# Essential Pre-Uni Chemistry F3.4

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use the reaction enthalpies given, and the combustion or formation enthalpies above to find the requested enthalpy change in each case:

**Part A** $\mathrm{NH_4Cl\,(s)}$

$\mathrm{NH_3\,(g) + HCl\,(g) \longrightarrow NH_4Cl\,(s)}$, $\Delta_r H^\ominus = -176\,\mathrm{kJ\,mol^{-1}}$ find $\Delta_f H^\ominus$ of $\mathrm{NH_4Cl\,(s)}$

**Part B** $\mathrm{MgCl_2\,(s)}$

$\mathrm{TiCl_4\,(l) + 2\,Mg\,(s) \longrightarrow 2\,MgCl_2\,(s) + Ti\,(s)}$ $\Delta_r H^\circ = -478.4\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{MgCl_2\,(s)}$

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**Part C** $\mathrm{CH_3COOCOH_3\,(l)}$

$\mathrm{CH_3COOCOCH_3\,(l) + H_2O\,(l) \longrightarrow 2\,CH_3COOH\,(l)}$ $\Delta_r H^\circ = -46\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\circ$ of $\mathrm{CH_3COOCOCH_3\,(l)}$ Give your answer to 4 significant figures.

---

**Part D** $\mathrm{C_6H_5CHCH_2}$

$\mathrm{4\,C_2H_2\,(g) \longrightarrow C_6H_5CHCH_2\,(l)}$, $\Delta_r H^\circ = -808.2\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\circ$ of $\mathrm{C_6H_5CHCH_2}$ Give your answer to 4 significant figures.

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**Part E** $\mathrm{Al_2O_3\,(s)}$

$\mathrm{4\,Al\,(s) + 3\,GeO_2\,(s) \longrightarrow 2\,Al_2O_3\,(s) + 3\,Ge\,(s)}$ $\Delta_r H^\circ = -1698.4\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{Al_2O_3\,(s)}$ Give your answer to 4 significant figures.

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**Part F** $\mathrm{Fe_2O_3}$

$\mathrm{Fe_2O_3\,(s) + 3\,CO\,(g) \longrightarrow 2\,Fe\,(s) + 3\,CO_2\,(g)}$, $\Delta_r H^\circ = -24.8\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{Fe_2O_3}$

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**Part G** $\mathrm{CuO\,(s)}$

$\mathrm{3\,CuO\,(s) + 2\,NH_3\,(g) \longrightarrow 3\,Cu\,(s) + N_2\,(g) + 3\,H_2O\,(l)}$, $\Delta_r H^\circ = -293.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{CuO\,(s)}$ Give your answer to 3 significant figures.

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**Part H** $\mathrm{H_3PO_4\,(s)}$

$\mathrm{2\,PCl_5\,(s) + 8\,H_2O\,(l) \longrightarrow 2\,H_3PO_4\,(s) + 10\,HCl\,(g)}$, $\Delta_r H^\ominus = -307.6\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\ominus$ of $\mathrm{H_3PO_4\,(s)}$ Give your answer to 3 significant figures.

**Part I** $\mathrm{Ga}$

$\mathrm{Ga_2O_3\,(s) + 3\,Mg\,(s) \longrightarrow 2\,Ga\,(s) + 3\,MgO\,(s)}$, $\Delta_r H^\ominus = -716.1\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\ominus$ of $\mathrm{Ga}$.

**Part J** $\mathrm{HCl\,(g)}$

$\mathrm{TiCl_4\,(l) + 2\,H_2O\,(l) \longrightarrow TiO_2\,(s) + 4\,HCl\,(aq)}$, $\Delta_r H^\ominus = -232.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_{sol} H^\ominus$ of $\mathrm{HCl\,(g)}$ Give your answer to 3 significant figures.

# $C_3H_6$ combustion

A Level

**A** and **B** are two isomers with the molecular formula $C_3H_6$. The standard enthalpies of formation, $\Delta_f H^\ominus$, of both **A** and **B** have been found by first measuring the standard enthalpies of combustion, $\Delta_c H^\ominus$, of each. These values are given in the table below, together with the standard enthalpies of combustion of carbon and hydrogen.

| | A | B | carbon | hydrogen |
|---|---|---|---|---|
| $\Delta_c H^\ominus / \text{kJ mol}^{-1}$ | $-2058$ | $-2091$ | $-393.5$ | $-241.8$ |

## Part A Combustion equation

Give the equation for the complete combustion of $C_3H_6$. (Balance it for one mole of the hydrocarbon.)

## Part B $\Delta_f H^\ominus$ of A

Calculate the standard enthalpy of formation of **A**.

## Part C $\Delta_f H^\ominus$ of B

Calculate the standard enthalpy of formation of **B**.

## Part D Isomerisation

Gaseous **B** needs to be stored carefully since it can convert explosively to the elements, to isomer **A**, or to other hydrocarbons. Calculate the standard enthalpy change for the reaction **B** $\longrightarrow$ **A**.

Adapted with permission from the Cambridge Chemistry Challenge 2011, Question 1

# Essential Pre-Uni Chemistry F3.3

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use enthalpies of formation and combustion to calculate the reaction enthalpy for the reaction:
$\mathrm{Ge\,(s) + 2\,H_2O\,(l) \longrightarrow GeO_2\,(s) + 2\,H_2\,(g)}$ Give your answer to 3 significant figures.

# Essential Pre-Uni Chemistry F3.2

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use standard enthalpies of combustion to calculate the reaction enthalpies for the following reactions:

**Part A** **(a)**

$$\mathrm{C_2H_2\,(g) + 2\,H_2\,(g) \longrightarrow C_2H_6\,(g)}$$

**Part B** **(b)**

$C_6H_6\,(l) + 3\,H_2\,(g) \longrightarrow C_6H_{12}\,(l)$

**Part C** **(c)**

$3\,C_2H_2\,(g) \longrightarrow C_6H_6\,(l)$

**Part D** **(d)**

$C_2H_4\,(g) + H_2O\,(l) \longrightarrow C_2H_5OH\,(l)$ Give your answer to 3 significant figures.

**Part E** **(e)**

$C_2H_5OH\,(l) + O_2\,(g) \longrightarrow CH_3COOH\,(l) + H_2O\,(l)$

**Part F** **(f)**

$C_6H_{14}\,(l) \longrightarrow C_2H_6\,(g) + 2\,C_2H_4\,(g)$

**Part G** **(g)**

$C_2H_5OH\,(l) + CH_3COOH\,(l) \longrightarrow CH_3COOC_2H_5\,(l) + H_2O\,(l)$ Give your answer to 2 significant figures.

**Part H** **(h)**

$2\,C_2H_2\,(g) + 2\,H_2O\,(l) + O_2\,(g) \longrightarrow 2\,CH_3COOH\,(l)$

# Essential Pre-Uni Chemistry F3.1

A Level

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use standard enthalpies of formation to calculate the reaction enthalpies for the following reactions. Unless stated otherwise in the question part, give your answers to 4 significant figures.

**Part A** **(a)**

$$\mathrm{2\,TiCl_3\,(s) + Cl_2\,(g) \longrightarrow 2\,TiCl_4\,(l)}$$

**Part B** **(b)**

$\mathrm{PCl_3\,(l) + Cl_2\,(g) \longrightarrow PCl_5\,(s)}$

**Part C** **(c)**

$\mathrm{2\,PCl_3\,(l) + O_2\,(g) \longrightarrow 2\,POCl_3\,(l)}$

**Part D** **(d)**

$\mathrm{CH_4\,(g) + 4\,Cl_2\,(g) \longrightarrow CCl_4\,(l) + 4\,HCl\,(g)}$

**Part E** **(e)**

$\mathrm{2\,GeO\,(s) \longrightarrow Ge\,(s) + GeO_2\,(s)}$

**Part F** **(f)**

$\mathrm{GeO\,(s) + PCl_3\,(l) \longrightarrow Ge\,(s) + POCl_3\,(l)}$. Give your answer to 3 significant figures.

**Part G** **(g)**

$\mathrm{PCl_5\,(s) + 2\,TiCl_3\,(s) \longrightarrow PCl_3\,(l) + 2\,TiCl_4\,(l)}$ Give your answer to 3 significant figures.

**Part H** **(h)**

$\mathrm{20\,Ti\,(s) + 12\,PCl_5\,(s) \longrightarrow 20\,TiCl_3\,(s) + 3\,P_4\,(s)}$ Give you answer to 5 significant figures.

# Essential Pre-Uni Chemistry F3.4

A Level - Practice (P2)

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use the reaction enthalpies given, and the combustion or formation enthalpies above to find the requested enthalpy change in each case:

**Part A** $\mathrm{NH_4Cl\,(s)}$

$\mathrm{NH_3\,(g) + HCl\,(g) \longrightarrow NH_4Cl\,(s)}$, $\Delta_r H^\ominus = -176\,\mathrm{kJ\,mol^{-1}}$ find $\Delta_f H^\ominus$ of $\mathrm{NH_4Cl\,(s)}$

**Part B** $\mathrm{MgCl_2\,(s)}$

$\mathrm{TiCl_4\,(l) + 2\,Mg\,(s) \longrightarrow 2\,MgCl_2\,(s) + Ti\,(s)}$ $\Delta_r H^\circ = -478.4\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{MgCl_2\,(s)}$

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**Part C** $\mathrm{CH_3COOCOH_3\,(l)}$

$\mathrm{CH_3COOCOCH_3\,(l) + H_2O\,(l) \longrightarrow 2\,CH_3COOH\,(l)}$ $\Delta_r H^\circ = -46\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\circ$ of $\mathrm{CH_3COOCOCH_3\,(l)}$ Give your answer to 4 significant figures.

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**Part D** $\mathrm{C_6H_5CHCH_2}$

$\mathrm{4\,C_2H_2\,(g) \longrightarrow C_6H_5CHCH_2\,(l)}$, $\Delta_r H^\circ = -808.2\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\circ$ of $\mathrm{C_6H_5CHCH_2}$ Give your answer to 4 significant figures.

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**Part E** $\mathrm{Al_2O_3\,(s)}$

$\mathrm{4\,Al\,(s) + 3\,GeO_2\,(s) \longrightarrow 2\,Al_2O_3\,(s) + 3\,Ge\,(s)}$ $\Delta_r H^\circ = -1698.4\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{Al_2O_3\,(s)}$ Give your answer to 4 significant figures.

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**Part F** $\mathrm{Fe_2O_3}$

$\mathrm{Fe_2O_3\,(s) + 3\,CO\,(g) \longrightarrow 2\,Fe\,(s) + 3\,CO_2\,(g)}$, $\Delta_r H^\circ = -24.8\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{Fe_2O_3}$

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**Part G** $\mathrm{CuO\,(s)}$

$\mathrm{3\,CuO\,(s) + 2\,NH_3\,(g) \longrightarrow 3\,Cu\,(s) + N_2\,(g) + 3\,H_2O\,(l)}$, $\Delta_r H^\circ = -293.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\circ$ of $\mathrm{CuO\,(s)}$ Give your answer to 3 significant figures.

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**Part H** $\mathrm{H_3PO_4\,(s)}$

$\mathrm{2\,PCl_5\,(s) + 8\,H_2O\,(l) \longrightarrow 2\,H_3PO_4\,(s) + 10\,HCl\,(g)}$, $\Delta_r H^\ominus = -307.6\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_f H^\ominus$ of $\mathrm{H_3PO_4\,(s)}$ Give your answer to 3 significant figures.

---

**Part I** $\mathrm{Ga}$

$\mathrm{Ga_2O_3\,(s) + 3\,Mg\,(s) \longrightarrow 2\,Ga\,(s) + 3\,MgO\,(s)}$, $\Delta_r H^\ominus = -716.1\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_c H^\ominus$ of $\mathrm{Ga}$.

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**Part J** $\mathrm{HCl\,(g)}$

$\mathrm{TiCl_4\,(l) + 2\,H_2O\,(l) \longrightarrow TiO_2\,(s) + 4\,HCl\,(aq)}$, $\Delta_r H^\ominus = -232.3\,\mathrm{kJ\,mol^{-1}}$, find $\Delta_{sol} H^\ominus$ of $\mathrm{HCl\,(g)}$ Give your answer to 3 significant figures.

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# $C_3H_6$ combustion

A Level - Practice (P2)

**A** and **B** are two isomers with the molecular formula $C_3H_6$. The standard enthalpies of formation, $\Delta_f H^\ominus$ , of both **A** and **B** have been found by first measuring the standard enthalpies of combustion, $\Delta_c H^\ominus$, of each. These values are given in the table below, together with the standard enthalpies of combustion of carbon and hydrogen.

| | A | B | carbon | hydrogen |
|---|---|---|---|---|
| $\Delta_c H^\ominus / \mathrm{kJ\,mol^{-1}}$ | $-2058$ | $-2091$ | $-393.5$ | $-241.8$ |

## Part A Combustion equation

Give the equation for the complete combustion of $C_3H_6$. (Balance it for one mole of the hydrocarbon.)

## Part B $\Delta_f H^\ominus$ of A

Calculate the standard enthalpy of formation of **A**.

## Part C $\Delta_f H^\ominus$ of B

Calculate the standard enthalpy of formation of **B**.

## Part D Isomerisation

Gaseous **B** needs to be stored carefully since it can convert explosively to the elements, to isomer **A**, or to other hydrocarbons. Calculate the standard enthalpy change for the reaction **B** $\longrightarrow$ **A**.

Adapted with permission from the Cambridge Chemistry Challenge 2011, Question 1

# Essential Pre-Uni Chemistry F3.3

A Level - Practice (P2)

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use enthalpies of formation and combustion to calculate the reaction enthalpy for the reaction:
$\mathrm{Ge\,(s) + 2\,H_2O\,(l) \longrightarrow GeO_2\,(s) + 2\,H_2\,(g)}$ Give your answer to 3 significant figures.

# Essential Pre-Uni Chemistry F3.2

A Level - Practice (P1)

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use standard enthalpies of combustion to calculate the reaction enthalpies for the following reactions:

**Part A** **(a)**

$$\mathrm{C_2H_2\,(g) + 2\,H_2\,(g) \longrightarrow C_2H_6\,(g)}$$

**Part B** **(b)**

$\mathrm{C_6H_6\,(l) + 3\,H_2\,(g) \longrightarrow C_6H_{12}\,(l)}$

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**Part C** **(c)**

$\mathrm{3\,C_2H_2\,(g) \longrightarrow C_6H_6\,(l)}$

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**Part D** **(d)**

$\mathrm{C_2H_4\,(g) + H_2O\,(l) \longrightarrow C_2H_5OH\,(l)}$ Give your answer to 3 significant figures.

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**Part E** **(e)**

$\mathrm{C_2H_5OH\,(l) + O_2\,(g) \longrightarrow CH_3COOH\,(l) + H_2O\,(l)}$

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**Part F** **(f)**

$\mathrm{C_6H_{14}\,(l) \longrightarrow C_2H_6\,(g) + 2\,C_2H_4\,(g)}$

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**Part G** **(g)**

$\mathrm{C_2H_5OH\,(l) + CH_3COOH\,(l) \longrightarrow CH_3COOC_2H_5\,(l) + H_2O\,(l)}$ Give your answer to 2 significant figures.

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**Part H** **(h)**

$\mathrm{2\,C_2H_2\,(g) + 2\,H_2O\,(l) + O_2\,(g) \longrightarrow 2\,CH_3COOH\,(l)}$

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# Essential Pre-Uni Chemistry F3.1

A Level - Practice (P1)

Data (all in $\mathrm{kJ\,mol^{-1}}$):

| | $\Delta_f H^\ominus$ | | $\Delta_c H^\ominus$ |
|---|---|---|---|
| $\mathrm{CH_4\,(g)}$ | $-74.8$ | $\mathrm{C_6H_6\,(l)}$ | $-3267.4$ |
| $\mathrm{CCl_4\,(l)}$ | $-129.6$ | $\mathrm{H_2\,(g)}$ | $-285.8$ |
| $\mathrm{HCl\,(g)}$ | $-92.3$ | $\mathrm{C_6H_{12}\,(l)}$ | $-3919.5$ |
| $\mathrm{TiCl_4\,(l)}$ | $-804.2$ | $\mathrm{C_2H_2\,(g)}$ | $-1300.8$ |
| $\mathrm{TiCl_3\,(s)}$ | $-720.9$ | $\mathrm{C_2H_6\,(g)}$ | $-1559.7$ |
| $\mathrm{PCl_3\,(l)}$ | $-319.7$ | $\mathrm{C_2H_5OH\,(l)}$ | $-1367.3$ |
| $\mathrm{PCl_5\,(s)}$ | $-443.5$ | $\mathrm{C_2H_4\,(g)}$ | $-1410.8$ |
| $\mathrm{POCl_3\,(l)}$ | $-597.1$ | $\mathrm{CH_3COOH\,(l)}$ | $-874.1$ |
| $\mathrm{GeO\,(s)}$ | $-212.1$ | $\mathrm{C_6H_{14}\,(l)}$ | $-4163.0$ |
| $\mathrm{GeO_2\,(s)}$ | $-551.0$ | $\mathrm{CH_3COOC_2H_5\,(l)}$ | $-2237.9$ |
| $\mathrm{NH_3\,(g)}$ | $-46.1$ | $\mathrm{CO\,(g)}$ | $-283.0$ |
| $\mathrm{TiO_2\,(s)}$ | $-939.7$ | $\mathrm{Mg\,(s)}$ | $-601.7$ |

Use standard enthalpies of formation to calculate the reaction enthalpies for the following reactions. Unless stated otherwise in the question part, give your answers to 4 significant figures.

**Part A** **(a)**

$$\mathrm{2\,TiCl_3\,(s) + Cl_2\,(g) \longrightarrow 2\,TiCl_4\,(l)}$$

**Part B** **(b)**

$\mathrm{PCl_3\,(l) + Cl_2\,(g) \longrightarrow PCl_5\,(s)}$

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**Part C** **(c)**

$\mathrm{2\,PCl_3\,(l) + O_2\,(g) \longrightarrow 2\,POCl_3\,(l)}$

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**Part D** **(d)**

$\mathrm{CH_4\,(g) + 4\,Cl_2\,(g) \longrightarrow CCl_4\,(l) + 4\,HCl\,(g)}$

---

**Part E** **(e)**

$\mathrm{2\,GeO\,(s) \longrightarrow Ge\,(s) + GeO_2\,(s)}$

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**Part F** **(f)**

$\mathrm{GeO\,(s) + PCl_3\,(l) \longrightarrow Ge\,(s) + POCl_3\,(l)}$. Give your answer to 3 significant figures.

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**Part G** **(g)**

$\mathrm{PCl_5\,(s) + 2\,TiCl_3\,(s) \longrightarrow PCl_3\,(l) + 2\,TiCl_4\,(l)}$ Give your answer to 3 significant figures.

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**Part H** **(h)**

$\mathrm{20\,Ti\,(s) + 12\,PCl_5\,(s) \longrightarrow 20\,TiCl_3\,(s) + 3\,P_4\,(s)}$ Give you answer to 5 significant figures.

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# Ethene Combustion

A Level - Practice (P1)

The standard enthalpy change of combustion of but-1-ene, $\mathrm{C_4H_8\,(g)}$, is $x\,\mathrm{kJ\,mol^{-1}}$.

The standard enthalpy change of the reaction $2\,\mathrm{C_2H_4\,(g)} \longrightarrow \mathrm{C_4H_8\,(g)}$ is $y\,\mathrm{kJ\,mol^{-1}}$.

Write down an expression, in terms of $x$ and $y$, for the standard enthalpy change of combustion of ethene, $\mathrm{C_2H_4\,(g)}$ when expressed in $\mathrm{kJ\,mol^{-1}}$ (your answer should not feature any units).

The following symbols may be useful: `x, y`

Adapted with permission from UCLES, A Level Chemistry, November 1993, Paper 4, Question 8

# Formation and Combustion

A Level - Practice (P1)

For which of the following reactions does the value of $\Delta H^{\ominus}$ represent **both** a standard enthalpy change of combustion and a standard enthalpy change of formation?

**1**. $\mathrm{C(s)} + \mathrm{O_2(g)} \longrightarrow \mathrm{CO_2\,(g)}$
**2**. $2\,\mathrm{C(s)} + \mathrm{O_2(g)} \longrightarrow 2\,\mathrm{CO\,(g)}$
**3**. $\mathrm{CO\,(g)} + \frac{1}{2}\,\mathrm{O_2(g)} \longrightarrow \mathrm{CO_2\,(g)}$

- None of the above
- **1** only
- **2** only
- **3** only
- **1** and **2** only
- **1** and **3** only
- **2** and **3** only
- All of the above

Adapted with permission from UCLES, A Level Chemistry, June 1994, Paper 4, Question 31

# Reducing carbon dioxide

A Level - Practice (P1)

The standard enthalpy changes of formation of carbon monoxide and carbon dioxide are $-110\,\mathrm{kJ\,mol^{-1}}$ and $-393\,\mathrm{kJ\,mol^{-1}}$, respectively.

## Part A Carbon monoxide formation

Write an equation, including state symbols, for the first of these enthalpy changes (formation of carbon monoxide).

## Part B Carbon dioxide formation

Write an equation, including state symbols, for the second of these enthalpy changes (formation of carbon dioxide).

## Part C Standard enthalpy change

Use the two standard enthalpy of formation values to calculate, in $\mathrm{kJ\,mol^{-1}}$, the standard enthalpy change of the reaction

$\mathrm{C} + \mathrm{CO_2} \longrightarrow 2\,\mathrm{CO}$

## Part D Condition

In light of the result obtained in the previous part, suggest what condition is necessary to obtain a reasonable yield of carbon monoxide by this reaction.

- Low pressure
- Presence of $O_2$
- Low temperature
- High temperature

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Adapted with permission from UCLES, A Level Chemistry, June 1990, Paper 2, Question 1

# Ethene Combustion

A Level

The standard enthalpy change of combustion of but-1-ene, $\mathrm{C_4H_8\,(g)}$, is $x\,\mathrm{kJ\,mol^{-1}}$.

The standard enthalpy change of the reaction $2\,\mathrm{C_2H_4\,(g)} \longrightarrow \mathrm{C_4H_8\,(g)}$ is $y\,\mathrm{kJ\,mol^{-1}}$.

Write down an expression, in terms of $x$ and $y$, for the standard enthalpy change of combustion of ethene, $\mathrm{C_2H_4\,(g)}$ when expressed in $\mathrm{kJ\,mol^{-1}}$ (your answer should not feature any units).

The following symbols may be useful: `x, y`

Adapted with permission from UCLES, A Level Chemistry, November 1993, Paper 4, Question 8

# Formation and Combustion

A Level

For which of the following reactions does the value of $\Delta H^{\ominus}$ represent **both** a standard enthalpy change of combustion and a standard enthalpy change of formation?

**1**. $\mathrm{C(s)} + \mathrm{O_2(g)} \longrightarrow \mathrm{CO_2\,(g)}$
**2**. $2\,\mathrm{C(s)} + \mathrm{O_2(g)} \longrightarrow 2\,\mathrm{CO\,(g)}$
**3**. $\mathrm{CO\,(g)} + \frac{1}{2}\,\mathrm{O_2(g)} \longrightarrow \mathrm{CO_2\,(g)}$

- None of the above
- **1** only
- **2** only
- **3** only
- **1** and **2** only
- **1** and **3** only
- **2** and **3** only
- All of the above

Adapted with permission from UCLES, A Level Chemistry, June 1994, Paper 4, Question 31

# Reducing carbon dioxide

A Level

The standard enthalpy changes of formation of carbon monoxide and carbon dioxide are $-110\,\mathrm{kJ\,mol^{-1}}$ and $-393\,\mathrm{kJ\,mol^{-1}}$, respectively.

## Part A Carbon monoxide formation

Write an equation, including state symbols, for the first of these enthalpy changes (formation of carbon monoxide).

## Part B Carbon dioxide formation

Write an equation, including state symbols, for the second of these enthalpy changes (formation of carbon dioxide).

## Part C Standard enthalpy change

Use the two standard enthalpy of formation values to calculate, in $\mathrm{kJ\,mol^{-1}}$, the standard enthalpy change of the reaction

$$\mathrm{C} + \mathrm{CO_2} \longrightarrow 2\,\mathrm{CO}$$

## Part D Condition

In light of the result obtained in the previous part, suggest what condition is necessary to obtain a reasonable yield of carbon monoxide by this reaction.

- High temperature
- Low pressure
- Low temperature
- Presence of $O_2$

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Adapted with permission from UCLES, A Level Chemistry, June 1990, Paper 2, Question 1