Please check the examination details below before entering your candidate information

| Candidate surname | Other names |
|---|---|
| | |

**Pearson Edexcel**
**International Advanced Level**

Centre Number | | | | | |

Candidate Number | | | | |

# Thursday 16 January 2020

Morning (Time: 1 hour 30 minutes) | Paper Reference **WCH12/01**

# Chemistry

## International Advanced Subsidiary/Advanced Level

**Unit 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols**

**Candidates must have: Scientific calculator**
**Data Booklet**
**Ruler**

Total Marks

## Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*

## Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

## Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Check your answers if you have time at the end.

*Turn over* ▶

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Pearson

## SECTION A

**Answer ALL the questions in this section.**

**You should aim to spend no more than 20 minutes on this section.**

**For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.**

**1** Which equation represents the standard enthalpy change of formation, $\Delta_f H^{\ominus}$, of hydrogen iodide?

☒ **A** $H(g) + I(g) \rightarrow HI(g)$

☒ **B** $H_2(g) + I_2(s) \rightarrow 2HI(g)$

☒ **C** $\frac{1}{2}H_2(g) + \frac{1}{2}I_2(g) \rightarrow HI(g)$

☒ **D** $\frac{1}{2}H_2(g) + \frac{1}{2}I_2(s) \rightarrow HI(g)$

**(Total for Question 1 = 1 mark)**

**2** When 50 $cm^3$ of hydrochloric acid of concentration 2.0 mol $dm^{-3}$ is added to 50 $cm^3$ of sodium hydroxide solution of concentration 2.0 mol $dm^{-3}$, the temperature increase is 13.0 °C.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

The experiment is repeated using 25 $cm^3$ of the same hydrochloric acid and 50 $cm^3$ of the same sodium hydroxide solution.

What is the temperature increase?

☒ **A** 4.9 °C

☒ **B** 6.5 °C

☒ **C** 8.7 °C

☒ **D** 13.0 °C

**(Total for Question 2 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

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**3** Nitrogen reacts with hydrogen to form ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta_r H = -92\,kJ\,mol^{-1}$$

| Bond | Bond energy / kJ mol$^{-1}$ |
|---|---|
| N≡N | 945 |
| H—H | 436 |

What is the mean bond energy, in kJ mol$^{-1}$, for the N—H bond?

☒ **A** 246

☒ **B** 360

☒ **C** 376

☒ **D** 391

**(Total for Question 3 = 1 mark)**

**4** How many moles of $CO_2$ are formed when 3.0 mol of chloroethene, $C_2H_3Cl$, is mixed with 10.0 mol of oxygen and react as shown?

$$2C_2H_3Cl + 5O_2 \rightarrow 4CO_2 + 2H_2O + 2HCl$$

☒ **A** 3.0

☒ **B** 4.0

☒ **C** 6.0

☒ **D** 8.0

**(Total for Question 4 = 1 mark)**

**5** Which compounds are arranged in order of **decreasing** boiling temperature?

☒ **A** $CH_3CH_2CH_2CH_3 > CH_3CH_2CH_2CH_2CH_3 > CH_3CH_2CH_2CH_2CH_2CH_3$

☒ **B** $CH_3CH_2CH_2CH_2CH_2CH_3 > (CH_3)_2CHCH_2CH_2CH_3 > (CH_3)_3CCH_2CH_3$

☒ **C** $CH_3CH_2CH_2OH > CH_3CHOHCH_2OH > CH_2OHCHOHCH_2OH$

☒ **D** $CH_3Cl > CH_3Br > CH_3I$

**(Total for Question 5 = 1 mark)**

**6** Chlorine is added to 2 $cm^3$ of a dilute solution of potassium iodide.

The equation for the reaction between chlorine and iodide ions is

$$Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$$

(a) Which statement is correct?

**(1)**

☒ **A** iodide ions oxidise chlorine

☒ **B** iodide ions reduce chlorine

☒ **C** chlorine reduces iodide ions

☒ **D** chlorine is neither oxidised nor reduced

(b) When the reaction is complete, 10 $cm^3$ of cyclohexane (density = 0.79 g $cm^{-3}$) is added. The mixture is shaken and left to settle into two layers.

Which description of one of these layers is correct?

**(1)**

☒ **A** the upper layer is purple

☒ **B** the lower layer is purple

☒ **C** the upper layer is brown

☒ **D** the lower layer is brown

**(Total for Question 6 = 2 marks)**

**7** Going from calcium to barium in Group 2, which property changes as stated?

☒ **A** ionic radius decreases

☒ **B** first ionisation energy decreases

☒ **C** melting temperature increases

☒ **D** reactivity with water decreases

**(Total for Question 7 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**8** The properties of Group 2 compounds change down the group from magnesium to barium.

Which statement is correct?

☒ **A** solubility of Group 2 sulfates increases

☒ **B** solubility of Group 2 hydroxides decreases

☒ **C** thermal stability of Group 2 nitrates increases

☒ **D** thermal stability of Group 2 carbonates decreases

**(Total for Question 8 = 1 mark)**

**9** Iodine reacts with hot sodium hydroxide solution.

$$a\ NaOH(aq) + b\ I_2(aq) \rightarrow c\ NaI(aq) + d\ NaIO_3(aq) + e\ H_2O(l)$$

What are the coefficients (a, b, c, d and e) needed to balance this equation?

| | a | b | c | d | e |
|---|---|---|---|---|---|
| ☒ **A** | 2 | 1 | 1 | 1 | 1 |
| ☒ **B** | 4 | 2 | 3 | 1 | 2 |
| ☒ **C** | 4 | 1 | 3 | 1 | 1 |
| ☒ **D** | 6 | 3 | 5 | 1 | 3 |

**(Total for Question 9 = 1 mark)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**10** Aqueous sodium iodide reacts with aqueous silver nitrate to form a precipitate of silver iodide.

$$NaI(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgI(s)$$

$M_r$ values: 149.9 169.9 85.0 234.8

(a) Which is correct for silver iodide?

**(1)**

| | Colour of precipitate | Solubility in concentrated aqueous ammonia |
|---|---|---|
| ☒ **A** | yellow | insoluble |
| ☒ **B** | yellow | soluble |
| ☒ **C** | cream | insoluble |
| ☒ **D** | cream | soluble |

(b) What is the percentage atom economy by mass for the production of silver iodide in this reaction?

**(1)**

☒ **A** 29%

☒ **B** 37%

☒ **C** 50%

☒ **D** 73%

**(Total for Question 10 = 2 marks)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**11** Ethanol can be prepared by reacting chloroethane with aqueous potassium hydroxide.

(a) What type of reaction occurs in this preparation?

**(1)**

☒ **A** addition

☒ **B** elimination

☒ **C** reduction

☒ **D** substitution

(b) How do the boiling temperatures of ethanol and chloroethane compare, and what is the reason for the difference?

**(1)**

| | Comparison of boiling temperature | Reason for the difference |
|---|---|---|
| ☒ **A** | ethanol is higher | ethanol molecules form hydrogen bonds |
| ☒ **B** | ethanol is higher | ethanol molecules have more atoms |
| ☒ **C** | ethanol is lower | ethanol molecules have fewer electrons |
| ☒ **D** | ethanol is lower | ethanol has a lower molar mass |

(c) Bromoethane and chloroethane react with aqueous potassium hydroxide at different rates.

Which is correct?

**(1)**

| | Difference in rate | Reason for difference |
|---|---|---|
| ☒ **A** | bromoethane is faster | C—Br bond is less polar than the C—Cl bond |
| ☒ **B** | bromoethane is faster | C—Br bond is weaker than the C—Cl bond |
| ☒ **C** | bromoethane is slower | C—Br bond is less polar than the C—Cl bond |
| ☒ **D** | bromoethane is slower | C—Br bond is stronger than the C—Cl bond |

**(Total for Question 11 = 3 marks)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**12** Butanol burns completely in oxygen.

$$C_4H_9OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$$

[ $M_r$ butanol = 74.0
Molar volume of a gas at room temperature and pressure (r.t.p.) = 24.0 $dm^3 mol^{-1}$ ]

7.40 g butanol was burned completely in 16.0 $dm^3$ oxygen and the mixture of gases produced was cooled to r.t.p.

(a) What is the final volume of the mixture of gases in **$dm^3$** at r.t.p.?

**(1)**

☒ **A** 9.60

☒ **B** 11.2

☒ **C** 21.6

☒ **D** 23.2

(b) If the final mixture of gases is passed through a U-tube containing sodium hydroxide, what is the final volume of gas in **$cm^3$**?

**(1)**

☒ **A** 0.0

☒ **B** 1600

☒ **C** 9600

☒ **D** 12000

**(Total for Question 12 = 2 marks)**

**Use this space for any rough working. Anything you write in this space will gain no credit.**

**13** A halogenoalkane is dissolved in aqueous ethanol. When aqueous silver nitrate is added, a white precipitate forms **immediately**.

What is the halogenoalkane?

☒ **A** 1-chlorobutane

☒ **B** 2-chlorobutane

☒ **C** 1-chloro-2-methylpropane

☒ **D** 2-chloro-2-methylpropane

**(Total for Question 13 = 1 mark)**

**14** Propanal ($CH_3CH_2CHO$) and propanone ($CH_3COCH_3$) are isomers.

(a) Which *m/z* peak would **not** be expected in the mass spectrum of propanone?

**(1)**

☒ **A** 15

☒ **B** 29

☒ **C** 43

☒ **D** 58

(b) Propanal and propanone can be distinguished by chemical tests.

Which pair of observations is correct?

**(1)**

| | Test | Observation with propanal | Observation with propanone |
|---|---|---|---|
| ☒ **A** | warm with Fehling's solution | no change | red precipitate |
| ☒ **B** | add solid phosphorus(V) chloride | no change | misty fumes |
| ☒ **C** | warm with acidified potassium dichromate(VI) | turns green | no change |
| ☒ **D** | add sodium hydrogencarbonate | fizzes | no change |

**(Total for Question 14 = 2 marks)**

**TOTAL FOR SECTION A = 20 MARKS**

## SECTION B

**Answer ALL the questions.**

**Write your answers in the spaces provided.**

**15** This question is about hydrated salts.

(a) The enthalpy change for the conversion of anhydrous copper(II) sulfate, $CuSO_4$, to the hydrated form, $CuSO_4.5H_2O$, can be found using Hess's Law.

$$CuSO_4(s) + 5H_2O(l) \xrightarrow{\Delta_r H} CuSO_4.5H_2O(s)$$

A student carried out experiments to determine the value of the enthalpy change, $\Delta_r H$. Known masses of anhydrous and hydrated copper(II) sulfate were dissolved separately in water in insulated containers, and the temperature changes measured.

The results are shown in the table.

| Compound | Mass / g | Volume of water used / $cm^3$ | Temperature change / °C | $\Delta_{soln}H$ / $kJ\,mol^{-1}$ |
|---|---|---|---|---|
| $CuSO_4.5H_2O(s)$ | 12.5 | 45.5 | −3.0 | +12.6 |
| $CuSO_4(s)$ | 8.00 | 50.0 | +16.0 | |

(i) State why different volumes of water are used in the two experiments. Justify your answer.

**(2)**

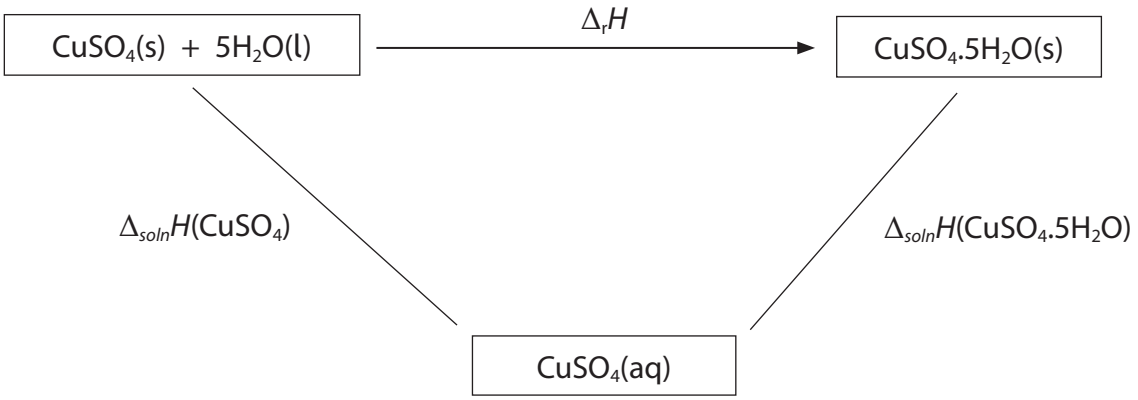
(ii) Calculate the enthalpy change of solution, $\Delta_{soln}H$, in kJ mol$^{-1}$, for the anhydrous salt, $CuSO_4$.

[ Assume: heat capacity of the solution = 4.2 J g$^{-1}$ °C$^{-1}$
density of solution = 1.0 g cm$^{-3}$ ]

**(3)**

(iii) Complete the Hess cycle by adding two arrowheads.

**(1)**




(iv) Calculate the value for the enthalpy change $\Delta_r H$, in kJ mol$^{-1}$, for the conversion of the anhydrous salt to the hydrated salt.
Use the value from the table for $\Delta_{soln}H$ ($CuSO_4.5H_2O$), the value for $\Delta_{soln}H$ ($CuSO_4$) calculated in (a)(ii) and the completed Hess cycle in (a)(iii).

**(2)**

(b) The hydration of anhydrous copper(II) sulfate is reversible.

$$CuSO_4(s) + 5H_2O(l) \rightleftharpoons CuSO_4.5H_2O(s)$$

The forward reaction is exothermic. The temperature changes for both the forward and reverse reactions are difficult to measure.

Suggest a reason in each case.

**(2)**

Forward .....

.....

.....

Reverse .....

.....

.....

(c) Describe the processes that occur when solid copper(II) sulfate dissolves in water.

**(2)**

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(d) Hydrates of sodium carbonate may be represented by the formula $Na_2CO_3.xH_2O$.

The value of x can be found by making up a solution of sodium carbonate and titrating this with a solution of hydrochloric acid of known concentration.

A known mass of $Na_2CO_3.xH_2O$ was dissolved in water, made up to the mark in a 250.0 $cm^3$ volumetric flask and mixed thoroughly.

25.0 $cm^3$ portions of the solution were titrated with 0.0900 mol $dm^{-3}$ hydrochloric acid using methyl orange indicator. The mean titre was 25.60 $cm^3$.

The equation for the neutralisation reaction is

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

(i) Calculate the amount, in moles, of sodium carbonate in the 250.0 $cm^3$ of solution.

**(2)**

(ii) The 250.0 $cm^3$ of solution was prepared by dissolving 3.29 g of $Na_2CO_3.xH_2O$.

Use this mass and your answer to (d)(i) to determine the value of x.
Give your answer to the appropriate number of significant figures.
You must show your working.

**(4)**

**(Total for Question 15 = 18 marks)**

**16** This question is about trends in the Periodic Table.

*(a) The boiling temperatures of some isoelectronic hydrides are shown.

| Hydride | $CH_4$ | $NH_3$ | $H_2O$ | HF |
|---|---|---|---|---|
| Boiling temperature / K | 112 | 240 | 373 | 293 |

Explain the differences in these boiling temperatures by considering all the intermolecular forces involved.
Detailed descriptions of the intermolecular forces involved are not required.

**(6)**

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(b) Compare and contrast the reactions of concentrated sulfuric acid with solid potassium chloride and with solid potassium bromide.

**(4)**

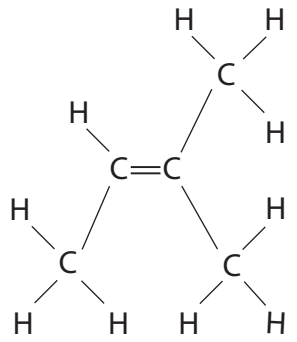
**(Total for Question 16 = 10 marks)**

**17** This question is about 2-methylbutan-2-ol, $C_5H_{11}OH$, and some related compounds.

(a) Draw the **displayed** formula of 2-methylbutan-2-ol.

**(1)**

(b) 2-methylbutan-2-ol forms **two** different alkenes in an elimination reaction.
One product is 2-methylbut-2-ene.




(i) Identify by name or formula a reagent for this reaction.

**(1)**

.....

(ii) Draw the displayed formula of the other alkene formed.

**(1)**

(iii) Explain whether or not these two alkenes show geometric isomerism.

**(2)**

(c) When dry hydrogen chloride gas reacts with 2-methylbut-2-ene, two isomeric chloroalkanes are formed.

Give the structure of the **major** product and the reason why more of this is formed.

**(2)**

Structure

Reason

(d) The major product formed in (c) can also be formed from 2-methylbutan-2-ol ($C_5H_{11}OH$) in one step, using phosphorus(V) chloride.

(i) Complete the equation for this reaction.

**(1)**

$C_5H_{11}OH + PCl_5 \longrightarrow$

(ii) Give **two** reasons why this reaction would produce a greater yield of this chloroalkane than the combined reactions in (b) and (c).

**(2)**

(iii) Give the bond and the wavenumber range of its absorption in the infrared spectrum of 2-methylbutan-2-ol which would **not** be in the infrared spectrum of this chloroalkane. Use the Data Booklet.

**(1)**

(e) In the liver, enzymes oxidise some alcohols as part of the process which removes them from the body. During this process any aldehydes produced are toxic.

Other alcohols are excreted unchanged. Between 1880 and 1950, 2-methylbutan-2-ol was used as an anaesthetic.

Explain why 2-methylbutan-2-ol was preferred to 2-methylbutan-1-ol.

**(2)**

**(Total for Question 17 = 13 marks)**

**TOTAL FOR SECTION B = 41 MARKS**

## SECTION C

**Answer ALL the questions.**

**Write your answers in the spaces provided.**

**18** Urea ($NH_2CONH_2$) and ammonium nitrate ($NH_4NO_3$) are nitrogen-rich, water-soluble fertilisers which are important to the agriculture industry worldwide.
Ammonium nitrate contains 35% nitrogen by mass.

(a) Calculate the percentage by mass of nitrogen in urea.

**(2)**

(b) Urea is supplied as solid pellets and is used widely in Africa and Asia, particularly in the cultivation of crops such as rice which are grown in fields immersed in water.
It hydrolyses to form ammonia and carbon dioxide.

$$NH_2CONH_2(s) + H_2O(l) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

After the urea is applied to the soil, the ammonia formed may escape into the atmosphere unless it dissolves in water. Crops cannot absorb ammonia or urea directly but can take up and use dissolved ammonium ions.

Suggest why urea is used as a fertiliser for crops such as rice but not in regions with unpredictable rainfall patterns.

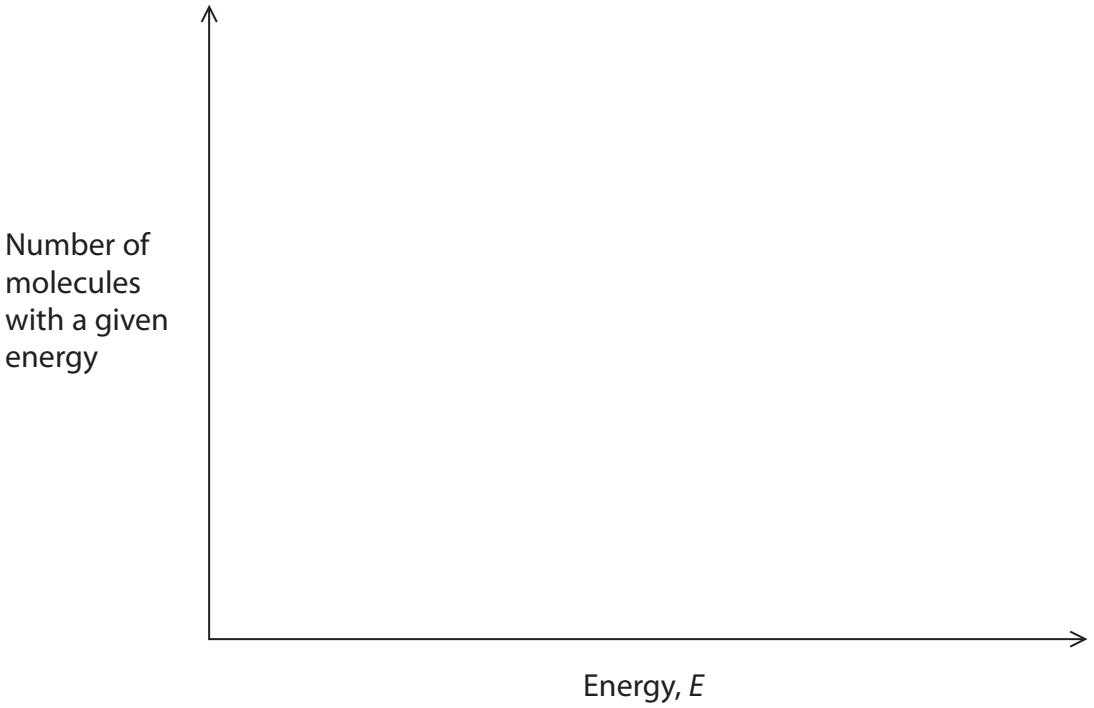
**(2)**

(c) Both urea and ammonium nitrate are made from ammonia.
Ammonia is manufactured in the Haber process in which nitrogen and hydrogen are passed over an iron catalyst at a temperature of 400 °C and a pressure of 200 atm.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Draw on the axes the Maxwell–Boltzmann distribution of molecular energies of the reactant gases, showing on your diagram the activation energies for the catalysed and uncatalysed reactions.

**(3)**




(ii) Explain, using your diagram, why the addition of a catalyst changes the rate of the reaction.

**(2)**

(iii) Explain the effect of increasing the pressure on the equilibrium yield of ammonia.

**(2)**

(d) Urea is also used in reducing harmful emissions from diesel engines which operate at high temperatures and emit nitrogen monoxide, NO. One way to decrease these emissions involves two reactions.

A solution of urea is added to the hot exhaust gases, and is hydrolysed.

**Reaction 1** $NH_2CONH_2(aq) + H_2O(l) \rightleftharpoons 2NH_3(g) + CO_2(g)$

The ammonia formed reacts with nitrogen monoxide and oxygen to form harmless products.

(i) State why Reaction 1 is **not** a redox reaction.

**(1)**

(ii) Suggest why it is an advantage to carry out Reaction 1 at a high temperature.

**(2)**

(iii) The ammonia produced by the hydrolysis of urea reacts with nitrogen monoxide and oxygen to produce nitrogen gas and water.

**Reaction 2** $4NH_3(g) + 4NO(g) + O_2(g) \longrightarrow 4N_2(g) + 6H_2O(g)$

Explain, using oxidation numbers, why this reaction **is** a redox reaction but **not** a disproportionation reaction.

**(3)**

(iv) Give **two** reasons why it is important to remove nitrogen oxides from the exhaust gases of diesel engines.

**(2)**

**(Total for Question 18 = 19 marks)**

**TOTAL FOR SECTION C = 19 MARKS**
**TOTAL FOR PAPER = 80 MARKS**