1 Iron(II) iodide, FeI_2, is formed when iron metal reacts with iodine.

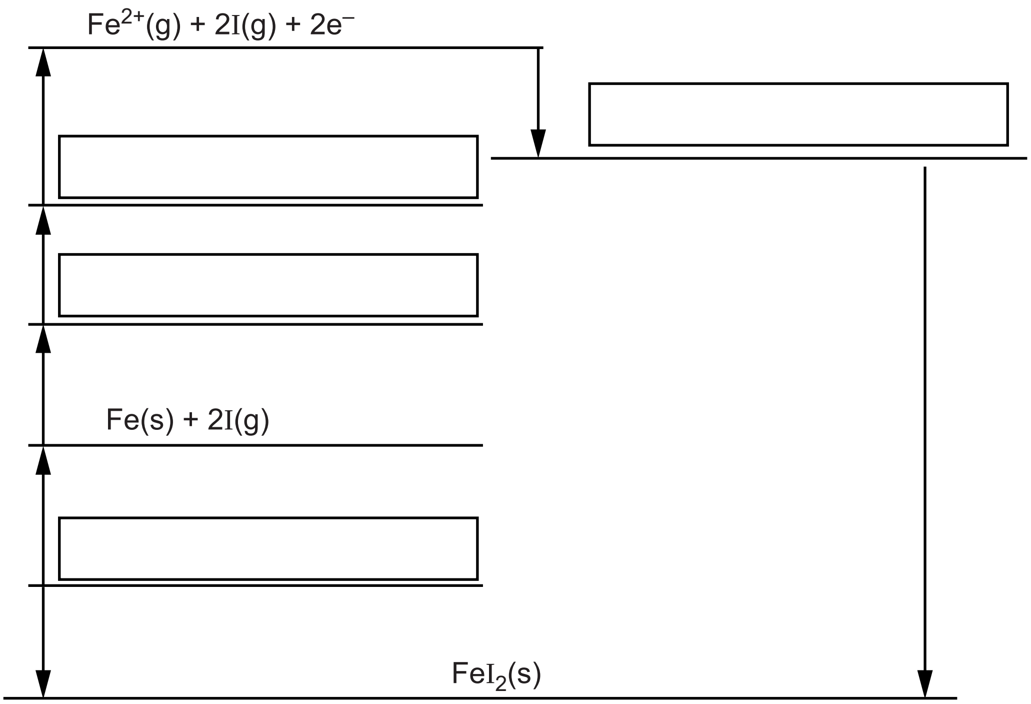
(a) The table below shows enthalpy changes involving iron, iodine and iron(II) iodide.

	Enthalpy change / kJ mol^{-1}
Formation of iron(II) iodide	–113
1st electron affinity of iodine	–295
1st ionisation energy of iron	+759
2nd ionisation energy of iron	+1561
Atomisation of iodine	+107
Atomisation of iron	+416

(i) The incomplete Born–Haber cycle below can be used to determine the lattice enthalpy of iron(II) iodide.

In the boxes, write the species present at each stage in the cycle.

Include state symbols for the species.



[4]

(ii) Define the term *lattice enthalpy*.

....

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....

.... **[2]**

(iii) Calculate the lattice enthalpy of iron(II) iodide.

lattice enthalpy = ... $kJ\,mol^{-1}$ **[2]**

(b) Some electrode potentials for ions are shown below.

$Fe^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Fe(s)$	$E^\ominus = -0.44V$
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	$E^\ominus = +0.77V$
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	$I^-(aq)$	$E^\ominus = +0.54V$
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	$Br^-(aq)$	$E^\ominus = +1.09V$
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	$Cl^-(aq)$	$E^\ominus = +1.36V$

(i) Complete the electron configurations for Fe^{2+} and Br^-.

Fe^{2+}: $1s^2$ ....

Br^-: $1s^2$ .... **[2]**

(ii) Predict the products of reacting Fe(s) separately with $I_2(aq)$, $Br_2(aq)$ and $Cl_2(aq)$.

Explain your predictions using the electrode potential data above.

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.... **[3]**

(c) Fe^{2+} ions can be used to test for NO_3^- ions.
In this test, aqueous iron(II) sulfate is added to a solution containing NO_3^- ions, followed by slow addition of concentrated sulfuric acid. The sulfuric acid forms a layer below the aqueous solution.
In the presence of NO_3^- ions, a brown ring forms between the two layers.

Two reactions take place.

Reaction 1: In the acid conditions Fe^{2+} ions reduce NO_3^- ions to NO.
Fe^{2+} ions are oxidised to Fe^{3+} ions.
Water also forms.

Reaction 2: A ligand substitution reaction of $[Fe(H_2O)_6]^{2+}$ takes place in which one NO ligand exchanges with one water ligand. A deep brown complex ion forms as the brown ring.

Construct equations for these two reactions.

Reaction 1:

....

Reaction 2:

.... **[3]**

[Total: 16]

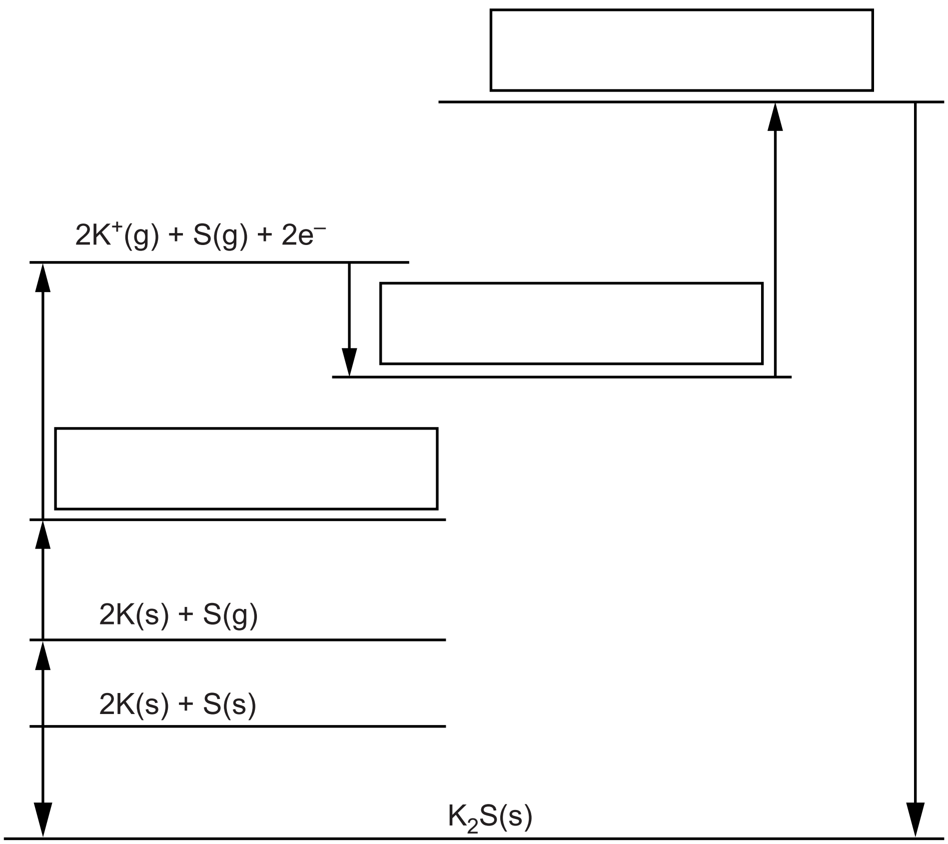
2 Born–Haber cycles can be used to calculate enthalpy changes indirectly.

(a) The table below shows enthalpy changes for a Born–Haber cycle involving potassium sulfide, K_2S.

	Enthalpy change / kJ mol^{-1}
Formation of potassium sulfide, K_2S	–381
1st electron affinity of sulfur	–200
2nd electron affinity of sulfur	+640
Atomisation of sulfur	+279
1st ionisation energy of potassium	+419
Atomisation of potassium	+89

(i) The incomplete Born–Haber cycle below can be used to determine the lattice enthalpy of potassium sulfide.

In the boxes, write the species present at each stage in the cycle.
Include state symbols for the species.



[3]

(ii) Define, in words, the term *lattice enthalpy*.

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.... **[2]**

(iii) Using the Born–Haber cycle, calculate the lattice enthalpy of potassium sulfide.

lattice enthalpy = ... $kJ\,mol^{-1}$ **[2]**

(b) Several ionic radii are shown below.

Ion	Na^{+}	K^{+}	Rb^{+}	Cl^{-}	Br^{-}	I^{-}
Radius / pm	95	133	148	181	195	216

Predict the order of melting points for NaBr, KI and RbC*l* from lowest to highest.

Explain your answer.

Lowest melting point ....

....

Highest melting point ....

Explanation ....

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[3]

[Total: 10]

3 Born–Haber cycles can be used to determine lattice enthalpies of ionic compounds.

(a) Define, in words, the term *lattice enthalpy*.

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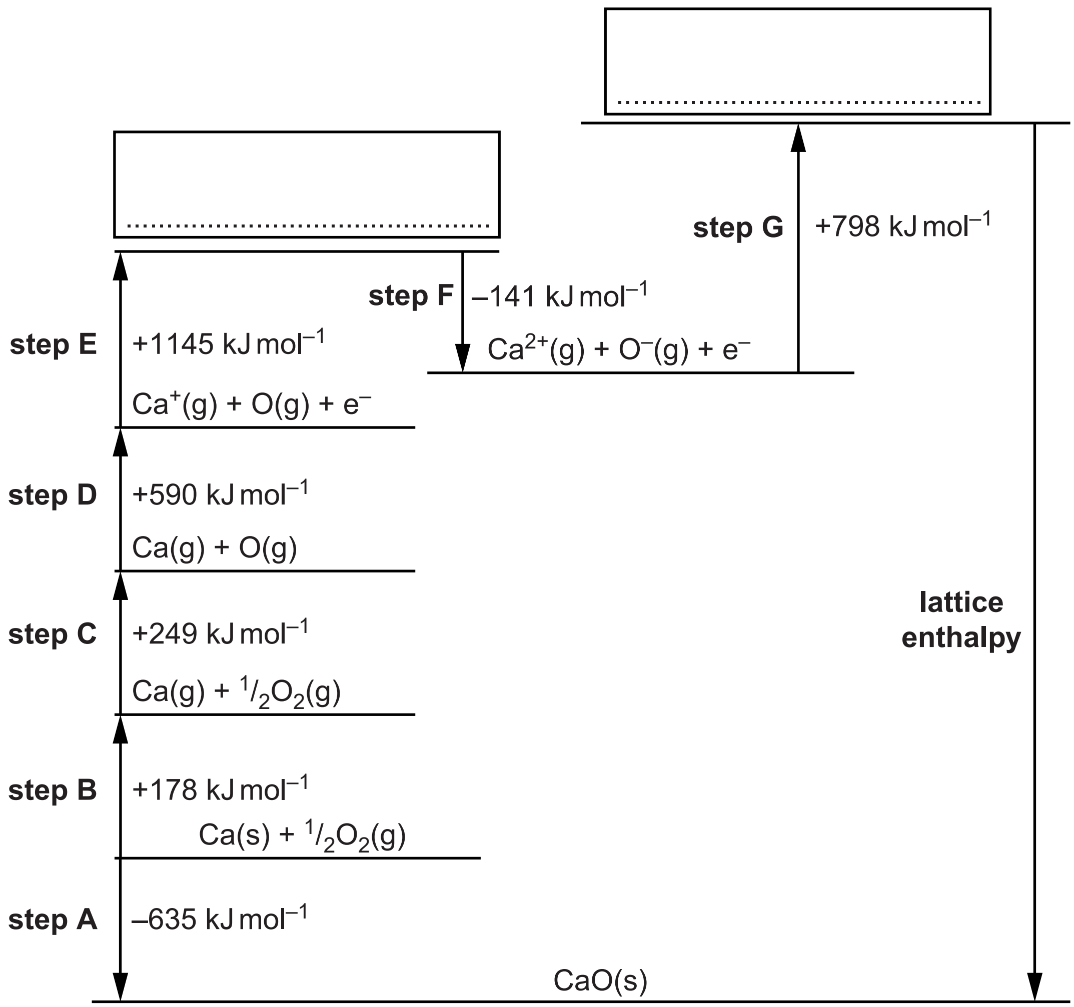
.... **[2]**

(b) The Born–Haber cycle below can be used to determine the lattice enthalpy of calcium oxide. The cycle includes the values for the enthalpy changes of the steps labelled **A–G**.

(i) Complete the Born–Haber cycle by adding the species present on the two dotted lines.

Include state symbols.



[2]

(ii) Name the enthalpy changes for the following steps in the Born–Haber cycle.

- **step A**

  ....

- **step C**

  ....

- **step G**

  ....
  [3]

(iii) Calculate the lattice enthalpy of calcium oxide.

answer = ... kJ mol^{-1} **[2]**

(c) Describe and explain the factors that affect the values of lattice enthalpies.

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.... **[3]**

[Total: 12]

4 Lattice enthalpy can be used as a measure of ionic bond strength. Lattice enthalpies can be determined indirectly using Born–Haber cycles.

The table below shows the enthalpy changes that are needed to determine the lattice enthalpy of lithium fluoride, LiF.

enthalpy change	**energy / $kJ\,mol^{-1}$**
1st electron affinity of fluorine	–328
1st ionisation energy of lithium	+520
atomisation of fluorine	+79
atomisation of lithium	+159
formation of lithium fluoride	–616

(a) Define the term *lattice enthalpy*.

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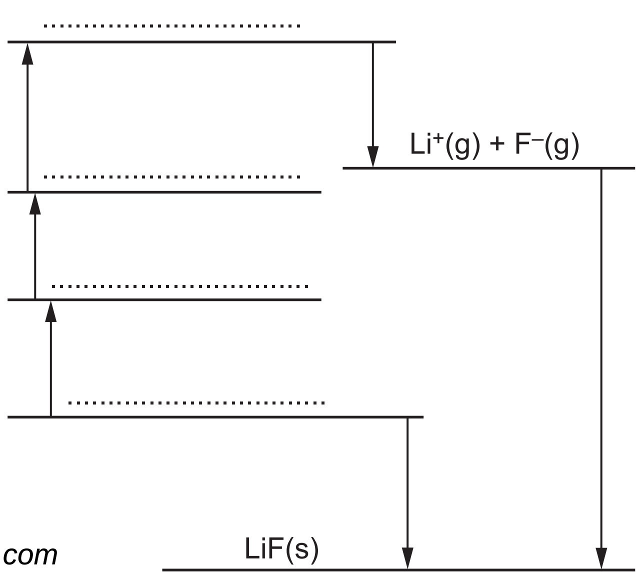
.... **[2]**

(b) The diagram below shows an incomplete Born–Haber cycle that would allow the lattice enthalpy of lithium fluoride to be determined.

(i) On the four dotted lines, add the species present, including state symbols.



[4]

(ii) Calculate the lattice enthalpy of lithium fluoride.

lattice enthalpy = ... $kJ\,mol^{-1}$ **[2]**

(c) The change that produces lattice enthalpy is spontaneous but has a negative entropy change.

Why is this change able to take place spontaneously?

....

....

.... **[1]**

(d) The lattice enthalpies of sodium fluoride, sodium chloride and magnesium fluoride are shown below.

compound	**lattice enthalpy / $kJ\,mol^{-1}$**
sodium fluoride	–918
sodium chloride	–780
magnesium fluoride	–2957

Explain the differences between these lattice enthalpies.

In your answer, your explanation should show how different factors affect lattice enthalpy.

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.... **[3]**

[Total: 12]