Chemical Energetics
A2 Level

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Chemical Energetics

(ii) Use the following data, together with relevant data from the *Data Booklet*, to calculate a value for the lattice energy of strontium chloride. You may find it helpful to construct a Born-Haber cycle.

electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}
standard enthalpy of atomisation of Sr(s)	+164 kJ mol^{-1}
standard enthalpy of formation of $SrCl_2$(s)	–830 kJ mol^{-1}

lattice energy = ... kJ mol^{-1}
[5]

w/14/qp43

3 **(a)** Write equations, with state symbols, to define the following.

(i) the C–Br bond energy in CH_3Br

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(ii) the Al–Cl bond energy in $AlCl_3$

....

[3]

(b) **(i)** Describe and explain the trend in bond energies of the bonds in Cl_2, Br_2 and I_2.

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(ii) Fluorine, F_2, does **not** follow this trend.
Suggest a possible reason why.

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[3]

(c) **(i)** Use data from the *Data Booklet* to calculate the enthalpy change of the following reaction.

$$H_2(g) + X_2(g) \rightarrow 2HX(g)$$

when X = Cl

ΔH = ... kJ mol^{-1}

when X = I

ΔH = ... kJ mol^{-1}

(ii) Use these results to describe and explain the trend in the thermal stabilities of the hydrides of Group VII.

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[5]

w/13/qp43

(d) **(i)** Write an equation to represent the lattice energy of $PbCl_2$. Show state symbols.

....

(ii) Use the following data, together with appropriate data from the *Data Booklet*, to calculate a value for the lattice energy of $PbCl_2$.

electron affinity of chlorine	=	$-349\ kJ\ mol^{-1}$
enthalpy change of atomisation of lead	=	$+195\ kJ\ mol^{-1}$
enthalpy change of formation of $PbCl_2(s)$	=	$-359\ kJ\ mol^{-1}$

lattice energy = ... $kJ\ mol^{-1}$

(iii) How might the lattice energy of $PbCl_2$ compare to that of $PbBr_2$? Explain your answer.

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....
[6]

s/14/qp42

(c) Copper(I) oxide and copper(II) oxide can both be used in the ceramic industry to give blue, green or red tints to glasses, glazes and enamels.

The table lists the $\Delta H_f^\ominus$ values for some compounds.

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$Cu_2O(s)$	–168.6
$CuO(s)$	–157.3
$Cu(NO_3)_2(s)$	–302.9
$NO_2(g)$	+33.2

(i) Copper(II) oxide can be produced in a pure form by heating copper(II) nitrate. Use suitable $\Delta H_f^\ominus$ values from the table to calculate the $\Delta H^\ominus$ for this reaction.

$$Cu(NO_3)_2(s) \rightarrow CuO(s) + 2NO_2(g) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

(ii) Copper(I) oxide can be produced from copper(II) oxide.

- Use suitable $\Delta H_f^\ominus$ values from the table to calculate $\Delta H^\ominus$ for the reaction.

$$2CuO(s) \rightleftharpoons Cu_2O(s) + \tfrac{1}{2}O_2(g)$$

$\Delta H^\ominus$ = ... kJ mol^{-1}

- Hence suggest whether a low or a high temperature of oxidation would favour the production of copper(I) oxide. Explain your reasoning.

....

....

[4]

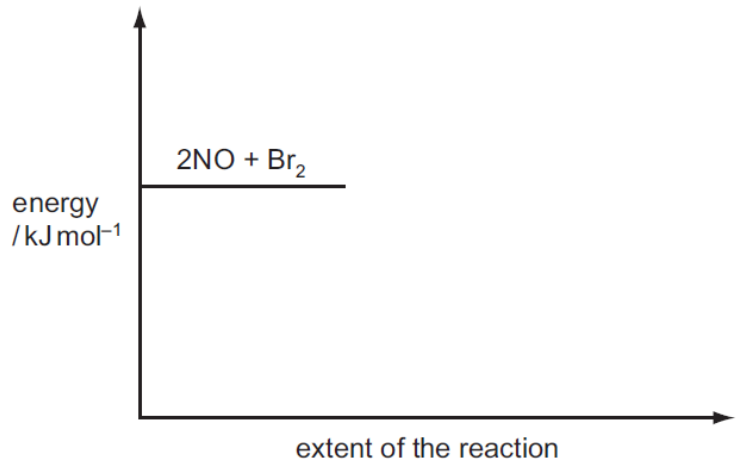
s/14/qp41

(c) Nitric oxide, NO, and bromine vapour react together according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H = -23\,kJ\,mol^{-1}$$

The reaction has an activation energy of $+5.4\,kJ\,mol^{-1}$.

Use the following axes to sketch a fully-labelled reaction pathway diagram for this reaction.
Include all numerical data on your diagram.



[2]

s/13/qp42

(c) **(i)** Write a chemical equation representing the lattice energy of AgBr.

....

(ii) Use the following data to calculate a value for the lattice energy of AgBr(s).

first ionisation energy of silver	=	+731 kJ mol^{-1}
electron affinity of bromine	=	–325 kJ mol^{-1}
enthalpy change of atomisation of silver	=	+285 kJ mol^{-1}
enthalpy change of atomisation of bromine	=	+112 kJ mol^{-1}
enthalpy change of formation of AgBr(s)	=	–100 kJ mol^{-1}

....

(iii) How might the lattice energy of Ag*Cl* compare to that of AgBr? Explain your answer.

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....

[4]

In photography a bromide ion absorbs a photon and releases an electron which reduces a silver ion to a silver atom.

$$Br^- \longrightarrow Br + e^-$$

$$Ag^+ + e^- \longrightarrow Ag$$

(d) Predict whether it would require **more** energy or **less** energy to initiate this process in a Ag*Cl* emulsion, compared to a AgBr emulsion. Explain your answer.

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....

.... [1]

w/05/qp4

3 Limestone is an important raw material, used in building, steel making and agriculture.

The first stage in using limestone is often to heat it in a kiln.

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ $\Delta H = +178\ \text{kJ mol}^{-1}$ reaction **1**

Water is then added to the 'quicklime' produced in the kiln, to make 'slaked lime'.

$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$ $\Delta H = -82\ \text{kJ mol}^{-1}$ reaction **2**

(a) **(i)** Suggest **two** reasons why reaction **1** needs heating to a high temperature.

....

....

(ii) Explain whether $MgCO_3$ would require a higher or a lower temperature than $CaCO_3$ for its decomposition.

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....

[5]

Before the widespread use of cement, bricks and stones used for buildings were bonded together with a mixture of slaked lime, sand and water, known as lime mortar. On exposure to the air, the lime mortar gradually set hard due to the following reaction.

$$Ca(OH)_2(s) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$$

(b) Use the data given above to calculate the enthalpy change for this reaction.

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....

.... [1]

s/05/qp4

One of the reasons the melting point of magnesium chloride is quite high is because it has a fairly high lattice energy.

(d) **(i)** Explain the term *lattice energy*.

....

....

(ii) Write a balanced equation including state symbols to represent the lattice energy of magnesium chloride.

....

....[4]

(e) Suggest, with an explanation in each case, how the lattice energy of magnesium chloride might compare with that of

(i) sodium chloride, NaC*l*,

....

....

(ii) calcium chloride, $CaCl_2$.

....

....[4]

(f) Use the following data to calculate a value for the lattice energy of sodium chloride.

ΔH_f (NaC*l*)	=	−411 kJ mol^{-1}
ΔH_{at} (Na)	=	107 kJ mol^{-1}
ΔH_{at} (C*l*)	=	122 kJ mol^{-1}
first ionisation energy of Na	=	494 kJ mol^{-1}
electron affinity of C*l*	=	−349 kJ mol^{-1}

lattice energy of NaC*l* = ... kJ mol^{-1} [3]

s/04/qp4

(c) The magnesium ions in seawater are mainly associated with chloride ions.

(i) Use the following ΔH_f° values to calculate a value for the ΔH° of the following reaction.

$$MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

species	ΔH_f° /kJ mol^{-1}
$MgCl_2$ (s)	–641
Mg^{2+}(aq)	–467
Cl^- (aq)	–167

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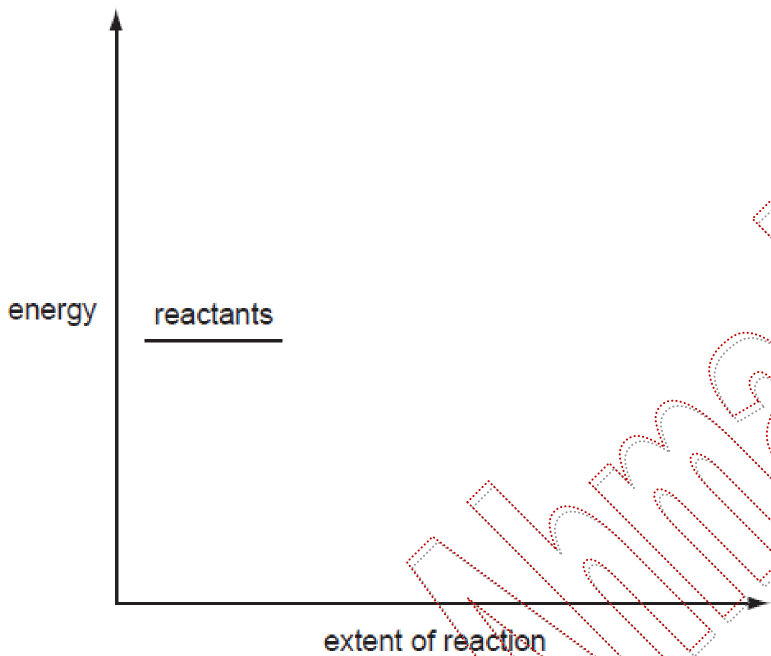
(ii) Use your answer to explain why $MgCl_2$ is very soluble in water.

....

[2]

s/03/qp4

(c) Use the following axes to draw a fully labelled reaction pathway diagram showing the effect of a catalyst on an exothermic reaction. Label the ΔH and E_a values.



[3]

[Total: 10]

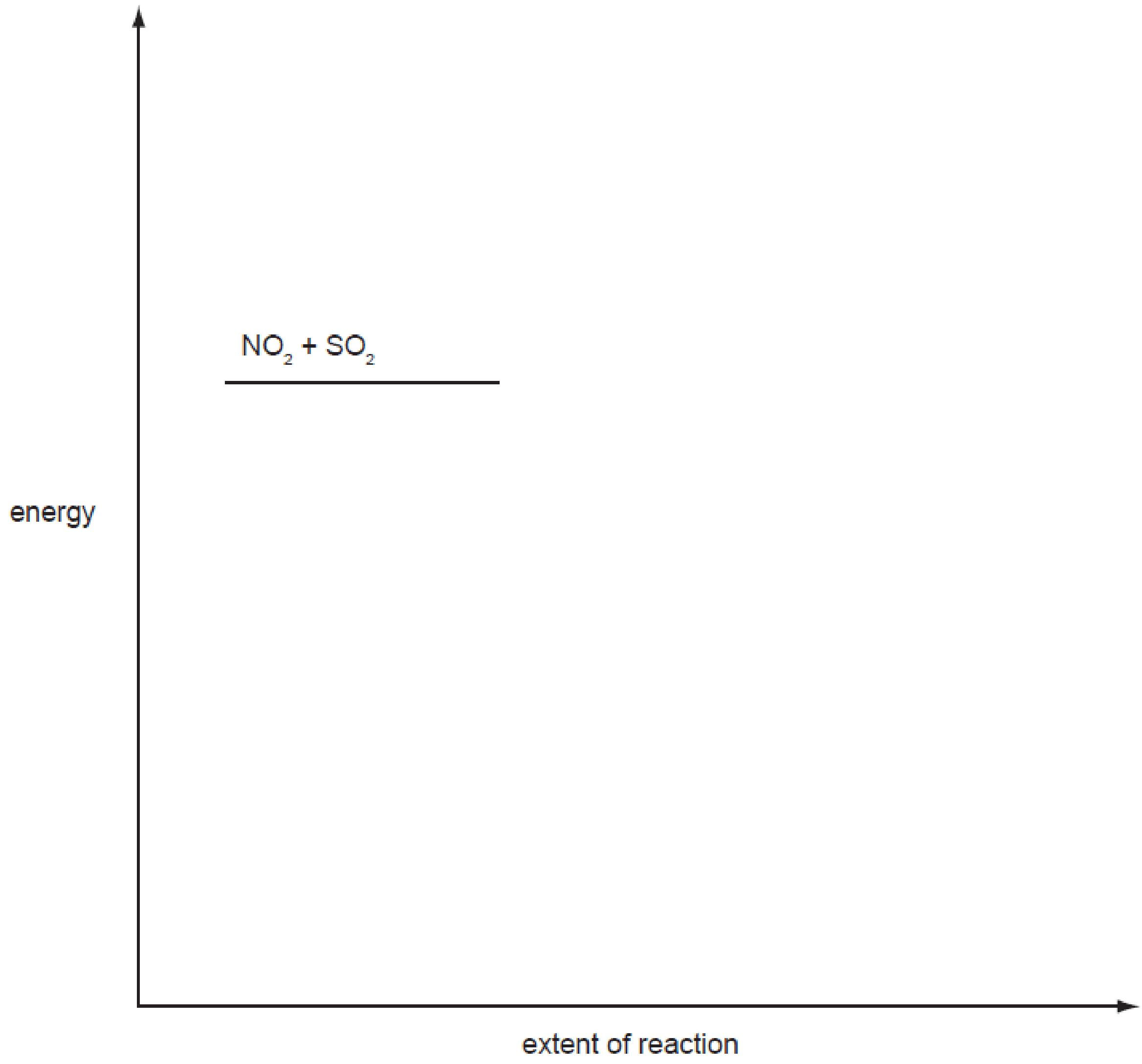
w/12/qp43

(b) The reaction between SO_2, NO_2 and O_2 occurs in two steps.

$$NO_2 + SO_2 \rightarrow NO + SO_3 \qquad \Delta H_1^{\ominus} = -88\,kJ\,mol^{-1}$$
$$NO + \tfrac{1}{2}O_2 \rightarrow NO_2 \qquad \Delta H_2^{\ominus} = -57\,kJ\,mol^{-1}$$

The activation energy of the first reaction, E_{a_1}, is higher than that of the second reaction, E_{a_2}.

Use the axes below to construct a fully-labelled reaction pathway diagram for this reaction, labelling E_{a_1}, E_{a_2}, $\Delta H_1^{\ominus}$ and $\Delta H_2^{\ominus}$.



[2]

w/12/qp41

(c) When $SiCl_4$ vapour is passed over Si at red heat, Si_2Cl_6 is formed. Si_2Cl_6 contains a Si-Si bond.
The reaction of Si_2Cl_6 and Cl_2 re-forms $SiCl_4$.

$$Si_2Cl_6(g) + Cl_2(g) \rightarrow 2SiCl_4(g)$$

Use bond energy data from the *Data Booklet* to calculate $\Delta H^{\ominus}$ for this reaction.

$\Delta H^{\ominus}$ = ... $kJ\,mol^{-1}$
[2]

w/12/qp41

2 Calcium chloride, $CaCl_2$, is an important industrial chemical used in refrigeration plants, for de-icing roads and for giving greater strength to concrete.

(a) Show by means of an equation what is meant by the lattice energy of calcium chloride.

.... [1]

(b) Suggest, with an explanation, how the lattice energies of the following salts might compare in magnitude with that of calcium chloride.

(i) calcium fluoride, CaF_2

....

....

(ii) calcium sulfide, CaS

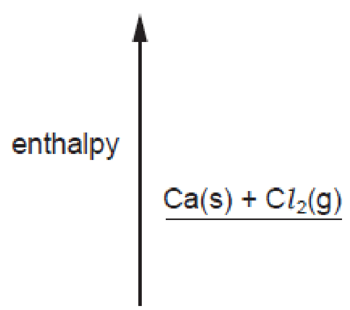
....

....

[3]

(c) Use the following data, together with additional data from the *Data Booklet*, to calculate the lattice energy of $CaCl_2$.

standard enthalpy change of formation of $CaCl_2$	–796 kJ mol^{-1}
standard enthalpy change of atomisation of Ca(s)	+178 kJ mol^{-1}
electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}



lattice energy = ... kJ mol^{-1} [3]

(d) When a solution of $CaCl_2$ is added to a solution of the dicarboxylic acid, malonic acid, the salt calcium malonate is precipitated as a white solid. The solid has the following composition by mass: Ca, 28.2%; C, 25.2%; H, 1.4%; O, 45.2%.

(i) Calculate the empirical formula of calcium malonate from these data.

(ii) Suggest the structural formula of malonic acid.

[3]

[Total: 10]

w/09/qp41

1 (a) The halogens chlorine and bromine react readily with hydrogen.

$$X_2(g) + H_2(g) \longrightarrow 2HX(g) \qquad [X = Cl \text{ or } Br]$$

(i) Describe how you could carry out this reaction using chlorine.

....

(ii) Describe **two** observations you would make if this reaction was carried out with bromine.

....

....

(iii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ for this reaction when

X = C*l*,

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

X = Br.

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(iv) What is the major reason for the difference in these two $\Delta H^{\ominus}$ values?

....

[8]

(b) Some halogens also react readily with methane.

$$CH_4(g) + X_2(g) \longrightarrow CH_3X(g) + HX(g)$$

(i) What conditions are needed to carry out this reaction when X is bromine, Br?

....

(ii) Use bond energy data from the *Data Booklet* to calculate the $\Delta H^{\ominus}$ of this reaction for the situation where X is iodine, I.

$\Delta H^{\ominus}$ = ... $kJ\,mol^{-1}$

(iii) Hence suggest why it is not possible to make iodomethane, CH_3I, by this reaction.

....

[4]

w/11/qp41

The recovered H_2S is converted to sulfur by the following two reactions.

I Part of the H_2S is burned in air.

$$H_2S + 1.5O_2 \longrightarrow SO_2 + H_2O$$

II The gas stream resulting from reaction **I** is then blended with the remaining H_2S and fed into an iron oxide catalyst bed, where sulfur and water are produced according to the following equation.

$$2H_2S(g) + SO_2(g) \longrightarrow 3S(g) + 2H_2O(g)$$

(v) Use the following data to calculate $\Delta H^\ominus$ for the reaction between H_2S and SO_2.

compound	$\Delta H^\ominus_f$ / kJ mol^{-1}
$H_2S(g)$	–21
$SO_2(g)$	–297
$H_2O(g)$	–242
$S(g)$	+11

$\Delta H^\ominus$ = ... kJ mol^{-1} [8]

w/10/qp43

1 **(a)** Write a balanced equation for the reaction of each of the following chlorides with water.

phosphorus(V) chloride ....

silicon(IV) chloride ....
[2]

(b) When sulfur is heated under pressure with chlorine, the major product is SCl_2 (Cl-S-Cl).

$$S_8(g) + 8Cl_2(g) \longrightarrow 8SCl_2(g)$$

Use data from the *Data Booklet* to calculate the enthalpy change, Δ*H*, for this reaction. The eight sulfur atoms in the S_8 molecule are all joined in a single ring by single bonds.

Δ*H* = ... kJ mol^{-1}
[2]

w/10/qp41

4 **(a)** What is meant by the term *bond energy*?

....

.... [2]

(b) Describe and explain what is observed when a red-hot wire is plunged into separate samples of the gaseous hydrogen halides HCl and HI.
How are bond energy values useful in interpreting these observations?

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.... [3]

(c) The following reaction occurs in the gas phase.

$$3F_2(g) + Cl_2(g) \longrightarrow 2ClF_3(g), \quad \Delta H_r^{\ominus} = -328 \text{ kJ mol}^{-1}$$

Use these and other data from the *Data Booklet* to calculate the average bond energy of the Cl-F bond in ClF_3. [2]

[Total: 7]

w/09/qp42

(c) (i) Use the following data and data from the *Data Booklet* to construct a Born-Haber cycle and calculate the lattice energy of BaS.

standard enthalpy change of formation of BaS(s)	–460 kJ mol^{-1}
standard enthalpy change of atomisation of Ba(s)	+180 kJ mol^{-1}
standard enthalpy change of atomisation of S(s)	+279 kJ mol^{-1}
electron affinity of the sulfur atom	–200 kJ mol^{-1}
electron affinity of the S^- ion	+640 kJ mol^{-1}

lattice energy = ... kJ mol^{-1}

(ii) Explain whether the magnitude of the lattice energy of BaS is likely to be greater or less than that of BaO.

....

....

[4]

[Total: 11]

w/09/qp42

4 **(a)** By choosing the chlorides of **two** of the Group IV elements as examples, describe the trend in the reactions of these chlorides with water. Suggest an explanation for any differences, and write equations for any reactions that occur.

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....[3]

(b) The standard enthalpy changes of formation of lead(II) chloride and lead(IV) chloride are given in the following table.

compound	$\Delta H_f^\ominus$ / kJ mol^{-1}
$PbCl_2(s)$	–359
$PbCl_4(l)$	–329

Use these data, and also bond energy data from the *Data Booklet*, to calculate the enthalpy changes for the following two reactions.

(i) $CCl_2(g) + Cl_2(g) \longrightarrow CCl_4(g)$

$\Delta H^\ominus$ = ... kJ mol^{-1}

(ii) $PbCl_2(s) + Cl_2(g) \longrightarrow PbCl_4(l)$

$\Delta H^\ominus$ = ... kJ mol^{-1}

(iii) Make use of your answers to parts **(i)** and **(ii)** to suggest how the relative stabilities of the two oxidation states vary down the Group.

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....

[3]

[Total: 6]

w/07/qp4

(b) The standard enthalpy change of formation, $\Delta H_f^{\ominus}$, of CO is –111 kJ mol^{-1}, and that of CO_2 is –394 kJ mol^{-1}.
Calculate the standard enthalpy change of the following reaction.

$$C(s) + CO_2(g) \rightarrow 2CO(g)$$

$\Delta H^{\ominus}$ = ... kJ mol^{-1}
[2]

s/12/qp42

1 (a) (i) What is meant by the term *enthalpy change of hydration*, ΔH°_{hyd}?

....

....

(ii) Write an equation that represents the ΔH°_{hyd} of the Mg^{2+} ion.

....

(iii) Suggest a reason why ΔH°_{hyd} of the Mg^{2+} ion is greater than ΔH°_{hyd} of the Ca^{2+} ion.

....

....

(iv) Suggest why it is impossible to determine the enthalpy change of hydration of the oxide ion, O^{2-}.

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....

[5]

(b) The enthalpy change of solution for $MgCl_2$, $\Delta H^{\circ}_{sol}(MgCl_2(s))$, is represented by the following equation.

$$MgCl_2(s) + aq \rightarrow Mg^{2+}(aq) + 2Cl^-(aq)$$

Describe the simple apparatus you could use, and the measurements you would make, in order to determine a value for $\Delta H^{\circ}_{sol}(MgCl_2(s))$ in the laboratory.

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.... [4]

(c) The table below lists data relevant to the formation of $MgCl_2(aq)$.

enthalpy change	value / kJ mol^{-1}
$\Delta H_f^{\ominus}(MgCl_2(s))$	–641
$\Delta H_f^{\ominus}(MgCl_2(aq))$	–801
lattice energy of $MgCl_2(s)$	–2526
$\Delta H_{hyd}^{\ominus}(Mg^{2+}(g))$	–1890

By constructing relevant thermochemical cycles, use the above data to calculate a value for

(i) $\Delta H_{sol}^{\ominus}(MgCl_2(s))$,

$\Delta H_{sol}^{\ominus}$ = ... kJ mol^{-1}

(ii) $\Delta H_{hyd}^{\ominus}(Cl^-(g))$.

$\Delta H_{hyd}^{\ominus}$ = ... kJ mol^{-1}
[3]

(d) Describe and explain how the solubility of magnesium sulfate compares to that of barium sulfate.

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.... [4]

[Total: 16]

s/12/qp42

2 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(a) **(i)** Suggest a 'dot-and-cross' electronic structure for nitrogen monoxide.

(ii) The enthalpy change of formation of nitrogen monoxide is +90 kJ mol^{-1}. What is the enthalpy change for the following reaction?

$2NO(g) \rightarrow N_2(g) + O_2(g)$ ΔH_r = ... kJ mol^{-1}

(iii) Explain why nitrogen monoxide is formed in the car engine.

....

(iv) Using bond enthalpy values from the *Data Booklet* and your answer in **(ii)** above, calculate a value for the bond energy of nitrogen monoxide.

bond energy = ... kJ mol^{-1}
[5]

s/12/qp41

1 (a) (i) What is meant by the term *lattice energy*?

....

....

(ii) Write an equation to represent the lattice energy of MgO.

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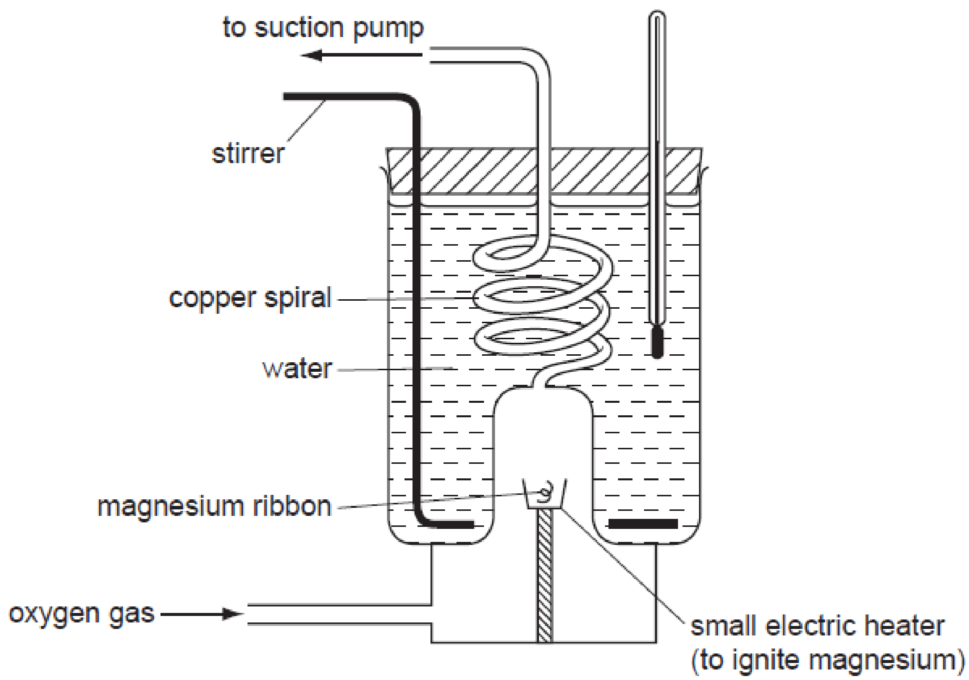
[3]

(b) The apparatus shown in the diagram can be used to measure the enthalpy change of formation of magnesium oxide, $\Delta H_f^{\ominus}(MgO)$.



List the measurements you would need to make using this apparatus in order to calculate $\Delta H_f^{\ominus}(MgO)$.

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.... [3]

(c) Use the following data, together with appropriate data from the *Data Booklet*, to calculate a value of $\Delta H_f^\ominus$(MgO).

lattice energy of MgO(s)	=	–3791 kJ mol^{-1}
enthalpy change of atomisation of Mg	=	+148 kJ mol^{-1}
electron affinity of the oxygen atom	=	–141 kJ mol^{-1}
electron affinity of the oxygen anion, O^-	=	+798 kJ mol^{-1}

$\Delta H_f^\ominus$(MgO) = ... kJ mol^{-1}

[3]

(d) Write equations, including state symbols, for the reactions, if any, of the following two oxides with water. Suggest values for the pH of the resulting solutions.

oxide	equation	pH of resulting solution
Na_2O		
MgO		

[3]

[Total: 12]

s/12/qp41

1 Taken together, nitrogen and oxygen make up 99% of the air. Oxygen is by far the more reactive of the two gases, and most of the substances that react with air combine with the oxygen rather than with the nitrogen.

(a) State **one** reason why the molecule of nitrogen, N_2, is so unreactive.

....[1]

Despite the apparent lack of reactivity of N_2, nitrogen atoms have been found to form bonds with almost all of the elements in the Periodic Table. Lithium metal reacts with nitrogen gas at room temperature to give lithium nitride, Li_3N. Magnesium produces magnesium nitride, Mg_3N_2, as well as magnesium oxide, when heated in air.

(b) Calculate the lattice energy of magnesium nitride using the following data, in addition to relevant data from the *Data Booklet*.

enthalpy change	value/kJ mol^{-1}
atomisation of Mg(s)	+148
total of electron affinities for the change $N(g) \longrightarrow N^{3-}(g)$	+2148
enthalpy of formation of $Mg_3N_2(s)$	–461

lattice energy = ...kJ mol^{-1} [3]

s/11/qp41

2 **(a)** Describe and explain how the solubilities of the sulfates of the Group II elements vary down the group.

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.... [3]

(b) The following table lists some enthalpy changes for magnesium and strontium compounds.

enthalpy change	value for magnesium / $kJ\,mol^{-1}$	value for strontium / $kJ\,mol^{-1}$
lattice enthalpy of ***M***$(OH)_2$	–2993	–2467
enthalpy change of hydration of ***M***$^{2+}$(g)	–1890	–1414
enthalpy change of hydration of OH^-(g)	–550	–550

(i) Use the above data to calculate values of $\Delta H^{\ominus}_{solution}$ for $Mg(OH)_2$ and for $Sr(OH)_2$.

$Mg(OH)_2$ ....

....

$\Delta H^{\ominus}_{solution}$ = ... $kJ\,mol^{-1}$

$Sr(OH)_2$ ....

....

$\Delta H^{\ominus}_{solution}$ = ... $kJ\,mol^{-1}$

(ii) Use your results in **(i)** to suggest whether $Sr(OH)_2$ is more or less soluble in water than is $Mg(OH)_2$. State any assumptions you make.

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(iii) Suggest whether $Sr(OH)_2$ would be more or less soluble in hot water than in cold. Explain your reasoning.

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[5]

s/10/qp43

(e) One of the many suggestions for converting biomass into liquid fuel for motor transport is the pyrolysis (i.e. heating in the absence of air) of cellulose waste, followed by the synthesis of alkanes.

(i) In the first reaction, cellulose, $(C_6H_{10}O_5)_n$, is converted into a mixture of carbon monoxide and hydrogen. Some carbon is also produced.

Complete and balance the equation for this reaction.

$(C_6H_{10}O_5)_n \longrightarrow$ ________________ + ________________ + ________________

(ii) The second reaction involves the combination of CO and H_2 to produce alkanes such as heptane.

$$7CO + 15H_2 \longrightarrow \underset{\text{heptane}}{C_7H_{16}} + 7H_2O$$

Using the value of 1080 kJ mol^{-1} as the value for the C≡O bond energy in CO, and other relevant bond energies from the *Data Booklet*, calculate the ΔH for this reaction.

ΔH = ... kJ mol^{-1} [5]

s/09/qp4

(d) **(i)** The Sn–C*l* bond energy is +315 kJ mol^{-1}. Use this and other values from the *Data Booklet* to calculate $\Delta H^{\ominus}$ for the reaction

$$MCl_2(g) + Cl_2(g) \rightarrow MCl_4(g)$$

for the following cases.

- M = Si

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

- M = Sn

$\Delta H^{\ominus}$ = ... kJ mol^{-1}

(ii) Do your results agree with the trend in relative stabilities of the +2 and +4 oxidation states in **(c)**? Explain your answer.

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[3]

s/08/qp4

2 This question is about the properties and reactions of the oxides of some elements in their +4 oxidation state.

(a) Chlorine dioxide, ClO_2, is an important industrial chemical, used to bleach wood pulp for making paper, and to kill bacteria in water supplies.

However, it is unstable and decomposes into its elements as follows.

$$2ClO_2(g) \rightarrow Cl_2(g) + 2O_2(g)$$

(i) The chlorine atom is in the middle of the ClO_2 molecule. Using the chlorine-oxygen bond energy as 278 kJ mol^{-1}, and other values from the *Data Booklet*, calculate ΔH for the above reaction.

ΔH = ... kJ mol^{-1}

(ii) Assuming the Cl-O bonds in chlorine dioxide are double bonds, predict the shape of the ClO_2 molecule. Explain your answer.

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s/08/qp4

(b) Iron(III) chloride readily dissolves in water.

$$FeCl_3(s) \rightarrow Fe^{3+}(aq) + 3Cl^-(aq)$$

(i) Use the following data to calculate the standard enthalpy change for this process.

species	$\Delta H_f^\ominus$/ kJ mol^{-1}
$FeCl_3(s)$	–399.5
$Fe^{3+}(aq)$	–48.5
$Cl^-(aq)$	–167.2

$\Delta H^\ominus$ = ...kJ mol^{-1}

s/08/qp4

(c) Use the following data, together with relevant data from the *Data Booklet*, to construct a Born-Haber cycle and calculate a value for the lattice energy of zinc chloride.

standard enthalpy change of formation of $ZnCl_2$	–415 kJ mol^{-1}
standard enthalpy change of atomisation of Zn(s)	+131 kJ mol^{-1}
electron affinity per mole of chlorine atoms	–349 kJ mol^{-1}

lattice energy = ... kJ mol^{-1} [3]

s/07/qp4