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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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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)

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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)

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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)

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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)

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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)

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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)

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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)

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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

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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)

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(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)

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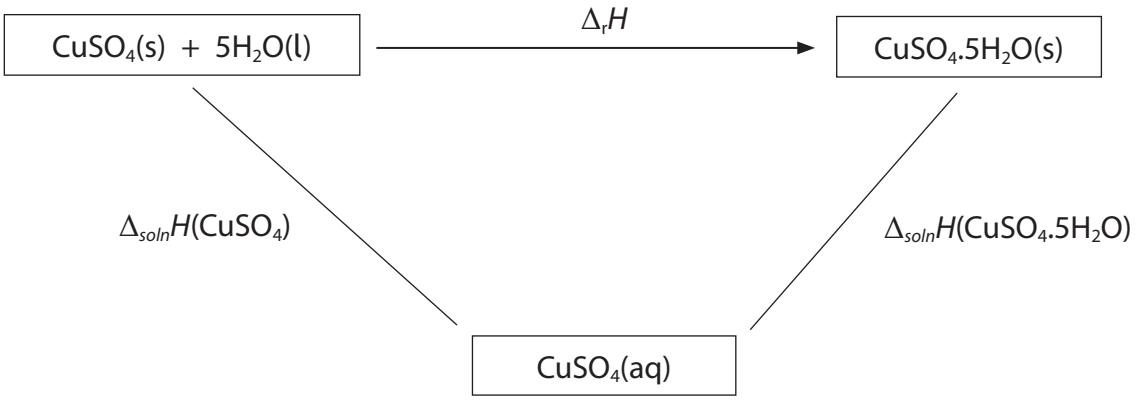
(iii) Complete the Hess cycle by adding two arrowheads.

(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)

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(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 .....

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Reverse .....

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(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)

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(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)

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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)

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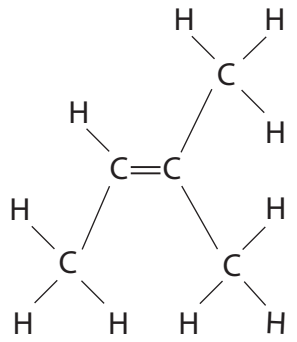
17 This question is about 2-methylbutan-2-ol, $C_5H_{11}OH$, and some related compounds.

(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)

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(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

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(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

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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)

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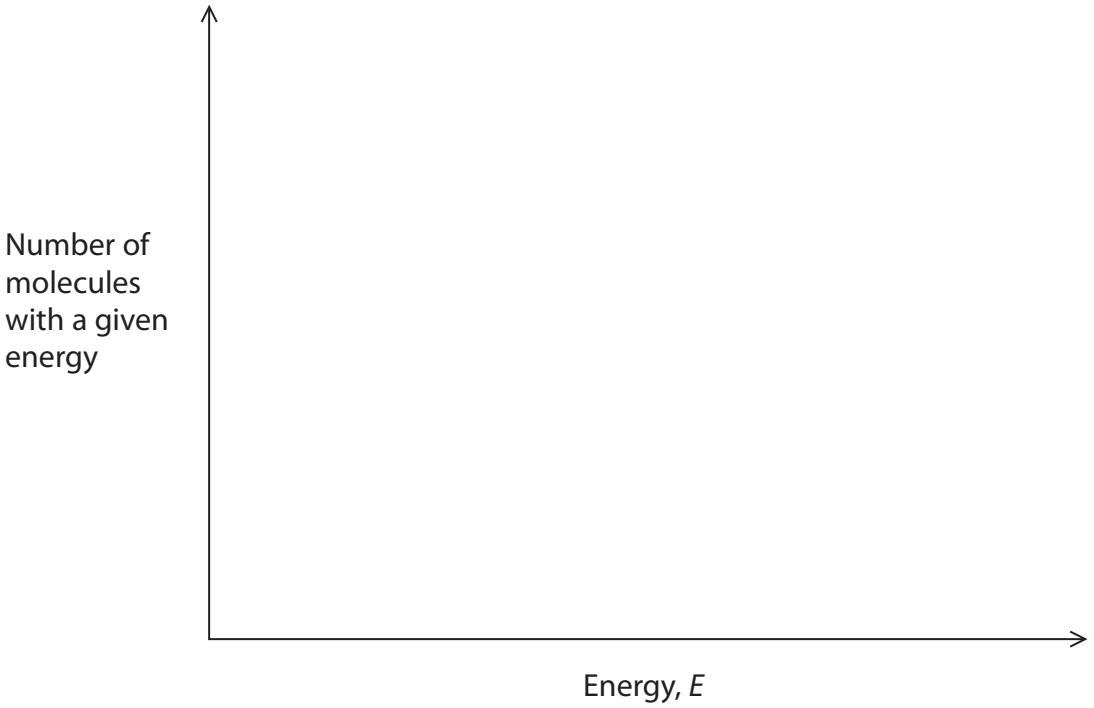
(c) Both urea and ammonium nitrate are made from ammonia.
Ammonia is manufactured in the Haber process in which nitrogen and hydrogen are passed over an iron catalyst at a temperature of 400 °C and a pressure of 200 atm.

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

(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)

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(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)

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(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

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series

* Actinide series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103

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