

Please check the examination details below before entering your candidate information

Candidate surname

Other names

**Pearson Edexcel
Level 3 GCE**

Centre Number

--	--	--	--	--

Candidate Number

--	--	--	--

Time 1 hour 45 minutes

Paper
reference

9CH0/01

Chemistry

Advanced

PAPER 1: Advanced Inorganic and Physical Chemistry

**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.*
- Show all your working in calculations and include units where appropriate.

Information

- The total mark for this paper is 90.
- 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.
- Check your answers if you have time at the end.
- Good luck with your examination.

Turn over ►

P65463A

©2021 Pearson Education Ltd.

1/1/1/1/




Pearson

Answer ALL questions.

Some questions must be answered with a cross .
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 is a question about atoms, isotopes and ions.

(a) Which of the following pairs of ions is isoelectronic?

(1)

- A N^{3-} and Cl^-
- B O^{2-} and S^{2-}
- C Na^+ and K^+
- D Na^+ and Mg^{2+}

(b) Which is a correct definition of relative isotopic mass?

(1)

- A the weighted mean mass of an atom of an element relative to one twelfth of the mass of an atom of the isotope carbon-12
- B the mass of one atom of an isotope relative to one twelfth of the mass of an atom of the isotope carbon-12
- C the weighted mean mass of an atom of an element relative to 12g of the isotope carbon-12
- D the mass of one atom of an isotope relative to the mass of 12g of the isotope carbon-12

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



(c) The percentage composition of the two bromine isotopes in a sample is given in the table.

Isotope	Relative isotopic mass	Percentage abundance
bromine-79	78.918	50.52
bromine-81	80.916	49.48

Calculate the relative atomic mass of bromine in this sample.
Give your answer to two decimal places.

(2)

(Total for Question 1 = 4 marks)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



2 Barium ions can be identified by their flame colour.

(a) Which of the following should be used for a flame test on barium carbonate? (1)

- A iron wire and water
- B iron wire and concentrated hydrochloric acid
- C nichrome wire and water
- D nichrome wire and concentrated hydrochloric acid

(b) What colour do barium ions give in a flame test? (1)

- A green
- B lilac
- C red
- D yellow

(c) A flame test was carried out on a mixture of barium chloride and magnesium chloride.

How does the presence of magnesium ions affect the appearance of the flame colour of barium ions? (1)

- A the colour is more intense
- B a bright white colour completely masks the barium colour
- C there is no change
- D the barium colour is decreased by the white magnesium flame colour

(Total for Question 2 = 3 marks)



3 This question is about catalytic converters.

(a) Catalytic converters contain metals such as platinum.

Describe the bonding in platinum.
You may include a diagram in your answer.

(2)

.....

.....

.....

.....

.....

.....

(b) A catalytic converter decreases the emissions of gases, such as carbon monoxide and nitrogen monoxide, from an internal combustion engine.

Describe the stages in a catalytic converter that result in this decrease.
No equations are required.

(3)

.....

.....

.....

.....

.....

.....

.....

.....

(Total for Question 3 = 5 marks)



4 Ionisation energies provide information about the number of electrons and the arrangement of the electrons in an atom of an element.

(a) A student's definition of first ionisation energy is shown.

First ionisation energy is the energy released when one mole of gaseous atoms loses one mole of electrons to form one mole of gaseous 1+ ions.

There is one incorrect word in the student's definition.

Identify the word, giving the reason why this word is incorrect.

(2)

(b) Write an equation for the **second** ionisation energy of oxygen.
Include state symbols.

(2)



(c) A sodium atom has 11 protons whereas a potassium atom has 19 protons.

Explain why the first ionisation energy of sodium is greater than that of potassium.

(3)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



(d) The successive ionisation energies for magnesium are given in the table.

Electron number removed	1	2	3	4	5	6	7	8	9	10	11	12
Ionisation energy / kJ mol^{-1}	738	1451	7733	10541	13629	17995	21704	25657	31644	35463	169996	189371
Log (ionisation energy)	2.87	3.16	3.89	4.02	4.13		4.34	4.41	4.50	4.55	5.23	

(i) Complete the table.

(1)

(ii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot a graph.

(1)

.....

.....

.....

.....

(iii) Give a reason why the successive ionisation energies increase.

(1)

.....

.....

.....

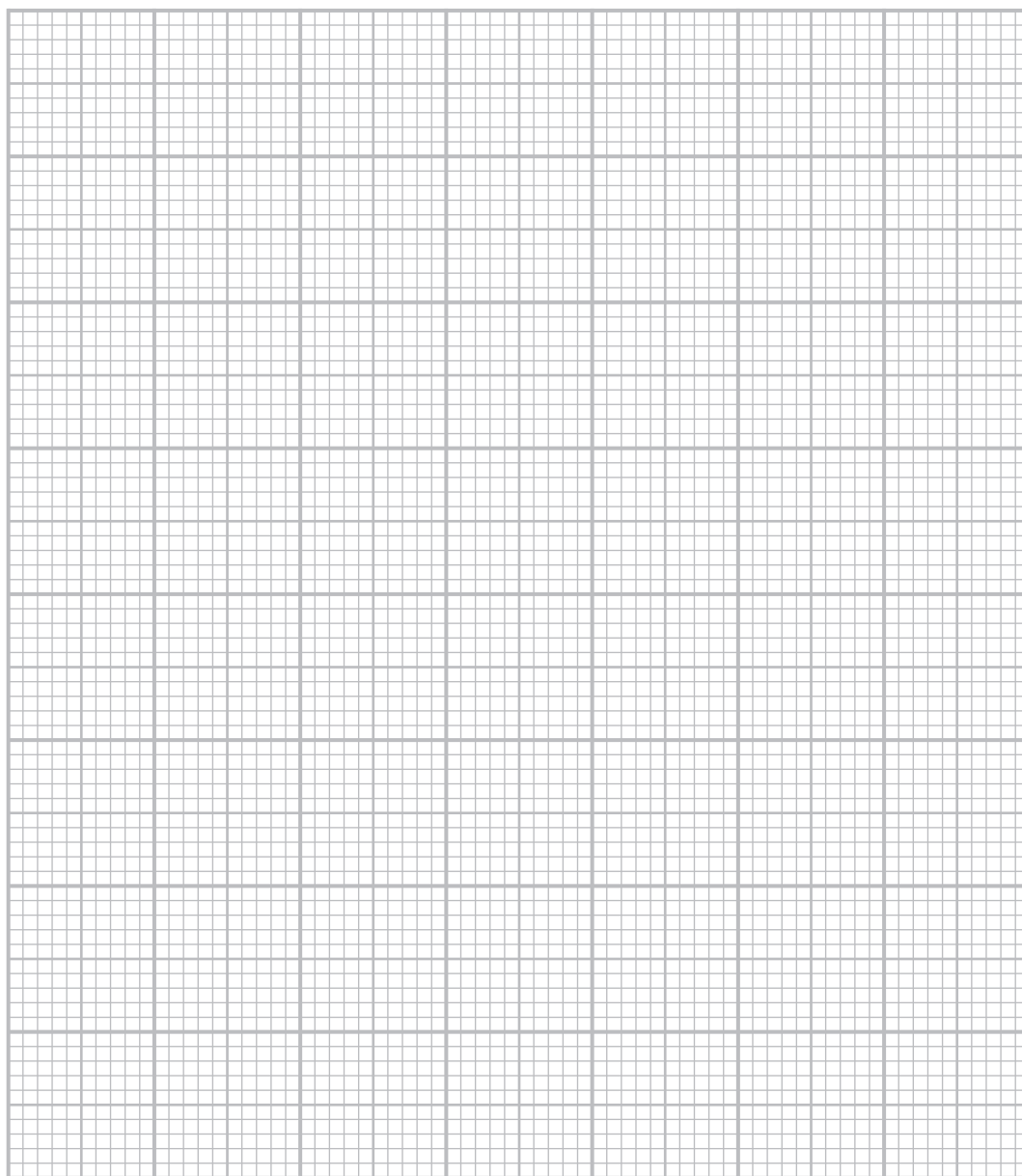
.....



(iv) Plot the graph of $\log(\text{ionisation energy})$ against electron number removed.

Join the individual points using straight lines.

(3)



(v) Identify on the graph, using a circle, the points that represent the removal of the electrons in the **outermost** energy level of magnesium.

(1)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



(e) Estimate a value for the first ionisation energy of oxygen given the data in the table.

(1)

Element	First ionisation energy / kJ mol^{-1}
carbon	1086
nitrogen	1402
oxygen

(Total for Question 4 = 15 marks)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

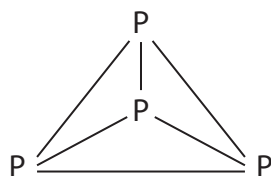


5 The halogens are elements in Group 7 of the Periodic Table.

(a) Chlorine compounds have many uses, including water treatment.

(i) Chlorine and phosphorus (P_4) can react to form phosphorus(V) chloride.

The structure of a molecule of phosphorus is



Some mean bond enthalpy values are shown in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
P—P	+198
Cl—Cl	+243
P—Cl	+326

Calculate the enthalpy change for the reaction between chlorine and phosphorus to form phosphorus(V) chloride.



(3)



(ii) Give a reason why bond enthalpy values are always positive.

(1)

.....

.....

.....

(b) Sodium chlorate(I) is a bleaching agent.

(i) Sodium chlorate(I) can be made by the reaction of chlorine with sodium hydroxide.

Show, by using oxidation numbers, that this reaction is disproportionation.



(2)

.....

.....

(ii) A different bleaching agent can be made by the reaction of chlorine with sodium hydroxide under different conditions.

Balance this equation.



(1)

(iii) What conditions are required for the reaction in (b)(ii)?

(1)

- A** cold and dilute alkali
- B** cold and concentrated alkali
- C** hot alkali
- D** excess chlorine

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



- (c) The halogens can be identified by their colour in an organic solvent such as hexane or cyclohexane.

Which sequence of colours is correct for chlorine, bromine and iodine dissolved in an organic solvent?

(1)

	Chlorine	Bromine	Iodine
<input type="checkbox"/> A	orange	red-brown	black
<input type="checkbox"/> B	pale green	orange	black
<input type="checkbox"/> C	orange	red-brown	purple
<input type="checkbox"/> D	pale green	orange	purple

- (d) Halide ions can be identified by their reaction with silver nitrate.

- (i) Write the **ionic** equation for the reaction between aqueous solutions of sodium iodide and silver nitrate. Include state symbols.

(2)

- (ii) A solution containing 0.010 mol of a halide ion was reacted with excess silver nitrate and produced 1.88 g of precipitate.

Identify the halide ion.
Justify your answer.

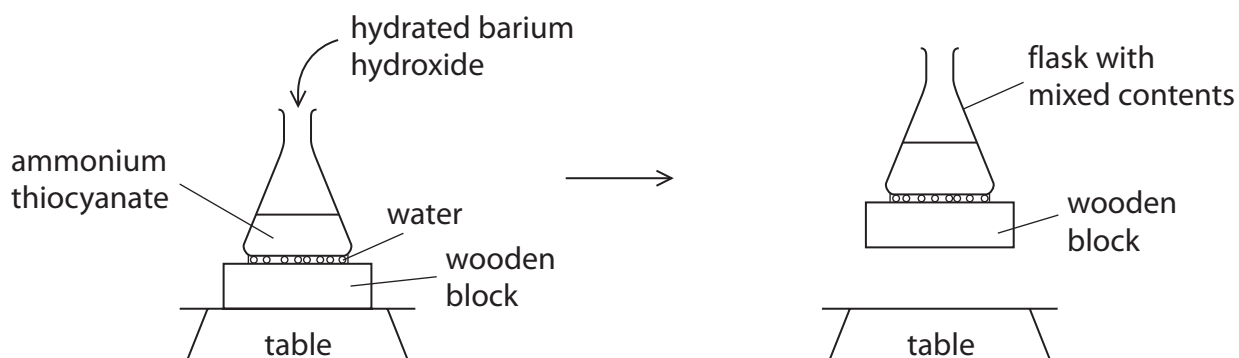
(2)

(Total for Question 5 = 13 marks)



6 This question is about entropy.

- (a) Some hydrated barium hydroxide is added to ammonium thiocyanate in a flask which is placed on a few drops of water on a wooden block. After the addition, the contents are stirred and then the flask can be lifted up with the wooden block attached, as shown.



The equation for the reaction is



- (i) Give **two** reasons why you would expect $\Delta S_{\text{system}}^\ominus$ to be positive.

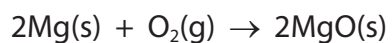
(2)

- (ii) Explain why the wooden block is lifted up by the flask.

(2)



(b) What is the standard molar entropy change, $\Delta S_{\text{system}}^{\ominus}$, in $\text{JK}^{-1} \text{mol}^{-1}$, for the reaction shown?



Substance	Standard molar entropy, $S^{\ominus} / \text{JK}^{-1} \text{mol}^{-1}$
Mg(s)	32.7
O ₂ (g)	205.0
MgO(s)	26.9

(1)

- A +210.8
- B -210.8
- C +216.6
- D -216.6

(Total for Question 6 = 5 marks)

DO NOT WRITE IN THIS AREA

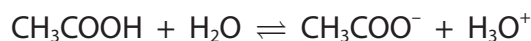
DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



7 This question is about acids and buffer solutions.

(a) Ethanoic acid, CH_3COOH , is a monobasic acid.



Give a reason why only the proton from the carboxylic acid group, and not from the methyl group, is donated to a water molecule.

(1)

.....

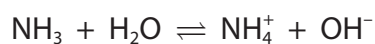
.....

.....

.....

.....

(b) The reaction of ammonia with water can be represented by



Which is the acid-conjugate base pair?

(1)

	Acid	Conjugate base
<input type="checkbox"/> A	NH_3	OH^-
<input type="checkbox"/> B	NH_3	NH_4^+
<input type="checkbox"/> C	H_2O	OH^-
<input type="checkbox"/> D	H_2O	NH_4^+



- (c) A commercial nitric acid solution, $\text{HNO}_3(\text{aq})$, has a concentration of 15.9 mol dm^{-3} .
A 15.0 cm^3 sample was made up to 100 cm^3 by adding deionised water.

Calculate the pH of this diluted solution.

(2)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



(d) Propanoic acid is a weak acid.

- (i) Calculate the pH of a $0.100 \text{ mol dm}^{-3}$ solution of propanoic acid at 298 K.
Give your answer to an appropriate number of significant figures.

$$[K_a = 1.35 \times 10^{-5} \text{ mol dm}^{-3} \text{ at } 298 \text{ K}]$$

(3)

- (ii) State **two** assumptions that you made in the calculation in d(i).

(2)

.....

.....

.....

.....

.....

.....

.....



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(e) A buffer solution was made using 20.0 cm^3 of a butanoic acid solution, of concentration $0.100 \text{ mol dm}^{-3}$ and 30.0 cm^3 of sodium butanoate solution, of concentration $0.305 \text{ mol dm}^{-3}$.

$[K_a = 1.52 \times 10^{-5} \text{ mol dm}^{-3} \text{ at } 298\text{K}]$

(i) Calculate the pH of this buffer solution at 298 K. (4)

(ii) Explain why the pH of the buffer solution hardly changes when a few drops of sodium hydroxide solution are added to it.
Include an equation or equations in your answer.
Use $\text{C}_3\text{H}_7\text{COOH}$ as the formula for butanoic acid. (2)

.....

.....

.....

.....

(Total for Question 7 = 15 marks)



8 Transition metals form complex ions.

(a) Complex ions have a central metal ion surrounded by ligands.

(i) Give a reason why the ammonium ion cannot act as a ligand.

(1)

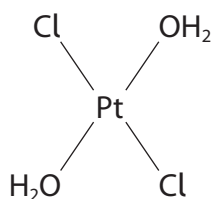
(ii) Explain why the complex ions $[\text{Co}(\text{NH}_3)_6]^{2+}$ and $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ are coloured and have different colours.

(4)

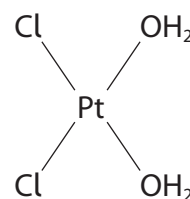
(b) Which of these complexes is used in the treatment of cancer?

(1)

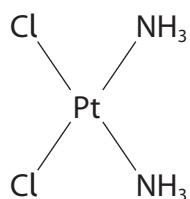
A



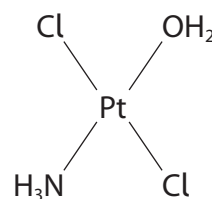
B



C

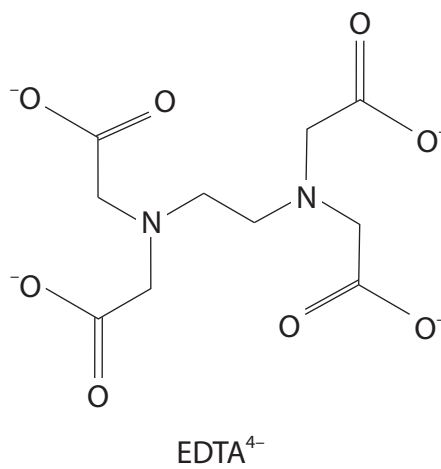
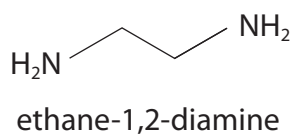


D



- (c) Compare and contrast the complex ions formed by cobalt(III) ions with the ligand ethane-1,2-diamine and with the ligand EDTA^{4-} .

Ignore any difference in colour.



(4)

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....



- (d) Hydrated chromium(III) chloride, $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$, dissolves in water to form a number of different complex ions containing both chloride and water ligands.

The general formula of these complex ions is $[\text{Cr}(\text{H}_2\text{O})_x(\text{Cl})_y]^{(3-y)+}$

In an experiment, 0.10 mol of a complex reacted with excess silver nitrate solution to produce 0.20 mol of silver chloride.

Chloride ions which are ligands within the complex do not react with silver nitrate.

Deduce the formula of this chromium(III) complex ion. Justify your answer.

(2)

.....

.....

.....

.....

.....

.....

.....

(Total for Question 8 = 12 marks)



9 This question is about lattice energies.

(a) The table shows the theoretical and experimental lattice energy values of two compounds.

Compound	Theoretical lattice energy / kJ mol^{-1}	Experimental lattice energy / kJ mol^{-1}
magnesium iodide	-1944	-2327
barium iodide	-1831	-1877

(i) State what can be deduced by the close similarity of the lattice energy values for barium iodide.

(1)

(ii) Explain why there is a significant difference in the lattice energy values for magnesium iodide.

(4)



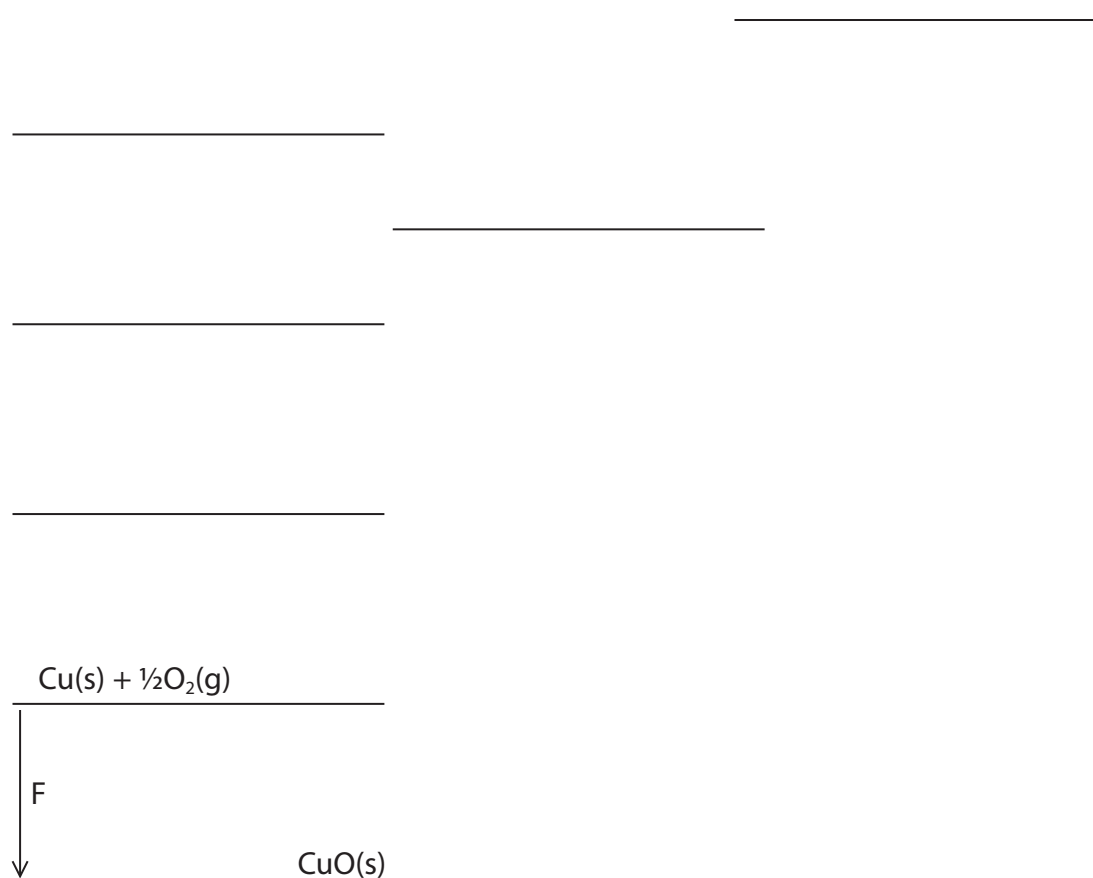
(b) Data for the Born-Haber cycle for copper(II) oxide are given in the table.

Label	Energy change	Value / kJ mol^{-1}
A	standard enthalpy change of atomisation of copper	+338
B	standard enthalpy change of atomisation of oxygen	+249
C	sum of first and second ionisation energies of copper	+2704
D	first electron affinity of oxygen	-141
E	second electron affinity of oxygen	+798
F	standard enthalpy change of formation of copper(II) oxide	-157

(i) Complete the diagram of the Born-Haber cycle for copper(II) oxide.

Include labels of enthalpy changes with arrows indicating the direction of change, and the respective species with state symbols.

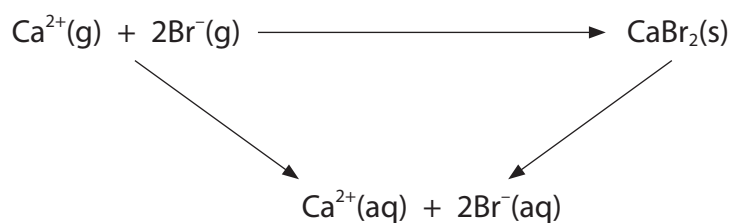
(4)



(ii) Calculate the lattice energy of copper(II) oxide.

(1)

(c) A different energy cycle can be used to calculate lattice energy.



Enthalpy change	Value / kJ mol^{-1}
enthalpy change of solution of CaBr_2	-73
enthalpy change of hydration of Ca^{2+}	-1577
enthalpy change of hydration of Br^{-}	-336

Calculate the lattice energy of calcium bromide.

(2)

(Total for Question 9 = 12 marks)



P 6 5 4 6 3 A 0 2 5 2 8

*10 A student wrote:

Whether or not a reaction occurs depends only on the thermodynamic feasibility calculated using

$$\Delta G = \Delta H - T\Delta S_{\text{system}}$$

Discuss this statement.

Include reference to:

- changes in the values and signs of the terms in the equation for both endothermic and exothermic reactions
- circumstances where a reaction that is predicted to be thermodynamically feasible may not occur in practice.

(6)

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA



DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

DO NOT WRITE IN THIS AREA

(Total for Question 10 = 6 marks)

TOTAL FOR PAPER = 90 MARKS



P 6 5 4 6 3 A 0 2 7 2 8

The Periodic Table of Elements

1 2 3 4 5 6 7 0 (8) (18)

1.0
H
hydrogen
1

Key
relative atomic mass
atomic symbol
name
atomic (proton) number

(1)	6.9 Li lithium 3	9.0 Be beryllium 4	23.0 Na sodium 11	24.3 Mg magnesium 12	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)		
	39.1 K potassium 19	40.1 Ca calcium 20	85.5 Rb rubidium 37	87.6 Sr strontium 38	138.9 Ba barium 56	132.9 Cs caesium 55	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		
	232 Th thorium 90	238 U uranium 92	231 Pa protactinium 91	237 Np neptunium 93	242 Pu plutonium 94	244 Am americium 95	247 Cm curium 96	251 Bk berkelium 97	254 Cf californium 98	259 Es einsteinium 99	263 Fm fermium 100	267 Md mendelevium 101	271 No nobelium 102	274 Lr lawrencium 103	288 Yb ytterbium 70	289 Lu lutetium 71	290 Ho holmium 67	291 Er erbium 68	292 Tm thulium 69	293 Dy dysprosium 66	294 Yb ytterbium 70	295 Lu lutetium 71	
	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	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71	176 Yb ytterbium 70	177 Lu lutetium 71	178 Yb ytterbium 70	179 Lu lutetium 71	180 Yb ytterbium 70	181 Lu lutetium 71	182 Yb ytterbium 70	183 Lu lutetium 71	184 Yb ytterbium 70	185 Lu lutetium 71
	223 Fr francium 87	226 Ra radium 88	227 Ac actinium 89	228 Th thorium 90	232 Pa protactinium 91	233 U uranium 92	235 Np neptunium 93	237 Pu plutonium 94	239 Am americium 95	241 Cm curium 96	243 Bk berkelium 97	245 Cf californium 98	247 Es einsteinium 99	249 Fm fermium 100	251 Md mendelevium 101	253 No nobelium 102	255 Lr lawrencium 103	257 Rf rutherfordium 104	259 Db dubnium 105	261 Rf rutherfordium 104	263 Db dubnium 105	265 Rf rutherfordium 104	267 Db dubnium 105
	88 Ra radium 88	89 Ac actinium 89	90 Th thorium 90	91 Pa protactinium 91	92 U uranium 92	93 Np neptunium 93	94 Pu plutonium 94	95 Am americium 95	96 Cm curium 96	97 Bk berkelium 97	98 Cf californium 98	99 Es einsteinium 99	100 Fm fermium 100	101 Md mendelevium 101	102 No nobelium 102	103 Lr lawrencium 103	104 Rf rutherfordium 104	105 Db dubnium 105	106 Rf rutherfordium 104	107 Db dubnium 105	108 Rf rutherfordium 104	109 Db dubnium 105	

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

* Lanthanide series
* Actinide series

