Enthalpy Change & Hess's Law

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Chemical Energetics
Sub-Topic	Enthalpy Change & Hess's Law
Paper Type	Theory
Booklet	Question Paper 2

Time Allowed:	**68 minutes**
Score:	**/56**
Percentage:	**/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	777.5%	70%	62.5%	57.5%	45%	<45%

1(a) The reaction between iodide ions and persulfate ions, $S_2O_8^{2-}$, is slow.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-} \qquad \textbf{1}$$

The reaction can be speeded up by adding a small amount of Fe^{2+} or Fe^{3+} ions. The following two reactions then take place.

$$2I^- + 2Fe^{3+} \longrightarrow I_2 + 2Fe^{2+} \qquad \textbf{2}$$

$$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2Fe^{3+} + 2SO_4^{2-} \qquad \textbf{3}$$

(i) What type of catalysis is occurring here?

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(ii) The rates of reactions **2** and **3** are both faster than that of reaction **1**. By considering the species involved in these reactions, suggest a reason for this.

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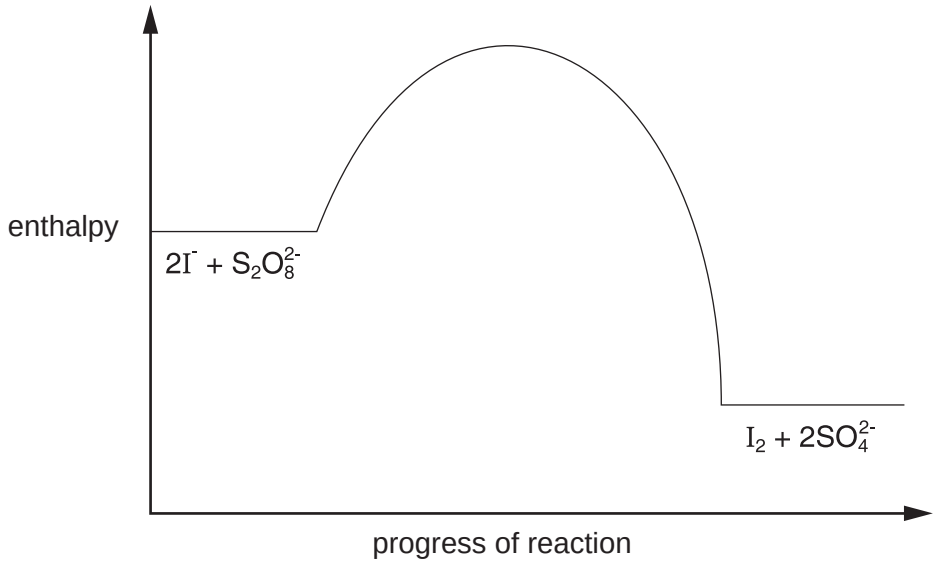
(iii) The following reaction pathway diagram shows the enthalpy profile of reaction **1**.



Use the same axes to draw the enthalpy profiles of reaction **2** followed by reaction **3**, starting reaction **2** at the same enthalpy level as reaction **1**.

[4]

(b) The oxidation of SO_2 to SO_3 in the atmosphere is speeded up by the presence of nitrogen oxides.

(i) Describe the environmental significance of this reaction.

.....

(ii) Describe a major source of SO_2 in the atmosphere.

.....

(iii) By means of suitable equations, show how nitrogen oxides speed up this reaction.

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[4]

[Total: 8]

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

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.....[2]

(b) Describe and explain what is observed when a red-hot wire is plunged into separate samples of the gaseous hydrogen halides HC*l* 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.

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

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

[Total: 7]

3 The elements of Group IV all form tetrachlorides with the general formula MCl_4.

(a) Draw a diagram of a molecule of $SiCl_4$ stating bond angles.

[2]

(b) Describe and explain how the volatilities of the Group IV chlorides vary down the group.

.....

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..... [2]

(c) The relative stabilities of the $M^{2+}(aq)$ and $M^{4+}(aq)$ ions also vary down Group IV.

(i) Use the *Data Booklet* to illustrate this observation when *M* = Sn and *M* = Pb.

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(ii) Use the *Data Booklet* to predict the products formed, and write equations for the reactions occurring, when

- an equimolar mixture of $Sn^{2+}(aq)$ and $Sn^{4+}(aq)$ is added to $I_2(aq)$,

.....

.....

- an equimolar mixture of $Pb^{2+}(aq)$ and $Pb^{4+}(aq)$ is added to $SO_2(aq)$.

.....

.....

[4]

(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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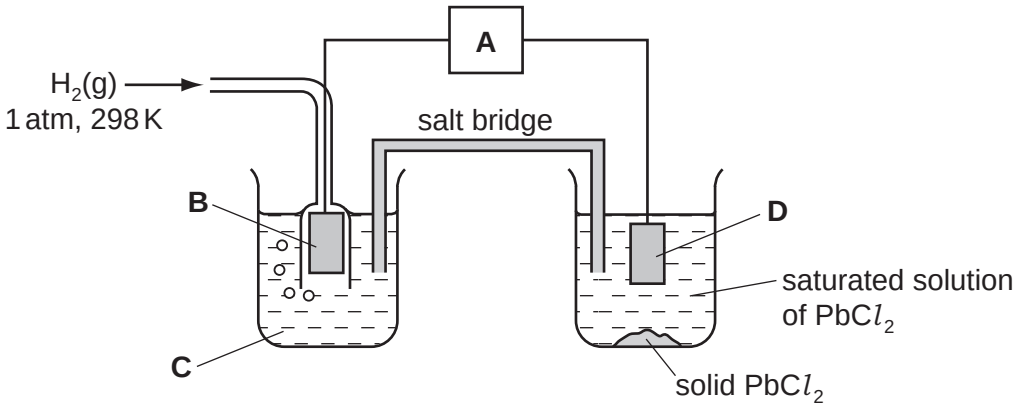
[3]

[Total: 11]

4 Lead(II) chloride, $PbCl_2$, can be used in the manufacture of some types of coloured glass.

$PbCl_2$ is only sparingly soluble in water. The $[Pb^{2+}]$ in a saturated solution of $PbCl_2$ can be estimated by measuring the cell potential, E_{cell}, of the following cell.



(a) In the spaces below, identify what the four letters **A**-**D** in the above diagram represent.

A ..... **B** .....

C ..... **D** .....

[4]

(b) In a saturated solution of $PbCl_2$, $[PbCl_2(aq)] = 3.5 \times 10^{-2}$ mol dm^{-3}.

(i) The $E^{\ominus}$ for the Pb^{2+}/Pb electrode is –0.13 V. Predict the potential of the right-hand electrode in the diagram above. Indicate this by placing a tick in the appropriate box in the table below.

electrode potential / V	place **one tick only** in this column
–0.17	
–0.13	
–0.09	
0.00	

Explain your answer.

.....

.....

(ii) Write an expression for the solubility product, K_{sp}, of $PbCl_2$.

.....

(iii) Calculate the value of K_{sp}, including units.

K_{sp} = ... units .....

[5]

(c) The behaviours of $PbCl_2$ and $SnCl_2$ towards reducing agents are similar, but their behaviours towards oxidising agents are very different.

(i) Illustrate this comparison by quoting and comparing relevant $E^{\ominus}$ values for the two metals and their ions. Explain what the relative $E^{\ominus}$ values mean in terms of the ease of oxidation or reduction of these compounds.

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(ii) Writing a balanced molecular or ionic equation in each case, suggest a reagent to carry out each of the following reactions.

the reduction of $PbCl_2$

.....

the oxidation of $SnCl_2$

.....

[5]

(d) 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]

[Total: 20]

5 Nitrogen oxides in the atmosphere are homogeneous catalysts in the formation of acid rain.

(a) What is meant by the following terms?

catalyst

.....

.....

homogeneous

.....

.....
[2]

(b) **(i)** State a major source of nitrogen oxides in the atmosphere, explaining how they are formed.

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(ii) Use equations to describe the chemical role played by nitrogen oxides in the formation of acid rain.

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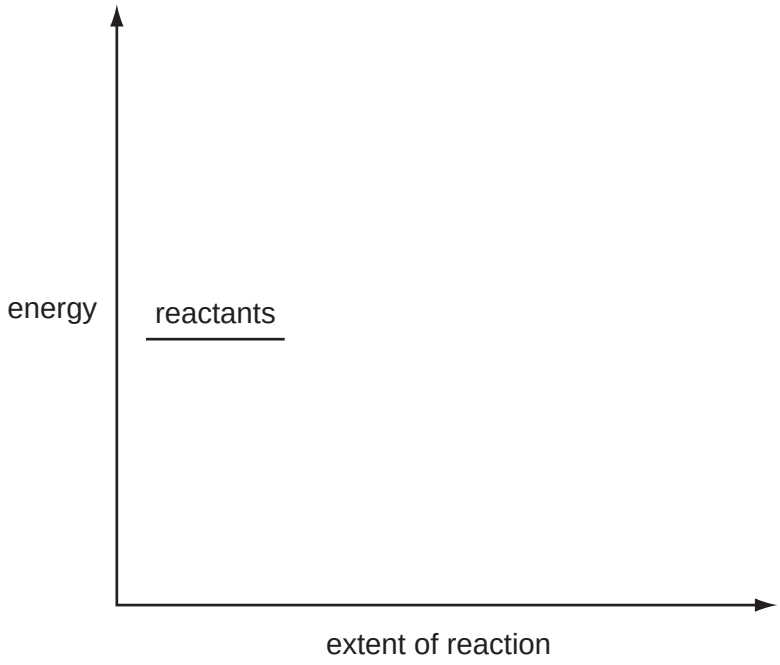
[5]

(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]