INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

N00/420/H(3)

CHEMISTRY
HIGHER LEVEL
PAPER 3

Wednesday 8 November 2000 (morning)

1 hour 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and 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 in a continuation answer booklet, and indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the boxes below.

OPTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
		/25	/25	/25
		/25	/25	/25
NUMBER OF CONTINUATION BOOKLETS USED	. . . . .	TOTAL /50	TOTAL /50	TOTAL /50

Option C – Human biochemistry

C1. Vitamin A is the general name for a group of substances that include retinol and retinal, both of which contain carbon to carbon double bonds.

(a) As their names suggest retinol and retinal differ in their structures by one functional group. Give the structure of the functional group for each compound. *[2]*

Retinol: . . . . . .

Retinal: . . . . . .

(b) In terms of electrons what is meant by the expression *double bond*? *[1]*

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(c) The molecular formula of retinol is $C_{19}H_{30}O$. 100 cm^3 of blood contains about 30 mg of retinol. Calculate the approximate concentration of retinol in blood in $mol\,dm^{-3}$. *[2]*

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(d) Given the above information, state whether the solubility of retinol will be greater in water or in fat and explain your answer. *[2]*

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C2. The structure of thyroxine, a hormone, is given in the Data Booklet.

(a) Name the element present in thyroxine which is absent from other hormones in the human body. *[1]*

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(b) Apart from the –OH group attached to the benzene ring, name and draw the structures of **two** other functional groups in thyroxine. *[4]*

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(c) State the general role of hormones and state how they are transported in the body. *[2]*

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(d) What is the specific role of thyroxine in the human body? *[1]*

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C3. Nucleic acids are made up of units called *nucleotides*. A nucleotide is composed of a phosphate group, a pentose sugar and a nitrogen-containing base.

(a) State the **two** main differences between the chemical composition of RNA and DNA. *[2]*

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(b) What type of chemical reaction takes place when nucleotides combine to form nucleic acids? *[1]*

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(This question continues on the following page)

(Question C3 continued)

(c) Using the structures of cytosine and guanine given in the Data Booklet, draw a diagram to account for the fact that guanine is always found opposite cytosine in the double helix structure of DNA. Name the type of bonding that exists between these two molecules. *[3]*

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(d) State what is meant by *DNA profiling* (genetic fingerprinting) and describe how a DNA profile is obtained. State **one** use for DNA profiling. *[4]*

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Option D – Environmental chemistry

D1. When the pH of rain water falls below about 5.6 it is known as *acid rain*.

(a) What is the ratio of the hydrogen ion concentration in acid rain with a pH of 4 compared to water with a pH of 7? *[1]*

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(b) One of the two major acids present in acid rain originates mainly from the burning of coal. **Name** this acid and give equations to show how it is formed. *[3]*

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(c) The second major acid responsible for acid rain originates mainly from internal combustion engines. **Name** this acid and state **two** different ways in which its production can be reduced. *[3]*

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(d) Acid rain has caused considerable damage to buildings and statues made of marble ($CaCO_3$). Write an equation to represent the reaction of acid rain with marble. *[1]*

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D2. (a) In order to survive, fish require water containing dissolved oxygen. Discuss briefly how an increase in each of the following factors affects the amount of dissolved oxygen in a lake. *[3]*

(i) Temperature: . . . . . .

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(ii) Organic pollutants: . . . . . .

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(iii) Nitrates and phosphates: . . . . . .

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(This question continues on the following page)

(Question D2 continued)

(b) Define *Biological Oxygen Demand* (*BOD*). *[1]*

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(c) In a method to find the concentration of dissolved oxygen, manganese(IV) oxide is formed. This is then used to release iodine which is titrated with standard thiosulfate solution. The equations for these three steps are:

$$2Mn^{2+}(aq) + 4OH^{-}(aq) + O_2(g) \rightarrow 2MnO_2(s) + 2H_2O(l)$$
$$MnO_2(s) + 2I^{-}(aq) + 4H^{+}(aq) \rightarrow Mn^{2+}(aq) + I_2(aq) + 2H_2O(l)$$
$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^{-}(aq)$$

1000 cm^3 of a sample of water was processed by this method. It was found that 10.0 cm^3 of 0.100 $mol\,dm^{-3}$ $Na_2S_2O_3$ solution were required to react with the iodine produced. Calculate the concentration of dissolved oxygen in $\mathbf{g\,dm^{-3}}$ in the water sample. *[3]*

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D3. (a) Oxygen in the upper atmosphere screens out harmful radiation with wavelengths shorter than about 220 nm due to the reaction:

$$O_2(g) \rightarrow 2O(g)$$

Use the value for the average bond enthalpy for oxygen (in $kJ\,mol^{-1}$) given in Table 10 and information from Tables 1 and 2 of the Data Booklet to calculate the maximum wavelength of light that is able to decompose oxygen. Give your answer to three significant figures. *[3]*

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(This question continues on the following page)

(Question D3 continued)

(b) Ozone absorbs radiation with a wavelength shorter than about 320 nm. Use Lewis structures to explain why ozone can be decomposed by light with a longer wavelength than that required to decompose oxygen. *[2]*

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(c) (i) Explain, with equations, how a CFC, such as dichlorodifluoromethane, is able to deplete ozone in the ozone layer. *[3]*

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(ii) Suggest an explanation to account for the fact that the depletion of ozone in the ozone layer is greatest as the winter months end over polar regions. *[2]*

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Option E – Chemical industries

E1. (a) When iron is produced in a blast furnace the product is known as *pig iron*. Pig iron contains about 5 % impurities.

(i) Name the major impurity found in pig iron. *[1]*

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(ii) *Wrought iron* has a higher melting point than pig iron. From this information what can be deduced about the percentage of iron in wrought iron compared to pig iron? *[1]*

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(b) Pig iron can be converted into steel in a basic oxygen converter. Iron is added to the converter, it is melted and then two chemicals are added.

(i) Name the **two** chemicals added. *[2]*

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(ii) Describe the essential processes that take place during the conversion of iron to steel. *[2]*

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(c) Both iron and aluminium can be recycled. Suggest **one** reason why it is more economical to recycle aluminium than steel. *[1]*

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E2. (a) Explain why crude oil contains small amounts of sulfur. *[1]*

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(b) Why must the sulfur be removed from crude oil before further refining takes place? *[1]*

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(c) One of the chemical processes used in the refining of crude oil is *cracking*. Give a balanced equation for the thermal cracking of $C_{10}H_{22}$ and explain why the process is important. *[2]*

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(This question continues on the following page)

(Question E2 continued)

(d) Crude oil can also be refined by *re-forming*. Two re-forming processes are *isomerisation* and *alkylation*. State the essential difference between the two processes. *[2]*

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(e) A third type of re-forming is *cyclisation and aromatisation.* One such example is the conversion of hexane to benzene using a catalyst at 500 °C and a pressure of 20 atmospheres.

(i) Write a balanced equation for this reaction. *[1]*

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(ii) For which important industrial process is the inorganic product from this reaction used as a feedstock? *[1]*

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E3. Chlorine can be produced by the electrolysis of sodium chloride solution using a diaphragm cell. State the materials used for the electrodes and the diaphragm and give balanced equations for the reactions that occur at the anode and cathode. Explain why the diaphragm cell is preferred to the mercury cathode cell and state **two** major uses (apart from disinfecting drinking water) for the chlorine produced. Explain how gases containing the C–Cl bond can cause depletion of ozone in the ozone layer. *[10]*

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Option F – Fuels and energy

F1. (a) When biomass, such as animal waste, decomposes in the absence of oxygen, *biogas* is formed. Name the main gas present in biogas. *[1]*

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(b) When wood and crop residues are burnt in a limited amount of oxygen, a mixture of gases known as *producer gas* is formed. Name **one** combustible gas present in producer gas. *[1]*

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(c) Name **two** substances hazardous to health which are produced when wood is burnt in an enclosed space. *[2]*

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(d) Why is biomass likely to become more important as a fuel in the future? *[1]*

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F2. (a) In the context of nuclear reactions, explain the meaning of *fission*. *[1]*

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(b) Explain why a fission reaction results in the release of a large quantity of energy. *[1]*

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(This question continues on the following page)

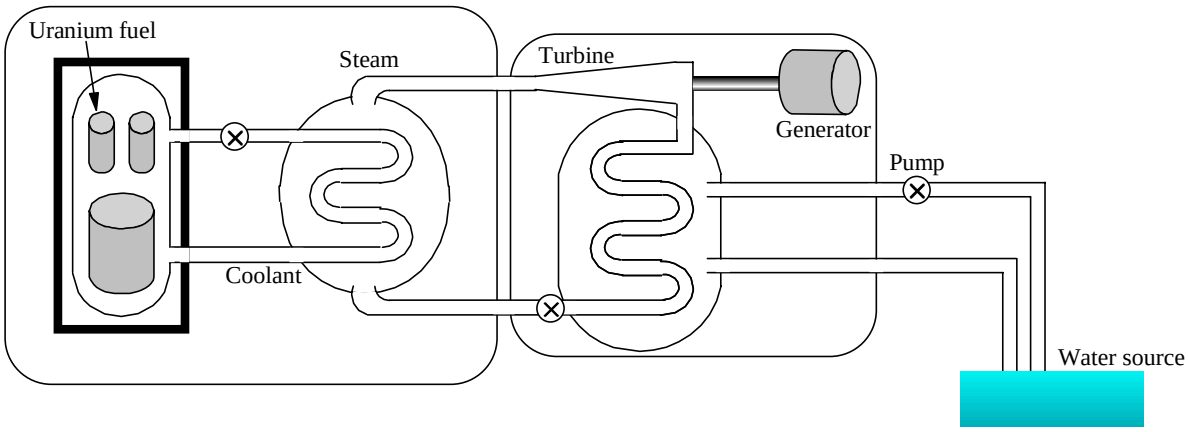
(Question F2 continued)

(c) The main reaction in a uranium reactor is fission of ^{235}U. A side reaction is caused when neutrons react with ^{238}U. Complete the following equation by filling in the symbols and values in the table below: *[4]*

$$^{238}_{a}U + {}^{b}_{c}X \rightarrow {}^{239}_{92}U \rightarrow {}^{239}_{94}Y + 2{}^{d}_{e}Z$$

X		b	
Y		c	
Z		d	
a		e	

(d) A diagram of a nuclear power plant to produce electricity is shown below:



The water which produces the steam to drive turbines in a nuclear power plant is not heated directly. Explain why more than one heat exchange loop is used and name **one** substance used in the primary cooling loop. *[2]*

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(This question continues on the following page)

(Question F2 continued)

(e) ^{14}C can be used for dating organic remains. Whilst a plant or animal is alive the amount of ^{14}C remains constant. At death the amount of ^{14}C decreases by a first order reaction with a half-life of 5730 years. In a living sample the $^{14}C : {}^{12}C$ ratio is 1.2×10^{-12}. If an object is found with a $^{14}C : {}^{12}C$ ratio of 1.5×10^{-13}, how old is the object? *[2]*

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F3. As the world's supply of fossil fuels is used up there is more interest in alternative technology sources. One alternative involves the use of silicon semiconductors. Describe how pure silicon is able to convert sunlight into electrical energy and explain why silicon is used for this purpose. State **two** disadvantages of using pure silicon for photovoltaic cells and describe and explain **two** ways in which the properties of silicon semiconductors can be altered to make them more efficient at trapping solar energy. *[10]*

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Option G – Modern analytical chemistry

G1. When *monochromatic* X-rays are directed towards the surface of a crystal, some undergo diffraction.

(a) What is meant by the term *monochromatic* and why is this important in X-ray crystallography? *[3]*

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(b) When X-rays with a wavelength of 154 pm are directed at a crystal of chromium the first order diffraction is found at 32.3°. Calculate the separation of the layers of atoms in the crystal. ($1\text{ pm} = 1.0 \times 10^{-12}$ m) *[2]*

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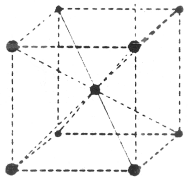
(c) (i)



The distance calculated in part (b) is half the side of the cubic unit cell of chromium shown. How many chromium atom equivalents does the unit cell contain? *[1]*

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(ii) Use appropriate data from the Data Booklet and the information about the dimensions of the unit cell to calculate the density of chromium. (If you could not calculate an answer for part (b), use a value of 150 pm, although this is not the correct value.) *[2]*

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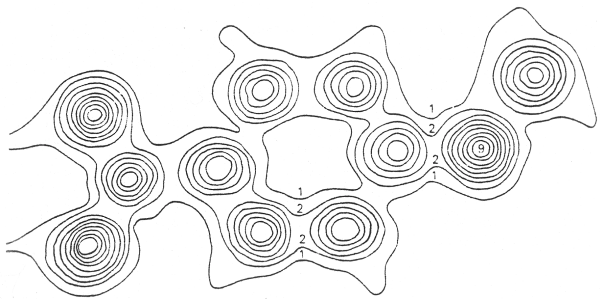
(Question G1 continued)

(d)



The diagram shown is an electron density map of 4-methylbenzoic acid obtained by X-ray diffraction.

(i) What must have been the physical state of the compound to obtain this map? *[1]*

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(ii) Which atoms in the molecule do not appear on this map? Why is this? *[2]*

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(iii) Comment on the electron density between atoms with reference to the type of bonding present. *[1]*

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(e) The technique above involves diffraction of the radiation. In absorption spectroscopy techniques, radiation of certain frequencies is absorbed as a result of changes to the molecule or ion.

(i) Explain why only certain frequencies are absorbed. *[2]*

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(ii) Changes in the rotational state of a particle absorb energy in the microwave region. What information does this give about the difference in energy of rotational states compared to the energy needed to cause changes in electrons or vibrations? *[1]*

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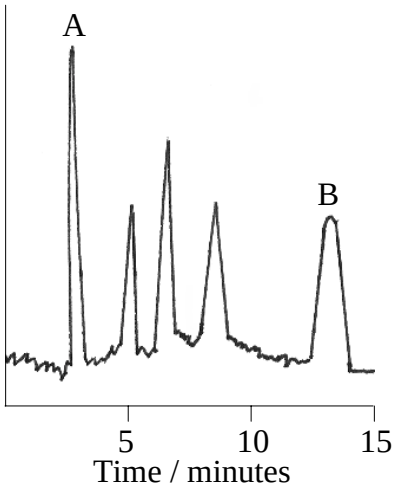
G2.



The diagram shows the separation of various pesticides using the technique of gas-liquid chromatography (GLC). Outline the way this technique operates, including how the components are detected. Explain the differences in the interactions of pesticide A and pesticide B that result in their separation. If the temperature is increased, what effect will this have on the chromatogram? Give **one** advantage and **one** disadvantage of choosing GLC instead of HPLC (high performance liquid chromatography). *[10]*

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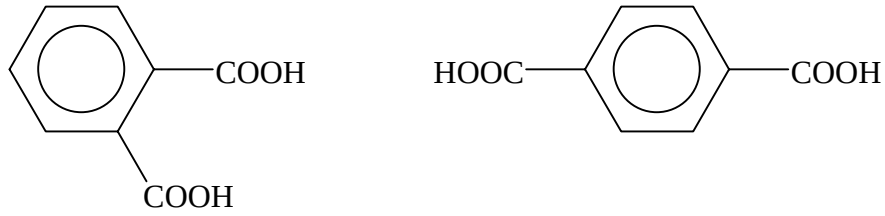
Option H – Further organic chemistry

H1. Benzene-1,2-dicarboxylic acid and benzene-1,4-dicarboxylic acid are isomers.



1,2-isomer 1,4-isomer

(a) Explain why the 1,2-isomer has a lower melting point than the 1,4-isomer. *[2]*

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(b) Explain why **one** of the isomers can undergo an elimination (condensation) reaction when it is heated whereas the other isomer is stable towards heat. Give the structure of the organic product formed when the elimination reaction has occurred. *[2]*

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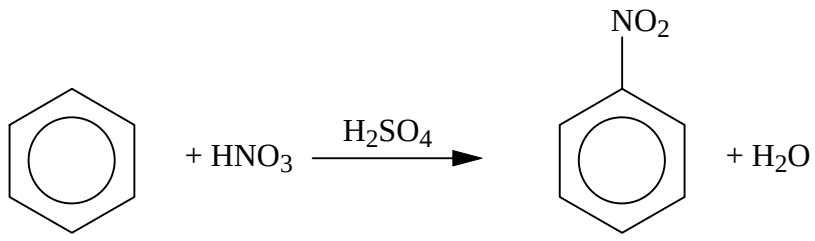
H2. Benzene reacts with a mixture of concentrated nitric acid and concentrated sulfuric acid at 50 °C to form nitrobenzene according to the equation:



(a) Name the mechanism by which this reaction proceeds. *[1]*

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(Question H2 continued)

(b) What is the initial role of the sulfuric acid when it functions as a catalyst in this reaction? *[1]*

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(c) The product, nitrobenzene, can be further nitrated with a mixture of concentrated nitric and sulfuric acid, but the temperature needs to be increased to 100 °C. Explain why nitrobenzene is less reactive towards nitration than benzene. *[2]*

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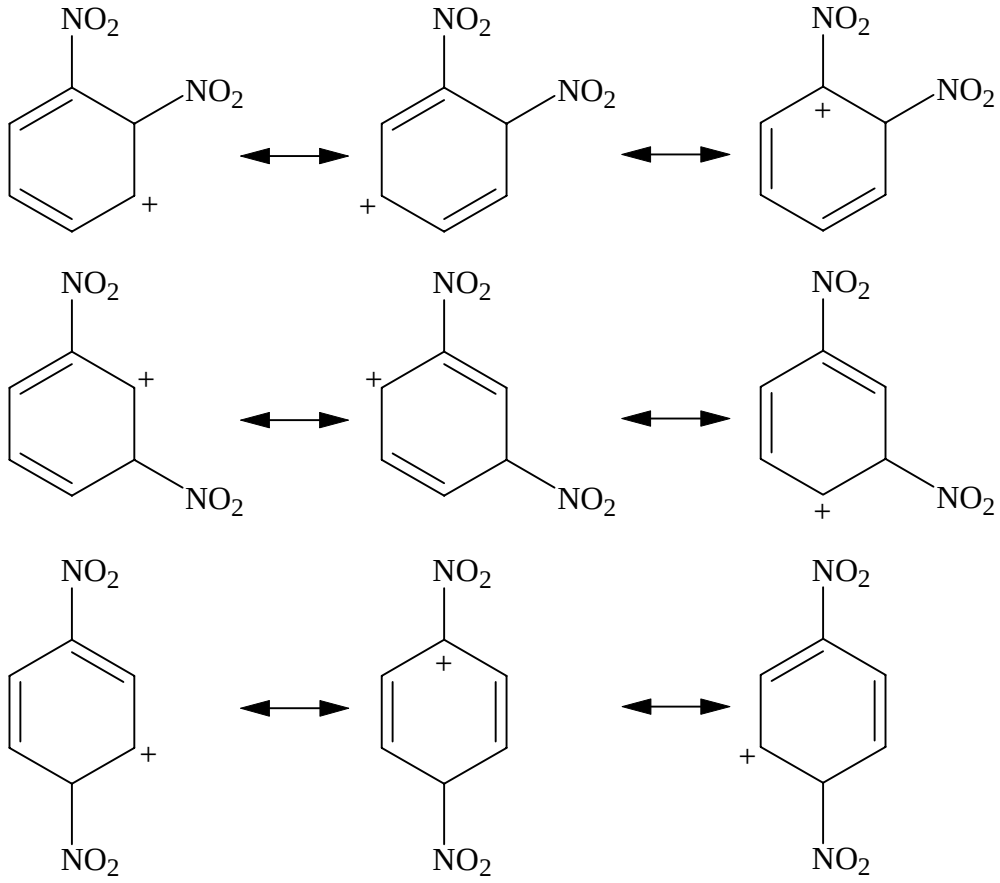
(This question continues on the following page)

(Question H2 continued)

(d) The further nitration of nitrobenzene can take place in the 2-, 3- or 4- position. The structures of the possible intermediate carbocations are given below:



(i) State what is meant by the term *resonance hybrid*. *[1]*

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(ii) Explain why the major product in the reaction is 1,3-dinitrobenzene rather than 1,2-dinitrobenzene or 1,4-dinitrobenzene. *[2]*

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(This question continues on the following page)

(Question H2 continued)

(e) When a student prepared 1,3-dinitrobenzene in a school laboratory she found that her recrystallised product melted over the range 82–86 °C. The data book value for the melting point of 1,3-dinitrobenzene is given as 90 °C. What could she deduce about her product? *[1]*

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H3. When aqueous silver nitrate is added to 1-bromobutane at room temperature no reaction is observed at first. After several minutes a faint precipitate appears. If 1-bromobutane is replaced by bromobenzene, no reaction with aqueous silver nitrate is observed even after several hours.

(a) What is the faint precipitate produced in the reaction between silver nitrate and 1-bromobutane? *[1]*

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(b) Why does the silver nitrate solution produce no immediate precipitate with 1-bromobutane? *[1]*

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(c) Suggest a reason why the precipitate appears after several minutes. *[1]*

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(d) Explain why no reaction takes place between bromobenzene and aqueous silver nitrate solution under the conditions described above. *[1]*

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(This question continues on the following page)

(Question H3 continued)

(e) Aqueous sodium hydroxide was warmed with:
(i) 1-bromobutane and
(ii) 2-bromo-2-methylpropane.

Write the structural formulas of the organic **products** for both reactions. Give the rate expression and equations to show the mechanism for each reaction. Explain the difference in the reaction mechanisms for the two reactions in terms of the effect of the carbon skeleton. *[9]*

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