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Baccalauréat International
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CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate session number

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Wednesday 9 May 2012 (morning)

1 hour 15 minutes

Examination code

2	2	1	2	–	6	1	1	5

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the 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 *[50 marks]*.

0140

Option A — Modern analytical chemistry

A1. Atomic absorption (AA) spectroscopy can be used to detect very small quantities of heavy metal ions in samples of water. An analyst used AA spectroscopy to determine the concentration of cadmium and mercury ions in a sample of water taken near to a zinc mine.

(a) Outline the major change that the analyst would need to make to the spectrometer, after measuring the absorbance due to the cadmium ions, before she could measure the absorbance due to the mercury ions. *[2]*

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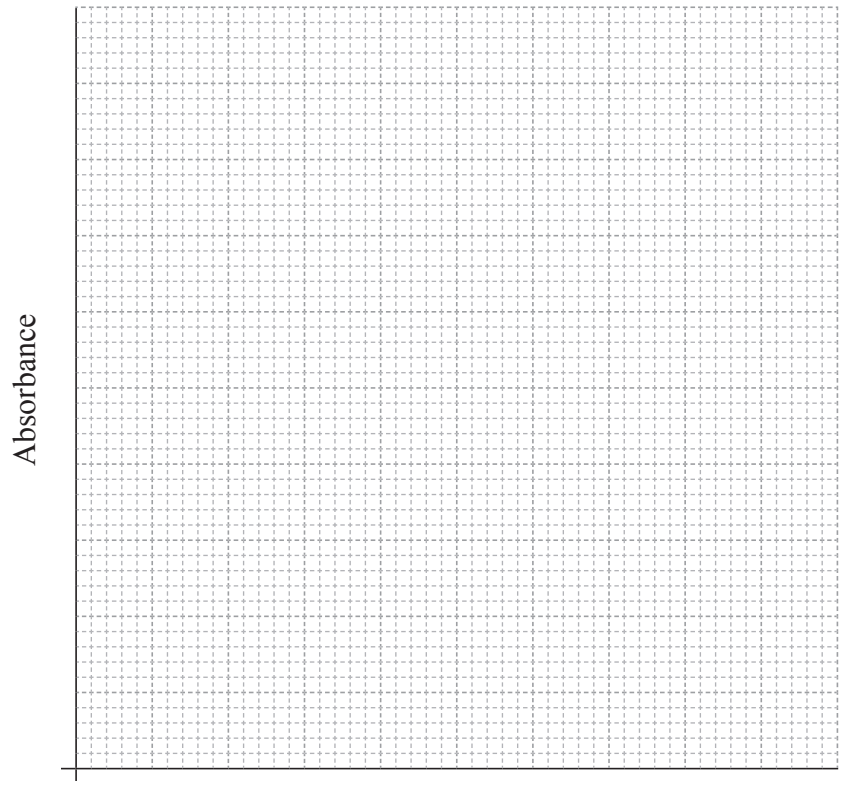
(This question continues on the following page)

(Question A1 continued)

(b) The analyst used solutions of known concentrations of cadmium to find their absorbance and also found the absorbance of the sample under the same conditions, to give the following results.

$[Cd^{2+}(aq)]$ / mg dm^{-3}	**Absorbance**
0.00	0.00
0.10	0.21
0.20	0.43
0.30	0.65
0.40	0.87
Sample with unknown concentration	0.78

Construct a calibration curve and determine the concentration of cadmium ions in the sample of water taken from near the zinc mine. *[3]*



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A2. Alumina, Al_2O_3, can be used as the stationary phase in both thin-layer chromatography (TLC) and column chromatography (CC). A solvent such as propanone can be used as the mobile phase.

(a) Explain the functions of both the stationary phase and the mobile phase in chromatography and explain their role in allowing a mixture to be separated into its individual components. *[3]*

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(b) Outline how a mixture containing two different coloured components could be separated **quantitatively** into its two pure components using column chromatography. Assume the column is packed with alumina and the mobile phase is propanone. *[4]*

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A3. (a) Deduce the number of peaks in the ^{1}H NMR spectra of 1-bromobutane and 2-bromobutane. Explain how the integration trace can be used to distinguish between the two compounds. *[3]*

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(b) Another structural isomer of C_4H_9Br is 2-bromo-2-methylpropane. Deduce the number of peaks and the splitting pattern in the ^{1}H NMR spectrum of this isomer. *[2]*

Number of peaks:

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Splitting pattern:

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(c) Outline the principle behind magnetic resonance imaging (MRI) used to diagnose and monitor conditions such as cancer in humans. *[3]*

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A4. (a) Transition metal complexes are coloured because electronic transitions occur within split d orbital energy levels. Identify **two** different factors that affect the colour of complexes of a specific transition metal. *[2]*

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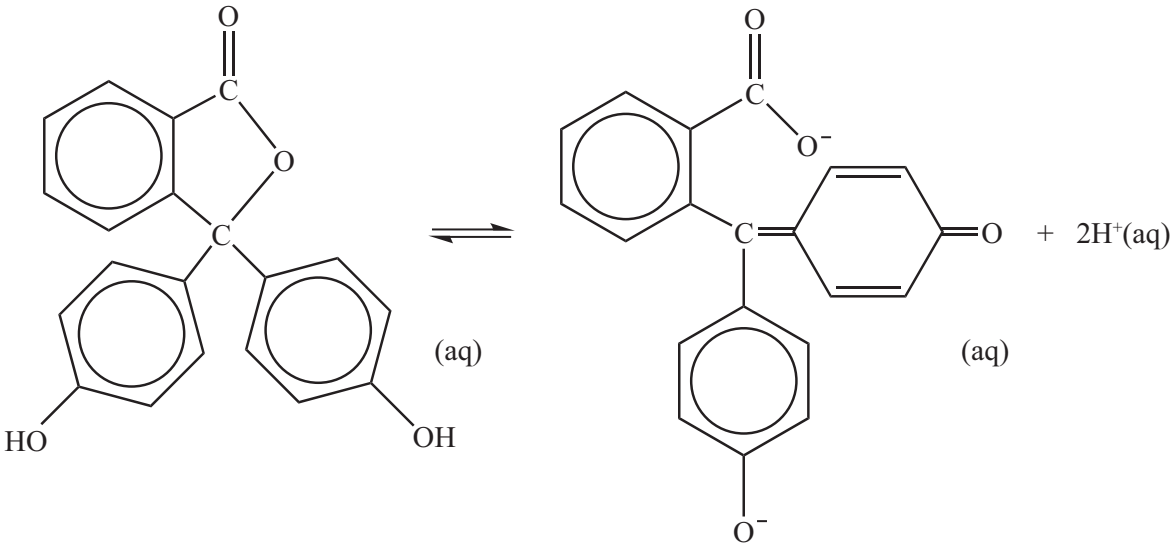
(b) Phenolphthalein indicator is colourless in solutions with a pH less than 8.2 but pink in solutions with a pH greater than 10.0. The molecule dissociates according to the equation:



pH < 8.2
colourless

pH > 10.0
pink

Explain, in terms of the structures, why the indicator is colourless at pH < 8.2 and is pink at pH > 10.0. *[3]*

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Option B — Human biochemistry

B1. (a) Outline the general function of hormones in the human body. *[1]*

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(b) Describe **one** specific effect of an insufficient amount of the hormone thyroxine in the human body. *[1]*

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(c) Estradiol, progesterone and testosterone are sex hormones. Their structures are given in Table 21 of the Data Booklet.

Explain, in terms of their named functional groups, how the structure of testosterone differs from the structure of progesterone. *[2]*

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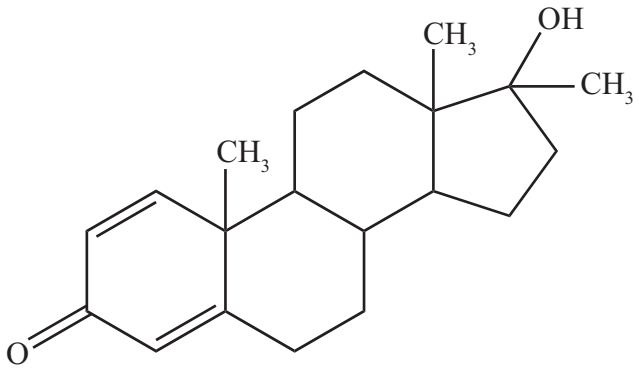
(This question continues on the following page)

(Question B1 continued)

(d) Some athletes have abused steroids in order to increase muscular strength and body mass. One such substance is dianabol (shown below) which has a structure similar to testosterone.



(i) Describe how the structure of dianabol differs from the structure of testosterone. *[1]*

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(ii) Suggest a reason why male bodybuilders who take dianabol may develop some female characteristics. *[1]*

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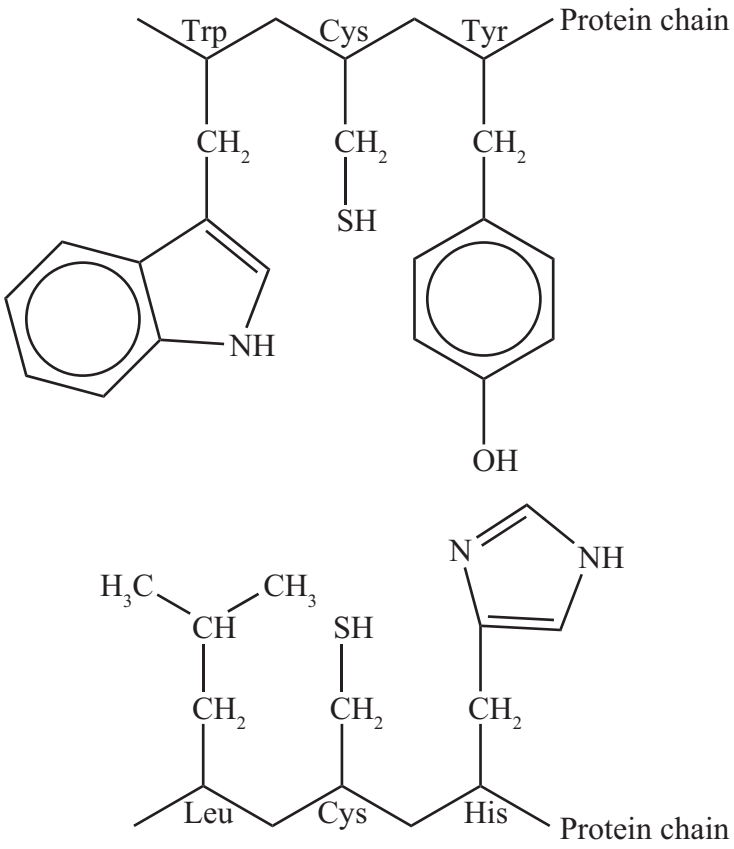
B2. (a) The primary structure of proteins describes how the different 2-amino acids are linked to each other in a linear chain. Draw the structures of the **two** different dipeptides that can be formed when alanine reacts with serine. (The structures of alanine and serine are given in Table 19 of the Data Booklet.) *[2]*

(This question continues on the following page)

(Question B2 continued)

(b) The tertiary structure of proteins describes the overall folding of the chains to give the protein its three-dimensional shape. This is caused by interactions between the side chains of distant amino acid residues. Consider the following two segments of a polypeptide chain.



(i) Deduce the type of interaction that can occur between the side chains of Trp and Leu, Cys and Cys, and Tyr and His. *[3]*

Trp and Leu: . . . . . .

Cys and Cys: . . . . . .

Tyr and His: . . . . . .

(This question continues on the following page)

(Question B2 continued)

(ii) State the name of **one** other type of interaction that can occur between the side chains of amino acid residues. *[1]*

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(c) Describe the *quaternary structure* of proteins. *[1]*

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(d) Outline how the iron in hemoglobin transports oxygen during the process of respiration. *[2]*

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B3. (a) State and explain how the rate of an enzyme-catalysed reaction is related to the substrate concentration. *[3]*

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(b) When an inhibitor is added it decreases the rate of an enzyme-catalysed reaction. State the effect that competitive and non-competitive inhibitors have on the value of V_{max}. Explain this in terms of where the inhibitor binds to the enzyme. *[4]*

Competitive inhibitor:

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Non-competitive inhibitor:

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(This question continues on the following page)

(Question B3 continued)

(c) (i) Sketch a graph to show the effect that a change in pH will have on the rate of an enzyme-catalysed reaction. *[1]*

(ii) Explain why changing the pH affects the catalytic ability of enzymes. *[2]*

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Option C — Chemistry in industry and technology

C1. (a) The pig iron produced in a blast furnace contains 4 –5 % carbon and smaller amounts of other elements such as phosphorus and silicon. It can be converted into steel using an oxygen converter.

(i) Other than pig iron, oxygen, and different transition metals, list **two** other substances that are added to the basic oxygen converter. *[2]*

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(ii) Explain how the phosphorus and silicon are removed. *[2]*

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(b) Steel is an alloy of iron, carbon and other metallic and non-metallic elements. Stainless steel contains about 18 % chromium and 8 % nickel. Explain why iron can form alloys with other transition metals. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(c) (i) The properties of alloys can be altered by heat treatment. Describe the process of annealing and state how this affects the properties of steel. *[2]*

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(ii) State how the properties of steel are affected if the steel is quenched after it has been annealed. *[1]*

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C2. (a) A fuel cell can be made using an electrolyte of aqueous sodium hydroxide with porous electrodes which allow the passage of water, hydrogen and oxygen. State the equations for the reactions that occur at the positive and negative electrodes. *[2]*

(+) electrode (cathode):

. . . . . .

(–) electrode (anode):

. . . . . .

(b) Electricity can also be generated from a lead–acid storage battery. The electrolyte is a solution of sulfuric acid and the electrodes are made of lead and lead(IV) oxide. State the equations for the reactions that occur at the positive and negative electrodes. *[2]*

(+) electrode (cathode):

. . . . . .

(–) electrode (anode):

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(c) Lead–acid batteries are heavy. Much lighter rechargeable cells are nickel–cadmium batteries used in electronic equipment.

Other than their chemical composition, discuss **two** major differences between fuel cells and nickel–cadmium cells. *[2]*

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C3. (a) Distinguish between thermotropic liquid crystals and lyotropic liquid crystals. *[2]*

Thermotropic:

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Lyotropic:

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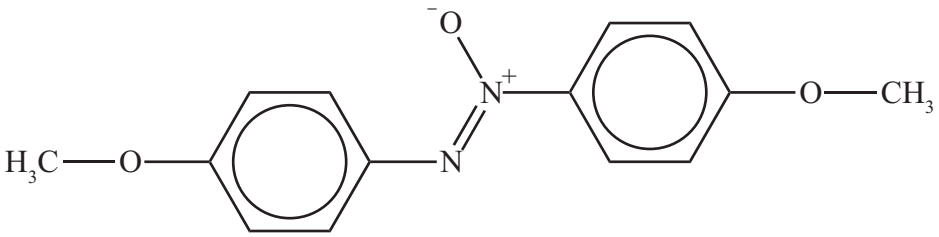
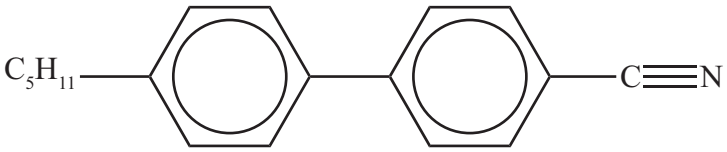
(b) Two substances that can be used in liquid crystals are commonly called PAA (4-azoxydianisole) and 5CB (4-pentyl-4'-cyanobiphenyl).



PAA



5CB

Discuss on the molecular level **three** different factors that explain their liquid-crystal properties. *[3]*

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(This question continues on the following page)

(Question C3 continued)

(c) Explain the workings of liquid crystals made up of compounds such as 5CB in liquid-crystal displays. *[5]*

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Option D — Medicines and drugs

D1. A well-known brand of antacids contains 0.160 g of aluminium hydroxide and 0.105 g of magnesium carbonate in each tablet.

(a) State the separate equations for the reactions of aluminium hydroxide and magnesium carbonate with hydrochloric acid. *[2]*

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(b) Determine which of the two components of the tablet will neutralize the most acid. *[2]*

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(c) The tablets also contain alginic acid and sodium hydrogencarbonate. The function of the sodium hydrogencarbonate is to react with the alginic acid to form sodium alginate. State the function of the sodium alginate produced. *[1]*

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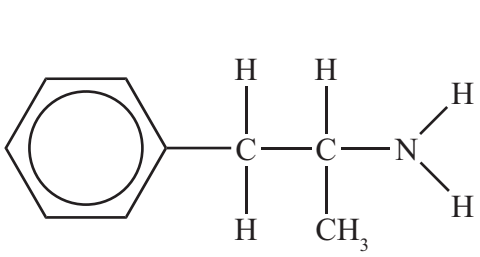
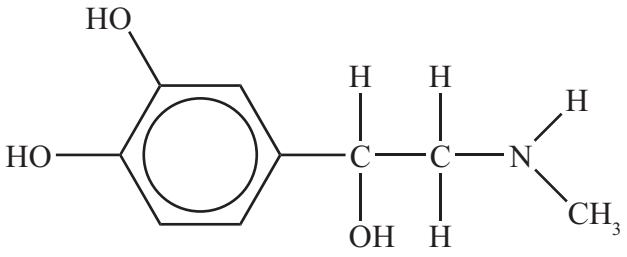
D2. Amphetamine is a stimulant and is known as a sympathomimetic drug. It has a structure with some similarities to epinephrine (adrenaline).



amphetamine



epinephrine (adrenaline)

(a) Explain the meaning of the term *sympathomimetic*. *[1]*

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(b) Determine whether amphetamine and epinephrine possess any chiral carbon atoms and label the chiral atom(s) by using an asterisk, *, in the structures above. *[1]*

(c) Discuss why it is important to test all the enantiomers of a potential drug before it can be licensed for clinical use. *[2]*

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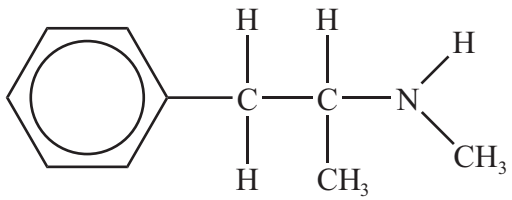
(Question D2 continued)

(d) Amphetamine and epinephrine both derive from the phenylethylamine structure. Draw the structure of phenylethylamine. *[1]*

(e) Methylamphetamine has the following structure.



Methylamphetamine sulphate is commonly called "speed". It is taken illegally to increase alertness.

(i) Suggest a reason why it is taken as the sulfate salt rather than as pure methylamphetamine. *[1]*

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(This question continues on the following page)

(Question D2 continued)

(ii) Draw the structure of the methylamphetamine ion. *[1]*

D3. The discovery of penicillin by Alexander Fleming in 1928 is often given as an example of serendipity in science.

(a) Describe the chance event that led to Alexander Fleming's discovery of penicillin. *[1]*

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(b) Outline the work of Florey and Chain in developing penicillin. *[3]*

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(c) Describe what happens to bacteria when they come into contact with penicillin. *[2]*

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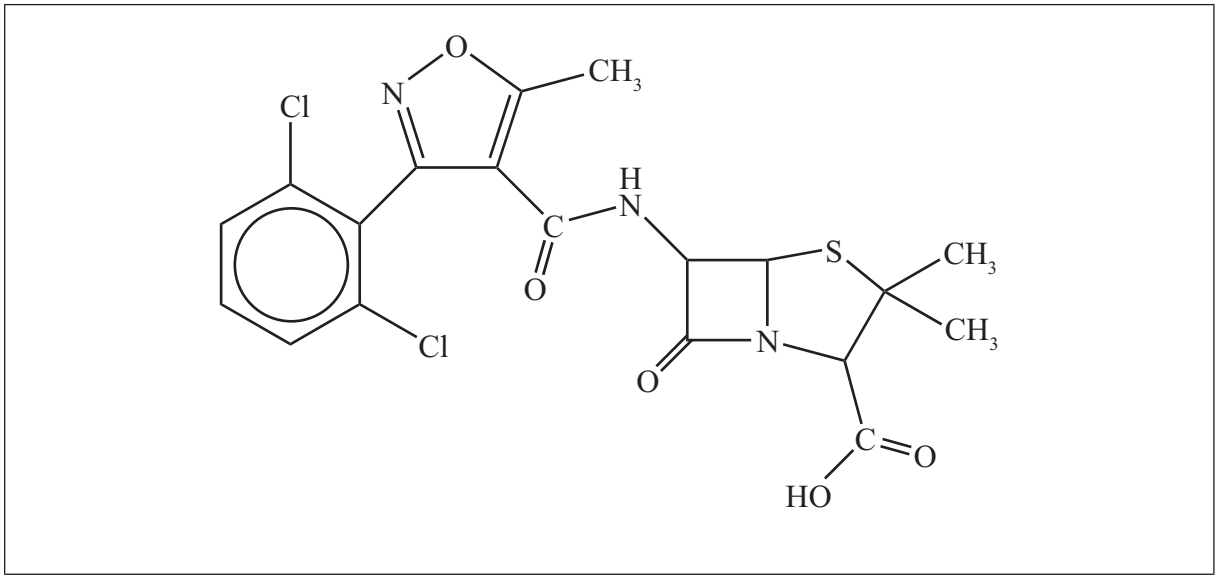
(Question D3 continued)

(d) The structure of a particular type of penicillin called dicloxacillin is shown below.



(i) Identify the β-lactam ring by drawing a circle around it. *[1]*

(ii) Explain why the β-lactam ring is so important in the mechanism of the action of penicillin. *[3]*

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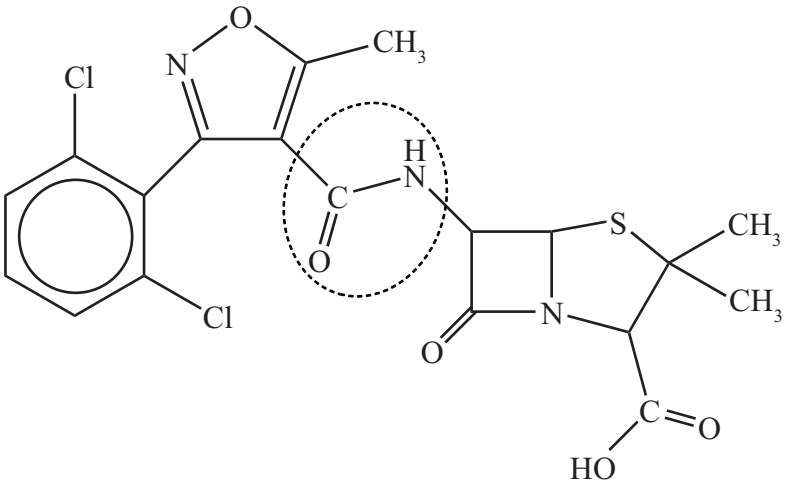
(Question D3 continued)

(iii) State the name of the functional group in dicloxacillin, circled below. *[1]*



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(e) Comment on the fact that many bacteria are now resistant to penicillins. *[2]*

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Option E — Environmental chemistry

E1. Catalytic converters are fitted to cars to convert polluting exhaust gases into less harmful gases.

(a) Describe how the combustion of petrol (gasoline) in an internal combustion engine produces carbon monoxide and oxides of nitrogen. *[2]*

Carbon monoxide:

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Oxides of nitrogen:

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(b) Other than carbon monoxide, carbon dioxide, and oxides of nitrogen, state **one** other pollutant gas emitted from an internal combustion engine. *[1]*

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(c) Identify **one** substance used as the catalyst in a catalytic converter and deduce the equation for the reaction that occurs between carbon monoxide and nitrogen(II) oxide inside the catalytic converter. *[3]*

Substance:

. . . . . .

Equation:

. . . . . .

(This question continues on the following page)

(Question E1 continued)

(d) Evaluate the effects of changing the fuel/air ratio in the internal combustion engine. *[2]*

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E2. Discuss soil pollution, nutrient depletion and salinization as causes of soil degradation. In each case explain the reason for the cause and how it degrades the soil. *[6]*

Soil pollution:

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Nutrient depletion:

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Salinization:

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E3. (a) Explain, in terms of their bonding, how the presence of oxygen and ozone in the ozone layer helps to prevent both higher and lower energy UV light from reaching the surface of the Earth. *[3]*

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(b) There is concern that the oxides of nitrogen released by jet aeroplanes flying at high altitudes can deplete the amount of ozone in the ozone layer. Describe, using equations, the mechanism for the catalytic decomposition of ozone by nitrogen(IV) oxide, NO_2. *[3]*

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(c) Outline why the depletion of ozone over polar regions is greater during early spring. *[3]*

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(Question E3 continued)

(d) Ozone can also be formed as a secondary pollutant in the lower atmosphere in photochemical smogs. Photochemical smogs typically occur in "bowl-shaped" cities. List **two** necessary conditions for a photochemical smog to form from primary pollutants. *[2]*

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Option F — Food chemistry

F1. Some foods contain natural antioxidants which help to prolong their shelf life.

(a) Explain the meaning of the term *shelf life*. *[1]*

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(b) The shelf life of oily fish decreases upon exposure to light.

(i) Identify the chemical feature in the oil in fish that is susceptible to photo-oxidation. *[1]*

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(ii) State the specific term given to food that is unsuitable for eating as a result of photo-oxidation. *[1]*

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(iii) Suggest how light initiates this process. *[1]*

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(This question continues on the following page)

(Question F1 continued)

(c) The compound 3-BHA is a synthetic antioxidant which is added to some foods. The structure of 3-BHA is given in Table 22 of the Data Booklet. Identify **two** features from its structure that are responsible for its antioxidant properties. *[2]*

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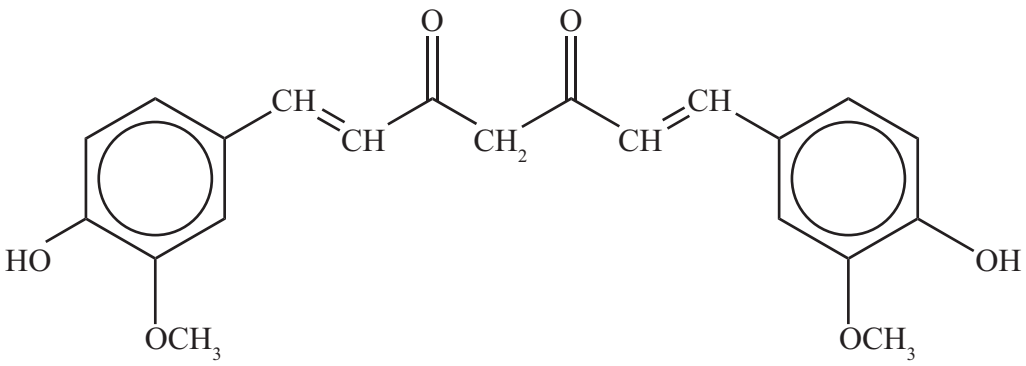
(d) Some foods contain a yellow spice called turmeric. The active ingredient in turmeric is curcumin, shown below.



Suggest which structural feature of curcumin is responsible for extending the shelf life of such a food. *[1]*

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F2. Fats and oils have some similarities and some differences in their chemical structures.

(a) State **two** major differences in their structures. *[2]*

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(b) Describe how an oil can be converted into a fat. *[2]*

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(c) Discuss **two** advantages and **two** disadvantages of converting oils into fats. *[4]*

Advantages:

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Disadvantages:

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F3. The American chemist Linus Pauling, who won two Nobel prizes, promoted the taking of vitamin C as a way of preventing the common cold. One of the functions of vitamin C in the body is as an antioxidant. During the process ascorbic acid, $C_6H_8O_6$, is converted into dehydroascorbic acid, $C_6H_6O_6$.

(a) Deduce the half-equation to show how vitamin C acts as an antioxidant. *[2]*

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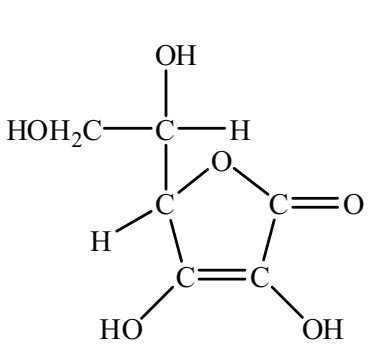
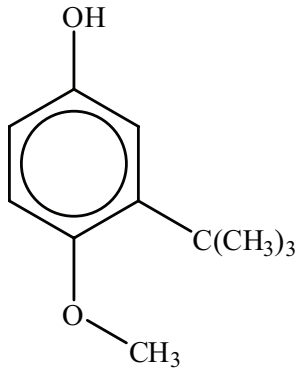
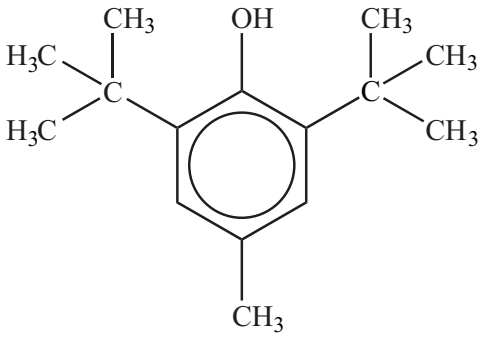
(b) The structures of vitamin C and the preservatives 2-BHA and BHT are shown below.



vitamin C



2-BHA



BHT

Determine any chiral carbon atoms in these three compounds by placing an asterisk, * , beside them. *[2]*

(c) Amino acids can exist in +(*d*) and –(*l*) forms. Describe how the +(*d*) form of alanine, $H_2NCH(CH_3)COOH$, differs in its physical properties to the –(*l*) form. *[1]*

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(This question continues on the following page)

(Question F3 continued)

(d) Explain the D and L convention for describing amino acids and draw the D form of alanine to show clearly its three-dimensional structure. *[3]*

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(e) Identify **one** substance whose enantiomers have different tastes or smells and describe these tastes or smells. *[2]*

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Option G — Further organic chemistry

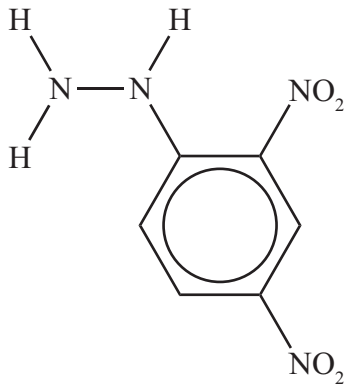
G1. Propan-2-ol is a secondary alcohol. It can undergo both elimination and oxidation reactions.

(a) In the presence of an acid catalyst, propan-2-ol can react to give an alkene. Explain the mechanism of this reaction using curly arrows to represent the movement of electron pairs. *[4]*

(This question continues on the following page)

(Question G1 continued)

(b) Propan-2-ol can be oxidized by an acidified solution of potassium dichromate(VI) to give propanone. This product can be identified by reacting it with 2,4-dinitrophenylhydrazine (shown below) to give a crystalline solid with a characteristic melting point.



(i) State the type of reaction taking place when propanone reacts with 2,4-dinitrophenylhydrazine. *[1]*

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(ii) State the structural formula of the organic compound formed when propanone reacts with 2,4-dinitrophenylhydrazine. *[1]*

G2. The number of carbon atoms in a ketone can be increased by reacting it with hydrogen cyanide.

(a) State the name given to the type of reaction taking place when propanone reacts with hydrogen cyanide. *[1]*

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(b) State how the product from the above reaction can be converted into 2-hydroxy-2-methylpropanoic acid. *[1]*

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(c) Outline how butanoic acid could be made starting with 1-bromopropane and magnesium metal. *[3]*

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G3. (a) Benzene and methylbenzene can both react with chlorine in the presence of aluminium chloride. Benzene forms chlorobenzene and methylbenzene forms a mixture of 1-chloro-2-methylbenzene and 1-chloro-4-methylbenzene as the major organic products.

(i) Describe, using equations and curly arrows to represent the movement of electron pairs, the mechanism of the reaction for the chlorination of benzene to form chlorobenzene. *[3]*

(ii) Explain why methylbenzene reacts more readily than benzene with chlorine in the presence of aluminium chloride. *[2]*

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(This question continues on the following page)

(Question G3 continued)

(iii) Explain why the methyl group in methylbenzene is 2- and 4- directing. *[2]*

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(b) Phenol, C_6H_5OH, also reacts with chlorine but the presence of aluminium chloride is not necessary for the reaction to proceed.

(i) State the equation for the reaction of phenol with chlorine and state the IUPAC name of the organic product. *[2]*

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(ii) Explain why the presence of aluminium chloride is not necessary. *[2]*

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G4. The pK_a values for ethanol, phenol and 2,4,6-trinitrophenol are given in Table 15 of the Data Booklet.

(a) Explain why phenol is more acidic than ethanol. *[2]*

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(b) Explain why 2,4,6-trinitrophenol is more acidic than phenol. *[1]*

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