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CHEMISTRY
HIGHER LEVEL
PAPER 3

Wednesday 12 November 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.

Option B – Medicines and drugs

B1. Both aspirin and heroin are analgesics. Their structures are given in Table 21 of the Data Booklet.

(a)   Explain why both aspirin and heroin can be described as esters.   *[1]*

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(b)   Describe the mode of action for each of the two analgesics.   *[4]*

aspirin   . . . .

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. . . .

heroin   . . . .

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(c)   State a serious side effect of aspirin.   *[1]*

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(d)   The taking of heroin can lead to tolerance. Describe what is meant by *tolerance* and explain why it is a particularly dangerous problem with heroin.   *[2]*

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B2. Magnesium hydroxide, $Mg(OH)_2$, and sodium hydrogencarbonate, $NaHCO_3$, are two common antacids.

   (a)   (i)   State an equation for each of these antacids to show how they neutralise excess hydrochloric acid in the stomach. *[2]*

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           (ii)   Explain which will be more effective as an antacid: 0.01 mol of magnesium hydroxide or 0.01 mol of sodium hydrogencarbonate. *[1]*

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   (b)   Antacids often contain alginates and anti-foaming agents. Explain their functions. *[2]*

alginates   . . . .

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anti-foaming agents   . . . .

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B3. (a)   Outline the major contributions made by Florey and Chain in the development of penicillin.   *[3]*

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(b)   The original penicillin was penicillin G. State **two** advantages of producing penicillins with altered side-chains compared to the original penicillin G.   *[2]*

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B4. 5-fluorouracil is a drug that has been used for several years to treat bowel and colon cancer. The structure of 5-fluorouracil is shown below with two of its functional groups circled and labelled A and B.
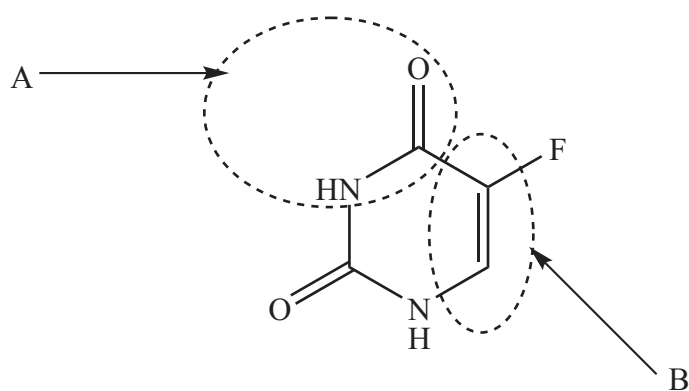
(a)   Identify the functional groups A and B.   *[2]*

A   . . . .

B   . . . .

(This question continues on the following page)

(Question B4 continued)

    (b)   State and explain whether 5-fluorouracil can exist as geometrical isomers.   *[1]*

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More recently cisplatin has supplemented or replaced 5-fluorouracil to treat these types of cancer. The structure of cisplatin is given in Table 21 of the Data Booklet.

    (c)   Draw the structure of **trans**platin.   *[1]*

    (d)   Suggest why transplatin, unlike cisplatin, is not effective as an anti-cancer drug.   *[1]*

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    (e)   The chemical structures of the following drugs are given in Table 21 of the Data Booklet: paracetamol (acetaminophen), ibuprofen, amphetamine, caffeine, lidocaine and mescaline. Deduce which of these six drugs can exist as enantiomers.   *[2]*

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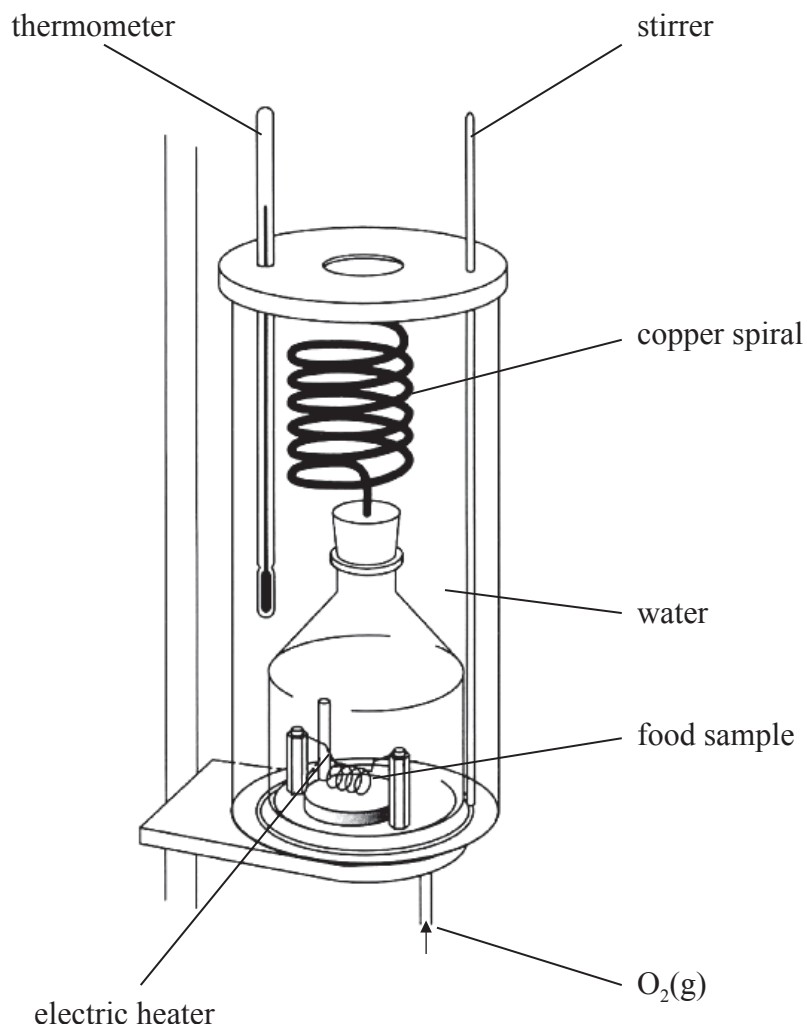. . . . .

Option C – Human biochemistry

C1. On the side of a packet of a breakfast cereal it states that 45.0 g of the cereal provides 649 kJ of energy.

To check this value a student combusted 2.19 g of the cereal in a food calorimeter.

The heat produced increased the temperature of 600 g of water in the calorimeter by 11.2 °C. The specific heat capacity of water = 4.18 J g^{-1} K^{-1}.

(a) (i) Calculate the energy content of 45.0 g of the breakfast cereal. *[2]*

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(This question continues on the following page)

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(Question C1 continued)

    (ii) Suggest **two** reasons why the result obtained was not completely accurate. *[2]*

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(b) It states on the side of the cereal packet that some of the energy comes from both saturated and unsaturated fats.

    (i) Give the structural formula of a fat, using R to represent an alkyl group. *[1]*

    (ii) Describe how the structure of an unsaturated fat is different from that of a saturated fat. *[1]*

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    (iii) Fats are often described by their iodine number. It was found that 7.61 g of iodine, I_2, reacted with 0.0100 mol of an unsaturated fat in the breakfast cereal. What can be deduced about the structure of this unsaturated fat in the breakfast cereal from this information? *[2]*

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(Question C1 continued)

Turn over

C2. The structure of vitamin D is given in the Data Booklet.

(a) Explain why it is not correct to classify vitamin D as a steroid. *[1]*

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(b) Explain why vitamin D is fat soluble even though it contains a polar –OH group. *[1]*

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(c) Describe and explain what will be observed in young children who are suffering from a severe and prolonged lack of vitamin D. *[2]*

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C3. (a) State what is meant by a *hormone*. *[1]*

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(b) One particular hormone is oestradiol. State where in the body oestradiol is produced. *[1]*

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(c) The structures of oestradiol and testosterone are given in Table 22 of the Data Booklet.

(i) Name **one** functional group present in oestradiol but absent in testosterone. *[1]*

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(ii) Name **two** functional groups present in testosterone but absent in oestradiol. *[1]*

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C4. In humans the concentration of potassium ions is higher inside a cell than outside, whereas the concentration of sodium ions is higher outside the cell than inside it. To maintain this difference the body uses a sodium-potassium pump. The pump consists of a protein to which the metal ions can bind.

(a) State **one** reason why it is necessary to maintain this difference in the sodium and potassium concentrations. *[1]*

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(b) Explain the importance of the radius of the potassium ion compared to the sodium ion in the working of the pump. *[2]*

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C5. (a) Explain what is meant by the terms V_{max} and K_m in the Michaelis-Menton equation used in enzyme kinetics. *[2]*

V_{max} . . . .

. . . .

K_m . . . .

. . . .

(b) State and explain the effect on the values of V_{max} and K_m when a non-competitive inhibitor is added to an enzyme-catalysed reaction. *[4]*

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Option D – Environmental chemistry

D1. (a) Explain why carbon dioxide is a greenhouse gas whereas nitrogen, which is the main constituent of air, is not.   *[3]*

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(b) Farm animals such as cows also contribute significantly to global warming by producing methane. Suggest why cows mainly convert grass into methane rather than carbon dioxide and water.   *[1]*

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(c) List **two** other gases apart from carbon dioxide and methane that also contribute to global warming.   *[1]*

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(d) Global warming can also be affected by the presence of particulates in the atmosphere. Outline how particulates can affect the Earth's temperature.   *[2]*

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D2. (a) When rain falls it dissolves and reacts with some of the carbon dioxide present in the air to form carbonic acid, $H_2CO_3(aq)$. Explain why rain water containing only carbonic acid is not classified as acid rain. *[2]*

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(b) List **two** acids from different sources that are present in acid rain and state **one** major source due to human activity for each acid. *[2]*

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(c) Acid rain can damage buildings containing calcium carbonate or magnesium carbonate. Give the **ionic** equation for the reaction of aqueous hydrogen ions with carbonate ions. *[1]*

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(d) Acid rain alters the soil. Explain what effect this has on plant growth. *[2]*

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D3. One group of pollutants which may be found in water is known as PCBs. These come from discarded electrical transformers and other electrical equipment. They can cause cancer and also affect the immune and reproductive systems of humans.

(a) State what PCB stands for. *[1]*

. . . .

(b) Other pollutants found in water are cadmium compounds. State **two** sources of cadmium compounds found in polluted water. *[1]*

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(c) The toxicity of pollutants such as PCBs can be measured in several ways, all of which have disadvantages.

(i) State what is meant by LD_{50}. *[1]*

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(ii) Suggest **two** reasons why LD_{50} is not a particularly good way to measure toxicity. *[2]*

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D4. The wavelength of light required to break the oxygen-to-oxygen bond in ozone is 3.30×10^{-7} m.

(a) State the region in the electromagnetic spectrum where this wavelength is located. *[1]*

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(b) Draw the Lewis structure of ozone and explain why the wavelength of light required to dissociate ozone is longer than that required to dissociate oxygen gas. *[3]*

....

....

....

....

(c) In 1995 the Nobel Prize in Chemistry was awarded to Paul Crutzen who showed that nitrogen dioxide emissions from jet airplanes could contribute to the destruction of the ozone layer. The overall equation for this process is given below.

$$NO_2(g) + O_3(g) \rightarrow NO(g) + 2O_2(g)$$
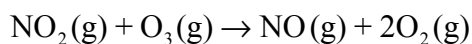
Suggest a mechanism for this reaction. *[2]*

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....

....

Option E – Chemical industries

E1. Iron is produced in a blast furnace. Traditionally the basic raw materials added to the furnace were iron ore, coke, limestone and hot air.

(a) The reducing agent in the blast furnace is mainly carbon monoxide. Give equations showing **two** different ways in which carbon monoxide is formed from the raw materials in a blast furnace. *[3]*

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(b) In a modern blast furnace the hot air is mixed with natural gas and the hydrogen produced also acts as a reducing agent. Give the equation for the reduction of the ore triiron tetroxide, Fe_3O_4, using hydrogen as the reducing agent. *[1]*

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(c) One of the impurities in the iron ore is silicon dioxide. Explain how this is removed during the production of iron in the blast furnace. *[2]*

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(d) State the main impurity in the iron produced in a blast furnace. *[1]*

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(e) Both steel and aluminium cans are often mixed together for recycling. Suggest a simple way in which they can be separated. *[1]*

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E2. (a) Suggest **two** reasons why it is necessary to remove the sulfur found in crude oil **before** the oil is refined. *[2]*

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   (b) State the major use for the sulfur that is removed from crude oil. *[1]*

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   (c) One of the refining processes is cracking. Describe the conditions used for hydrocracking. *[2]*

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   (d) Another type of cracking is thermal cracking. State the equation for the cracking of decane, $C_{10}H_{22}$, to produce octane and state the major use for the other organic product. *[2]*

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        . . . .

E3. Silicon used in microprocessors is required in a very pure state. It is first obtained by reducing silica, SiO_2, with carbon.

(a) State the equation for the reduction of silica with carbon. *[1]*

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(b) Explain why the silicon obtained by this process is then converted into silicon tetrachloride. *[2]*

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(c) The silicon tetrachloride is reduced back to silicon, which then undergoes zone refining. Describe the process of zone refining. *[2]*

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(d) Describe how sunlight increases the electrical conductivity of silicon. *[2]*

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(e) The efficiency of the photoelectric effect can be improved by adding a group 3 element such as aluminium or gallium to silicon. Outline how this changes the electrical conductivity of the silicon. *[2]*

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(f) State the type of semi-conductor formed when a small amount of arsenic is added to silicon. *[1]*

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Turn over

Option F – Fuels and energy

F1. (a) Give the nuclear equation to describe the emission of one alpha particle from an atom of uranium-235. *[2]*

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(b) U-235 decays in a series of steps to give Pb-207 as the final product. Deduce the number of alpha and beta particles emitted during the conversion of one atom of U-235 to one atom of Pb-207. *[2]*

Number of alpha particles emitted   ....

Number of beta particles emitted   ....

(c) The half-life of U-235 is 7.13×10^8 years. If 2.40 kg of U-235 were present in a particular area 4.278×10^9 years ago, calculate the mass of the original U-235 that remains today. *[2]*

....

....

....

....

(d) Nuclear energy can be obtained from the bombardment of U-235 with neutrons. As well as the fuel rods, nuclear reactors also contain moderators and control rods. For each of these, state **one** material used and describe its function. *[4]*

Moderator:

Made from   ....

Function   ....

....

Control rods:

Made from   ....

Function   ....
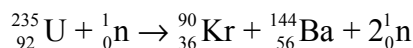
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(Question F1 continued)

(e)   An equation to describe the fission of uranium-235 with neutrons is given below.

$$_{92}^{235}\text{U} + {}_0^1\text{n} \rightarrow {}_{36}^{90}\text{Kr} + {}_{56}^{144}\text{Ba} + 2{}_0^1\text{n}$$

The table below shows some relative masses.

Species	Neutron	U-235	Kr-90	Ba-144
Relative mass	1.0087	235.0439	89.9470	143.8810

Calculate the theoretical maximum amount of energy that could be obtained from the fission of one mole of uranium-235.   *[2]*

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F2. (a)   Octane, C_8H_{18}, comes from petroleum, and natural gas is essentially methane. The enthalpies of combustion of methane and octane are −890 and −5510 kJ mol^{-1} respectively. Determine which of the two fuels provides more heat energy when 1.00 kg of each fuel is completely combusted.   *[2]*

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(b)   In the future, cars may be powered by hydrogen-oxygen fuel cells rather than gasoline (petrol). Give the half-equations for the reactions taking place at the positive electrode and the negative electrode in a hydrogen-oxygen fuel cell.   *[2]*

Positive electrode   . . . .

Negative electrode   . . . .

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F3. One method of storing energy is to pump water to a higher level reservoir, then use it to produce hydroelectric power when energy is needed. Another method is to produce hydrogen from water, then burn the hydrogen when the energy is required.

(a) Explain why no method of storing energy can ever be 100 % efficient. *[1]*

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(b) Neither of the above two methods produce any chemical pollutants. Discuss **two** advantages and **two** disadvantages for each method. *[8]*

Pumping water:

Advantages   . . . .

. . . .

. . . .

. . . .

Disadvantages . . . .

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. . . .

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Hydrogen:

Advantages   . . . .

. . . .

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Disadvantages . . . .

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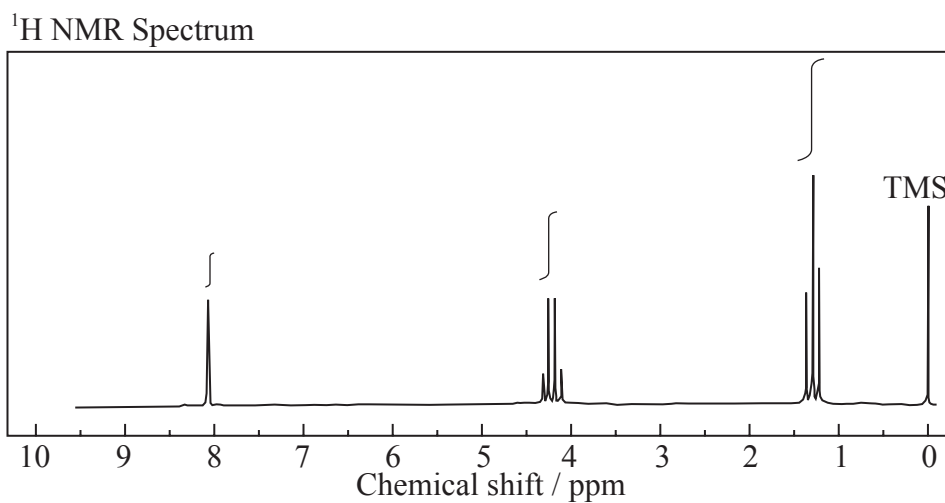
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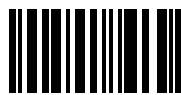
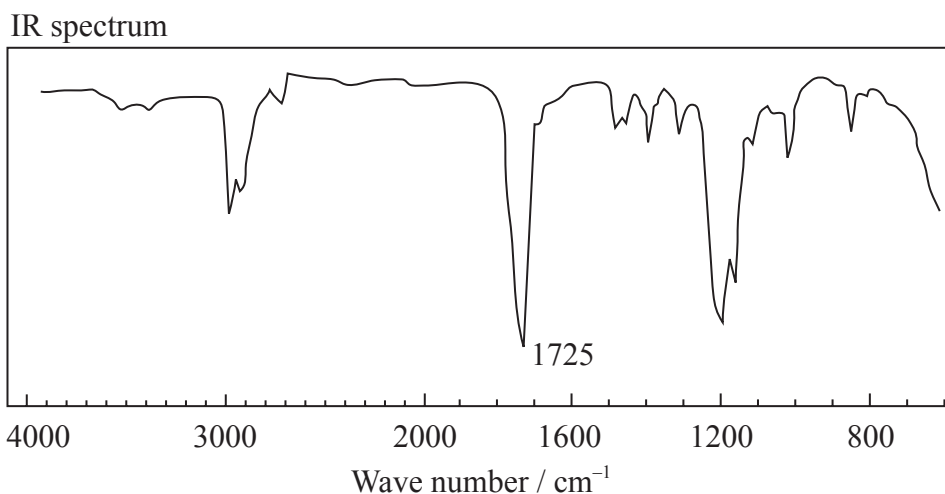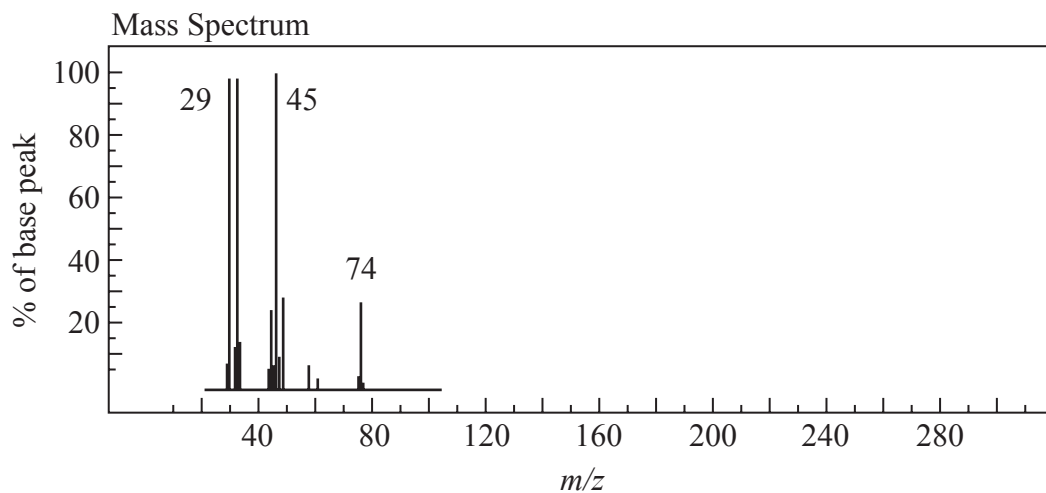**Option G – Modern analytical chemistry**

G1. Compounds can be identified using information from their mass spectra, infrared spectra and ^{1}H NMR spectra.

The spectra below are for ethyl methanoate, $HCOOC_2H_5$.

Mass Spectrum

IR spectrum

^{1}H NMR Spectrum

[Source: Spectra taken from: L.Field, S. Sternhell & J. Kalman, *Organic Stuctures from Spectra*, John Wiley and Sons, 1995]

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(a) (i) Identify the species responsible for the peaks at *m/z* values of 74, 45 and 29 in the
          mass spectrum.   *[3]*

          74   . . . .

          45   . . . .

          29   . . . .

     (ii) Explain why there is also a small peak with an *m/z* value of 75.   *[1]*

          . . . .

          . . . .

(b) Chemical bonds vibrate at particular frequencies. Explain why some vibrations of
     chemical bonds absorb in the infrared region of the spectrum but others do not.   *[1]*

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     . . . .

(c) The absorption at 1725 cm^{-1} in the infrared spectrum on the previous page is due to the
     stretching vibration of the C=O bond in ethyl methanoate. Explain why other compounds
     containing a C=O bond do not absorb at exactly 1725 cm^{-1} in the infrared region of
     the spectrum.   *[1]*

     . . . .

     . . . .

(d) The ^{1}H NMR spectrum for ethyl methanoate shows three separate peaks. Use the
     integration trace to determine which hydrogen atom(s) is/are responsible for the peak with
     a shift of 1.3 ppm.   *[1]*

     . . . .

     . . . .

(e) Explain why the peak at 1.3 ppm in the ^{1}H NMR spectrum is split into a triplet.   *[1]*

     . . . .

     . . . .

(This question continues on the following page)

(Question G1 continued)

(f) The chemical shifts of protons are influenced by several factors including the solvent. The values given in the Data Booklet are not always precise. Explain how information from the integration trace and the splitting pattern can be used to identify which hydrogen atom(s) is/are responsible for the peak with a shift of 8.1 ppm. *[3]*

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(g) An isomer of ethyl methanoate is methyl ethanoate, CH_3COOCH_3. Describe how the following features of the spectra of methyl ethanoate will differ, if at all, from those of ethyl methanoate.

(i) The molecular ion peak in the mass spectrum. *[1]*

. . . .

. . . .

(ii) The number of peaks and the integration trace in the ^{1}H NMR spectrum. *[2]*

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. . . .

(iii) The splitting patterns in the ^{1}H NMR spectrum. *[1]*

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(h) Propanoic acid is an isomer of both esters in (g). Describe **two** ways in which its infrared spectrum differs from that of the two esters, other than the exact position of the C=O absorption. *[2]*

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G2. (a) Gas-liquid chromatography can be used to separate a mixture of esters. Outline the
principles of gas-liquid chromatography, from the injection of the sample to the detection
of the components.   *[5]*

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(b) Identify which chromatographic technique would be most suitable to separate:

   (i) a mixture of non-volatile liquids that decompose near their boiling points   *[1]*

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   (ii) two coloured substances where a large amount of one is required in a pure state   *[1]*

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   (iii) a mixture of dyes to determine whether it contains any illegal coloured substances. *[1]*

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Option H – Further organic chemistry

H1. But-1-ene, $CH_3CH_2CH=CH_2$, can undergo an electrophilic addition reaction with hydrogen bromide to form either 1-bromobutane or 2-bromobutane.

    (a)   Explain how **two** possible intermediates can be formed in this reaction, using curly arrows to represent the movement of pairs of electrons. *[3]*

    (b)   Identify the major product in this reaction and explain why it is formed in preference to the other possible product. *[2]*

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    (c)   The boiling point of 1-bromobutane is $101\,°C$ at atmospheric pressure. State, giving a reason, whether the boiling point of 2-bromobutane is the same, higher or lower than $101\,°C$ at atmospheric pressure. *[2]*

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(This question continues on the following page)

(Question H1 continued)

(d)   State and explain whether 1-bromobutane and/or 2-bromobutane can exist in enantiomeric forms.   *[2]*

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(e)   State **one** physical property that is different for two enantiomers of the same compound and describe how this property can be used to distinguish between them.   *[2]*

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H2. Methylbenzene reacts with chlorine when warmed with aluminium chloride in the dark.

(a)   Identify the **two** main organic products formed in this reaction.   *[1]*

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(b)   Explain the function of the aluminium chloride. Include an equation in your answer.   *[2]*

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(c)   Explain why the reaction between methylbenzene and chlorine under these conditions is faster than the reaction between benzene and chlorine under the same conditions.   *[2]*

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(d)   Explain why the reaction between methylbenzene and chlorine under these conditions can be described as a redox reaction.   *[1]*

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(e)   Explain why this reaction can also be described as an acid-base reaction and identify clearly the acid and the base in the reaction.   *[2]*

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(This question continues on the following page)

(Question H2 continued)

(f)   Methylbenzene also reacts with chlorine in the presence of ultraviolet light. Give the structural formula of the organic product.   *[1]*

(g)   State the name of the mechanism for this reaction and explain the function of the ultraviolet light.   *[2]*

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H3. (a)   Explain why phenylamine, $C_6H_5NH_2$, is more soluble in an aqueous solution of hydrochloric acid than it is in pure water.   *[1]*

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(b)   Explain why phenylamine is a weaker base than ethylamine.   *[1]*

. . . .

. . . .

(c)   Explain why 4-nitrophenylamine is a weaker base than phenylamine.   *[1]*

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