Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 3

Tuesday 15 November 2016 (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 – 2

Section B	Questions
Answer all of the questions from one of the options.	
Option A — Materials	3 – 10
Option B — Biochemistry	11 – 16
Option C — Energy	17 – 22
Option D — Medicinal chemistry	23 – 29

8816 – 6103

Section A

Answer **all** questions. Write your answers in the boxes provided.

1. In order to provide safe drinking water, a water supply is often treated with disinfectants, which aim to inactivate disease-causing bacteria in the water.

To compare the effectiveness of different disinfectants, a **CT value** is used as a measure of the dosage of disinfectant needed to achieve a certain level of inactivation of specific bacteria.

CT value ($mg\,min\,dm^{-3}$) = C ($mg\,dm^{-3}$) concentration of disinfectant × T (min) contact time with water

(a) The table below compares the CT values of different disinfectants necessary to achieve 99 % inactivation of two types of bacteria, listed as **A** and **B**.

Disinfectant	**CT value / $mg\,min\,dm^{-3}$ for 99 % inactivation of bacteria**	
	Bacterium A	**Bacterium B**
Hypochlorous acid, HOCl	4×10^{-2}	8×10^{-2}
Hypochlorite ion, OCl^-	9.2×10^{-1}	3.3
Chlorine dioxide, ClO_2	1.8×10^{-1}	1.3×10^{-1}
Monochloramine, NH_2Cl	64	94

(i) Deduce the oxidation state of chlorine in the following disinfectants. [1]

HOCl:

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ClO_2:

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(This question continues on the following page)

(Question 1 continued)

(ii) From the data on CT values, justify the statement that bacterium **B** is generally more resistant to disinfection than bacterium **A**. [1]

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(iii) CT values can be used to determine whether a particular treatment process is adequate. Calculate the CT value, in $mg\,min\,dm^{-3}$, when $1.50 \times 10^{-5}\,g\,dm^{-3}$ of chlorine dioxide is added to a water supply with a contact time of 9.82 minutes. [1]

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(iv) From your answer to (a) (iii) and the data in the table, comment on whether this treatment will be sufficient to inactivate 99 % of bacteria **A**. [1]

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(This question continues on the following page)

(Question 1 continued)

(b) CT values are influenced by temperature and by pH. The table below shows the CT values for chlorine needed to achieve 99 % inactivation of a specific bacterium at stated values of pH and temperature.

pH	Temperature / °C				
	0.5	**5.0**	**10.0**	**15.0**	**20.0**
6.0	97	69	52	35	26
7.0	137	97	73	49	37
8.0	197	140	105	70	53
9.0	281	201	151	101	75

(i) With reference to the temperature data in the table, suggest why it may be more difficult to treat water effectively with chlorine in cold climates. [1]

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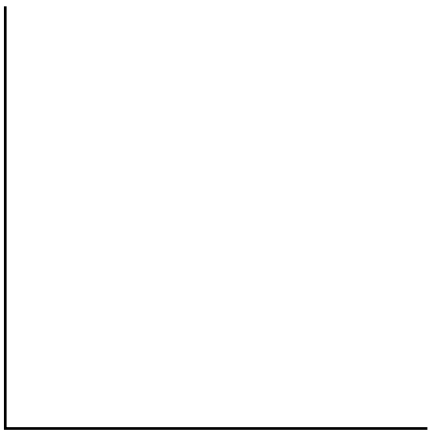
(ii) Sketch a graph on the axes below to show how the CT value (at any temperature) varies with pH. [1]



(This question continues on the following page)

(Question 1 continued)

(iii) Comment on the relative CT values at pH 6.0 and pH 9.0 at each temperature. [1]

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(iv) Chlorine reacts with water as follows:

$$Cl_2(g) + H_2O(l) \rightleftharpoons HOCl(aq) + HCl(aq)$$

$$HOCl(aq) \rightleftharpoons OCl^-(aq) + H^+(aq)$$

Predict how the concentrations of each of the species $HOCl(aq)$ and $OCl^-(aq)$ will change if the pH of the disinfected water increases. [1]

$HOCl(aq)$:

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$OCl^-(aq)$:

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(c) Despite widespread improvements in the provision of safe drinking water, the sale of bottled water has increased dramatically in recent years. State **one** problem caused by this trend. [1]

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2. In a class experiment, students were asked to determine the value of **x** in the formula of a hydrated salt, $BaCl_2 \cdot \mathbf{x}H_2O$. They followed these instructions:

1. Measure the mass of an empty crucible and lid.
2. Add approximately 2 g sample of hydrated barium chloride to the crucible and record the mass.
3. Heat the crucible using a Bunsen burner for five minutes, holding the lid at an angle so gas can escape.
4. After cooling, reweigh the crucible, lid and contents.
5. Repeat steps 3 and 4.

Their results in three trials were as follows:

	Trial 1	**Trial 2**	**Trial 3**
Mass of crucible + lid / g ±0.001	20.088	20.122	20.105
Mass of crucible + lid + $BaCl_2 \cdot \mathbf{x}H_2O$ before heating / g ±0.001	22.166	22.184	22.186
Mass of crucible + lid + $BaCl_2$ after 1st heating / g ±0.001	21.859	22.080	21.926
Mass of crucible + lid + $BaCl_2$ after 2nd heating / g ±0.001	21.859	21.865	21.927

(a) State and explain the further work students need to carry out in trial 2 before they can process the results alongside trial 1. [2]

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(b) In trial 3, the students noticed that after heating, the crucible had turned black on the outside. Suggest what may have caused this, and how this might affect the calculated value for **x** in the hydrated salt. [2]

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(This question continues on the following page)

(Question 2 continued)

(c) List **two** assumptions made in this experiment. [2]

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Section B

Answer **all** of the questions from **one** of the options.

Option A — Materials

3. Materials science involves understanding the properties of materials and applying those properties to desired structures.

(a) Magnesium oxide, MgO, and silicon carbide, SiC, are examples of ceramic materials. State the name of the predominant type of bonding in each material. [1]

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(b) Predict the predominant type of bonding for a binary compound AB in which the electronegativity of both atoms is low. Use section 29 of the data booklet. [1]

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4. A student wanted to determine the formula of indium sulfate. She applied an electrical current of 0.300 A to an aqueous solution of indium sulfate for 9.00×10^3 s and found that 1.07 g of indium metal deposited on the cathode.

(a) Calculate the charge, in coulombs, passed during the electrolysis. [1]

$$\left(\text{current } I = \frac{\text{charge } Q}{\text{time } t}\right)$$

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(Option A continues on the following page)

(Option A, question 4 continued)

(b) Calculate the amount, in mol, of electrons passed using section 2 of the data booklet. [1]

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(c) Calculate the mass of indium deposited by one mole of electrons. [1]

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(d) Calculate the number of moles of electrons required to deposit one mole of indium.
Relative atomic mass of indium, $A_r = 114.82$. [1]

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(e) Deduce the charge on the indium ion and the formula of indium sulfate. [1]

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(Option A continues on the following page)

(Option A continued)

5. Research has led to the discovery of new catalysts that are in high demand and used in many chemical industries.

(a) Explain, with reference to their structure, the great selectivity of zeolites as catalysts. [2]

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(b) Nanocatalysts play an essential role in the manufacture of industrial chemicals.

(i) Describe the high pressure carbon monoxide (HIPCO) method for the production of carbon nanotubes. [2]

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(ii) Outline one benefit of using nanocatalysts compared to traditional catalysts in industry. [1]

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(Option A continues on the following page)

(Option A continued)

6. Polymers are made up of repeating monomer units which can be manipulated in various ways to give structures with desired properties.

(a) Deduce the repeating unit of poly(2-methylpropene). [1]

(b) Deduce the percentage atom economy for polymerization of 2-methylpropene. [1]

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(c) (i) Suggest why incomplete combustion of plastic, such as polyvinyl chloride, is common in industrial and house fires. [1]

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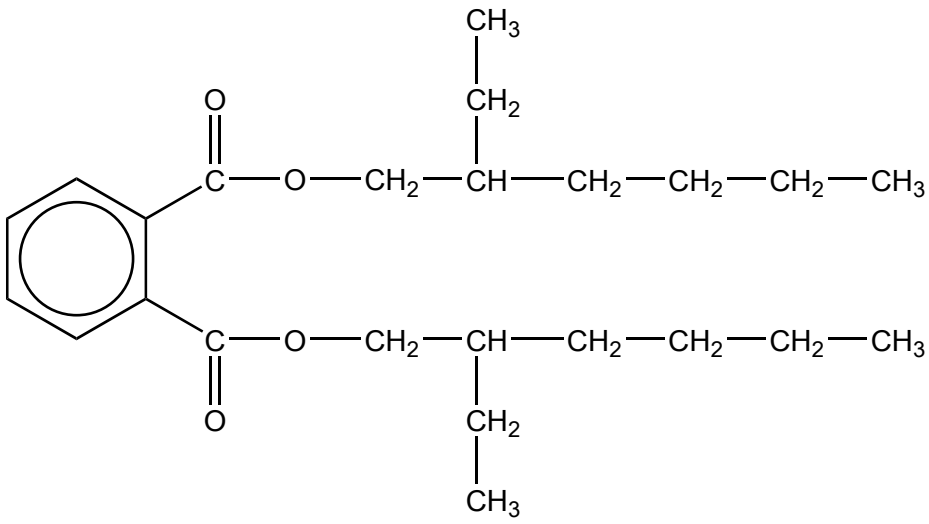
(Option A continues on the following page)

(Option A, question 6 continued)

(ii) Phthalate plasticizers such as DEHP, shown below, are frequently used in polyvinyl chloride.



With reference to bonding, suggest a reason why many adults have measurable levels of phthalates in their bodies. [1]

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(d) Fermentation of sugars from corn starch produces propane-1,3-diol, which can be polymerized with benzene-1,4-dicarboxylic acid to produce the PTT polymer (polytrimethylene terephthalate).

(i) Draw the molecular structure of each monomer. [1]

(Option A continues on the following page)

(Option A, question 6 continued)

(ii) Deduce the name of the linkage formed on polymerization between the two monomers and the name of the inorganic product. [1]

Name of linkage:

. . . . . .

Name of inorganic product:

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7. Liquid crystals have many applications.

Outline how a lyotropic liquid crystal differs from a thermotropic liquid crystal. [2]

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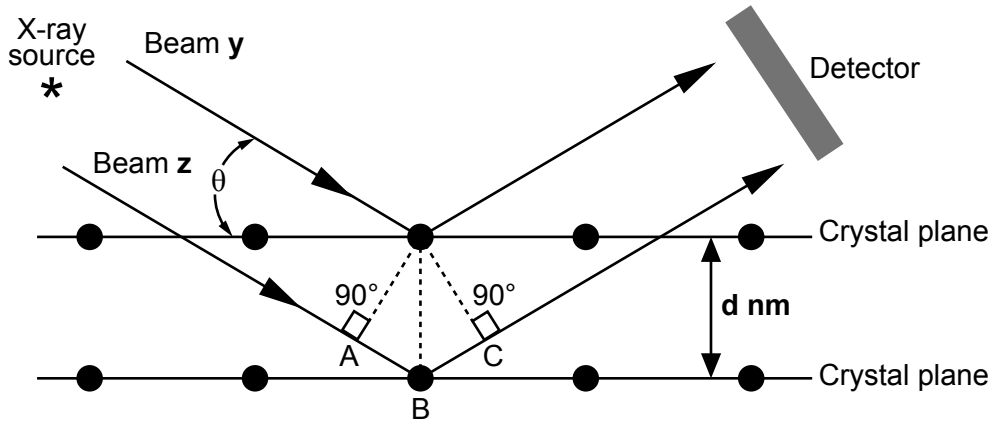
(Option A continues on the following page)

(Option A continued)

8. Chromium forms coloured compounds and is used to make stainless and hard steel. The distance between layers of chromium atoms in the metal can be obtained using X-ray crystallography.

(a) (i) The diagram below shows the diffraction of two X-ray beams, **y** and **z** of wavelength λ, shining on a chromium crystal whose planes are a distance **d** nm apart.



Deduce the extra distance travelled by the second beam, **z**, compared to the first one, **y**. [1]

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(ii) State the Bragg's condition for the observed diffraction to be at its strongest (constructive interference). [1]

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(Option A continues on the following page)

(Option A, question 8 continued)

(b) (i) The mass of one unit cell of chromium metal is 17.28×10^{-23} g. Calculate the number of unit cells in one mole of chromium. $A_r(\text{Cr}) = 52.00$. [1]

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(ii) Deduce the number of atoms of chromium per unit cell. [1]

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9. Superconductors are materials that conduct electric current with practically zero resistance.

(a) Describe the Meissner effect. [1]

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(b) Outline one difference between type 1 and type 2 superconductors. [1]

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(Option A continues on the following page)

(Option A continued)

10. The Fenton and Haber–Weiss reactions convert organic matter in waste water to carbon dioxide and water.

(a) Compare and contrast the Fenton and Haber–Weiss reaction mechanisms. [2]

One similarity:

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One difference:

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(b) Adsorption and chelation are two methods of removing heavy metal ion pollution from the environment.

(i) Describe the process of adsorption. [1]

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(ii) Deduce the structure of the complex ion formed by the reaction of three $H_2N{-}CH_2{-}CH_2{-}NH_2$ chelating molecules with a mercury(II) ion. [1]

End of Option A

Option B — Biochemistry

11. Lipids are an important part of the human diet.

(a) Fatty acids react with glycerol to form fats and oils. State the name of the chemical link formed in this reaction and the name of the other product. [1]

Name of the chemical link:

. . . . . .

Name of the other product:

. . . . . .

(b) The table below shows average figures for the percentage fatty acid composition of some common fats and oils.

Source of fat or oil	% saturated fatty acids (total)	% monounsaturated fatty acid oleic	% polyunsaturated fatty acids	
			linoleic	linolenic
Beef fat	59	38	3	-
Coconut oil	90	8	2	-
Corn oil	25	26	47	2
Cotton seed oil	22	35	43	-
Olive oil	15	78	7	-
Soybean oil	14	28	50	8

(i) Deduce, with a reason, which fat or oil from the table above has the lowest iodine number. [1]

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(ii) Deduce, with a reason, which fat or oil from the table above is most likely to become rancid when exposed to the air. [1]

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(Option B continues on the following page)

(Option B, question 11 continued)

(iii) The **P/S index** of a fat or oil is the ratio of polyunsaturated fat to saturated fat present. It is sometimes used to compare the relative health benefits of different lipids in the diet. Calculate the P/S index of beef fat and soybean oil. [1]

Beef fat:

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Soybean oil:

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(iv) Suggest why a P/S index of greater than 1 is considered beneficial to health. [1]

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(v) Cotton seed oil and corn oil have similar iodine numbers but the melting point of cotton seed oil is higher than that of corn oil. Suggest an explanation in terms of the structure and bonding in these two oils. [2]

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(Option B continues on the following page)

(Option B continued)

12. Carbohydrates are energy-rich molecules which can be synthesized in some plant cells from inorganic compounds.

(a) State the raw materials and source of energy used in the process described above. [1]

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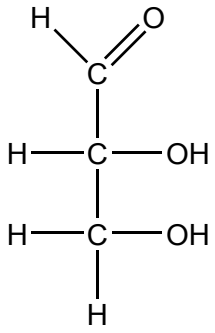
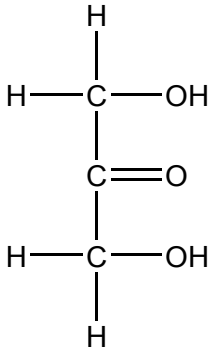
(b) The structures of two molecules, **X** and **Y**, are shown below.

X:



Y:



(i) Justify why both these molecules are carbohydrates. [1]

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(ii) Distinguish between these molecules in terms of their functional groups. [1]

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(Option B continues on the following page)

(Option B, question 12 continued)

(c) Amylose is an unbranched polysaccharide composed of repeating units of glucose.

(i) Draw the structure of the repeating unit of amylose. Use section 34 of the data booklet. [1]

(ii) Amylose is a major component of starch. Corn starch can be used to make replacements for plastics derived from oil, especially for packaging. Discuss **one** potential advantage and **one** disadvantage of this use of starch. [2]

Advantage:

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Disadvantage:

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(Option B continues on the following page)

(Option B continued)

13. Amino acids are usually identified by their common names. Use section 33 of the data booklet.

(a) State the IUPAC name for leucine. [1]

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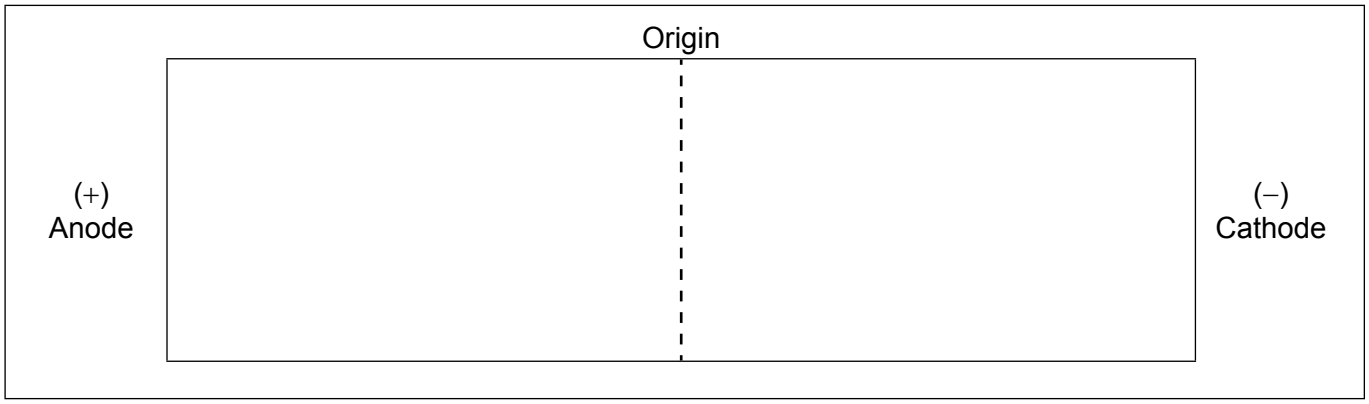
(b) A mixture of amino acids is separated by gel electrophoresis at pH 6.0. The amino acids are then stained with ninhydrin.

(i) On the diagram below draw the relative positions of the following amino acids at the end of the process: Val, Asp, Lys and Thr. [2]



(ii) Suggest why glycine and isoleucine separate slightly at pH 6.5. [1]

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(Option B continues on the following page)

(Option B, question 13 continued)

(c) Amino acids act as buffers in solution. In aspartic acid, the side chain (R group) carboxyl has p$K_a = 4.0$. Determine the percentage of the side chain carboxyl that will be ionized ($–COO^-$) in a solution of aspartic acid with pH = 3.0. Use section 1 of the data booklet. [3]

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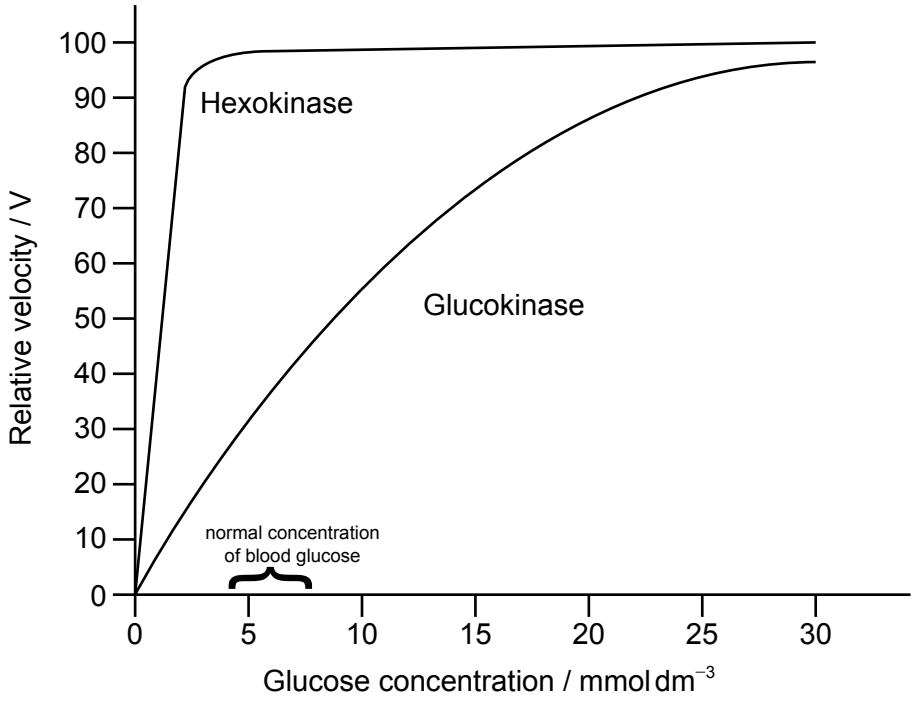
14. Glucokinase and hexokinase are both enzymes that catalyse the conversion of glucose to glucose-6-phosphate. The enzymes differ, however, in their affinity for the substrate, as shown in the graph below.



[Source: http://themedicalbiochemistrypage.org/glycolysis.php]

(Option B continues on the following page)

(Option B, question 14 continued)

(a) (i) Estimate the K_m values of the two enzymes. [1]

K_m hexokinase:

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K_m glucokinase:

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(ii) Suggest, with a reason, which enzyme will be more responsive to changes in the concentration of glucose in the blood. [1]

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(b) (i) Outline what is meant by product inhibition as it applies to hexokinase. [1]

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(ii) Product inhibition of hexokinase does not affect its K_m value. Using this information, deduce the type of binding site that the inhibitor attaches to. [1]

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(Option B continues on the following page)

(Option B continued)

15. The structure of DNA (deoxyribonucleic acid) has been studied in many different ways.

(a) State the name of the component of DNA responsible for the migration of its fragments to the positive electrode in gel electrophoresis. [1]

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(b) In 2010, scientists claimed that they had discovered a species of bacteria capable of incorporating arsenic in place of phosphorus into the bacterial DNA. This claim has since proved controversial. Suggest **one** technique or evidence that might help support the claim. [1]

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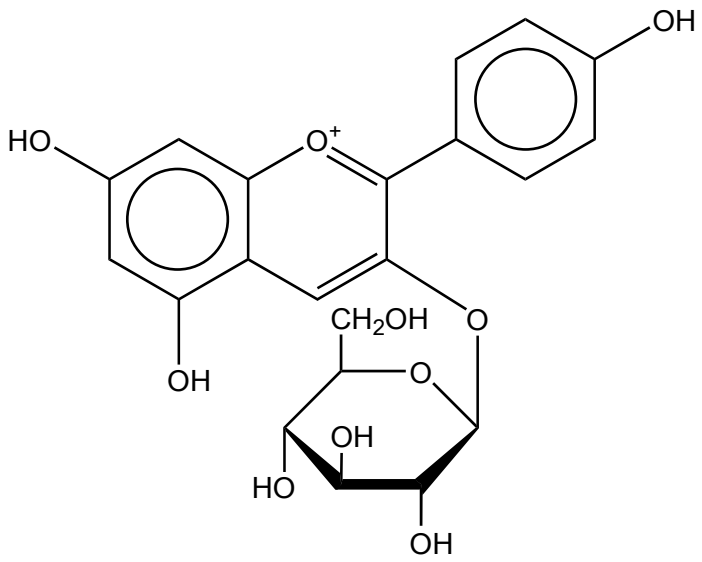
16. Anthocyanins are pigments that give colour to many flowers and fruits. The red colour of ripe strawberries is mainly due to the anthocyanin pigment whose structure is shown below.



(Option B continues on the following page)

(Option B, question 16 continued)

(a) Outline why this molecule absorbs visible light. [1]

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(b) With reference to its chemical structure, outline whether this pigment is found in aqueous solution in the cells or in the lipid-based membranes. [1]

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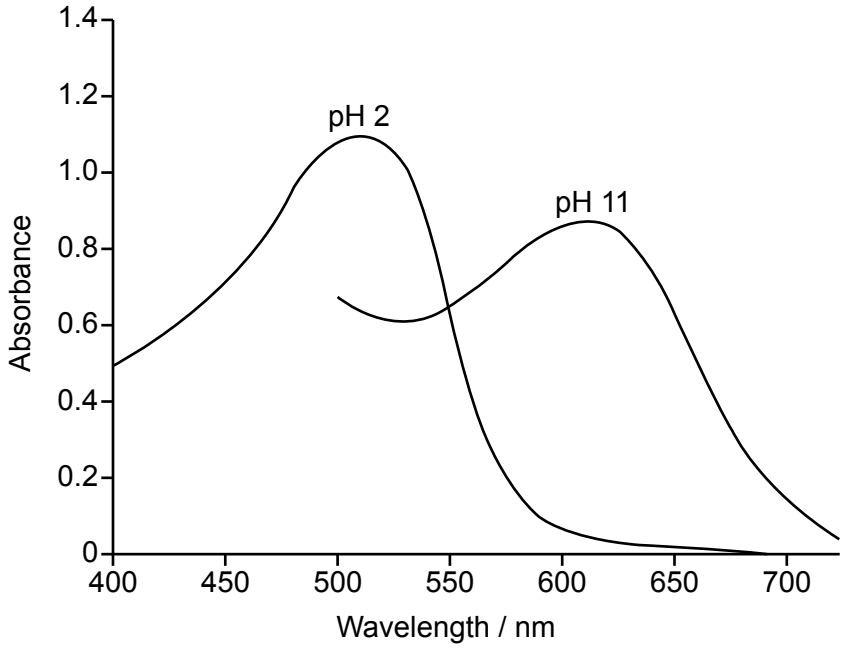
(Option B continues on the following page)

(Option B, question 16 continued)

(c) A student investigated the ability of anthocyanins to act as pH indicators. He extracted juice from blackberries and used a UV-vis spectrophotometer to produce absorption spectra at different pH values. His results are shown below.



Deduce the colour of the juice at each pH, giving your reasoning. Use section 17 of the data booklet. [2]

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End of Option B

Option C — Energy

17. Chemical energy from redox reactions can be used as a portable source of electrical energy. A hybrid car uses a lithium ion battery in addition to gasoline as fuel.

(a) (i) Calculate the specific energy of the lithium ion battery, in $MJ\,kg^{-1}$, when 80.0 kg of fuel in the battery releases 1.58×10^7 J. Use section 1 of the data booklet. [1]

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(ii) The specific energy of gasoline is $46.0\,MJ\,kg^{-1}$. Suggest why gasoline may be considered a better energy source than the lithium ion battery based on your answer to part (a) (i). [1]

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(b) (i) The energy density of gasoline is $34.3\,MJ\,dm^{-3}$. Calculate the volume of gasoline, in dm^3, that is equivalent to the energy in 80.0 kg of fuel in the lithium ion battery. Use section 1 of the data booklet. [1]

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(ii) The efficiency of energy transfer by this lithium ion battery is four times greater than that of gasoline. Determine the distance, in km, the car can travel on the lithium ion battery power alone if the gasoline-powered car uses 1.00 dm^3 gasoline to travel 32.0 km. [1]

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(Option C continues on the following page)

(Option C continued)

18. Auto-ignition of hydrocarbon fuel in a car engine causes “knocking”. The tendency of a fuel to knock depends on its molecular structure.

(a) Discuss how the octane number changes with the molecular structure of the alkanes. [2]

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(b) Catalytic reforming and cracking reactions are used to produce more efficient fuels. Deduce the equation for the conversion of heptane to methylbenzene. [1]

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19. Carbon dioxide and water vapour are greenhouse gases produced by the combustion of fossil fuels.

(a) Explain the effect of the increasing concentration of atmospheric carbon dioxide on the acidity of oceans. [2]

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(Option C continues on the following page)

(Option C, question 19 continued)

(b) Describe the changes that occur at the molecular level when atmospheric carbon dioxide gas absorbs infrared radiation emitted from the Earth's surface. [2]

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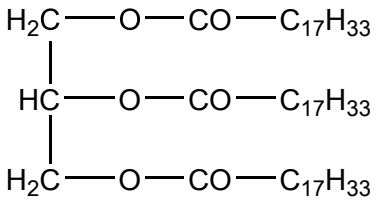
20. Biofuels are renewable energy sources derived mainly from plants.

State the equation for the complete transesterification of the triglyceride given below with methanol. [2]



(Option C continues on the following page)

(Option C continued)

21. A fuel cell is an energy conversion device that generates electricity from a spontaneous redox reaction.

(a) The *Geobacter* species of bacteria can be used in microbial fuel cells to oxidise aqueous ethanoate ions, $CH_3COO^-(aq)$, to carbon dioxide gas.

State the half-equations for the reactions at both electrodes. [2]

Negative electrode (anode):

. . . . . .

Positive electrode (cathode):

. . . . . .

(b) A concentration cell is an example of an electrochemical cell.

(i) State the difference between a concentration cell and a standard voltaic cell. [1]

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(ii) The overall redox equation and the standard cell potential for a voltaic cell are:

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s) \qquad E^{\ominus}_{cell} = +1.10\,V$$

Determine the cell potential E at 298 K to three significant figures given the following concentrations in mol dm^{-3}:

$$[Zn^{2+}] = 1.00 \times 10^{-4} \qquad [Cu^{2+}] = 1.00 \times 10^{-1}$$

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

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(Option C continues on the following page)

(Option C, question 21 continued)

(iii) Deduce, giving your reason, whether the reaction in (b) (ii) is more or less spontaneous than in the standard cell. [1]

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(c) Dye-sensitized solar cells (DSSC) convert solar energy into electrical energy.

(i) Describe how a DSSC converts sunlight into electrical energy. [2]

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(ii) Explain the role of the electrolyte solution containing iodide ions, I^-, and triiodide ions, I_3^-, in the DSSC. [2]

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(Option C continues on the following page)

(Option C continued)

22. Nuclear reactions transform one nuclide into another. Fission, splitting a large nucleus into two smaller nuclei, releases vast amounts of energy.

(a) (i) Explain why fusion, combining two smaller nuclei into a larger nucleus, releases vast amounts of energy. Use section 36 of the data booklet. [2]

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(ii) Outline **one** advantage of fusion as a source of energy. [1]

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(b) Radioactive phosphorus, ^{33}P, has a half-life of 25.3 days.

(i) Calculate ^{33}P decay constant λ and state its unit. Use section 1 of the data booklet. [1]

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(ii) Determine the fraction of the ^{33}P sample remaining after 101.2 days. [1]

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(Option C continues on the following page)

(Option C, question 22 continued)

(c) (i) Uranium hexafluoride, UF_6, is used in the uranium enrichment process that produces fuel for nuclear reactors.
State the molecular shape of uranium hexafluoride. [1]

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(ii) Explain why uranium dioxide, UO_2, has a very high melting point whereas uranium hexafluoride vapourises easily into gas. [2]

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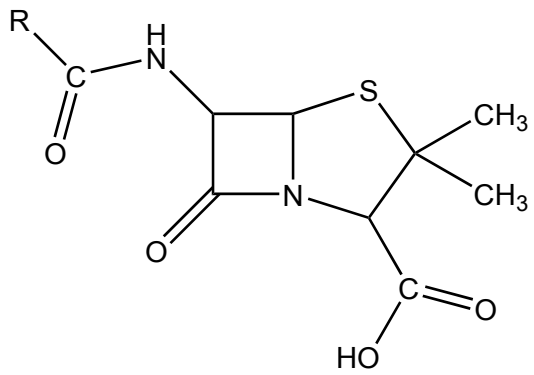
End of Option C

Option D — Medicinal chemistry

23. Penicillin is an antibiotic which contains a beta-lactam ring. Its general structure is shown below.



(a) (i) Outline what is meant by the term "ring strain". [1]

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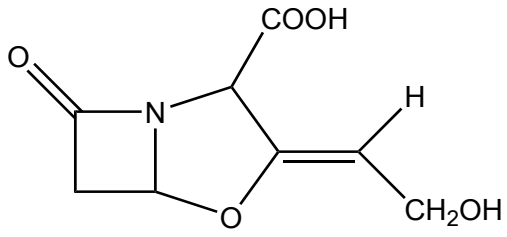
(ii) On the diagram above, label with asterisk/s (*) the carbon atom/s that experience ring strain. [1]

(b) (i) Some antibiotic-resistant bacteria produce a beta-lactamase enzyme which destroys penicillin activity. Suggest how adding clavulanic acid to penicillin enables the antibiotic to retain its activity. [1]



Clavulanic acid

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(Option D continues on the following page)

(Option D, question 23 continued)

(ii) Populations of antibiotic-resistant bacteria have increased significantly over the last 60 years. Outline why antibiotics such as penicillin should not be prescribed to people suffering from a viral infection. [2]

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24. Oseltamivir (Tamiflu) and zanamivir (Relenza) are both used as antivirals to help prevent the spread of the flu virus, but are administered by different methods.

(a) Zanamivir must be taken by inhalation, not orally. Deduce what this suggests about the bioavailability of zanamivir if taken orally. [1]

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(b) Oseltamivir does not possess the carboxyl group needed for activity until it is chemically changed in the body. Deduce the name of the functional group in oseltamivir which changes into a carboxyl group in the body. Use section 37 of the data booklet. [1]

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(Option D continues on the following page)

(Option D continued)

25. The mild analgesic aspirin can be prepared in the laboratory from salicylic acid.

$$(CH_3CO)_2O + HOC_6H_4COOH \rightarrow CH_3CO_2C_6H_4COOH + CH_3COOH$$

Salicylic acid Aspirin

After the reaction is complete, the product is isolated, recrystallized, tested for purity and the experimental yield is measured. A student's results in a single trial are as follows.

	Mass / g ±0.001	**Melting point / °C ±1**
Initial salicylic acid	1.552	
Crude product	1.398	106–114
Product after recrystallization	1.124	122–125

Literature melting point data: aspirin = 138–140 °C

(a) Determine the percentage experimental yield of the product after recrystallization. The molar masses are as follows: M(salicylic acid) = 138.13 g mol^{-1}, M(aspirin) = 180.17 g mol^{-1}. (You do not need to process the uncertainties in the calculation.) [2]

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(b) Suggest why isolation of the crude product involved the addition of ice-cold water. [1]

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(Option D continues on the following page)

(Option D, question 25 continued)

(c) Justify the conclusion that recrystallization increased the purity of the product, by reference to **two** differences between the melting point data of the crude and recrystallized products. [2]

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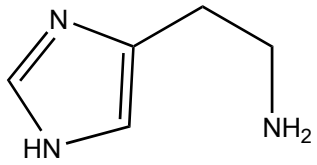
26. Excess stomach acid leads to medical conditions that affect many people worldwide. These conditions can be treated with several types of medical drugs.

(a) Ranitidine (Zantac) is a drug that inhibits stomach acid production. Outline why the development of this drug was based on a detailed knowledge of the structure of histamine, shown below. [1]



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(b) Two other drugs, omeprazole (Prilosec) and esomeprazole (Nexium), directly prevent the release of acid into the stomach. Identify the site of action in the body. [1]

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(Option D continues on the following page)

(Option D, question 26 continued)

(c) Omeprazole exists as a racemic mixture whereas esomeprazole is a single enantiomer. Outline how, starting from a non-chiral molecule, esomeprazole but not omeprazole, could be synthesized. Details of chemicals and conditions are not required. [2]

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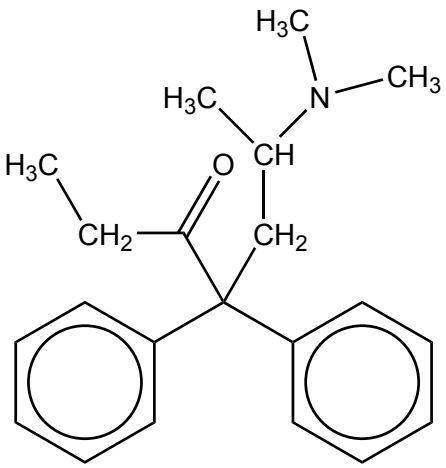
(Option D continues on the following page)

(Option D continued)

27. Methadone, a synthetic opioid, binds to opioid receptors in the brain.



Methadone

(a) Compare and contrast the functional groups present in methadone and diamorphine (heroin), giving their names. Use section 37 of the data booklet. [2]

One similarity:

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One difference:

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(b) Methadone is sometimes used to help reduce withdrawal symptoms in the treatment of heroin addiction. Outline **one** withdrawal symptom that an addict may experience. [1]

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(Option D continues on the following page)

(Option D continued)

28. Technetium-99m is the most widely used medical radioisotope. It is usually made on-site in medical facilities from isotopes of molybdenum.

(a) Deduce equations for the following nuclear reactions:

(i) Molybdenum-98 absorbs a neutron. [1]

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(ii) The isotope produced in (a) (i) decays into technetium-99m. [1]

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(b) Molybdenum-99 has a half-life of 66 hours, while technetium-99m has a half-life of 6 hours. Outline why technetium-99m is made on-site. [1]

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(c) Outline **two** reasons, other than its half-life, why technetium-99m is so useful in medical diagnosis. [2]

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(Option D continues on the following page)

(Option D, question 28 continued)

(d) Outline the nature of the radioactive waste that is generated by the use of technetium-99m in medical diagnosis. [1]

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29. The use of performance-enhancing drugs presents a challenge in the world of competitive sports. New regulations have lowered the acceptable concentrations of certain drugs in athletes' bodies.

(a) Suggest what may have led to these changes in acceptable concentrations. [1]

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(b) One class of performance-enhancing drugs is the anabolic steroids. Detection of these drugs in urine samples uses a combination of gas chromatography and mass spectrometry (GC/MS).

(i) Describe how gas chromatography enables the components of urine to be analysed. [2]

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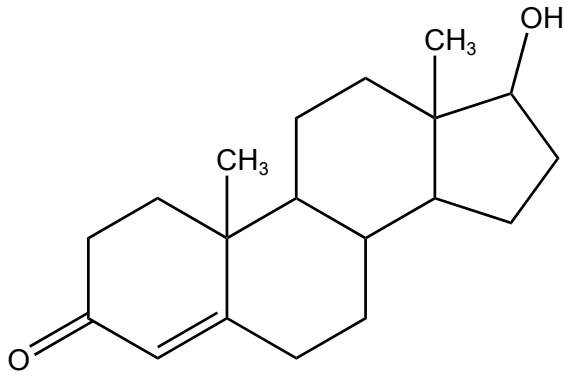
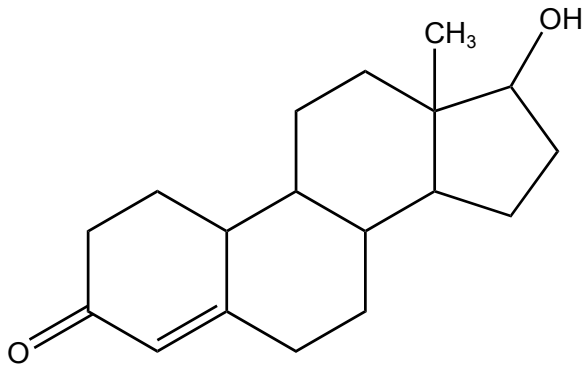
(Option D continues on the following page)

(Option D, question 29 continued)

(ii) The structures of two steroids, testosterone and nandrolone, are given below.

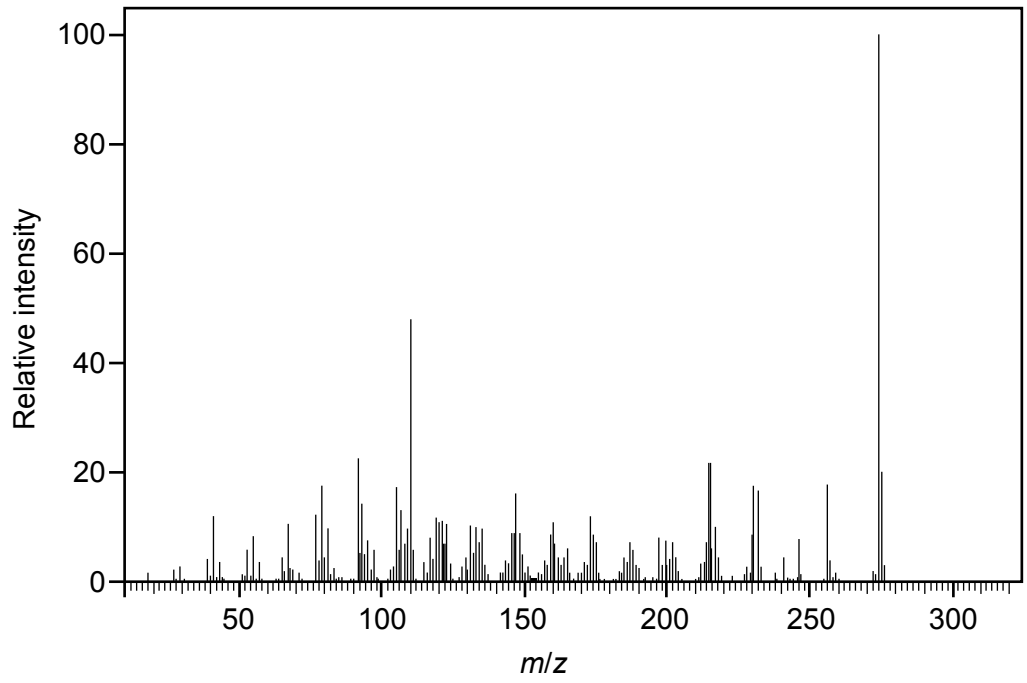


Testosterone $C_{19}H_{28}O_2$



Nandrolone $C_{18}H_{26}O_2$

With reference to the molar masses of the two steroids, determine, with a reason, which can be identified from the mass spectrum below. [2]



[Source: http://sdbs.db.aist.go.jp/ accessed 2015-08-23]

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End of Option D

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