IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
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N04/4/CHEMI/HP3/ENG/TZ0/XX

88046103

CHEMISTRY
HIGHER LEVEL
PAPER 3

School code

Candidate code

Thursday 18 November 2004 (morning)

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your school code and candidate code 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 school code and candidate code 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. Depressants such as tranquilizers and sedatives are capable of affecting the central nervous system.

(a) State **two** effects, in **each** case, on the body of taking

(i) a low dose of a tranquilizer. *[2]*

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(ii) a high dose of a sedative. *[2]*

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

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(c) List **two** depressants whose structures are shown in Table 21 of the Data Booklet. *[1]*

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(d) One problem with many drugs is that users develop *tolerance*. Explain what is meant by the term *tolerance* and state why it could increase the risk to the user. *[2]*

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B2. Caffeine and nicotine are two stimulants whose structures are shown in Table 21 of the Data Booklet.

(a) Describe **two** similarities in their structures, not including the presence of double bonds, methyl groups and nitrogen atoms. *[2]*

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(b) Discuss the problems associated with nicotine consumption, distinguishing between short-term and long-term effects. *[6]*

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B3. The effect of some drugs used to treat cancer depends on geometrical isomerism. One successful anti-cancer drug is cisplatin, whose formula is $PtCl_2(NH_3)_2$. Describe the structure of cisplatin by referring to the following:

- the meaning of the term *geometrical isomerism* as applied to cisplatin
- diagrams to show the structure of cisplatin and its geometrical isomer
- the types of bonding in cisplatin.

[4]

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B4. An anesthetic mixture at a pressure of 105 kPa was made from the gases nitrous oxide, halothane and oxygen, using the following amounts:

0.13 mol nitrous oxide
0.01 mol halothane
0.07 mol oxygen

(a) Use Dalton's Law to determine the partial pressures of each gas in the mixture. *[3]*

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(b) Outline **one** advantage and **one** disadvantage of halothane as an anesthetic. *[2]*

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Option C – Human biochemistry

C1. The structures of the amino acids cysteine and serine are shown in Table 20 of the Data Booklet. They can react with each other to form a dipeptide.

(a) State the type of reaction occurring when amino acids react together and identify the other product of the reaction. *[2]*

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(b) Draw the structures of the **two** possible dipeptides formed in the reaction between one molecule of each of cysteine and serine. *[2]*

(c) Six tripeptides can be formed by reacting together one molecule of each of the amino acids arginine, histidine and leucine. Predict the primary structures of these six tripeptides using the symbols shown in Table 20 of the Data Booklet to represent the amino acids. *[3]*

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(This question continues on the following page)

(Question C1 continued)

(d) When many amino acid molecules react together a protein is formed. These proteins have primary, secondary and tertiary structures.

(i) State the type of intermolecular force responsible for maintaining the secondary structure. *[1]*

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(ii) State **two** other ways in which the tertiary structure of the protein is maintained. *[2]*

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C2. (a) State the empirical formula of all monosaccharides. *[1]*

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(b) The structural formula of lactose is shown in Table 22 of the Data Booklet.

(i) Deduce the structural formula of **one** of the monosaccharides that reacts to form lactose and state its name. *[2]*

(ii) State the name of the **other** monosaccharide. *[1]*

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(c) State **two** major functions of polysaccharides in the body. *[2]*

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C3. Enzymes are proteins that can catalyse the reactions of some molecules in living matter.

(a) The action of an enzyme is *specific*. Outline what is meant by the term *specific* and explain how an enzyme works. (You may use the symbols E for enzyme, S for substrate and P for product.) *[4]*

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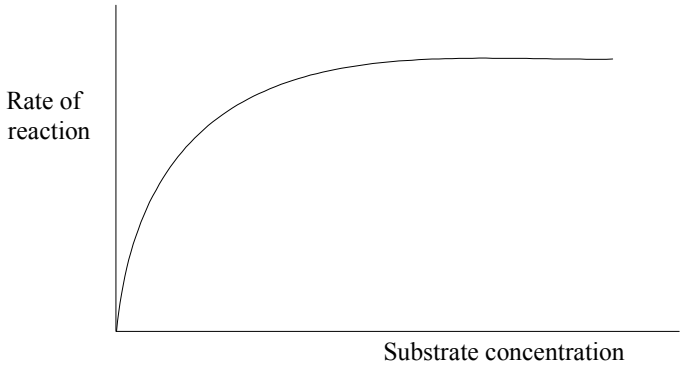
(b) Enzyme-catalysed reactions are sometimes slowed down by inhibitors. The following graph represents the rate of an enzyme-catalysed reaction at different substrate concentrations.



(i) Explain how a non-competitive inhibitor would slow down such a reaction and draw a line on the graph to show its effect. *[3]*

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(ii) State the effect of a non-competitive inhibitor on the values of *[2]*

V_{max} . . . . . .

K_m . . . . . .

Option D – Environmental chemistry

D1. Particulates are a type of primary air pollutant produced in several industries and by the burning of fuels.

(a) The emission of particulates by some industries is reduced by an electrostatic method. Explain how this is done. *[3]*

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(b) State **one** type of fuel that is very likely to produce particulates when burned. *[1]*

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(c) Deduce the equation for a combustion reaction of methane in which particulates are formed. *[1]*

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D2. (a) Explain, with the help of an equation, why rain is naturally acidic. *[2]*

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(b) Catalytic converters are used in motor vehicles to reduce the emissions of acidic gases.

(i) Give an equation to show the formation of nitrogen(II) oxide in a motor vehicle and identify the acid it forms in the atmosphere. *[2]*

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(ii) Nitrogen(II) oxide reacts with carbon monoxide in a catalytic converter to produce harmless substances. Deduce the equation for this reaction. *[2]*

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D3. (a) State what is meant by the term *biological oxygen demand (BOD)*. *[2]*

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(b) Organic matter in water can be decomposed by both aerobic and anaerobic bacteria.

(i) State which type of bacteria is more likely to be active in water with a low BOD value. *[1]*

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(ii) The following elements can occur in organic matter. Suggest **one** gas that is likely to be produced from each element when organic matter is decomposed by anaerobic bacteria. *[3]*

carbon . . . . . .

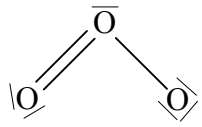
nitrogen . . . . . .

sulfur . . . . . .

D4. The natural concentration of ozone in the upper atmosphere is kept unchanged by a sequence of reactions, including the following:

reaction I: $O_2 \xrightarrow{\lambda=242\,\text{nm}} 2O$ reaction II : $O_3 \rightarrow O_2 + O$

The bonding in the ozone molecule can be represented as two resonance hybrids, one of which is shown below.



(a) Draw a Lewis structure for the oxygen molecule. *[1]*

(b) By reference to the bonding in ozone and oxygen, state and explain whether the wavelength and energy of the radiation required for reaction II would be less than or greater than that required for reaction I. *[3]*

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D5. Compounds of heavy metals are one type of toxic substance found in water. Outline **one** source in water supplies and **one** effect, different in each case, on human health, for **each** of the metals mercury and lead. *[4]*

mercury

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lead

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Option E – Chemical industries

E1. The extraction of metals from their ores often begins by using water to separate the ores from other materials found in the rock.

(a) State what is done to the rock before water is used. *[1]*

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(b) One method of extracting ores from rock uses *froth flotation*. Outline this method by referring to the substances used, apart from the ore and water, and stating how the ore is separated from the rock. *[3]*

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E2. Aluminium and iron are extracted from their ores by different chemical methods. For aluminium, electrolysis is used.

(a) (i) Identify the compound from which most aluminium is extracted. *[1]*

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(ii) Electrolysis of this compound gives aluminium and another product. Write a half-equation for the formation of each product. *[3]*

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(b) Most iron is produced by heating iron ore with coke in a blast furnace.

(i) State **two** other raw materials used in the blast furnace. *[1]*

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(ii) Give the equation for the reduction of iron(III) oxide in the blast furnace. *[2]*

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E3. The most widely-used polymer is polythene, which is made in low-density and high-density forms.

(a) Discuss the differences between these **two** forms by referring to the amount of branching, the forces between the polymer chains and the physical properties. *[4]*

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(b) Both forms of polythene are described as *thermoplastics*. State the meaning of this term. *[1]*

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E4. (a) The manufacture of low-density polyethene uses a free-radical reaction mechanism.

(i) State the names of the **three** steps common to most free-radical mechanisms. *[2]*

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(ii) One step in the mechanism can be represented as follows:

$$R_3C\bullet + CH_2{=}CH_2 \rightarrow R_3C{-}CH_2{-}CH_2\bullet$$

Outline what happens in this step, by reference to the electrons involved. *[2]*

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(b) State the type of mechanism and the catalyst used in the manufacture of high-density polyethene. *[2]*

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E5. Ellingham diagrams for some reactions involving metal oxides are shown in Table 12 of the Data Booklet. Analyse the data shown to

- estimate the lowest temperature at which carbon could be used to reduce zinc oxide
- estimate the value of $\Delta G_f^{\ominus}$, and hence the feasibility of the reaction, for the reduction of titanium(IV) oxide by carbon at 1000 K. *[3]*

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Option F – Fuels and energy

F1. Crude oil contains many hydrocarbons, including hexane, C_6H_{14}.

(a) Outline how crude oil was formed. *[3]*

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(b) The equation for the complete combustion of hexane is shown below.

$$C_6H_{14}(g) + 9½O_2(g) \rightarrow 6CO_2(g) + 7H_2O\,(g)$$

Determine a value for the enthalpy of combustion of hexane using the following enthalpy of formation data. *[3]*

Compound	$C_6H_{14}(g)$	$CO_2(g)$	$H_2O\,(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–167	–394	–242

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F2. (a) Outline **two** features of chemical reactions that do **not** apply to nuclear reactions. *[2]*

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(b) The isotope ^{218}Po can undergo either α-decay or β-decay. Deduce the symbol and mass number of the element formed in each case. *[2]*

α-decay . . . . . .

β-decay . . . . . .

(c) Discuss the concerns about safety in nuclear power plants by commenting on **two** aspects of **each** of the following.

- the withdrawal of all the control rods from the core
- the presence of oxygen in the coolant gas passing through the graphite moderator
- the breakage of a pipe carrying molten sodium in a breeder reactor. *[6]*

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F3. (a) Define the terms *mass defect* and *nuclear binding energy*. *[2]*

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(b) Values of relative atomic masses are quoted on a scale where 1 mol ^{12}C has a mass of 12.0000 g. On this scale, an accurate value for the relative atomic mass of the isotope ^{90}Kr is 89.9470. On the same scale the relative masses of the sub-atomic particles are:

proton = 1.0073
neutron = 1.0087

(i) Determine the mass defect for ^{90}Kr, giving your answer in kg. *[3]*

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(ii) Use your answer to (b)(i), together with relevant information from Tables 1 and 2 of the Data Booklet, to determine the nuclear binding energy for ^{90}Kr, giving your answer in J. *[1]*

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F4. Silicon is increasingly used to generate electricity in photovoltaic cells. Its electrical conductivity is less than that of sodium but greater than that of sulfur. Use your knowledge of the electron arrangements of sodium and sulfur, together with relevant information from Table 7 of the Data Booklet, to explain this. *[3]*

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Option G – Modern analytical chemistry

G1. Aqueous solutions containing complexes of transition metals are usually coloured. This is due to the absorption of part of the spectrum of white light passing through the solution.

(a) Three factors help to determine the colour absorbed.

For each of the following pairs, state the difference between the **two** complexes that is responsible for the difference in colour. *[3]*

$[Co(NH_3)_6]^{2+}$ and $[Ni(NH_3)_6]^{2+}$

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$[Fe(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$

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$[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[Cu(H_2O)_6]^{2+}$

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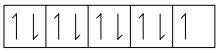
(b) The wavelength of colour absorbed by the complex can be explained in terms of the splitting of the d orbitals in the metal ion.

The arrangement of electrons in the d orbitals of the Cu^{2+} ion is shown in the following diagram.



Draw a diagram to show how the electrons are arranged in Cu^{2+} when it is present in the $[Cu(H_2O)_6]^{2+}$ ion. *[1]*

(This question continues on the following page)

(Question G1 continued)

(c) Predict whether the splitting of the d orbitals in $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ would be less than or greater than the splitting in $[Cu(H_2O)_6]^{2+}$. *[1]*

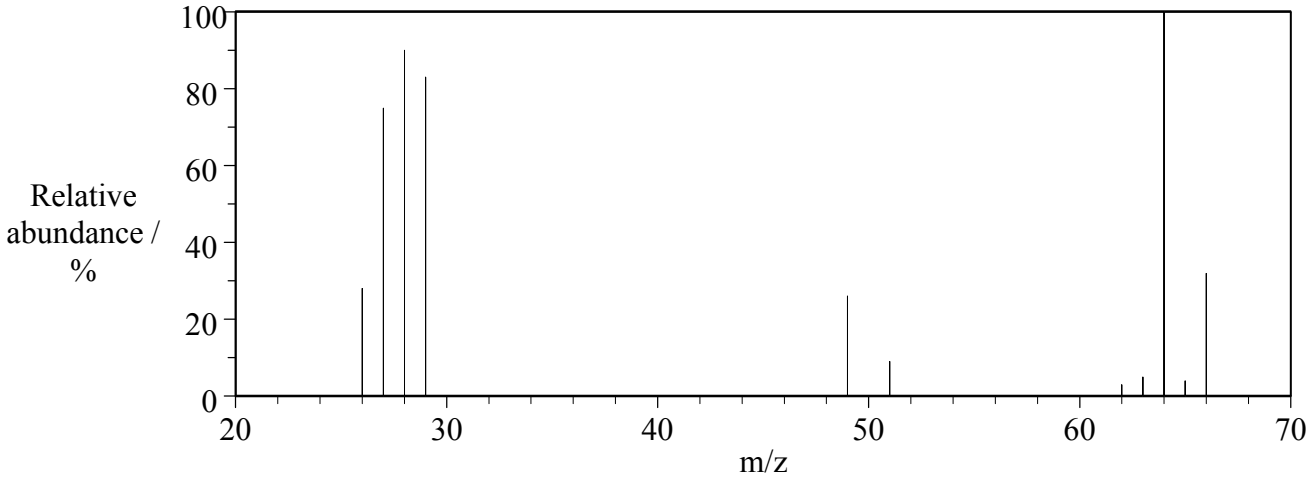
splitting in $[Cu(NH_3)_4(H_2O)_2]^{2+}$ . . . . . .

splitting in $[CuCl_4]^{2-}$ . . . . . .

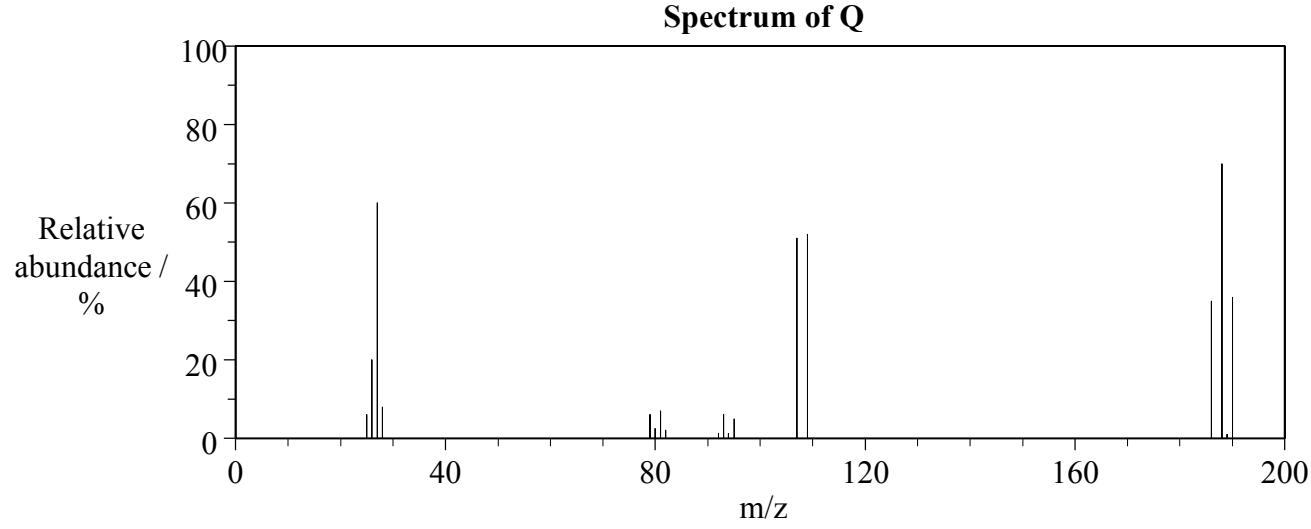
G2. The mass spectra of halogenoalkanes show more than one line corresponding to the molecular ion. This is due to the presence of isotopes such as ^{35}Cl, ^{37}Cl, ^{79}Br and ^{81}Br.

(a) Analyse the following spectra of halogenoalkanes **P** and **Q** and deduce the formula of all the molecular ion species. *[3]*

Spectrum of P



Spectrum of Q



[Source: NIST Mass Spec Data Center, S E Stein, director, "IR and Mass Spectra" in NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. P J Linstrom and W G Mallard, July 2001, National Institute of Standards and Technology, Gaithersburg MD, 20899 (http://webbook.nist.gov)]

species in **P** . . . . . .

species in **Q** . . . . . .

(b) Predict the m/z values of the molecular ions for the compounds C_2H_5Br and $C_2H_4Cl_2$. *[2]*

C_2H_5Br . . . . . .

$C_2H_4Cl_2$ . . . . . .

G3. This question is about the three organic compounds involved in the following reaction.

$$\underset{\mathbf{W}}{C_2H_4O_2} + \underset{\mathbf{X}}{C_2H_6O} \rightarrow \underset{\mathbf{Y}}{C_4H_8O_2} + H_2O$$

(a) The infrared spectra of all three compounds showed several absorptions. Describe what happens on a molecular level when molecules absorb infrared radiation. *[3]*

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(b) Use the following information about their infrared spectra to deduce which bonds are present in the three compounds. *[3]*

All three compounds showed an absorption close to 1200 cm^{-1}.
There were broad absorptions in both **W** and **X**. The one in **W** was centred around 3000 cm^{-1}, and in **X** around 3400 cm^{-1}.
Compounds **W** and **Y** showed absorptions close to 1700 cm^{-1}.

bonds in **W** . . . . . .

bonds in **X** . . . . . .

bonds in **Y** . . . . . .

(This question continues on the following page)

(Question G3 continued)

(c) The ^{1}H NMR spectra of the three compounds were available. State what can be deduced from each of the following.

(i) The presence of **two** peaks in the spectrum of **W**. *[1]*

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(ii) The presence of a triplet and a quartet, with areas in the ratio 3:2, respectively, in the spectra of both **X** and **Y**. *[1]*

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(d) Use your answers to (b) and (c) to deduce the structures of the three compounds. *[3]*

W . . . . . .

. . . . . .

X . . . . . .

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Y . . . . . .

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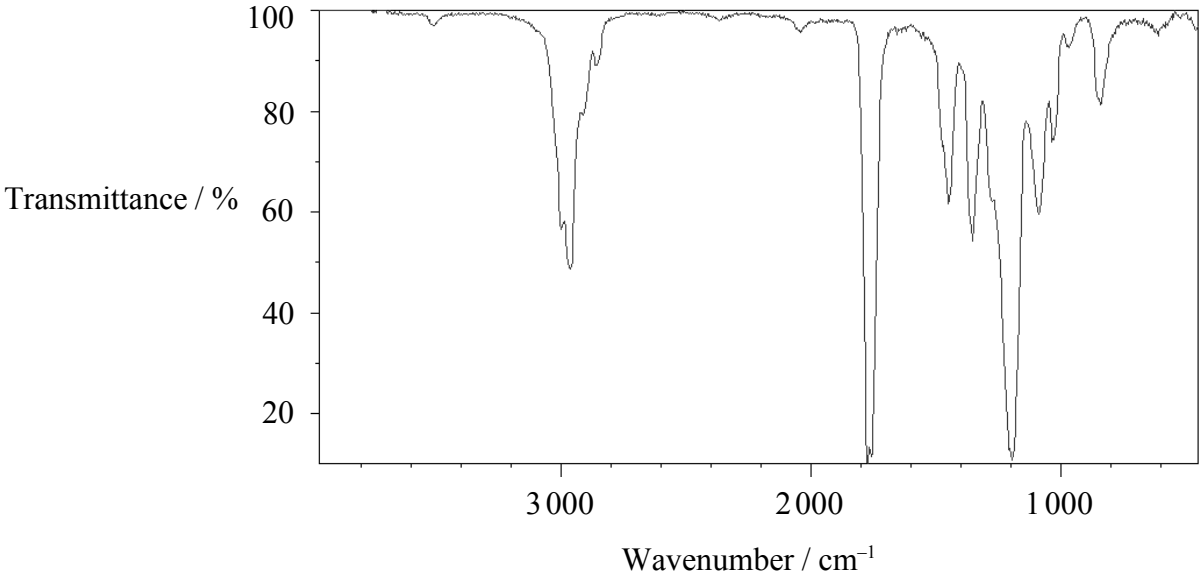
(This question continues on the following page)

(Question G3 continued)

(e) The infrared spectrum of compound **Z**, an isomer of **Y**, is shown below.



(i) Estimate the wavenumber values of the **three** most prominent absorptions in this spectrum and suggest which bonds are responsible for them. *[3]*

absorption 1 . . . . . .

absorption 2 . . . . . .

absorption 3 . . . . . .

(ii) Deduce the structure of **Z**. *[1]*

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Option H – Further organic chemistry

H1. The compound methylbenzene, $C_6H_5CH_3$, was reacted with chlorine under two different conditions.

In the presence of aluminium chloride two organic products, **F** and **G**, were formed, both with the molecular formula C_7H_7Cl.

Under the other set of conditions three organic products, **J**, **K** and **L**, were formed, with molecular formulas of C_7H_7Cl, $C_7H_6Cl_2$ and $C_7H_5Cl_3$, respectively.

(a) Deduce the structures of **F** and **G**. *[2]*

F

G

(b) State the type of mechanism that occurs in the formation of **F** and **G**. *[1]*

. . . . . .

(c) Write equations, using curly arrows to represent the movement of electron pairs, to show the mechanism of the reaction in which either **F** or **G** is formed. Use Cl^+ to represent the attacking species. *[3]*

(This question continues on the following page)

(Question H1 continued)

(d) Deduce the structures of compounds **J**, **K** and **L**. *[3]*

J

K

L

(e) State the type of mechanism that occurs in the formation of **J**, **K** and **L**. *[1]*

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(f) Write an equation to show the initiation step that occurs before either **J**, **K** or **L** can be formed, and state the condition needed. *[2]*

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(g) Write equations to show **two** propagation steps in the mechanism for the formation of compound **K**. *[2]*

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(This question continues on the following page)

(Question H1 continued)

(h) Write an equation to show a termination step in which compound **L** is formed. *[1]*

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(i) Predict, giving a reason, whether methylbenzene or compound **L** undergoes nitration more readily. *[3]*

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H2. The compound 2-bromobutane, $CH_3CHBrCH_2CH_3$, can react with sodium hydroxide to form compounds **M**, **N** and **O**.

Compound **M**, $C_4H_{10}O$, exists as a pair of optically active isomers. Compounds **N** and **O**, C_4H_8, are structural isomers, and compound **O** exists as a pair of geometrical isomers.

(a) Draw diagrams to show the relationship between the **two** isomers of **M**. *[2]*

(b) Draw diagrams to show the shapes of the **two** isomers of **O**. *[2]*

(c) Write equations, using curly arrows to represent the movement of electron pairs, to show the mechanism of the reaction in which **N** is formed. *[3]*