Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

2 November 2023

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

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

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	2 – 4
Option B — Biochemistry	5 – 8
Option C — Energy	9 – 11
Option D — Medicinal chemistry	12 – 14

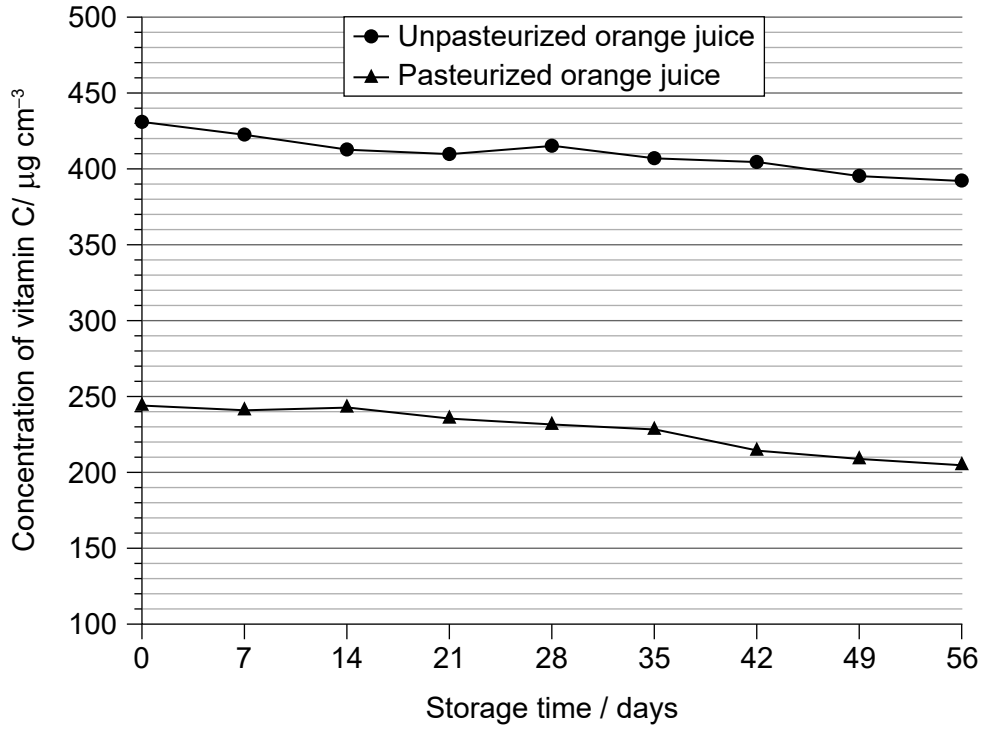
8823 – 6112

25 pages

Section A

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

1. Pasteurization is used to eliminate pathogenic bacteria. The concentration of vitamin C was monitored over a period of time in pasteurized and unpasteurized orange juice.



(a) (i) Identify the dependent variable represented in the graph. [1]

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(ii) Calculate the decrease in the concentration of vitamin C, in $\mu g\,cm^{-3}$, caused by pasteurization. [1]

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(This question continues on the following page)

(Question 1 continued)

(iii) Calculate the average rate of decrease of vitamin C concentration for pasteurized juice, in $\mu g\,cm^{-3}day^{-1}$, for the first 56 days. [1]

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(iv) Deduce, referring to the graph, whether pasteurization affects the rate of change of vitamin C concentration during storage of orange juice. [1]

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(v) The absolute uncertainty in each vitamin C concentration measurement was $\pm 2\,\mu g\,cm^{-3}$. Deduce, with a reason, whether the concentration of vitamin C in pasteurized or unpasteurized orange juice has a larger percentage uncertainty. [1]

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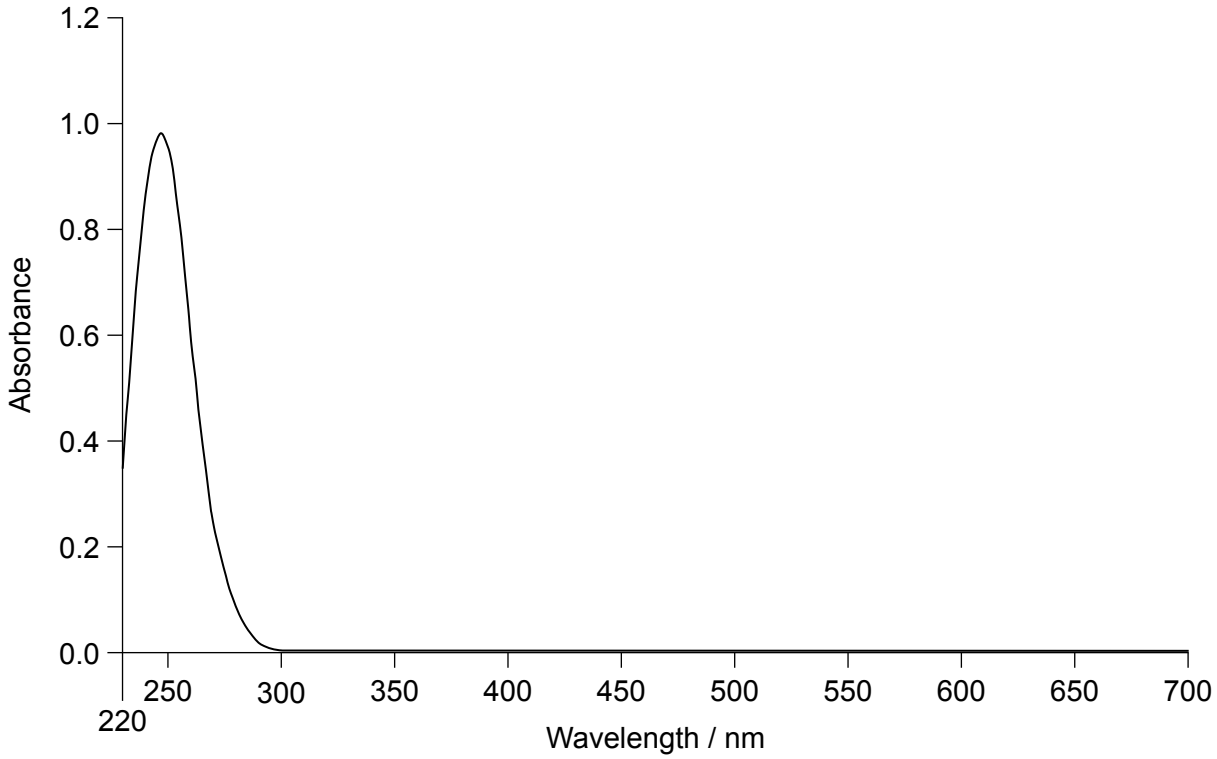
(This question continues on the following page)

(Question 1 continued)

(b) UV treatment is an alternative to pasteurization that minimizes loss of nutritional components.

(i) Deduce the type of electromagnetic radiation absorbed in the absorption spectrum of vitamin C. Use section 3 of the data booklet.



[1]

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(ii) Suggest why the use of UV light is not effective for the elimination of pathogenic bacteria in orange juice. [1]

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(This question continues on the following page)

(Question 1 continued)

(iii) Identify **two** ways to decrease the rate of change of vitamin C concentration due to oxidation during the storage of orange juice. [2]

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(iv) Vitamin C is easily oxidized. Outline why this makes vitamin C a good antioxidant. [1]

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(c) The concentration of vitamin C and pH of different fruits were measured.

	Concentration of vitamin C / mg dm^{-3}	**pH**
Watermelon	29	5.07
Banana	46	5.05
Apple	69	4.18
Pineapple	139	3.51
Orange	185	4.25

Deduce, with a reason, whether the data show a correlation between concentration of vitamin C and pH. [1]

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(This question continues on the following page)

(Question 1 continued)

(d) The concentration of vitamin C (ascorbic acid) can be measured by performing a redox titration using acidified iodate, IO_3^-, and iodide ions. Starch reacts with excess iodine once the vitamin C is consumed to produce a dark-blue complex.

Reaction 1: $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$

Reaction 2: ascorbic acid (aq) + $I_2(aq) \rightarrow 2I^-(aq)$ + dehydroascorbic acid (aq)

(i) Identify the oxidizing agent in reaction 1. [1]

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(ii) The student recorded the end point and then noticed the blue colour in the conical flask disappeared. Suggest why this occurred. [1]

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(iii) State the effect the recorded end point has on the value of the calculated concentration of vitamin C. [1]

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(iv) Suggest why this method cannot be used to measure the concentration of vitamin C in blueberry juice. [1]

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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

2. Sodium hydride forms a crystalline lattice.

(a) Estimate the percent ionic character of this compound using sections 8 and 29 of the data booklet. [1]

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(b) Deduce, giving a reason, whether sodium hydride could be classified as a Brønsted–Lowry acid or a Brønsted–Lowry base. [1]

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(c) Materials with high ion-exchange capacity, such as zeolites, can be used to soften water by replacing calcium ions with sodium ions. Outline **two** reasons for using zeolites for ion exchange. [2]

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(Option A continues on the following page)

(Option A continued)

3. Properties of materials are dependent upon their chemical structure.

(a) Outline why polar molecules can exhibit liquid crystal behaviour. [2]

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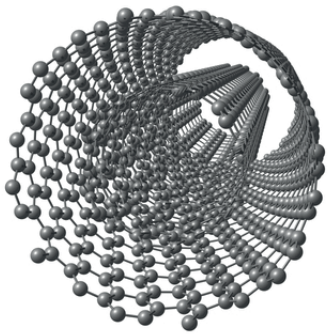
(b) Suggest why double walled carbon nanotubes are excellent conductors of heat along the tube but poor conductors across the width of the tube. [2]



[Source: iStock.com/ollaweila.]

Good conductors along the length of the tube:

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Poor conductors across the width of the tube:

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(Option A continues on the following page)

(Option A, question 3 continued)

(c) Outline how an inductively coupled plasma (ICP) torch converts argon into plasma. [3]

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(d) (i) Contrast the physical properties of polymers with extensive covalently bonded cross-links to polymers which only have a few of these links, giving an example of each. [4]

	Physical properties	**Example**
Extensive covalent cross-links:	. . . . .	. . . . .
Few covalent cross-links:	. . . . .	. . . . .

(ii) Making new plastics from recycling material is energy intensive. State **two** essential recycling processes that involve using energy. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(iii) Suggest **one** Resin Identification Code (RIC) for a non-recyclable plastic, with a reason for it not being recycled. Use section 30 of the data booklet. [1]

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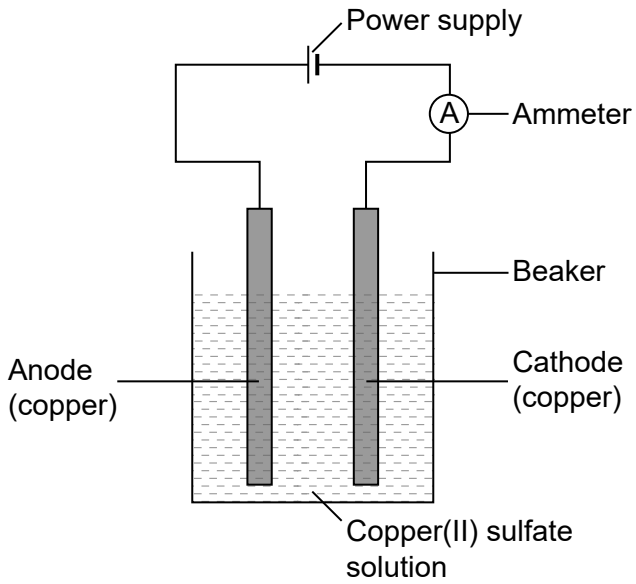
4. Copper can be obtained by electrolysis.

(a) An experiment to calculate Faraday's constant (F) was performed by electrolysing a solution of copper(II) sulfate using pure copper electrodes. A charge of 900.0 C was passed through the cell resulting in a mass loss of 0.296 g at the anode.



Suggest why mass gained at the cathode is a less accurate measure of electrolysed copper than mass loss at the anode. [1]

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(Option A continues on the following page)

(Option A, question 4 continued)

(b) Calculate a value for Faraday's constant from this experiment. [2]

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End of Option A

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will not be marked.

Option B — Biochemistry

5. A variety of methods are used to analyse proteins.

(a) State the type of bonding involved in the primary level of protein structure. [1]

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(b) (i) Outline how to use paper chromatography to identify the composition of amino acids in a polypeptide. [3]

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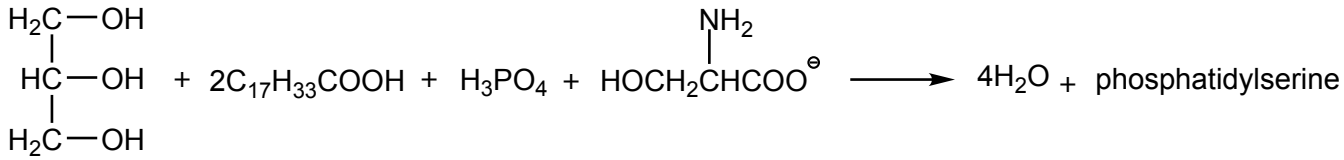
(ii) Isoleucine was identified as one of the amino acids. Draw the structure of the predominant form of this amino acid at pH = 4.50. Use section 33 of the data booklet. [1]

(Option B continues on the following page)

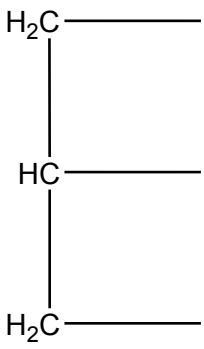
(Option B continued)

6. Phosphatidylserine is an example of a phospholipid.

(a) Phosphatidylserine may be formed from propane-1,2,3-triol, 2 oleic acid molecules, phosphoric acid and the serine anion.



Sketch the structural formula of phosphatidylserine. [2]



(b) Phosphatidylserine can be composed of different fatty acids such as stearic acid and linoleic acid.

Predict, giving **two** reasons, which of these fatty acids would have a higher melting point. Use section 34 of the data booklet. [2]

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(Option B continues on the following page)

(Option B, question 6 continued)

(c) Contrast the processes of hydrolytic and oxidative rancidity in fats with respect to the site of reactivity and conditions, other than temperature, that favour reaction. [2]

	Hydrolytic rancidity	**Oxidative rancidity**
Site of reactivity:	. . . .	. . . .
Conditions that favour reaction:	. . . .	. . . .

(d) State **one** function of lipids in the body. [1]

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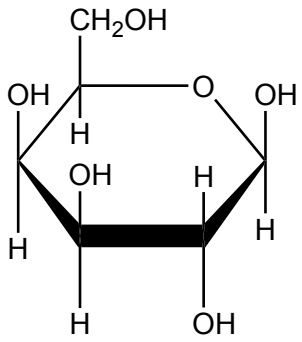
(Option B continues on the following page)

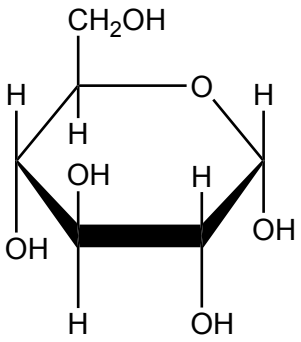
(Option B continued)

7. Lactose is the main disaccharide in milk.

(a) Lactose is composed of galactose and glucose.

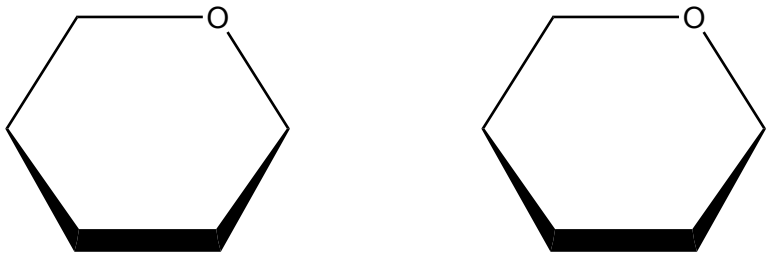


Galactose



Glucose

(i) Draw the structure of lactose. [2]



(ii) State the type of bond and reaction that forms the disaccharide. [2]

Type of bond:

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Type of reaction:

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(Option B continues on the following page)

(Option B, question 7 continued)

(b) Milk is fortified with vitamin D. State a disease related to vitamin D deficiency. [1]

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8. Host–guest chemistry has been used for the removal of xenobiotics in the environment.

(a) Outline what is meant by *xenobiotic*. [1]

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(b) Compare the bonding of synthetic host molecules and enzymes to substrates. [1]

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(c) Suggest a specific environmental application of host–guest chemistry. [1]

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End of Option B

Option C — Energy

9. The spontaneity of nuclear fission and fusion reactions can be explained by changes in nuclear binding energy.

(a) State why the average binding energy per nucleon for the isotope ^{1}H is zero. [1]

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(b) Determine the energy released, in MeV, when a helium-4 nucleus (^{4}He) is formed from deuteron (^{2}H) and triton (^{3}H). Use section 36 of the data booklet.

$$^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$$ [2]

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(c) (i) The average energy release in the fission of one atom of ^{235}U is 193.4 MeV. Calculate the specific energy of ^{235}U in MJ per gram.

$$1\,\text{MeV} = 1.60 \times 10^{-19}\,\text{MJ}.$$ [1]

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(ii) Explain whether the energy density, in MJ dm^{-3}, or specific energy, in MJ kg^{-1}, of hydrogen has a higher value at standard conditions of temperature and pressure. [1]

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(Option C continues on the following page)

(Option C, question 9 continued)

(d) (i) Write the nuclear alpha decay equation of ^{235}U forming a helium-4 nucleus and a product with a much shorter half-life. [1]

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(ii) The half-life of the product is 25.5 hours. Calculate the time taken, in hours, for 1.000 g of the product to decay to 0.03125 g. [2]

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(Option C continues on the following page)

(Option C continued)

10. Many molecules interact with light.

(a) (i) Contrast, at the molecular level, how carbon dioxide and a coloured pigment, such as chlorophyll, interact with electromagnetic radiation. [4]

Carbon dioxide:

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Chlorophyll:

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(ii) Identify the range of wavelengths absorbed by carbon dioxide and chlorophyll. Use section 3 of the data booklet. [1]

Carbon dioxide:

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Chlorophyll:

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(b) Upper atmosphere temperatures recorded by satellites are becoming lower over time.

Suggest how greenhouse gases could be responsible for this trend. [2]

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(Option C continues on the following page)

(Option C continued)

11. Natural gas is a fossil fuel.

(a) State the chemical process by which fossil fuels were formed from biological compounds. [1]

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(b) State the main component of natural gas. [1]

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(c) Outline **one** advantage and **one** disadvantage, apart from cost, of using natural gas over other fossil fuels. [2]

Advantage:

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Disadvantage:

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(d) Suggest a reason why syngas, produced from coal or biomass gasification, may be considered a viable alternative to crude oil. [1]

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End of Option C

Option D — Medicinal chemistry

12. Aspirin and morphine are two analgesics.

(a) State the site and mode of action of aspirin. [2]

Site of action:

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Mode of action:

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(b) (i) Aspirin is synthesized from salicylic acid. Discuss **two** ways in which the melting point of crystallized aspirin can indicate the presence of impurities. [2]

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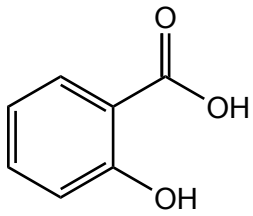
(ii) Deduce the range of wavenumbers in the IR spectrum which would indicate that the impure aspirin contains salicylic acid. Use sections 26 and 37 of the data booklet.



Salicylic acid [1]

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(Option D continues on the following page)

(Option D, question 12 continued)

(c) Morphine can be administered both orally and intravenously.

Suggest **one** reason why drugs administered orally have lower bioavailability than drugs administered intravenously. [1]

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(d) Morphine has a much greater affinity for the opioid receptor in the central nervous system compared to diamorphine.

Explain why diamorphine is a more potent analgesic. Use section 37 of the data booklet. [2]

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(Option D continues on the following page)

(Option D continued)

13. Excess stomach acid is a common health condition.

(a) Explain how omeprazole regulates stomach pH. [2]

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(b) Write an equation for the reaction of a solution of sodium hydrogen carbonate with stomach acid, including state symbols. [1]

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(c) Predict, with a reason, whether the neutralization of acid by ranitidine in a titration is a reliable measure of its effectiveness in regulating stomach acid. [1]

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14. Viruses and bacteria must be targeted in different ways.

(a) (i) Describe how oseltamivir (Tamiflu) works as a preventative agent against flu viruses. [2]

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(Option D continues on the following page)

(Option D, question 14 continued)

(ii) The production of oseltamivir requires shikimic acid, a precursor originally obtained from star anise.

Comment on an advancement made in the production of shikimic acid and its importance in terms of green chemistry. [2]

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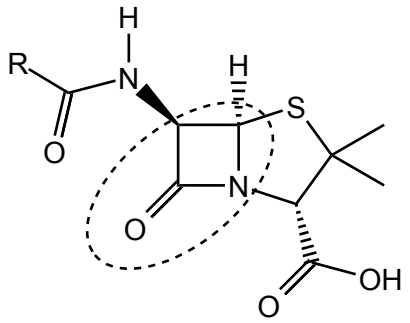
(b) (i) State the name of the part of the core structure of penicillin circled in the following diagram.



[1]

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(ii) Describe the role of this structure in the action of penicillin against bacteria. [2]

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(iii) State a consequence of bacteria gaining increased resistance to antibiotics. [1]

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End of Option D

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References:

1. Oulé, M., Dickman, M., Arul, J., 2013. *Properties of Orange Juice with Supercritical Carbon Dioxide Treatment*. [graph] Available at: https://www.researchgate.net/publication/263368607_Properties_of_Orange_Juice_with_Supercritical_Carbon_Dioxide_Treatment [Accessed 4 May 2020]. Source adapted.

1(b)(i). Koutchma, T., 2010. *UV irradiation improves safety of foods and beverages*. [graph] Available at: https://www.researchgate.net/figure/Measured-absorption-spectra-of-apple-juice-and-vitamin-C-as-well-as-emission-spectra-of_fig1_274630712 [Accessed 4 May 2020]. Source adapted.

1(c). Unaegbu, M., Godwill, E. A., et al., 2016. *Heavy metal, nutrient and antioxidant status of selected fruit samples sold in Enugu, Nigeria*. [table] Available at: https://www.researchgate.net/figure/pH-acidity-ascorbic-acid-and-antioxidantactivity-of-fruit-samples_tbl2_305691722 [Accessed 4 May 2020]. Under creative commons CC BY 4.0 DEED licence. https://creativecommons.org/licenses/by/4.0/. Source adapted (table simplified and redrawn).

3(b). iStock.com/ollaweila.

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