Please check the examination details below before entering your candidate information

Candidate surname	Other names
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Centre Number | Candidate Number

Pearson Edexcel Level 3 GCE

Tuesday 23 May 2023

Morning (Time: 1 hour 30 minutes)

Paper reference **8CH0/02**

Chemistry

Advanced Subsidiary
PAPER 2: Core Organic and Physical Chemistry

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing 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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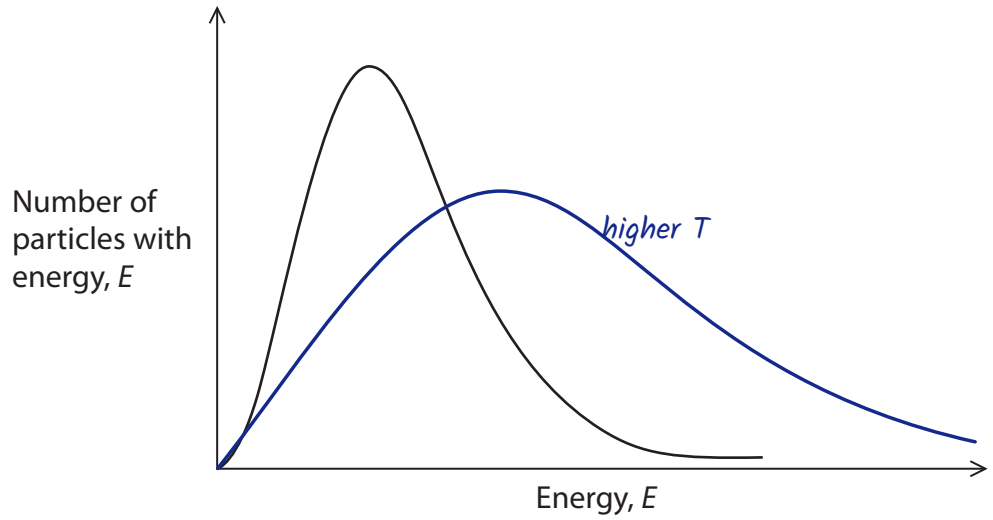
Answer ALL questions.

Some questions must be answered with a cross in a box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 This question is about collision theory.

The Maxwell-Boltzmann distribution of molecular energies for a reaction at a particular temperature is shown in the graph.

Add another line on the graph to represent the same reaction with the same number of particles at a **higher** temperature.



(Total for Question 1 = 2 marks)

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2 This question is about alkanes and some of their reactions.

(a) Hexane is a saturated hydrocarbon.

State what is meant by the term 'saturated hydrocarbon'.
Your answer should refer to both words in the term.

(2)

Saturated: all the bonds between the carbon atoms are single bonds (no C=C), so no more hydrogen can be added.

Hydrocarbon: a compound containing hydrogen and carbon only.

(b) When methane reacts with gaseous chlorine, the initiation step is bond breaking in the chlorine molecule to form chlorine free radicals.

The equation for this step is shown.

$$Cl_2(g) \rightarrow 2Cl\bullet(g)$$

Two equations for the propagation step are shown.

$$Cl\bullet(g) + CH_4(g) \rightarrow CH_3\bullet(g) + HCl(g)$$
$$CH_3\bullet(g) + Cl_2(g) \rightarrow CH_3Cl(g) + Cl\bullet(g)$$

(i) Write the overall equation for this reaction of methane with chlorine.
State symbols are not required.

(1)

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

(ii) Calculate the maximum **mass**, in grams, of chloromethane produced when 7.00 g of chlorine gas reacts completely with excess methane.

[Molar mass of CH_3Cl = 50.5 g mol^{-1}]

(2)

mol Cl_2 = 7.00 ÷ 71.0 = 0.098592 mol

1 mol Cl_2 gives 1 mol CH_3Cl, so mol CH_3Cl = 0.098592 mol

mass CH_3Cl = 0.098592 × 50.5 = 4.98 g

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(iii) Write an equation for a termination step for this reaction.
State symbols are not required.

(1)

$CH_3\cdot + Cl\cdot \rightarrow CH_3Cl$

(iv) Further substitution of chloromethane can occur, producing dichloromethane, which is a liquid at room temperature.

Calculate the maximum volume, in cm^3, of dichloromethane liquid that could be produced from 12.5 g of chloromethane.
Give your answer to an appropriate number of significant figures.

(3)

$$CH_3Cl(g) + Cl_2(g) \rightarrow CH_2Cl_2(l) + HCl(g)$$

[Density of dichloromethane, $CH_2Cl_2(l) = 1.32\,g\,cm^{-3}$]

mol CH_3Cl = 12.5 ÷ 50.5 = 0.24752 mol

1 : 1 ratio, so mol CH_2Cl_2 = 0.24752 mol

M_r CH_2Cl_2 = 12.0 + 2(1.0) + 2(35.5) = 85.0

mass CH_2Cl_2 = 0.24752 × 85.0 = 21.040 g

volume = mass ÷ density = 21.040 ÷ 1.32 = 15.939

volume = 15.9 cm^3 (3 s.f.)

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(c) Commercial diesel fuel is a mixture of hydrocarbons.

One of the components of commercial diesel fuel is a hydrocarbon with the formula $C_{12}H_{26}$.

An equation for the complete combustion of $C_{12}H_{26}$ is shown.

$$C_{12}H_{26}(l) + 18\frac{1}{2}O_2(g) \rightarrow 12CO_2(g) + 13H_2O(l)$$

(i) Calculate the maximum volume, in m^3, of carbon dioxide gas produced in an engine by the complete combustion of 1.00 **kg** of $C_{12}H_{26}$ at 200 °C, at a pressure of 6.0×10^6 Pa.

[The ideal gas equation is $pV = nRT$
Gas constant, $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(4)

$M_r\ C_{12}H_{26} = 12(12.0) + 26(1.0) = 170$

$mol\ C_{12}H_{26} = 1000 \div 170 = 5.8824\ mol$

$mol\ CO_2 = 12 \times 5.8824 = 70.588\ mol$

$T = 200 + 273 = 473\ K$

$pV = nRT \quad so \quad V = nRT \div p$

$V = (70.588 \times 8.31 \times 473) \div (6.0 \times 10^6)$

$V = 0.0462\ m^3 \quad (4.62 \times 10^{-2}\ m^3)$

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(ii) Biodiesel is derived from plants and petrodiesel is derived from crude oil. Biodiesel is increasingly widely used, although it is more expensive and provides less energy per kg when burned than petrodiesel.

Give **one** reason why biodiesel is now preferred to petrodiesel.

(1)

Biodiesel is a renewable (sustainable) resource: it is made from plants, which can be regrown, whereas crude oil is finite and will run out.

(Total for Question 2 = 14 marks)

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3 This question is about alkenes and some of their reactions.

(a) Alkenes have the same general formula as cycloalkanes.

Explain why this general formula is different from that of alkanes.
Include the general formulae in your answer.

(3)

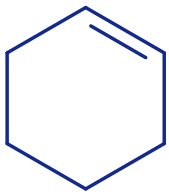
Alkenes and cycloalkanes have the general formula C_nH_{2n}, but alkanes have the general formula C_nH_{2n+2}.

Alkenes contain a C=C double bond, so they have two fewer hydrogen atoms than the alkane.

Cycloalkanes have their carbon atoms joined in a ring, so they also have two fewer hydrogen atoms.

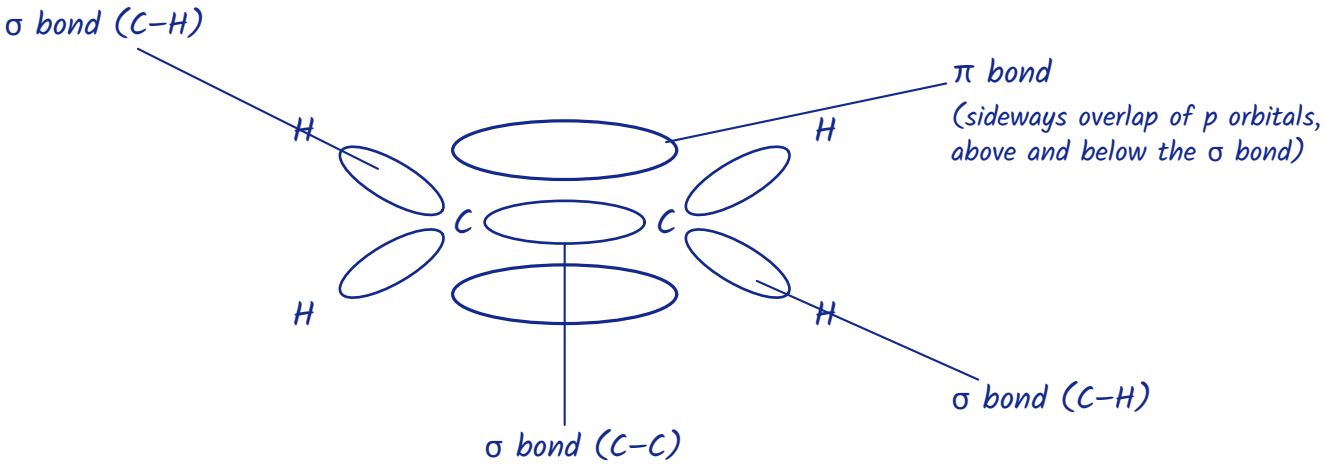
(b) Draw the **skeletal** formula of cyclohexene.

(1)



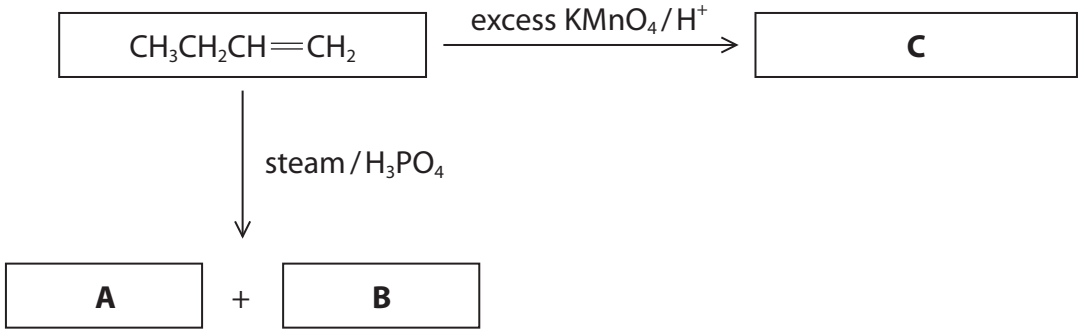
(c) Draw a diagram of an ethene molecule showing the shape of **all** the bonding electron clouds.
Include labels for all the bond types within the molecule.

(3)



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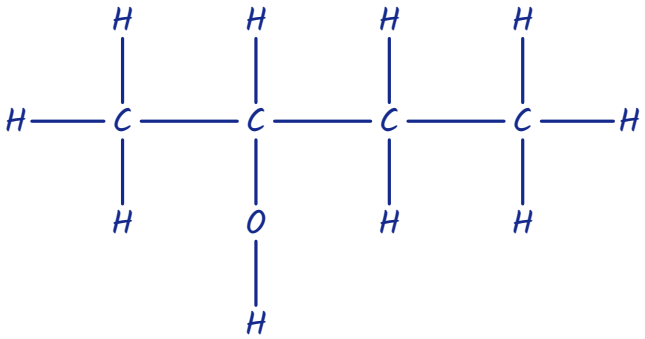
(d) The reaction scheme shows some of the reactions of but-1-ene.



A and **B** are structural isomers. **A** is butan-1-ol.

(i) Draw the fully **displayed** formula of isomer **B**.

(1)



(ii) Draw the **structural** formula of product **C**, which is formed by the reaction of but-1-ene with potassium manganate(VII) in acid conditions.

(1)

$CH_3CH_2CH(OH)CH_2OH$

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(e) The industrial manufacture of margarine involves the addition of hydrogen to an alkene.

Which catalyst is used for this process?

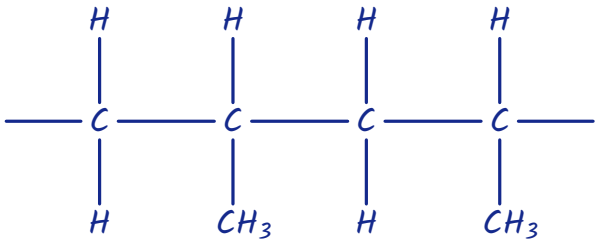
(1)

- ☒ **A** iron
- ☒ **B** nickel
- ☒ **C** phosphoric acid
- ☒ **D** sodium hydroxide

(f) Polymers can be produced by the addition polymerisation of alkenes. Poly(propene) can be made from propene.

Draw the structure of poly(propene), showing **two** repeat units.

(1)

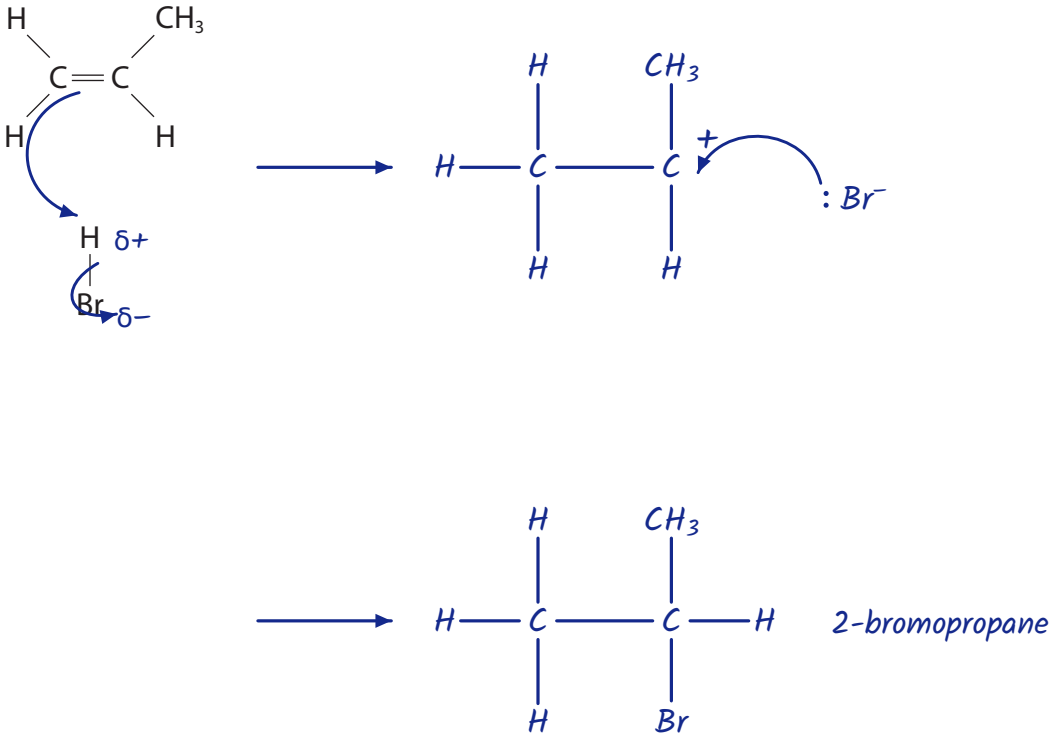


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(g) Propene reacts with hydrogen bromide to form a mixture of products.

(i) Complete the mechanism of the reaction of propene with hydrogen bromide to form 2-bromopropane.
Include curly arrows and any relevant lone pairs and dipoles.

(4)



(ii) What is the type and mechanism for the reaction of hydrogen bromide with propene?

(1)

☒ **A** electrophilic addition

☒ **B** electrophilic substitution

☒ **C** nucleophilic addition

☒ **D** nucleophilic substitution

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(h) Various methods are used to reduce the problem of plastic waste, including the incineration, recycling and introduction of biodegradable polymers.

(i) Describe how the toxic gas hydrogen chloride produced during the incineration of poly(chloroethene) could be removed.

(1)

Pass the waste gases through an alkaline solution such as NaOH(aq), or over solid CaO, which neutralises the HCl (scrubbing).

(ii) Give a reason why some polymers cannot be recycled.

(1)

It is difficult to separate mixed waste plastic into the different polymer types, and thermosetting polymers cannot be melted and remoulded.

(Total for Question 3 = 18 marks)

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4 This question is about halogenoalkanes and some of their reactions.

(a) **X**, **Y** and **Z** are three different halogenoalkanes.

X is 1-chloropropane

Y is 1-bromopropane

Z is 1-iodopropane

An experiment is carried out to compare the rates of hydrolysis of these compounds.

Outline procedure:

1 cm^3 of each of the three halogenoalkanes, **X**, **Y** and **Z**, is added to separate test tubes, each containing 5 cm^3 of ethanol and 5 cm^3 of aqueous silver nitrate solution, in a water bath at 50 °C.

The time taken for a precipitate to form in each test tube is measured.

(i) Give **three** reasons why these reaction **conditions** are specified.

(3)

Ethanol is the solvent so that the halogenoalkane (insoluble in water) and the aqueous silver nitrate mix and are in the same phase.

The same volume of each halogenoalkane, ethanol and silver nitrate is used so that it is a fair test.

The water bath at 50 °C speeds up the slow hydrolysis and keeps all three tubes at the same temperature (fair test).

(ii) Explain why a precipitate forms.

(2)

The halogenoalkane is hydrolysed by water, releasing halide ions: $R-X + H_2O \rightarrow R-OH + H^+ + X^-$

The halide ions react with the silver ions to give an insoluble silver halide precipitate: $Ag^+(aq) + X^-(aq) \rightarrow AgX(s)$

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(iii) The three halogenoalkanes were placed in order of **increasing** rate of reaction.

Which is the correct sequence?

(1)

☒ **A** **X, Y, Z**

☐ **B** **X, Z, Y**

☐ **C** **Y, X, Z**

☐ **D** **Z, Y, X**

(b) The results table shows the time taken to produce a precipitate when three bromoalkanes react with aqueous ethanolic silver nitrate solution.

Halogenoalkane	Time to produce a precipitate / s
1-bromobutane	58
2-bromobutane	33
2-bromo-2-methylpropane	2

Give a reason why the times taken to produce a precipitate for these isomeric bromoalkanes are different.

(1)

The tertiary bromoalkane (2-bromo-2-methylpropane) reacts fastest and the primary bromoalkane (1-bromobutane) reacts slowest.

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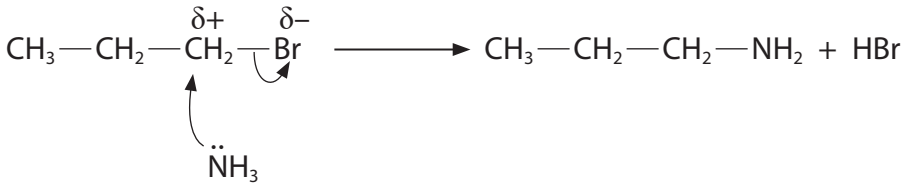
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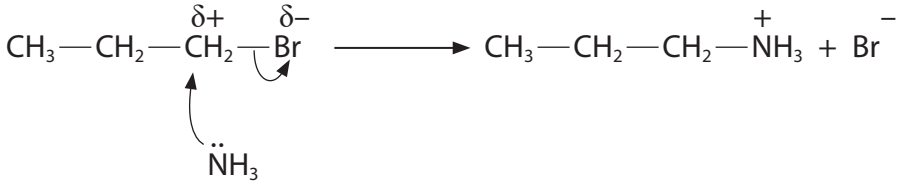
(c) (i) Which equation shows the first step of the mechanism for the reaction of 1-bromopropane with ammonia?

(1)

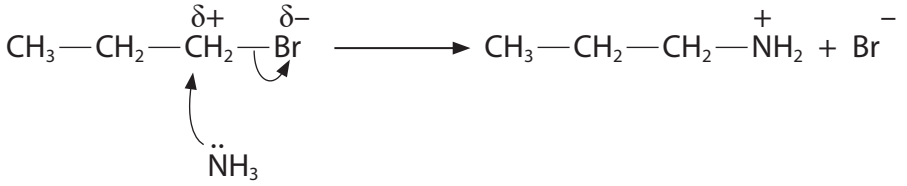
☒ **A**



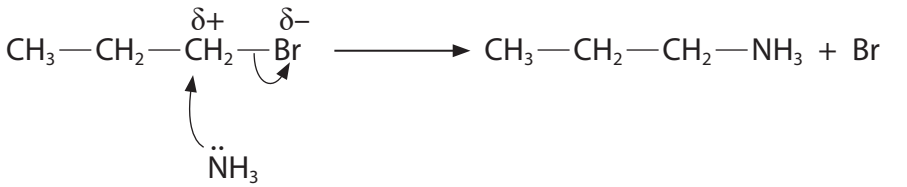
☒ **B**



☒ **C**



☒ **D**



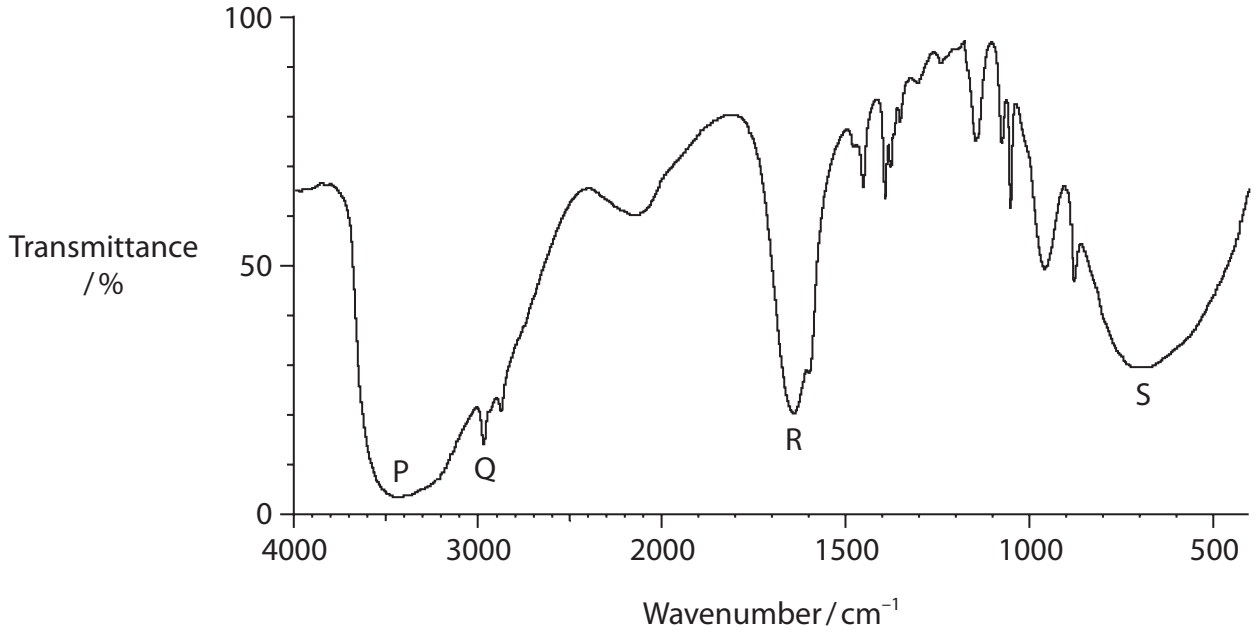
(ii) Write the formula of the final inorganic product of the reaction of 1-bromopropane with **excess** ammonia.

(1)

$NH_4^+Br^-$

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(iii) The infrared spectrum of ethylamine is shown.



Which absorption peak confirms this as an amine?

(1)

- ☒ **A** absorption P
- ☐ **B** absorption Q
- ☐ **C** absorption R
- ☐ **D** absorption S

(d) 1-bromopropane undergoes reactions when heated with different reagents.

(i) Give **two** reasons why organic reactions are often heated for a long time but the yield is frequently low.

(2)

Many organic reactions are slow (high activation energy) or are reversible equilibria, so they are incomplete.

Side reactions also occur, giving by-products, e.g. elimination competing with substitution.

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(ii) Give the name or formula of the reagent and the condition, other than heat, used to increase the carbon chain length by one carbon atom, starting from 1-bromopropane.

(2)

Reagent: potassium cyanide, KCN

Condition: dissolved in ethanol (ethanolic solution)

(iii) 1-bromopropane, $CH_3CH_2CH_2CH_2Br$, can be converted into but-1-ene, $CH_3CH_2CH{=}CH_2$.

Give the name or formula of the reagent and the condition, other than heat, used for this reaction.

(2)

Reagent: concentrated potassium hydroxide, KOH

Condition: dissolved in ethanol (ethanolic solution)

(Total for Question 4 = 16 marks)

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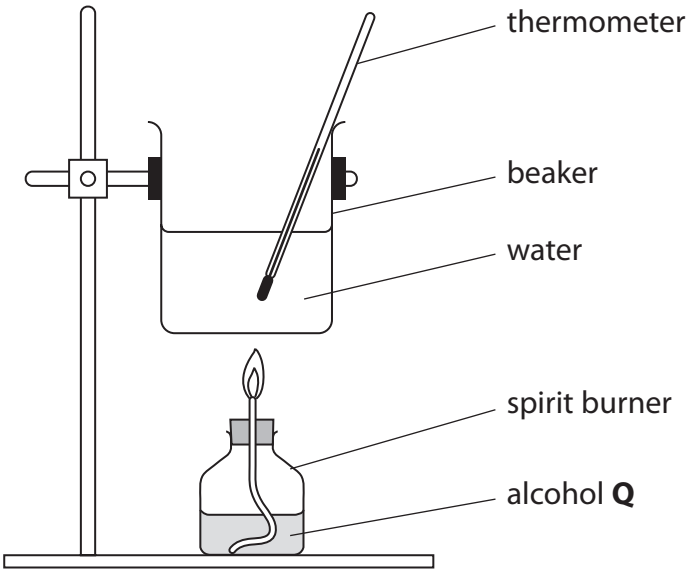
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5 A student found a bottle of a colourless liquid that was thought to be an alcohol. However, the label was missing and the identity of the alcohol was unknown.

The student decided to attempt to identify this alcohol (**Q**) by measuring its enthalpy change of combustion, and comparing the result with values in a data book.

The student used the equipment shown in the diagram to determine the enthalpy change of combustion of alcohol **Q**.



Data

Mass of spirit burner + alcohol **Q** before combustion	= 20.24 g
Mass of spirit burner + alcohol **Q** after combustion	= 19.48 g
Mass of water in the beaker	= 500 g
Temperature of the water before the experiment	= 17.8 °C
Temperature of the water at the end of the experiment	= 28.7 °C
Specific heat capacity of water	= 4.18 $J\,g^{-1}\,°C^{-1}$

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(a) (i) Calculate the enthalpy change, in **kJ g^{-1}**, when 1.00 g of alcohol **Q** is burned. Include a sign in your final answer.

(3)

$\Delta T = 28.7 - 17.8 = 10.9\ °C$

$Q = mc\Delta T = 500 \times 4.18 \times 10.9 = 22781\ J = 22.781\ kJ$

mass of Q burned = 20.24 − 19.48 = 0.76 g

energy per gram = 22.781 ÷ 0.76 = 29.975 kJ g^{-1}

$\Delta H = -30.0\ kJ\ g^{-1}$

(ii) At the end of the experiment there was a black deposit of carbon on the bottom of the beaker.

Explain the effect of formation of the carbon deposit on your answer to (a)(i).

(2)

The magnitude of the enthalpy change will be smaller (less negative), as less energy is released per gram.

This is because the carbon shows incomplete combustion: carbon forms instead of CO_2, so fewer bonds are made and less energy is given out.

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(b) Give one theoretical and one practical reason why this procedure is insufficient to identify the alcohol.

(2)

Theoretical reason

The molar mass of Q is unknown, so ΔH cannot be found in kJ mol^{-1} to compare with data book values (they would have to be converted to kJ g^{-1}).

Practical reason

The experiment is very inaccurate because of large heat losses to the surroundings, e.g. from the flame to the air and from the beaker walls.

(c) The student concluded that alcohol **Q** was either propan-1-ol or propan-2-ol because the mass spectrum had the molecular ion peak at $m / z = 60$.

Explain **one** peak that you would expect to be present in the mass spectrum of propan-1-ol but not in the mass spectrum of propan-2-ol.

(2)

Propan-1-ol gives a peak at m/z = 31, which is due to the CH_2OH^+ ion, formed when the C–C bond next to the CH_2OH group breaks. Propan-2-ol has no CH_2OH group, so it cannot give this peak.

(Total for Question 5 = 9 marks)

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6 Ammonium carbamate has the formula NH_2COONH_4. When a sample of ammonium carbamate is placed in a sealed tube and heated, it partially decomposes to the compounds used to synthesise it.

The equation for this reversible reaction is

$$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

Which is the expression for the equilibrium constant, K_c, for this reaction?
All concentration terms are at equilibrium.

☒ **A** $\dfrac{[NH_3][CO_2]}{[NH_2COONH_4]}$

☒ **B** $\dfrac{[2NH_3][CO_2]}{[NH_2COONH_4]}$

☒ **C** $[NH_3]^2[CO_2]$

☒ **D** $\dfrac{[NH_3]^2[CO_2]}{[NH_2COONH_4]}$

(Total for Question 6 = 1 mark)

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7 This question is about the primary alcohol butan-1-ol.

(a) Which are the intermolecular force(s) between butan-1-ol molecules in the liquid phase?

(1)

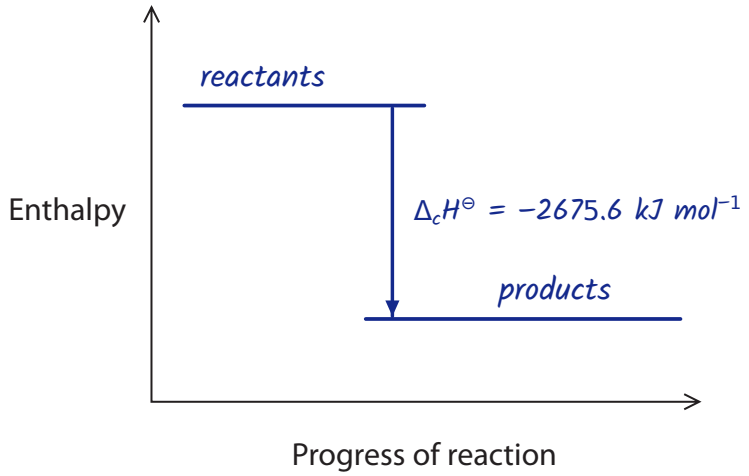
- ☒ **A** hydrogen bonding only
- ☒ **B** hydrogen bonding and permanent dipole-dipole forces only
- ☒ **C** hydrogen bonding, permanent dipole-dipole forces and London forces
- ☒ **D** London forces only

(b) The equation for the complete combustion of butan-1-ol is shown.

$$CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l) \quad \Delta_cH^{\ominus} = -2675.6\,kJ\,mol^{-1}$$

Draw a labelled enthalpy level diagram for this reaction, using the axes provided. You may use the labels 'reactants' and 'products' in place of the formulae shown in the equation.

(2)



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(c) Butan-1-ol can be oxidised to produce butanal or butanoic acid.

(i) Which is a suitable test and result for butan-1-ol?

(1)

		Test reagent	Observation
☒	**A**	phosphorus(V) chloride $PCl_5(s)$	white smoke
☐	**B**	phosphorus(V) chloride $PCl_5(s)$	steamy fumes
☐	**C**	sodium carbonate $Na_2CO_3(aq)$	carbon dioxide given off
☐	**D**	sodium carbonate $Na_2CO_3(aq)$	effervescence

(ii) State how to produce butanal in high yield when butan-1-ol reacts with acidified potassium dichromate(VI).

(1)

Set up the apparatus for distillation (not reflux), so the butanal distils off as soon as it forms.

(iii) Describe a chemical test, including the expected results, that would confirm the presence of an aldehyde such as butanal.

(2)

Warm the sample with Fehling's (or Benedict's) solution in a hot water bath. An aldehyde gives a red-brown precipitate (the blue solution turns to a red-brown solid); butan-1-ol gives no change.

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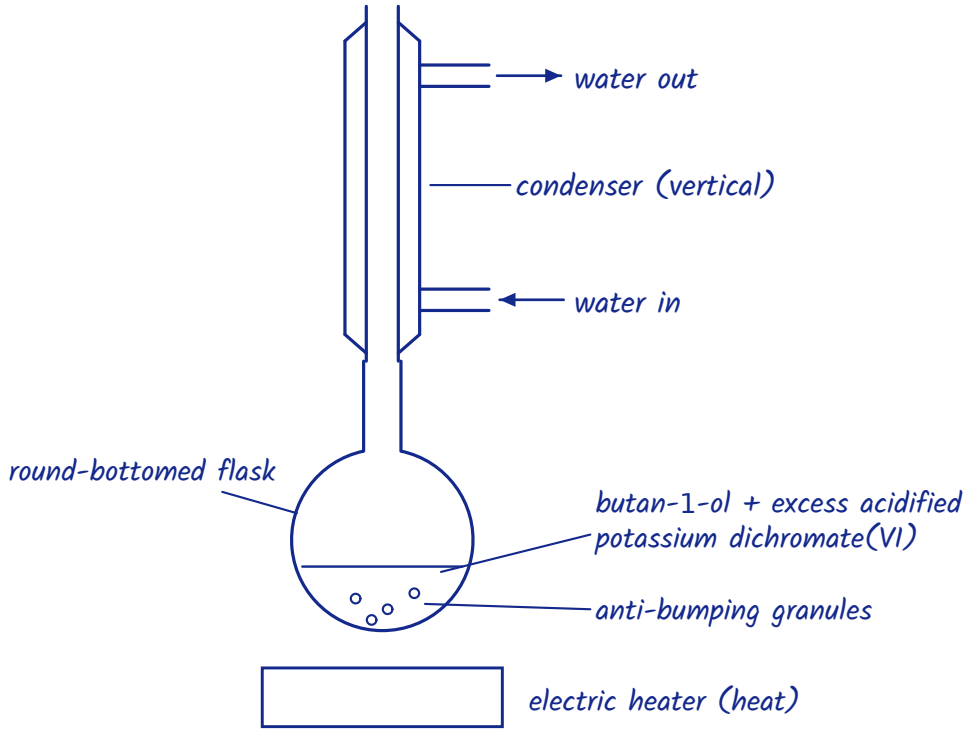
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*(iv) Describe, including practical details, how a sample of butanoic acid (boiling temperature 166 °C) could be prepared from butan-1-ol (boiling temperature 117 °C) using acidified potassium dichromate(VI).
Include labelled diagrams of the apparatus you would use for the reaction, and for collecting the product.
You may assume that all necessary safety precautions are observed.

(6)

Diagram 1: heating under reflux open top



Put butan-1-ol in a round-bottomed flask with an excess of potassium dichromate(VI) acidified with dilute sulfuric acid, and add a few anti-bumping granules for smooth boiling.

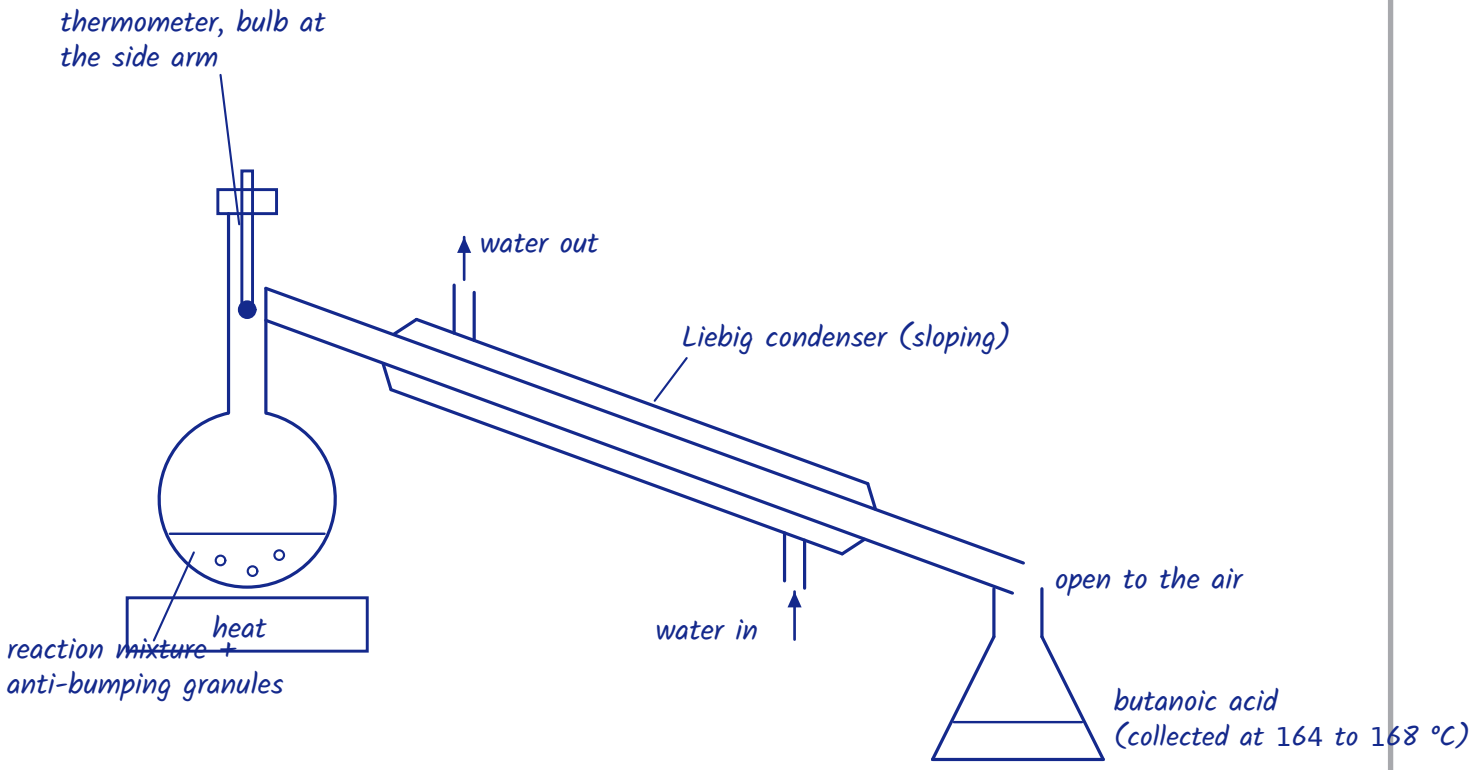
Heat under reflux for about 30 minutes using an electric heater (diagram 1). The vertical condenser, with water in at the bottom and out at the top, condenses vapours of butan-1-ol and butanal back into the flask, so the alcohol is fully oxidised to butanoic acid.

The orange solution turns green as $Cr_2O_7^{2-}$ is reduced to Cr^{3+}.

Then rearrange the apparatus for distillation (diagram 2): a still head with the thermometer bulb level with the side arm, a sloping condenser (water in at the lower

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Diagram 2: distillation to collect the product



end) and a collecting flask that is open to the air, so the apparatus is not sealed.

Heat the flask and collect the liquid that distils between 164 and 168 °C, close to the boiling temperature of butanoic acid (166 °C); liquid distilling at lower temperatures is discarded.

(Total for Question 7 = 13 marks)

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8 A data book gave the following information.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^{\ominus} = -285.8\,kJ\,mol^{-1}$$

(a) State the **two** conditions denoted by the standard symbol $^{\ominus}$ for this reaction.

(2)

a pressure of 100 kPa (1 bar)

a stated temperature, usually 298 K (25 °C)

(b) (i) Draw a Hess's Law cycle that would enable you to use the data provided to calculate the enthalpy change of formation of gaseous water, $\Delta_r H$.

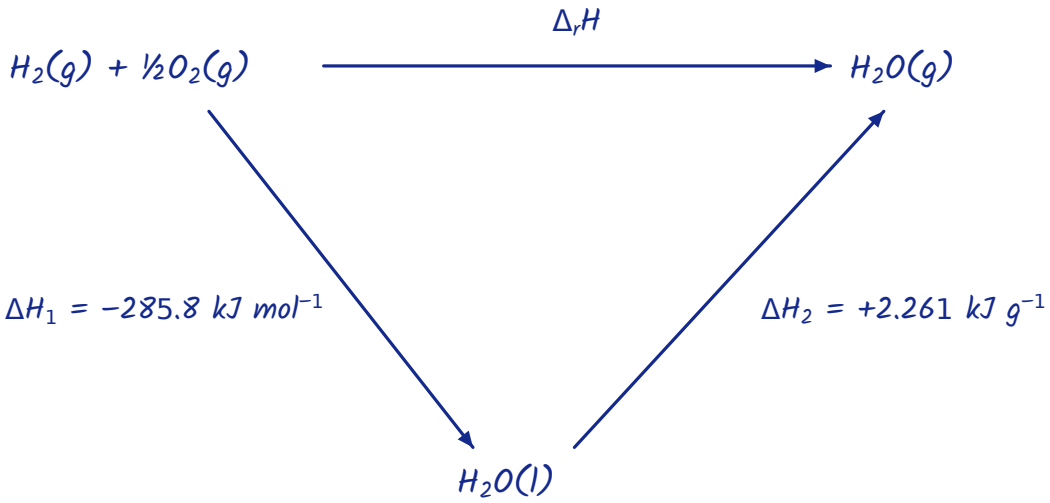
(2)

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g)$$

Data:

$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H_1^{\ominus} = -285.8\,kJ\,mol^{-1}$

$H_2O(l) \rightarrow H_2O(g) \qquad \Delta H_2^{\ominus} = +2.261\,kJ\,g^{-1}$



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(ii) Calculate the enthalpy change for the reaction shown.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g)$$

(3)

$\Delta H_2 = +2.261\ kJ\ g^{-1} \times 18.0\ g\ mol^{-1} = +40.698\ kJ\ mol^{-1}$

Hess's Law: $\Delta_r H = \Delta H_1 + \Delta H_2$

$\Delta_r H = -285.8 + (+40.698)$

$\Delta_r H = -245.1\ kJ\ mol^{-1}$

(Total for Question 8 = 7 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)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass atomic symbol name atomic (proton) number									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	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
* Actinide series	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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