Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Standard level
Paper 3

Thursday 23 May 2019 (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 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 6
Option B — Biochemistry	7 – 10
Option C — Energy	11 – 13
Option D — Medicinal chemistry	14 – 19

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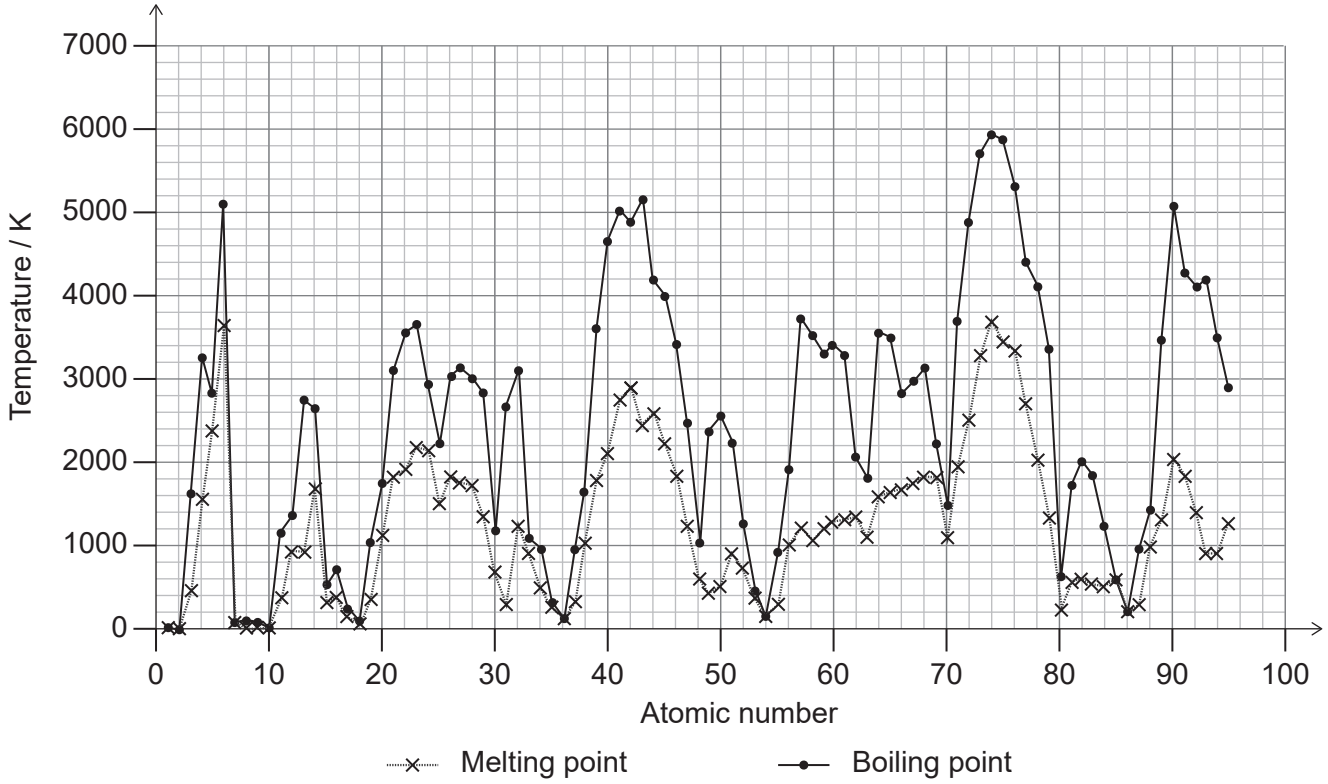
Section A

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

1. Physical properties of elements vary according to atomic number. Sections 6 to 9 of the data booklet list some of these properties.

Melting points and boiling points of elements 1 to 95



[Source: www.mrbigler.com/documents/Periodic-Table.xls, used with the kind permission of Jeff Bigler]

(a) Deduce, giving a reason, the group of elements in the periodic table most likely to undergo sublimation. [2]

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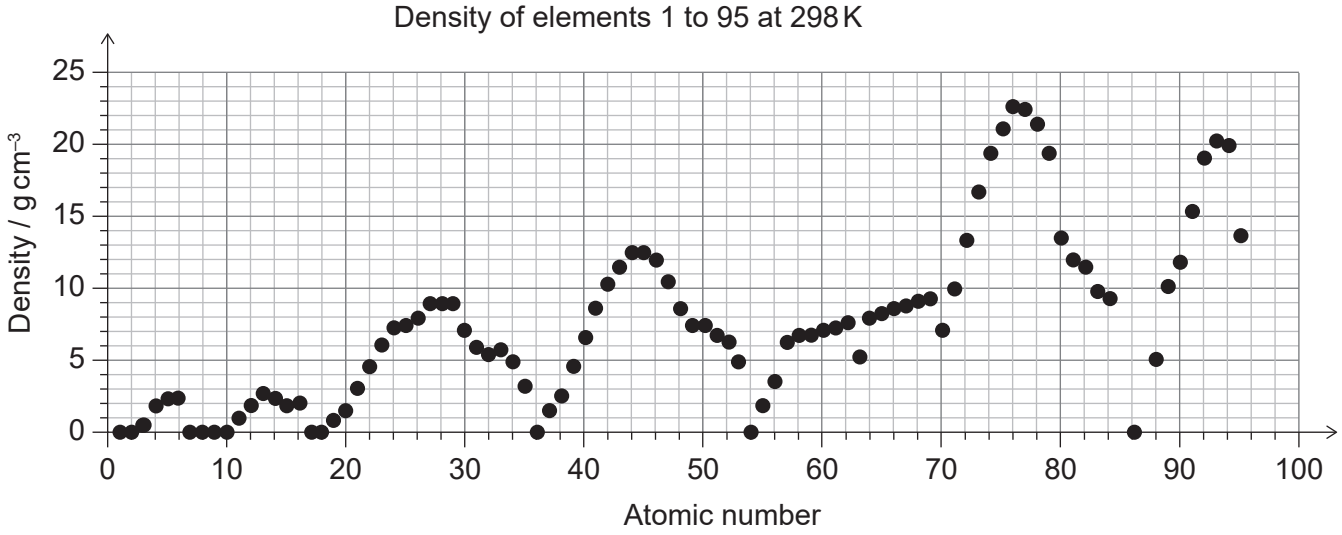
(Question 1 continued)

(b) (i) Describe the density trend across periods 4 and 5 of the periodic table. [1]



[Source: © International Baccalaureate Organization 2019]

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(ii) Suggest, with a reason, whether the lanthanoids or actinoids of the f-block would have the higher density. [1]

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(iii) Compare the ease of oxidation of s-block and d-block metals to their melting points **and** densities. Use section 25 of the data booklet. [2]

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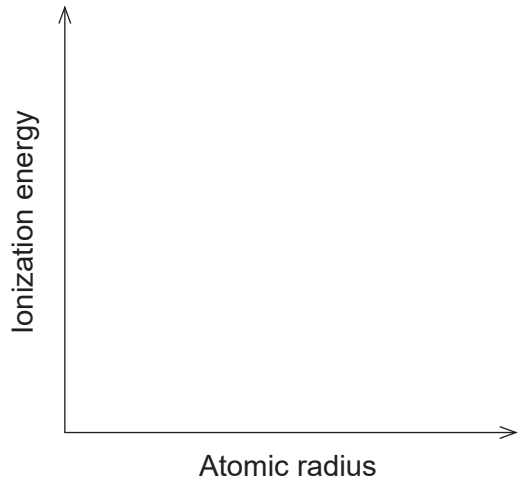
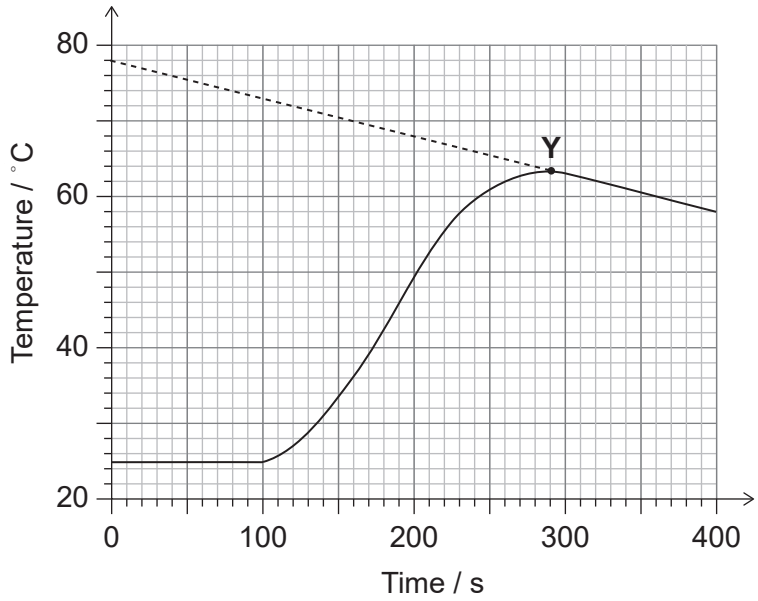
(Question 1 continued)

(iv) Sketch how the first ionization energies of elements vary with their atomic radius. [1]



2. Powdered zinc was reacted with 25.00 cm^3 of 1.000 mol dm^{-3} copper(II) sulfate solution in an insulated beaker. Temperature was plotted against time.



[Source: © International Baccalaureate Organization 2019]

(a) (i) Estimate the time at which the powdered zinc was placed in the beaker. [1]

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(This question continues on the following page)

(Question 2 continued)

(ii) State what point **Y** on the graph represents. [1]

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(b) (i) The maximum temperature used to calculate the enthalpy of reaction was chosen at a point on the extrapolated (dotted) line.

State the maximum temperature which should be used and outline **one** assumption made in choosing this temperature on the extrapolated line. [2]

Maximum temperature:

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Assumption:

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(ii) To determine the enthalpy of reaction the experiment was carried out five times. The same volume and concentration of copper(II) sulfate was used but the mass of zinc was different each time. Suggest, with a reason, if zinc or copper(II) sulfate should be in excess for each trial. [1]

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(This question continues on the following page)

(Question 2 continued)

(iii) The formula $q = mc\Delta T$ was used to calculate the energy released. The values used in the calculation were $m = 25.00\,g$, $c = 4.18\,J\,g^{-1}\,K^{-1}$.

State an assumption made when using these values for m and c. [2]

Value	Assumption
$m = 25.00\,g$	....
$c = 4.18\,J\,g^{-1}\,K^{-1}$	....

(iv) Predict, giving a reason, how the final enthalpy of reaction calculated from this experiment would compare with the theoretical value. [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. Lithium has many uses.

(a) (i) Identify the type of bonding in lithium hydride, using sections 8 and 29 of the data booklet. [1]

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(ii) Explain why lithium is paramagnetic while lithium hydride is diamagnetic by referring to electron configurations. [2]

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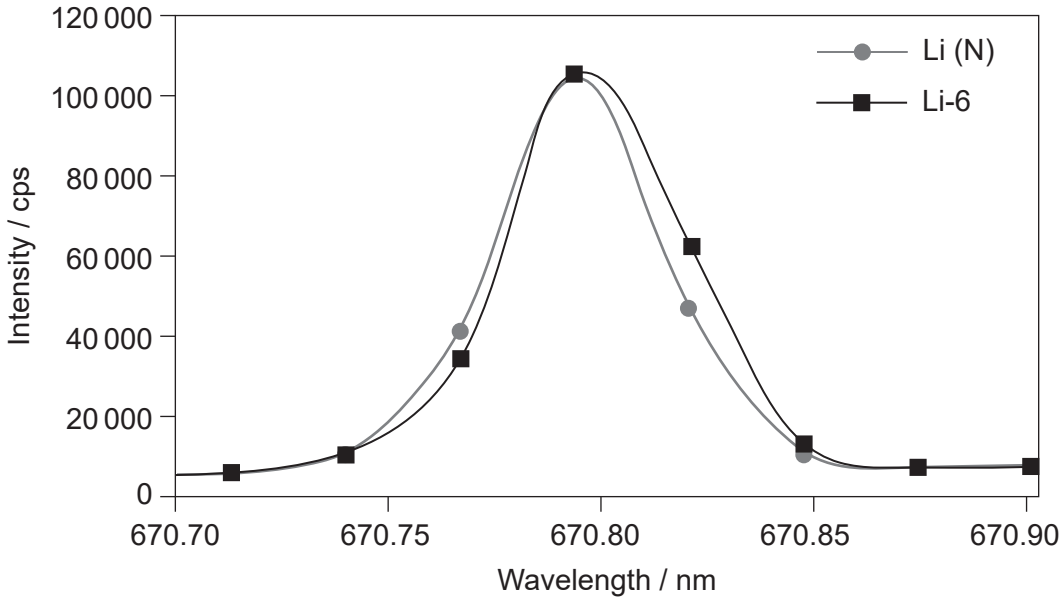
(Option A continues on the following page)

(Option A, question 3 continued)

(b) The emission spectra obtained by ICP-OES for a mixture containing the isotope ^{6}Li (Li-6) and naturally occurring lithium (Li (N)) is shown.



[Source: *J. Anal. At. Spectrom.*, 2015, **30**, 2003–2009, https://doi.org/10.1039/C5JA00181A – Reproduced by permission of The Royal Society of Chemistry. https://pubs.rsc.org/en/content/articlelanding/2015/JA/C5JA00181A#!divAbstract]

(i) Suggest why ICP-OES does not give good quantitative results for distinguishing ^{6}Li from naturally occurring lithium. [1]

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(ii) Suggest a better method. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(c) Lithium is obtained by electrolysis of molten lithium chloride. Calculate the time, in seconds, taken to deposit 0.694 g Li using a current of 2.00 A.

$$Q \text{ (charge)} = I \text{ (current)} \times t \text{ (time)}$$ [2]

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4. Polybutadiene, used in truck tyres, is a polymer of buta-1,3-diene. The spatial arrangement of atoms in the polymer depends on the type of catalyst used.

(a) Outline **two** differences between heterogeneous and homogeneous catalysts. [2]

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(b) Suggest, giving a reason, how elastomers used for the tyre tread can increase the traction between the tyre and the road. [2]

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(Option A continues on the following page)

(Option A, question 4 continued)

(c) (i) Tyre fires emit trace quantities of polychlorinated dibenzofurans and polychlorinated dibenzo-*p*-dioxin.

Outline, using section 31 of the data booklet, why polychlorinated dibenzofuran is not classed chemically as a dioxin but considered "dioxin-like". [2]

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(ii) The trace quantities of dioxins from tyre fires are rarely inhaled and instead settle on the ground.

Describe why this is a health concern. [1]

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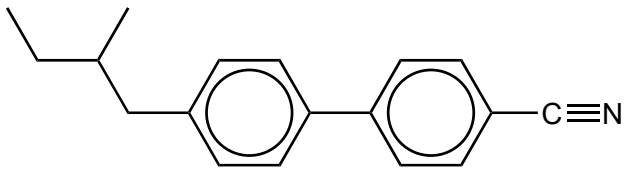
5. Liquid-crystal displays (LCDs) have many uses.

A molecule which acts as a thermotropic liquid crystal is shown.



(a) State the name of the functional group which allows the molecule to be responsive to applied electric fields. [1]

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(Option A continues on the following page)

(Option A, question 5 continued)

(b) Explain the effects of very low and high temperatures on the liquid-crystal behaviour of this molecule. [2]

Low temperature:

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High temperature:

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6. Nanotechnology has allowed the manipulation of materials on the atomic level.

(a) Describe the structure and bonding of a carbon nanotube. [2]

Structure:

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Bonding:

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(b) Suggest **one** application for carbon nanotubes. [1]

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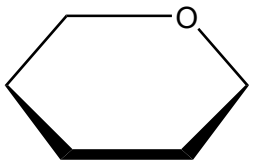
End of Option A

Option B — Biochemistry

7. Starch is a natural polymer of glucose.

(a) Draw the structure of the repeating unit of starch and state the type of linkage formed between these units. [2]



Type of linkage:

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(b) Formulate the equation for the complete hydrolysis of a starch molecule, $(C_6H_{10}O_5)_n$. [1]

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(c) Calculate the energy released, in $kJ\,g^{-1}$, when 3.49 g of starch are completely combusted in a calorimeter, increasing the temperature of 975 g of water from 21.0 °C to 36.0 °C. Use section 1 of the data booklet. [2]

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(Option B continues on the following page)

(Option B, question 7 continued)

(d) Explain how the inclusion of starch in plastics makes them biodegradable. [2]

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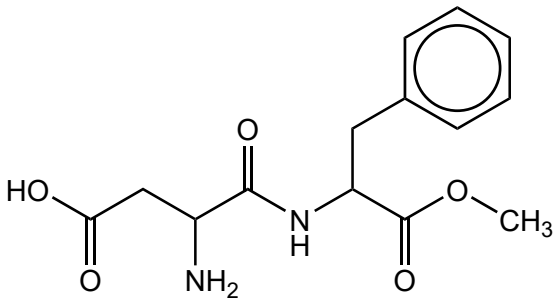
8. Aspartame is a derivative of a dipeptide formed between two amino acids, phenylalanine (Phe) and aspartic acid (Asp).

(a) Draw a circle around the functional group formed between the amino acids and state its name. [2]



Name:

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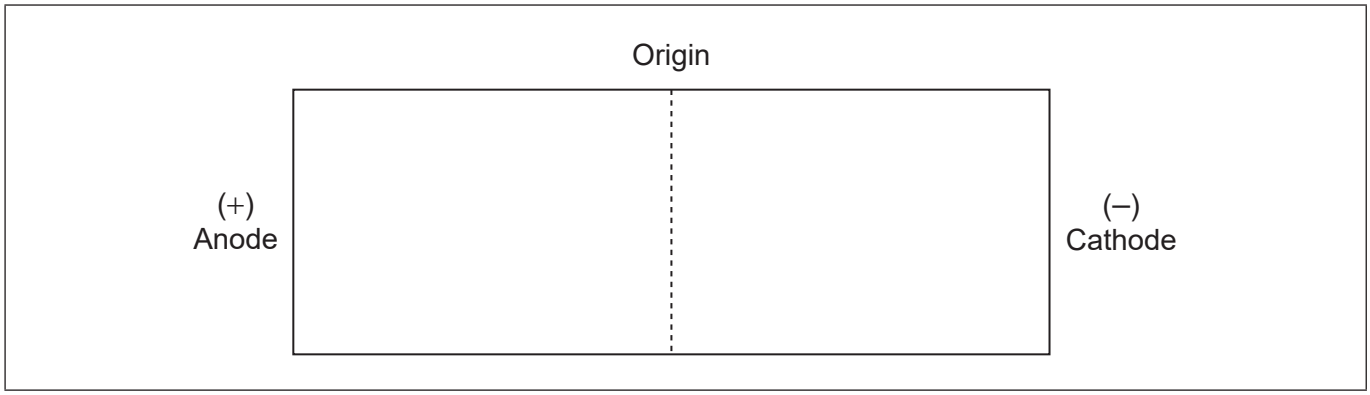
(Option B continues on the following page)

(Option B, question 8 continued)

(b) A mixture of phenylalanine and aspartic acid is separated by gel electrophoresis with a buffer of pH = 5.5.

Deduce their relative positions after electrophoresis, annotating them on the diagram. Use section 33 of the data booklet. [2]



9. The main fatty acid composition of cocoa butter and coconut oil is detailed below.

Source	**Saturated fatty acids / %**						**Mono-unsaturated / %**	**Poly-unsaturated / %**
	Octanoic ($C_8H_{16}O_2$)	Lauric ($C_{12}H_{24}O_2$)	Myristic ($C_{14}H_{28}O_2$)	Palmitic ($C_{16}H_{32}O_2$)	Stearic ($C_{18}H_{36}O_2$)	Others	Oleic ($C_{18}H_{34}O_2$)	Total
Cocoa butter	0.0	0.0	0.1	26.9	35.2	0.0	34.6	3.3
Coconut oil	7.5	46.2	18.4	9.4	2.8	6.8	7.0	1.9

[Source: U.S. Department of Agriculture, Agricultural Research Service. FoodData Central, 2019. fdc.nal.usda.gov.]

(Option B continues on the following page)

(Option B, question 9 continued)

(a) The melting points of cocoa butter and coconut oil are 34 °C and 25 °C respectively.

Explain this in terms of their saturated fatty acid composition. [3]

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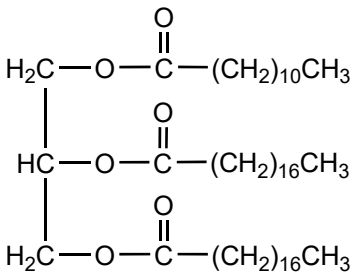
(b) Fats contain triglycerides that are esters of glycerol and fatty acids. Deduce an equation for the acid hydrolysis of the following triglyceride. [2]



(c) The addition of partially hydrogenated cocoa butter to chocolate increases its melting point and the content of *trans*-fatty acids (*trans*-fats).

Outline **two** effects of *trans*-fatty acids on health. [2]

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(Option B continues on the following page)

(Option B continued)

10. Ascorbic acid and retinol are two important vitamins.

Explain why ascorbic acid is soluble in water and retinol is not. Use section 35 of the data booklet. [2]

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End of Option B

Option C — Energy

11. Natural gas is an energy source composed mainly of methane.

(a) Calculate the specific energy of methane, in MJ kg^{-1}, using sections 1, 6 and 13 of the data booklet. [1]

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(b) Natural gas is burned to produce steam which turns turbines in an electricity generating power plant.

The efficiency of several sources for power plants is given below.

Type of power plant	Maximum efficiency
Natural gas	up to 58 %
Coal	up to 47 %
Nuclear	up to 36 %
Hydroelectric	up to 95 %

[Source: Eurelectric]

(i) Calculate the maximum electric energy output, in MJ, which can be obtained from burning 1.00 kg of methane by using your answer from (a). [1]

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(Option C continues on the following page)

(Option C, question 11 continued)

(ii) Hydroelectric power plants produced 16 % of the world's energy in 2015, down from 21 % in 1971.

Suggest why hydroelectric power production has a higher efficiency than the other sources given in (b) and why its relative use has decreased despite the high efficiency. [2]

Reason for higher efficiency:

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Reason for decreased use:

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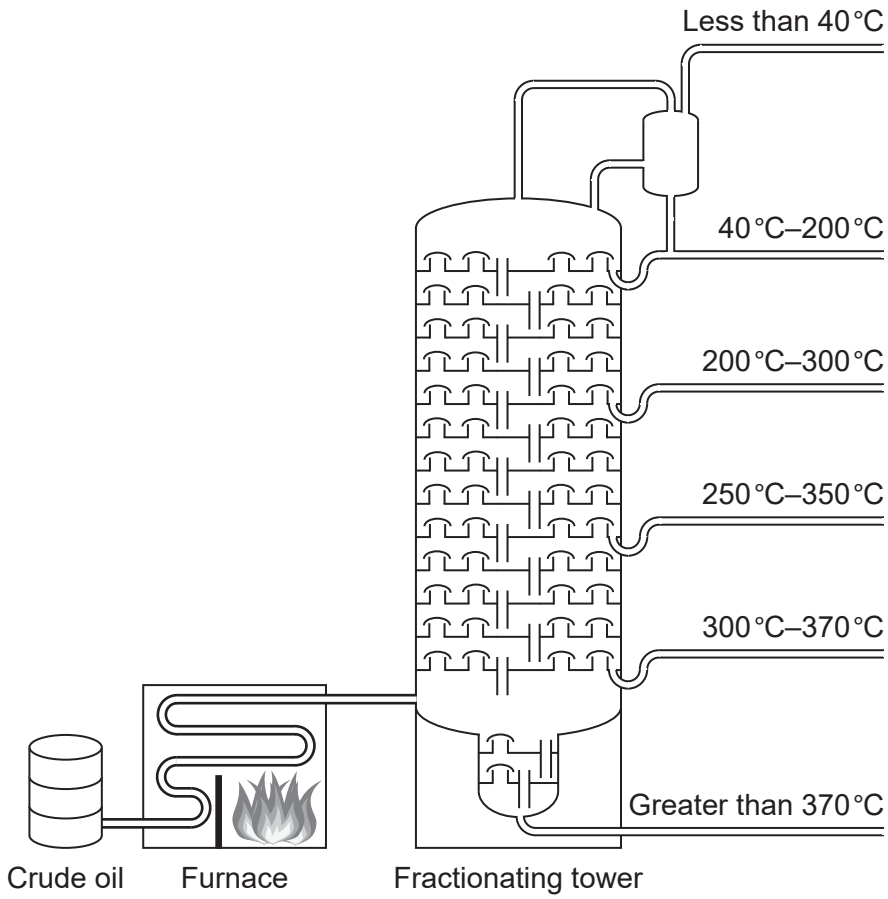
(Option C continues on the following page)

(Option C, question 11 continued)

(c) (i) Methane can also be obtained by fractional distillation of crude oil.



[Source: Image used with kind permission of science-resources.co.uk]

Draw a circle on the diagram to show where the methane fraction is withdrawn. [1]

(ii) List the following products, which are also obtained by fractional distillation, according to **decreasing** volatility: asphalt, diesel, gasoline, lubricating motor oil. [1]

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(Option C continues on the following page)

(Option C, question 11 continued)

(d) (i) Explain how methane absorbs infrared (IR) radiation by referring to its molecular geometry and dipole moment. [3]

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(ii) Compare methane's atmospheric abundance and greenhouse effect to that of carbon dioxide. [1]

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12. Uranium-235, ^{235}U, is bombarded with a neutron causing a fission reaction.

(a) Two products of the fission of ^{235}U are ^{144}Ba and ^{89}Kr.

(i) Write the nuclear equation for this fission reaction. [1]

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(ii) Outline why the reaction releases energy. [1]

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(Option C continues on the following page)

(Option C, question 12 continued)

(b) The critical mass for weapons-grade uranium can be as small as 15 kg. Outline what is meant by critical mass by referring to the equation in (a)(i). [2]

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(c) The daughter product, ^{89}Kr, has a half-life of 3.15 min.

Calculate the time required, in minutes, for the mass of ^{89}Kr to fall to 6.25 % of its initial value. [1]

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(Option C continues on the following page)

(Option C continued)

13. E10 is composed of 10 % ethanol and 90 % normal unleaded fuel.

(a) Ethanol has a Research Octane Number (RON) of 108.6.

Outline how higher octane fuels affect engine performance. [1]

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(b) Show that, for combustion of equal masses of fuel, ethanol ($M_r = 46\,g\,mol^{-1}$) has a lower carbon footprint than octane ($M_r = 114\,g\,mol^{-1}$). [3]

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(c) Biodiesel containing ethanol can be made from renewable resources.

Suggest **one** environmental disadvantage of producing biodiesel from renewable resources. [1]

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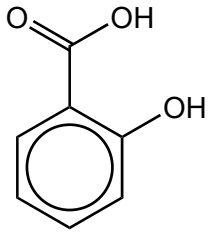
End of Option C

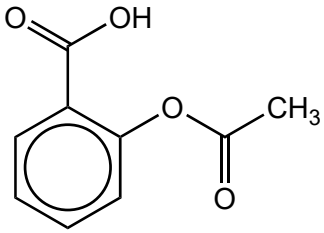
Option D — Medicinal chemistry

14. Aspirin can be obtained from salicylic acid.

Unreacted salicylic acid may be present as an impurity in aspirin and can be detected in the infrared (IR) spectrum.



Salicylic acid



Aspirin

Name the functional group and identify the absorption band that differentiates salicylic acid from aspirin. Use section 26 of the data booklet. [2]

Name:

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Absorption band:

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15. *Staphylococcus aureus* (*S. aureus*) infections have been successfully treated with penicillin and penicillin derivatives.

(a) Identify the feature in penicillin responsible for its antibiotic activity. [1]

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(b) (i) The widespread use of penicillin and its derivatives has led to the appearance of resistant *S. aureus* strains.

Outline how these bacteria inactivate the antibiotics. [1]

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(Option D continues on the following page)

(Option D, question 15 continued)

(ii) Outline how the structure of penicillin has been modified to overcome this resistance. [1]

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16. Mild heartburn is treated with antacids such as calcium carbonate.

(a) (i) Formulate an equation for the neutralization of stomach acid with calcium carbonate, $CaCO_3(s)$. [1]

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(ii) Determine the volume of $CO_2(g)$, in dm^3, produced at STP, when 1.00 g of $CaCO_3(s)$ reacts completely with stomach acid.

$M_r CaCO_3 = 100.09$ [2]

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(b) Acid secretion can be regulated by other types of drugs such as omeprazole and ranitidine. Outline how each of these drugs acts to reduce excess stomach acid. [2]

Omeprazole:

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Ranitidine:

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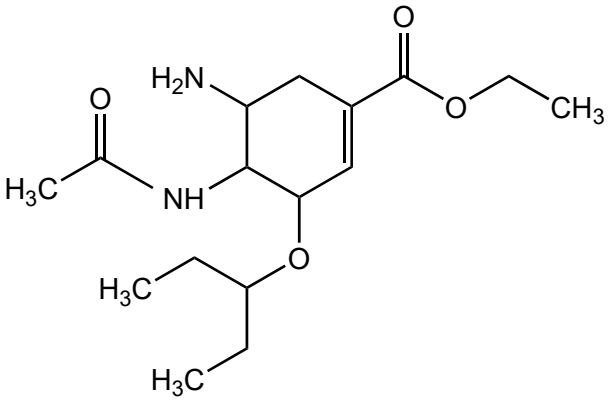
(Option D continues on the following page)

(Option D continued)

17. This question is about antiviral drugs.

(a) Oseltamivir, used for the treatment of severe flu, is inactive until converted in the liver to its active carboxylate form.

(i) Draw a circle around the functional group that can be converted to the carboxylate by hydrolysis. [1]



(ii) Suggest a reason for using a phosphate salt of oseltamivir in oral tablets. [1]

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(b) Anti-HIV drugs, such as zidovudine, often become less effective over time.

Explain the development of resistant virus strains in the presence of antiviral drugs. [2]

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(Option D continues on the following page)

(Option D continued)

18. Opium and its derivatives have been used for thousands of years as strong analgesics.

(a) Explain how opiates act to provide pain relief. [2]

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(b) Discuss how the difference in structure of two opiates, codeine and morphine, affect their ability to cross the blood–brain barrier. Use section 37 of the data booklet. [2]

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19. Most of the nuclear waste generated in a hospital is low-level waste (LLW).

(a) Outline what is meant by low-level waste. [1]

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(b) Outline the disposal of LLW. [1]

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End of Option D

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