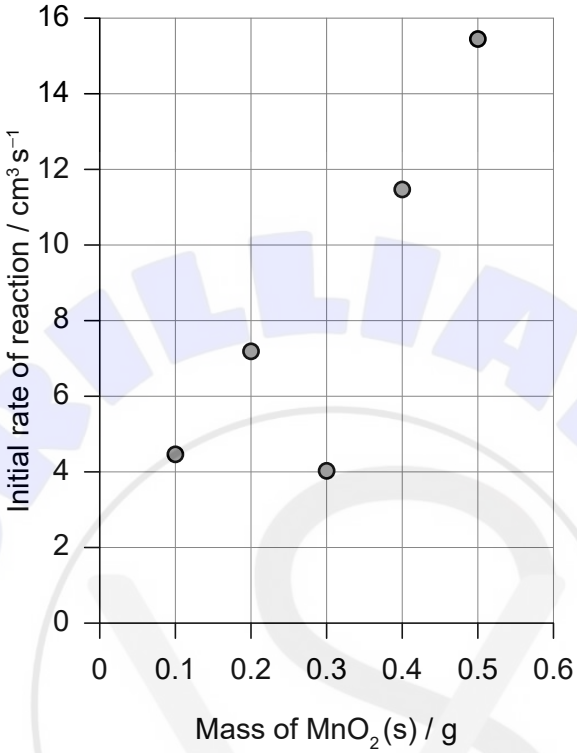
(This question continues on the following page)

(Question 1 continued)

(c) The results from **Figure 1** were processed to produce a graph showing how the initial rate varied with the mass of catalyst.

Figure 2



(i) Outline how the y-axis values on **Figure 2** were obtained from the results in **Figure 1**. [2]

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(ii) Suggest, giving a reason, whether a best-fit line for **Figure 2** should pass through the origin. [1]

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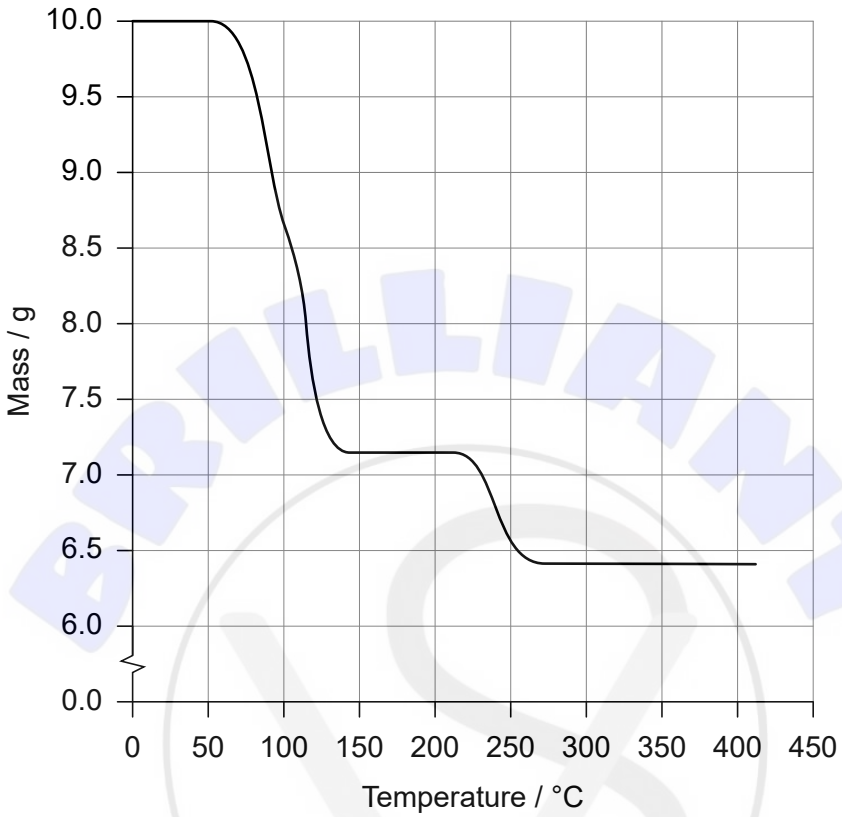
2. The **Figure 3** shows the change in mass when 10.0 g of copper (II) sulfate crystals are heated from 20 °C to 400 °C. Only water vapour is lost during this process and no further water vapour is lost on heating to higher temperatures.

Figure 3



(a) Demonstrate that this data is consistent with the formula $CuSO_4 \cdot 5H_2O$. [2]

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(This question continues on the following page)

(Question 2 continued)

(b) The uncertainty in the mass readings is $\pm$ 0.05 g.

(i) Calculate the percentage uncertainty in mass loss. [2]

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(ii) From your answer in (b)(i), calculate the absolute uncertainty of the ratio of $CuSO_4$:H_2O in $CuSO_4 \cdot 5H_2O$ (the uncertainty in the 5), to two significant figures. [1]

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(c) Deduce what the graph shows about the water in hydrated copper (II) sulfate. [2]

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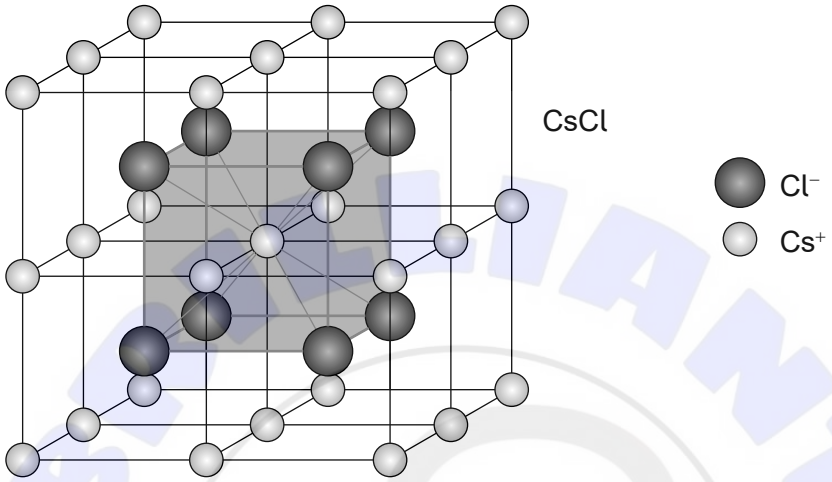
Section B

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

Option A — Materials

3. Caesium chloride, CsCl, has the ionic lattice structure shown.



(a) (i) Demonstrate, using sections 8 and 29 of the data booklet, how this type of bonding could be predicted. [2]

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(ii) Outline the nature of the forces holding this structure together. [1]

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(iii) Outline why caesium chloride crystals are very brittle. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(b) Justify why caesium chloride is diamagnetic. [1]

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(c) Caesium metal is produced by electrolysis of molten caesium chloride.

(i) Outline why caesium can only be produced by electrolysis. [1]

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(ii) State the half-equation for the formation of caesium by electrolysis. [1]

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(iii) Determine the charge, in C, required to produce 1.00 g of caesium.
Use sections 2 and 6 of the data booklet. [2]

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(Option A continues on the following page)

(Option A, question 3 continued)

(d) Caesium metal and Cu–Ni nanoparticles are combined as the heterogeneous catalyst in the synthesis of long-chain alcohols.

(i) Compare and contrast homogeneous and heterogeneous catalysts. [2]

One similarity:

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One difference:

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(ii) State why many heterogeneous catalysts involve nanoparticles. [1]

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(iii) Nanoparticles are often produced by chemical vapour deposition (CVD). Suggest why this is carried out in an inert atmosphere. [1]

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(iv) Suggest **one** ethical concern about the use of nanoparticles. [1]

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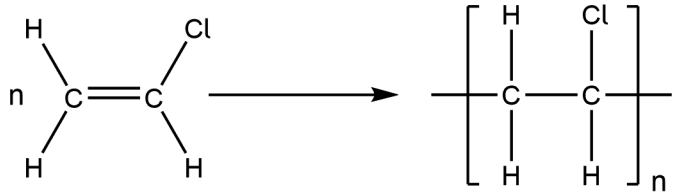
(Option A continues on the following page)

(Option A continued)

4. Polychloroethene, often known as polyvinylchloride or PVC, is synthesized from chloroethene.



(a) Phthalates are often added as plasticisers to PVC.

Outline, giving a reason, how these affect the physical properties of the plastic. [2]

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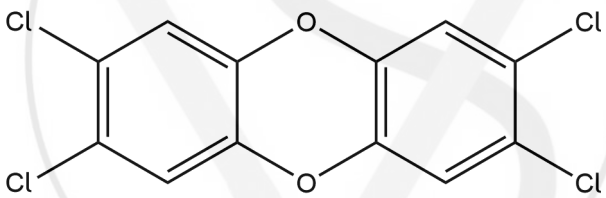
(b) The formula of a toxic product from the combustion of PVC is shown.



Identify the class of compounds to which it belongs and one harmful effect it has on humans. [2]

Class:

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Effect:

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(Option A continues on the following page)

(Option A, question 4 continued)

(c) Plastics are often stamped with a resin identification code, RIC.

(i) State the principal reason for RIC. [1]

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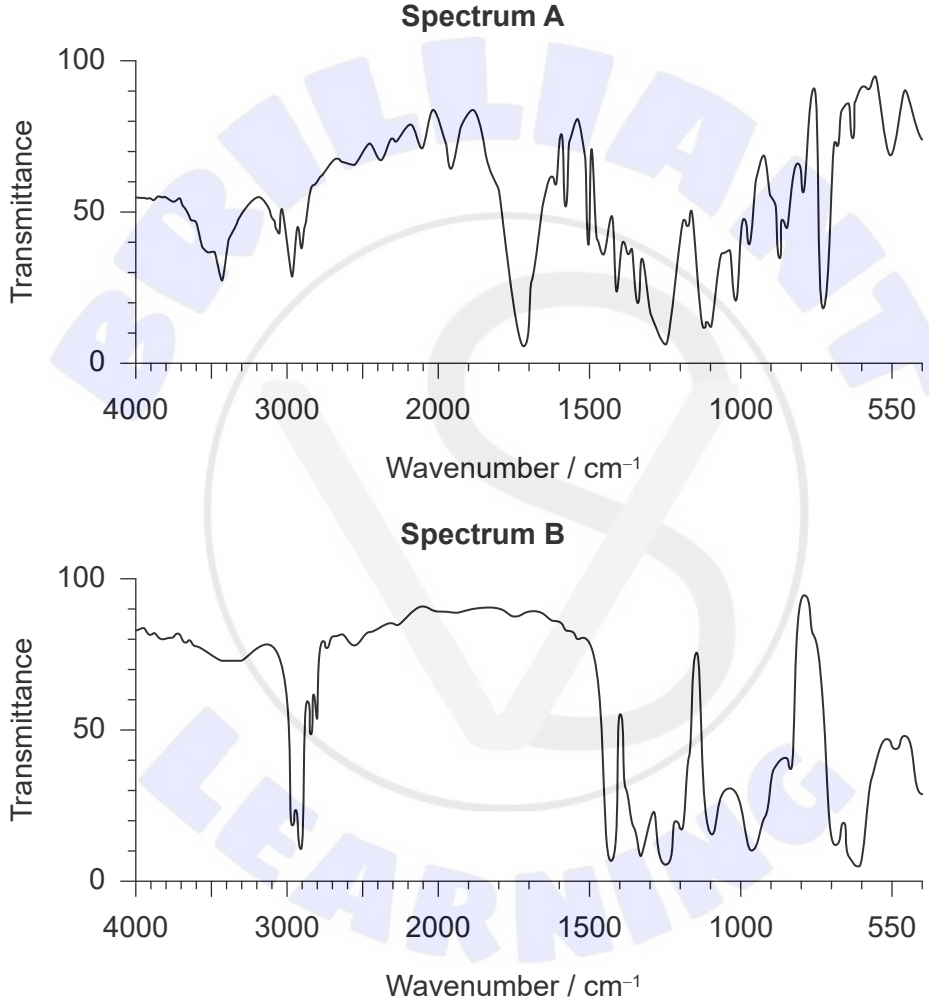
(ii) The IR spectra below are those of plastics with RIC 1 and 3.



[Source: SDBS, National Institute of Advanced Industrial Science and Technology.]

Deduce, giving a reason, which spectrum shows RIC 1. Use sections 26 and 30 of the data booklet. [1]

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End of Option A

Option B — Biochemistry

5. Glucose is an energy-rich molecule that can be synthesized in plants.

(a) Write the equation for photosynthesis. [1]

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(b) (i) Glucose is polymerized in the plant cell to form starch. Identify the type of reaction and the by-product. [1]

Type of reaction:

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By-product:

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(ii) Outline, in terms of its properties, why starch cannot be used as a direct energy source. [1]

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(iii) State how the energy in starch can be made available for respiration. [1]

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(Option B continues on the following page)

(Option B continued)

6. Lipids, such as fats and oils, are triglycerides of fatty acids. The table shows the fatty acid composition of commonly used oils and fats.

Source	Fatty acids / %		
	Saturated	Monounsaturated	Polyunsaturated
Corn oil	13	28	59
Sunflower oil	10	48	42
Olive oil	14	75	11
Canola oil	8	64	28
Butter	66	30	4

(a) Suggest, with a reason, which lipid will be most likely to undergo oxidative rancidity. [1]

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(b) 5.00 g of olive oil reacts completely with 33.0 cm^3 of 0.500 mol dm^{-3} iodine solution. Calculate the iodine number of olive oil. [3]

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(c) Explain why butter is solid at room temperature with reference to the structure and bonding of its fatty acids. [2]

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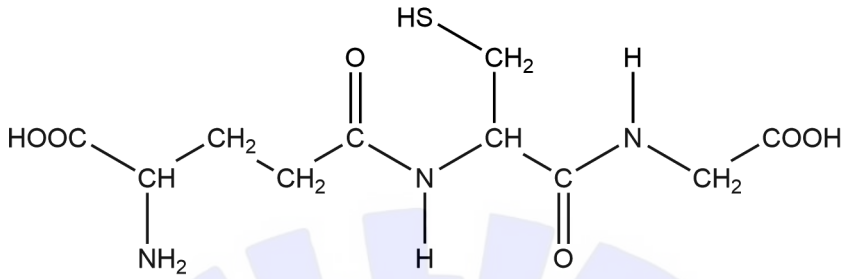
(Option B continues on the following page)

(Option B continued)

7. 2-amino acids can be combined to form peptides and proteins.

(a) The tripeptide glutathione is shown. Circle all the amide links. [1]



(b) Glutathione can undergo hydrolysis in the cell. Identify the products using section 33 of the data booklet. [1]

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(c) The products of the hydrolysis were analysed by electrophoresis using a buffer of pH = 6. Deduce which amino acid did not move when the voltage was applied using section 33 of the data booklet. [1]

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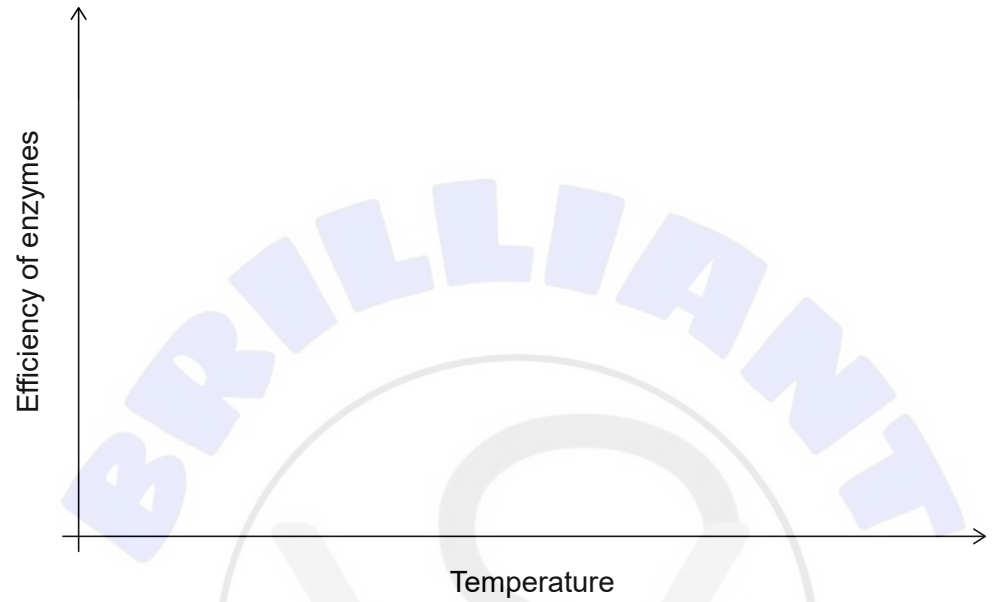
(Option B continues on the following page)

(Option B continued)

8. Biological laundry detergents contain enzymes that can efficiently remove stains at low temperatures.

(a) (i) Sketch a graph to show how the efficiency of the enzyme varies with temperature. [1]



(ii) Explain why enzymes are less effective at low and high temperatures. [2]

Low temperature:

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High temperature:

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(Option B continues on the following page)

(Option B, question 8 continued)

(b) Suggest why biological detergents have a lower environmental impact than non-biological detergents. [1]

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(c) State **one** use of enzymes and microorganisms to reduce environmental damage resulting from human activities. [1]

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9. Citrus fruit juices are good sources of ascorbic acid (vitamin C). Explain why vitamin C is soluble in water, referring to its structure. Use section 35 of the data booklet. [2]

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End of Option B

Option C — Energy

10. Methane clathrate looks like ice but burns when ignited because it turns back to water and methane.

(a) Write an equation for the complete combustion of methane. [1]

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(b) Calculate the specific energy of methane, in $kJ\,g^{-1}$. Use sections 1, 6 and 13 of the data booklet. [1]

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(c) Suggest why methane clathrate has a lower specific energy but higher energy density than methane. [2]

Lower specific energy:

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Higher energy density:

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(Option C continues on the following page)

(Option C, question 10 continued)

(d) Outline how the energy in methane originates from sunlight. [2]

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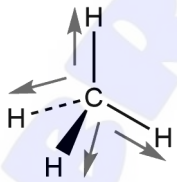
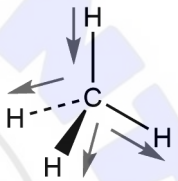
(e) Methane has both symmetric and asymmetric stretching modes as illustrated.

Symmetric stretch



Asymmetric stretch



State, giving a reason, which of these modes is responsible for greenhouse gas activity. [1]

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(f) There are significant quantities of methane clathrate on the ocean bed and in arctic permafrost layers.

Suggest why burning methane clathrate is preferable to allowing the methane it contains to escape into the atmosphere. [1]

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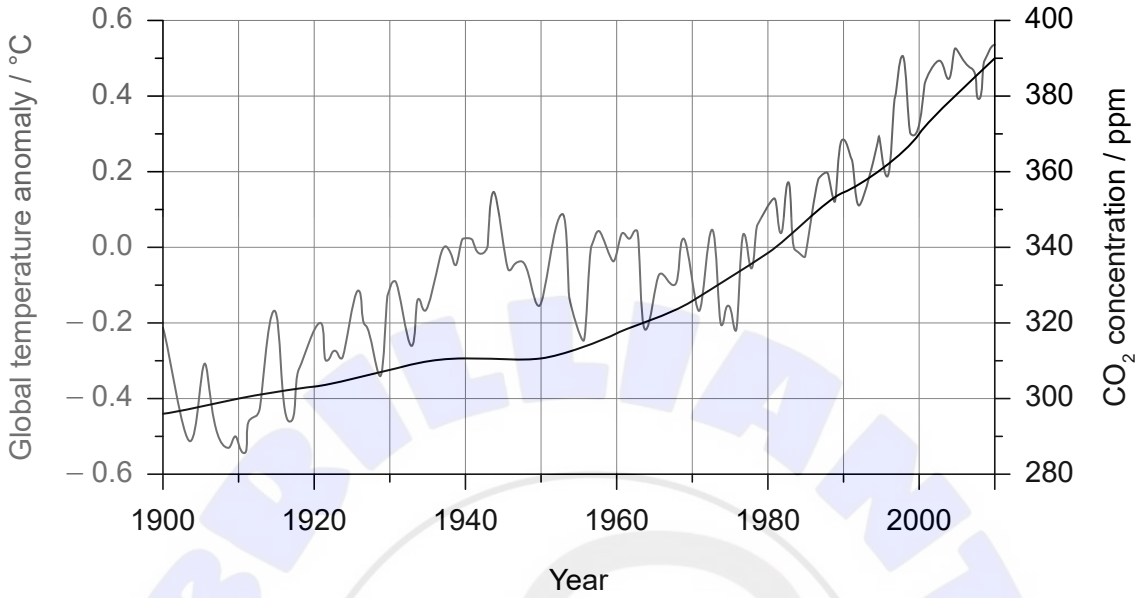
(Option C continues on the following page)

(Option C, question 10 continued)

(g) The graph shows the increase in temperature and the level of carbon dioxide in the atmosphere.



Discuss how this data could be used to both support and refute the theory that carbon dioxide is a cause of global warming. [2]

Support:

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Refute:

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(Option C continues on the following page)

(Option C continued)

11. Methane, gasoline and biodiesel are used as fuels for transport.

(a) (i) Outline why the combustion of methane has a lower environmental impact than gasoline. [2]

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(ii) Suggest why gasoline is more widely used than methane as a car fuel, even though it is more expensive in most countries. [1]

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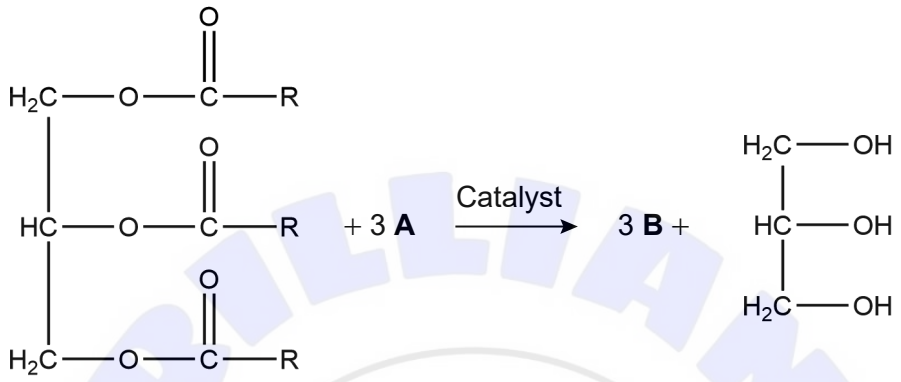
(Option C continues on the following page)

(Option C, question 11 continued)

(b) Transesterification is used to convert vegetable oils into a sustainable alternative fuel for internal combustion engines.

(i) Complete the equation for transesterification. [1]



A: . . . . . .

B: . . . . . .

(ii) Vegetable oils cannot be used directly as a fuel in a standard internal combustion engine.

Outline why the product can however be used as a fuel, giving the underlying reason in terms of intermolecular forces. [2]

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(Option C continues on the following page)

(Option C continued)

12. Fusion and fission both involve changes to atomic nuclei.

(a) Compare and contrast the nuclear processes involved in fusion and fission. [2]

Similarity:

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Difference:

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(b) Outline how we know that helium, the product of hydrogen fusion, is present in the sun. [1]

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(c) Suggest why, apart from the inherent dangers of radioactive materials, some countries would like to prevent others building nuclear fission reactors. [1]

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End of Option C

Option D — Medicinal chemistry

13. Penicillin was the first of a class of antibiotics known as β-lactams.

(a) Suggest, with reference to their mechanism of action, why these antibiotics affect bacteria but not animal cells. [1]

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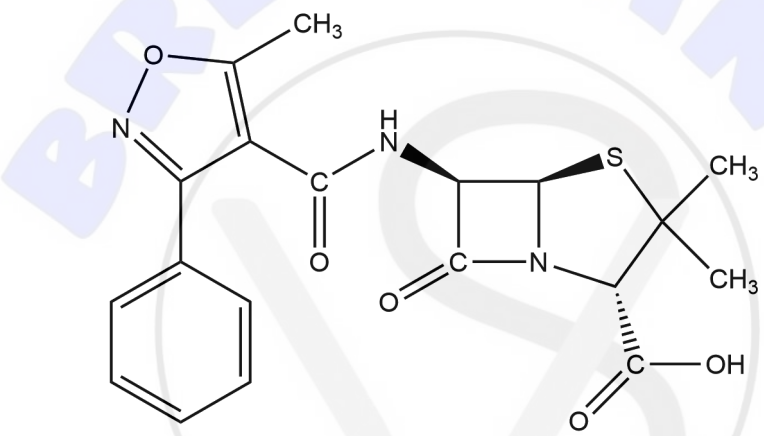
(b) Oxacillin was developed to treat infections with bacteria that produce beta-lactamase.



(i) Suggest why modifying the side-chain generates penicillinase resistance. [1]

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(ii) The sodium salt of oxacillin is used to increase its solubility in water. Draw a circle on the structure in (b) identifying the group in the oxacillin molecule that can react with a base to form the salt. [1]

(Option D continues on the following page)

(Option D, question 13 continued)

(c) Explain how the addition of antibiotics to animal feeds has contributed to the development of antibiotic-resistant bacteria. [2]

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14. Morphine and its derivatives (opiates) are only used to treat severe pain due to their side effects.

(a) (i) State **one** side effect of the long-term use of opiates. [1]

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(ii) Prolonged use of opiates can lead to tolerance. Outline what is meant by tolerance. [1]

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(Option D continues on the following page)

(Option D, question 14 continued)

(b) Codeine is generally produced by semi-synthesis from morphine.

(i) Describe how the morphine molecule must be modified to produce codeine. Use section 37 of the data booklet. [1]

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(ii) Codeine is less potent than morphine. Suggest, with reference to their structures, why you would expect the opposite. [2]

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(Option D continues on the following page)

(Option D continued)

15. Aspirin is a mild analgesic and can reduce fever and inflammation.

(a) State **one** other effect of aspirin. [1]

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(b) Suggest why aspirin should not be taken together with alcohol. [1]

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16. Excessive acidity of gastric juice can be treated at different levels.

(a) Antacids such as aluminium hydroxide, $Al(OH)_3$, are bases that react directly with the stomach acid. State an equation for the reaction of $Al(OH)_3$ with stomach acid. [1]

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(b) Outline how omeprazole reduces stomach acidity. [1]

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(c) In the intestine, the gastric juice is buffered.

$$H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq) \quad pK_a = 6.31 \text{ (at } 37\,^\circ\text{C)}$$

Calculate the concentration of HCO_3^- in a buffer of pH = 7.43 when the concentration of H_2CO_3 is $2.03 \times 10^{-3}\,\text{mol dm}^{-3}$. Use section 1 of the data booklet. [2]

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(Option D continues on the following page)

(Option D continued)

17. Antiviral drugs act by interfering with the virus replication cycle.

(a) Outline **one** difference between bacteria and viruses that make antibiotics ineffective against viruses. [1]

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(b) Osetalmivir and zanamivir are two antiviral drugs used to prevent flu.

(i) Outline how these drugs work. [2]

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(ii) Predict, with a reason, which of the two drugs is more soluble in water. Use section 37 of the data booklet. [1]

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End of Option D

References:

4.(c)(ii) SDBS, National Institute of Advanced Industrial Science and Technology.

6. U.S. Department of Agriculture (USDA). FoodData Central - Oil, corn, industrial and retail, all purpose salad or cooking. https://fdc.nal.usda.gov/fdc-app.html#/food-details/171029/nutrients. Public domain. Source adapted.

10.(g) Van der Werf, G., *Global temperature anomaly*. [graph] Available at: https://www.geo.vu.nl/~gwerf/climate.html [Accessed 3 April 2019]. Source adapted.