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

N03/420/H(3)+

CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate number

Monday 10 November 2003 (morning)

1 hour 15 minutes

INSTRUCTIONS TO CANDIDATES

- Write your candidate number in the box 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 candidate 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. (a) List the **three** different ways in which drugs can be **injected** into the body. Predict, giving a reason, which of the three methods will result in the drug having the most rapid effect. *[4]*

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(b) State what is meant by *tolerance* towards a drug and explain why it is potentially dangerous. *[2]*

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B2. (a) One method for detecting alcohol in breath involves blowing through a tube containing crystals of acidified potassium dichromate(VI). The alcohol turns the crystals from orange to green. Explain what happens to both the dichromate(VI) ion and the alcohol in this reaction. *[2]*

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(b) A modern method for accurately determining the amount of alcohol in breath uses an intoximeter. Explain how an intoximeter works. *[3]*

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(This question continues on the following page)

(Question B2 continued)

(c) Suggest why it is advisable not to drink alcohol when taking other drugs. *[2]*

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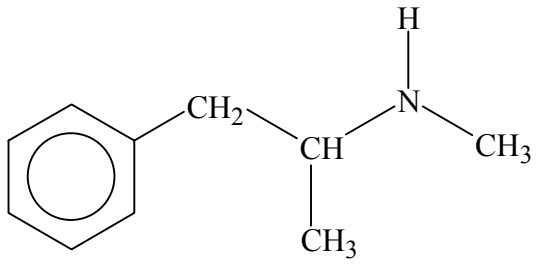
B3. Methylamphetamine (also known as methamphetamine or "speed") is a stimulant with the following structure.



(a) Draw a ring around the amine group in methylamphetamine and state whether it is a primary, secondary or tertiary amine. *[2]*

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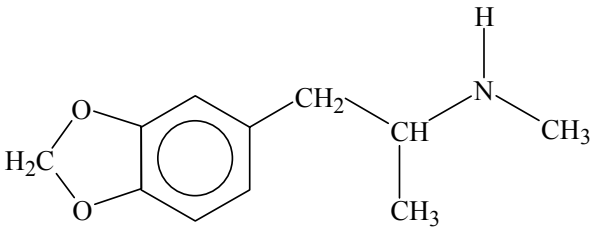
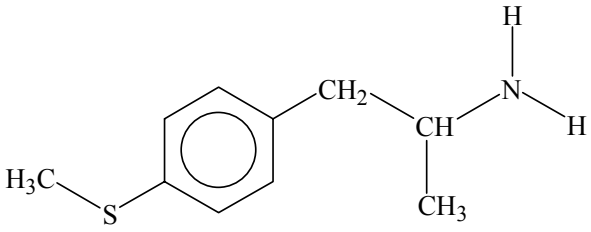
(b) A "designer drug" with a structure related to methylamphetamine is Ecstasy. Ecstasy tablets are sometimes contaminated with a substance called 4-MTA.



Ecstasy



4-MTA

State how the type of amine group in 4-MTA differs from the amine group in Ecstasy. *[1]*

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(c) (i) Methylamphetamine, Ecstasy and 4-MTA are sympathomimetic drugs. Identify the structural similarity between the three drugs and adrenaline, the structure of which is given in the Data Booklet. *[1]*

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(ii) Outline what is meant by the term *sympathomimetic drug* and state **one** example of a short-term effect sympathomimetic drugs have on the human body. *[2]*

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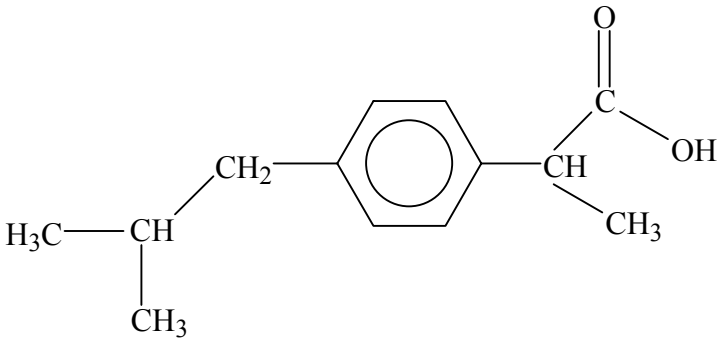
B4. Ibuprofen is an analgesic with the following structure:



(a) Identify the chiral carbon atom(s) in the structure of ibuprofen using an asterisk (*). *[1]*

(b) Describe how chiral auxiliaries can be used to synthesize only the desired enantiomeric form of a drug from a non-chiral starting compound. Explain why it is important to use only the desired enantiomeric form of a drug and state an example of what can happen if a racemic mixture is used. *[5]*

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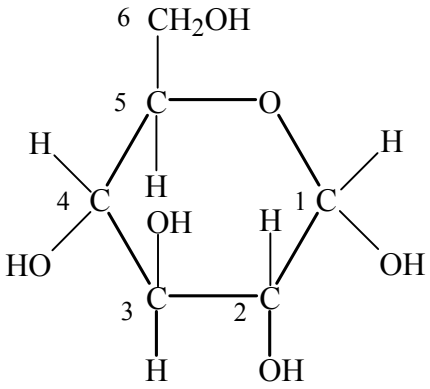
Option C – Human Biochemistry

C1. (a) Draw the straight chain structure of glucose. *[1]*

(b) The structure of α-glucose is shown below:



Outline the structural difference between α-glucose and β-glucose. *[1]*

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(c) Glucose molecules can condense to form starch which can exist in two forms, amylose and amylopectin. Describe the structural differences between the two forms. *[2]*

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(This question continues on the following page)

(Question C1 continued)

(d) 1.00 g of sucrose, $C_{12}H_{22}O_{11}$, was completely combusted in a food calorimeter. The heat evolved was equivalent to increasing the temperature of 631 g of water from 18.36°C to 24.58°C. Calculate the calorific value of sucrose (in kJ mol^{-1}) given the specific heat capacity of water in Table 2 of the Data Booklet. *[3]*

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C2. Linoleic acid, $C_{17}H_{31}COOH$, ($M_r = 280$) and stearic acid, $C_{17}H_{35}COOH$, ($M_r = 284$), both contain eighteen carbon atoms and have similar molar masses.

(a) Explain why the melting point of linoleic acid is considerably lower than the melting point of stearic acid. *[3]*

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(b) Determine the maximum mass of iodine, I_2, ($M_r = 254$) that can add to

(i) 100 g of stearic acid: . . . . . *[1]*

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(ii) 100 g of linoleic acid: . . . . . *[2]*

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(c) (i) Draw the simplified structural formula of a fat containing one stearic acid and two linoleic acid residues. *[1]*

(ii) Give the formulas of the products formed when this fat is hydrolyzed by sodium hydroxide. *[1]*

C3. Genetic information is stored in chromosomes which contain a very long DNA sequence.

(a) (i) A nucleotide of DNA contains deoxyribose, a phosphate group and an organic base. Outline how nucleotides are linked together to form polynucleotides. *[2]*

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(ii) Describe the bonding between the two strands in the double helical structure of DNA. *[2]*

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(b) Explain how the sequence of different bases in DNA is related to the genetic information carried in the chromosomes. *[2]*

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(c) Describe how a DNA profile can be obtained from a sample of blood taken from a child and explain how it could be used to prove whether or not a particular adult is the child's parent. *[4]*

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Option D – Environmental Chemistry

D1. For each of the primary pollutants below, state **one** chemical method used to reduce the amount entering the atmosphere and give **one** relevant equation relating to the chemistry behind the method.

(a) Carbon monoxide, CO: . . . . . *[2]*

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(b) Nitrogen(II) oxide, NO: . . . . . *[2]*

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(c) Sulfur(IV) oxide, SO_2: . . . . . *[2]*

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(d) Gasoline (petrol), C_8H_{18}: . . . . . *[2]*

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D2. (a) Explain using an equation why rain falling in unpolluted air is acidic with a pH of about 5.7. *[2]*

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(b) "Acid rain" has a pH less than 5.6. Explain using an equation how the burning of coal can contribute to acid rain formation. *[2]*

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(c) "Acid rain" can affect plants and buildings.

(i) Outline how an acidic soil can damage the growth of trees. *[1]*

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(ii) Give an equation for the reaction of acid rain on marble statues **or** limestone buildings. *[1]*

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(d) Explain how the addition of calcium oxide to lakes could neutralize the effects of "acid rain". *[1]*

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D3. (a) Discuss the **disadvantages** of the different ways of expressing toxicity. Your answer should include the definitions of the terms LD_{50} and *maximum daily tolerance*. *[6]*

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(b) The maximum safe limit for nitrates in drinking water has been set at $50\ \text{mg dm}^{-3}$ by the World Health Organization. Calculate the maximum mass of sodium nitrate permissible in one litre $(1.00\ \text{dm}^3)$ of drinking water assuming no other source of nitrate is present. *[2]*

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(c) Nitrates are thought to pose a risk to very small babies as they can lead to oxygen starvation. State why nitrates are also toxic to adults. *[2]*

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Option E – Chemical Industries

E1. (a) (i) Apart from the availability of raw materials, energy and a good transport system, list **three** factors that influence the location of modern chemical industries producing consumer products. *[3]*

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(ii) State the difference between intermediate products and consumer products in the chemical industry and give **one** example of each. *[2]*

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(b) State **one** example of the use of biotechnology in chemical manufacture. *[1]*

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E2. (a) The manufacture of low density poly(ethene) is carried out at very high pressures and at a temperature of about 500 K. A catalyst (either an organic peroxide or a trace of oxygen) is added to the ethene. Explain how the catalyst reacts and describe the mechanism of the polymerization. *[3]*

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(b) State the catalyst used to manufacture high density poly(ethene) and describe the feature of the catalyst that enables it to form intermediate complexes with the π electrons of ethene molecules. *[2]*

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E3. Traditionally, the raw materials for the production of iron are iron ore, coke, limestone and preheated air. Iron oxides are reduced in a blast furnace by both carbon and carbon monoxide to form iron.

(a) Explain why the Ellingham diagram for the formation of iron from iron(II) oxide shows a *downwards* slope as the temperature decreases and why the Ellingham diagram for the formation of carbon from carbon monoxide shows an *upwards* slope as the temperature decreases. *[4]*
(See page 10 of the Data Booklet.)

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(b) Explain why iron(II) oxide will be reduced by carbon but **not** by carbon monoxide at temperatures above 1000 K. *[3]*

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(c) In many modern blast furnaces, hydrocarbons (such as methane) are also added to the preheated air. This produces carbon monoxide and hydrogen. The hydrogen formed can also act as a reducing agent. Give the equation for the reduction of magnetite, Fe_3O_4, by hydrogen. *[1]*

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(This question continues on the following page)

(Question E3 continued)

(d) The iron produced in the blast furnace is known as "pig iron". It contains about 5 % carbon, together with small amounts of other elements such as phosphorus and silicon.

Explain the chemical principles behind the conversion of iron into steel using the basic oxygen converter. *[6]*

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Option F – Fuels and Energy

F1. (a) State **two** essential differences between chemical bond breaking and nuclear fission. *[2]*

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(b) (i) Deduce the identity of the product X in the following nuclear reaction. *[1]*

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{144}_{56}\mathrm{Ba} + {}^{90}_{36}\mathrm{Kr} + 2\mathrm{X}$$

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(ii) The mass defect for each mole of uranium in the above reaction is 0.2072 g. Calculate the maximum amount of energy evolved when one mole of $^{235}_{92}\mathrm{U}$ reacts completely according to the above equation. *[1]*

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(c) The half-life of $^{238}_{92}\mathrm{U}$ is 4.50×10^{9} years. Deduce the time taken for 1000 tonnes of $^{238}_{92}\mathrm{U}$ to decay to 125 tonnes of the same isotope. *[1]*

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(d) A nuclear reactor contains control rods and moderators.

(i) Explain the function of *[2]*

control rods: . . . . . .

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moderators: . . . . . .

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(ii) State **one** example of a material used in control rods. *[1]*

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(e) Both nuclear and conventional power stations use a turbine to drive a generator to produce electricity. Explain why nuclear power stations contain a secondary coolant whereas conventional power stations may only have a primary coolant. *[1]*

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F2. Automobiles in some countries are able to run on either gasoline (petrol) or on a mixture of gasoline and ethanol known as "gasohol".

(a) Explain what is meant when gasoline is said to have an octane rating of 98. *[1]*

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(b) Give the equation for the complete combustion of octane. *[1]*

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(c) Give the equation for the fermentation of glucose, $C_6H_{12}O_6$, to produce ethanol. *[1]*

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(d) The enthalpies of combustion of octane and ethanol are given in the Data Booklet. Deduce the maximum amount of energy available from burning:

(i) 1.00 kg of octane $(M_r = 114.0)$. *[1]*

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(ii) 1.00 kg of gasohol which contains 20 % ethanol $(M_r = 46.0)$ and 80 % octane by mass. *[2]*

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F3. Discuss **two** advantages and **two** disadvantages of converting water into hydrogen as a means of storing energy. *[4]*

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F4. Explain how a photovoltaic cell works. Your answer should include an explanation of how doping can lead to different types of semi-conductors. *[6]*

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Option G – Modern Analytical Chemistry

G1. Explain the following observations:

(a) The absorptions obtained from ^{1}H NMR spectroscopy occur at much lower frequencies than those obtained from IR spectroscopy. *[3]*

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(b) Hydrogen iodide is infrared active whereas iodine is infrared inactive. *[2]*

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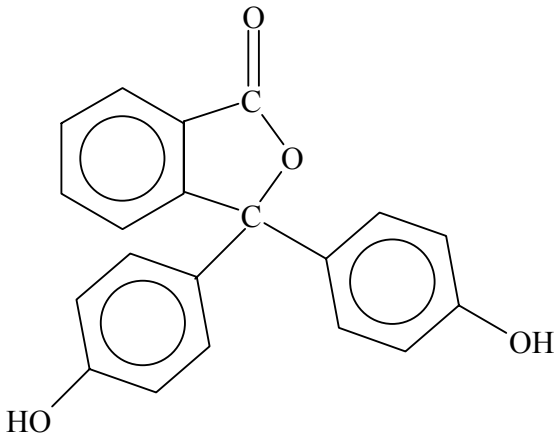
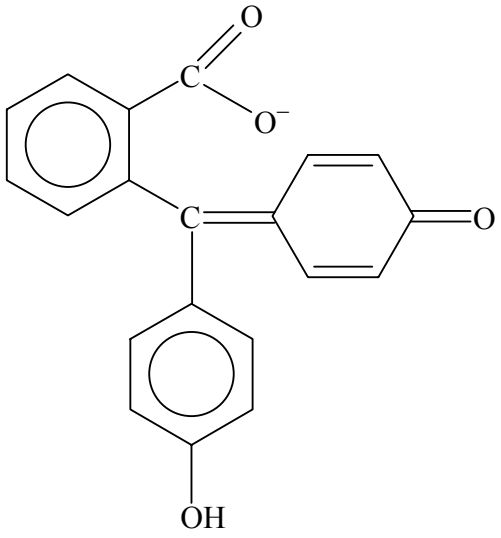
(c) Phenolphthalein is colourless in acidic solutions but coloured in alkaline solutions. *[2]*



structure in acidic solution



structure in alkaline solution

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G2. (a) The colour of transition metal complexes depends on several factors.

(i) Use $[Mn(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{2+}$ as examples to outline why the colour depends on the identity of the transition metal itself. *[3]*

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(ii) Outline why the colour depends on the oxidation state of the transition metal. *[1]*

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(iii) Outline why the colour depends on the identity of the ligand. *[1]*

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(b) A student wanted to determine a more accurate value for the concentration of a solution of $Mn^{2+}(aq)$ which was known to be between 0.10 and 0.010 mol dm^{-3}. She was provided with a solution of 1.00 mol dm^{-3} manganese(II) sulfate, $MnSO_4$. Describe how she could determine the unknown concentration using a visible spectrometer and explain the importance of the Beer-Lambert law in the method used. *[5]*

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G3. Describe the IR and ^{1}H NMR spectra of propanal and propanone. Your answer should include both the similarities and the differences between the spectra of both compounds. *[8]*

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Option H – Further Organic Chemistry

H1. Propene contains a C═C double bond whereas propanal contains a C═O double bond.

(a) State and explain **two** similarities and **two** differences in the way in which the atoms are bonded in the covalent double bond in the two compounds. *[4]*

Similarities: . . . . . .

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Differences: . . . . . .

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(b) Both propene and propanal typically undergo addition reactions. State the type of addition reaction that takes place with each compound. *[2]*

Propene: . . . . . .

Propanal: . . . . . .

(c) Hydrogen cyanide reacts with ethanal to form 2-hydroxypropanenitrile. Describe the mechanism of this reaction using "curly arrows" to show the movement of pairs of electrons. *[4]*

(This question continues on the following page)

(Question H1 continued)

(d) 2-hydroxypropanenitrile can be hydrolyzed under acidic conditions to form 2-hydroxypropanoic acid.

(i) Draw the two enantiomers of 2-hydroxypropanoic acid. *[2]*

(ii) State how the two enantiomers differ in their chemical and physical properties. *[2]*

Chemical: . . . . . .

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Physical: . . . . . .

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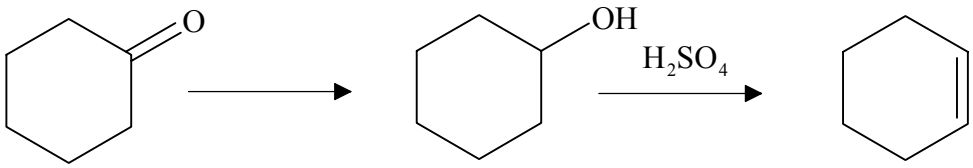
H2. Consider the following reaction sequence for the conversion of cyclohexanone into cyclohexene.



(a) State the type of reaction taking place when cyclohexanone is converted into cyclohexanol. *[1]*

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(b) Describe each step in the mechanism (using "curly arrows" to show the movement of pairs of electrons) for the conversion of cyclohexanol to cyclohexene. Explain clearly the two different roles played by the concentrated sulfuric acid in the reaction. *[5]*

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(c) Suggest a reason why concentrated phosphoric acid, H_3PO_4, is usually preferred to concentrated sulfuric acid in the above reaction. *[1]*

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(This question continues on the following page)

(Question H2 continued)

(d) Cyclohexanone can react with 2,4-dinitrophenylhydrazine in aqueous solution.

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

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(ii) Write a balanced equation for this reaction using structural formulas for the reactants and products. *[2]*

(iii) Explain how the product from this particular reaction can be used to confirm that the reactant was cyclohexanone and not any other carbonyl compound. *[1]*

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