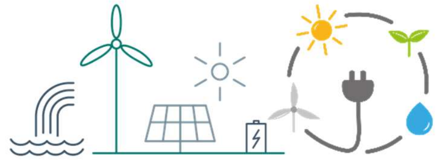
المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة كيمياء في الفصل الأول	
3	مراجعة القسم الأول Energy الطاقة من وحدة and Energy الكيميائية والتغيرات الطاقة Chemical Change
4	مذكرة الوحدة الأولى الطاقة والتغيرات الكيميائية أسئلة الاختبارات الوزارية السابقة
5	تدريبات على الوحدة الأولى الطاقة والتغيرات الكيميائية

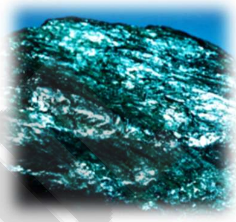
Chapter: Energy & Chemical Change

Section (4): Calculating Enthalpy Change



Sometimes it is impossible or impractical to measure the ΔH of a reaction by using a calorimeter.

<u>For example,</u>



- The conversion of carbon in its allotropic form, diamond, to carbon in its allotropic form, graphite.

$$C\ (s,\ diamond) \rightarrow C\ (s,\ graphite)$$

This reaction occurs so slowly that measuring the enthalpy change is impossible.

- In other cases, some chemical reactions occur in multiple steps that happen concurrently.

$$2\ S\ (s) + 3\ O_2\ (g) \rightarrow 2\ SO_3\ (g) \quad \Delta H = ?$$

Step (1)	$2\ S\ (s) + 2\ O_2\ (g) \rightarrow 2\ SO_2\ (g)$	$\Delta H = -594\ kJ$
Step (2)	$2\ SO_2\ (g) + O_2\ (g) \rightarrow 2\ SO_3\ (g)$	$\Delta H = -198\ kJ$
TOTAL	$2\ S\ (s) + 3\ O_2\ (g) \rightarrow 2\ SO_3\ (g)$	$\Delta H = -792\ kJ$

<u>HESS's LAW</u>

If you can add two or more thermochemical equations to produce a final equation for a reaction, then the <u>sum of the enthalpy changes</u> for the individual reactions is the enthalpy change for the final reaction.

$$\Delta H_{net} = \sum \Delta H_r$$

ΔH_{net} = net change in enthalpy

$\sum \Delta H_r$ = sum change in enthalpy reactions

Examples.

(1) Use Equations (a) and (b) to determine ΔH for the following reaction.

$$2\ CO\ (g) + 2\ NO\ (g) \rightarrow 2\ CO_2\ (g) + N_2\ (g) \quad \Delta H = ?$$

a. $2\ CO\ (g) + O_2\ (g) \rightarrow 2\ CO_2\ (g)$ $\Delta H = -566.0$ kJ

b. $N_2\ (g) + O_2\ (g) \rightarrow 2\ NO\ (g)$ $\Delta H = -180.6$ kJ

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(2) $C_4H_{10}O_{(l)} \rightarrow C_4H_{8(g)} + H_2O_{(g)}$

2-methylpropan-1-ol → *2-methylpropene*

Using the data below, calculate the enthalpy change, in kJ mol^{-1}, for the production of methylpropene from 2-methylpropan-1-ol.

$$4C_{(s)} + 5H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightarrow C_4H_{10}O_{(l)} \quad \Delta H = -335\ kJ\ mol^{-1}$$

$$4C_{(s)} + 4H_{2(g)} \rightarrow C_4H_{8(g)} \quad \Delta H = -17\ kJ\ mol^{-1}$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)} \quad \Delta H = -242\ kJ\ mol^{-1}$$

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(3) Calculate ΔH for the reaction: $C_2H_4\ (g) + H_2\ (g) \rightarrow C_2H_6\ (g)$, using following data:

$C_2H_4\ (g) + 3\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 2\ H_2O\ (l)$ $\Delta H = -1411$ kJ / mole

$H_2\ (g) + \tfrac{1}{2}\ O_2\ (g) \rightarrow H_2O\ (l)$ $\Delta H = -285.8$ kJ / mole

$C_2H_6\ (g) + 7/2\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 3\ H_2O\ (l)$ $\Delta H = -1560.$ kJ / mole

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(4) The equation for the reaction is:

$$CaO_{(s)} + H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)}$$

Using the following data, calculate the enthalpy change, in kJ mol^{-1}, for this reaction

$Ca_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow CaO_{(s)}$ $\Delta H = -635$ kJ mol^{-1}

$H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(\ell)}$ $\Delta H = -286$ kJ mol^{-1}

$Ca_{(s)} + O_{2(g)} + H_{2(g)} \rightarrow Ca(OH)_{2(s)}$ $\Delta H = -986$ kJ mol^{-1}

$Ca(OH)_{2(s)} \rightarrow Ca(OH)_{2(aq)}$ $\Delta H = -82$ kJ mol^{-1}

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(5) ΔH for the following reaction is -1789 kJ. Use this and Equation a to determine ΔH for Equation b.

$4\ Al\ (s) + 3\ MnO_2\ (s) \rightarrow 2\ Al_2O_3\ (s) + 3\ Mn\ (s)$ $\Delta H = -1789$ kJ

(a) $4\ Al\ (s) + 3\ O_2\ (g) \rightarrow 2\ Al_2O_3\ (s)$ $\Delta H = -3352$ kJ

(b) $Mn\ (s) + O_2\ (g) \rightarrow MnO_2\ (s)$ $\Delta H = ?$

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(6) Use Hess's law to determine ΔH for the reaction

$$NO(g) + O(g) \rightarrow NO_2(g)\ \Delta H = ?$$

Given the following reactions.

a. $O_2\ (g) \rightarrow 2O\ (g)$ $\Delta H = -495$ kJ

b. $2O_3\ (g) \rightarrow 3\ O_2\ (g)$ $\Delta H = -427$ kJ

c. $NO\ (g) + O_3\ (g) \rightarrow NO_2\ (g) + O_2\ (g)$ $\Delta H = -199$ kJ

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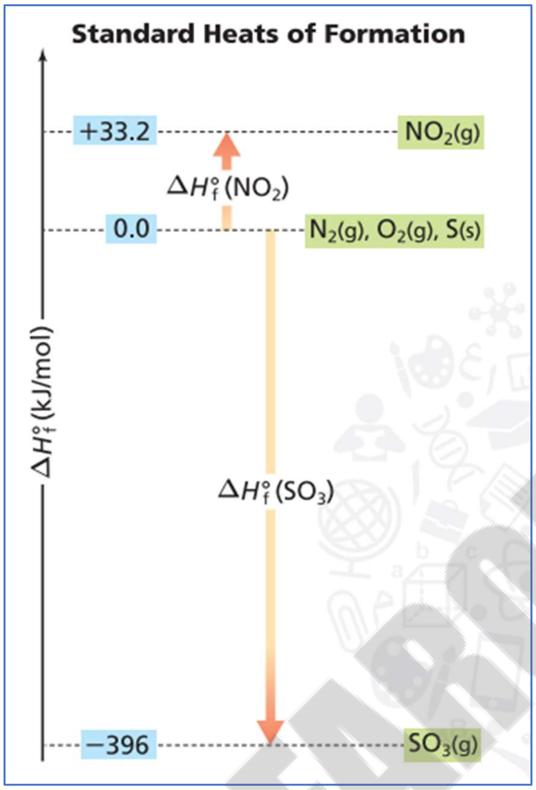
STANDARD ENTHALPY (HEAT) OF FORMATION

The change in enthalpy that accompanies the **formation of one mole** of the compound ***from its elements*** in their standard states.

$$S(s) + \frac{3}{2}O_2(g) \rightarrow SO_3(g) \qquad \Delta H_f^\circ = -396 \text{ kJ}$$

Sulfur Trioxide (SO_3), a suffocating gas that produces acid rain when mixed with moisture in the atmosphere.



Standard Enthalpies of Formation

Compound	Formation Equation	ΔH_f°(kJ/mol)
$H_2S(g)$	$H_2(g) + S(s) \rightarrow H_2S(g)$	−21
$HF(g)$	$\frac{1}{2}H_2(g) + \frac{1}{2}F_2(g) \rightarrow HF(g)$	−273
$SO_3(g)$	$S(s) + \frac{3}{2}O_2(g) \rightarrow SO_3(g)$	−396
$SF_6(g)$	$S(s) + 3F_2(g) \rightarrow SF_6(g)$	−1220

Sulfur hexafluoride (SF_6) is used to manufacture patterns on silicon slides in the production semiconductor electronic devices.

<u>**Exercise:**</u> Use the following formation equations to calculate the ΔH°_{rxn} of the given reaction. $H_2S(g) + 4F_2(g) \rightarrow 2HF(g) + SF_6(g)$ $\Delta H^\circ_{rxn} = ?$

a. $\frac{1}{2}H_2(g) + \frac{1}{2}F_2(g) \rightarrow HF(g) \qquad \Delta H_f^\circ = -273 \text{ kJ}$

b. $S(s) + 3F_2(g) \rightarrow SF_6(g) \qquad \Delta H_f^\circ = -1220 \text{ kJ}$

c. $H_2(g) + S(s) \rightarrow H_2S(g) \qquad \Delta H_f^\circ = -21 \text{ kJ}$

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THE SUMMATION EQUATION

ΔH°_{rxn} can be obtained by subtracting the sum of heats of formation of the reactants from the sum of the heats of formation of the products.

$$\Delta H^\circ_{rxn} = \Sigma \Delta H^\circ_f(\text{products}) - \Sigma \Delta H^\circ_f(\text{reactants})$$

ΔH°_{rxn} represents the standard enthalpy of the reaction.
Σ represents the sum of the terms.
ΔH°_f(products) and ΔH°_f(reactants) represent the standard enthalpies of formation of all the products and all the reactants.

<u>Examples.</u>

(1) Calculate the ΔH°_{rxn} of the following reaction, given the heats of formations of its compounds.

$$X + Y \rightarrow Z + R \qquad \Delta H^\circ_{rxn} = ?$$

Given : $\Delta H^\circ_f(X) = 410$ kJ $\quad \Delta H^\circ_f(Y) = -140$ kJ

$\Delta H^\circ_f(Z) = 570$ kJ $\quad \Delta H^\circ_f(R) = 220$ kJ

$$\Delta H^\circ_{rxn} = \sum \Delta H^\circ_f(\text{products}) - \sum \Delta H^\circ_f(\text{Reactants})$$
$$\Delta H^\circ_{rxn} = [\Delta H^\circ_f(Z) + \Delta H^\circ_f(R)] - [\Delta H^\circ_f(X) + \Delta H^\circ_f(Y)]$$
$$= [(570\text{ kJ}) + (220\text{ kJ})] - [(410\text{ kJ}) + (-140\text{ kJ})]$$
$$= 520\text{ kJ}$$

NOTES :

- Heat of formation of pure elements in their standard states = Zero.
- Heat of formations of compounds are multiplied by their coefficients.

<u>Example</u>

$$H_2S(g) + 4F_2(g) \rightarrow 2HF(g) + SF_6(g)$$

$$\Delta H^\circ_{rxn} = [(2)\Delta H^\circ_f(HF) + \Delta H^\circ_f(SF_6)] - [\Delta H^\circ_f(H_2S) + (4)\Delta H^\circ_f(F_2)]$$
$$\Delta H^\circ_{rxn} = [(2)(-273\text{ kJ}) + (-1220\text{ kJ})] - [-21\text{ kJ} + (4)(0.0\text{ kJ})]$$
$$\Delta H^\circ_{rxn} = -1745\text{ kJ}$$

given

EXERCISES

(1) Use standard enthalpies of formation to calculate $\Delta H°_{rxn}$ for the combustion of methane. $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O\ (l)$

Given that $\Delta H°_f\ (CO_2) = -394$ kJ $\Delta H°_f\ (H_2O) = -286$ kJ $\Delta H°_f\ (CH_4) = -75$ kJ

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(2) calculate $\Delta H°_{rxn}$ for the following reaction.

$$4\ NH_3(g) + 7\ O_2(g) \rightarrow 4\ NO_2(g) + 6\ H_2O\ (l)$$

Given that $\Delta H°_f\ (NH_3) = -45.8$ kJ $\Delta H°_f\ (NO_2) = 33.2$ kJ $\Delta H°_f\ (H_2O) = -286$ kJ

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(3) Two enthalpy of formation equations, (a) and (b) , combine to form the equation for the reaction of nitrogen oxide and oxygen. The product of the reaction is nitrogen dioxide. What is $\Delta H°_f$ for Equation (b)?

$$NO\ (g) + ½\ O_2\ (g) \rightarrow NO_2\ (g) \qquad \Delta H°_{rxn} = -58.1\ kJ$$

a. $½\ N_2(g) + ½\ O_2\ (g) \rightarrow NO\ (g)$ $\Delta H°_f = 91.3$ kJ

b. $½\ N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H°_f = ?$

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(4) Determine $\Delta H°_{comb}$ for butanoic acid,

$$C_3H_7COOH\ (l) + 5\ O_2\ (g) \rightarrow 4\ CO_2(g) + 4\ H_2O\ (l).$$

Use the following data:

$4\ C\ (s) + 4\ H_2\ (g) + O_2\ (g) \rightarrow C_3H_7COOH\ (l)$ $\Delta H°_f = -534$ kJ

$\Delta H°_f\ (H_2O) = -286$ Kj

$\Delta H°_f\ (CO_2) = -394$ kJ

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