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CHEMISTRY
STANDARD LEVEL
PAPER 3

Friday 9 May 2008 (morning)

1 hour

Candidate session number

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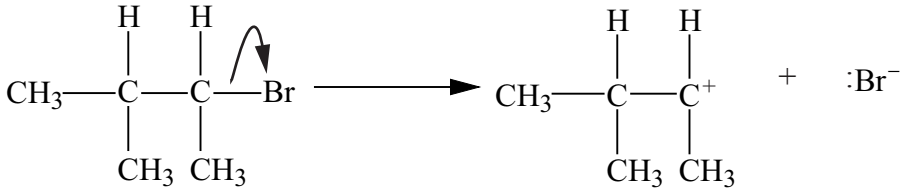
INSTRUCTIONS TO CANDIDATES

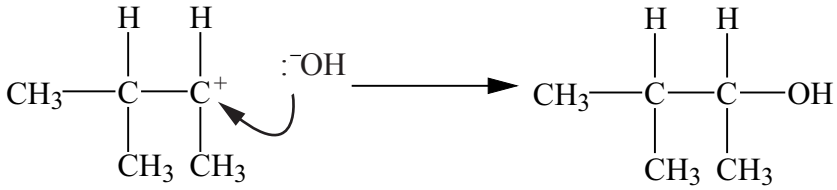
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them 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.

0120

Option A – Higher physical organic chemistry

A1. Compound **A** is a halogenoalkane with the structural formula $(CH_3)_2CHCH(CH_3)Br$. Compound **A** reacts with sodium hydroxide solution to form compound **B** by two different mechanisms. The S_N1 mechanism can be shown as follows.

I 

II 

(a) (i) State whether compound **A** is a primary, secondary or tertiary halogenoalkane, giving a reason for your choice. *[1]*

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(ii) State the meaning of each of the three symbols in the term S_N1. *[2]*

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(iii) Identify which of the steps I and II: *[2]*

shows bond formation . . . . . .

shows the formation of a carbocation . . . . . .

is the rate-determining step. . . . . .

(This question continues on the following page)

(Question A1 continued)

(iv) Deduce the name of compound **B**. *[1]*

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(v) Predict the rate expression for this S_N1 reaction, using RBr to represent compound **A**. *[1]*

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(b) Compound **A** also reacts with sodium hydroxide solution by an S_N2 mechanism. Explain how this reaction occurs by using curly arrows to represent the movement of electron pairs, and show the structure of the transition state. *[3]*

(c) Compounds **A** and **B** can be distinguished by spectroscopic methods.

(i) Predict the number of peaks in the ^{1}H NMR spectrum of compound **A**. *[1]*

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(ii) Predict the ratio of areas under each peak in this ^{1}H NMR spectrum. *[1]*

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(iii) Identify **one** wavenumber range for an absorption in the infrared spectrum of compound **B** that is not present in the infrared spectrum of compound **A**. *[1]*

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A2. The pK_a values of some organic acids are shown in Table 16 of the Data Booklet.

(a) Identify the acid in Table 16 that is the strongest halogenated carboxylic acid, and calculate its K_a value. *[2]*

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(b) One of the phenols in Table 16 has a K_a value of 9.77×10^{-5} mol dm^{-3}. Calculate its pK_a value and identify which phenol it is. *[1]*

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(c) Deduce the K_a expression for propanoic acid. *[1]*

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(d) The K_a value of propanoic acid is 1.35×10^{-5} mol dm^{-3}. Determine the pH value of a solution of propanoic acid of concentration 0.25 mol dm^{-3}. *[3]*

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Option B – Medicines and drugs

B1. Antacid tablets are used to neutralize some of the hydrochloric acid in the stomach. Two substances commonly used in the tablets are calcium carbonate and sodium hydrogencarbonate.

(a) Write an equation to represent each of these neutralization reactions. *[2]*

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(b) Explain, with reference to the equations in part (a), why a tablet containing 0.01 mol of calcium carbonate is more effective than one containing 0.01 mol of sodium hydrogencarbonate. *[1]*

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(c) Explain why alginates are often included in antacid tablets. *[1]*

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(d) Dimethicone is often included in antacid tablets because of its anti-foaming action.

(i) Explain, with reference to the equations in part (a), why dimethicone is included. *[1]*

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(ii) Identify another base used in antacid tablets for which dimethicone need not be included. *[1]*

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B2. Some medicines prescribed by doctors are classified as depressants. These depress the central nervous system.

(a) Describe **one** effect of depressants on the human body:

(i) at a moderate dose; *[1]*

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. . . . . .

(ii) at a high dose. *[1]*

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(b) Explain why depressants are sometimes referred to as anti-depressants. *[1]*

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(c) One depressant not prescribed by doctors but widely used in some societies is ethanol.

(i) Describe **two** long-term effects of consuming large quantities of ethanol on the human body, other than those you have given in part (a). *[2]*

1 . . . . . .

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2 . . . . . .

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(ii) One method used to check whether a car driver has consumed ethanol is the breathalyser. This makes use of an oxidation reaction of ethanol. For this reaction, identify: *[3]*

the reagent used . . . . . .

the colour change . . . . . .

a possible organic product. . . . . .

B3. The term *penicillins* is used to describe a range of substances that are effective against bacteria, but not against viruses. The general structure of penicillins is shown in Table 21 of the Data Booklet. The first substance to include the term penicillin in its name was penicillin G (benzylpenicillin), in which R is $C_6H_5CH_2$.

(a) Deduce the number of carbon atoms in one molecule of penicillin G. *[1]*

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(b) Some bacteria are resistant to penicillin G.

(i) Explain how these bacteria are able to resist the effect of penicillin G. *[1]*

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(ii) Describe how the structure of penicillin G was modified to overcome this problem. *[1]*

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(c) Explain how penicillins are able to destroy bacteria. *[1]*

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(d) A doctor prescribes a broad-spectrum antibiotic for a patient, then some days later prescribes a narrow-spectrum antibiotic.

(i) Describe what the doctor does to allow the medication to be changed to the narrow-spectrum antibiotic. *[1]*

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(ii) State the main disadvantage of using a broad-spectrum antibiotic. *[1]*

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Option C – Human biochemistry

C1. Table 20 of the Data Booklet shows the structural formulas of some amino acids.

(a) Deduce the structures of the two dipeptides that can be formed from one molecule of each of the amino acids alanine and cysteine. *[2]*

(b) State the type of reaction that occurs in the formation of a dipeptide and identify the other product of the reaction. *[2]*

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(c) A polypeptide can be analysed using electrophoresis.

(i) Explain why hydrochloric acid is used before electrophoresis can occur. *[1]*

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(ii) Describe how amino acids are identified by electrophoresis. *[4]*

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C2. Two fatty acids found in rapeseed oil are behenic acid and erucic acid.
Both contain the same number of carbon atoms in a molecule.
Behenic acid is saturated and erucic acid is monounsaturated.
The abbreviated structural formula of erucic acid is $CH_3(CH_2)_7CH{=}CH(CH_2)_{11}COOH$ and its relative molecular mass is 338.

(a) (i) Deduce the abbreviated structural formula of behenic acid. *[1]*

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. . . . . .

(ii) Determine the relative molecular mass of behenic acid. *[1]*

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(b) Explain why the melting point of erucic acid is lower than that of behenic acid. *[3]*

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(c) The term *iodine number* is the number of grams of iodine that react with 100 g of a fat.
The iodine number of arachidonic acid (M_r = 304) is approximately 334.
Deduce the number of C=C double bonds in one molecule of arachidonic acid. *[2]*

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C3. Adrenaline and thyroxine are important hormones in the human body. Their structures are shown in Table 22 of the Data Booklet.

(a) Complete the table of information about them. *[2]*

	Adrenaline	**Thyroxine**
Elements present, other than carbon, hydrogen, oxygen	nitrogen	
Where produced		

(b) Identify the **two** glands in the human body involved in controlling the release of hormones. *[2]*

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Option D – Environmental chemistry

D1. The table below gives information about some primary air pollutants.

Pollutant	Possible natural source	Possible man-made source
NO	reaction in air during thunderstorms	reaction in air during combustion of gasoline
SO_2	eruptions of volcanoes	smelting of sulfide ores
hydrocarbons	emissions from plants and trees	evaporation of organic solvents

(a) Write the equation for the formation of NO that applies to both sources in the table. *[1]*

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(b) Some of the SO_2 produced in volcanoes is formed by the oxidation of hydrogen sulfide, H_2S. Deduce the equation for this reaction. *[1]*

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(c) Outline the effect on human health that can be caused by both NO and SO_2. *[1]*

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(d) Both NO and CO are present in the exhaust gases of gasoline-fuelled cars. Write the equation for the reaction in a catalytic converter that removes both pollutants. *[1]*

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(e) The stoichiometric air:fuel ratio for a car is approximately 14.6:1. A lean burn engine using a 16:1 ratio changes the amounts of pollutants formed in the exhaust gases. In a lean burn engine, identify a pollutant whose amount is: *[2]*

increased . . . . . .

decreased. . . . . .

(f) State how particulates are removed by an electrical method. *[1]*

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D2. (a) N_2O and CO_2 are both greenhouse gases.

(i) State why N_2O could be considered more important than CO_2 as a greenhouse gas. *[1]*

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(ii) State why CO_2 could be considered more important than N_2O as a greenhouse gas. *[1]*

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(b) Discuss the greenhouse effect. Include in your answer reference to:

- radiation of two different wavelengths
- **one** consequence of an increased greenhouse effect. *[4]*

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D3. (a) Discuss the use of chlorine and ozone to treat drinking water. Include in your answer reference to:

- the reason for the difference in cost
- the retention times
- the quality of water after treatment. *[4]*

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(b) Outline the method of reverse osmosis used to obtain drinking water from sea water. *[3]*

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Option E – Chemical industries

E1. One compound in the ores used in the blast furnace to obtain iron is Fe_3O_4.
The other solid raw materials used are coke and limestone.
Hot air is blasted into the furnace. In some furnaces the air is mixed with natural gas.

(a) Deduce an equation for each of the following reactions in this blast furnace.

(i) The partial combustion of methane to form carbon monoxide and hydrogen. *[1]*

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(ii) The partial reduction of Fe_3O_4 by hydrogen to form iron(II) oxide and steam. *[1]*

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(iii) The complete reduction of iron(II) oxide by carbon monoxide. *[1]*

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(b) Iron from the blast furnace has a typical carbon content of 4% and smaller amounts of silicon and phosphorus. The amounts of these elements are decreased in the basic oxygen converter in reactions such as these:

$$C + O_2 \rightarrow CO_2$$
$$Si + O_2 \rightarrow SiO_2$$
$$4P + 5O_2 \rightarrow 2P_2O_5$$

(i) State **one** important change to the properties of iron caused by the decrease in carbon content. *[1]*

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(ii) State the type of reaction that occurs when lime (calcium oxide) is added to the converter. *[1]*

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E2. Aluminium is extracted from its purified ore by electrolysis.

(a) Explain why a blast furnace is not used to extract aluminium. *[1]*

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(b) The purified ore, mostly Al_2O_3, is mixed with cryolite. State **one** function of cryolite in the extraction. *[1]*

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(c) Write the equations for the reactions that occur at each electrode during electrolysis. *[2]*

positive electrode

. . . . . .

negative electrode

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(d) Identify the material used for the positive electrodes and explain why these electrodes have to be replaced frequently. *[2]*

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E3. (a) An important process in the oil industry is the fractional distillation of crude oil. In this process, crude oil vapour is passed into a tall column. Explain how the column separates the crude oil into fractions. *[3]*

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(b) Some of the fractions are cracked. Information about three methods of cracking is shown in the table below. Complete the table using examples other than those already given. *[4]*

Type of cracking	Catalyst used	Other substance present	Example of type of product formed
Steam cracking	none	steam	
Catalytic cracking		none	branched alkanes
Hydrocracking			aromatic compounds

(c) One example of a cracking reaction is the conversion of one molecule of heptane, C_7H_{16}, into two molecules of ethene and one molecule of an alkane. Deduce the equation for this reaction. *[1]*

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(d) Cyclization is used in the oil industry to convert alkanes into cyclic alkanes. One example is the conversion of hexane into cyclohexane, C_6H_{12}. Deduce the equation for this reaction. *[1]*

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Option F – Fuels and energy

F1. Fossil fuels are often compared by calculating the amount of heat generated by the combustion of 1 g of fuel. Values of enthalpy of combustion of pure substances, measured in $kJ\ mol^{-1}$, appear in Table 13 of the Data Booklet.

(a) Use this information to calculate the heat produced, in $kJ\ g^{-1}$, when 1 g of each of the following fossil fuels is burned.

- Coal (assumed to be graphite)
- Natural gas (assumed to be methane)
- Gasoline (assumed to be octane) *[3]*

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(b) One problem with using coal as a fuel is the air pollution it causes.

(i) Suggest **one** pollutant that is much more likely to be formed when burning coal than when burning natural gas or gasoline. *[1]*

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(ii) Coal gasification involves heating coal with steam to form a mixture of two flammable gases. Deduce the equation for this reaction. *[1]*

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F2. (a) Outline **two** characteristics of nuclear reactions that are not found in chemical reactions. *[2]*

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(b) One reaction used to produce energy involves the conversion of uranium-235 into barium-144 and krypton-90. The reaction occurs when an atom of ^{235}U is hit by a neutron. Deduce the equation for this reaction, showing the mass number and atomic number of each species. *[2]*

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(c) The half-life of the radio-isotope ^{214}Bi is 20 minutes.

(i) Define the term *half-life*. *[1]*

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(ii) A sample of ^{214}Bi with a mass of 128 mg is left for two hours. Calculate the mass of ^{214}Bi remaining after this time. *[2]*

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(This question continues on the following page)

(Question F2 continued)

(iii) ^{214}Bi decays by emitting either an alpha particle or a beta particle. Deduce the symbol of the element formed in each case. *[2]*

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(iv) State **two** differences in the movement of alpha and beta particles in an electric field. *[2]*

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F3. The lead-acid battery is used in automobiles. Each cell contains lead(IV) oxide as the positive electrode and lead metal as the negative electrode. The electrolyte, sulfuric acid, contains H^+ and SO_4^{2-} ions.

(a) When the battery produces an electric current, reduction occurs at the positive electrode and oxidation at the negative electrode. In both cases lead(II) sulfate is formed. Deduce the equation for each of these reactions. *[2]*

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(b) The voltage of this cell is 2 V.

(i) Explain why it is not possible to substantially increase the voltage produced by a cell. *[1]*

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(ii) Explain why most lead-acid batteries produce a voltage of 12 V. *[1]*

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