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 ▶

Pearson

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 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 12 g of the isotope carbon-12

☒ **D** the mass of one atom of an isotope relative to the mass of 12 g of the isotope carbon-12

(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)

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)

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(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)

(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	10 541	13 629	17 995	21 704	25 657	31 644	35 463	169 996	189 371
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)

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

(1)

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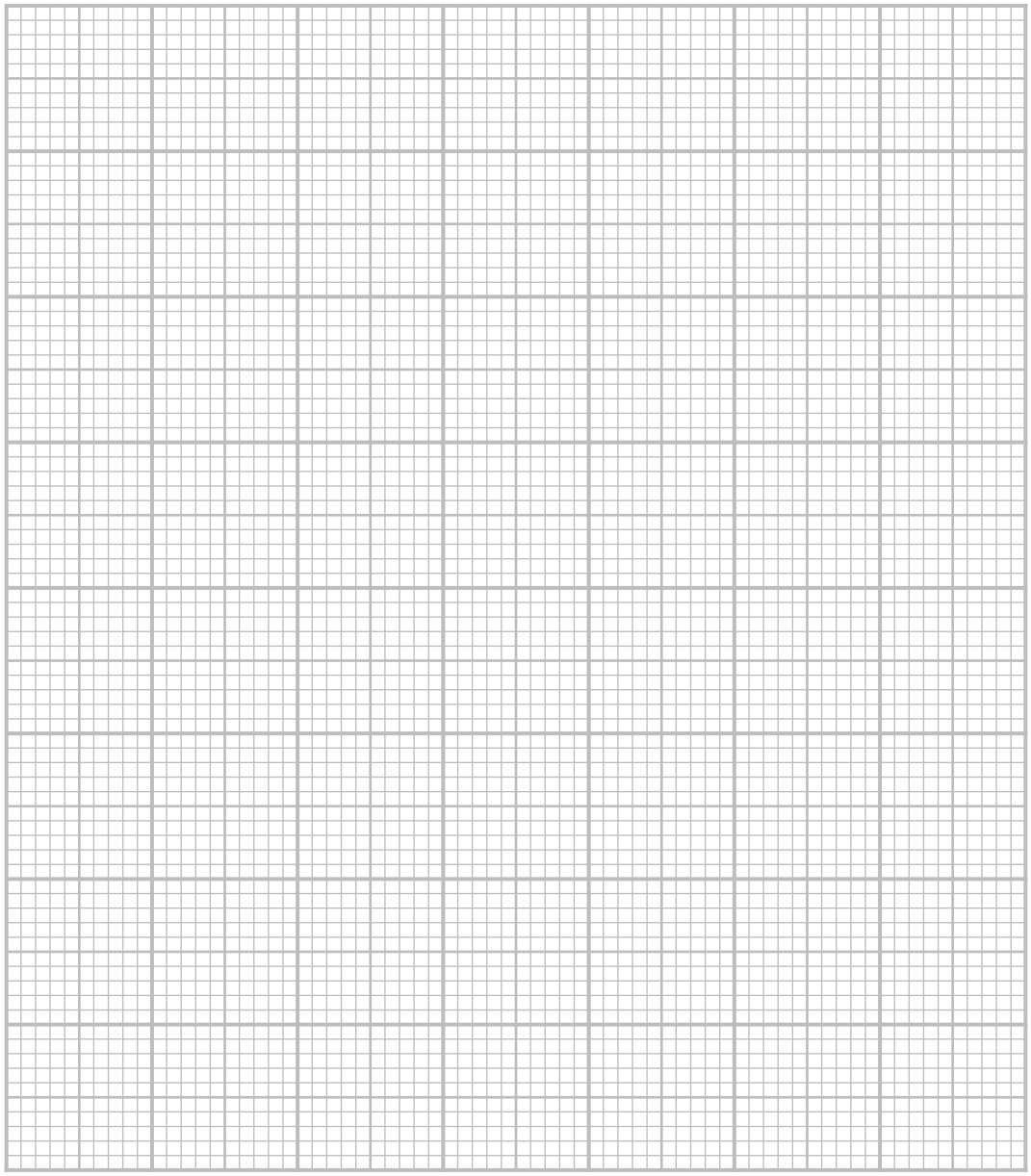
(iv) Plot the graph of log(ionisation energy) against electron number removed.

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)

(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	.....

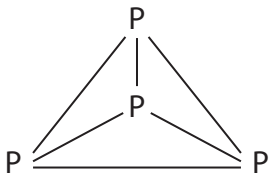
(Total for Question 4 = 15 marks)

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.

$$10Cl_2 + P_4 \rightarrow 4PCl_5$$

(3)

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

(1)

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(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.

$$2NaOH + Cl_2 \rightarrow NaClO + NaCl + H_2O$$

(2)

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

Balance this equation.

$$\text{.....}NaOH + \text{.....}Cl_2 \rightarrow NaClO_3 + \text{.....}NaCl + \text{.....}H_2O$$

(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

(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
☒ **A**	orange	red-brown	black
☒ **B**	pale green	orange	black
☒ **C**	orange	red-brown	purple
☒ **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)

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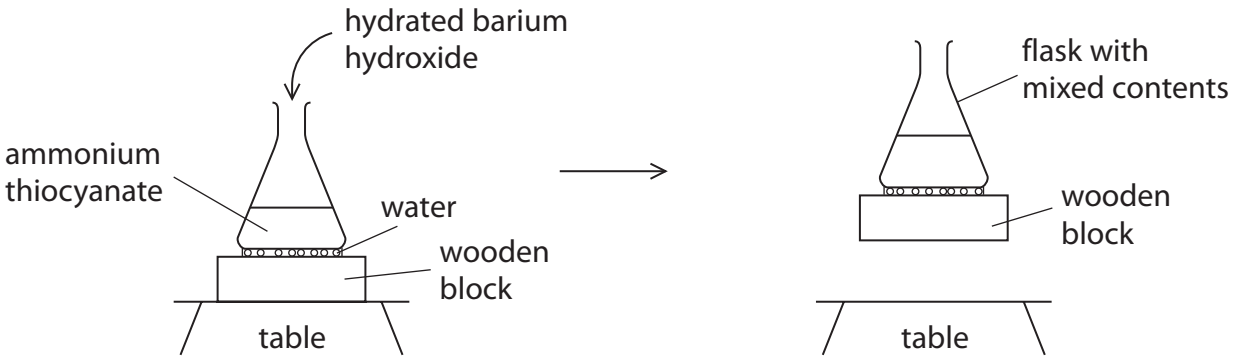
.....

(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

$$Ba(OH)_2.8H_2O(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(aq) + 2NH_3(g) + 10H_2O(l)$$

(i) Give **two** reasons why you would expect $\Delta S^{\ominus}_{system}$ 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, $\Delta S^{\ominus}_{system}$, in $J\,K^{-1}\,mol^{-1}$, for the reaction shown?

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$$

Substance	Standard molar entropy, $S^{\ominus}$ / $J\,K^{-1}\,mol^{-1}$
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)

7 This question is about acids and buffer solutions.

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

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

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

$$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$$

Which is the acid-conjugate base pair?

(1)

	Acid	Conjugate base
☒ **A**	NH_3	OH^-
☒ **B**	NH_3	NH_4^+
☒ **C**	H_2O	OH^-
☒ **D**	H_2O	NH_4^+

(c) A commercial nitric acid solution, $HNO_3(aq)$, 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)

(d) Propanoic acid is a weak acid.

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

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

(3)

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

(2)

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

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

(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 C_3H_7COOH as the formula for butanoic acid.

(2)

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(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)

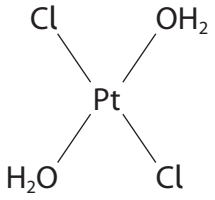
(ii) Explain why the complex ions $[Co(NH_3)_6]^{2+}$ and $[Co(H_2O)_6]^{2+}$ are coloured and have different colours.

(4)

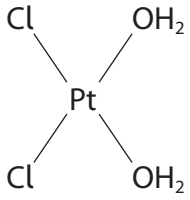
(b) Which of these complexes is used in the treatment of cancer?

(1)

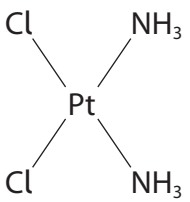
☒ **A**



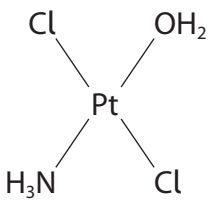
☒ **B**



☒ **C**

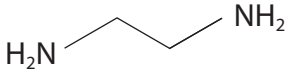


☒ **D**

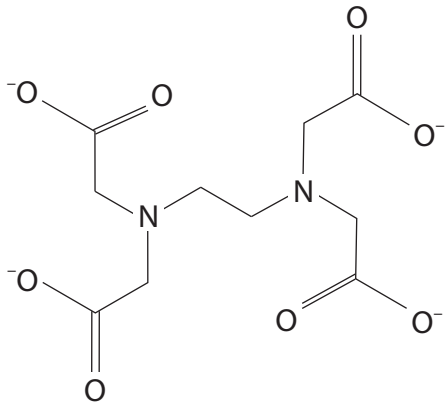


(c) Compare and contrast the complex ions formed by cobalt(III) ions with the ligand ethane-1,2-diamine and with the ligand $EDTA^{4-}$.

Ignore any difference in colour.



ethane-1,2-diamine



$EDTA^{4-}$

(4)

(d) Hydrated chromium(III) chloride, $CrCl_3.6H_2O$, 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 $[Cr(H_2O)_x(Cl)_y]^{(3-y)+}$

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)

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(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)

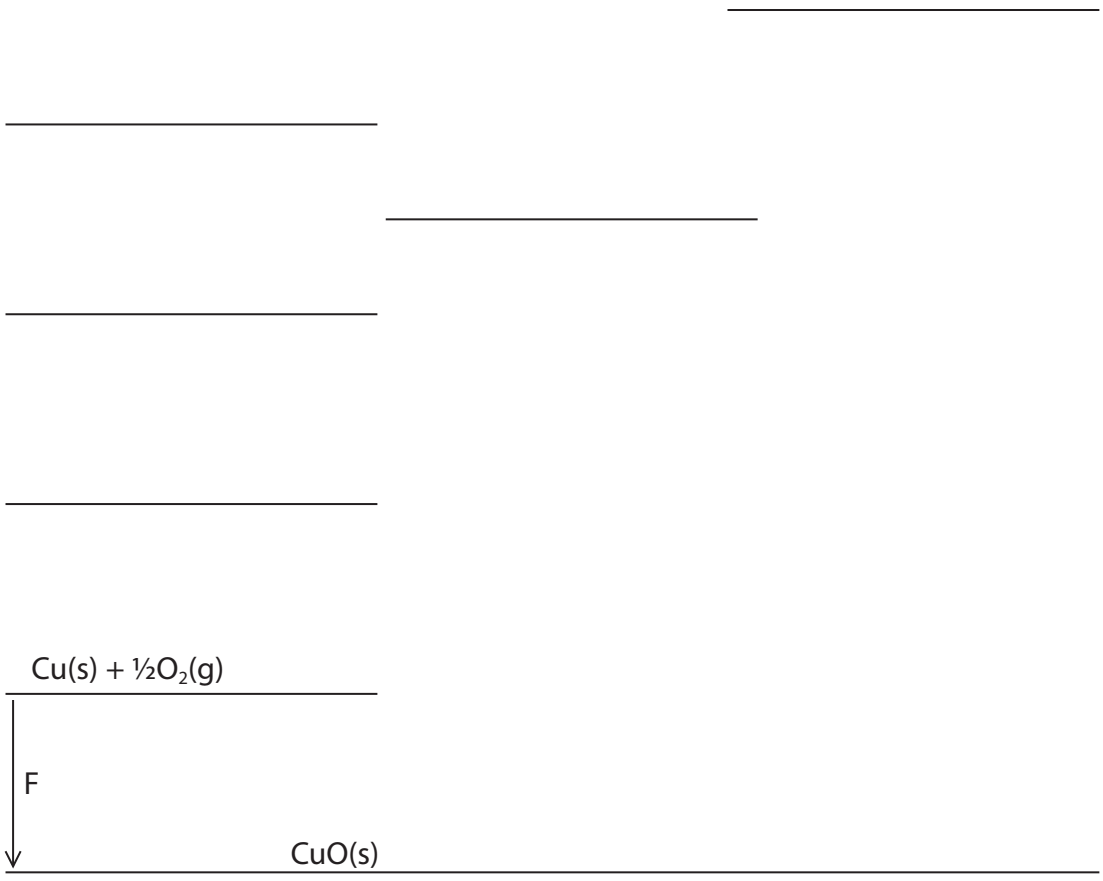
(b) Data for the Born-Haber cycle for copper(II) oxide are given in the table.

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.

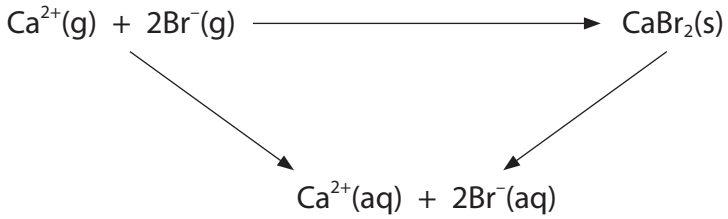
(4)



(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)

*10 A student wrote:

> Whether or not a reaction occurs depends only on the thermodynamic feasibility calculated using
>
> $$\Delta G = \Delta H - T\Delta S_{system}$$

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)

(Total for Question 10 = 6 marks)

TOTAL FOR PAPER = 90 MARKS

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