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**CHEMISTRY
HIGHER LEVEL
PAPER 3**

Tuesday 8 November 2011 (morning)

1 hour 15 minutes

Candidate session number

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Examination code

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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.
- Write your answers in the boxes provided.



0140

Option A — Modern analytical chemistry

A1. Spectroscopy involves techniques that can identify substances and determine their concentrations.

- (a) Identify the atomic or molecular processes associated with the UV and microwave regions of the electromagnetic spectrum. [2]

UV: Microwave:

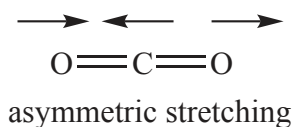
- (b) Atomic absorption (AA) spectroscopy is used for the detection of metal ions.

Besides the detection of calcium ions in blood, water or soil samples, state **two** other uses of AA spectroscopy. Your answer should list the detection of two different metal ions, each from a different source. [1]

Metal ion	Source
1. <i>calcium</i> <i>blood</i>
2.
3.



A2. (a) One type of molecular vibration that occurs when CO₂ molecules are exposed to IR radiation is illustrated in the diagram below.



Identify **two** other types of molecular vibrations that occur when CO₂ molecules are exposed to IR radiation. Illustrate your answer with appropriate diagrams. [2]

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(b) Explain which molecular vibration of CO₂ in (a) above is IR **active** and which is IR **inactive**. [3]

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A3. Nuclear magnetic resonance (NMR) and mass spectrometry are diagnostic techniques often used in the identification of organic compounds.

- (a) Deduce **two similarities** and **one difference** in the ^1H NMR spectra of the two isomers CH_3COOH , a carboxylic acid, and HCOOCH_3 , an ester. ^1H NMR data are given in Table 18 of the Data Booklet. [3]

Similarities:

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Difference:

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- (b) The mass spectrum of one of the two isomers above has significant peaks at mass to charge ratios of 15, 45 and 60, while the other isomer has peaks at 15, 29, 31 and 60. Analyse these fragmentation patterns in the two mass spectra in order to distinguish between the two isomers. [2]

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- (c) Outline how the technique of magnetic resonance imaging (MRI) is used in body scanners. [2]

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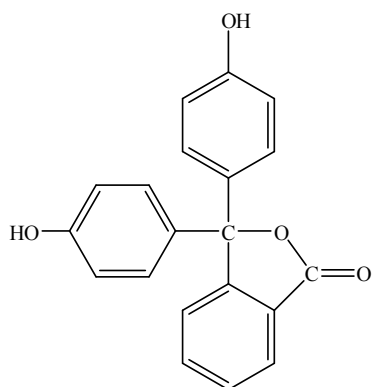
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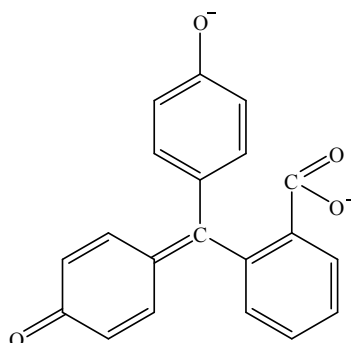
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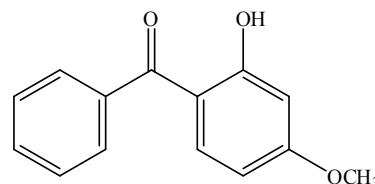
A4. Phenolphthalein indicator is colourless in an acidic solution but coloured in an alkaline solution. Oxybenzone sunscreen is colourless in an aqueous solution. Structures of the three species are shown below.



Phenolphthalein indicator, colourless in an acidic solution



Phenolphthalein indicator, coloured in an alkaline solution



Oxybenzone sunscreen, colourless in an aqueous solution

- (a) Describe and explain, in terms of the difference in conjugation of double bonds, why phenolphthalein indicator has different colours in acidic and alkaline solutions. [2]

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- (b) In acidic solution, phenolphthalein indicator absorbs from about 230 nm to 270 nm. In alkaline solution it absorbs from about 540 nm to 560 nm. Based on the structure of oxybenzone sunscreen, predict and explain the range over which the sunscreen would absorb electromagnetic radiation. Use Table 3 of the Data Booklet to arrive at your answer. [2]

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A5. Chromatography involves a broad range of techniques that can be used to separate and analyse complex mixtures.

(a) Explain why gas-liquid chromatography (GLC) is suitable for the determination of blood alcohol levels but not for the separation of sugar samples. [2]

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(b) Outline the technique of high-performance liquid chromatography (HPLC). [4]

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Option B — Human biochemistry

B1. A student carried out an experiment to determine the energy value of 100.00 g of a food product by burning some of it. A 5.00 g sample was burned and the heat produced was used to heat water in a glass beaker.

She recorded the following data:

Mass of water heated = 100.00 g

Initial temperature of water = 19.2 °C

Highest temperature of water = 28.6 °C

Other data:

Heat capacity of the glass beaker = 90.2 J K⁻¹

Specific heat capacity of water = 4.18 J g⁻¹ K⁻¹

Calculate the energy value for 100.00 g of the food product, in kJ, showing your working. [3]

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B2. Proteins are macromolecules formed from 2-amino acids. Once a protein has been hydrolysed, chromatography and electrophoresis can be used to identify the amino acids present.

(a) State the name of the linkage that is broken during the hydrolysis of a protein and draw its structure. [2]

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(b) Explain how electrophoresis is used to analyse a protein. [4]

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B3. Hormones are involved in a variety of different processes in the body and can vary greatly in their chemical composition and structure. The structures of some hormones are shown in Table 21 of the Data Booklet.

(a) State the function of hormones. [1]

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(b) State the name of **one** functional group present in both estradiol and testosterone. [1]

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B4. Starch and cellulose are polysaccharides found in many plants.

Compare the structures of starch and cellulose. [3]

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B5. Enzymes are protein molecules that catalyse specific biochemical reactions. The phosphorylation of glucose is the first step of glycolysis (the oxidation of glucose) and is catalysed by the enzyme hexokinase.

(a) Explain how enzymes, such as hexokinase, are able to catalyse reactions. [2]

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(b) State and explain the effect of increasing the temperature from 20 °C to 60 °C on an enzyme-catalysed reaction. [4]

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B6. DNA is the genetic material that individuals inherit from their parents. Genetic information is stored in chromosomes which are very long strands of DNA.

(a) Describe the structure of a nucleotide of DNA. [1]

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(b) Outline how nucleotides are linked together to form polynucleotides. [1]

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(c) Outline the steps involved in the DNA profiling of a blood sample. [3]

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Option C — Chemistry in industry and technology

C1. The Industrial Revolution was the result of large-scale extraction of iron from its ore and had significant impact worldwide.

(a) In a blast furnace, a large volume of air is introduced under pressure near the bottom while a mixture of limestone, coke and iron(III) oxide is introduced at the top.

(i) State the equation for the reaction of coke with air in the blast furnace. [1]

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(ii) The product formed in part (i) reacts with coke to produce carbon monoxide. Explain, giving an equation, why this reaction is important in the extraction of iron. [2]

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(b) Iron formed in the blast furnace contains about 5 % carbon, together with other impurities such as phosphorus, silicon and sulfur. Describe, using equations, the chemical principle behind the conversion of impure iron into steel using the basic oxygen converter and explain how the impurities are removed. [3]

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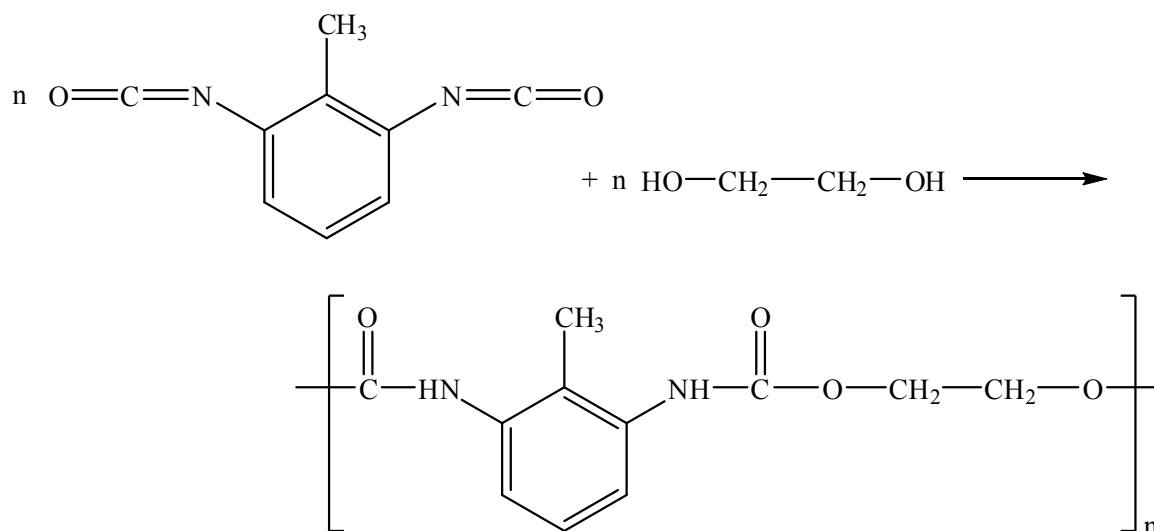


C2. Since the accidental discovery of polyethene in the 1930s, polymers have played an essential role in daily life because of their wide range of properties and uses.

- (a) Titanium compounds are used as catalysts in the manufacture of high-density polyethene (HDPE). Discuss **two** factors scientists would have considered in choosing these catalysts. [2]

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- (b) Polyurethanes are made from dialcohol (diol) and diisocyanate monomers. By considering the structures of the two monomers and the repeating unit of the polymer given below, suggest why it could be argued that this reaction is **not** an example of a condensation polymer. [2]



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(Question C2 continued)

- (c) Kevlar is another example of a condensation polymer. Explain how the great strength of Kevlar depends on its structure. [2]

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- (d) State **one** environmental impact of the disposal of these polyethenes by using incineration. [1]

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C3. Fuel cells convert chemical energy directly into electrical energy that can be used in applications ranging from spacecraft to remote weather stations.

(a) Describe the composition of the electrodes in a hydrogen-oxygen fuel cell. [1]

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(b) State the half-equation at each electrode in the hydrogen-oxygen **alkaline** cell. [2]

Positive electrode (cathode):
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Negative electrode (anode):
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C4. It was over a hundred years after the accidental discovery of liquid crystals that liquid-crystal displays (LCDs) came into common use in the 1990s. Liquid crystals are formed over a temperature range between the solid and the liquid state.

(a) Describe the nematic liquid-crystal phase in terms of the arrangement of the molecules. [2]

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(b) Explain the effect of increasing the temperature on the nematic liquid crystal. [2]

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C5. The chlor-alkali industry manufactures two important products (sodium hydroxide and chlorine) from the electrolysis of aqueous sodium chloride. The membrane cell is increasingly used in this process.

(a) (i) State either the composition **or** the type of membrane used in this cell. [1]

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(ii) State the half-equation for the reaction taking place at each electrode in the membrane cell. [2]

Positive electrode (anode):
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Negative electrode (cathode):
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(b) Discuss **two** reasons why the membrane cell is replacing the mercury-cathode and diaphragm cells in the chlor-alkali industry. [2]

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Option D — Medicines and drugs

D1. Medicines and drugs are natural or synthetic substances used for their effects on the body.

- (a) List **two** general effects of medicines and drugs on the functioning of the body. [1]

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- (b) Describe the placebo effect and state its importance in drug development. [2]

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D2. Stimulants stimulate the brain and the central nervous system and tend to increase alertness and physical activity. Structural formulas of some stimulants are given in Table 20 of the Data Booklet.

(a) Compare the structures of the two stimulants amphetamine and epinephrine (adrenaline). [2]

Similarity: Difference:
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(b) Predict and explain which of these two stimulants would be more water soluble. [2]

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(This question continues on the following page)



(Question D2 continued)

(c) Caffeine and nicotine are also stimulants.

(i) Identify the type of amine that is present in both caffeine and nicotine. [1]

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(ii) Deduce whether an aqueous solution of caffeine is acidic, basic or neutral and explain your reasoning. [2]

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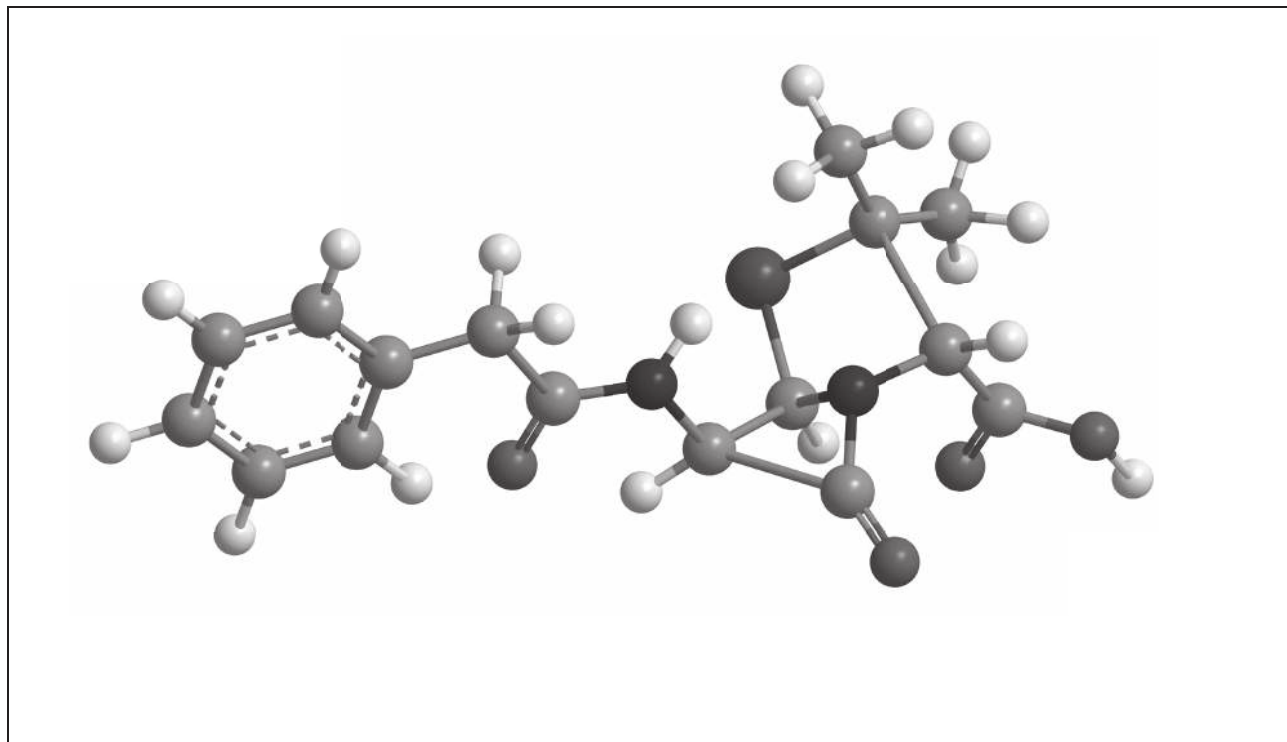
(iii) Describe **two** effects of caffeine when it is consumed in large amounts. [1]

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D3. Antibiotics treat infections by stopping the growth of bacteria or destroying them.

- (a) Identify the side-chain by drawing a circle around the side-chain in the structure of benzyl penicillin given below (the structure of penicillin is given in Table 20 of the Data Booklet). [1]



- (b) Discuss **two** problems associated with the overprescription of penicillin and explain how these are overcome. [3]

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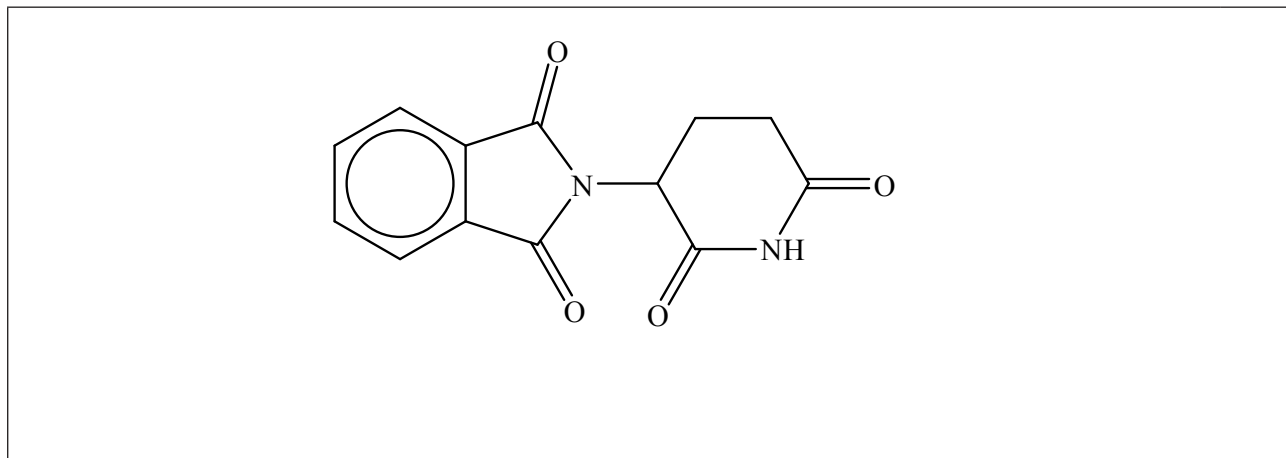
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D4. Chirality plays an important role in the action of drugs.

(a) Using an asterisk (*), identify the chiral carbon atom in the structure of thalidomide. [1]



(b) Describe the composition of a racemic mixture. [1]

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(c) Discuss the importance of chirality in drug action using thalidomide as the example. [2]

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D5. (a) Some drugs can be converted into ionic salts in order to increase their solubility in water.

(i) State the equation for the formation of the ionic salt of aspirin, $\text{CH}_3\text{COO}(\text{C}_6\text{H}_4)\text{COOH}$. [1]

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(ii) State the equation for the formation of the ionic salt of fluoxetine, $\text{F}_3\text{C}(\text{C}_6\text{H}_4)\text{OCH}(\text{C}_6\text{H}_5)\text{CH}_2\text{CH}_2\text{NHCH}_3$. [1]

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(b) Chiral auxiliaries are used in drug design. Describe how a chiral auxiliary works. [2]

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(c) Discuss **one** argument for and **one** argument against the legalization of cannabis. [2]

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Option E — Environmental chemistry

E1. Nitrogen dioxide and sulfur dioxide are two air pollutants.

- (a) Nitrogen dioxide is formed in a two-stage process. Describe **one** anthropogenic (man-made) source of nitrogen dioxide and state the **two** chemical equations for its formation. [2]

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- (b) Apart from using renewable technologies, state **one** method in each case for the removal of nitrogen dioxide and sulfur dioxide from emission gases before they enter the atmosphere. [2]

Nitrogen dioxide:
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Sulfur dioxide:
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- (c) Both of these air pollutants also contribute to acid deposition. Outline mechanisms for the formation of HNO_3 and SO_3 . [4]

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E2. The temperature of the Earth is increasing. There is considerable scientific evidence to suggest this is due to an increase in the concentration of greenhouse gases as a result of human activity.

(a) Explain how this enhanced greenhouse effect causes the average temperature of the Earth to increase. [3]

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(b) Compare the contributions of carbon dioxide and methane to the enhanced greenhouse effect. [2]

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E3. (a) Raw sewage is the water-carried waste that flows away from a community. If it is discharged untreated into rivers and the sea it causes pollution. Therefore, waste water should be treated before it is discharged.

Phosphate ions are one of the pollutants removed from sewage water by chemical precipitation using calcium ions.

The solubility product, K_{sp} , of calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$, is 1.20×10^{-26} at 298 K.

Determine the concentration of phosphate ions, in mol dm^{-3} , in a saturated solution of calcium phosphate. [3]

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(This question continues on the following page)



(Question E3 continued)

- (b) In many countries the reserves of fresh water are scarce, so fresh water is obtained from sea water. Antigua, for example, produces much of its fresh water by reverse osmosis whereas the UAE produces much of its fresh water through multi-stage distillation.

Evaluate these two processes. Your answer should include at least **one** advantage and **one** disadvantage for each process.

[4]

<p>Advantage distillation:</p> <p>.....</p> <p>.....</p> <p>Disadvantage distillation:</p> <p>.....</p> <p>.....</p> <p>Advantage reverse osmosis:</p> <p>.....</p> <p>.....</p> <p>Disadvantage reverse osmosis:</p> <p>.....</p> <p>.....</p>



E4. Soil can be polluted by a variety of substances.

List **two** common organic soil pollutants and state their sources.

[2]

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E5. One of the winners of the 1995 Nobel Prize in Chemistry was Paul J. Crutzen, who showed that emissions of nitrogen oxides from jet airplanes could contribute to the destruction of the ozone layer.

Using chemical equations, outline a mechanism by which nitrogen oxides are able to deplete ozone.

[3]

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Option F — Food chemistry

F1. A healthy diet consists of a range of food groups in the right proportions that provide the energy for the body to function, grow and repair itself.

(a) State the empirical formula and structural features of monosaccharides. [2]

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(b) (i) State the structural formula of 2-aminoethanoic acid. [1]

(ii) Deduce the structural formula of a triester formed from **three** long-chain carboxylic acid molecules, RCOOH, and **one** propane-1,2,3-triol molecule, HO-CH₂CH(OH)-CH₂OH. Identify **one** of the ester linkages in the structure by drawing a rectangle around it. [2]

(This question continues on the following page)



(Question F1 continued)

(c) Examples of straight-chain fatty acids include $C_{19}H_{39}COOH$, $C_{19}H_{31}COOH$ and $C_{19}H_{29}COOH$.

(i) Deduce the number of C=C bonds present in one molecule of each fatty acid. [2]

$C_{19}H_{39}COOH$:
$C_{19}H_{31}COOH$:
$C_{19}H_{29}COOH$:

(ii) Deduce the **least** stable of the three fatty acids and explain your reasoning. [2]

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F2. The oxidative rancidity reaction in foods involves a free-radical mechanism. State an equation for each of the following steps, using RH to represent an unsaturated fatty acid. [3]

Initiation:

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Propagation:

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Termination:

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F3. The browning of food during cooking is caused by two different processes, *caramelization* and *non-enzymatic browning* (Maillard reaction). These processes lead to a pleasant colour and flavour in a variety of food products. In the foods listed below, assume the following formulas:

- Sugar: $C_6H_{12}O_6$
- Reducing sugar: $HOCH_2(CH(OH))_4CHO$
- Amino acid: $H_2N-CHR-COOH$

Compare the two browning processes with respect to the chemical composition of the foods affected and state the chemical equation for the Maillard reaction.

[4]

Chemical composition of foods that undergo the caramelization process:

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Chemical composition of foods that undergo the non-enzymatic browning process:

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Maillard reaction equation:

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F4. Foods derived from genetically modified organisms were introduced in the early 1990s. State **one** benefit and **one** concern of consuming genetically modified foods. [2]

Benefit:

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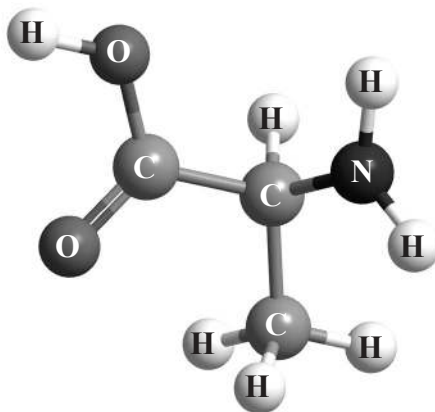
Concern:

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F5. Stereochemistry is the study of the spatial arrangement of atoms in molecules. A molecule containing a chiral carbon atom exists as two enantiomers. Three different conventions can be used for naming purposes.

- (a) Use the CORN rule to determine whether the structure of 2-aminopropanoic acid (alanine) represents the D or L form. Justify your answer. [2]



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- (b) State the (*d*) or the (*l*) convention. [1]

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F6. A food product is often judged simply by its colour. Natural pigments that give rise to food colour include anthocyanins, carotenes, chlorophyll and heme. The structures of these pigments are shown in Table 22 of the Data Booklet.

(a) Explain why these natural pigments are coloured. [2]

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(b) Deduce from their structures whether anthocyanins and carotenes are water-soluble or fat-soluble. [2]

Anthocyanins:

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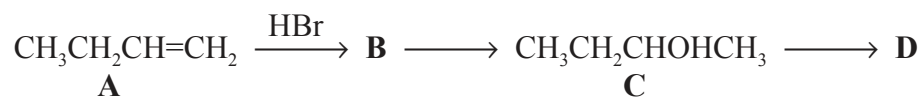
Carotenes:

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Option G — Further organic chemistry

G1. Consider the following reaction pathway starting with compound **A** which is but-1-ene.



- (a) (i) **A** reacts with HBr to form a major and a minor product. Draw the structural formulas of these two isomers. [1]

- (ii) Explain the mechanism of the reaction of **A** with HBr to form the major product, **B**, using curly arrows to represent the movement of electron pairs. [4]

(This question continues on the following page)



(Question G1 continued)

(iii) Explain why **B** is the major product formed in the reaction of **A** with HBr. [2]

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(b) (i) Compound **C** can be converted directly to compound **A**. Identify the reagent used for this conversion. [1]

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(ii) State the chemical equation for the reaction of compound **C** with ethanoyl chloride, CH_3COCl , and draw the structural formula of the organic product formed in this reaction. [2]

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(This question continues on the following page)



(Question G1 continued)

(c) Compound **D**, molecular formula C_4H_8O , is formed when **C** is heated with acidified potassium dichromate(VI).

(i) Compound **D** reacts with 2,4-dinitrophenylhydrazine, $H_2NNH-C_6H_3(NO_2)_2$, to give a solid **E**. Deduce the structural formula of **E**. [1]

(ii) Compound **D** reacts with the Grignard reagent methylmagnesium bromide, CH_3MgBr , and water to give the organic product **F**. Deduce the structural formula of **F**. [1]

(iii) State the name of the type of mechanism when **D** reacts with hydrogen cyanide to produce **G**. [1]

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(iv) Deduce the structural formula of the organic product formed when **G** is hydrolysed by an acid. [1]



G2. By referring to Table 15 of the Data Booklet, compare and explain the relative basicities of ammonia, methylamine and dimethylamine. [3]

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G3. Benzene, C_6H_6 , reacts with bromomethane, CH_3Br , under appropriate conditions, to form methylbenzene, $C_6H_5CH_3$.

(a) Explain the mechanism for the reaction of benzene with bromomethane, using curly arrows to represent the movement of electron pairs. [3]

(This question continues on the following page)



(Question G3 continued)

(b) Both benzene and methylbenzene undergo electrophilic substitution reactions to synthesize other compounds.

(i) Deduce the structural formula of **one** organic product formed when methylbenzene reacts with bromine by electrophilic substitution. [1]

(ii) Compare and explain the relative rates of the electrophilic substitution reaction of benzene and methylbenzene with bromine. [4]

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