TUTOR ZONE

Percentage	
Grade	

A Level Chemistry

Enthalpy

Duration: 1 hour 30 min

Total Marks: 84

Information for Candidates:

- Use black or blue ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional paper is used, the question number(s) must be clearly shown
- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.

Do not write in this table	
Question	Mark
TOTAL	

box

2 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.

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

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(1 mark)

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

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(1 mark)

2 (c) State Hess's Law.

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(1 mark)

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

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(3 marks)

2 (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

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

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(1 mark)

2 (e) (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 marks)

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

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(1 mark)

11

Turn over ▶

24 Aqueous lead(II) nitrate, $Pb(NO_3)_2(aq)$, and aqueous potassium iodide, KI(aq), react together. The equation is shown below.

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

A student carries out an experiment to determine the enthalpy change of reaction, $\Delta_r H$, of this reaction.

The student follows the method outlined below.

- Add 50.0 cm^3 of 1.50 mol dm^{-3} $Pb(NO_3)_2(aq)$ to a polystyrene cup.
- Measure out 50.0 cm^3 of a solution of KI(aq), which is in excess.
- Measure the temperature of both solutions.
- Add the KI(aq) to the polystyrene cup, stir the mixture and record the maximum temperature.

Temperature readings

Initial temperature of both solutions	= 19.5 °C
Maximum temperature of mixture	= 30.0 °C

(a) Calculate $\Delta_r H$, in kJ mol^{-1}, for the reaction shown in the equation above.

Give your answer to an **appropriate** number of significant figures.

Assume that the density of all solutions and specific heat capacity, *c*, of the reaction mixture is the same as for water.

$\Delta_r H$ = ... kJ mol^{-1} **[4]**

(b) Write an ionic equation for the reaction that the student carries out.

Include state symbols.

..... **[1]**

(c) The 50.0 cm^3 of KI(aq) used in the experiment contains 10% more KI than is needed to react with 50.0 cm^3 of 1.50 $mol\,dm^{-3}$ $Pb(NO_3)_2$(aq).

$$Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$$

Calculate the concentration, in $mol\,dm^{-3}$, of KI that the student used.

concentration of KI = ... $mol\,dm^{-3}$ **[2]**

12 The enthalpy change of formation of butane can be calculated using the enthalpy changes of combustion, $\Delta_c H$, below.

Substance	C(s)	$H_2(g)$	$C_4H_{10}(g)$
$\Delta_c H$ **/ kJ mol^{-1}**	–394	–286	–2877

Calculate the enthalpy change of formation of $C_4H_{10}(g)$.

$$4C(s) + 5H_2(g) \rightarrow C_4H_{10}(g)$$

A –2197 kJ mol^{-1}

B –129 kJ mol^{-1}

C +129 kJ mol^{-1}

D +2197 kJ mol^{-1}

Your answer ☐ **[1]**

4 The table below shows enthalpy changes of formation, $\Delta_f H$.

Compound	$TiCl_4(l)$	$H_2O(l)$	$TiO_2(s)$	HCl(g)
$\Delta_f H$ **/ kJ mol^{-1}**	–804	–286	–945	–92

What is the value of the enthalpy change of reaction, $\Delta_r H$, for the reaction in the following equation?

$$TiCl_4(l) + 2H_2O(l) \rightarrow TiO_2(s) + 4HCl(g)$$

A –63 kJ mol^{-1}

B –53 kJ mol^{-1}

C +53 kJ mol^{-1}

D +63 kJ mol^{-1}

3 Enthalpy changes of reaction can be determined by experiment or by using bond enthalpies.

(a) What is meant by the term *enthalpy change of reaction*?

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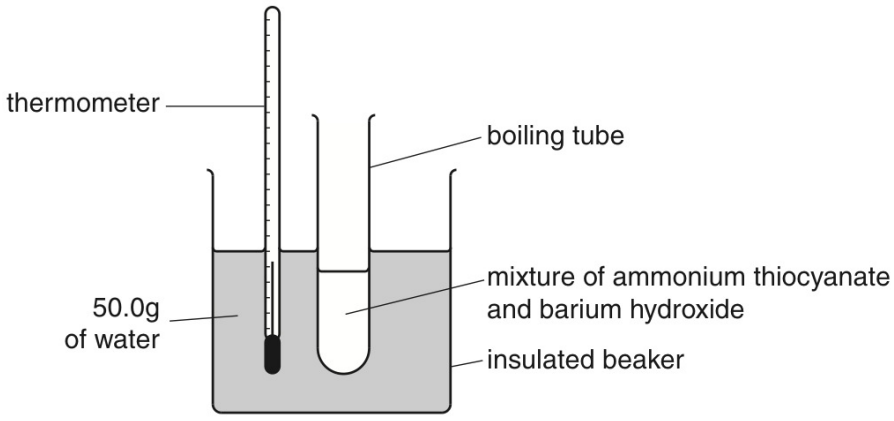
..... **[2]**

(b) Solid ammonium thiocyanate, NH_4SCN, reacts with solid barium hydroxide, $Ba(OH)_2$, as shown in the equation below.

$$2NH_4SCN(s) + Ba(OH)_2(s) \longrightarrow Ba(SCN)_2(s) + 2H_2O(l) + 2NH_3(g)$$

A research chemist carries out an experiment to determine the enthalpy change of this reaction.



In the experiment, 15.22 g of NH_4SCN is reacted with a slight excess of $Ba(OH)_2$. The reaction absorbs energy, cooling the 50.0 g of water from 21.9 °C to 10.9 °C.

(i) Calculate the energy absorbed, in kJ, during this reaction.

The specific heat capacity of water = 4.2 J g^{-1} K^{-1}.

energy = ...kJ **[2]**

(ii) Calculate the amount, in moles, of NH_4SCN used by the research chemist.

amount = ... mol **[1]**

(iii) Calculate the enthalpy change of reaction.

Include the sign in your answer.

Give your answer to **two** significant figures.

ΔH_r = ...kJ mol^{-1} **[3]**

PART (c) CONTINUES ON PAGE 10

(c) Standard enthalpy changes of reaction can also be determined using average bond enthalpies.

(i) What is meant by the term *average bond enthalpy*?

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..... **[2]**

Table 3.1 below shows some average bond enthalpies.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C–C	+345
C=C	+611

Table 3.1

(ii) Explain the bonding in a C=C double bond. Use the orbital overlap model.

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..... **[2]**

(iii) Suggest why the average bond enthalpy of a C=C bond is **not** twice the bond enthalpy of a C–C bond.

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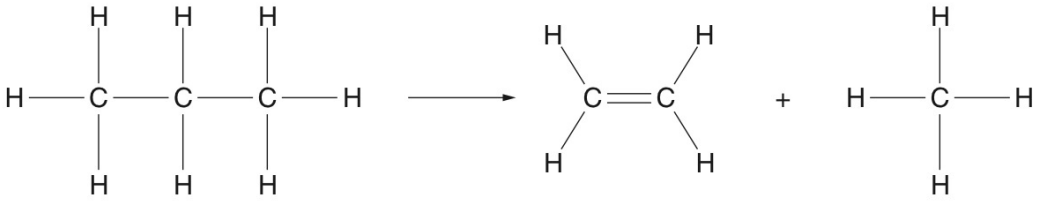
..... **[1]**

(iv) Propane can be cracked to make ethene.



Using the average bond enthalpies in **Table 3.1**, calculate the enthalpy change of this reaction.

ΔH_r = ...kJ mol^{-1} **[2]**

(v) The actual value for the enthalpy change of this reaction is +81 kJ mol^{-1}.

Suggest a reason why the actual value for the enthalpy change of this reaction is different from the calculated value.

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..... **[1]**

[Total: 16]

1 (a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

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(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

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(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	$HF(g)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = ... kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

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(4)
(Total 10 marks)

outside the box

2 Standard enthalpy of combustion data can be used to calculate enthalpies of formation.

2 (a) State the meaning of the term standard enthalpy of combustion.

[3 marks]

2 (b) The equation corresponding to the enthalpy of formation of propan-1-ol is shown.

$$3C(s) + 4H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2CH_2OH(l)$$

Table 1 contains some standard enthalpy of combustion data.

Table 1

	C(s)	**H_2(g)**	**$CH_3CH_2CH_2OH$(l)**
$\Delta H_c^{\ominus}$ / kJ mol^{-1}	–394	–286	–2010

Use data from **Table 1** to calculate a value for the standard enthalpy of formation of propan-1-ol. Show your working.

[3 marks]

2 (c) An equation for the complete combustion of gaseous propan-1-ol is shown.

$$CH_3CH_2CH_2OH(g) + 4\tfrac{1}{2}O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H = -1893 \text{ kJ mol}^{-1}$$

Table 2 shows some bond enthalpy data.

Table 2

	C–H	C–O	O–H	C=O	O=O
Bond enthalpy / kJ mol^{-1}	412	360	463	805	496

Use data from **Table 2** and the enthalpy change for this reaction to calculate a value for the bond enthalpy of a C–C bond in propan-1-ol.

[3 marks]

9

Turn over for the next question

6 Hydrazine (N_2H_4) decomposes in an exothermic reaction. Hydrazine also reacts exothermically with hydrogen peroxide when used as a rocket fuel.

6 (a) Write an equation for the decomposition of hydrazine into ammonia and nitrogen only.

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(1 mark)

6 (b) State the meaning of the term *mean bond enthalpy*.

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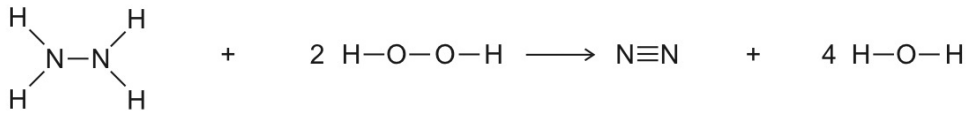
(2 marks)

6 (c) Some mean bond enthalpies are given in the table.

	N—H	N—N	N≡N	O—H	O—O
Mean bond enthalpy / kJ mol^{-1}	388	163	944	463	146

Use these data to calculate the enthalpy change for the gas-phase reaction between hydrazine and hydrogen peroxide.



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(3 marks)

6

Turn over ▶

3 This question is about the extraction of metals.

3 (a) Manganese can be extracted from Mn_2O_3 by reduction with carbon monoxide at high temperature.

3 (a) (i) Use the standard enthalpy of formation data from the table and the equation for the extraction of manganese to calculate a value for the standard enthalpy change of this extraction.

	$Mn_2O_3(s)$	$CO(g)$	$Mn(s)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−971	−111	0	−394

$$Mn_2O_3(s) + 3CO(g) \longrightarrow 2Mn(s) + 3CO_2(g)$$

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(3 marks)

3 (a) (ii) State why the value for the standard enthalpy of formation of Mn(s) is zero.

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(1 mark)

3 (b) Titanium is extracted in industry from titanium(IV) oxide in a two-stage process.

3 (b) (i) Write an equation for the first stage of this extraction in which titanium(IV) oxide is converted into titanium(IV) chloride.

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(2 marks)

3 (b) (ii) Write an equation for the second stage of this extraction in which titanium(IV) chloride is converted into titanium.

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(2 marks)

3 (c) Chromium is extracted in industry from chromite ($FeCr_2O_4$).

3 (c) (i) In the first stage of this extraction, the $FeCr_2O_4$ is converted into Na_2CrO_4

Balance the equation for this reaction.

..... $FeCr_2O_4$ + ... Na_2CO_3 + ... O_2 $\longrightarrow$ ..... Na_2CrO_4 + $2Fe_2O_3$ + $8CO_2$

(1 mark)

3 (c) (ii) In the final stage, chromium is extracted from Cr_2O_3 by reduction with aluminium.

Write an equation for this reaction.

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(1 mark)

10

Turn over for the next question

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

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

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(1 mark)

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

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(1 mark)

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

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

$$C(s,graphite) + \tfrac{1}{2}O_2(g) \longrightarrow CO(g)$$

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(1 mark)

4 (b) (ii) State Hess's Law.

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(1 mark)

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

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(3 marks)

(Extra space) .....

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4 (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.

	$Fe_2O_3(s)$	$CO(g)$	$Fe(l)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−822	−111	+14	−394

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$$

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(3 marks)

(Extra space) .....

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

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(1 mark)

4 (d) (ii) State why the value quoted in part **(c)** for the standard enthalpy of formation of $CO_2(g)$ is the same as the value for the standard enthalpy of combustion of carbon.

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(1 mark)

12

Turn over ▶

11 The table below shows standard enthalpy changes of formation, $\Delta_f H$.

Compound	$NH_4NO_3(s)$	$H_2O(g)$	$CO_2(g)$
$\Delta_f H$ **/ kJ mol^{-1}**	–366	–242	–394

What is the enthalpy change for the following reaction?

$$2NH_4NO_3(s) + C(s) \rightarrow 2N_2(g) + 4H_2O(g) + CO_2(g)$$

A –630 kJ mol^{-1}

B –540 kJ mol^{-1}

C +540 kJ mol^{-1}

D +630 kJ mol^{-1}

Your answer ☐

[1]