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# Chemistry

## Higher level

### Paper 3

Thursday 23 May 2019 (morning)

Candidate session number

1 hours 15 minutes

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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 **[45 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 – 8
Option B — Biochemistry	9 – 13
Option C — Energy	14 – 20
Option D — Medicinal chemistry	21 – 27



**Section A**

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

1. This question is about a mug made of a lead alloy.



The rate of lead dissolving in common beverages with various pH values was analysed.

**Lead dissolving in beverages at various times and temperatures**

Experiment	Beverage	pH	Time / min	Temp. / °C	Lead concentration / $\text{mg dm}^{-3}$
1	Cola	2.5	5	16	6
2	Cola	2.5	30	16	14
3	Cola	2.5	60	16	23
4	Cola	2.5	5	18	11
5	Lemonade	2.9	5	18	14
6	Orange juice	3.7	5	18	18
7	Beer	4.2	5	18	2.3
8	Tap water	5.9	5	18	15

[Source: first published in *Chemistry in Australia*, chemaust.raci.org.au]

(This question continues on the following page)



**(Question 1 continued)**

- (a) Identify the experiment with the highest rate of lead dissolving. [1]

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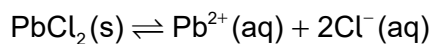
- (b) (i) Suggest why the relationship between time and lead concentration for Cola at 16 °C is not linear. [1]

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- (ii) Examine, giving a reason, whether the rate of lead dissolving increases with acidity at 18 °C. [1]

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- (c) (i) Lead(II) chloride, PbCl<sub>2</sub>, has very low solubility in water.



Explain why the presence of chloride ions in beverages affects lead concentrations. [2]

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**(This question continues on the following page)**



**(Question 1 continued)**

- (ii) A mean daily lead intake of greater than  $5.0 \times 10^{-6}$  g per kg of body weight results in increased lead levels in the body.

Calculate the volume, in  $\text{dm}^3$ , of tap water from experiment 8 which would exceed this daily lead intake for an 80.0 kg man. [2]

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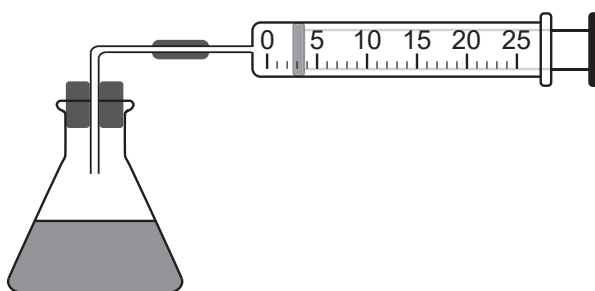
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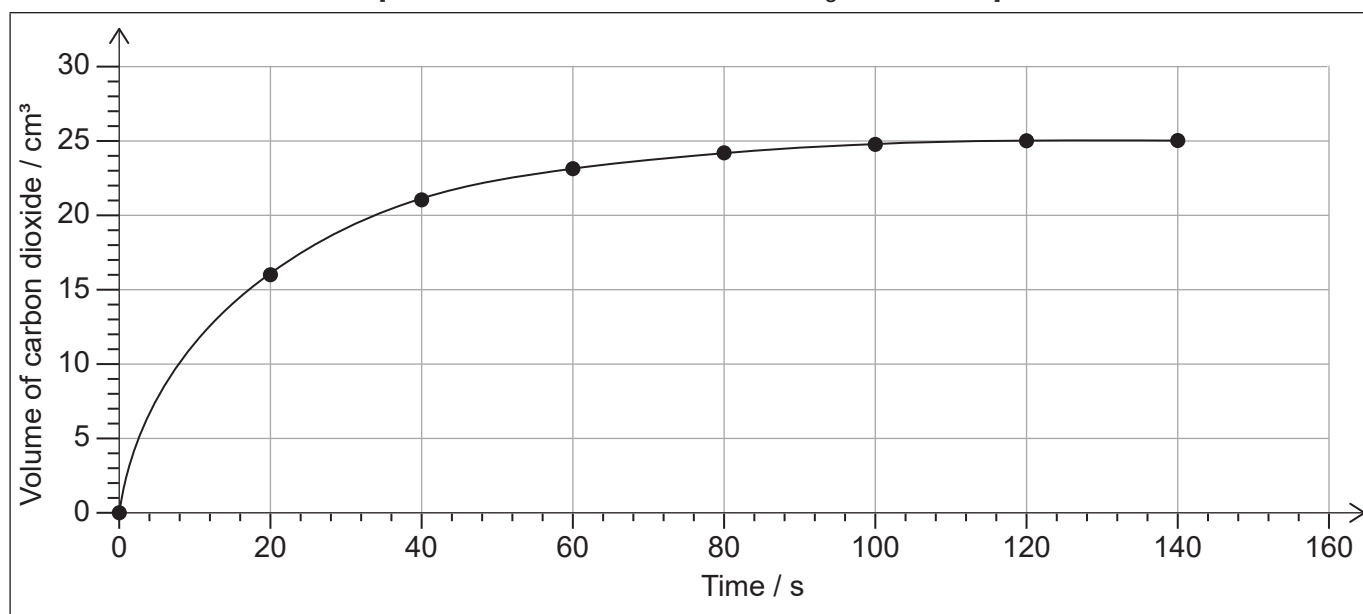
**2. Bromine and methanoic acid react in aqueous solution.**



The reaction was monitored by measuring the volume of carbon dioxide produced as time progressed.



[Source: © International Baccalaureate Organization 2019]



[Source: © International Baccalaureate Organization 2019]

**(This question continues on the following page)**



**(Question 2 continued)**

(a) Determine from the graph the rate of reaction at 20 s, in  $\text{cm}^3 \text{s}^{-1}$ , showing your working. [3]

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(b) Outline, with a reason, another property that could be monitored to measure the rate of this reaction. [2]

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(c) (i) Describe **one** systematic error associated with the use of the gas syringe, and how the error affects the calculated rate. [2]

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(ii) Identify **one** error associated with the use of an accurate stopwatch. [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

3. Describe the characteristics of the nematic liquid crystal phase. [2]

Shape of molecules:

.....

Distribution:

.....

.....

4. Metals are extracted from their ores by several methods, including electrolysis and reduction with carbon.
- (a) Determine the mass of aluminium, in g, that could be extracted from an appropriate solution by a charge of 48 250 C. Use sections 2 and 6 of the data booklet. [3]

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(Option A continues on the following page)



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

- (b) Once extracted, the purity of the metal can be assessed using ICP-MS. Suggest **two** advantages of using plasma technology rather than regular mass spectrometry. [2]

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- (c) Explain the action of metals as heterogeneous catalysts. [2]

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- (d) Outline how alloys conduct electricity and why they are often harder than pure metals. [2]

Conduct electricity:

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Harder than pure metals:

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- (e) Carbon nanotubes are added to metals to increase tensile strength.  
Write an equation for the formation of carbon nanotubes from carbon monoxide. [1]

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



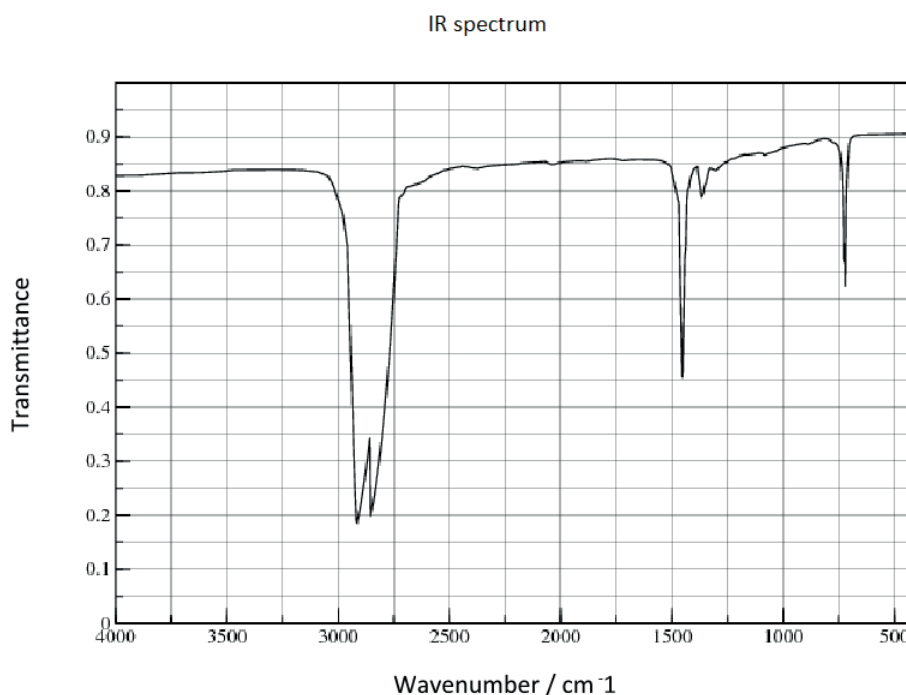


(Option A continued)

5. Polymers have a wide variety of uses but their disposal can be problematic.

(a) Draw a section of isotactic polychloroethene (polyvinylchloride, PVC) showing all the atoms and all the bonds of **four** monomer units. [2]

(b) The infrared (IR) spectrum of polyethene is given.



[Source: used with kind permission from Dr Aubrey Jaffer]

Suggest how the IR spectrum of polychloroethene would differ, using section 26 of the data booklet. [1]

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(Option A continues on the following page)



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

(c) Explain how plasticizers affect the properties of plastics. [2]

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(d) Suggest why the addition of plasticizers is controversial. [1]

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(e) Outline, giving a reason, how addition and condensation polymerization compare with regard to green chemistry. [1]

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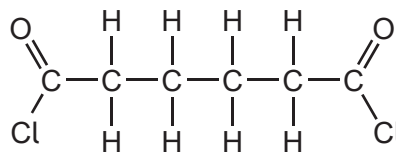
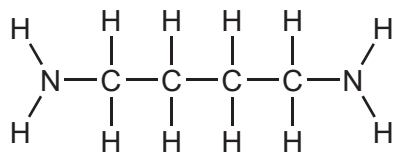
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**(Option A continues on the following page)**

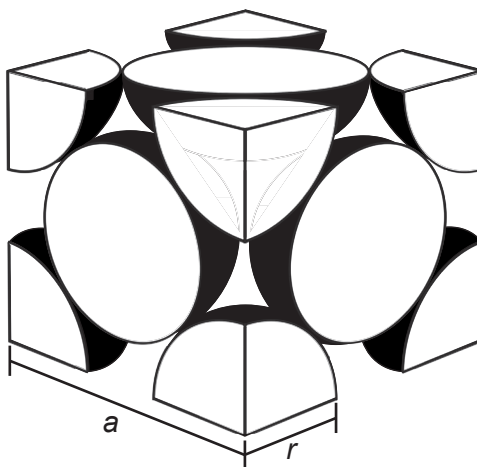


(Option A, question 5 continued)

- (f) Draw the full structural formula of the organic functional group formed during the polymerization of the two reactants below. [1]



6. Calcium has a face-centred cubic (cubic close packing) arrangement of atoms.



[Source: © International Baccalaureate Organization 2019]

$a$  = unit cell dimension,  $r$  = metallic radius

- (a) State the number of atoms in the unit cell. [1]

.....

.....

(Option A continues on the following page)



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

(b) Determine the density of calcium, in  $\text{g cm}^{-3}$ , using section 2 of the data booklet.

$A_r = 40.08$ ; metallic radius ( $r$ ) =  $1.97 \times 10^{-10} \text{ m}$

[3]

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7. Superconductivity has many applications.

(a) State what is meant by a superconductor.

[1]

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(b) Outline the difference in behaviour of Type 1 and Type 2 superconductors when the temperature is lowered.

[1]

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



**(Option A continued)**

8. Heavy metals are toxic even in very low concentrations.

(a) Outline why heavy metals are toxic.

[1]

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(b) Determine the maximum concentration of lead(II) ions at 298 K in a solution in which the concentration of carbonate ions is maintained at  $1.10 \times 10^{-4} \text{ mol dm}^{-3}$ . Use section 32 of the data booklet.

[2]

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(c) State a method, other than precipitation, of removing heavy metal ions from solution.

[1]

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**End of Option A**



**Option B — Biochemistry**

9. Proteins have structural or enzyme functions.

(a) (i) Some proteins form an  $\alpha$ -helix. State the name of another secondary protein structure. [1]

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(ii) Compare and contrast the bonding responsible for the two secondary structures. [2]

One similarity:  
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.....

One difference:  
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(b) Explain why an increase in temperature reduces the rate of an enzyme-catalyzed reaction. [2]

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(c) State and explain how a competitive inhibitor affects the maximum rate,  $V_{max}$ , of an enzyme-catalyzed reaction. [2]

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(Option B continues on the following page)



**(Option B, question 9 continued)**

(d) Oil spills are a major environmental problem.

(i) Suggest **two** reasons why oil decomposes faster at the surface of the ocean than at greater depth. [2]

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(ii) Oil spills can be treated with an enzyme mixture to speed up decomposition.

Outline **one** factor to be considered when assessing the greenness of an enzyme mixture. [1]

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



**(Option B continued)**

**10.** Amino acids contain both acidic and basic functional groups.

(a) An aqueous solution of glutamine contains  $0.600 \text{ mol dm}^{-3}$  of the zwitterion and  $0.300 \text{ mol dm}^{-3}$  of the anionic form.

$$pK_{a1} = 2.2 \text{ and } pK_{a2} = 9.1$$

(i) Outline which  $pK_a$  value should be used when calculating the pH of the solution, giving your reason. [1]

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.....

(ii) Calculate the pH of the glutamine solution using section 1 of the data booklet. [1]

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(b) Describe what is meant by the genetic code and how it relates to protein synthesis. [2]

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

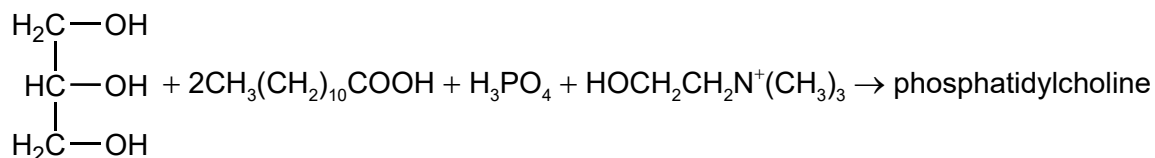




**(Option B continued)**

11. Phosphatidylcholine is an example of a phospholipid found in lecithin.

(a) Phosphatidylcholine may be formed from propane-1,2,3-triol, two lauric acid molecules, phosphoric acid and the choline cation.



(i) Deduce the structural formula of phosphatidylcholine. [2]

$\begin{array}{c} \text{H}_2\text{C}- \\   \\ \text{HC}- \\   \\ \text{H}_2\text{C}- \end{array}$
---

(ii) Identify the type of reaction in (a). [1]

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(b) Lecithin is a major component of cell membranes. Describe the structure of a cell membrane. [2]

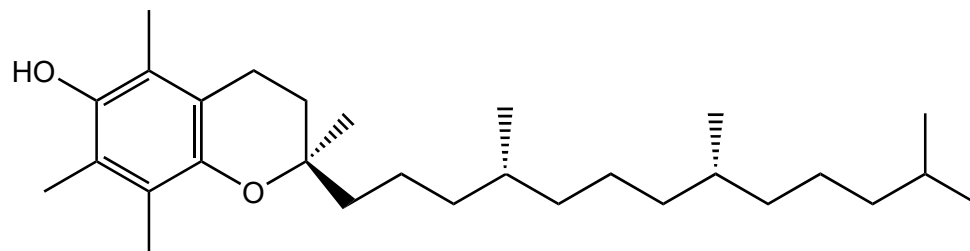
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**(Option B continues on the following page)**



(Option B, question 11 continued)

(c) Lecithin aids the body's absorption of vitamin E.



The  $\alpha$ -tocopherol form of vitamin E.

Suggest why vitamin E is fat-soluble.

[1]

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(d) Phospholipids are also found in lipoprotein structures.

Describe **one** effect of increased levels of low-density lipoprotein (LDL) on health.

[1]

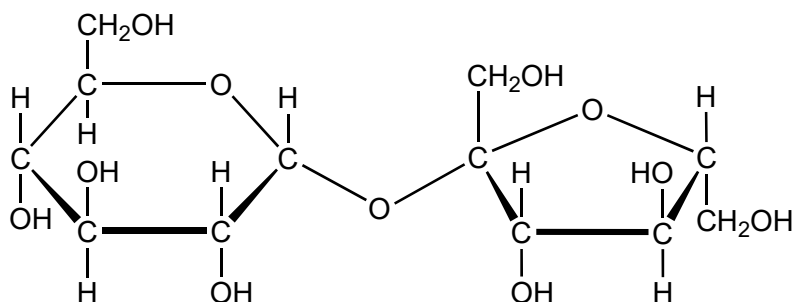
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(Option B continues on the following page)



**(Option B continued)**

12. Sucrose is a disaccharide.



(a) State the name of the functional group forming part of the ring structure of each monosaccharide unit. [1]

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(b) Classify, giving your reason, the hexose (six-membered) ring of sucrose as an  $\alpha$  or  $\beta$  isomer. [1]

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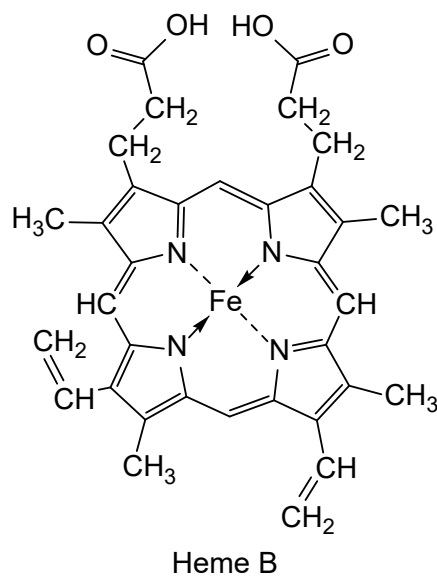
(c) Sketch the cyclic structures of the two monosaccharides which combine to form sucrose. [2]

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



**(Option B continued)**

13. Hemoglobin contains heme groups with the porphyrin ring bound to an iron(II) ion.



(a) Outline why the complex formed between Fe<sup>2+</sup> and oxygen is red. Refer to the diagram above and section 17 of the data booklet.

[2]

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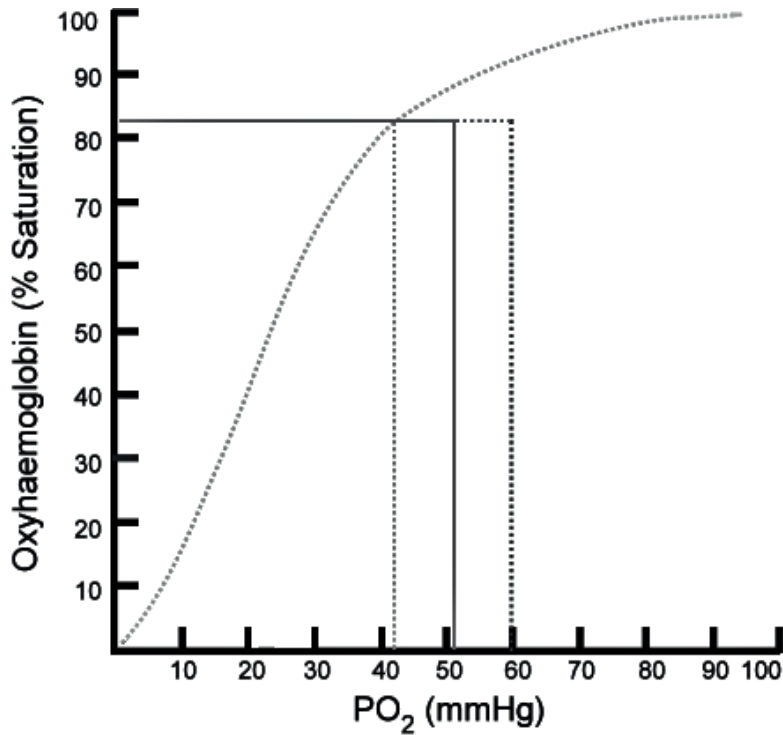
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**(Option B continues on the following page)**



(Option B, question 13 continued)

(b) A hemoglobin's oxygen dissociation curve is shown.



[Source: Ratznum, [https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin\\_dissociation\\_curve.png](https://commons.wikimedia.org/wiki/File:Oxyhaemoglobin_dissociation_curve.png)]

(i) Explain the shape of the curve.

[2]

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(ii) Sketch another line to show the effect of an increase in body temperature on the oxygen saturation of hemoglobin.

[1]

**End of Option B**



**Option C — Energy**

**14.** The regular rise and fall of sea levels, known as tides, can be used to generate energy.

State **one** advantage, other than limiting greenhouse gas emissions, and **one** disadvantage of tidal power.

[2]

Advantage: ..... .....
Disadvantage: ..... .....

**15.** This question is about fuel for engines.

(a) Crude oil can be converted into fuels by fractional distillation and cracking.

Contrast these two processes.

[2]

Fractional distillation	Cracking
..... ..... .....	..... ..... .....
..... ..... .....	..... ..... .....

(Option C continues on the following page)



**(Option C, question 15 continued)**

- (b) Determine the specific energy, in  $\text{kJg}^{-1}$ , and energy density, in  $\text{kJcm}^{-3}$ , of hexane,  $\text{C}_6\text{H}_{14}$ . Give both answers to three significant figures.

Hexane:  $M_r = 86.2$ ;  $\Delta H_c = -4163 \text{ kJ mol}^{-1}$ ; density =  $0.660 \text{ g cm}^{-3}$  [2]

Specific energy:

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.....

Energy density:

.....  
.....

- (c) Hydrocarbons need treatment to increase their octane number to prevent pre-ignition (knocking) before they can be used in internal combustion engines.

Describe how this is carried out and the molecular changes that take place. [2]

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

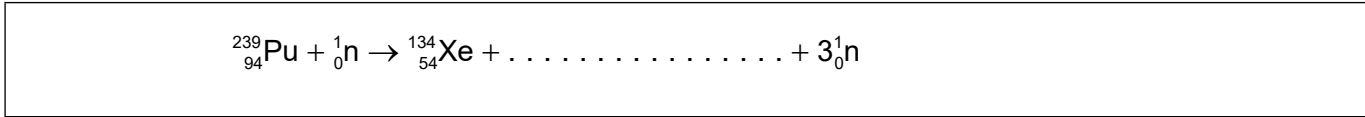


**(Option C continued)**

**16.** This question is about nuclear reactions.

(a) Fission of a nucleus can be initiated by bombarding it with a neutron.

(i) Determine the other product of the fission reaction of plutonium-239. [1]



(ii) Outline the concept of critical mass with respect to fission reactions. [1]

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(iii) Outline **one** advantage of allowing all countries access to the technology to generate electricity by nuclear fission. [1]

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(b) State **one** advantage of using fusion reactions rather than fission to generate electrical power. [1]

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(c) Outline how the energy of a fission reaction can be calculated. [1]

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





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

- (d) Calculate the half-life of an isotope whose mass falls from  $5.0 \times 10^{-5}$  g to  $4.0 \times 10^{-5}$  g in 31.4 s, using section 1 of the data booklet. [2]

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**17.** This question is about biofuel.

Evaluate the use of biodiesel in place of diesel from crude oil.

[2]

Strength:

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Limitation:

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**18.** This question is about global warming.

- (a) Describe the effect of infrared (IR) radiation on carbon dioxide molecules.

[2]

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



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

- (b) Outline **one** approach to controlling industrial emissions of carbon dioxide. [1]

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**19.** Electricity can be generated in a variety of ways.

- (a) Outline how a microbial fuel cell produces an electric current from glucose.



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- (b) The cell potential for the spontaneous reaction when standard magnesium and silver half-cells are connected is +3.17 V.

Determine the cell potential at 298 K when:

$$[\text{Mg}^{2+}] = 0.0500 \text{ mol dm}^{-3}$$

$$[\text{Ag}^+] = 0.100 \text{ mol dm}^{-3}$$

Use sections 1 and 2 of the data booklet. [2]

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



(Option C, question 19 continued)

(c) Outline **one** difference between a primary and a secondary cell.

[1]

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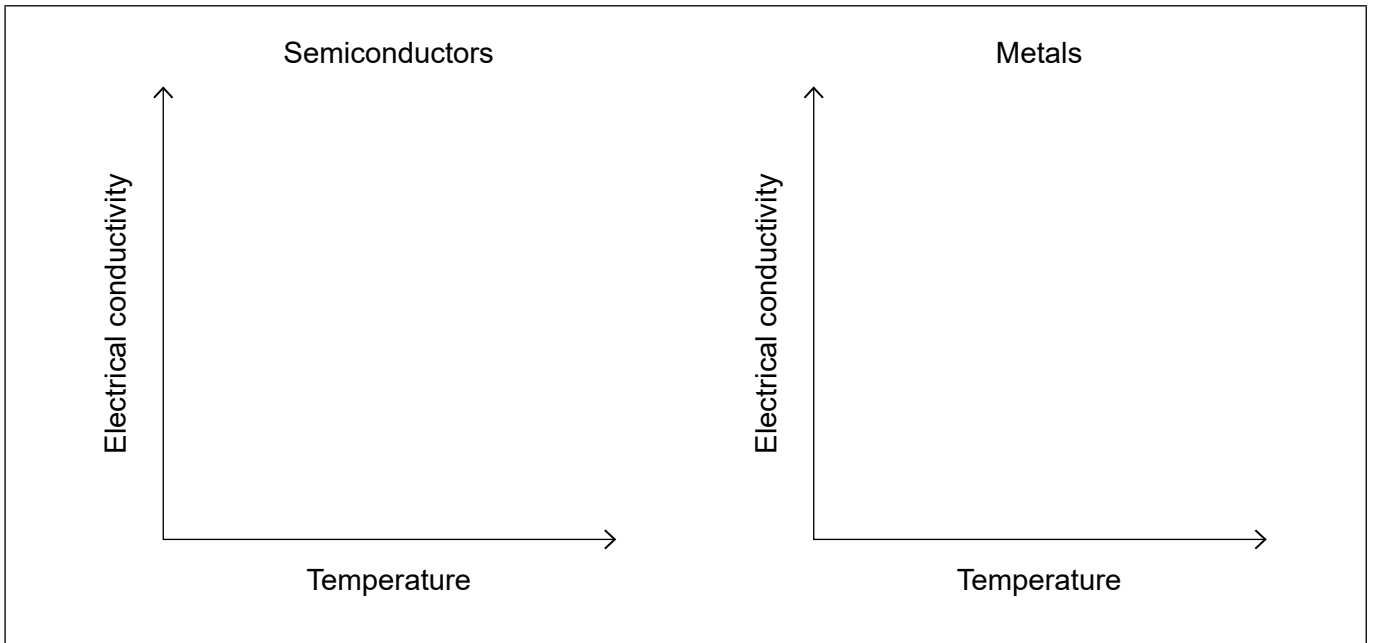
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20. Semiconductors and light-sensitive dyes are used in photovoltaic cells.

(a) Sketch graphs to show the general effect of increasing temperature on the electrical conductivity of semiconductors and metals on the axes below.

[2]



(b) Explain the function of dyes in a dye-sensitized solar cell (DSSC).

[2]

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**End of Option C**



36EP26

**Option D — Medicinal chemistry**

**21.** Medicines and drugs are tested for effectiveness and safety.

(a) Distinguish between therapeutic window and therapeutic index in humans. [2]

Therapeutic window:

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Therapeutic index:

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(b) Explain why diamorphine (heroin) is more potent than morphine using section 37 of the data booklet. [2]

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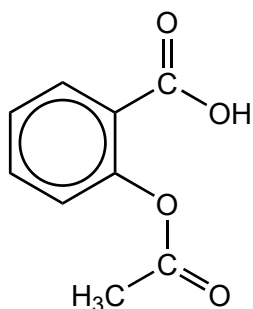
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**(Option D continues on the following page)**



(Option D continued)

22. A student synthesized aspirin, acetylsalicylic acid, in a school laboratory.



Aspirin  
 $M_r = 180.17$

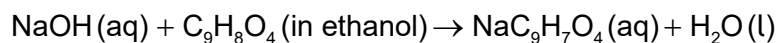
- (a) Predict **one** absorption band present in an infrared (IR) spectrum of aspirin, using section 26 of the data booklet.

[1]

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.....

- (b) 0.300 g of crude aspirin was dissolved in ethanol and titrated with sodium hydroxide solution, NaOH(aq).



- (i) Determine the mass of aspirin which reacted with 16.25 cm<sup>3</sup> of 0.100 mol dm<sup>-3</sup> NaOH solution.

[2]

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- (ii) Determine the percentage purity of the synthesized aspirin.

[1]

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(Option D continues on the following page)



**(Option D, question 22 continued)**

(c) Outline how aspirin can be chemically modified to increase its solubility in water. [1]

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(d) State why aspirin should not be taken with alcohol. [1]

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**23.** Excess acid in the stomach can cause breakdown of the stomach lining.

(a) (i) Outline how ranitidine (Zantac) inhibits stomach acid production. [1]

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(ii) Outline **two** advantages of taking ranitidine instead of an antacid which neutralizes excess acid. [2]

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



**(Option D, question 23 continued)**

- (b) Some antacids contain carbonates.

Determine the pH of a buffer solution which contains  $0.160 \text{ mol dm}^{-3} \text{ CO}_3^{2-}$  and  $0.200 \text{ mol dm}^{-3} \text{ HCO}_3^-$ , using section 1 of the data booklet.

$\text{p}K_a (\text{HCO}_3^-) = 10.32$

[1]

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**24.** Antiviral medications have recently been developed for some viral infections.

- (a) Outline **one** way in which antiviral drugs work.

[1]

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- (b) Discuss **two** difficulties associated with solving the AIDS problem.

[2]

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



**(Option D continued)**

**25.** Taxol is a drug that was once obtained from yew trees and is now produced using chiral auxiliaries.

(a) Examine the synthesis of taxol in terms of green chemistry criteria. [2]

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(b) Outline the operation of a polarimeter used to distinguish between enantiomers. [2]

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





**(Option D continued)**

**26.** Technetium-99m, Tc-99m, is a gamma-ray emitter commonly used as a medical tracer. Its half-life is 6.0 hours.

(a) Evaluate the suitability of technetium-99m for this use. [2]

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(b) Calculate the percentage of technetium-99m remaining after 10.0 hours. Use section 1 of the data booklet. [2]

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



**(Option D continued)**

27. The presence of alcohol in the breath can be detected using a breathalyser.

(a) Describe how a fuel cell breathalyser works.

[3]

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(b) Alcohol levels in the breath can also be determined using IR spectroscopy.

Suggest, giving a reason, which bond's absorbance is most useful for detecting ethanol in breath.

[2]

Bond:  
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Reason:  
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**End of Option D**



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