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CHEMISTRY
HIGHER LEVEL
PAPER 3

Friday 9 May 2008 (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.

0134

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

(a) Describe **two** long-term effects of consuming large quantities of ethanol on the human body. *[2]*

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2. . . . . .

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(b) 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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B4. Anesthetics given to patients before surgery are classified as either local or general.

(a) The structures of the local anesthetics lidocaine and procaine are shown in Table 21 of the Data Booklet. Both anesthetics contain amine groups.

(i) Identify **one** other functional group present in both anesthetics. *[1]*

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(ii) Identify **one** other functional group present only in lidocaine. *[1]*

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(iii) Identify **one** other functional group present only in procaine. *[1]*

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(b) The formulas of some anesthetics are shown in the table.

A	B	C	D
$CH_3CH_2OCH_2CH_3$	$CHCl_3$	$(CH_2)_3$	$CF_3CHBrCl$

Use the letters **A**, **B**, **C** and **D** to identify

(i) **two** anesthetics that are flammable. *[1]*

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(ii) the anesthetic that has the greatest effect on the ozone layer. *[1]*

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(This question continues on the following page)

(Question B4 continued)

(c) An anesthetic mixture is made from 1.2 mol nitrous oxide, 0.7 mol oxygen and 0.1 mol halothane. The total pressure of the mixture is 120 kPa.
Determine the partial pressure, in kPa, of the halothane in the mixture. *[3]*

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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. The structures of the bases present in nucleotides are shown in Table 22 of the Data Booklet.

Describe the structure of DNA, including reference to:

- the components of a nucleotide
- the pairing of bases
- the type and number of bonds between the bases. *[4]*

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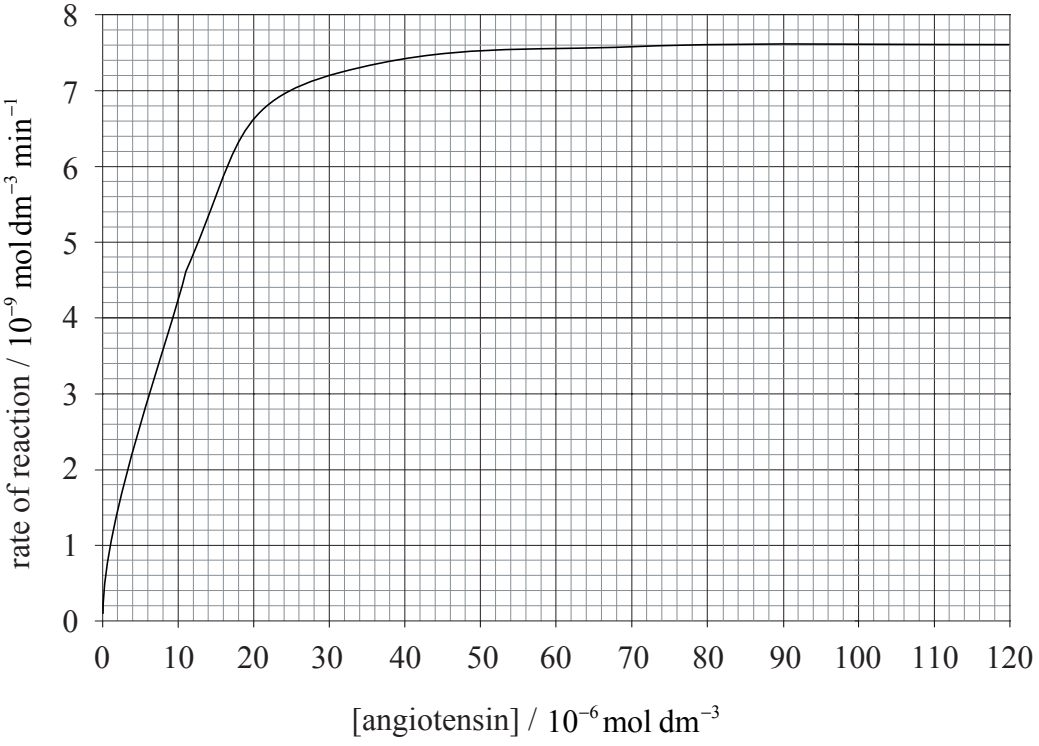
C4. Angiotensin is a substance responsible for regulating blood pressure in the human body. The following graph shows how the rate of a reaction of angiotensin depends on concentration when catalysed by the enzyme ACE-2.



(a) Determine the values of V_{max} and K_m for this reaction. *[2]*

V_{max} . . . . . .

K_m . . . . . .

(b) Draw a line on the graph to show the effect of adding a non-competitive inhibitor to the reaction mixture. *[1]*

(c) Explain how a non-competitive inhibitor works. *[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) 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. 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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D4. A constituent of photochemical smog is formed when the primary pollutant nitrogen monoxide leads to the formation of an aldehyde secondary pollutant.

One possible sequence of reactions is described below.

- $HO_2\bullet$ radicals in the atmosphere react with nitrogen monoxide to form hydroxyl radicals, $HO\bullet$.
- Hydroxyl radicals convert hydrocarbon molecules (RCH_3) to hydrocarbon radicals.
- Hydrocarbon radicals are oxidized by atmospheric oxygen to peroxyl radicals ($RCH_2O_2\bullet$).
- Peroxyl radicals convert nitrogen monoxide to nitrogen dioxide.
- The $RCH_2O\bullet$ radicals formed in reaction four react with atmospheric oxygen to form an aldehyde and regenerate the $HO_2\bullet$ radical.

Deduce an equation for each reaction in this sequence. *[5]*

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D5. Heavy metals can be defined as those metals and their compounds that are toxic to humans at low concentrations. Complete the table showing information about two of these metals. *[5]*

Metal	Two possible sources	One specific effect on human health
Cadmium	1 . . . . 2	. . . .
Mercury	1 . . . . 2	Minamata disease

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

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

positive electrode

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negative electrode

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(c) 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) 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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(c) 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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E4. Polyethene is manufactured in both low-density and high-density forms (LDPE and HDPE). Discuss the differences between these two processes in terms of:

- the type of intermediate species formed in each mechanism
- the amount of branching formed
- the type and strength of forces between the polymer chains. *[4]*

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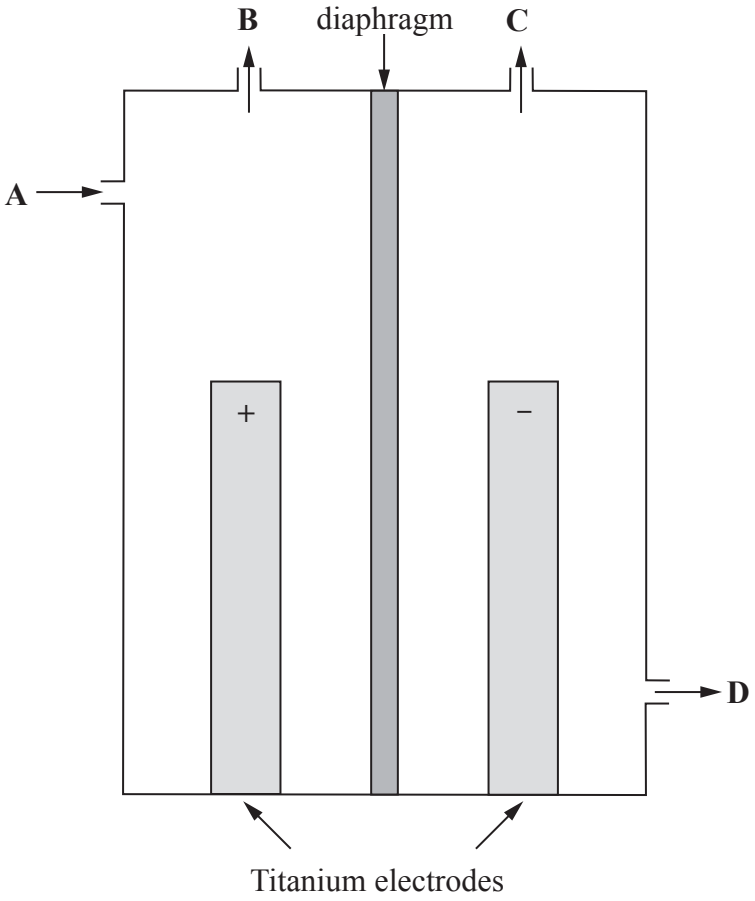
E5. The diagram represents a diaphragm cell used in the chlor-alkali industry.



(a) Identify the **substances** labelled **A** to **D**. *[4]*

A . . . . . .

B . . . . . .

C . . . . . .

D . . . . . .

(b) Write an equation for the reaction occurring at each electrode. *[2]*

positive electrode

. . . . . .

negative electrode

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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. *[3]*

- Coal (assumed to be graphite)
- Natural gas (assumed to be methane)
- Gasoline (assumed to be octane)

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(b) 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) 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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(b) 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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(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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F4. One way in which an atom of uranium-235 undergoes fission when hit by a neutron can be represented by this equation.

$$^{235}U + {}^{1}n \rightarrow {}^{148}La + {}^{85}Br + 3{}^{1}n$$

The relative masses of the species involved are:

^{235}U	235.0943
^{1}n	1.0087
^{148}La	147.9322
^{85}Br	84.9165

Calculate the mass loss, in kg, during this fission of 1 mol of uranium-235 and hence the energy released, in J, using relevant information from Tables 1 and 2 of the Data Booklet. *[4]*

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F5. A photovoltaic cell contains the elements arsenic, gallium and silicon.

Explain how the addition of arsenic and gallium to silicon leads to the production of an electric current when a photovoltaic cell is exposed to sunlight. *[4]*

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Option G – Modern analytical chemistry

G1. Several analytical techniques are based on the absorption of energy from different parts of the electromagnetic spectrum.
The following diagram shows part of the electromagnetic spectrum.

X-rays	**P**	visible	**Q**	microwaves

(a) (i) Identify the types of radiation labelled **P** and **Q**. *[1]*

P . . . . . .

Q . . . . . .

(ii) Identify which **one** of the five regions of the spectrum has radiation of the lowest frequency. *[1]*

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(b) Identify **one** analytical technique, not involving the absorption of energy from the electromagnetic spectrum, that is used to determine the structures of organic compounds and accurate values of relative atomic masses. *[1]*

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(c) (i) The absorption of infrared radiation causes bonds in a molecule to stretch. Explain why a molecule of hydrogen bromide is IR active but a molecule of oxygen is not. *[2]*

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(ii) Describe a different way, other than stretching, in which a molecule of water can absorb infrared radiation. *[1]*

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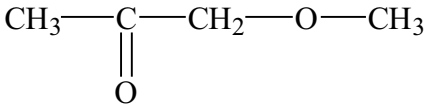
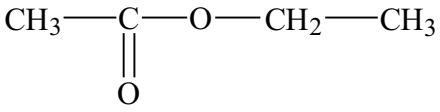
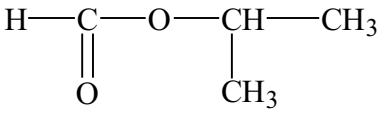
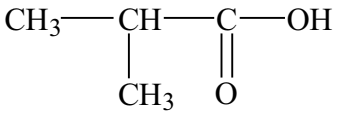
G2. Use information from Table 18 in the Data Booklet to help answer this question.

There are several isomers with the molecular formula $C_4H_8O_2$. The structural formulas of some of them are shown below.

A. 

B. 

C. 

D. 

(a) (i) Identify **two** wavenumber ranges, other than 2840–3095 cm^{-1}, of absorptions that are present in the infrared spectra of all four isomers. *[1]*

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(ii) Identify **one** wavenumber range of an absorption that is present in the infrared spectrum of only one isomer. *[1]*

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(iii) Suggest a structural formula for another isomer of $C_4H_8O_2$ that has an absorption close to 1650 cm^{-1}. *[1]*

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(This question continues on the following page)

(Question G2 continued)

(b) The technique of ^{1}H NMR spectroscopy can also be used to distinguish between different organic compounds. State what information can be obtained from: *[3]*

the number of peaks

. . . . . .

the ratio of areas under each peak

. . . . . .

the splitting pattern.

. . . . . .

(c) For isomers **B** and **C** deduce the ratio of peak areas and the splitting pattern. *[4]*

B ratio of peak areas

. . . . . .

B splitting pattern

. . . . . .

C ratio of peak areas

. . . . . .

C splitting pattern

. . . . . .

(d) The ratio of peak areas and the splitting pattern are the same for isomers **C** and **D**. State how their ^{1}H NMR spectra differ. *[1]*

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(e) Suggest the structural formula of an isomer of $C_4H_8O_2$ that has the same ratio of peak areas and splitting pattern as isomer **B**. *[1]*

G3. (a) Ascending paper chromatography was used to show that a food dye consisted of a mixture of three different permitted dyes.

Draw a diagram to show the appearance of the paper at the end of the experiment. Explain, with reference to your diagram, the meaning of the terms *stationary phase, mobile phase, solvent front* and R_f *value.* *[5]*

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(b) Identify whether adsorption or partition is the main process occurring in each of the following chromatographic techniques: *[2]*

paper chromatography . . . . . .

column chromatography . . . . . .

gas-liquid chromatography. . . . . .

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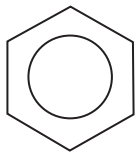
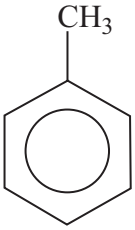
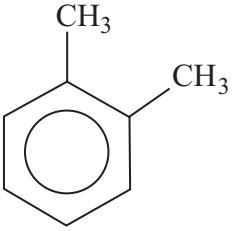
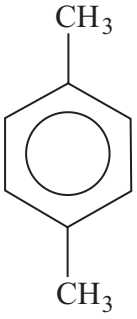
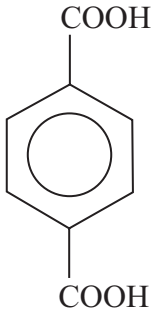
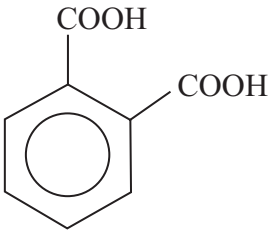
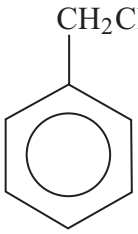
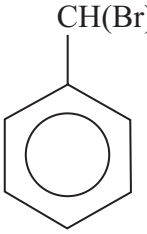
Option H – Further organic chemistry

H1. This question is about the eight organic compounds shown in the following table.

A 	B 	C 	D 
E 	F 	G 	H 

(a) Choose from the letters **A** to **H** to identify the compound(s) described as follows. *[2]*

Two compounds with the empirical formula C_4H_5.

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The compound that exists as optical isomers.

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(b) (i) Draw diagrams of the **two** optical isomers of the compound identified in part (a). *[1]*

(This question continues on the following page)

(Question H1 continued)

(ii) Outline how these isomers can be distinguished using a polarimeter. *[2]*

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(iii) Explain what is meant by the term *racemic mixture*. *[1]*

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(c) Compounds **E** and **F** are isomers with the molecular formula $C_8H_6O_4$. These isomers have many properties that are similar and some that are different.

(i) Suggest, with reference to the forces of attraction in each case, which isomer has the higher melting point. *[3]*

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(ii) Suggest, with a reason, which isomer forms a compound with the molecular formula $C_8H_4O_3$ on heating. *[2]*

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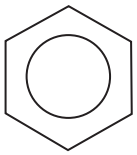
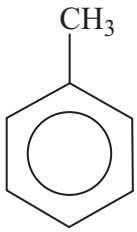
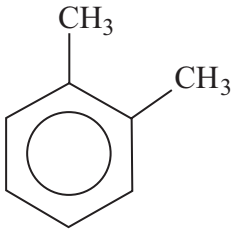
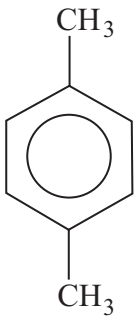
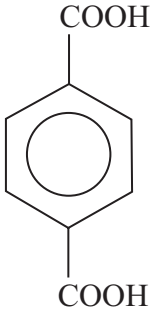
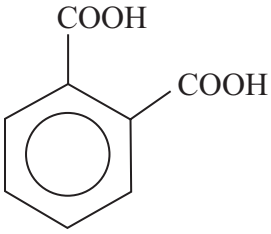
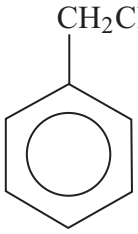
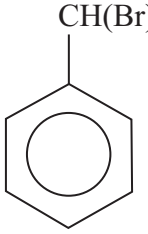
(Question H1 continued)

A 	B 	C 	D 
E 	F 	G 	H 

(d) The conversion of **B** to **C** is an example of an electrophilic substitution reaction that is catalysed by aluminium chloride. Give the mechanism, using curly arrows to represent the movement of electron pairs, to explain how this reaction occurs. Include an equation to show the formation of the electrophile. *[5]*

(This question continues on the following page)

(Question H1 continued)

(e) (i) Explain why the conversion of **B** to **C** is a faster reaction than the conversion of **A** to **B**. *[2]*

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(ii) Suggest the structures of **two** compounds formed by monosubstitution when **B** reacts with chlorine in the presence of aluminium chloride. *[2]*

H2. The strength of a carboxylic acid RCOOH can be explained in terms of the position of equilibrium of this reaction:

$$RCOOH \rightleftharpoons RCOO^- + H^+$$

In stronger acids, the position of equilibrium lies further to the right. Values of pK_a for some acids are shown in Table 16 of the Data Booklet.

(a) Identify the stronger acid in each of the following pairs, giving a reason for your choice.

- Methanoic acid and ethanoic acid
- Ethanoic acid and chloroethanoic acid
- Chloroethanoic acid and iodoethanoic acid *[3]*

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(b) Suggest, with a reason, how the pK_a values of these acids compare with each other and with that of butanoic acid.

$CH_3CH_2CHClCOOH$ (2-chlorobutanoic acid)
$CH_2ClCH_2CH_2COOH$ (4-chlorobutanoic acid) *[2]*

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