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.

$$2I^- + S_2O_8^{2-} \longrightarrow I_2 + 2SO_4^{2-} \qquad \textbf{1}$$
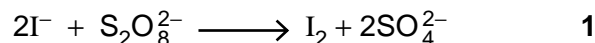
The reaction can be speeded up by adding a small amount of Fe^{2+} or Fe^{3+} ions. The following two reactions then take place.

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

$$2Fe^{2+} + S_2O_8^{2-} \longrightarrow 2Fe^{3+} + 2SO_4^{2-} \qquad \textbf{3}$$
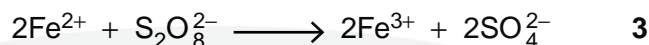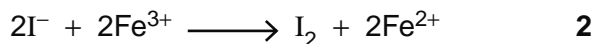
(i) What type of catalysis is occurring here?

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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.

....

....

(iii) The following reaction pathway diagram shows the enthalpy profile of reaction **1**.
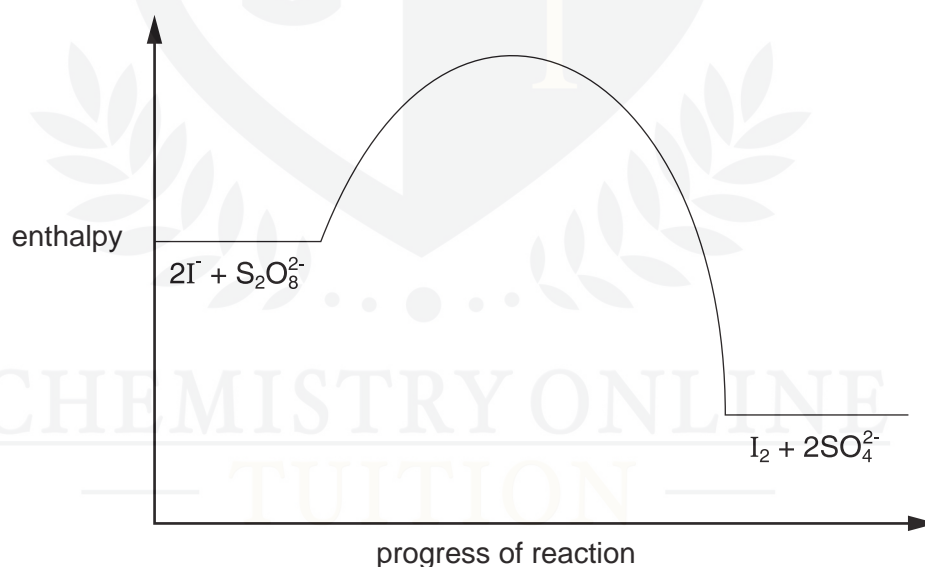
Use the same axes to draw the enthalpy profiles of reaction **2** followed by reaction **3**, starting reaction **2** at the same enthalpy level as reaction **1**.

[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.

   ....

   ....

[4]

[Total: 8]
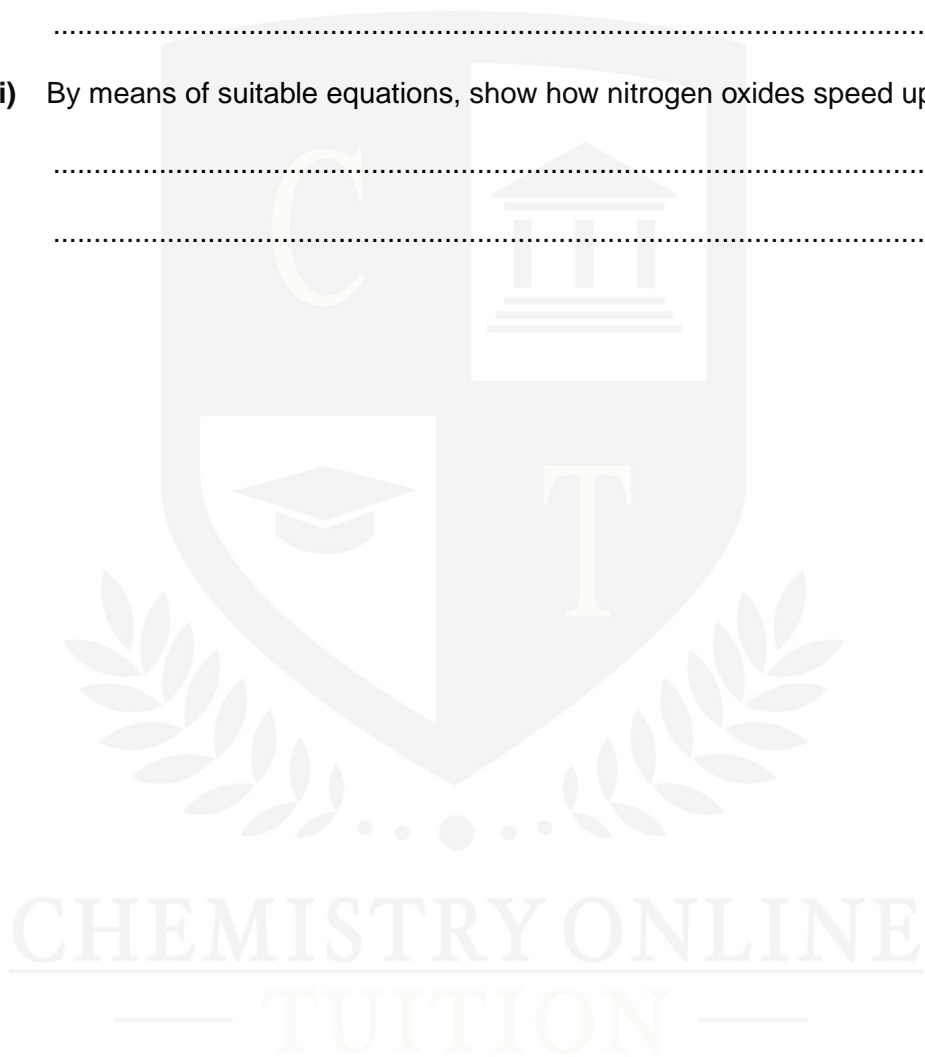
2 (a) What is meant by the term *bond energy*?

....

....[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.

$$3F_2(g) \ + \ Cl_2(g) \ \longrightarrow \ 2ClF_3(g), \qquad \Delta H^{\ominus}_r = -328\,kJ\,mol^{-1}$$
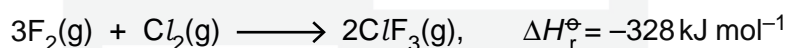
Use these and other data from the *Data Booklet* to calculate the average bond energy of the Cl-F bond in ClF$_3$. [2]

[Total: 7]

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.

....

....

.... [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–Cl bond energy is $+315\,\text{kJ}\,\text{mol}^{-1}$. Use this and other values from the *Data Booklet* to calculate $\Delta H^{\ominus}$ for the reaction

$$MCl_2(g) \;+\; Cl_2(g) \;\longrightarrow\; MCl_4(g)$$
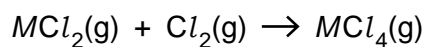
for the following cases.

- $M = \text{Si}$

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

- $M = \text{Sn}$

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

(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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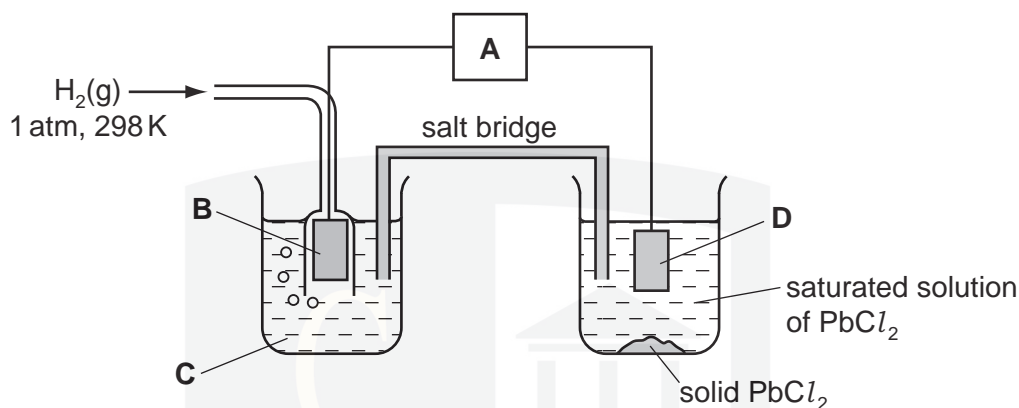...

[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.

....

....

....

[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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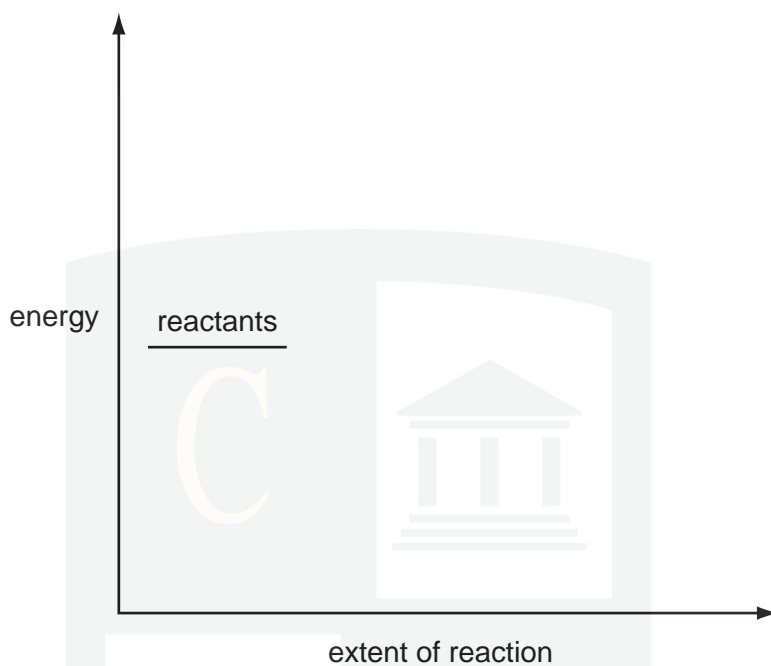
[5]

(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.

energy | reactants

extent of reaction

[3]

[Total: 10]