IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

N07/4/CHEMI/SP3/ENG/TZ0/XX+

88076106

CHEMISTRY
STANDARD LEVEL
PAPER 3

Thursday 15 November 2007 (morning)

1 hour

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

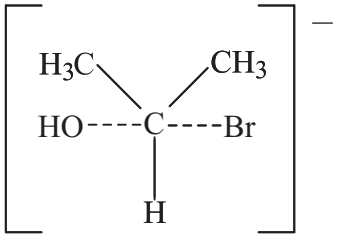
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers on answer sheets. Write your session number on each answer sheet, and attach them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

0122

© IBO 2007

Option A – Higher physical organic chemistry

A1. The following transition state is formed during the reaction of a halogenoalkane with aqueous sodium hydroxide:



(a) Deduce the structure of the halogenoalkane. Classify it as primary, secondary or tertiary, giving a reason for your choice. *[2]*

. . . . . .

. . . . . .

(b) The mechanism of this reaction is described as S_N2. Explain what is meant by the symbols in S_N2. Predict a rate expression for this reaction. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) The same halogenoalkane reacts with sodium hydroxide by an S_N1 mechanism. Deduce the structure of the intermediate formed in this reaction. *[1]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

A2. There are four structural isomers that are alcohols with the formula C_4H_9OH.

(a) Explain why the infrared spectra of all four alcohols show very similar absorptions around 3350 cm^{-1} and 2900 cm^{-1}. *[2]*

. . . . . .

. . . . . .

. . . . . .

(b) Describe how these alcohols can be distinguished using their infrared spectra. *[1]*

. . . . . .

. . . . . .

(c) Explain why the mass spectra of all four alcohols show a peak at $m/z = 74$. *[1]*

. . . . . .

. . . . . .

(d) Suggest the formulas of the fragments formed from C_4H_9OH with the following m/z values: *[2]*

$m/z = 57$ . . . . . .

$m/z = 45$ . . . . . .

(e) The numbers of peaks, and the areas under them, in the ^1H NMR spectra of these alcohols can be used to identify them.

(i) Explain why the ^1H NMR spectrum of $(CH_3)_2CHCH_2OH$ has four peaks. Predict the ratio of the areas under the peaks. *[2]*

. . . . . .

. . . . . .

(ii) Deduce the structure of the alcohol whose ^1H NMR spectrum has two peaks with areas in the ratio 9 : 1. *[1]*

. . . . . .

. . . . . .

. . . . . .

A3. The hydrogen ion concentration in pure water varies with temperature. At a particular temperature $[H^+] = 1.7 \times 10^{-7}$ mol dm^{-3}.

(a) State the expression for the ionic product constant of water, K_w, and calculate the value of K_w at this temperature. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Calculate the pH of water at this temperature. *[1]*

. . . . . .

. . . . . .

(c) State and explain whether water at this temperature is acidic, neutral or alkaline. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option B – Medicines and drugs

B1. It takes many years to introduce a new drug onto the market.

(a) Explain the purpose of making many structural modifications to a drug in the research stage. *[1]*

. . . . . .

. . . . . .

(b) Explain the meaning of these terms:

(i) The LD_{50} test. *[1]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) The placebo effect. *[1]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

B2. Antacids can be taken for indigestion caused by excess acidity.

(a) Identify the substance responsible for the low pH value of the liquid in the human stomach. *[1]*

. . . . . .

. . . . . .

(b) Two active ingredients in antacids are $Mg(OH)_2$ and $NaHCO_3$. Write an equation to show how each ingredient can relieve indigestion. *[2]*

. . . . . .

. . . . . .

(c) Three antacid preparations contain 0.01 mol of one of the following – $Mg(OH)_2$, $Al(OH)_3$ and $NaHCO_3$. Identify the most effective antacid. Give a reason for your choice, with reference to the formula of the antacid. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(d) Give **two** reasons why alginates are included in many antacids. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

B3. Refer to Table 21 of the Data Booklet when answering this question about analgesics.

(a) Describe the different ways in which mild and strong analgesics prevent pain. *[4]*

mild analgesics:. . . . . .

. . . . . .

. . . . . .

. . . . . .

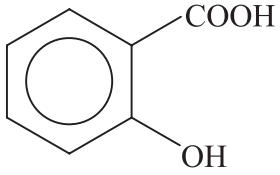
strong analgesics: . . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Some mild analgesics are derivatives of salicylic acid. The structure of salicylic acid is



(i) Salicylic acid can be converted to aspirin. Give the formula of the group that replaces one hydrogen atom in a molecule of salicylic acid in this conversion. *[1]*

. . . . . .

. . . . . .

(ii) State the names of **two** functional groups present in acetaminophen (paracetamol) and **one** functional group present in ibuprofen. *[3]*

acetaminophen (paracetamol). . . . . .

. . . . . .

ibuprofen . . . . . .

(iii) Identify, giving a reason for your choice, which of the analgesics in (b) (ii) exists as optical isomers. *[2]*

. . . . . .

. . . . . .

. . . . . .

Option C – Human biochemistry

C1. (a) An experiment to determine the calorific value of a food product was carried out using a calorimeter. The following results were obtained:

mass of food sample burned = 5.00 g
mass of water heated = 400 g
initial temperature of water = 18.3 °C
final temperature of water = 65.1 °C

Determine the calorific value of the food product in kJ per 100 g. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The packaging on the food product states "Contains a healthy balance of nutrients from all main food groups". Identify **four** of these food groups and suggest which **one** produces the **smallest** amount of heat in the calorimeter. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question C1 continued)

(c) One of the ingredients in the food product is an unsaturated organic compound. A 0.01 mol sample of this compound reacts with 5 g of iodine.

(i) State the type of reaction that occurs. *[1]*

. . . . . .

. . . . . .

(ii) Determine the number of C=C double bonds in one molecule of this compound. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

C2. The structure of sucrose is shown in Table 22 of the Data Booklet.

(a) State the name of the oxygen-containing link between the two rings in the structure. *[1]*

. . . . . .

(b) Deduce the ring structures of the two monosaccharides that condense to form a molecule of sucrose. *[2]*

(c) Identify the other product formed during this condensation reaction. *[1]*

. . . . . .

(d) State the empirical formula of a monosaccharide. *[1]*

. . . . . .

C3. The structures of three vitamins are shown in Table 22 of the Data Booklet.

(a) Predict which of the three vitamins is most soluble in water, giving a reason for your choice. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) Name **two** functional groups present in all three vitamins. *[1]*

. . . . . .

. . . . . .

(c) State the function of vitamin D in the human body and describe **one** effect of vitamin D deficiency. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option D – Environmental chemistry

D1. The combustion of fuel in cars produces several primary pollutants. Modern cars contain ways of reducing their emission of pollutants into the atmosphere.

(a) Discuss how this is done. Include in your answer *[4]*

- **two** pollutants whose amounts are reduced by recirculation of exhaust gases.
- a catalyst used in catalytic converters.
- an equation for the reaction that takes place in the catalytic converter.

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The theoretical air to fuel ratio needed for the complete combustion of a typical fuel is about 15:1. A lean-burn engine uses a higher ratio than 15:1.
Write an equation to show how the amount of carbon monoxide is reduced in a lean-burn engine. *[1]*

. . . . . .

. . . . . .

D2. The presence of ozone in the upper atmosphere is important for life on earth.

(a) Identify the radiation absorbed by ozone in the upper atmosphere, and describe **two** effects on life on earth that would result from a decrease in ozone concentration. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The mechanism of the formation of ozone by natural processes can be represented by the following equations:

$$O_2 \rightarrow 2O\bullet$$
$$O_2 + O\bullet \rightarrow O_3$$

Write **two** equations to represent the depletion of ozone by natural processes. *[2]*

. . . . . .

. . . . . .

. . . . . .

(c) Identify **two** pollutants, and **one** source of each, that cause depletion of the ozone layer. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

D3. The treatment of waste water (sewage) is often divided into three stages. The methods used, some of the materials removed, and the substances used to remove them, can be summarized in a table. Complete the table. *[6]*

<table>
<tr><th>Stage</th><th>Primary</th><th>Secondary</th><th>Tertiary</th></tr>
<tr><td>Method</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Material removed</td><td rowspan="2">large objects</td><td rowspan="2"></td><td>heavy metal ions</td></tr>
<tr><td>phosphates</td></tr>
<tr><td rowspan="2">Substances used</td><td rowspan="2"></td><td rowspan="2">oxygen
bacteria</td><td></td></tr>
<tr><td></td></tr>
</table>

Option E – Chemical industries

E1. The extraction of lead from its ore involves several processes.

(a) Flotation (also known as froth flotation) is a physical process used to separate metal ores from the surrounding rock. Outline how this process can be used to extract galena (mostly lead sulfide, PbS) from a lump of rock. *[3]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) The lead sulfide is then heated in air (roasted) to form lead oxide, PbO, and sulfur dioxide.

(i) Write an equation for the reaction that occurs during roasting. *[1]*

. . . . . .

. . . . . .

(ii) Identify a substance that can be manufactured from the sulfur dioxide formed. *[1]*

. . . . . .

(This question continues on the following page)

(Question E1 continued)

(c) The lead oxide is heated with coke and air in a blast furnace. Some of the coke forms carbon monoxide.

(i) Identify the type of reaction that occurs to lead oxide in the blast furnace. *[1]*

. . . . . .

. . . . . .

(ii) Deduce **two** equations for reactions in which lead is formed in the blast furnace. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

E2. Electrolysis is used to extract aluminium from alumina.

(a) Explain why aluminium is not extracted using a blast furnace. *[1]*

. . . . . .

. . . . . .

(b) The electrolytic cell is lined with graphite and filled with molten alumina and one other substance.

(i) Identify the other substance and explain its purpose. *[3]*

. . . . . .

. . . . . .

. . . . . .

(ii) The equation for the reaction occurring at the negative electrode (cathode) is

$$Al^{3+} + 3e^- \rightarrow Al$$

Write an equation for the reaction occurring at the positive electrodes (anodes), and explain why these electrodes must be replaced at regular intervals. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(c) Many uses of metals depend on their ability to conduct heat and electricity. Suggest **one** other property, different in each case, that makes aluminium

(i) preferable to copper in overhead electricity cables, *[1]*

. . . . . .

. . . . . .

(ii) preferable to iron in saucepans. *[1]*

. . . . . .

. . . . . .

E3. One method used to increase the amount of gasoline from an oil refinery is hydrocracking. Describe how hydrocracking is carried out, and state the type of structure found in the molecules formed. *[4]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

. . . . . .

Option F – Fuels and energy

F1. (a) One way to compare fuels is to calculate their calorific values in kJ g^{-1}. Information about three substances derived from fossil fuels is shown in the following table. *[4]*

Fuel	$\Delta H_c^{\ominus}$ / kJ mol^{-1}	M_r	Calorific value / kJ g^{-1}
C(s)			
$CH_4(g)$			
$C_8H_{18}(l)$	–5512	114.26	48.2

Complete the table using information from Tables 5 and 13 of the Data Booklet.

(b) (i) Write an equation to represent the complete combustion of methane. *[1]*

. . . . . .

. . . . . .

(ii) Explain why the combustion of methane is an exothermic reaction. *[1]*

. . . . . .

. . . . . .

F2. Low-grade coal can be heated with steam to produce a gaseous fuel called synthesis gas.

(a) Deduce an equation for the main reaction that occurs in the formation of synthesis gas. *[1]*

. . . . . .

. . . . . .

(b) (i) Explain why the burning of synthesis gas is less polluting than burning coal. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(ii) State the main disadvantage of converting coal to synthesis gas as compared to burning coal directly. *[1]*

. . . . . .

. . . . . .

F3. Fission and fusion are two types of nuclear reaction.

(a) Explain the relevance of the equation $E = mc^2$ to fission and fusion reactions. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(b) One example of a nuclear reaction is the emission of a $^{0}_{-1}e$ particle from Bi-213.

(i) Deduce the atomic number, mass number and symbol of the element formed. *[2]*

. . . . . .

. . . . . .

(ii) Bi-213 has a half-life of 20 minutes. Calculate the mass of Bi-213 remaining after a 0.12 g sample of it was left for 1 hour. *[2]*

. . . . . .

. . . . . .

. . . . . .

. . . . . .

(This question continues on the following page)

(Question F3 continued)

(c) When an atom of Li-7 is bombarded with a proton, alpha particles are formed.

(i) Deduce the nuclear equation for this reaction, showing the atomic number and mass number of each species. *[1]*

. . . . . .

. . . . . .

(ii) Compare the relative behaviour of alpha and beta particles by completing the following table. *[3]*

Particle	Penetrating power in air	Behaviour in electric field	
		Direction of movement	Amount of deflection
alpha			
beta			