Application of Hess's Law

Question Paper 3

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.4 Energetics
Sub-Topic	3.1.4.3 Application of Hess's Law
Booklet	Question Paper 3

Time Allowed: **58 minutes**

Score: **/56**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. 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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(1)

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

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(1)

(c) State Hess's Law.

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(1)

(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)
$\Delta H_f^{\ominus}$/ 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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(1)

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

$$TiCl_4(g) + 4Na(l) \longrightarrow 4NaCl(s) + Ti(s)$$

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(3)

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

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(1)

(Total 11 marks)

Q2. 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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(1)

(b) State Hess's Law.

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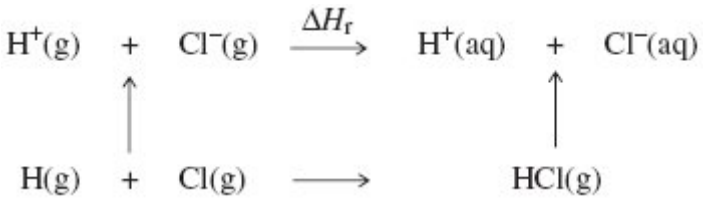
(1)

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

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

Q3. Barium can be extracted from barium oxide (BaO) in a process using aluminium. A mixture of powdered barium oxide and powdered aluminium is heated strongly. The equation for this extraction process is shown below.

$$3BaO(s) + 2Al(s) \rightarrow 3Ba(s) + Al_2O_3(s)$$

Some standard enthalpies of formation are given in the table below.

Substance	BaO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–558	–1669

(a) (i) State what is meant by the term *standard enthalpy of formation*.

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(3)

(ii) State why the standard enthalpy of formation of barium and that of aluminium are both zero.

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(1)

(iii) Use the data to calculate the standard enthalpy change for the reaction shown by the equation above.

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(3)

(b) (i) Suggest the major reason why this method of extracting barium is expensive.

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(1)

(ii) Using barium oxide and aluminium powders increases the surface area of the reactants. Suggest **one** reason why this increases the rate of reaction.

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(1)

(c) (i) Write an equation for the reaction of barium with water.

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(1)

(ii) A solution containing barium ions can be used to test for the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction which occurs and state what is observed.

Simplest ionic equation

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Observation .....

(2)

(iii) State how barium sulfate can be used in medicine. Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

Explanation .....

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(2)
(Total 14 marks)

Q4.(a) Define the term *standard enthalpy of formation*, $\Delta H_f^\ominus$

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(3)

(b) Use the data in the table to calculate the standard enthalpy of formation of liquid methylbenzene, C_7H_8

Substance	C(s)	$H_2(g)$	$C_7H_8(l)$
Standard enthalpy of combustion, $\Delta H_c^\ominus$ /kJ mol^{-1}	–394	–286	–3909

$7C(s) + 4H_2(g) \rightarrow C_7H_8(l)$

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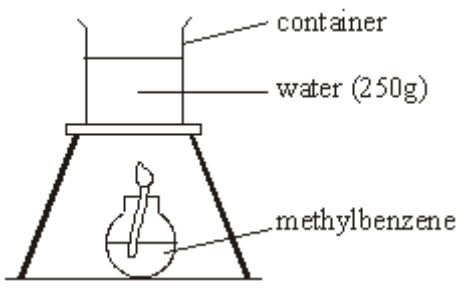
(3)

(c) An experiment was carried out to determine a value for the enthalpy of combustion of liquid methylbenzene using the apparatus shown in the diagram.



Burning 2.5 g of methylbenzene caused the temperature of 250 g of water to rise by 60°C. Use this information to calculate a value for the enthalpy of combustion of methylbenzene, C_7H_8

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}. Ignore the heat capacity of the container.)

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(4)

(d) A 25.0 cm^3 sample of 2.00 mol dm^{-3} hydrochloric acid was mixed with 50.0 cm^3 of a 1.00 mol dm^{-3} solution of sodium hydroxide. Both solutions were initially at 18.0 °C.

After mixing, the temperature of the final solution was 26.5°C.

Use this information to calculate a value for the standard enthalpy change for the following reaction.

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

In your calculation, assume that the density of the final solution is 1.00 g cm^{-3} and that its specific heat capacity is the same as that of water. (Ignore the heat capacity of the container.)

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(4)

(e) Give **one** reason why your answer to part (d) has a much smaller experimental error than your answer to part (c).

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(1)

(Total 15 marks)

Q5. The combustion of hydrocarbons is an important source of energy.

(a) Define the term *standard enthalpy of combustion*.

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(3)

(b) (i) Write an equation for the complete combustion of ethane, C_2H_6.

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(ii) Use the standard enthalpies of formation given below to calculate the standard enthalpy of combustion of ethane.

Formula and state of compound	$C_2H_6(g)$	$CO_2(g)$	$H_2O(l)$
Standard enthalpy of formation (at 298 K)/kJ mol^{-1}	–85	–394	–286

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(4)

(c) A container and its contents of total heat capacity 120 J K^{-1} were heated using a methane burner. Calculate the maximum theoretical temperature rise when 0.10 g of methane was completely burned. The standard enthalpy of combustion of methane is –890 kJ mol^{-1}.

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(4)
(Total 11 marks)