

Q1.(a) Iron is extracted from iron(III) oxide using carbon at a high temperature.

(i) State the type of reaction that iron(III) oxide undergoes in this extraction.

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(1)

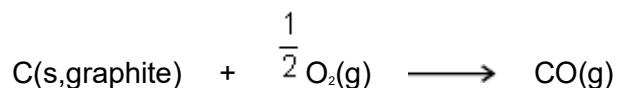
(ii) Write a half-equation for the reaction of the iron(III) ions in this extraction.

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(b) At a high temperature, carbon undergoes combustion when it reacts with oxygen.

(i) Suggest why it is **not** possible to measure the enthalpy change directly for the following combustion reaction.



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(ii) State Hess's Law.

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(iii) State the meaning of the term *standard enthalpy of combustion*.

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 (Extra space)

(3)

- (c) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change for the extraction of iron using carbon monoxide.

	Fe ₂ O ₃ (s)	CO(g)	Fe(l)	CO ₂ (g)
$\Delta H_f^\circ / \text{kJ mol}^{-1}$	- 822	- 111	+14	- 394



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 (Extra space)

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- (d) (i) Write an equation for the reaction that represents the standard enthalpy of formation of carbon dioxide.

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- (ii) State why the value quoted in part (c) for the standard enthalpy of formation of

CO₂(g) is the same as the value for the standard enthalpy of combustion of carbon.

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(Total 12 marks)

Q2. This question is about the extraction of titanium from titanium(IV) oxide by a two-stage process.

The first stage in the process produces titanium(IV) chloride. In the second stage, titanium(IV) chloride is converted into titanium.

The enthalpy change for the second stage can be determined using Hess's Law.

(a) Give **one** reason why titanium is **not** extracted directly from titanium(IV) oxide using carbon.

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(b) Give the meaning of the term *enthalpy change*.

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(c) State Hess's Law.

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(d) Define the term *standard enthalpy of formation*.

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(3)

(e) The following standard enthalpy of formation data refer to the second stage in the extraction of titanium.

	TiCl ₄ (g)	Na(l)	NaCl(s)	Ti(s)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-720	+3	-411	0

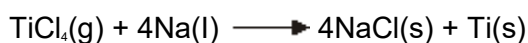
(i) State why the value for the standard enthalpy of formation of Na(l) is **not** zero.

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(ii) Use data from the table to calculate a value for the standard enthalpy change of the following reaction.



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(iii) State the role of sodium in this reaction.

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(Total 11 marks)

Q3. Hess's Law is used to calculate the enthalpy change in reactions for which it is difficult to determine a value experimentally.

(a) State the meaning of the term *enthalpy change*.

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(b) State Hess's Law.

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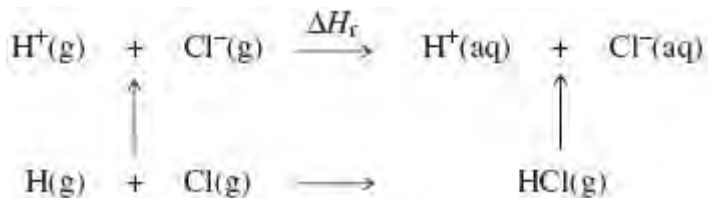
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(c) Consider the following table of data and the scheme of reactions.

Reaction	Enthalpy change / kJ mol ⁻¹
$\text{HCl(g)} \rightarrow \text{H}^{\text{+}}(\text{aq}) + \text{Cl}^{-}(\text{aq})$	-75
$\text{H(g)} + \text{Cl(g)} \rightarrow \text{HCl(g)}$	-432
$\text{H(g)} + \text{Cl(g)} \rightarrow \text{H}^{\text{+}}(\text{g)} + \text{Cl}^{-}(\text{g)}$	+963



Use the data in the table, the scheme of reactions and Hess's Law to calculate a value for ΔH_{r}

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(3)
(Total 5 marks)

Q4. Comparison of lattice enthalpies from Born-Haber cycles with lattice enthalpies from calculations based on a perfect ionic model are used to provide information about bonding in crystals.

(a) Define the terms *enthalpy of atomisation* and *lattice dissociation enthalpy*.

Enthalpy of atomisation

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Lattice dissociation enthalpy

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(b) Use the following data to calculate a value for the lattice dissociation enthalpy of sodium chloride.

	$\Delta H^\ominus/\text{kJ mol}^{-1}$
$\text{Na(s)} \longrightarrow \text{Na(g)}$	+109
$\text{Na(g)} \longrightarrow \text{Na}^+(\text{g}) + \text{e}^-$	+494
$\text{Cl}_2(\text{g}) \longrightarrow 2\text{Cl}(\text{g})$	+242
$\text{Cl}(\text{g}) + \text{e}^- \longrightarrow \text{Cl}^-(\text{g})$	-364
$\text{Na(s)} + \frac{1}{2}\text{Cl}_2(\text{g}) \longrightarrow \text{NaCl(s)}$	-411

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(c) Consider the following lattice dissociation enthalpy ($\Delta H_{\text{L}}^\ominus$) data.

	NaBr	AgBr
$\Delta H_{\text{L}}^\ominus(\text{experimental})/\text{kJ mol}^{-1}$	+733	+890
$\Delta H_{\text{L}}^\ominus(\text{theoretical})/\text{kJ mol}^{-1}$	+732	+758

The values of $\Delta H_{\text{L}}^\ominus$ (experimental) have been determined from Born–Haber cycles.

The values of $\Delta H_{\text{L}}^\ominus$ (theoretical) have been determined by calculation using a perfect ionic model.

(i) Explain the meaning of the term *perfect ionic model*.

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(ii) State what you can deduce about the bonding in NaBr from the data in the

table.

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(iii) State what you can deduce about the bonding in AgBr from the data in the table.

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(Total 11 marks)

Q5. A scientist used mass spectrometry to analyse a sample of the air near a fertiliser factory. The sample of air included traces of a gas which was shown by its molecular ion to have a precise $M_r = 44.00105$

(a) State the meaning of the term *molecular ion*.

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(b) (i) Use the following data to show that the trace gas was dinitrogen oxide (N_2O).

Show your working.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{14}N	14.00307
^{16}O	15.99491

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- (ii) Propane is used as a fuel in the fertiliser factory. State why both propane and its combustion product, carbon dioxide, might have been identified as the trace gas if the scientist had used relative molecular masses calculated to one decimal place.

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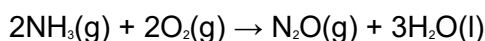
(1)

- (iii) State why the precise relative atomic mass for the ^{12}C isotope is exactly 12.00000

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(1)

- (c) Dinitrogen oxide is formed when ammonia is oxidised according to the following equation.



- (i) Use the standard enthalpies of formation in the table below to calculate a value for the standard enthalpy change of this reaction.

	$\text{NH}_3(\text{g})$	$\text{O}_2(\text{g})$	$\text{N}_2\text{O}(\text{g})$	$\text{H}_2\text{O}(\text{l})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-46	0	+82	-286

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- (ii) State **one** condition necessary for enthalpies of formation to be quoted as standard values at a specified temperature of 298 K.

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(Total 8 marks)