Diploma Programme
Programme du diplôme
Programa del Diploma

**Chemistry
Higher level
Paper 3**

Thursday 8 November 2018 (morning)

Candidate session number

1 hour 15 minutes

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

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	2 – 5
Option B — Biochemistry	6 –11
Option C — Energy	12 – 15
Option D — Medicinal chemistry	16 – 23

37 pages

40EP01

International Baccalaureate
Baccalauréat International
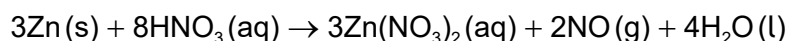Bachillerato Internacional

Section A

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

1.   Alloys containing at least 60 % copper reduce the presence of bacteria on their surface. The percentage of copper in brass, an alloy of copper and zinc, can be determined by UV-vis spectrometry.

A sample of brass is dissolved in concentrated nitric acid and then made up to 250.0 cm^3 with water before analysis.

$$Cu\,(s) + 4HNO_3\,(aq) \rightarrow Cu(NO_3)_2\,(aq) + 2NO_2\,(g) + 2H_2O\,(l)$$

$$3Zn\,(s) + 8HNO_3\,(aq) \rightarrow 3Zn(NO_3)_2\,(aq) + 2NO\,(g) + 4H_2O\,(l)$$
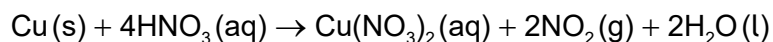
The concentration of copper(II) ions in the resulting solution is then determined from a calibration curve, which is plotted by measuring the light absorbance of standard solutions.

Calibration curve
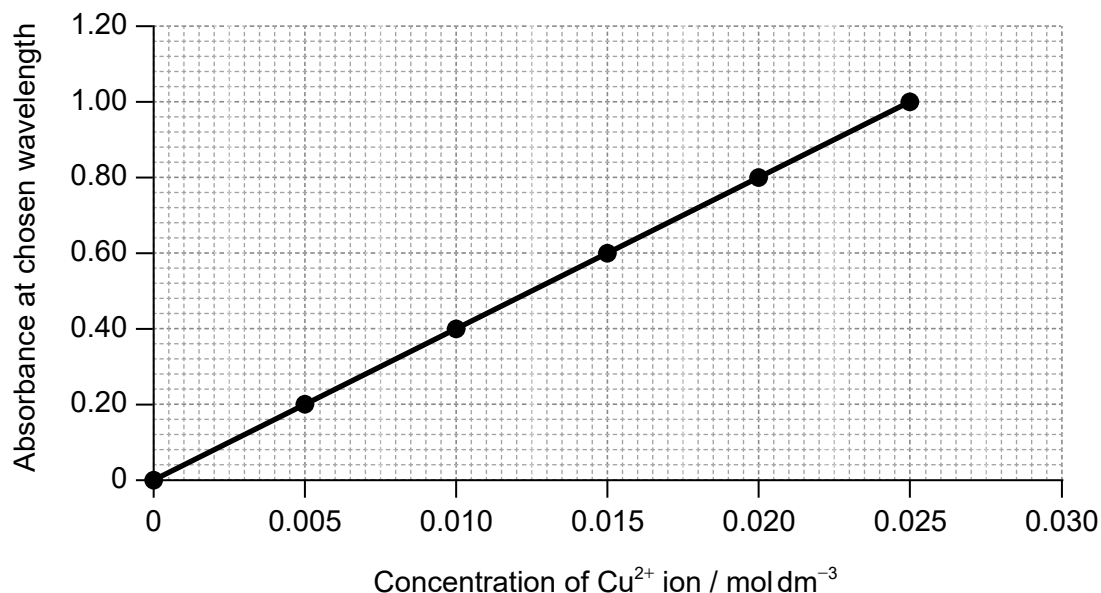
You may find the following chart and diagram helpful.

Colour wheel
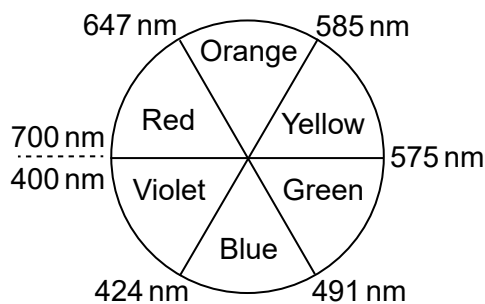
(This question continues on the following page)

(Question 1 continued)

The electromagnetic spectrum

energy

10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4} 10^{6} 10^{8} wavelength (m)

| γ rays | X-rays | UV | | IR | microwaves | radio waves |

V I B G Y O R
400   700
wavelength (nm)
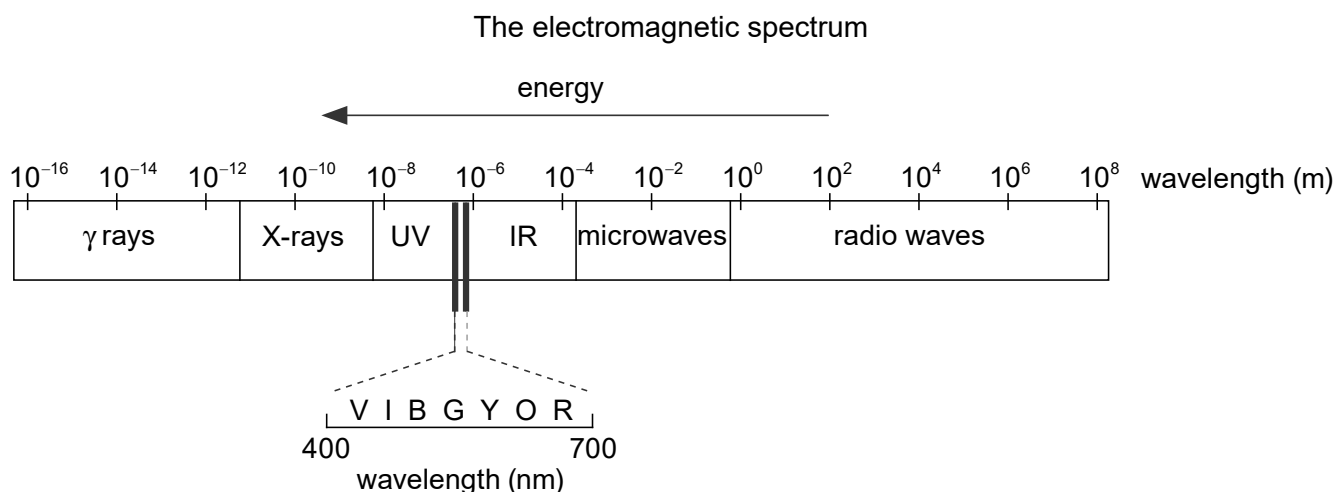
(a)   Outline why the initial reaction should be carried out under a fume hood.   [1]

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(b)   Deduce the equation for the relationship between absorbance and concentration.   [2]

Slope (gradient):

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Equation:

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(This question continues on the following page)

(Question 1 continued)

(c) Copper(II) ion solutions are blue. Suggest, giving your reason, a suitable wavelength of light for the analysis. [2]

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(d) Outline how a solution of $0.0100\,mol\,dm^{-3}$ is obtained from a standard $1.000\,mol\,dm^{-3}$ copper(II) sulfate solution, including **two** essential pieces of glassware you would need. [3]

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(This question continues on the following page)

(Question 1 continued)

(e)   (i)   The original piece of brass weighed 0.200 g. The absorbance was 0.32.

Calculate, showing your working, the percentage of copper by mass in the brass.   [3]

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(ii)   Deduce the appropriate number of significant figures for your answer in (e)(i).   [1]

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(f)   (i)   Comment on the suitability of using brass of this composition for door handles in hospitals.   [1]

If you did not obtain an answer to (e)(i), use 70 % but this is not the correct answer.

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(ii)   Suggest another property of brass that makes it suitable for door handles.   [1]

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(This question continues on the following page)

(Question 1 continued)

(g) Titration is another method for analysing the solution obtained from adding brass to nitric acid.

Copper(II) ions are reduced to copper(I) iodide by the addition of potassium iodide solution, releasing iodine that can be titrated with sodium thiosulfate solution, $Na_2S_2O_3(aq)$. Copper(I) iodide is a white solid.

$$4I^-(aq) + 2Cu^{2+}(aq) \rightarrow 2CuI(s) + I_2(aq)$$

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$
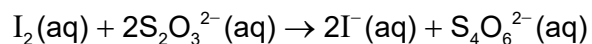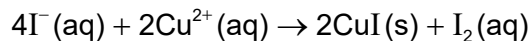
Suggest why the end point of the titration is difficult to determine, even with the addition of starch to turn the remaining free iodine black. [1]

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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.   One way of classifying materials is based on the type of bonding present.

   (a)   Outline why this type of classification is not entirely satisfactory by using magnesium diboride, MgB_2, as an example. Refer to sections 8 and 29 of the data booklet.   [2]

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(Option A continues on the following page)

Turn over

(Option A, question 2 continued)

(b)   Structures of poly(methyl acrylate), PMA, and Bakelite® are shown.

PMA
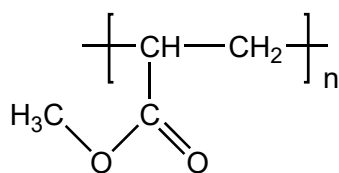
Bakelite®
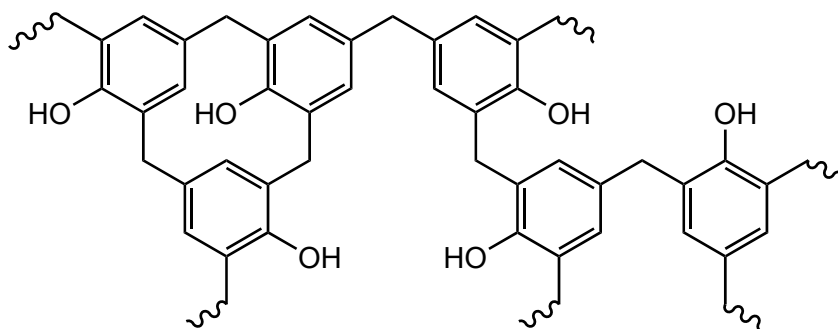
Suggest, giving reasons, which is the thermoplastic polymer and which is the thermosetting polymer.   [2]

Thermoplastic polymer:

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Thermosetting polymer:

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(Option A continues on the following page)

(Option A, question 2 continued)

(c)   One reaction to convert cyclohexanone to caprolactam using concentrated sulfuric acid
      as a catalyst is shown.

Cyclohexanone   Caprolactam
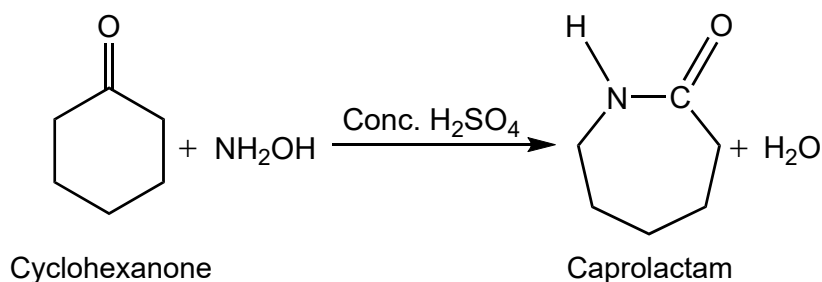
A zeolite is an alternative catalyst for this reaction.
Explain how zeolites act as selective catalysts.   [2]

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(d)   Caprolactam reacts with water to form compound **X**, a monomer.

Caprolactam   **X**
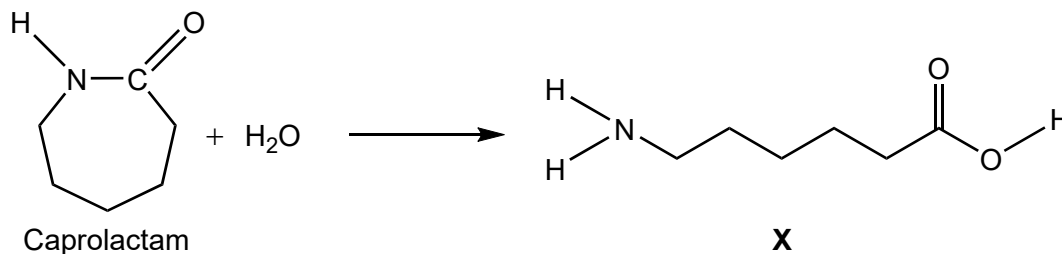
(i)   State the names of the two terminal functional groups in **X**.   [1]

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(Option A continues on the following page)

(Option A, question 2 continued)

      (ii)   Deduce the repeating unit of the polymer of **X**.   [1]

      (iii)   Repeating units of several polymers are listed.
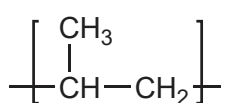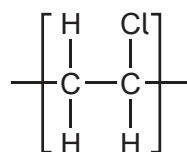
Polypropene (PP)   Polyvinyl chloride (PVC)
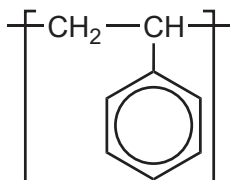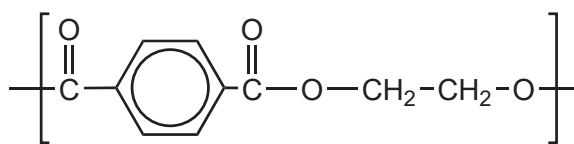
Polystyrene (PS)   Polyethylene terephthalate (PETE)

The infrared (IR) spectrum of one of these polymers is shown.
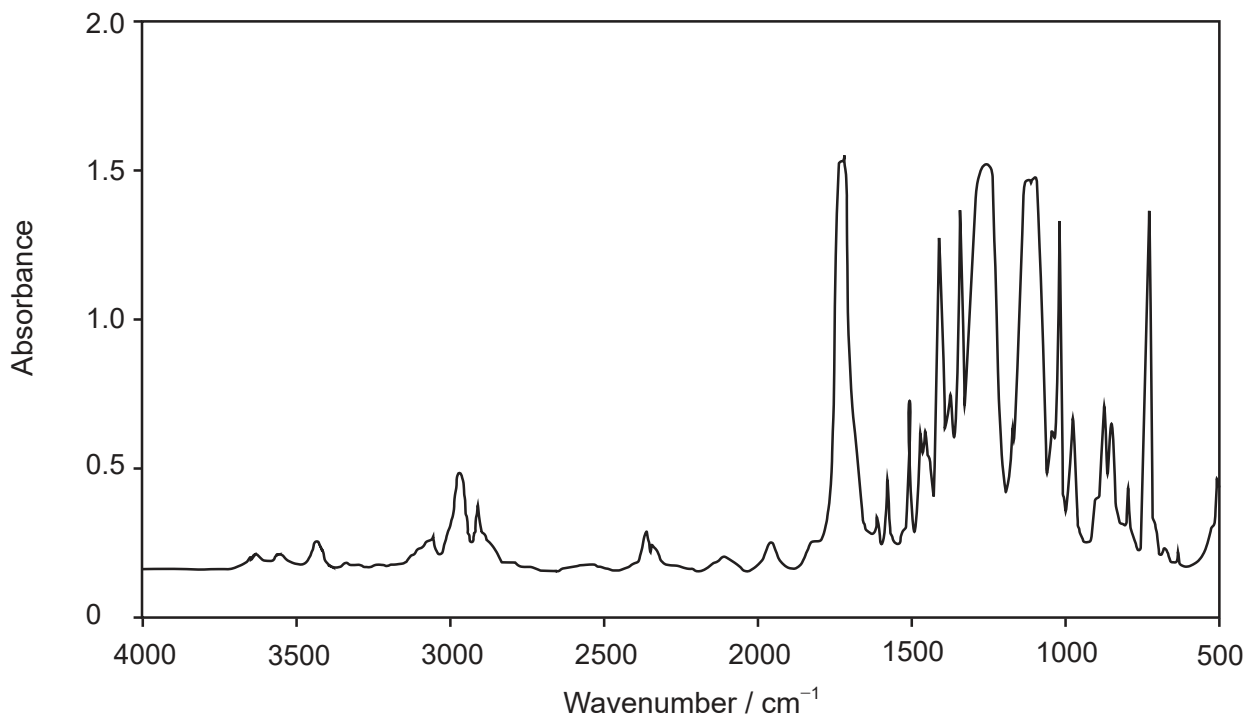
[Source: http://iopscience.iop.org/article/10.1088/1757-899X/5/1/012005 Cristina Bach, Xavier Dauchy and Serge Etienne © 2009 IOP Publishing Ltd IOP Conference Series: Materials Science and Engineering, Volume 5, Number 1]

(Option A continues on the following page)

(Option A, question 2 continued)

Deduce, giving a reason, the name of this polymer and its Resin Identification Code (RIC), using sections 26 and 30 in the data booklet.   [2]

Name and reason:

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RIC:

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3. The presence of very small amounts of lead in calcium-based antacids can be determined using inductively coupled plasma-mass spectroscopy (ICP-MS).

(a) State the type of particle present in the plasma formed.   [1]

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(b) An unknown antacid sample has a lead ion concentration of $0.50\,\mu g\,dm^{-3}$.

(i) Calculate the concentration of lead ions in the sample in $mol\,dm^{-3}$.   [2]

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(Option A continues on the following page)

(Option A, question 3 continued)

(ii)   Lead ions are toxic and can be precipitated using hydroxide ions.

$$Pb^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Pb(OH)_2(s)$$
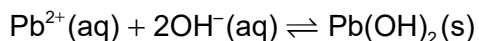
Sufficient sodium hydroxide solid is added to the antacid sample to produce a $1.0 \times 10^{-2}\,mol\,dm^{-3}$ hydroxide ion solution at 298 K.

Deduce if a precipitate will be formed, using section 32 of the data booklet.   [2]

If you did not calculate the concentration of lead ions in (b)(i), use the value of $2.4 \times 10^{-4}\,mol\,dm^{-3}$, but this is not the correct value.

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(c)   Electrolysis is used to obtain lead from $Pb^{2+}(aq)$ solution.

Determine the time, in hours, required to produce 0.0500 mol lead using a current (I) of 1.34 A. Use section 2 of the data booklet and the equation, charge (Q) = current (I) × time (t, in seconds).   [2]

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(Option A continues on the following page)

(Option A, question 3 continued)

(d)   Chelating agents can be used to treat heavy metal poisoning.

   (i)   State **one** feature of a chelating agent.   [1]

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   (ii)   An aqueous lead(II) ion reacts with three ethane-1,2-diamine molecules to form an octahedral chelate ion.

   Outline why the chelate ion is more stable than the reactants.   [1]

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4.   While heating solid cholesteryl benzoate, Reinitzer discovered the liquid crystal phase.

(a)   Outline **two** observations that he could have made.   [2]

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(Option A continues on the following page)

(Option A, question 4 continued)

(b)   The structure of biphenyl nitrile is shown.
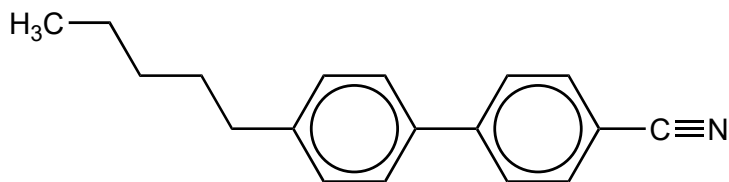
Describe, giving a reason, a feature of the molecular structure, other than its polarity, that allows biphenyl nitrile to show liquid crystal behaviour.   [1]

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(c)   Arc discharge, consisting of two inert metal electrodes in a liquid solvent, is one method of producing carbon nanotubes (CNTs).

Predict, giving a reason, the electrode at which the solvent cyclohexane, C_6H_{12}, will decompose to form CNTs.   [2]

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(Option A continues on the following page)

(Option A continued)

5. A representation of the unit cell of gold is shown.
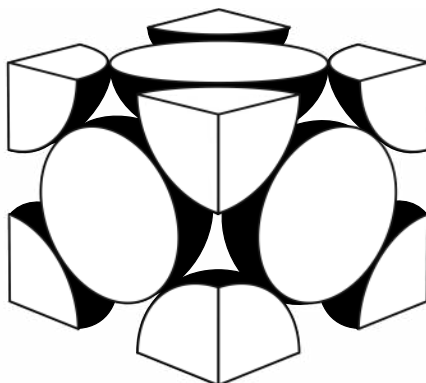
(a) (i) State the name of the crystal structure of gold. [1]

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(ii) Calculate the number of atoms per unit cell of gold, showing your working. [2]

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(Option A continues on the following page)

Turn over

(Option A, question 5 continued)

(b)   The edge length of the gold unit cell is 4.08×10^{-8} cm.

Determine the density of gold in $g\,cm^{-3}$, using sections 2 and 6 of the data booklet.   [3]

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End of Option A

Option B — Biochemistry

6.   Dietary recommendations are made by scientists.

(a)   The formation of proteins from amino acids is an example of an anabolic reaction in the human body.

State the source of energy for such a synthetic reaction.   [1]

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(b)   Suggest why it is advisable for those living in northerly or southerly latitudes (that is away from the equator) to take vitamin D supplements during the winter.   [1]

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(c)   Explain how a xenobiotic is biomagnified.   [2]

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(Option B continues on the following page)

(Option B continued)

7.   Genetic information is stored in DNA.

   (a)   State the feature of DNA that determines the primary structure of proteins synthesised
        by a cell.   [1]

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   (b)   Suggest one concern about the use of genetically modified, GM, food.   [1]

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8.   Enzymes are mainly globular proteins.

   (a)   Describe the interaction responsible for the secondary structure of a protein.   [2]

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(Option B continues on the following page)

(Option B, question 8 continued)

(b) Explain the action of an enzyme and state one of its limitations. [3]

Enzyme action:

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Limitation:

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(c) Contrast the actions of non-competitive and competitive inhibitors of an enzyme and state their effects on the maximum rate of reaction, V_{max}, and the Michaelis–Menten constant, K_m. [4]

	Action of inhibitor	Effect on V_{max}	Effect on K_m
Non-competitive	....	....	....
Competitive	....	....	....

(Option B continues on the following page)

Turn over

(Option B continued)

9. Lipids play several roles in our bodies.

    (a) The iodine number is the maximum mass of iodine that reacts with 100 g of an unsaturated compound.

    Determine the iodine number of stearidonic acid, $C_{17}H_{27}COOH$. [3]

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    (b) State **two** functions of lipids in the body. [2]

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    (c) Outline one effect of increased levels of low-density lipoproteins in the blood. [1]

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(Option B continues on the following page)

(Option B continued)

10. Lactose, found in milk and dairy products, is a disaccharide formed from two different monosaccharides. The structure of lactose is shown with numbered carbon atoms.
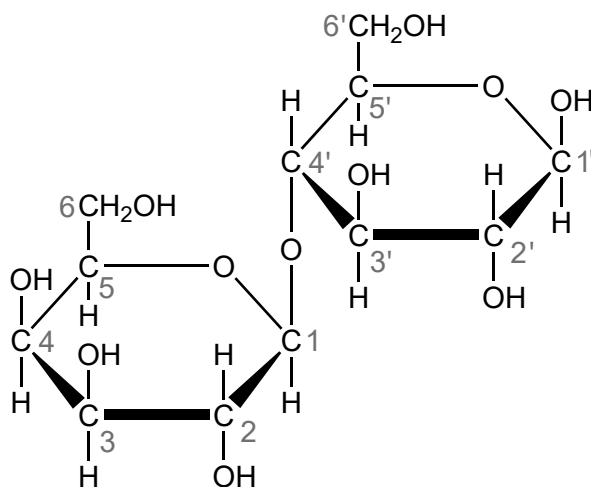
(a)   Name the type of link between the two monosaccharide residues.   [1]

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(b)   Outline how the two monomer structures, galactose and glucose, differ.   [1]

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(c)   Starch and cellulose are both formed from glucose and have similar structures.

(i)   Outline the difference between their structures.   [1]

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(Option B continues on the following page)

Turn over

(Option B, question 10 continued)

(ii)   Outline why cellulose is an essential part of human diet.   [2]

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11.   The transport of oxygen around the body is essential for life.

(a)   A graph showing saturation of oxygen against partial pressure of oxygen is shown.
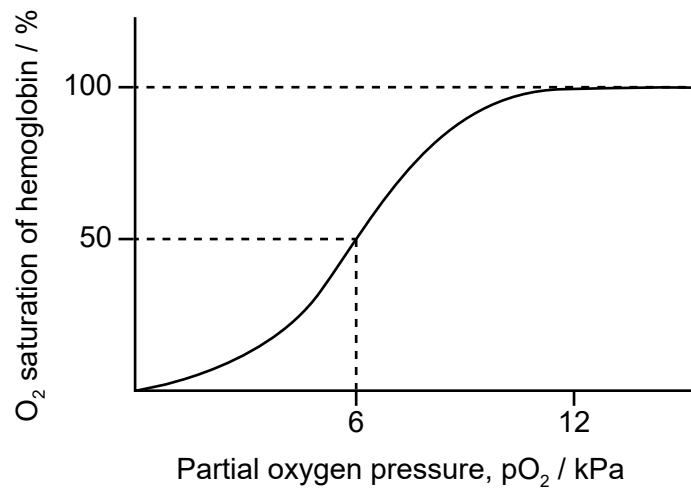
Explain the shape of the graph from 0 to 50 % saturation.   [2]

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(Option B continues on the following page)

40EP22

(Option B, question 11 continued)

(b) Explain why carbon monoxide is very toxic and how it may be possible to treat carbon monoxide poisoning. [2]

Toxicity:

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Treatment:

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End of Option B

40EP23

Option C — Energy

12.   The Sun's energy is produced by the fusion of hydrogen nuclei.

(a)   Explain fusion reactions with reference to binding energy.   [2]

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(b)   Uranium-238 produces plutonium-239, which is used as fuel in breeder reactors.

(i)   Outline why the term breeder is used for the reactors.   [1]

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(ii)   Deduce the fission reaction when ^{239}Pu is bombarded with a neutron to produce ^{133}Xe and ^{103}Zr.   [1]

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(c)   Nuclear disasters release radioactive caesium into the atmosphere, which presents serious health risks.

Cs-137 has a half-life of 30 years.

Calculate the percentage of Cs-137 remaining in the atmosphere after 240 years.   [2]

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(Option C continues on the following page)

40EP24

(Option C, question 12 continued)

     (d)   Nuclear energy produces ionizing radiation which leads to the formation of free radicals.

          (i)   Deduce a Lewis (electron dot) structure of the superoxide, O_2^-, free radical.   [1]

          (ii)   Explain why free radicals are harmful to living cells.   [2]

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13.   Coal can be converted to clean-burning synthetic natural gas.

     (a)   Formulate equation(s) for the conversion of coal and steam to methane.   [1]

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(Option C continues on the following page)

Turn over

(Option C, question 13 continued)

(b)   Automobile companies use hydrogen as an alternative to fossil fuels. Some properties of fuels are shown.

Compound	Molar mass / $g\,mol^{-1}$	Density at STP / $g\,dm^{-3}$	ΔH_c / $kJ\,mol^{-1}$	Energy density at STP / $kJ\,dm^{-3}$	Specific energy / $kJ\,g^{-1}$
Hydrogen	2.02	0.0890	−286	12.6	141.6
Methane	16.05	0.707	−891	39.3	55.5

Comment on the specific energies of hydrogen and methane.   [1]

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(c)   Calculate the mass, in kg, of carbon dioxide produced by the complete combustion of $72.0\,dm^3$ octane, C_8H_{18}.

Density of $C_8H_{18} = 703\,g\,dm^{-3}$

$$C_8H_{18}(l) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$$ [2]

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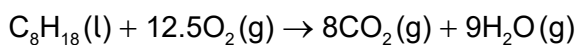
(Option C continues on the following page)

(Option C continued)

14. Solar energy, which is freely available, is indispensable to life on earth.

    (a) Suggest another advantage and one disadvantage of solar energy. [2]

    Advantage:

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    Disadvantage:

    . . . .

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    (b) (i) State a physical property of vegetable oils that makes them very difficult to use as fuel in internal combustion engines. [1]

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    (ii) Describe how vegetable oils can be converted to a more suitable fuel. [1]

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    (c) Contrast the importance of carbon dioxide and methane as greenhouse gases. [2]

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Turn over

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

Answers written on this page
will not be marked.

(Option C, question 14 continued)

(d) Explain, using an equation, the effect of increased carbon dioxide in the atmosphere on the pH of lake water. [2]

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15. Chemical energy from redox reactions can be used as a source of electrical energy.

(a) Outline how a rechargeable battery differs from a primary cell. [1]

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(b) Formulate half-equations for the reactions at the anode (negative electrode) and cathode (positive electrode) during discharge of a lithium-ion battery. [2]

Anode (negative electrode):

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....

Cathode (positive electrode):

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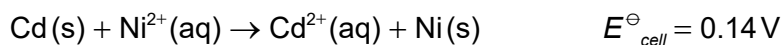...

(Option C continues on the following page)

(Option C, question 15 continued)

(c)   A voltaic cell consists of a nickel electrode in $1.0\,mol\,dm^{-3}$ $Ni^{2+}(aq)$ solution and a cadmium electrode in a $Cd^{2+}(aq)$ solution of unknown concentration.

$$Cd\,(s) + Ni^{2+}(aq) \rightarrow Cd^{2+}(aq) + Ni\,(s) \qquad E^{\ominus}{}_{cell} = 0.14\,V$$

Determine the concentration of the $Cd^{2+}(aq)$ solution if the cell voltage, *E,* is $0.19\,V$ at $298\,K$. Use section 1 of the data booklet.   [2]

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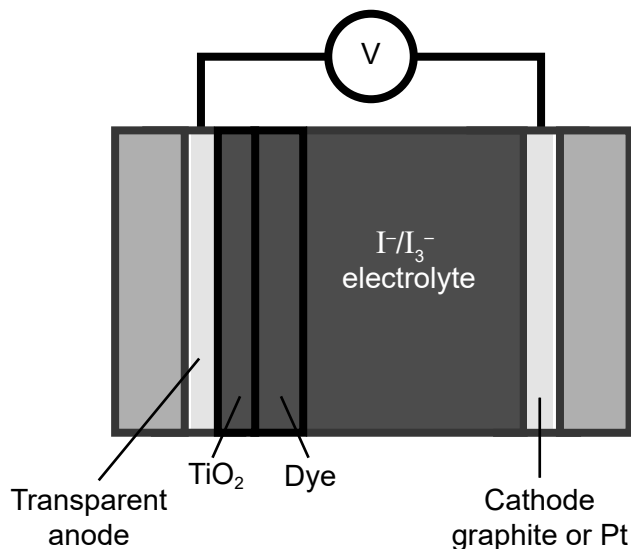
(d)   The chemical structure of a photosensitive dye found in blueberries and a schematic diagram of a solar cell are shown.

Cyanidin in blueberries

I⁻/I₃⁻ electrolyte

Transparent anode TiO_2 Dye   Cathode graphite or Pt
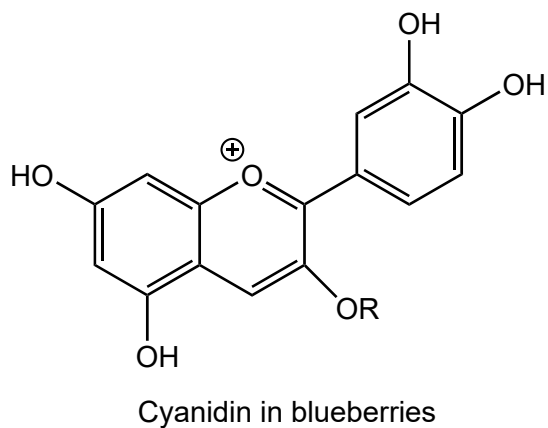
(i)   Identify the structural feature of the dye that allows the conversion of solar energy into electrical energy.   [1]

. . . .

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(Option C continues on the following page)

(Option C, question 15 continued)

    (ii)   Outline the effect of sunlight on the dye in the solar cell. [1]

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    (iii)   State the purpose of TiO_2. [1]

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    (iv)   Deduce the reduction half-equation at the cathode. [1]

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End of Option C

Turn over

Option D — Medicinal chemistry

16. The structure of penicillin is shown in section 37 of the data booklet.

    (a) State the internal bond angles in the β-lactam ring and the expected bond angles in sp^2 and sp^3 hybridised atoms.   [2]

	Bond angle
β-lactam ring	. . . .
sp^2	. . . .
sp^3	. . . .

    (b) Explain how the open β-lactam ring kills bacteria.   [2]

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    (c) State how the structure of penicillin can be modified to combat the effect of resistance caused by over prescription.   [1]

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    (d) Suggest why human cells are not affected by penicillin.   [1]

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(Option D continues on the following page)

(Option D continued)

17. Opiates are strong analgesics.

(a) Explain why diamorphine (heroin) crosses the blood–brain barrier more easily than morphine.   [2]

(b) Outline the meaning of the bioavailability of a drug.   [1]

18. Buffer systems control pH in the body.

(a) Determine the pH of a buffer solution that is $0.0100 \, mol \, dm^{-3}$ sodium hydrogen carbonate and $0.0200 \, mol \, dm^{-3}$ sodium carbonate, using section 1 of the data booklet.

K_a (hydrogen carbonate ion) $= 4.8 \times 10^{-11}$ [2]

(Option D continues on the following page)

(Option D, question 18 continued)

(b) State the equation for the reaction of calcium carbonate, the active ingredient in some antacids, with stomach acid. [1]

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(c) Suggest a technique for measuring the percentage mass of calcium carbonate in this type of antacid tablet. [1]

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19. Viruses and bacteria both cause diseases and are frequently confused.

Outline **two** different ways in which antiviral medications work. [2]

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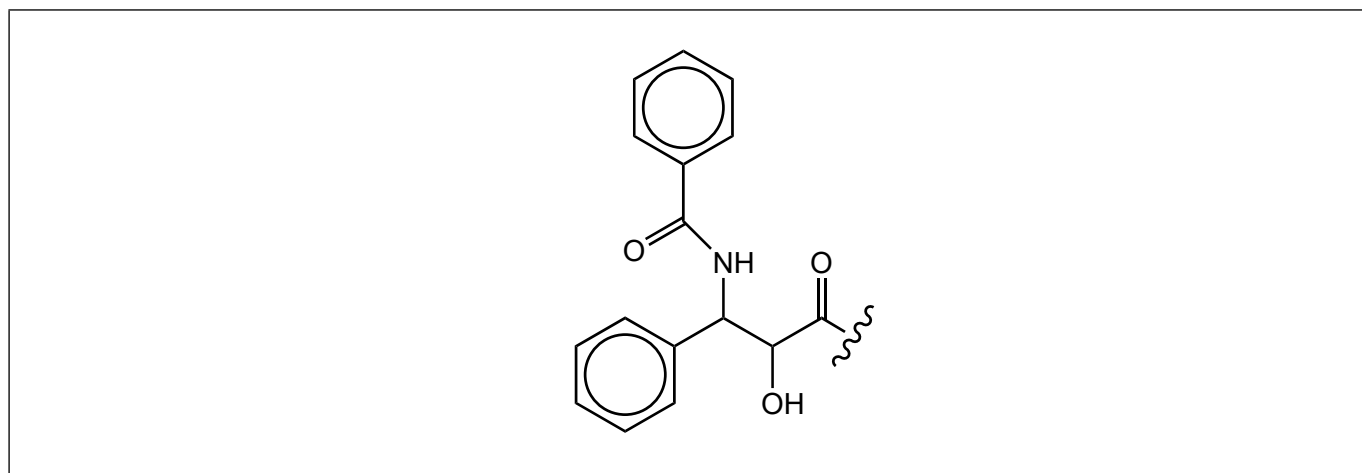**(Option D continues on the following page)**

(Option D continued)

20. Suggest **two** reasons why chlorinated solvents should neither be released into the atmosphere nor incinerated (burnt). [2]

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21. Taxol is a chiral cancer drug which is synthesized using a chiral auxiliary.

(a) The diagram shows part of a Taxol molecule in skeletal form.

Draw a circle around each chiral carbon. [1]

(b) Outline how chiral auxiliaries are used to synthesize the desired enantiomer. [2]

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(Option D continues on the following page)

(Option D, question 21 continued)

(c)   Explain the process of solvent extraction by which Taxol is isolated.   [2]

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22.   Nuclear isotopes are used in the treatment of cancer.

(a)   Alpha particles are more damaging to human cells than any other nuclear radiation and yet they are used in targeted alpha therapy (TAT).

Explain how TAT is relatively safe to use in the treatment of dispersed cancers.   [2]

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(b)   Gamma radiation is also used in radiotherapy.

(i)   Technetium-99m ($^{99m}_{43}$Tc) has a half-life of 6.0 hours. Calculate the percentage of $^{99m}_{43}$Tc remaining in a sample of the radioisotope after two days.   [2]

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(Option D continues on the following page)

(Option D, question 22 continued)

       (ii)   Suggest why the percentage of technetium-99m remaining in the human body
              two days after injection will be lower than that calculated in (b)(i).   [1]

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23.   Scientists have developed various analytical techniques.

    (a)   State an analytical technique used to separate anabolic steroids from other compounds
          in an athlete's urine or blood.   [1]

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    (b)   Ethanol in breath can be detected by a redox reaction. Outline this method of
          detection. An equation is not required.   [2]

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End of Option D

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