Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 3

Thursday 17 May 2018 (morning)

1 hour 15 minutes

Candidate session number

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 – 5
Option B — Biochemistry	6 – 10
Option C — Energy	11 – 15
Option D — Medicinal chemistry	16 – 20

2218 – 6109

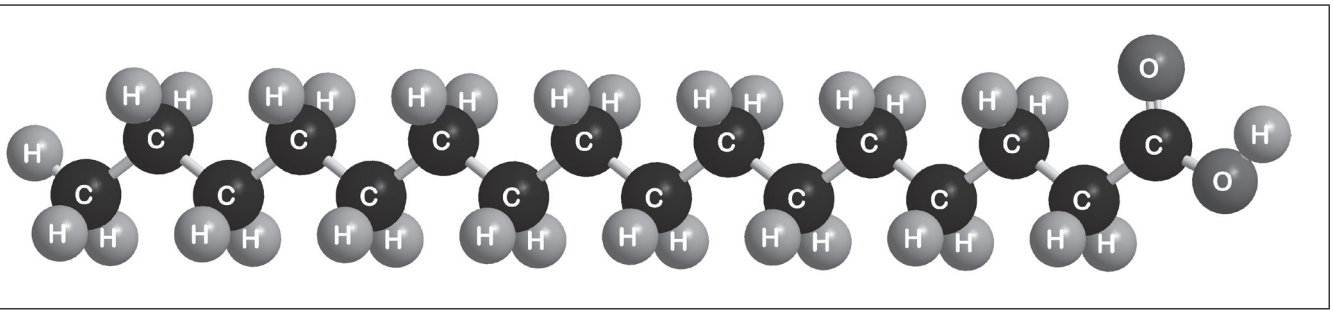
Please **do not** write on this page.

Answers written on this page
will not be marked.

Section A

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

1. Palmitic acid has a molar mass of 256.5 g mol^{-1}.



(a) (i) Part of this molecule is hydrophilic (bonds readily to water) and part hydrophobic (does not bond readily to water). Draw a circle around all of the hydrophilic part of the molecule. [1]

(ii) When a small amount of palmitic acid is placed in water it disperses to form a layer on the surface that is only one molecule thick. Explain, in terms of intermolecular forces, why this occurs. [2]

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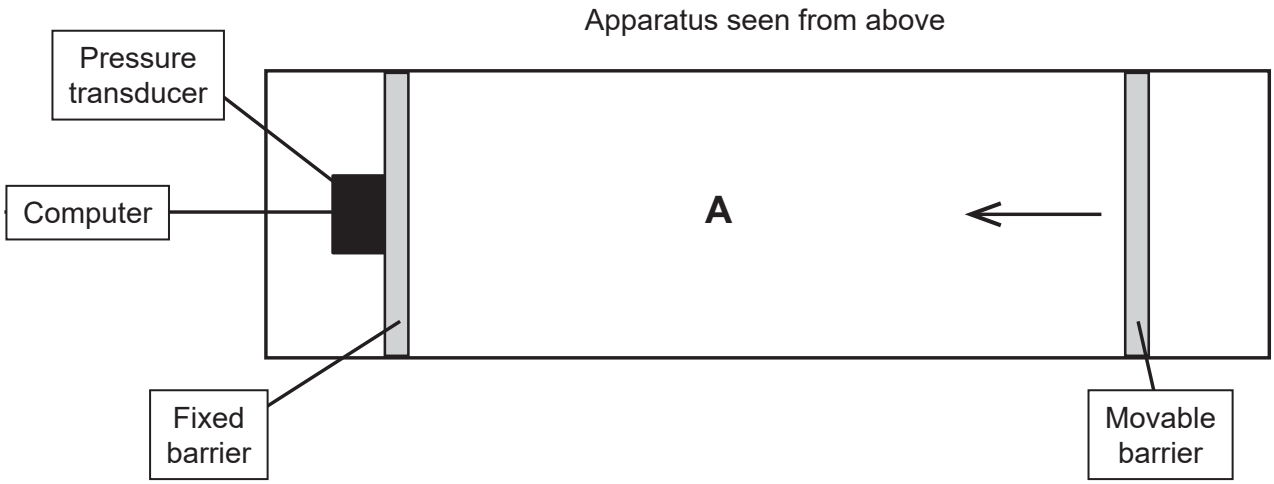
(This question continues on the following page)

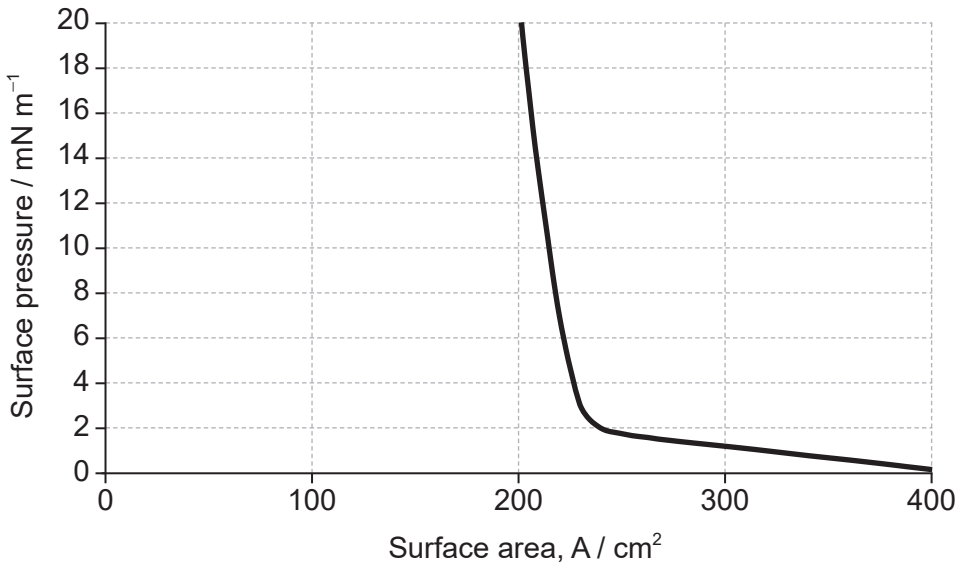
(Question 1 continued)

(b) The apparatus in the diagram measures the surface pressure created by palmitic acid molecules on the surface of water. This pressure is caused by palmitic acid molecules colliding with the fixed barrier. The pressure increases as the area, **A**, available to the palmitic acid is reduced by the movable barrier.



[Source: Physical Chemistry Chemical Physics, 2001, 3, 4774-4783 - Reproduced by permission of The Royal Society of Chemistry]

When a drop of a solution of palmitic acid in a volatile solvent is placed between the barriers, the solvent evaporates leaving a surface layer. The graph of pressure against area was obtained as the area **A** was reduced.



[Source: Influence of Lecithin on Structure and Stability of Parenteral Fat Emulsions, Christoph Wabel, 1998, Figure 34. Used with permission.]

(This question continues on the following page)

(Question 1 continued)

(i) Suggest why there is a small increase in the surface pressure as the area is reduced to about 240 cm^2, but a much faster increase when it is further reduced. [2]

Above about 240 cm^2:

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At less than about 240 cm^2:

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(ii) The solution of palmitic acid had a concentration of 0.0034 mol dm^{-3}. Calculate the number of molecules of palmitic acid present in the 0.050 cm^3 drop, using section 2 of the data booklet. [2]

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(iii) Assuming the sudden change in gradient occurs at 240 cm^2, calculate the area, in cm^2, that a single molecule of palmitic acid occupies on surface of the water.

If you did not obtain an answer for (b)(ii) use a value of 8.2×10^{16}, but this is not the correct answer. [1]

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2. Students were asked to investigate how a change in concentration of hydrochloric acid, HCl, affects the initial rate of its reaction with marble chips, $CaCO_3$.

They decided to measure how long the reaction took to complete when similar chips were added to 50.0 cm^3 of 1.00 mol dm^{-3} acid and 50.0 cm^3 of 2.00 mol dm^{-3} acid.

Two methods were proposed:
(1) using small chips, keeping the acid in excess, and recording the time taken for the solid to disappear
(2) using large chips, keeping the marble in excess, and recording the time taken for bubbles to stop forming.

(a) Annotate the balanced equation below with state symbols. [1]

$$CaCO_3(\_\_) + 2HCl(\_\_) \rightarrow CaCl_2(\_\_) + CO_2(\_\_) + H_2O(\_\_)$$

(b) Neither method actually gives the initial rate. Outline a method that would allow the initial rate to be determined. [1]

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(c) (i) Deduce, giving a reason, which of the two methods would be least affected by the chips not having exactly the same mass when used with the different concentrations of acid. [1]

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(ii) State a factor, that has a significant effect on reaction rate, which could vary between marble chips of exactly the same mass. [1]

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(This question continues on the following page)

(Question 2 continued)

(d) A group recorded the following results with 1.00 mol dm^{-3} hydrochloric acid:

Trial	Time / s ±0.01 s
1	120.56
2	136.83
3	108.49
Mean	121.96

(i) Justify why it is inappropriate to record the uncertainty of the mean as ±0.01 s. [1]

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(ii) If doubling the concentration doubles the reaction rate, suggest the mean time you would expect for the reaction with 2.00 mol dm^{-3} hydrochloric acid. [1]

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(iii) Another student, working alone, always dropped the marble chips into the acid and then picked up the stopwatch to start it. State, giving a reason, whether this introduced a random or systematic error. [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. Aluminium and high density polyethene (HDPE) are both materials readily found in the kitchen, for example as saucepans and mixing bowls respectively. In these applications it is important that they are impermeable to water.

(a) Discuss, in terms of its structure, why an aluminium saucepan is impermeable to water. [2]

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(b) Both materials are also used in other applications that are more demanding of their physical properties. Carbon nanotubes are often incorporated into their structures to improve certain properties.

(i) State the name given to a material composed of two distinct solid phases. [1]

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(ii) State one physical property of HDPE that will be affected by the incorporation of carbon nanotubes. [1]

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(Option A continues on the following page)

(Option A, question 3 continued)

(iii) Describe how carbon nanotubes are produced by chemical vapour deposition (CVD). [3]

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(iv) State the property of carbon nanotubes that enables them to form a nematic liquid crystal phase. [1]

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(Option A continues on the following page)

(Option A continued)

4. Both HDPE (high density polyethene) and LDPE (low density polyethene) are produced by the polymerization of ethene.

(a) (i) Compare and contrast the structures of HDPE and LDPE. [2]

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(ii) State **one** way in which a physical property of HDPE, other than density, differs from that of LDPE as a result of this structural difference. [1]

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(b) (i) The production of HDPE involves the use of homogeneous catalysts. Outline how homogeneous catalysts reduce the activation energy of reactions. [1]

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(ii) Trace amounts of metal from the catalysts used in the production of HDPE sometimes remain in the product. State a technique that could be used to measure the concentration of the metal. [1]

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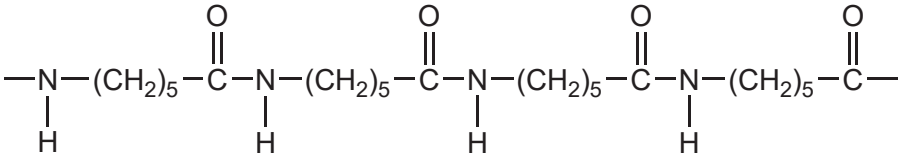
(Option A continues on the following page)

(Option A, question 4 continued)

(c) An alternative method of polymerizing molecules is condensation polymerization. One of the earliest condensation polymers was nylon-6. A short section of the polymer chain of nylon-6 is shown below.



(i) Draw the structure of the monomer from which nylon-6 is produced by a condensation reaction. [2]

(ii) Deduce, giving a reason, whether the atom economy of a condensation polymerization, such as this, would be greater or less than an addition polymerization, such as the formation of HDPE. [1]

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(Option A continues on the following page)

(Option A, question 4 continued)

(d) Suggest **two** of the major obstacles, other than collection and economic factors, which have to be overcome in plastic recycling. [2]

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(e) Suggest why there are so many different ways in which plastics can be classified. HDPE can, for example, be categorized thermoplastic, an addition polymer, having Resin Identification Code (RIC) 2, *etc*. [1]

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5. Aluminium is produced by the electrolysis of a molten electrolyte containing bauxite.

(a) Determine the mass, in g, of aluminium produced by the passage of a charge of 1.296×10^{13} C. Use sections 2 and 6 of the data booklet. [3]

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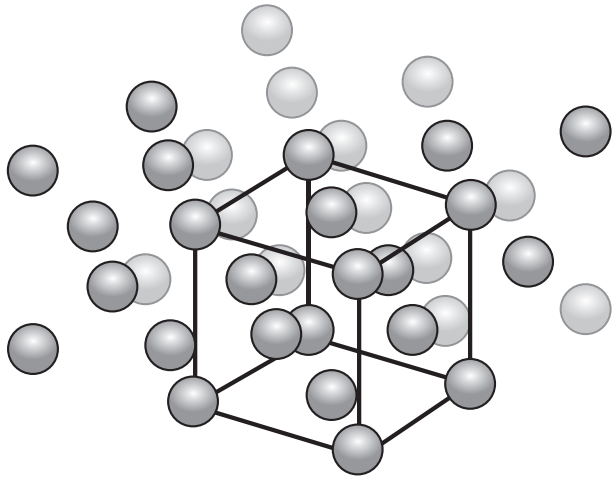
(Option A continues on the following page)

(Option A, question 5 continued)

(b) The diagram illustrates the crystal structure of aluminium metal with the unit cell indicated. Outline the significance of the unit cell. [1]



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(c) When X-rays of wavelength 0.154 nm are directed at a crystal of aluminium, the first order diffraction pattern is observed at 18°. Determine the separation of layers of aluminium atoms in the crystal, in m, using section 1 of the data booklet. [2]

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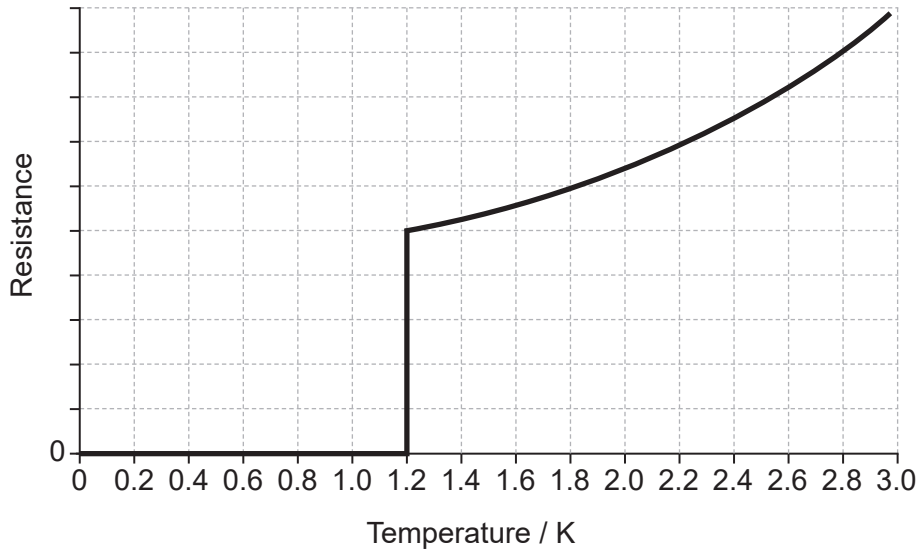
(Option A continues on the following page)

(Option A, question 5 continued)

(d) The graph of the resistance of aluminium with temperature is shown below.



(i) Deduce what the shape of the graph indicates about aluminium. [2]

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(ii) Outline why the resistance of aluminium increases above 1.2 K. [1]

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(e) The concentration of aluminium in drinking water can be reduced by precipitating aluminium hydroxide. Calculate the maximum concentration of aluminium ions in water of pH 7 at 298 K. Solubility product of aluminium hydroxide = 3.3×10^{-34} at 298 K. [2]

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End of Option A

Option B — Biochemistry

6. Insulin was the first protein to be sequenced. It was determined that the end of one chain had the primary structure Phe–Val–Asn–Gln.

(a) Draw the structural formula of a dipeptide containing the residues of valine, Val, and asparagine, Asn, using section 33 of the data booklet. [2]

(b) Deduce the strongest intermolecular forces that would occur between the following amino acid residues in a protein chain. [2]

Phenylalanine and valine:

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Glutamine and asparagine:

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(c) Paper chromatography can be used to identify the amino acids in insulin.

(i) State the name of the process used to break down the insulin protein into its constituent amino acids. [1]

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(Option B continues on the following page)

(Option B, question 6 continued)

(ii) Outline how the amino acids may be identified from a paper chromatogram. [1]

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(d) Describe how DNA determines the primary structure of a protein such as insulin. [2]

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7. Saturated lipids found in butter and unsaturated lipids found in fish oil readily become rancid.

(a) Identify the type of rancidity occurring in saturated lipids and the structural feature that causes it. [2]

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(b) Butter contains varying proportions of oleic, myristic, palmitic and stearic acids. Explain in terms of their structures why stearic acid has a higher melting point than oleic acid, using section 34 of the data booklet. [3]

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(Option B continues on the following page)

(Option B, question 7 continued)

(c) (i) Fish oil is an excellent dietary source of omega-3 fatty acids. Outline **one** impact on health of consuming omega-3 fatty acids. [1]

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(ii) Predict the solubility of retinol (vitamin A) in body fat, giving a reason. Use section 35 of the data booklet. [1]

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(iii) Explain why sharks and swordfish sometimes contain high concentrations of mercury and polychlorinated biphenyls (PCBs). [2]

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(iv) Plastics are another source of marine pollution. Outline one way in which plastics can be made more biodegradable. [1]

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(Option B continues on the following page)

(Option B continued)

8. Polymers of glucose include starch and cellulose.

(a) A person with diabetes suffering very low blood sugar (hypoglycaemia) may be advised to consume glucose immediately and then eat a small amount of starchy food such as a sandwich. Explain this advice in terms of the properties of glucose and starch. [2]

Glucose:

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Starch:

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(b) Outline why cellulose fibres are strong. [2]

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9. An inhibitor reduces the rate, *V*, of an enzyme-catalysed reaction.

(a) Explain with reference to the binding site on the enzyme how a non-competitive inhibitor lowers the value of V_{max}. [2]

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(Option B continues on the following page)

(Option B, question 9 continued)

(b) Outline the significance of the value of the Michaelis constant, K_m. [1]

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10. Anthocyanins are naturally occurring plant pigments. Depending on the solution pH, they can exist as quinoidal bases or flavylium cations as shown in section 35 of the data booklet.

(a) Outline why anthocyanins are coloured. [2]

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(b) Explain why the blue colour of a quinoidal base changes to the red colour of a flavylium cation as pH decreases. [3]

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End of Option B

Option C — Energy

11. Greenhouse gases absorb infrared radiation.

(a) Identify one naturally occurring greenhouse gas, other than carbon dioxide or water vapour, and its natural source. [2]

Gas:

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Source:

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(b) Formulate an equation that shows how aqueous carbon dioxide produces hydrogen ions, $H^+(aq)$. [1]

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(c) The concentrations of oxygen and nitrogen in the atmosphere are much greater than those of greenhouse gases. Outline why these gases do not absorb infrared radiation. [1]

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(Option C continues on the following page)

(Option C continued)

12. The increased concentration of carbon dioxide in the atmosphere is thought to result from the increased combustion of fossil fuels such as petroleum.

(a) Petroleum contains many hydrocarbons. Explain how these are separated by fractional distillation. [3]

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(b) (i) Determine the specific energy and energy density of petrol (gasoline), using data from sections 1 and 13 of the data booklet. Assume petrol is pure octane, C_8H_{18}. Octane: molar mass = 114.26 g mol^{-1}, density = 0.703 g cm^{-3}. [2]

Specific energy in kJ g^{-1}:

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Energy density in kJ cm^{-3}:

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(ii) Outline why the energy available from an engine will be less than these theoretical values. [1]

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(Option C continues on the following page)

(Option C continued)

13. One suggestion for the reduction of carbon footprints is the use of biofuels, such as vegetable oils, as a substitute for petroleum based fuels.

(a) Outline the major technical problem affecting the direct use of vegetable oils as fuels in internal combustion engines and the chemical conversion that has overcome this. [2]

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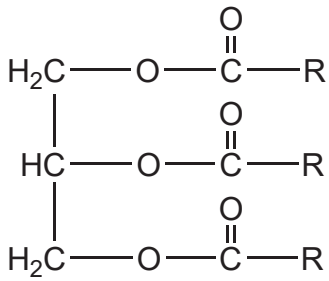
(b) State the formula of a fuel that might be produced from the vegetable oil whose formula is shown. [1]



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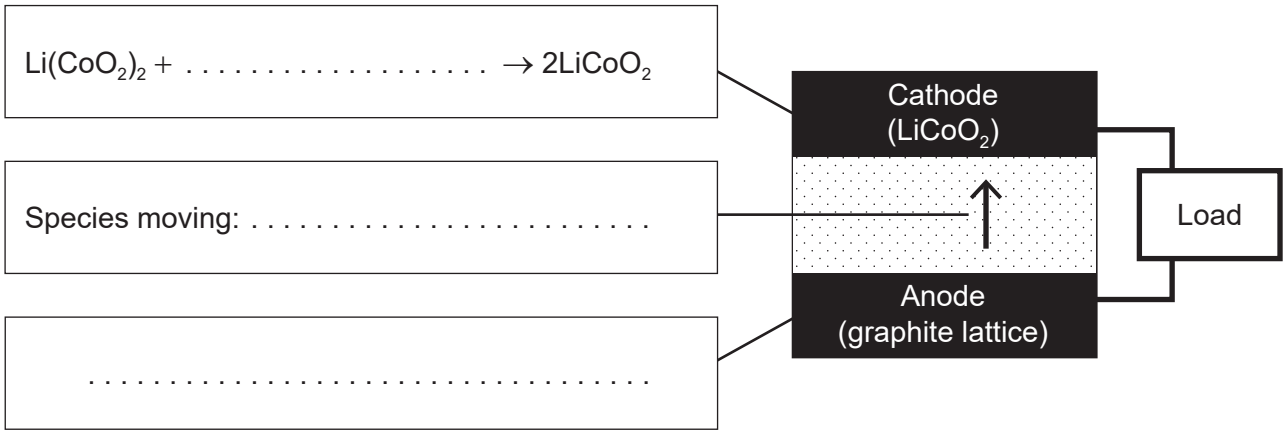
(Option C continues on the following page)

(Option C continued)

14. Modern electric cars store their energy in lithium ion batteries.

(a) The diagram represents a cell in such a battery delivering a current.

(i) Complete the half-equations on the diagram and identify the species moving between the electrodes. [3]



(ii) State the factor that limits the maximum current that can be drawn from this cell and how electrodes are designed to maximize the current. [2]

Limiting factor:

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Electrodes design:

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(Option C continues on the following page)

(Option C, question 14 continued)

(b) The carbon footprint of electric cars depends on how the electricity is produced. Nuclear fission of ^{235}U is one source of electrical energy that has a minimal carbon footprint.

(i) Natural uranium needs to be enriched to increase the proportion of ^{235}U. Suggest a technique that would determine the relative abundances of ^{235}U and ^{238}U. [1]

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(ii) Explain how the proportion of ^{235}U in natural uranium is increased. [3]

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(iii) Explain how ^{235}U fission results in a chain reaction, including the concept of critical mass. [3]

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(Option C continues on the following page)

(Option C, question 14 continued)

(iv) Suggest one reason why there is opposition to the increased use of nuclear fission reactors. [1]

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15. Photovoltaic cells are much less hazardous than nuclear fission.

(a) Early photovoltaic cells were based on silicon containing traces of other elements. State the type of semiconductor produced by doping silicon with indium, In, giving a reason that refers to its electronic structure. [1]

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(b) Dye-sensitized solar cells, DSSCs, use a dye to absorb the sunlight. State **two** advantages that DSSCs have over traditional silicon based photovoltaic cells. [2]

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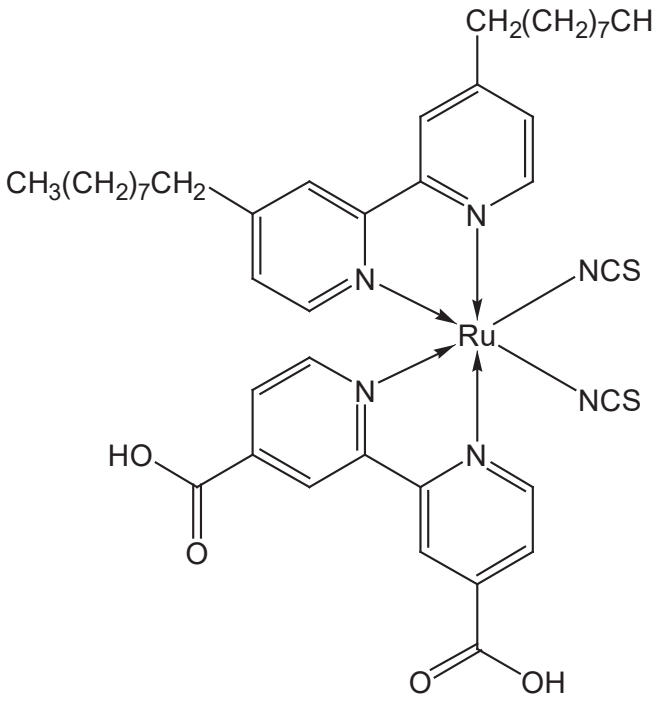
(Option C continues on the following page)

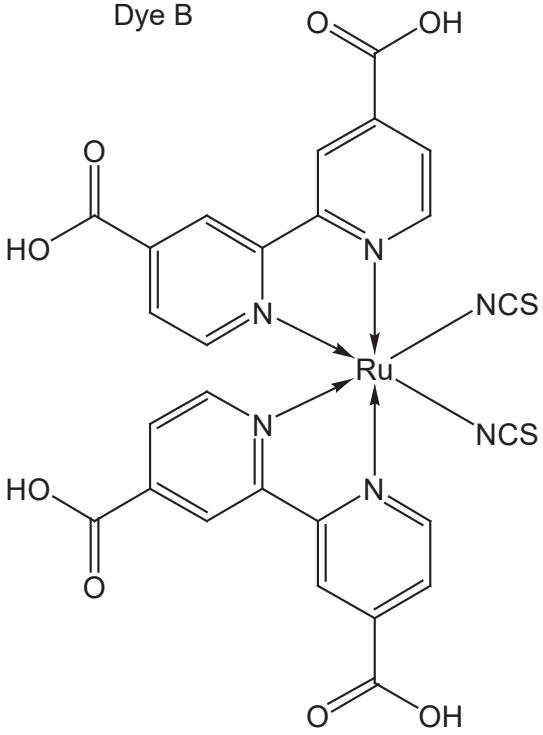
(Option C, question 15 continued)

(c) The structure of two dyes used in DSSCs are shown.

Dye A



Dye B



Predict, giving a reason, which dye will absorb light of longer wavelength. [1]

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End of Option C

Option D — Medicinal chemistry

16. Many drugs, including aspirin, penicillin, codeine and taxol, have been modified from compounds that occur naturally.

(a) Aspirin is often taken to reduce pain, swelling or fever. State one other use of aspirin. [1]

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(b) (i) State what is meant by the bioavailability of a drug. [1]

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(ii) Outline how the bioavailability of aspirin may be increased. [1]

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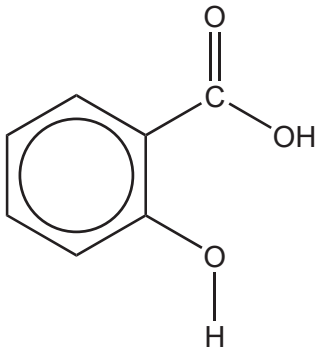
(Option D continues on the following page)

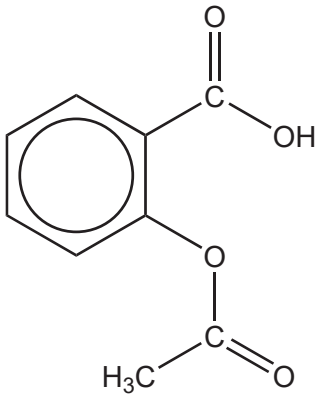
(Option D, question 16 continued)

(c) (i) Compare and contrast the IR spectrum of aspirin with that of salicylic acid, using section 26 of the data booklet. [2]

Structure of salicylic acid



Structure of aspirin



One absorption found in both spectra:

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One absorption found in only one of the spectra:

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(ii) Describe how penicillin combats bacterial infections. [2]

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(Option D continues on the following page)

(Option D, question 16 continued)

(iii) Outline **two** consequences of prescribing antibiotics such as penicillin unnecessarily. [2]

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(iv) State how penicillins may be modified to increase their effectiveness. [1]

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(d) (i) Morphine and codeine are strong analgesics. Outline how strong analgesics function. [1]

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(ii) Suggest one reason why codeine is more widely used than morphine as an analgesic. [1]

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(Option D continues on the following page)

(Option D, question 16 continued)

(e) Many drugs are chiral. Explain how a polarimeter can be used to determine the relative proportion of two enantiomers. [3]

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17. Excess stomach acid can be counteracted by a range of medications.

(a) (i) An antacid tablet contains 680 mg of calcium carbonate, $CaCO_3$, and 80 mg of magnesium carbonate, $MgCO_3$.

State the equation for the reaction of magnesium carbonate with hydrochloric acid. [1]

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(ii) Determine the amount, in mol, of hydrochloric acid neutralized by **one antacid tablet**. [2]

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(Option D continues on the following page)

(Option D, question 17 continued)

(b) Explain how omeprazole (Prilosec) reduces stomach acidity. [2]

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18. Antiviral drugs are a major research focus.

Oseltamivir (Tamiflu) and zanamivir (Relenza) are used against flu viruses. Explain how these drugs function. [2]

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19. Radiotherapy is one type of treatment for cancer.

(a) Describe how ionizing radiation destroys cancer cells. [2]

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(Option D continues on the following page)

(Option D, question 19 continued)

(b) Outline how Targeted Alpha Therapy (TAT) is used for treating cancers that have spread throughout the body. [2]

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20. Organic solvents are commonly used in the pharmaceutical industry.

(a) Hexane and propanone have vapour pressures of 17 kPa and 24 kPa respectively at 20 °C.

Calculate the vapour pressure, in kPa, at 20 °C of a mixture containing 60 % hexane and 40 % propanone by mole fraction, using Raoult's law and assuming the mixture is ideal. [1]

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(b) Explain how hexane and propanone may be separated by fractional distillation. [3]

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End of Option D