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**CHEMISTRY**
**STANDARD LEVEL**
**PAPER 3**

Candidate session number

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Tuesday 8 November 2011 (morning)

1 hour

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.

**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:

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Microwave:

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

(i) Describe **three principles** of AA spectroscopy. *[3]*

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*(This question continues on the following page)*

*(Question A1 continued)*

(ii) 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.** ..... ***calcium*** ..... | ..... ***blood*** ..... |
| **2.** ..... | ..... |
| **3.** ..... | ..... |

(iii) Explain how a student can determine the concentration of a metal ion in solution using AA spectroscopy. *[2]*

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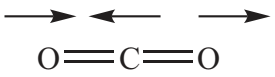
**A2.** (a) One type of molecular vibration that occurs when $CO_2$ molecules are exposed to IR radiation is illustrated in the diagram below.




asymmetric stretching

Identify **two** other types of molecular vibrations that occur when $CO_2$ molecules are exposed to IR radiation. Illustrate your answer with appropriate diagrams. *[2]*

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(b) Explain which molecular vibration of $CO_2$ 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 $^1$H NMR spectra of the two isomers $CH_3COOH$, a carboxylic acid, and $HCOOCH_3$, an ester. $^1$H 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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**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 names of **two** functional groups present in both testosterone and progesterone. *[2]*

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

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(d) Explain **three** different ways oral contraceptives taken by women prevent pregnancy. *[3]*

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

(a) Compare the structures of starch and cellulose. *[3]*

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(b) Explain why humans cannot digest cellulose. *[1]*

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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) Describe a structural feature of low-density polyethene (LDPE) that explains why LDPE has a different melting point from that of HDPE. *[4]*

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(c) 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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**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.** Medicines are classified by the effect each has on the body and the mind. One such example is depressants.

(a) Describe **one** effect of depressants on the human body when a moderate dose is used and **one** when a high dose is used. *[2]*

Moderate dose:

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High dose:

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(b) Breathalysers use acidified potassium dichromate(VI) to oxidize any ethanol vapour in an individual's breath to ethanoic acid.

(i) Deduce the half-equation for the oxidation of ethanol with water to form ethanoic acid and hydrogen ions. *[1]*

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(ii) Deduce the half-equation for the reduction of acidified dichromate(VI) ions to $Cr^{3+}(aq)$ and water. *[1]*

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(c) State **two** other methods that can detect ethanol in the human body. *[1]*

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**D3.** 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:

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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 D3 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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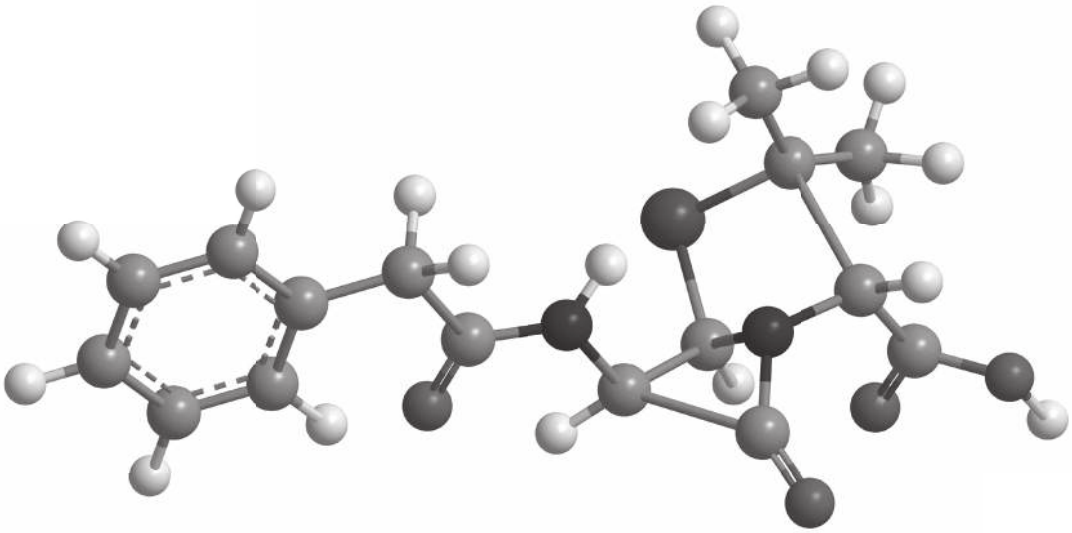
**D4.** Antibiotics treat infections by stopping the growth of bacteria or destroying them.

(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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**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. State **one** chemical equation for **each** gas to describe how each forms an acidic solution. *[2]*

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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.** 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]*

Advantage distillation:

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Disadvantage distillation:

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Advantage reverse osmosis:

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Disadvantage reverse osmosis:

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**E4.** Ozone is a naturally occurring component of the stratosphere. The ozone layer occurs in the stratosphere about 30 km above the surface of the Earth.

Stratospheric ozone is in dynamic equilibrium with oxygen and is continually being formed and decomposed.

(a) State the condition needed for the depletion of ozone in the stratosphere by natural processes. State the **two** chemical equations for the process. *[3]*

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(b) State the names of **two** ozone-depleting pollutants and state their sources. *[2]*

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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, $HO–CH_2CH(OH)–CH_2OH$. 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.** Food shelf life is the time it takes for a particular foodstuff to become unsuitable for eating because it no longer meets customer or regulatory expectations. As a result, in many parts of the world, packaged foods have a date before which they should be consumed.

(a) State the meaning of the term *rancidity* as it applies to fats. *[1]*

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(b) Rancidity in lipids occurs by *hydrolytic* and *oxidative* processes.

(i) Compare the two rancidity processes. *[2]*

Hydrolytic process:

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Oxidative process:

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*(This question continues on the following page)*

*(Question F2 continued)*

(ii) State **one** example of a food containing lipids that undergoes hydrolytic rancidity and **one** that undergoes oxidative rancidity. *[2]*

Hydrolytic rancidity:

. . . . . .

Oxidative rancidity:

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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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**Option G — Further organic chemistry**

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

$$\underset{\mathbf{A}}{CH_3CH_2CH{=}CH_2} \xrightarrow{HBr} \mathbf{B} \longrightarrow \underset{\mathbf{C}}{CH_3CH_2CHOHCH_3} \longrightarrow \mathbf{D}$$

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

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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) Deduce the structural formula of **D**. *[1]*

(ii) 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]*

(iii) Explain the mechanism for the reaction of **D** with hydrogen cyanide to form **F**, using curly arrows to represent the movement of electron pairs. *[4]*

**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, $C_6H_6$, is the simplest aromatic hydrocarbon.

Describe and explain the structure of benzene. *[3]*

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