1 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 (a)(ii) and (a)(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)

(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)

(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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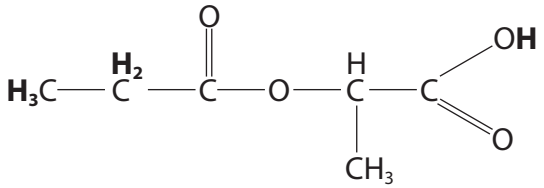
(d) An organic compound, **Q**, is found to contain 49.3% carbon and 6.8% hydrogen by mass.

(i) Use these data to confirm its empirical formula is $C_3H_5O_2$.

(3)

(ii) The structure of **Q** is shown below.



The table below summarises some information about parts of the nmr spectrum of compound **Q**.

Use the Data Booklet, and your knowledge of splitting patterns, to complete the table with respect to the features of compound **Q** shown in bold.

(4)

Feature of compound **Q**	Chemical shift / ppm	Splitting pattern
C**H**$_3$	0.1 – 1.9	
C**H**$_2$		
COO**H**		singlet

(Total for Question = 22 marks)

2 Lattice energies can be calculated from experimental data using Born-Haber cycles.

In the table below are the enthalpy changes needed to calculate the lattice energy of sodium oxide, Na_2O.

Letter	Enthalpy change	Value / kJ mol^{-1}
A	1st electron affinity of oxygen	–141
B	2nd electron affinity of oxygen	+790
C	1st ionization energy of sodium	+496
D	enthalpy change of atomization of sodium	+108
E	enthalpy change of atomization of oxygen, $½O_2(g)$	+249
F	enthalpy change of formation of sodium oxide	–414
G	lattice energy of sodium oxide	

(a) Define the term **lattice energy**.

(2)

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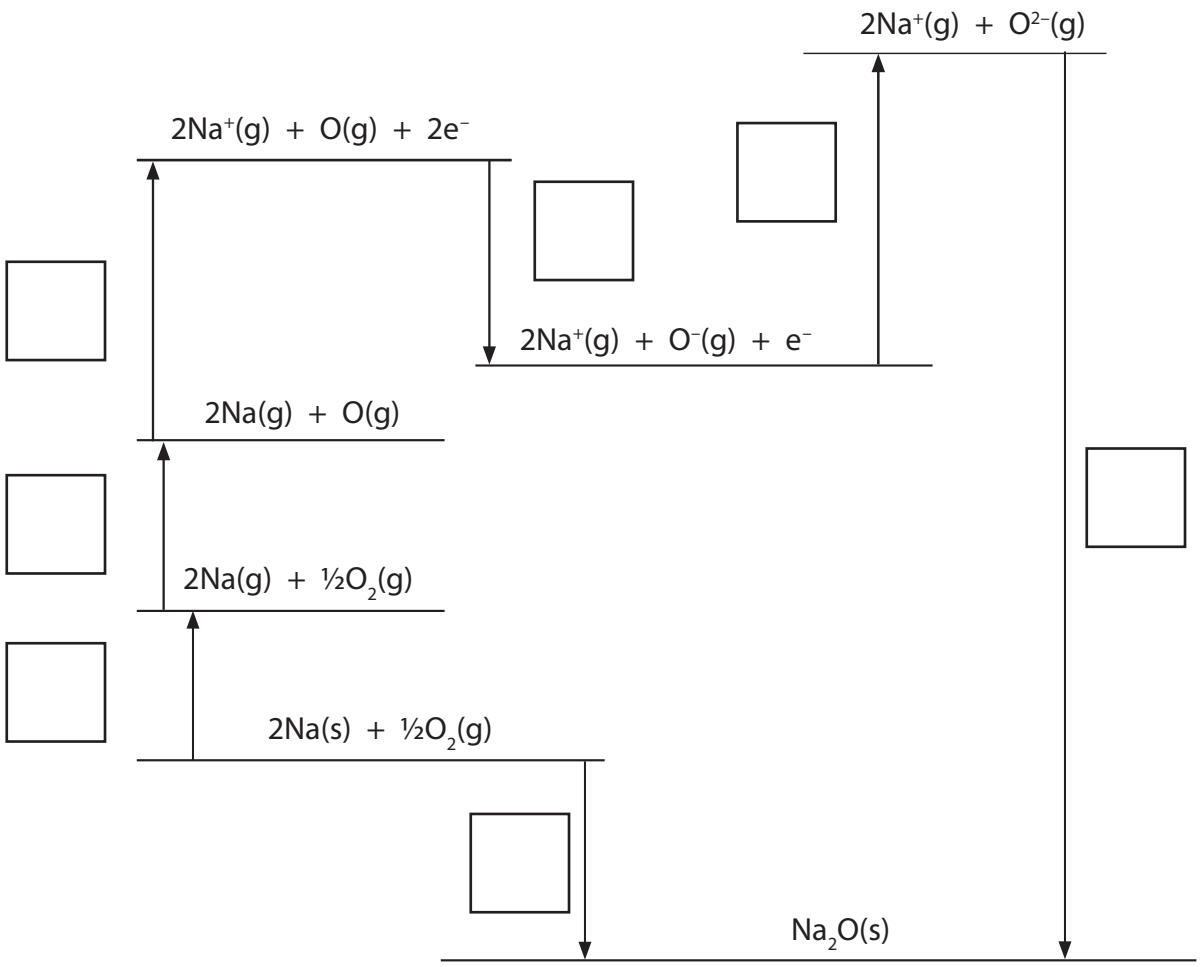
(b) (i) Write the correct letters from the table of data to label the Born-Haber cycle below.

(3)



(ii) Calculate the lattice energy of sodium oxide, enthalpy change **G**, in kJ mol^{-1}.

(2)

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

*(c) Predict whether the lattice energy of magnesium oxide, MgO, is more or less exothermic than the lattice energy of magnesium sulfide, MgS.

Justify your answer in terms of the sizes and the charges of the ions involved.

(4)

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(Total for Question = 11 marks)

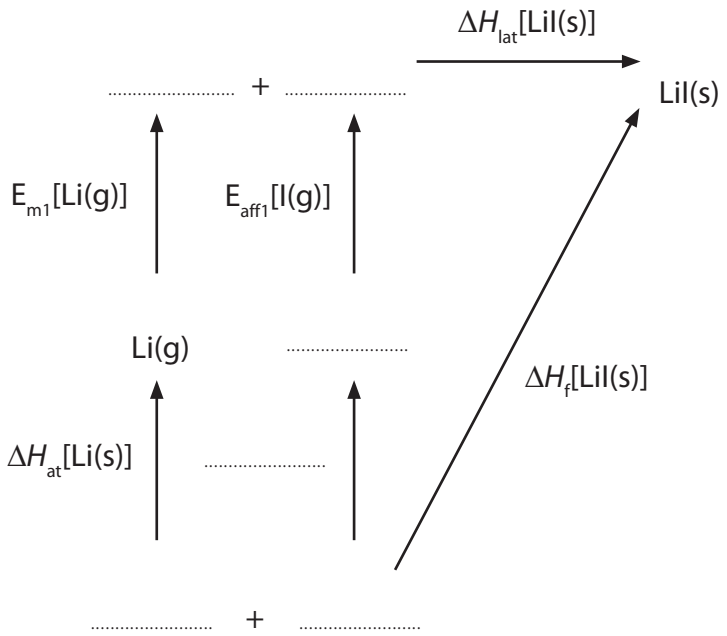
3 This question is about lithium iodide, an ionic salt.

(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)

4 Magnesium chloride can be made by reacting solid magnesium carbonate, $MgCO_3$, with dilute hydrochloric acid.

(a) Write an equation for the reaction, including state symbols.

(2)

(b) Give TWO observations you would make when the reaction is taking place.

(2)

(c) In an experiment to make crystals of hydrated magnesium chloride, $MgCl_2.6H_2O$, magnesium carbonate was added to 25 cm^3 of hydrochloric acid with concentration 2.0 mol dm^{-3}. The molar mass of magnesium carbonate is 84.3 g mol^{-1}.

(i) How many moles of acid are used in the reaction?

(1)

(ii) What mass of magnesium carbonate, in grams, reacts with this amount of acid?

(1)

(iii) Suggest why slightly more than this mass of magnesium carbonate is used in practice.

(1)

(iv) How would you separate the magnesium chloride solution from the reaction mixture in (iii)?

(1)

(v) The magnesium chloride solution was left to crystallise. The crystals were separated and dried carefully. A sample of 3.75 g of hydrated crystals, $MgCl_2.6H_2O$, which have molar mass 203.3 g mol^{-1}, was obtained. Calculate the percentage yield of this reaction.

(2)

(vi) Give ONE reason why the yield of crystals is less than 100%, even when pure compounds are used in the preparation.

(1)

(d) Lattice energies can be measured using the Born-Haber cycle, or calculated from electrostatic theory. Lattice energies of magnesium chloride and magnesium iodide are shown below.

Salt	Lattice energy from Born-Haber cycle using experimental data / kJ mol^{-1}	Lattice energy from electrostatic theory / kJ mol^{-1}
$MgCl_2$	–2526	–2326
MgI_2	–2327	–1944

(i) What does this data indicate about the bonding in magnesium chloride?

(1)

*(ii) Explain why there is a greater difference between the experimental (Born-Haber) and theoretical lattice energies for magnesium iodide, MgI_2, compared with magnesium chloride.

(2)

(e) Blood plasma typically contains 20 parts per million (ppm) of magnesium, by mass.

(i) Calculate the mass of magnesium, in grams, present in 100 g of plasma.

(1)

(ii) Magnesium chloride can be used as a supplement in the diet to treat patients with low amounts of magnesium in the blood. Suggest ONE property which makes it more suitable for this purpose than magnesium carbonate.

(1)

(Total for Question = 16 marks)