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Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 30 minutes

Paper reference **WCH12/01**

Chemistry

International Advanced Subsidiary/Advanced Level
UNIT 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

You must have:
Scientific calculator, Data Booklet, ruler

January 2022

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 are correct for the reaction shown?

$$CH_3COOH + KOH \rightarrow CH_3COO^-K^+ + H_2O \qquad \Delta H = -55.8\,kJ\,mol^{-1}$$

		Type of reaction	Type of enthalpy change
☒	**A**	endothermic	formation
☒	**B**	endothermic	neutralisation
☒	**C**	exothermic	formation
☒	**D**	exothermic	neutralisation

(Total for Question 1 = 1 mark)

2 Which equation does **not** represent a standard enthalpy change of atomisation?

☒ **A** $Mg(s) \rightarrow Mg(g)$

☒ **B** $Cl_2(g) \rightarrow 2Cl(g)$

☒ **C** $\frac{1}{2}O_2(g) \rightarrow O(g)$

☒ **D** $Hg(l) \rightarrow Hg(g)$

(Total for Question 2 = 1 mark)

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3 5.20 g of sodium hydrogencarbonate is added to an excess of acid.

The temperature increases and the energy change is calculated to be 1030 J.

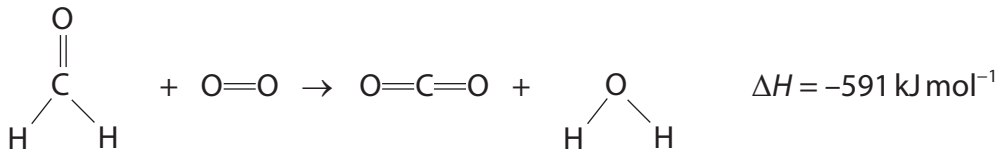
What is the enthalpy change per mole of sodium hydrogencarbonate?

[M_r $NaHCO_3$ = 84.0]

- ☒ **A** $-12.3\ kJ\ mol^{-1}$
- ☒ **B** $-16.6\ kJ\ mol^{-1}$
- ☒ **C** $-63.8\ kJ\ mol^{-1}$
- ☒ **D** $-16\,600\ kJ\ mol^{-1}$

(Total for Question 3 = 1 mark)

4 The equation for the complete combustion of methanal is shown.



Some bond enthalpy data are shown.

Bond	Bond enthalpy / $kJ\ mol^{-1}$
C—H	413
O=O	498
C=O in CO_2	805
O—H	464

What is the C=O bond enthalpy in methanal?

- ☒ **A** $623\ kJ\ mol^{-1}$
- ☒ **B** $678\ kJ\ mol^{-1}$
- ☒ **C** $805\ kJ\ mol^{-1}$
- ☒ **D** $1036\ kJ\ mol^{-1}$

(Total for Question 4 = 1 mark)

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5 Which sequence shows the molecules in order of **increasing** boiling temperature?

- ☒ **A** $H_2O < Br_2 < Cl_2 < CH_4$
- ☒ **B** $Br_2 < CH_4 < Cl_2 < H_2O$
- ☒ **C** $Cl_2 < CH_4 < H_2O < Br_2$
- ☒ **D** $CH_4 < Cl_2 < Br_2 < H_2O$

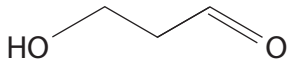
(Total for Question 5 = 1 mark)

6 Which is **not** correct about ice?

- ☒ **A** ice has a lower density than water
- ☒ **B** H_2O molecules are further apart in ice than in water
- ☒ **C** the H–O–H bond angle is the same in ice and in water
- ☒ **D** H_2O molecules in ice are held together by hydrogen bonds

(Total for Question 6 = 1 mark)

7 Which intermolecular forces exist **between** the molecules of the compound shown?



- ☒ **A** hydrogen bonding and London forces only
- ☒ **B** hydrogen bonding and permanent dipole-permanent dipole forces only
- ☒ **C** London forces and permanent dipole-permanent dipole forces only
- ☒ **D** hydrogen bonding, permanent dipole-permanent dipole forces and London forces

(Total for Question 7 = 1 mark)

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8 This question is about alkanes.

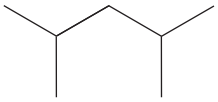
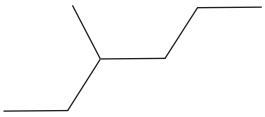
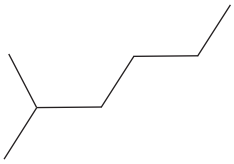
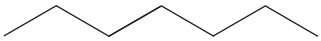
(a) Which of these alkanes has the **highest** boiling temperature?

(1)

- ☒ **A** butane
- ☒ **B** hexane
- ☒ **C** pentane
- ☒ **D** propane

(b) Which of these alkanes has the **lowest** boiling temperature?

(1)

- ☒ **A** 
- ☒ **B** 
- ☒ **C** 
- ☒ **D** 

(Total for Question 8 = 2 marks)

9 Which solvent dissolves the greatest amount of hydrocarbon $C_{35}H_{72}$?

- ☒ **A** butan-1-ol
- ☒ **B** ethanoic acid
- ☒ **C** hexane
- ☒ **D** water

(Total for Question 9 = 1 mark)

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10 Which reagent would convert an alcohol into an alkene?

- ☒ **A** acidified potassium dichromate(VI)
- ☒ **B** anhydrous calcium sulfate
- ☒ **C** concentrated phosphoric acid
- ☒ **D** ethanolic potassium hydroxide

(Total for Question 10 = 1 mark)

11 Which name is correct for the ion SO_4^{2-}?

- ☒ **A** sulfate(II)
- ☒ **B** sulfate(IV)
- ☒ **C** sulfate(VI)
- ☒ **D** sulfate(VIII)

(Total for Question 11 = 1 mark)

12 In which compound is the oxidation number of nitrogen +5?

- ☒ **A** $Ca(NO_3)_2$
- ☒ **B** Mg_3N_2
- ☒ **C** N_2O_3
- ☒ **D** $NaNO_2$

(Total for Question 12 = 1 mark)

13 In which reaction is the copper species acting as an oxidising agent?

- ☒ **A** $Cu^{2+} + 2Ag \rightarrow 2Ag^{+} + Cu$
- ☒ **B** $2Cu^{+} + O^{2-} \rightarrow Cu_2O$
- ☒ **C** $3Cu + O_2 \rightarrow Cu_2O + CuO$
- ☒ **D** $Cu + Hg^{2+} \rightarrow Hg + Cu^{2+}$

(Total for Question 13 = 1 mark)

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14 Two half-equations for a reaction are shown.

$$Cu \rightarrow Cu^{2+} + 2e^-$$

$$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$$

What is the overall ionic equation for this reaction?

☒ **A** $Cu + NO_3^- + 4H^+ \rightarrow Cu^{2+} + NO + 2H_2O$

☒ **B** $2Cu + NO_3^- + 4H^+ \rightarrow 2Cu^{2+} + NO + 2H_2O$

☒ **C** $3Cu + 2NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

☒ **D** $6Cu + 2NO_3^- + 8H^+ \rightarrow 6Cu^{2+} + 2NO + 4H_2O$

(Total for Question 14 = 1 mark)

---

15 A titre of 13.25 cm^3 was obtained using a 50 cm^3 burette.

What is the percentage uncertainty in the titre?

[Each reading of the burette has an uncertainty of $\pm 0.05\ cm^3$]

☒ **A** ±0.38 %

☒ **B** ±0.75 %

☒ **C** ±1.5 %

☒ **D** ±7.5 %

(Total for Question 15 = 1 mark)

---

16 Barium hydroxide reacts with sulfuric acid as shown.

$$Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$$

Which is the ionic equation for this reaction?

☒ **A** $Ba^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$

☒ **B** $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

☒ **C** $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$

☒ **D** $Ba^{2+}(aq) + 2OH^-(aq) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Ba^{2+}(s) + SO_4^{2-}(s) + 2H_2O(l)$

(Total for Question 16 = 1 mark)

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17 Four tests used to identify ions are shown:

1 flame test
2 addition of acidified barium nitrate solution
3 addition of acidified silver nitrate solution
4 addition of sodium hydroxide solution, then testing any gas with indicator paper

Which tests could be used to positively identify the ions in ammonium chloride?

☒ **A** 1 and 2

☒ **B** 1 and 3

☒ **C** 2 and 4

☒ **D** 3 and 4

(Total for Question 17 = 1 mark)

18 Which conditions give the highest yield for the forward reaction?

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g) \qquad \Delta H = +176\,kJ\,mol^{-1}$$

☒ **A** high temperature, high pressure

☒ **B** high temperature, low pressure

☒ **C** low temperature, high pressure

☒ **D** low temperature, low pressure

(Total for Question 18 = 1 mark)

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19 Nitrogen dioxide and dinitrogen tetroxide exist in equilibrium.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$

brown gas colourless gas

When an equilibrium is set up in a gas syringe, the mixture is pale brown.

When the mixture is compressed the colour becomes

- ☒ **A** darker
- ☒ **B** lighter
- ☒ **C** darker and then lighter
- ☒ **D** lighter and then darker

(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

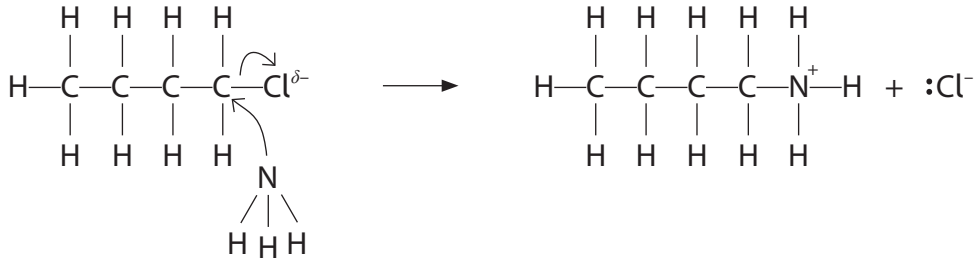
20 Ammonia reacts with 1-chlorobutane.

(a) State the type and mechanism of this reaction.

(2)

.....

(b) A student drew the first step of the mechanism for the reaction.



(i) Identify **two** omissions in the student's mechanism.

(2)

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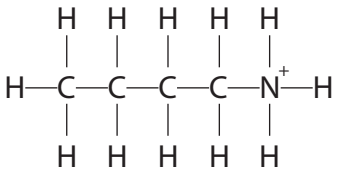
(ii) To obtain butylamine, sodium hydroxide solution is added.

Complete the next step of the mechanism to form butylamine, showing curly arrows, relevant lone pairs and the reaction products.

(3)



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(c) The reactions of ammonia and of hydroxide ions with halogenoalkanes are similar.

Compare the rate of reaction of ammonia with 1-chlorobutane and with 2-bromo-2-methylpropane.
Justify your answer.

(3)

(Total for Question 20 = 10 marks)

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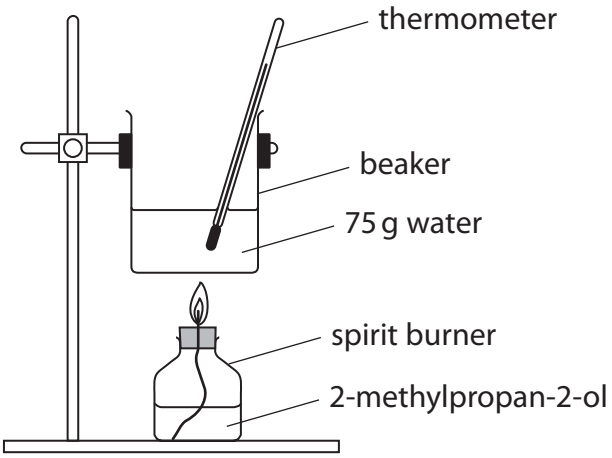
21 Enthalpy changes of combustion can be determined using calorimetry or calculated using Hess cycles. Apparatus for a calorimetry experiment is shown.



A sample of 2-methylpropan-2-ol was burned in a spirit burner and used to heat 75 g of water. The results are shown.

	At the start	At the end	Change
Mass of spirit burner / g	267.35	266.78	
Temperature of water / °C	19.5	65.3	

(a) (i) Complete the table.

(1)

(ii) Calculate the enthalpy change of combustion, $\Delta_c H$, of 2-methylpropan-2-ol. Give a sign and units in your answer.
[Specific heat capacity of water = 4.18 J g^{-1} °C^{-1}]

(4)

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(b) The standard enthalpy change of combustion, $\Delta_c H^{\ominus}$, can be calculated using standard enthalpy changes of formation.

Compound	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
2-methylpropan-2-ol	–359
carbon dioxide	–394
water	–286

(i) State why no $\Delta_f H^{\ominus}$ value has been given for oxygen.

(1)

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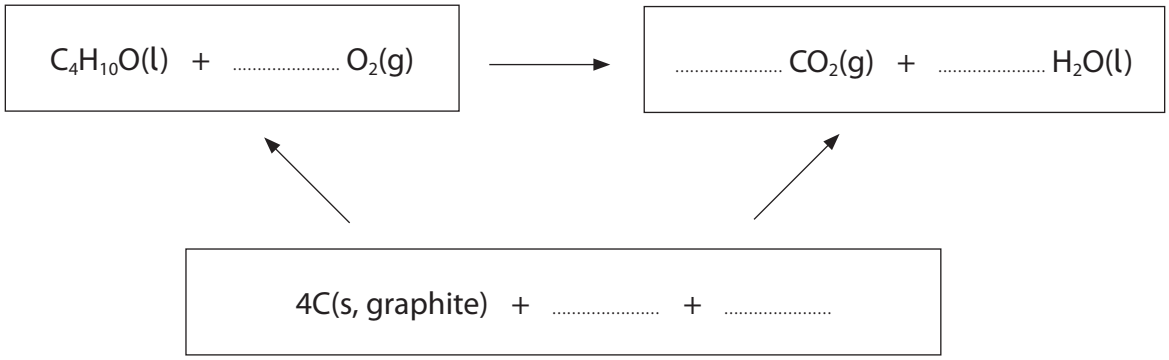
(ii) Complete the Hess cycle.



(2)

(iii) Calculate the standard enthalpy change of combustion of 2-methylpropan-2-ol using the data in the table and the completed Hess cycle.

(2)

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(c) The value for $\Delta_c H$ obtained in part (a)(ii) is much less exothermic than $\Delta_c H^{\ominus}$ calculated in (b)(iii).

Suggest **two** reasons for this other than non-standard conditions.

(2)

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(Total for Question 21 = 12 marks)

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22 This question is about the elements in Group 7.

(a) Use your knowledge of the trends in the properties of Group 7 elements to predict the colour and physical state of astatine at room temperature.

(1)

(b) (i) State the meaning of the term electronegativity.

(1)

(ii) Explain the trend in electronegativity down Group 7.

(2)

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*(c) Compare and contrast the reactions of chlorine with

- water
- cold, dilute aqueous alkali
- hot, concentrated aqueous alkali

Include an equation for each reaction, stating the type of reaction and the oxidation numbers of the chlorine involved. State symbols are not required.

(6)

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(Total for Question 22 = 10 marks)

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23 Magnesium ethanedioate (MgC_2O_4) decomposes on gentle heating to form magnesium carbonate and carbon monoxide.

$$MgC_2O_4 \rightarrow MgCO_3 + CO$$

(a) (i) State why the thermal decomposition of magnesium ethanedioate should be carried out in a fume cupboard.

(1)

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(ii) After heating a 6.0 g sample of magnesium ethanedioate for three minutes, the decomposition was 70 % complete.

Calculate the total mass of the solid mixture that remains.

(4)

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(b) Magnesium carbonate undergoes thermal decomposition at a higher temperature than magnesium ethanedioate.

$$MgCO_3 \rightarrow MgO + CO_2$$

Explain the trend in the thermal decomposition of Group 2 carbonates going down the group.

(3)

(Total for Question 23 = 8 marks)

TOTAL FOR SECTION B = 40 MARKS

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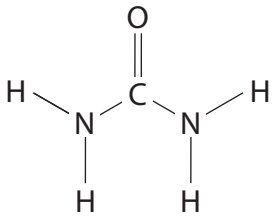
SECTION C

Answer all the questions. Write your answers in the spaces provided.

24 Some diesel cars contain an extra catalytic converter for the reduction of nitrogen oxides (NO_x) in exhaust gases.
A solution of urea is used for this process.



urea

(a) Urea has a melting temperature of 133 °C.

Explain why this value is higher than expected for a relatively small molecule.

(3)

(b) A saturated solution of urea has a concentration of 9.07 mol dm^{-3} at 25 °C.

Calculate the mass of urea in 150 cm^3 of a saturated solution.

(2)

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(c) State why NO_x emissions are harmful to the environment.

(1)

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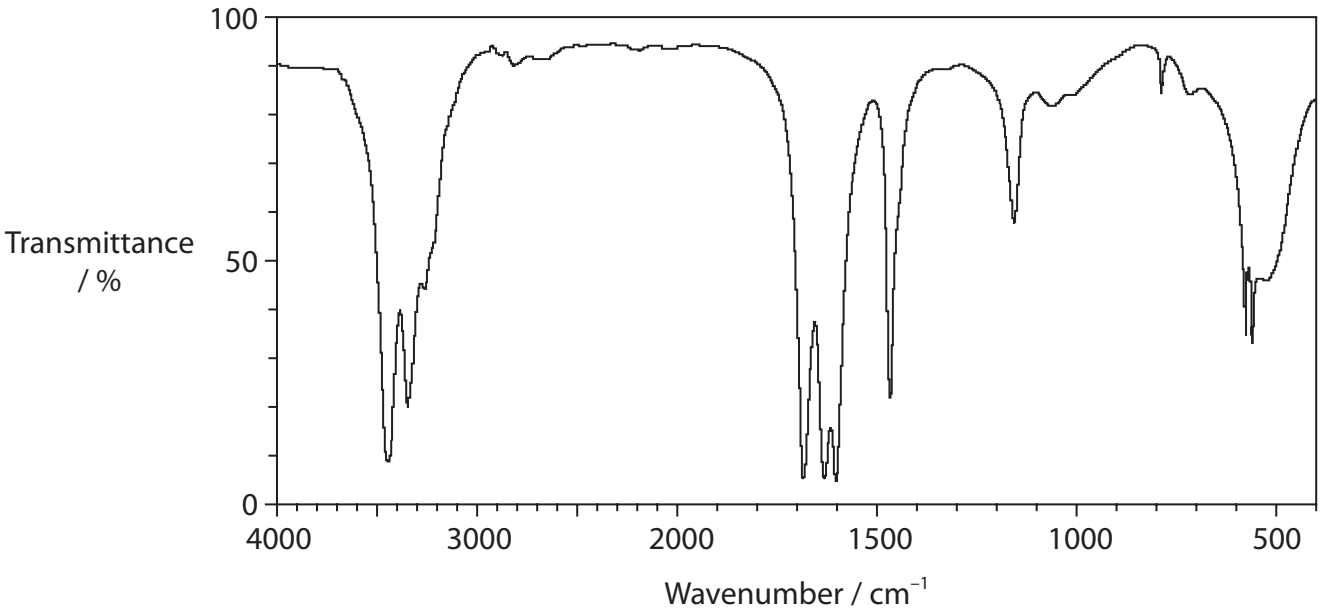
(d) An infrared spectrum of urea is shown.
Refer to your Data Booklet.



(i) Draw a circle around an absorption in the spectrum that could be due to the stretching of the N—H bond.

(1)

(ii) Identify the bond responsible for the absorption at 1683 cm^{-1}.

(1)

.....

(e) In a diesel car exhaust system, the urea reacts with water to form ammonia and carbon dioxide. The enthalpy change for this reaction is +133 kJ mol^{-1}.

(i) Complete the equation for this **reversible** reaction.

State symbols are not required.

(1)

$(NH_2)_2CO + H_2O$ .....

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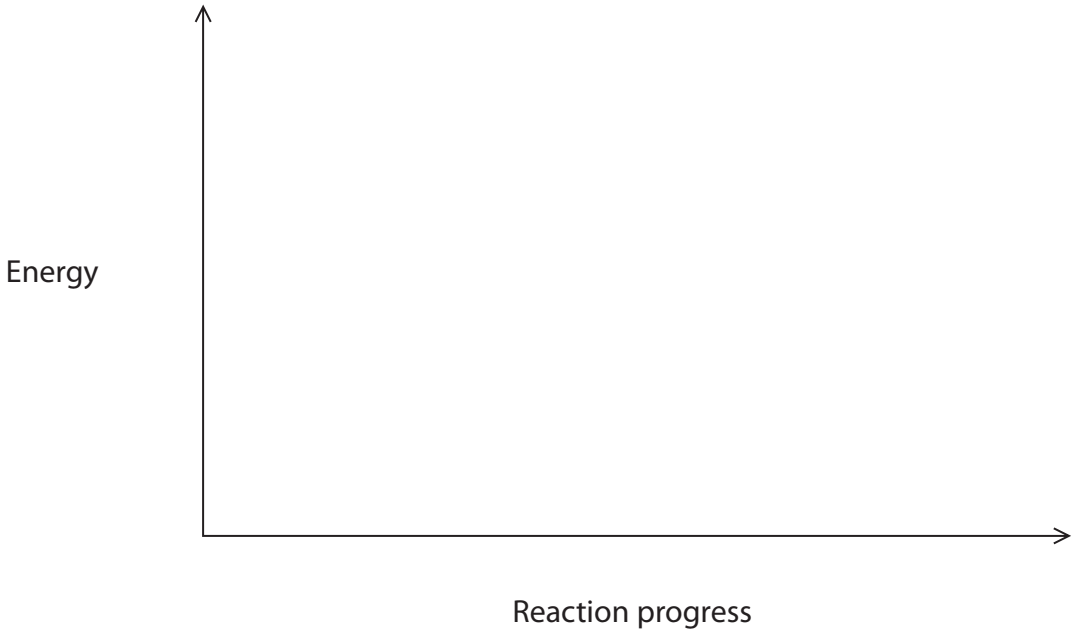
(ii) Sketch the reaction profile for the forward reaction on the axes provided.

Include labels for ΔH and the activation energy (E_a).



(3)

(f) The catalytic converter contains metal oxides. When the exhaust gases pass through the catalytic converter, ammonia reacts with NO_x gases to form nitrogen and water.

(i) Explain why it is **not** correct to state that urea is acting as a catalyst in the reaction.

(1)

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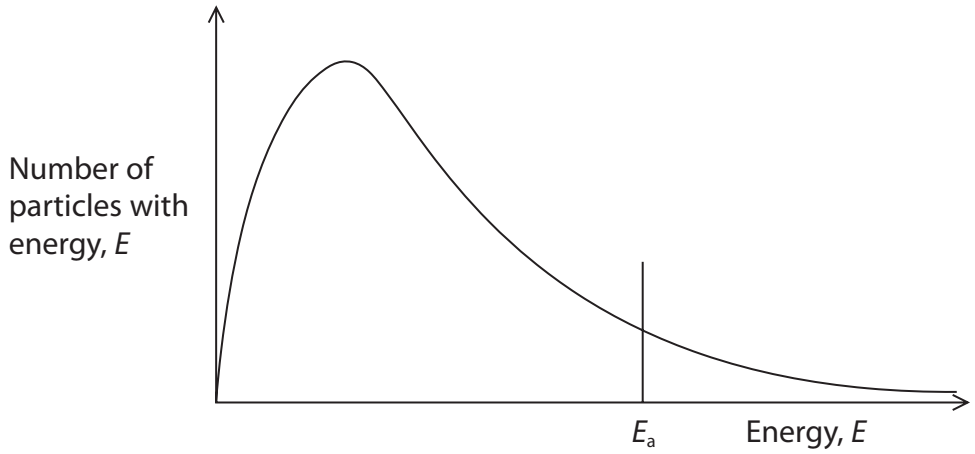
(ii) Explain how a catalyst increases the rate of a chemical reaction.

Use the Maxwell-Boltzmann distribution shown and refer to the collision theory.

(3)



(g) The catalytic converter works best at a temperature of around 350 °C.

(i) Suggest how the catalytic converter reaches this temperature.

(1)

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(ii) The chemical reactions in the exhaust system of a diesel car, using a catalytic converter, form 89.3 m^3 of nitrogen per hour.

Calculate the number of molecules of nitrogen formed per hour.

[Molar volume at 350 °C = 51.1 $dm^3\,mol^{-1}$

Avogadro constant, $L = 6.02 \times 10^{23}\,mol^{-1}$]

(3)

(Total for Question 24 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(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							

Key

relative atomic mass
atomic symbol
name
atomic (proton) number

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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