PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 13: ENERGETICS II

SCORE	PERCENTAGE
/279	%

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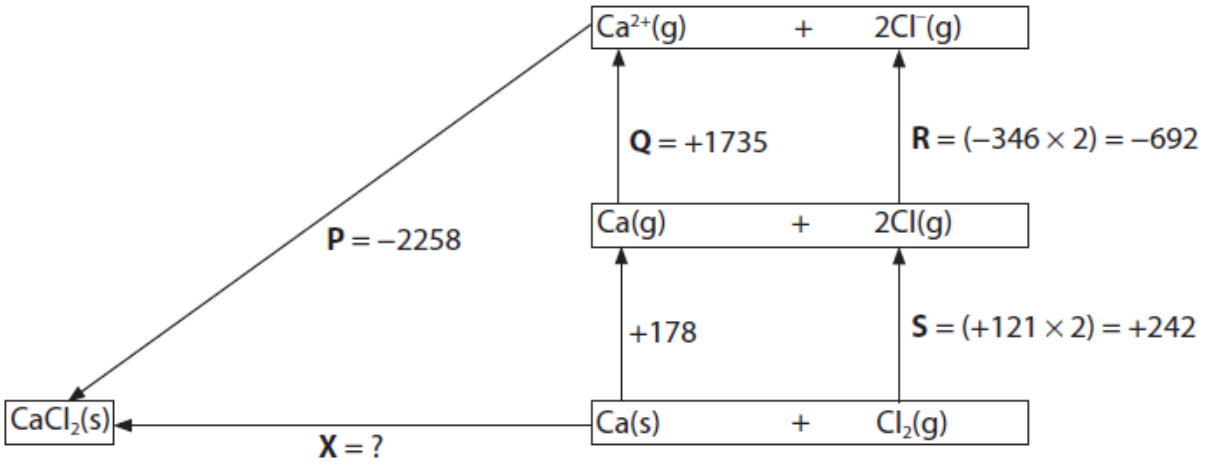
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Q1.

The diagram shows a Born-Haber cycle for calcium chloride. It is not drawn to scale.
All units are in kJ mol^{-1}.



(a) Which enthalpy change is correctly labelled on the diagram?

(1)

☒ **A** Enthalpy change for the formation of calcium chloride (**P**).

☒ **B** First ionization energy of calcium (**Q**).

☒ **C** Electron affinity of chlorine (**R**).

☒ **D** Twice the enthalpy change of atomization of chlorine (**S**).

(b) What is the value of **X**, in kJ mol^{-1}?

(1)

☒ **A** +795

☒ **B** −795

☒ **C** +3721

☒ **D** −3721

(Total for question = 2 marks)

Q2.

Adipic acid, $HOOC(CH_2)_4COOH$, is a dicarboxylic acid used in the production of polymers. It can

be made by the reaction of buta-1,3-diene with carbon monoxide and water.

$$CH_2CHCHCH_2(g) + 2CO(g) + 2H_2O(l) \rightarrow HOOC(CH_2)_4COOH(s)$$

(a) (i) Use the Data Booklet to complete the table below.

(2)

	$CH_2CHCHCH_2(g)$	$CO(g)$	$H_2O(l)$	$HOOC(CH_2)_4COOH(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+109.9			–994.3
$S^{\ominus}$ / J mol^{-1} K^{-1}	278.7			250.0

(ii) Use data from the table to calculate the standard enthalpy change, in kJ mol^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iii) Use data from the table to calculate the standard entropy change of the system, in J mol^{-1} K^{-1}, when adipic acid is formed from buta-1,3-diene, carbon monoxide and water.

(2)

(iv) Use your answers to (ii) and (iii) to calculate $\Delta S_{surroundings}$ and ΔS_{total} for the reaction at 298 K.

(3)

(v) It was suggested that **decreasing** the temperature of the reaction to less than 298 K would produce a greater yield of adipic acid.

Explain, in terms of the effect on ΔS_{system}, $\Delta S_{surroundings}$ and hence ΔS_{total}, whether this would be the case.

(3)

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(b) Infrared spectroscopy can be used to follow the progress of reactions. During the reaction to produce adipic acid, suggest **one** peak which diminishes and **one** peak which appears.

Use information from the Data Booklet to identify two such possible peaks, giving their wave numbers and the bonds involved.

(2)

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(c) Adipic acid is used as an additive in some fruit jellies. Suggest what effect the adipic acid will have on the flavour of the jelly.

(1)

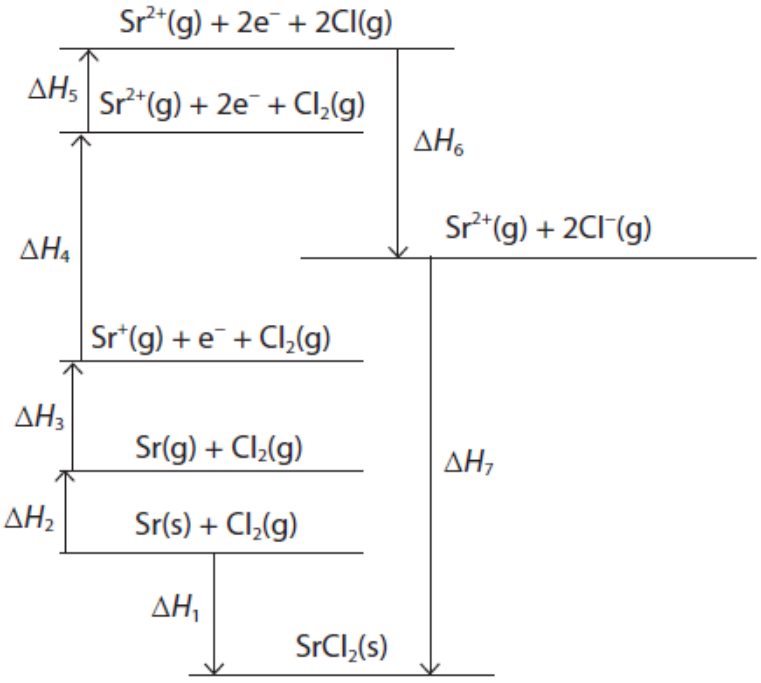
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(Total for question = 15 marks)

Q3.

(a) The diagram shows the Born-Haber cycle for the formation of strontium chloride from its elements.



The table gives the values of enthalpy changes ΔH_1 through to ΔH_6.

Enthalpy change	ΔH_1	ΔH_2	ΔH_3	ΔH_4	ΔH_5	ΔH_6
Value / kJ mol^{-1}	– 828	+ 164	+ 548	+ 1060	+ 242	– 728

(i) Give the names of the enthalpy changes represented by ΔH_1 and ΔH_2.

(2)

ΔH_1

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ΔH_2

.....

(ii) Write an expression linking all the enthalpy changes listed in the Born-Haber cycle and use it to calculate a value for ΔH_7.

(2)

(b) Why is the lattice energy of magnesium chloride more exothermic than that of strontium chloride?

(1)

☒ **A** there are more cation-to-anion interactions in magnesium chloride

☒ **B** the inter-ionic distance is smaller in magnesium chloride

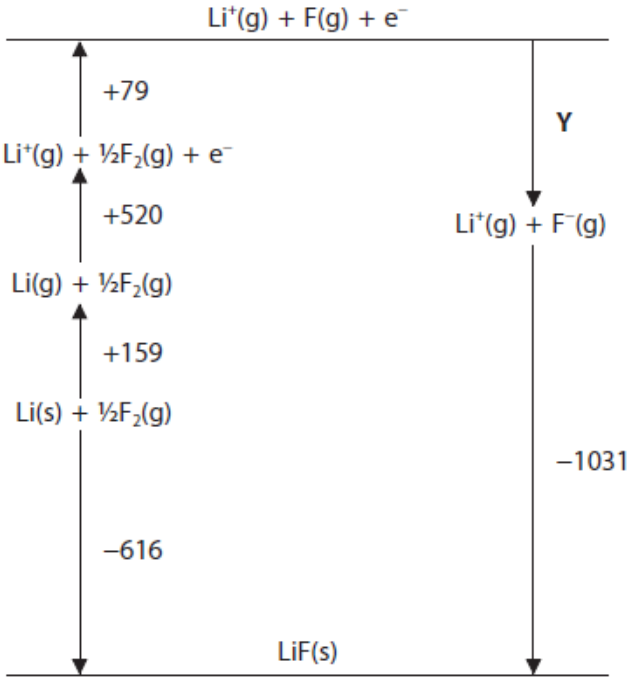
☒ **C** magnesium chloride has less covalent character

☒ **D** the magnesium ion has a greater charge than the strontium ion

Q4.

This question is about ions and ionic compounds.

The diagram, which is not drawn to scale, shows the Born-Haber cycle for lithium fluoride. The energy changes are given in kJ mol^{-1}.



What is the value for **Y**, in kJ mol^{-1}?

(1)

- ☒ **A** −273
- ☒ **B** −343
- ☒ **C** −432
- ☒ **D** −889

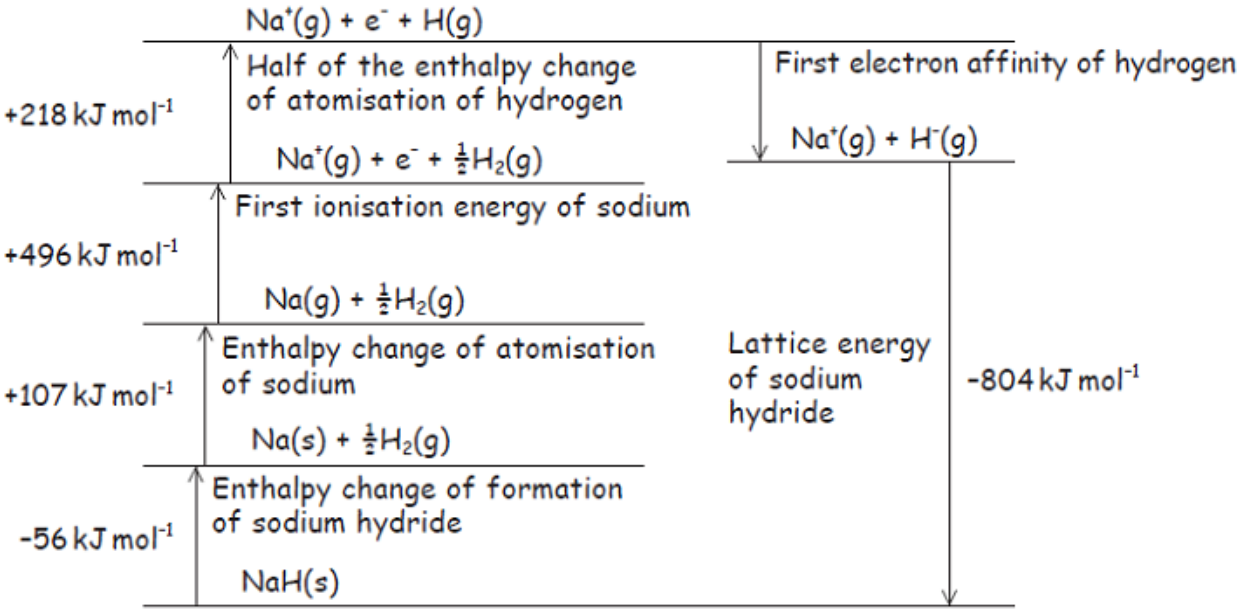
(Total for question = 1 mark)

Q5.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

In order to calculate the first electron affinity of hydrogen, a student was asked to draw a Born-Haber cycle for sodium hydride.

The cycle had **two** errors but the numerical data were correct.



(i) Identify and correct the **two** errors in this Born-Haber cycle.

(2)

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(ii) Calculate the first electron affinity, in kJ mol^{-1}, of hydrogen, using the values given in the cycle.

(1)

(Total for question = 3 marks)

Q6.

This question is about entropy.

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, $S^{\ominus}$ / $JK^{-1}mol^{-1}$
Mg(s)	32.7
$O_2(g)$	205.0
MgO(s)	26.9

(1)

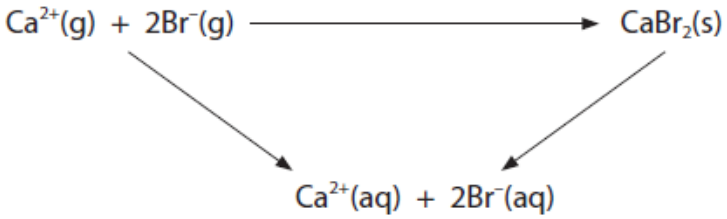
- ☒ **A** +210.8
- ☒ **B** –210.8
- ☒ **C** +216.6
- ☒ **D** –216.6

(Total for question = 1 mark)

Q7.

This question is about lattice energies.

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

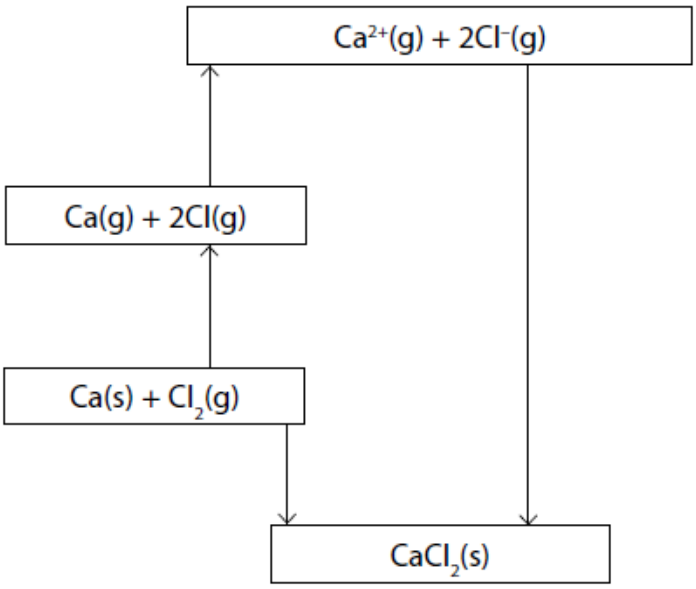
Calculate the lattice energy of calcium bromide.

(2)

(Total for question = 2 marks)

Q8.

The diagram shows a Born-Haber cycle for calcium chloride, $CaCl_2$



	kJ mol^{-1}
Enthalpy of formation of $CaCl_2(s)$	–796
Lattice energy of $CaCl_2(s)$	–2258
Enthalpy of atomisation of Ca(s) → Ca(g)	178
Enthalpy of atomisation of ½$Cl_2(g)$ → Cl(g)	122
First ionisation energy of Ca(g)	590
Electron affinity of Cl(g)	–349

Calculate the second ionisation energy of calcium, in kJ mol^{-1}.

(2)

Q9.

This question is about magnesium chloride, $MgCl_2$.

It can be formed by burning magnesium in chlorine.

$Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$ $\quad \Delta S^{\ominus}_{surroundings} = +2152 \text{ J mol}^{-1} \text{ K}^{-1}$

Remember to include a sign and units in your answers to the calculations in this question.

(a) (i) The standard molar entropy at 298 K for 1 mol chlorine molecules, Cl_2, is +165 J mol^{-1} K^{-1}. Use this, and appropriate values from your Data Booklet, to calculate the standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this reaction.

(2)

*(ii) Explain fully why the sign for the standard entropy change of the system, $\Delta S^{\ominus}_{system}$, is as you would expect.

(2)

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(b) Calculate the total entropy change, $\Delta S^{\ominus}_{total}$, in J $mol^{-1}K^{-1}$, for this reaction, giving your answer to three significant figures.

(2)

(c) Use the standard entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$, to calculate the standard enthalpy change, $\Delta H^{\ominus}$, in kJ mol^{-1}, for the reaction at 298 K.

(2)

(d) 0.0300 mol of magnesium chloride, prepared by burning magnesium in chlorine, is added to 51.5 cm^3 of water.
50.0 cm^3 of 1.00 mol dm^{-3} solution is formed, and the temperature rise, ΔT, is 22.5°C.

(i) Calculate the energy transferred in joules for this process using:

Energy transferred in joules = volume of **solution** × 4.2 × ΔT

(1)

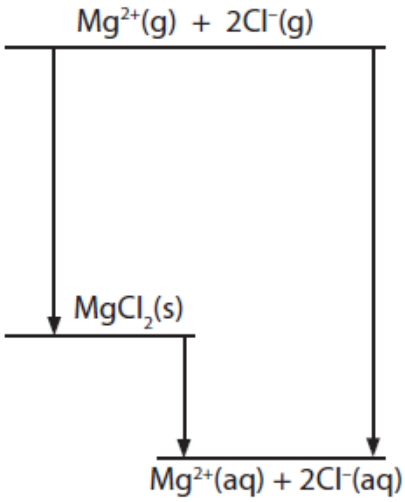
(ii) Calculate the enthalpy change of solution, $\Delta H_{solution}$, of magnesium chloride in kJ mol^{-1}.

(2)

*(iii) The enthalpy change of hydration of $Mg^{2+}(g)$ is −1920 kJ mol^{-1}.

Use this, your value from (d)(ii), and the experimental lattice energy from your Data Booklet, to calculate the enthalpy change of hydration of $Cl^-(g)$.

(3)



Answer ..... kJ mol^{-}

(iv) Draw a diagram to represent a hydrated chloride ion.

(1)

(Total for question = 15 marks)

Q10.

This question is about calcium chloride, $CaCl_2$.

It can be formed by burning calcium in chlorine.

$$Ca(s) + Cl_2(g) \rightarrow CaCl_2(s) \qquad \Delta S^{\ominus}_{surroundings} = +2670 \text{ J mol}^{-1} \text{ K}^{-1}$$

You must include a sign and units in your answers to the calculations in this question.

(a) (i) The standard molar entropy at 298 K for 1 mole of chlorine molecules, Cl_2, is +165 J mol^{-1} K^{-1}. Use this, and appropriate values from your Data Booklet, to calculate the standard entropy change, $\Delta S^{\ominus}_{system}$, for this reaction.

(2)

*(ii) Explain fully why the sign for the standard entropy change of the system, $\Delta S^{\ominus}_{system}$ is as you would expect.

(2)

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.....

(b) Calculate the total entropy change, $\Delta S^{\ominus}_{\text{total}}$, in J mol^{-1} K^{-1}, for this reaction, giving your answer to three significant figures.

(2)

(c) Use the standard entropy change of the surroundings, $\Delta S^{\ominus}_{\text{surroundings}}$, to calculate the standard enthalpy change, $\Delta H^{\ominus}$, in kJ mol^{-1}, for the reaction at 298 K.

(2)

(d) 0.0500 mol of calcium chloride, prepared by burning calcium in chlorine, is added to 51.8 cm^3 of water.

50.0 cm^3 of a 1.00 mol dm^{-3} solution is formed, and the temperature rise, ΔT, is 15.0°C.

(i) Calculate the energy transferred, in joules, for this process using:

Energy transferred in joules = volume of **solution formed** × 4.2 × ΔT

(1)

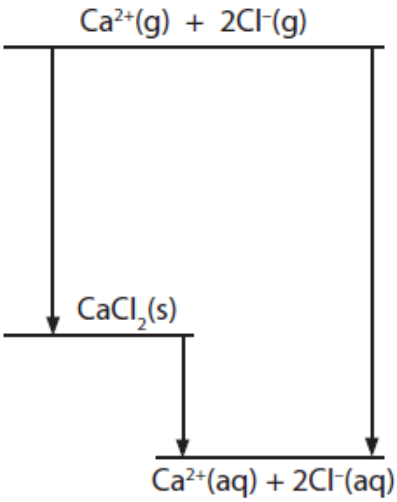
(ii) Calculate the enthalpy change of solution, $\Delta H_{\text{solution}}$, of calcium chloride in kJ mol^{-1}.

(2)

*(iii) The enthalpy change of hydration of $Ca^{2+}(g)$ is −1560 kJ mol^{-1}.

Use this, your value from (d)(ii) and the experimental lattice energy from your Data Booklet, to calculate the standard enthalpy change of hydration of $Cl^-(g)$.

(3)



Answer ..... kJ mol^{-1}

(iv) Draw diagrams to represent hydrated calcium ions and hydrated chloride ions.

(2)

(v) Suggest why the addition of anhydrous calcium chloride to water results in an increase in

temperature and a decrease in volume.

(2)

Temperature increases

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Volume decreases

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(Total for question = 18 marks)

Q11.

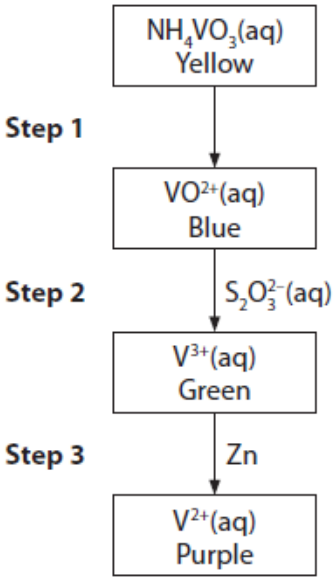
The element vanadium exists in a variety of oxidation numbers in its compounds.

(a) Calculate the oxidation number of vanadium in the compound NH_4VO_3.

(1)

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(b) NH_4VO_3 forms VO_2^+ in solution and can be reduced stepwise to form the ion, $V^{2+}(aq)$.



(i) Use the Data Booklet to give a suitable reducing agent for **Step 1** in order to only produce the blue solution.

(1)

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(ii) Give a possible reason why the reducing agent you choose may not be suitable.

(1)

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(iii) Explain what you would see during **Step 1**.

(2)

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(iv) Justify the choice of reducing agent for **Step 2**.
Write an equation for the reaction. State symbols are not required.

(2)

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Q12.

This question is about lattice energies.

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)

(Total for question = 5 marks)

Q13. Which of the equations below represents the first electron affinity for oxygen?

☒ **A** $O_2(g) + 2e^- \rightarrow 2O^-(g)$

☒ **B** $O_2(g) - 2e^- \rightarrow 2O^-(g)$

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

☒ **D** $O(g) + e^- \rightarrow O^-(g)$

(Total for Question = 1 mark)

Q14.

This question is about chlorine.

Write the equation for the first electron affinity of chlorine. Include state symbols.

(2)

(Total for question = 2 marks)

Q15.

This question is about energy changes involved in the formation of ionic compounds.

(a) What is the order of increasing first ionisation energy for the elements beryllium, helium and lithium?

(1)

☒ **A** lithium < helium < beryllium

☒ **B** beryllium < lithium < helium

☒ **C** helium < beryllium < lithium

☒ **D** lithium < beryllium < helium

(b) The **second** ionisation energy of calcium has a magnitude of 1150 kJ mol^{-1}.

Which of the following represents the **second** ionisation energy of calcium?

(1)

☒ **A** $Ca(g) \rightarrow Ca^{2+}(g) + 2e^-$ $\Delta H^{\ominus} = +1150$ kJ mol^{-1}

☒ **B** $Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ $\Delta H^{\ominus} = +1150$ kJ mol^{-1}

☒ **C** $Ca(g) \rightarrow Ca^{2+}(g) + 2e^-$ $\Delta H^{\ominus} = -1150$ kJ mol^{-1}

☒ **D** $Ca^+(g) \rightarrow Ca^{2+}(g) + e^-$ $\Delta H^{\ominus} = -1150$ kJ mol^{-1}

(c) The formation of potassium ions can be represented by the equation

$$K(s) \rightarrow K^+(g) + e^-$$

Which statement corresponds to the energy change for this process?

(1)

☒ **A** the first electron affinity of potassium

☒ **B** the first ionisation energy of potassium

☒ **C** the sum of the enthalpy change of atomisation of potassium and the first electron affinity of potassium

☒ **D** the sum of the enthalpy change of atomisation of potassium and the first ionisation energy of potassium

Q16.

The table shows some data about metal ions, non-metal ions and their compounds.

Ion	Enthalpy change of hydration / kJ mol^{-1}	Compound	Lattice energy / kJ mol^{-1}
$Mg^{2+}(g)$	–1921	$MgCl_2(s)$	–2526
$Cl^-(g)$	–340		
$Cs^+(g)$	–276	$CsF(s)$	–747
$F^-(g)$	–483		

Use the data to calculate

(a) the standard enthalpy change, in kJ mol^{-1}, for the following process.

$$Mg^{2+}(g) + 2Cl^{-}(g) \rightarrow Mg^{2+}(aq) + 2Cl^{-}(aq)$$

(1)

☒ **A** −1241

☒ **B** −1581

☒ **C** −2261

☒ **D** −2601

(b) the standard enthalpy change of solution, in kJ mol^{-1}, of caesium fluoride, CsF.

(1)

☒ **A** −12

☒ **B** +12

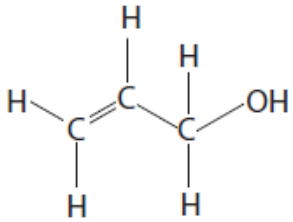
☒ **C** −1506

☒ **D** +1506

(Total for question = 2 marks)

Q17.

Prop-2-en-1-ol is an unsaturated alcohol with the structure shown.



A student planned to use bond enthalpy data to calculate a value for the enthalpy change of combustion of prop-2-en-1-ol.

(i) When researching the bond enthalpy data, the student claimed that it was not necessary to find the value for the C=C
bond as they could use the value for a C–C bond and multiply it by two.
Explain why the student is **incorrect**.

(2)

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(ii) Calculate a value for the enthalpy of combustion of prop-2-en-1-ol using the data shown.

$$C_3H_6O(g) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$$

Bond	C–C	C=C	C–O	C=O	O–H	C–H	O=O
Bond enthalpy / kJ mol^{-1}	347	612	358	805	464	413	498

(3)

(iii) Explain, in terms of entropy, why the combustion of prop-2-en-1-ol is always feasible in the gaseous state.

(2)

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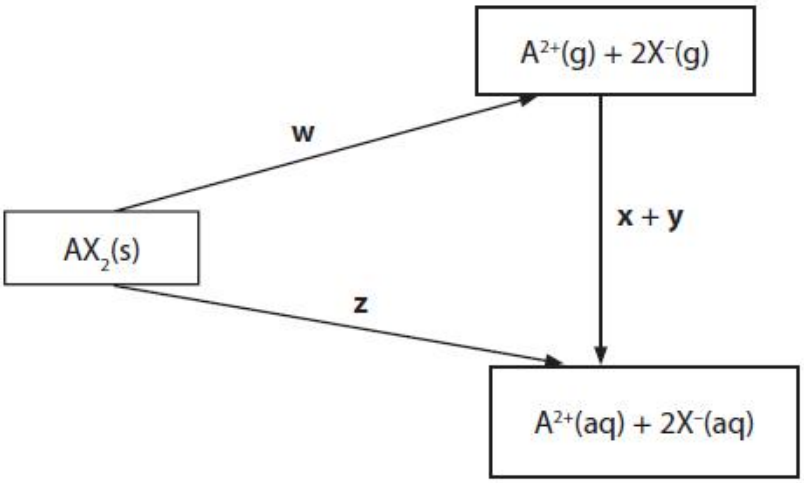
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(Total for question = 7 marks)

Q18.

The following cycle represents the enthalpy changes **w**, **x**, **y** and **z**, occurring when an ionic solute, $AX_2(s)$, dissolves in water.



Which of the changes is the lattice energy of $AX_2(s)$?

☒ **A** ½ **w**

☒ **B** − **w**

☒ **C** **z**

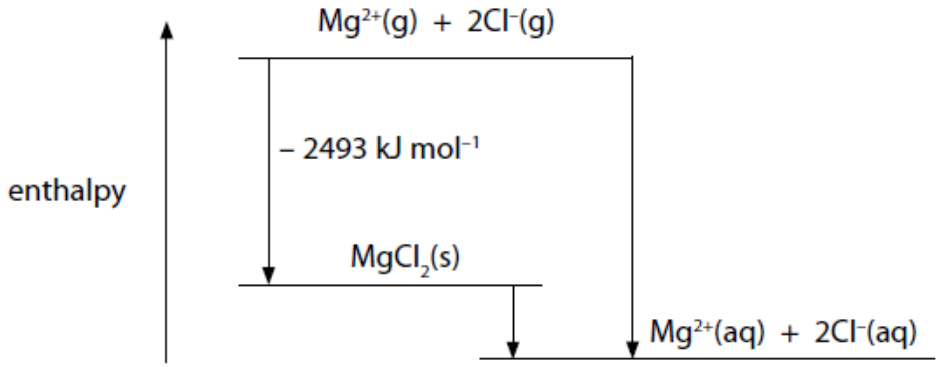
☒ **D** **z − x − y**

(Total for question = 1 mark)

Q19.

This question is about some Group 2 compounds.

(b) Magnesium chloride is soluble in water. The enthalpy level diagram for the dissolving of magnesium chloride is



The enthalpy changes of hydration of the ions are:

Mg^{2+} −1920 kJ mol^{-1}

Cl^{-1} −364 kJ mol^{-1}

Calculate the enthalpy change of solution, $\Delta H_{solution}$, of $MgCl_2(s)$ in kJ mol^{-1}.

(2)

(c) The table shows some data relating to the dissolving of magnesium sulfate, $MgSO_4$, in water at 298 K.

$\Delta H^{\ominus}_{solution}$ / kJ mol⁻¹	$\Delta S^{\ominus}_{system}$ / J K⁻¹ mol⁻¹
−87	−210

(i) Explain why the dissolving of magnesium sulfate in water is exothermic by considering the enthalpy changes involved.

(2)

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(ii) Use the data in the table to calculate $\Delta G^{\ominus}$ when magnesium sulfate dissolves in water at 298 K. State the significance of your answer.

(2)

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*(d) The table shows some data relating to the dissolving of barium sulfate and calcium sulfate in water at 298 K.

Salt	$\Delta H^{\ominus}_{solution}$ / kJ mol^{-1}	$T\Delta S^{\ominus}_{system}$ / kJ mol^{-1}
$BaSO_4$	+19	−31
$CaSO_4$	−18	−43

Comment on the relative solubility in water of barium sulfate and calcium sulfate at 298 K, using data from the table.

(6)

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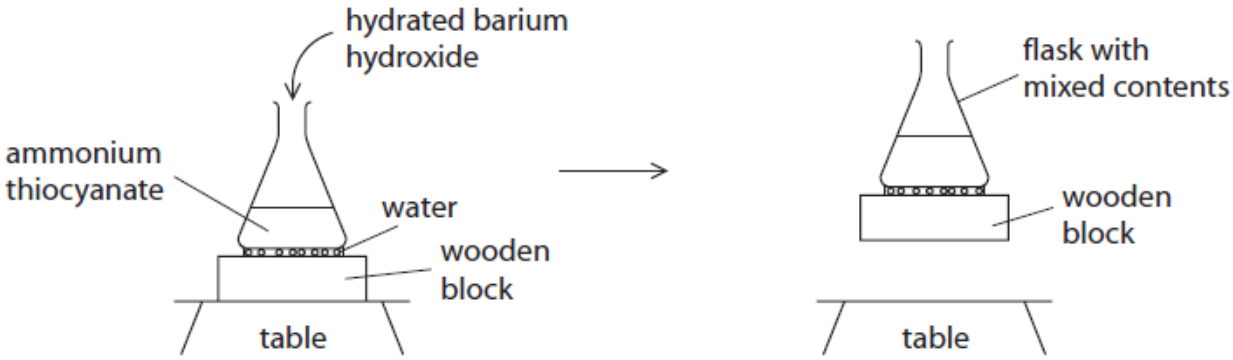
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Q20.

This question is about entropy.

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

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

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

(2)

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

(2)

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(Total for question = 4 marks)

Q21. 2-methylpropane has a smaller standard molar entropy at 298 K than butane. The best explanation for this is that 2-methylpropane has

☒ **A** a lower boiling temperature.

☒ **B** a higher standard molar enthalpy change of formation.

☒ **C** fewer ways of distributing energy quanta.

☒ **D** more ways of distributing energy quanta.

(Total for Question = 1 mark)

Q22. The equation for the combustion of hydrogen is

$$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$$

(a) Use the standard molar entropies on page 2 and page 25 of the data booklet to calculate the standard entropy change of the system ($\Delta S^{\ominus}_{system}$) for this reaction.

Note that the standard molar entropies of the elements are given **per atom** so that the standard molar entropy of oxygen, $S^{\ominus}[½O_2(g)] = +102.5 \text{ J mol}^{-1} \text{ K}^{-1}$.

(3)

(b) The standard enthalpy change for the combustion of hydrogen is $-285.8 \text{ kJ mol}^{-1}$. Use this value to calculate the entropy change of the surroundings for the combustion of hydrogen at 298 K. Give your answer to **3** significant figures and include a sign and units.

(3)

(c) Use your answers to (a) and (b) to calculate the total entropy change ($\Delta S^{\ominus}_{total}$) for the combustion of 1 mol of hydrogen. Include a sign and units in your answer.

(2)

*(d) By considering both the thermodynamic stability and the kinetic inertness of a mixture of hydrogen and oxygen, explain why hydrogen does not react with oxygen unless ignited.

(2)

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(Total for Question = 10 marks)

Q23. This question is about the equilibrium reaction below.

$$Fe^{2+}(aq) + Ag^{+}(aq) \quad \Delta S^{\ominus}_{total} = R \ln K \quad Fe^{3+}(aq) + Ag(s)$$

The equilibrium is reached slowly.

*(a) Describe the changes you would see if aqueous solutions of iron(II) sulfate and silver nitrate were mixed and allowed to stand for a few hours.

(2)

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(b) The concentration of silver ions in the equilibrium mixture can be found by titration with potassium thiocyanate. Silver thiocyanate precipitates.

$$Ag^{+}(aq) + CNS^{-}(aq) \quad \Delta S^{\ominus}_{total} = R \ln K \quad AgCNS(s)$$

When all the silver ions have reacted, a deep red complex ion of iron(III) thiocyanate forms.

In an experiment, 25.0 cm^3 of 0.100 mol dm^{-3} silver nitrate solution was added to 25.0 cm^3 of 0.100 mol dm^{-3} of iron(II) sulfate solution, mixed thoroughly, and allowed to stand overnight in an air-tight container.

10.0 cm^3 samples of the reaction mixture were then titrated with 0.0200 mol dm^{-3} potassium thiocyanate solution. The average titre was 5.60 cm^3.

(i) The initial concentrations of silver ions and iron(II) ions **in the reaction mixture** are the same.

Calculate this initial concentration in mol dm^{-3}.

(1)

(ii) Calculate the number of moles of silver ions in the 10.0 cm^3 sample at equilibrium and hence calculate the equilibrium concentration of silver ions in the mixture.

(2)

(iii) Deduce the equilibrium concentration of iron(II) ions.

(1)

(iv) Hence calculate the equilibrium concentration of iron(III) ions.

(1)

(v) Write the expression for the equilibrium constant, K_c, for the reaction

$$Fe^{2+}(aq) + Ag^{+}(aq) \quad \Delta S^{\ominus}_{total} = R \ln K \quad Fe^{3+}(aq) + Ag(s)$$

Calculate its value and give your answer, with appropriate units, to **three** significant figures.

(4)

(c) (i) The relationship between the total entropy change for a reaction and the equilibrium constant is

$$\Delta S^{\ominus}_{total} = R \ln K$$

Calculate the total entropy change for this reaction, giving a sign and appropriate units.

[R = 8.31 J mol^{-1} K^{-1}]

(2)

(ii) $Fe^{2+}(aq) + Ag^{+}(aq) \quad \Delta S^{\ominus}_{total} = R \ln K \quad Fe^{3+}(aq) + Ag(s)$

$\Delta S^{\ominus}_{system}$ for this reaction is −208.3 J mol^{-1} K^{-1}

Use ideas about entropy to explain why this value is negative.

(2)

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(iii) Calculate the entropy change of the surroundings, $\Delta S^{\ominus}_{surroundings}$.

(1)

(iv) Use your answer to (c)(iii) to calculate the standard enthalpy change, $\Delta H^{\ominus}$, for this reaction at 298 K.

Hence state and explain the effect of increasing temperature on the value of $^{\ominus}$

(3)

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*(d) After the samples from the original mixture for the titration are taken, the remainder was filtered and then allowed to stand overnight, in an air-tight container at the same temperature. Another 10.0 cm^3 sample was taken and titrated. How, if at all, would you expect the titre to change?

Justify your answer. A calculation is not required.

(2)

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(Total for Question = 21 marks)

Q24. Calcium carbonate decomposes at high temperature to form calcium oxide and carbon dioxide:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Calcium carbonate is **thermodynamically** stable at room temperature because for this reaction

☒ **A** the activation energy is high.

☒ **B** the enthalpy change, ΔH, is positive.

☒ **C** entropy change of the system (ΔS_{system}) is positive.

☒ **D** entropy change of the system (ΔS_{system}) is negative.

(Total for Question = 1 mark)

Q25.

Ethanoic acid and ethanol react together to form the ester ethyl ethanoate, $CH_3COOC_2H_5$, and water.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

(a) (i) Give the expression for K_c.

(1)

(ii) An equilibrium was reached when the amounts of substances shown in the table below were used.

Complete the table to show the amounts of each substance present at equilibrium.

(2)

Component	$CH_3COOH(l)$	$CH_3CH_2OH(l)$	$CH_3COOCH_2CH_3(l)$	$H_2O(l)$
Initial amount / mol	0.40	0.30	0.00	0.15
Equilibrium amount / mol	0.20			

(iii) Explain why K_c for this reaction has no units.

(1)

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(iv) Calculate the numerical value of K_c.

(1)

(b) The esterification reaction above was carried out in the presence of hydrochloric acid as the catalyst.

State the effect on the equilibrium position and the rate of attainment of equilibrium if the concentration of the acid catalyst were to be increased.

(2)

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(c) (i) Identify which bonds are broken and which bonds are made in the esterification reaction.

(2)

Bonds broken:

Bonds made:

(ii) Explain why ΔH for this reaction is not **exactly** zero.
(A calculation is not required.)

(1)

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(d) (i) State the relationship between ΔS_{total} and the equilibrium constant, K, of a reaction.

(1)

*(ii) Use entropy considerations and your answer to (d)(i) to predict any effect of an increase in temperature on the value of the equilibrium constant of a reaction for which ΔH is zero. Assume that ΔS_{system} does not change with temperature.

(3)

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(e) An alternative method for preparing ethyl ethanoate is to react ethanoyl chloride with ethanol.

(i) Give the equation for the reaction.

(1)

(ii) Draw the **skeletal** formula of ethyl ethanoate.

(1)

(iii) Ethanoyl chloride also reacts with concentrated ammonia. Draw the **displayed** formula of the organic product of this reaction.

(1)

(f) (i) Complete the equation below for the alkaline hydrolysis of ethyl ethanoate using sodium hydroxide. State symbols are **not** required.

(1)

$CH_3COOCH_2CH_3 + NaOH \rightarrow$

(ii) Explain why the reaction in (f)(i) gives a better yield of the alcohol compared with acid hydrolysis of the ethyl ethanoate.

(1)

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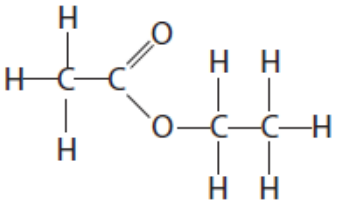
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(Total for question = 19 marks)

Q26.

Ethyl ethanoate is an ester.



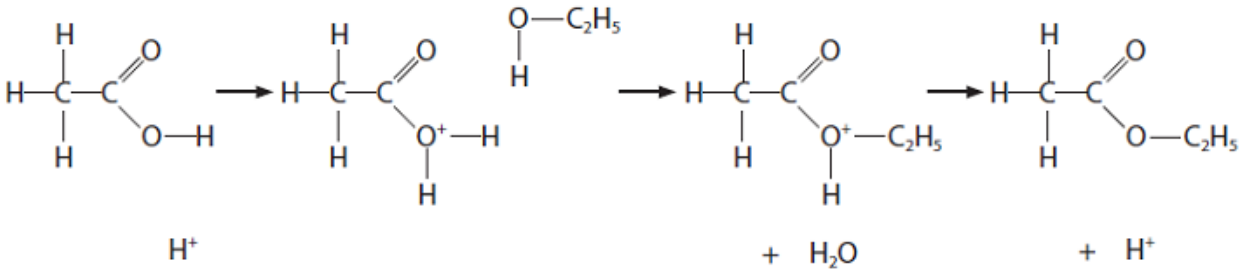
One method for the formation of ethyl ethanoate is the reaction between ethanol and ethanoic acid, which is catalysed by hydrogen ions.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

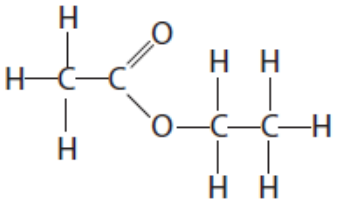
An incomplete simplified mechanism for this reaction is shown.

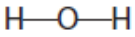
(i) Add curly arrows and relevant lone pairs of electrons to complete the mechanism.

(4)



(ii) In an experiment, the oxygen atom in ethanol is replaced by the oxygen-18 isotope, ^{18}O. The products of the esterification are



and 

Label the ^{18}O oxygen atom in one of the products.
Justify your answer.

(2)

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(iii) Calculate the standard molar entropy of ethyl ethanoate using your knowledge of Gibbs free energy, ΔG,
and the data in the table.

Include sign and units in your answer.

Use $\Delta G = -RT \ln K$ and other appropriate equations.

Quantity	Value
Gas constant, R	8.31 J mol^{-1} K^{-1}
Temperature, T	298 K
Equilibrium constant of esterification reaction, K	4.0
Enthalpy change of esterification reaction, ΔH	−6.0 kJ mol^{-1}
Standard molar entropy of ethanoic acid, $S^{\ominus}$	159.8 J K^{-1} mol^{-1}
Standard molar entropy of ethanol, $S^{\ominus}$	160.7 J K^{-1} mol^{-1}
Standard molar entropy of water, $S^{\ominus}$	69.9 J $K^{-1}mol^{-1}$

(6)

(Total for question = 12 marks)

Q27.

This question is about enthalpy changes and entropy changes.

What is the expression for ΔS_{total}?

(1)

☒ **A** $\Delta S_{surroundings} + \frac{\Delta H}{T}$

☒ **B** $\Delta S_{surroundings} - \frac{\Delta H}{T}$

☒ **C** $\Delta S_{system} + \frac{\Delta H}{T}$

☒ **D** $\Delta S_{system} - \frac{\Delta H}{T}$

(Total for question = 1 mark)

Q28.

Ammonia is produced industrially by reacting nitrogen and hydrogen.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^{\ominus} = -92.0 \text{ kJ mol}^{-1}$$

A temperature in the range of 673 to 773 K is used.

The standard entropies, $S^{\ominus}$ of $N_2(g)$, $H_2(g)$ and $NH_3(g)$ at 298 K are given in the table.

substance	$N_2(g)$	$H_2(g)$	$NH_3(g)$
$S^{\ominus}$ / JK^{-1}mol^{-1}	192	131	193

(a) Show that this reaction is feasible at 298 K by calculating $\Delta G^{\ominus}$ in kJ mol^{-1}. Give your answer to an appropriate number of significant figures.

(5)

(b) Explain, in terms of entropy, why this reaction is not feasible at very high temperatures.

(2)

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Q29.

This question is about enthalpy changes and entropy changes.

Calcium carbonate decomposes on heating.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

$\Delta_r H = +178 \text{ kJ mol}^{-1}$

$\Delta S_{system} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$

Show, by calculating the value for the free energy change, ΔG, that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose.

(3)

(Total for question = 3 marks)

Q30.

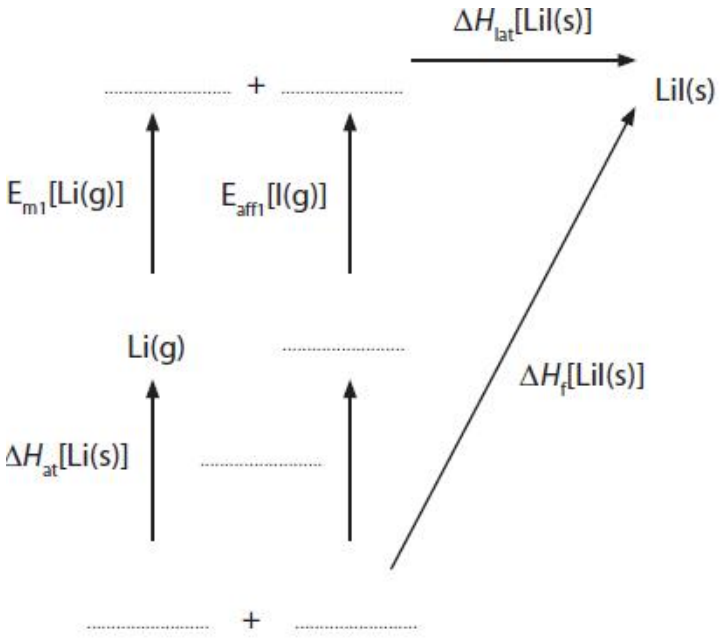
This question is about lithium iodide, an ionic salt.

(a) Draw dot and cross diagrams for the lithium and iodide ions. Show all the electrons in the lithium ion but only outer shell electrons in the iodide ion.

(2)

(b) On the Born-Haber cycle below, fill in the missing formulae (including state symbols) and the missing enthalpy change.

(3)



(c) Calculate the electron affinity of iodine, E_{aff1}[I(g)], using the data below.

	ΔH/kJ mol^{-1}
Lattice energy for lithium iodide, ΔH_{lat}	–759
Enthalpy change of atomization of lithium, ΔH_{at}	+159
Enthalpy change of atomization of iodine, ΔH_{at}	+107
First ionization energy of lithium, E_{m1}	+520
Enthalpy change of formation of lithium iodide, ΔH_f	–270

(2)

(d) The experimental lattice energy for lithium iodide is −759 kJ mol^{-1}. The theoretical lattice energy is different from this value.

Will the experimental lattice energy be more negative or less negative than the theoretical lattice energy? Justify your answer.

(3)

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(e) State and explain how electron affinity values change as you go down Group 7 from chlorine to iodine.

(2)

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(Total for question = 12 marks)

Q31.

Energy is evolved when one mole of gaseous calcium ions is hydrated.

$$Ca^{2+}(g) + aq \rightarrow Ca^{2+}(aq)$$

This reaction is more exothermic than the corresponding value for barium ions, Ba^{2+}, because the

☒ **A** ionization energy of calcium is greater than that of barium.

☒ **B** lattice energy of calcium oxide is more exothermic than that of barium oxide.

☒ **C** solubility of calcium hydroxide in water is less than that of barium hydroxide.

☒ **D** ionic radius of Ca^{2+} is less than that of Ba^{2+}.

(Total for question = 1 mark)

Q32.

Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

A sample of yellow gold is analysed using the steps below.

Step **1** Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

$$2HNO_3(aq) + e^- \rightarrow NO_3^-(aq) + NO_2(g) + H_2O(l)$$

Step **2** The mixture is diluted with distilled water and the gold is filtered off.

Step **3** Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Step **4** The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g.

Step **5** Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Step **6** The resulting mixture is titrated with 0.100 mol dm^{-3} sodium thiosulfate solution.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The titre is 39.40 cm^3.

State the indicator used and its colour change at the end-point in the titration in Step **6**.

(2)

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(Total for question = 2 marks)

Q33.

Sulfur dioxide and oxygen react together to form sulfur trioxide in a reversible reaction that can reach a position of equilibrium. The equation for the reaction is:

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta_r H^{\ominds} = -98.0 \text{ kJ mol}^{-1}$$

The numerical value of the equilibrium constant, K_p, for this reaction at 298 K is 2.00×10^{12}.

The expression for K_p for this reaction is

(1)

☒ **A** $\frac{p^2_{SO_3}}{p^2_{SO_2} \cdot p_{O_2}}$

☒ **B** $\frac{p_{SO_3}}{p_{SO_2} \cdot p^{½}_{O_2}}$

☒ **C** $\frac{p^2_{SO_2} \cdot p_{O_2}}{p^2_{SO_3}}$

☒ **D** $\frac{p_{SO_2} \cdot p^{½}_{O_2}}{p_{SO_3}}$

(b) State what the value of K_p suggests about the relative amounts of the components in the equilibrium mixture at 298 K.

(1)

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(c) Explain, in terms of K_p, how an increase in temperature will affect the yield of sulfur trioxide in the equilibrium mixture.

(2)

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(d) Calculate the value for $\Delta_r G^{-}$ at 298 K using the equation $\Delta_r G^{\ominus} = -RT \ln K_p$.
Hence confirm the thermodynamic feasibility of the reaction at this temperature.

(2)

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(e) Give a reason why, in industry, the reaction is carried out at a temperature of 687 K.

(1)

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(Total for question = 7 marks)

Q34.

This question is about lattice energies.

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)

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

(4)

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(Total for question = 5 marks)

Q35.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

Lattice energies provide an indication of ionic bond strength.

Which are the lattice energies of the hydrides NaH, KH and MgH_2?

(1)

	Lattice energy / kJ mol^{-1}		
	Sodium hydride, NaH	Potassium hydride, KH	Magnesium hydride, MgH_2
☐ **A**	–804	–711	–1018
☐ **B**	–804	–711	–2718
☐ **C**	–804	–911	–1018
☐ **D**	–804	–911	–2718

(Total for question = 1 mark)

Q36. Which of the following quantities, used in the calculation of the lattice energy of lithium oxide, Li_2O, has a negative value?

☒ **A** The enthalpy change of atomization of lithium.

☒ **B** The first ionization energy of lithium.

☒ **C** The first electron affinity of oxygen.

☒ **D** The second electron affinity of oxygen.

(Total for Question = 1 mark)

Q37.

This question is about the solubility of metal hydroxides.

When excess magnesium hydroxide is added to water and shaken, a saturated solution is formed and the mixture reaches equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

The equilibrium constant, K_c , for this reaction is

$$K_c = [Mg^{2+}(aq)][OH^-(aq)]^2$$

(i) Give a reason why the magnesium hydroxide is not included in the expression for K_c.

(1)

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(ii) Give the units for K_c.

(1)

(iii) Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

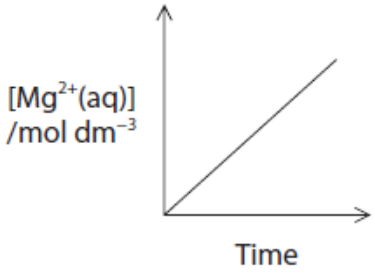
Energy or enthalpy change	Value / kJ mol^{-1}
Lattice energy of $Mg(OH)_2(s)$	−2842
$\Delta_{hyd}H$ ($Mg^{2+}(aq)$)	−1920
$\Delta_{hyd}H$ ($OH^-(aq)$)	−460

(2)

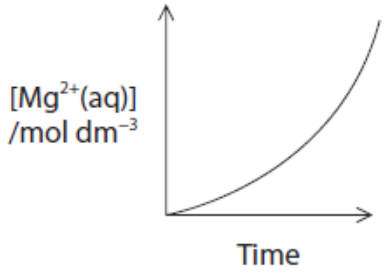
(iv) Which graph shows the change in the concentration of the $Mg^{2+}(aq)$ ions when some solid magnesium hydroxide is shaken with water and left to reach equilibrium?

(1)

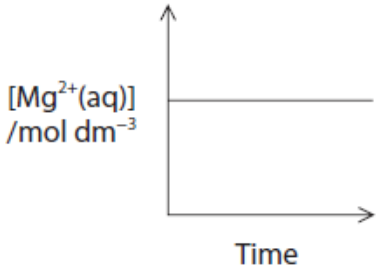
☒ **A**



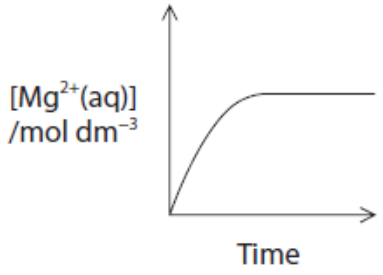
☒ **B**



☒ **C**



☒ **D**



(v) Predict the effect, if any, of adding each of the following to a saturated solution of magnesium hydroxide in contact with solid magnesium hydroxide. Justify your answers in terms of the effect on the equilibrium.

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$$

(4)

Magnesium sulfate solution

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Dilute hydrochloric acid

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(Total for question = 9 marks)

Q38.

The propulsion system of a torpedo is powered by sulfur hexafluoride, SF_6, in an exothermic reaction with solid lithium.

The equation for the reaction of sulfur hexafluoride with lithium is:

$$SF_6(g) + 8Li(s) \rightarrow Li_2S(s) + 6LiF(s) \qquad \Delta_r H^{\ominus} = -2\,934 \text{ kJ mol}^{-1}$$

(a) Calculate the mass of lithium needed to react with 398 kg of sulfur hexafluoride.
Give your answer to an appropriate number of significant figures.

[Molar masses: SF_6 = 146.1g mol^{-1}; Li = 6.90 g mol^{-1}]

(3)

Mass of lithium needed = ... kg

(b) The table gives the standard molar entropies, $S^{\ominus}$, at 298 K, of $SF_6(g)$, Li(s), $Li_2S(s)$ and LiF(s).

	$SF_6(g)$	Li(s)	$Li_2S(s)$	LiF(s)
$S^{\ominus}$ / JK^{-1}mol^{-1}	+292	+29.1	+63.0	+35.6

Calculate the standard total entropy change, $\Delta S^{\ominus}_{\text{total}}$ total, at 298 K, for the reaction between sulfur hexafluoride and lithium. Include units in your final answer.

(4)

$\Delta S^{\ominus}_{\text{total}}$.....

(c) The reaction between sulfur hexafluoride and lithium is started using a fuse.
Justify the need for a fuse, in view of your answer to part (b).

(2)

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Q39.

This question is about enthalpy changes and entropy changes.

Which reaction has a negative value for ΔS_{system}?

(1)

☒ **A** $2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

☒ **B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

☒ **C** $MgCO_3(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + CO_2(g)$

☒ **D** $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

(Total for question = 1 mark)

Q40.

The table shows the ionic radius and charge of each of six ions.

Ion	D^+	E^+	G^{2+}	X^-	Y^-	Z^{2-}
Ionic radius / nm	0.14	0.18	0.15	0.14	0.18	0.15

The ionic solids DX, EY and GZ have the same lattice structure.

Deduce the order of magnitude of their lattice energies, giving the most exothermic first.

Justify your answer.

(3)

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Q41. In which of the following compounds is the **anion** most polarized?

☒ **A** LiF

☒ **B** LiI

☒ **C** LiI

☒ **D** KI

(Total for Question = 1 mark)

Q42. The overall equation for a reaction between two chemicals, M and N, is

$$M + 2N \rightarrow P + Q$$

(a) This reaction occurs spontaneously at room temperature. Which of the following **must** be true?

(1)

$\ominus_{total}$ **A** $\Delta H^{\ominus}_{reaction}$ is positive.

$\ominus_{total}$ **B** $\Delta H^{\ominus}_{reaction}$ is negative.

$\ominus_{total}$ **C** $\Delta S^{\ominus}_{total}$ is positive.

$\ominus_{total}$ **D** $\Delta S^{\ominus}_{total}$ is negative.

(b) The reaction above occurs in two stages via an intermediate, T.

$$M + N \rightarrow T \qquad \text{slow}$$

$$N + T \rightarrow P + Q \qquad \text{fast}$$

From this it can be deduced that the rate equation for the reaction between M and N is

(1)

$\ominus_{total}$ **A** rate = k[M][N]

○ total **B** rate = k[M][N]^2

○ total **C** rate = k[M][T]

○ total **D** rate = k[N][T]

(Total for Question = 2 marks)

Q43.

Sodium hydride, NaH, can be used to generate hydrogen for fuel cells.

The equation for the formation of sodium hydride is

$$Na(s) + \tfrac{1}{2}H_2(g) \rightarrow NaH(s) \qquad \Delta_f H^{\ominus} = -56\,kJ\,mol^{-1}$$

The standard entropy change of the system, $\Delta S^{\ominus}_{system}$, for this reaction is –76.5 J K^{-1} mol^{-1}.

(i) Deduce the feasibility of this reaction at 298 K by calculating the free energy change, ΔG.

(2)

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(ii) Calculate the temperature at which $\Delta G = 0$.

(1)

(Total for question = 3 marks)

Q44.

Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

A sample of yellow gold is analysed using the steps below.

Step **1** Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are

$$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$$

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

$$2HNO_3(aq) + e^- \rightarrow NO_3^-(aq) + NO_2(g) + H_2O(l)$$

Step **2** The mixture is diluted with distilled water and the gold is filtered off.

Step **3** Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Step **4** The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g.

Step **5** Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Step **6** The resulting mixture is titrated with 0.100 mol dm^{-3} sodium thiosulfate solution.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The titre is 39.40 cm^3.

Write the equation for the reaction of copper with concentrated nitric acid, using the half-equations given in Step **1**. State symbols are not required.

(1)

(Total for question = 1 mark)

Q45.

Chemists are researching a process to make ethanol and ethene directly from carbon dioxide and water.

$4CO_2(g) + 5H_2O(l) \rightarrow CH_3CH_2OH(l) + C_2H_4(g) + 6O_2(g)$ $\Delta H^\ominus = +2778$ kJ mol^{-1}

	$CO_2(g)$	$H_2O(l)$	$CH_3CH_2OH(l)$	$C_2H_4(g)$	$O_2(g)$
$S^\ominus$ / J K^{-1} mol^{-1}	213.6	69.9	160.7	219.5	205.0

Calculate $\Delta S^\ominus_{total}$ for the reaction and hence determine whether the reaction is feasible under standard conditions.

(5)

(Total for question = 5 marks)

Q46.

This question is about entropy and free energy.

Complete the table by giving the sign of the entropy change of the system, ΔS_{system} , for each reaction.

(2)

Reaction	Sign of ΔS_{system}
$CO_2(s) \rightarrow CO_2(g)$	
$NaCl(s) + aq \rightarrow NaCl(aq)$	
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	

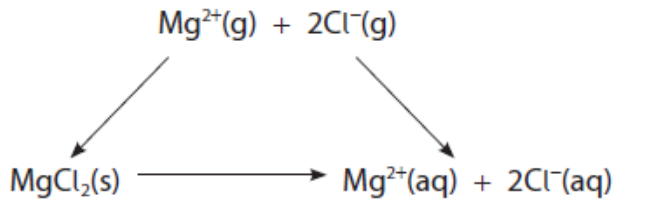
(Total for question = 2 marks)

Q47.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

This question is about dissolving different compounds.

What is the value, in kJ mol^{-1}, for the standard enthalpy change of solution of magnesium chloride?



Lattice energy $MgCl_2(s)$ $= -2526\ kJ\,mol^{-1}$

Hydration enthalpy of $Cl^-(g)$ $= -\ 381\ kJ\,mol^{-1}$

Hydration enthalpy of $Mg^{2+}(g)$ $= -1921\ kJ\,mol^{-1}$

(1)

☒ **A** +157

☒ **B** −157

☒ **C** +224

☒ **D** −224

(Total for question = 1 mark)

Q48. In the Born-Haber cycle for potassium iodide, which of the following steps is **exothermic**?

☒ **A** $K(s) \rightarrow K(g)$

☒ **B** $K(g) \rightarrow K^+(g) + e^-$

☒ **C** $\frac{1}{2}I_2(s) \rightarrow I(g)$

☒ **D** $I(g) + e^- \rightarrow I^-(g)$

(Total for Question = 1 mark)

Q49.

This question is about entropy and free energy.

Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta_r H = -288.4\,kJ\,mol^{-1}$

The standard molar entropy values at 298 K are given in the table.

	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
$S^{\ominus}$ / $JK^{-1}mol^{-1}$	+248.1	+205.0	+95.6

(i) Calculate the entropy change of the system, ΔS_{system} , for the forward reaction.

Include a sign and units in your answer.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

(2)

(ii) Calculate the free energy change, ΔG, at 298 K and hence deduce whether the reaction is feasible.

(3)

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.....

(iii) In industry, the reaction is carried out at about 700 K using a vanadium(V) oxide catalyst.

Calculate the value of the equilibrium constant, K, at 700 K.

ΔG at 700 K is –60 kJ mol^{-1}

(3)

(iv) The equilibrium constant has a larger value at 298 K than at 700 K.

Explain why the reaction is carried out at 700 K and not at 298 K.

(2)

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(Total for question = 10 marks)

Q50.

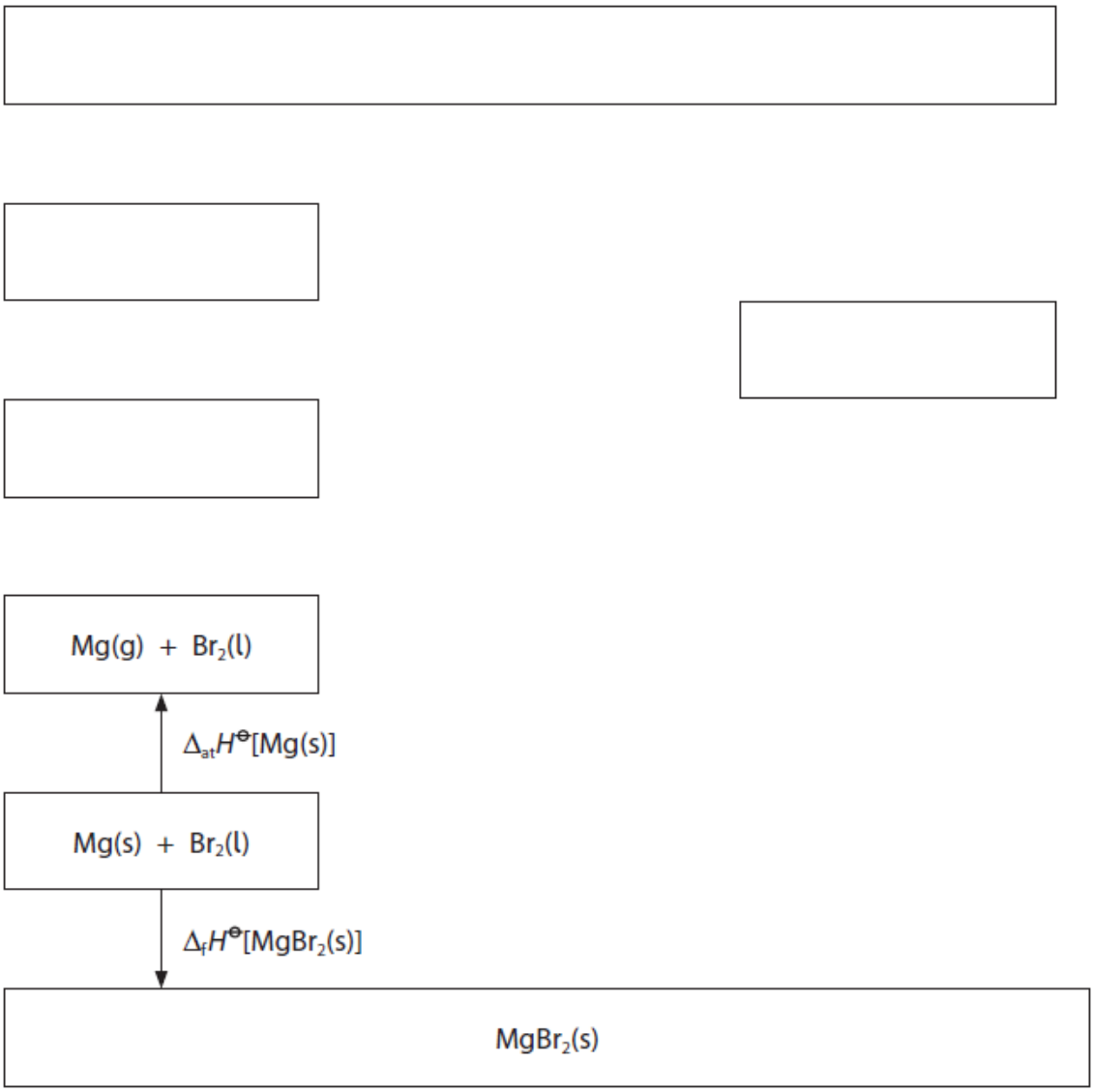
Magnesium bromide, $MgBr_2$, is an ionic compound.

The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	Value / kJ mol^{-1}
enthalpy change of atomisation of magnesium, $\Delta_{at}H^{\ominus}$[Mg(s)]	+148
1st ionisation energy of magnesium, 1st IE[Mg(g)]	+738
2nd ionisation energy of magnesium, 2nd IE[Mg^+(g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{at}H^{\ominus}$[½Br_2(l)]	+112
lattice energy of magnesium bromide, LE[$MgBr_2$(s)]	–2 440
enthalpy change of formation of magnesium bromide, $\Delta_fH^{\ominus}$[$MgBr_2$(s)]	–524

(i) Complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale.

(3)



(ii) Calculate the first electron affinity of bromine, in kJ mol^{-1}.

(2)

(Total for question = 5 marks)

Q51.

This question is about ions and ionic compounds.

* 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}
lithium chloride, LiCl	−845	−848
magnesium iodide, MgI_2	−1944	−2327

Comment on the theoretical and experimental lattice energy values, giving the reasons for any differences and similarities.

(6)

(Total for question = 6 marks)

Q52.

* 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 = 6 marks)

Q53.

This question is about entropy and free energy.

Calculate the total entropy change, ΔS_{total} , for the thermal decomposition of calcium carbonate at 298 K.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

[Data: $\Delta_r H = +178\,kJ\,mol^{-1}$ $\Delta S_{system} = +160\,J\,K^{-1}\,mol^{-1}$]