22106109

International Baccalaureate®
Baccalauréat International
Bachillerato Internacional

CHEMISTRY
HIGHER LEVEL
PAPER 3

Thursday 13 May 2010 (morning)

1 hour 15 minutes

Candidate session number

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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 in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them to this examination paper and your cover sheet using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the candidate box on your cover sheet and indicate the number of answer sheets used in the appropriate box on your cover sheet.

Option A — Modern analytical chemistry

A1. Butan-1-ol, butan-2-ol, 2-methylpropan-1-ol and 2-methylpropan-2-ol are four structural isomers with the molecular formula $C_4H_{10}O$.

(a) Details of the ^1H NMR spectra of two of these alcohols are given below.

Spectrum 1

Two peaks: A singlet at 1.3 ppm (relative to the TMS reference) with an integration trace of nine units, and another singlet at 2.0 ppm with an integration trace of one unit.

Spectrum 2

Four peaks: A doublet at 0.9 ppm with an integration trace of six units.
A complex pattern at 1.7 ppm with an integration trace of one unit.
A singlet at 2.1 ppm with an integration trace of one unit.
A doublet at 3.4 ppm with an integration trace of two units.

Consider the proton environments present in each of the alcohol molecules when answering the following questions.

(i) Identify which alcohol gives spectrum 1 and explain your answer by stating which hydrogen atoms in the molecule are responsible for each of the two peaks. *[3]*

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(ii) Deduce which alcohol gives spectrum 2. Explain which hydrogen atoms are responsible for the peaks at 0.9 ppm and 3.4 ppm and explain why both of these peaks are split into doublets. *[4]*

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(Question A1 continued)

(b) The mass spectrum of one of the alcohols shows peaks at *m/z* values of 74, 59 and 45.

(i) Deduce which **two** of the alcohols could produce this spectrum and identify the species responsible for the three peaks. *[4]*

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(ii) The spectrum also shows a significant peak at *m/z* = 31. Suggest which alcohol is responsible for this spectrum and deduce the species responsible for the peak at *m/z* = 31. *[2]*

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(c) Explain why the infrared spectra of all four alcohols are very similar. *[2]*

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A2. Atomic absorption spectroscopy can be used to determine the concentration of lead ions in a contaminated sample of drinking water.

(a) Describe the function of each of the following in an atomic absorption spectrophotometer. *[3]*

The fuel:

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The atomizer:

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The monochromatic light source:

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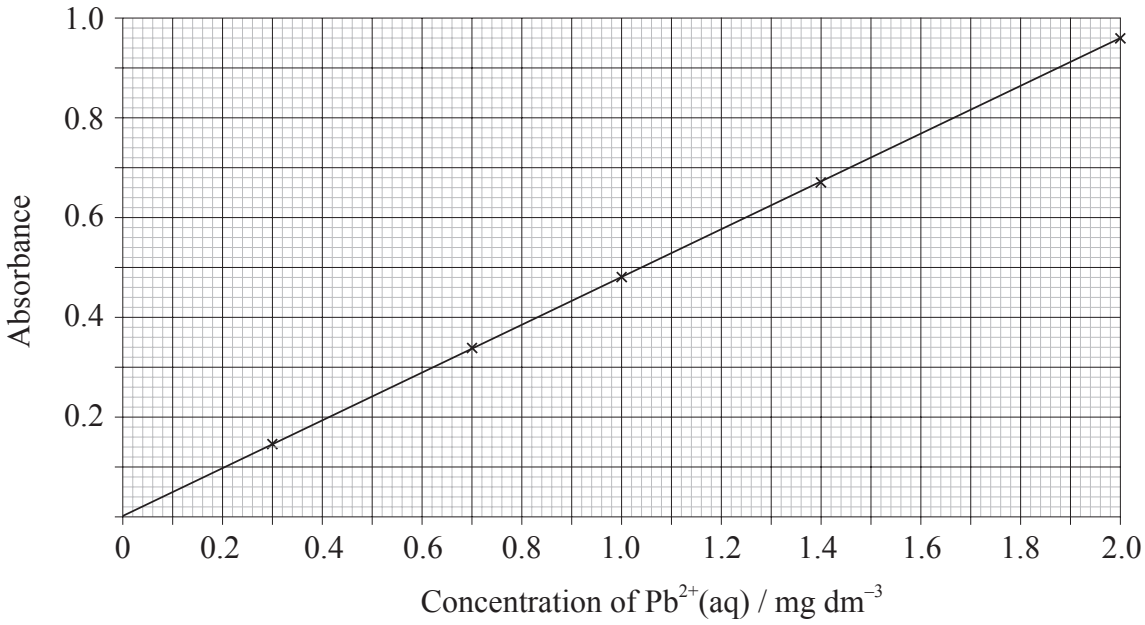
(Question A2 continued)

(b) A calibration curve was plotted using water with known concentrations of lead ions.



100 dm^3 of the contaminated drinking water was reduced by boiling, to 7.50 dm^3. It was found that when the reduced volume was tested it had an absorbance of 0.55. Calculate the concentration of lead ions (in mg dm^{-3}) in the original contaminated drinking water. *[2]*

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A3. (a) The structures of retinol and cholesterol are given in Table 21 of the Data Booklet. Both are slightly soluble in a colourless non-polar solvent. Explain why retinol forms a coloured solution whereas the solution of cholesterol remains colourless. *[2]*

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(b) When excess ammonia solution is added to a solution of copper(II) sulfate the oxidation number of the copper ion does not change but there is a noticeable colour change. Outline the reasons for this change in colour. *[3]*

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Option B — Human biochemistry

B1. Individual 2-amino acids have different structures depending on the pH of the solution they are dissolved in. The structures of serine and cysteine are given in Table 19 of the Data Booklet.

(a) Deduce the structure of serine in

(i) a solution with a pH of 2. *[1]*

(ii) a solution with a pH of 12. *[1]*

(b) Deduce the structure of serine at the isoelectric point. *[1]*

(c) Deduce the structures of the two different dipeptides that can be formed when one molecule of serine reacts with one molecule of cysteine. *[2]*

(This question continues on the following page)

(Question B1 continued)

(d) The tertiary structures of proteins made up of 2-amino acid residues such as serine and cysteine, are the result of interactions between amino acids to give a three-dimensional shape. State **five** different types of interaction that can occur, in each case identify the atoms or groups joined together. *[5]*

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B2. (a) State the causes of the three deficiency diseases, beriberi, goitre and pellagra. *[3]*

Beriberi:

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Goitre:

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Pellagra:

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(b) Suggest **three** ways in which society can solve the problems associated with malnutrition. *[3]*

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B3. The structure of thymine is given in Table 21 of the Data Booklet. Thymine is one of four nitrogen-containing bases present in DNA.

(a) Explain how thymine forms part of a nucleotide in DNA. *[2]*

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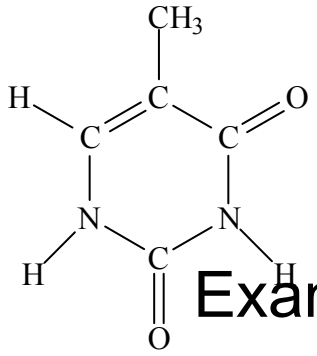
(b) The four nitrogen-containing bases are responsible for the double helix structure of DNA. Using the structure of thymine below and the structure of one of the other bases in Table 21, draw a diagram to explain how thymine is able to play a role in forming a double helix. Identify the type of interactions between the two bases. *[3]*



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(c) Describe how the order in which the four nitrogen-containing bases occur in DNA provides the information necessary to synthesize proteins in a cell. *[2]*

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(This question continues on the following page)

(Question B3 continued)

(d) It is now possible to purchase a work of art made from your own DNA profile.

[Source: www.dna11.com]

Outline the role that restriction enzymes play in making a DNA profile. *[2]*

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Option C — Chemistry in industry and technology

C1. (a) Explain why iron is obtained from its ores using chemical reducing agents but aluminium is obtained from its ores using electrolysis. *[2]*

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(b) Both carbon monoxide and hydrogen can be used to reduce iron ores. State the equations for the reduction of magnetite, Fe_3O_4, with

(i) carbon monoxide. *[1]*

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(ii) hydrogen. *[1]*

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(c) Explain why much of the iron produced in a blast furnace is converted into steel. *[2]*

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(d) State the materials used for the positive and negative electrodes in the production of aluminium by electrolysis. *[2]*

Positive electrode:

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Negative electrode:

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(This question continues on the following page)

(Question C1 continued)

(e) Aluminium is one of the most abundant elements found on Earth. Discuss why it is important to recycle aluminium. *[2]*

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C2. (a) Use high-density poly(ethene) and low-density poly(ethene) as examples to explain the difference that branching can make to the properties of a polymer. *[3]*

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(b) Outline the different mechanisms involved in the manufacture of low-density poly(ethene) and high-density poly(ethene). *[2]*

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(c) During the formation of poly(styrene), a volatile hydrocarbon such as pentane is often added. Describe how this affects the properties of the polymer and give **one** use for this product. *[2]*

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(d) Kevlar can be made by reacting 1,4-diaminobenzene, $H_2NC_6H_4NH_2$, with 1,4-benzenedicarbonyl chloride, $ClOCC_6H_4COCl$. Write the equation for the reaction of n molecules of 1,4-diaminobenzene reacting with n molecules of 1,4-benzenedicarbonyl chloride. *[2]*

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(This question continues on the following page)

(Question C2 continued)

(e) Kevlar is an example of a lyotropic liquid crystal. Outline what is meant by *lyotropic liquid crystal*. *[2]*

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C3. Discuss the production of chlorine and sodium hydroxide from brine using a membrane cell. Include in your answer the materials used for the electrodes, the equations taking place at each electrode and why this method has replaced the mercury cell. *[4]*

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Option D — Medicines and drugs

D1. Aspirin, paracetamol (acetaminophen), morphine and diamorphine (heroin) are all pain killers. Their structures are given in Table 20 of the Data Booklet.

(a) Aspirin is thought to interfere with the production of prostaglandins. Explain how this produces an analgesic effect. *[1]*

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(b) Explain how morphine can prevent pain. *[1]*

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(c) Paracetamol (acetaminophen) is generally considered to be safe to use as an analgesic in small doses. Other than the possibility of death, outline the problems associated with taking larger doses of paracetamol. *[2]*

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(d) State **one** important use for aspirin other than the relief of pain and fever. *[1]*

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(e) Other than the phenyl group, state the name of **one** other functional group that is common to

(i) both paracetamol and morphine. *[1]*

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(ii) both aspirin and diamorphine. *[1]*

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(f) Suggest a reagent that could be used to convert morphine into diamorphine and state the name of the type of reaction taking place. *[2]*

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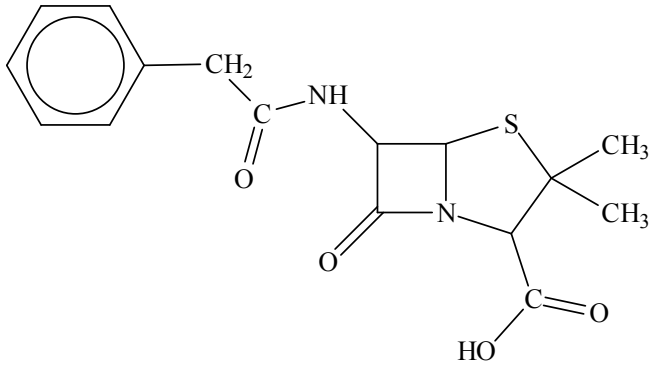
D2. The first penicillin to be used was benzylpenicillin (Penicillin G), its structure is shown below.



(a) Explain how penicillins are able to act as antibacterials. *[2]*

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(b) Modern penicillins have a similar structure to Penicillin G but a different side-chain. State **two** advantages of modifying the side-chain. *[2]*

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(c) The active part of penicillins is the beta-lactam ring. Determine the functional group present in the beta-lactam ring and explain why the ring is important in the functioning of penicillin as an antibacterial. *[3]*

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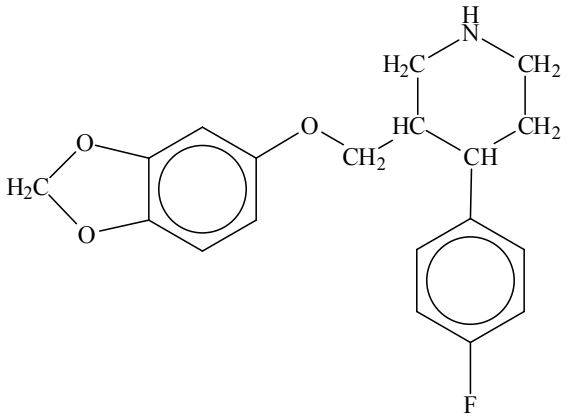
D3. Paroxetine, whose structure is shown below, is a drug prescribed to people suffering from mental depression.



(a) Identify the **two** chiral carbon atoms in the structure above with an asterisk (*). *[2]*

(b) Explain, with an example, the importance of chirality in drug action. *[2]*

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(c) Describe the use of chiral auxiliaries to synthesize the desired enantiomer of a drug. *[2]*

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(d) Paroxetine is usually prescribed in the form of its hydrochloride salt.

(i) Explain why it is used in this form. *[2]*

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(ii) State the structural feature of a molecule of paroxetine that enables it to form a salt. *[1]*

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Option E — Environmental chemistry

E1. (a) Two primary air pollutants are carbon monoxide and oxides of nitrogen. State **one** man-made source for each of these pollutants. *[2]*

Carbon monoxide:

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Oxides of nitrogen:

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(b) Explain how a catalytic converter works and give the equation for the catalysed reaction between carbon monoxide, CO, and nitrogen monoxide, NO. *[3]*

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(c) State **one** other type of primary pollutant, other than carbon monoxide and oxides of nitrogen, that can also be removed from the air by a catalytic converter. *[1]*

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(d) Particulates may be produced by the burning of fossil fuels. Explain how small particulates can be removed from the exhaust gases of coal-burning power stations before they enter the atmosphere. *[2]*

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E2. (a) The disposal of all types of waste is an increasing problem. One method of removing waste is incineration. State **one** advantage and **one** disadvantage of incinerating waste. *[2]*

Advantage:

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Disadvantage:

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(b) State the characteristics and sources of low-level nuclear waste. *[2]*

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(c) The disposal of nuclear waste in the sea is now banned in many countries. Discuss **one** method of storing high-level nuclear waste and two problems associated with it. *[3]*

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E3. (a) There are three main stages of treatment that waste water may undergo before it is fit for drinking. During the primary stage, filtration and sedimentation occur. Describe how most of the oxygen-demanding waste is removed during the secondary stage of treatment. *[2]*

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(b) The tertiary treatment removes nitrates, phosphates and heavy metal ions. Outline why it is difficult to remove nitrate ions by chemical means. *[1]*

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(c) Phosphate ions can be removed by adding calcium or aluminium ions. Give the ionic equation for the reaction of aluminium ions with phosphate ions. *[1]*

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(d) Heavy metal ions can be removed by adding hydroxide ions. When hydroxide ions are added to a solution containing nickel ions, a precipitate of nickel(II) hydroxide, $Ni(OH)_2$, is formed. The solubility product of nickel(II) hydroxide is 6.50×10^{-18} at 298 K. Determine the mass of nickel ions that remains in one litre (1.00 dm^3) of water at 298 K with a pH of 7 after the precipitation reaction has occurred. *[4]*

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(e) Suggest, with an explanation, a chemical method by which this amount of nickel dissolved in the water could be reduced even further. *[2]*

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Option F — Food chemistry

F1. Simple sugars are nutrients and are also described as monosaccharides.

(a) Distinguish between a *food* and a *nutrient*. *[2]*

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(b) State **three** characteristic features of all monosaccharide molecules. *[3]*

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(c) Explain the chemistry behind the non-enzymatic browning reaction that occurs when making fudge from sugar and cream. *[3]*

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F2. (a) Explain why pigments such as anthocyanins are coloured. *[2]*

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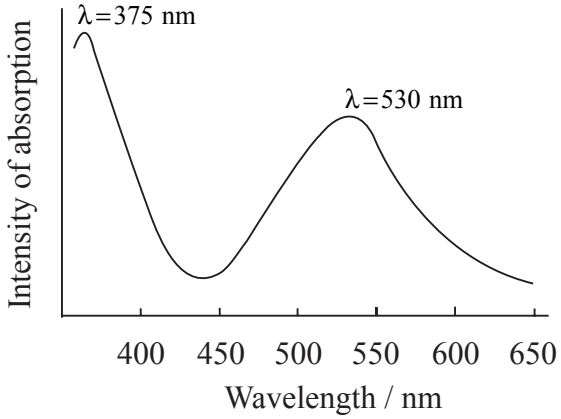
(b) The wavelength of visible light lies between 400 and 750 nm. The absorption spectrum of a particular anthocyanin is shown below.



(i) Explain what effect, if any, the absorption at 375 nm will have on the colour of the anthocyanin. *[1]*

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(ii) Explain what effect, if any, the absorption at 530 nm will have on the colour of the anthocyanin. *[1]*

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(c) List **two** factors which could alter the precise colour of a particular anthocyanin. *[2]*

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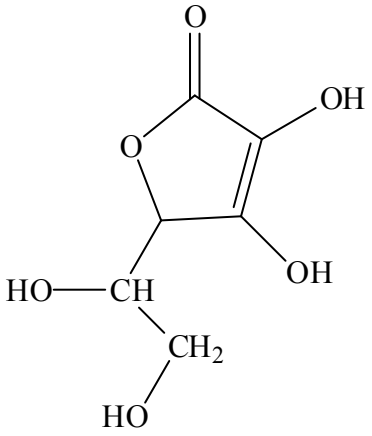
F3. The structure of vitamin C is given below.



(a) Refer to the structure to explain why vitamin C can exist in a +(*d*) form and a –(*l*) form and explain the difference between the two forms. *[2]*

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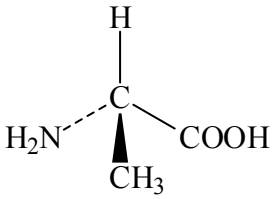
(b) The amino acid alanine is optically active. One of its enantiomers (labelled **A**) is represented below.



A **B**

(i) In the space above draw the other enantiomer of alanine (labelled **B**). *[1]*

(ii) Explain which of the two enantiomers (**A** or **B**) is the D isomer. *[3]*

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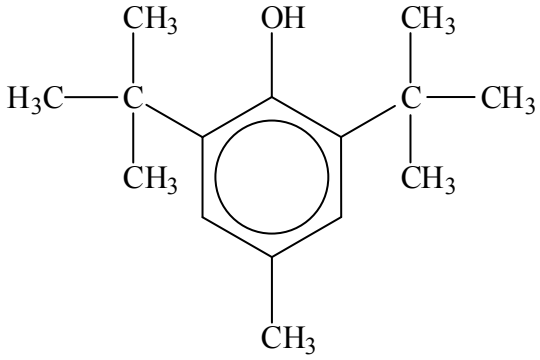
F4. (a) During oxidative rancidity hydroperoxides are formed. These degrade to produce volatile aldehydes and ketones which produce the unpleasant smells associated with food that has "gone off". One way of prolonging the shelf life of food is to add the antioxidant BHT.



(i) Describe two structural features of BHT which are responsible for its antioxidant properties. *[2]*

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(ii) Explain how BHT can prolong the shelf life of food. *[1]*

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(b) Another antioxidant is vitamin C. This works in a different way to BHT. Outline how vitamin C functions as an antioxidant. *[2]*

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Option G — Further organic chemistry

G1. When bromoethane reacts with magnesium in the presence of a non-polar solvent, a Grignard reagent is formed.

(a) Give the equation for the reaction of this Grignard reagent with water. *[2]*

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(b) This Grignard reagent can also react with aldehydes and ketones to give an initial product which can then be hydrolysed by water to form an alcohol. State the names and formulas of the alcohols formed when the Grignard reagent reacts with

(i) ethanal. *[2]*

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(ii) propanone. *[2]*

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(This question continues on the following page)

(Question G1 continued)

(c) Alcohols can undergo elimination reactions in the presence of hot concentrated phosphoric acid.

(i) Name the organic product formed when butan-1-ol undergoes an elimination reaction. *[1]*

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(ii) Explain the mechanism for this elimination reaction using curly arrows to represent the movement of electron pairs. *[3]*

G2. Alkenes can undergo electrophilic addition reactions with bromine and with hydrogen bromide.

(a) Explain how a bromine molecule is able to act as an electrophile. *[1]*

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(b) Name the product formed when but-2-ene reacts with

(i) bromine. *[1]*

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(ii) hydrogen bromide. *[1]*

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(c) When but-1-ene reacts with hydrogen bromide, two possible organic products could be formed but in practice only one organic product is obtained in high yield. Explain the mechanism for this reaction using curly arrows to represent the movement of electron pairs and explain clearly why only one organic product is formed. *[4]*

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G3. Methylbenzene can be prepared from benzene and iodomethane.

(a) State the catalyst used in this reaction and explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. *[4]*

Catalyst: . . . . . .

(b) Methylbenzene reacts when heated with a mixture of concentrated sulfuric acid and concentrated nitric acid.

(i) Name the major organic products formed. *[1]*

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(ii) Identify the electrophile in this reaction and explain how it is formed. *[3]*

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