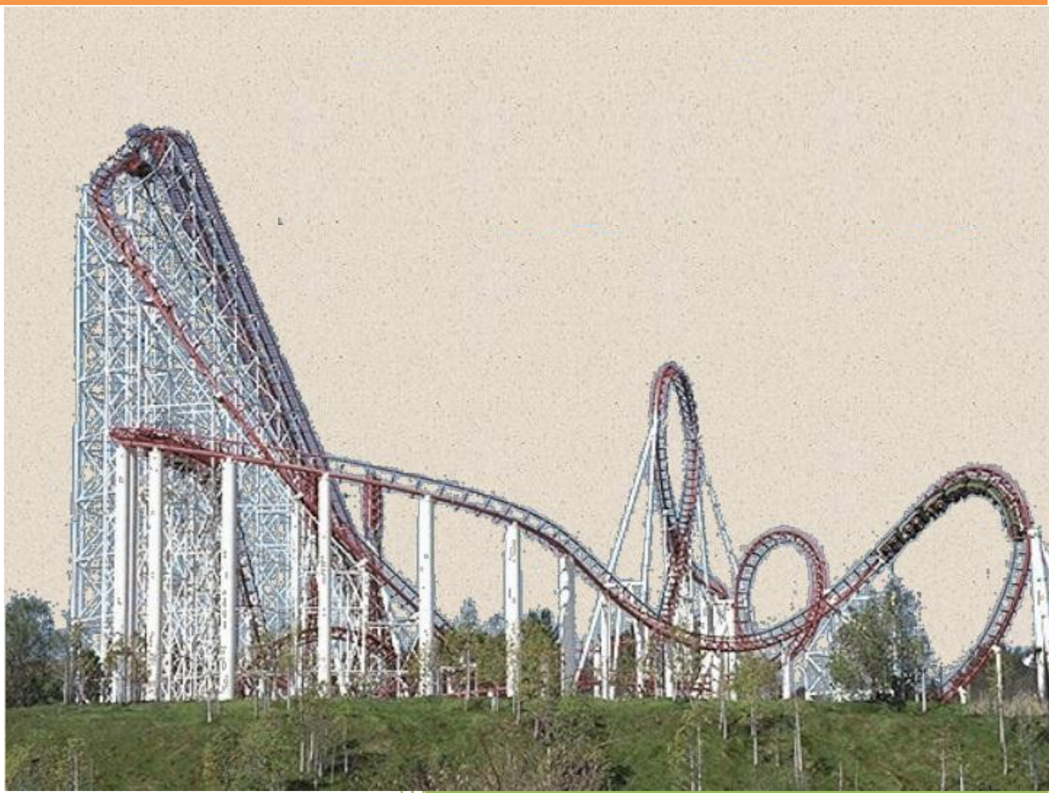
Salam Prep secondary School
Language department
Secondary stage

2020

Hess's law



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Chapter 4

Thermochemistry

Hess's Law

Heat of reaction is a constant amount in standard conditions, whether the reaction is carried out in one step or a number of steps.

Here we have two types of reactions to get the same results

Type 1: reaction carried out in one step

Type 2: reaction carried out in more than one step

The problem here is :

How to get **type 1** (one equation)

from **type 2** (more than one equation)

Note

Any equation consists of two sides

Reactants side and Product side

Note

Hess's law is dealing with the chemical equations as if they were algebraic equations that can be:

* added together
* subtracted from each other
* multiplying their coefficients in a constant factor

When the chemical substance in the opposite side of chemical equation:

The products we need found in the reactants side .

The reactants we need found in the products side

Exercises

By applying Hess's law, calculate the heat of formation of carbon mono oxide CO from the two following equations:

(1) $C_{(g)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\triangle H_1 = -393.5 KJ/mol$

(2) $CO_{(g)} + \frac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)}$ $\triangle H_2 = -283.3 KJ/mol$

Here the product we need is CO

But it lies in the reactants side in equation (2)

to change it from reactants side to products side we need to change its sign from (+) to (-)

by multiplying equation (2) by (-) sign to be –(2)

$$- CO_{(g)} - \frac{1}{2} O_{2(g)} \longrightarrow - CO_{2(g)} \quad \triangle H_2 = - (-283.3 KJ/mol)$$

$$\triangle H_2 = + 283.3 KJ/mol$$

Then we adding the two equations (1) + [- (2)]

$$C_{(g)} + O_{2(g)} \longrightarrow CO_{2(g)} \quad \triangle H_1 = -393.5 \ KJ/mol$$

$$- CO_{(g)} - \frac{1}{2} O_{2(g)} \longrightarrow - CO_{2(g)} \quad \triangle H_2 = + 283.3 \ KJ/mol$$

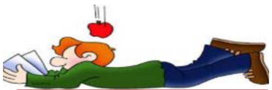
$$C_{(g)} + O_{2(g)} - CO_{(g)} - \frac{1}{2} O_{2(g)} \longrightarrow CO_{2(g)} - CO_{2(g)}$$

$$\triangle H = -393.5 + 283.3$$

$$C_{(g)} + \frac{1}{2}O_{2(g)} - CO_{(g)} \longrightarrow \ldots\ldots\ldots\ldots \quad \triangle H = - 110.2 \ KJ/mol$$

$$C_{(g)} + \frac{1}{2}O_{2(g)} \longrightarrow CO_{(g)} \quad \triangle H = - 110.2 \ KJ/mol$$

This is the required reaction for formation of carbon monoxide CO



Exercises

Calculate the heat of combustion of nitric oxide NO in the following equations:

$$NO_{(g)} + \frac{1}{2}O_2 \longrightarrow NO_2$$

By knowing the two following equations:

$$(1)\quad \frac{1}{2} N_{2\,(g)} + \frac{1}{2}O_{2\,(g)} \longrightarrow NO_{(g)} \qquad \triangle H_1 = +90.29 \text{ KJ/mol}$$

$$(2)\quad \frac{1}{2} N_{2\,(g)} + O_{2\,(g)} \longrightarrow NO_{2\,(g)} \qquad \triangle H_2 = +33.2 \text{ KJ/mol}$$

Here the reactant we need is NO

But it lies in the products side in equation (1)

to change it from products side to reactants side we need to change its sign from (+) to (-)

by multiplying equation (1) by (-) sign to be –(1)

$$- \frac{1}{2} N_{2\,(g)} - \frac{1}{2}O_{2\,(g)} \longrightarrow - NO_{(g)} \qquad \triangle H_1 = - (+90.29 \text{ KJ/mol})$$

Then we adding the two equations [- (1)] + (2)

$$- \frac{1}{2} N_{2\,(g)} - \frac{1}{2}O_{2\,(g)} \longrightarrow - NO_{(g)} \qquad \triangle H_1 = - (+90.29 \text{ KJ/mol})$$

$$\frac{1}{2} N_{2\,(g)} + O_{2\,(g)} \longrightarrow NO_{2\,(g)} \qquad \triangle H_2 = +33.2 \text{ KJ/mol}$$

$$- \frac{1}{2} N_{2\,(g)} - \frac{1}{2}O_{2\,(g)} + \frac{1}{2} N_{2\,(g)} + O_{2\,(g)} \longrightarrow - NO_{(g)} + NO_{2\,(g)}$$

$$\triangle H = - (+90.29) + 33.2$$

$$\frac{1}{2}O_{2\,(g)} \longrightarrow - NO_{(g)} + NO_{2\,(g)}$$

$$\triangle H = -57.09 \text{ KJ/mol}$$

$$\frac{1}{2}O_{2\,(g)} + NO_{(g)} \longrightarrow NO_{2\,(g)} \qquad \triangle H = -57.09 \text{ KJ/mol}$$

This is the required reaction for combustion of nitric oxide N

Case 2

When the chemical substance in the opposite side of chemical equation:

With difference in coefficients:

Exercises

What is the value of $\triangle H$ of the reaction:

$$Na_2O_{(s)} + H_2O_{(\ell)} \longrightarrow 2\ NaOH_{(s)}$$

By knowing the two following equations:

(1) $H_{2(g)} + {}^{1}/_{2}\ O_{2(g)} \longrightarrow H_2O_{(\ell)}$ $\triangle H_1 = -286$ KJ

(2) $2Na_{(s)} + {}^{1}/_{2}\ O_{2(g)} \longrightarrow Na_2O_{(s)}$ $\triangle H_2 = -414$ KJ

(3) $Na_{(s)} + {}^{1}/_{2}\ O_{2(g)} + {}^{1}/_{2}\ H_{2(g)} \longrightarrow NaOH_{(s)}$ $\triangle H_3 = -425$ KJ

Here the reactants we need are $Na_2O_{(s)}$ and $H_2O_{(\ell)}$

$Na_2O_{(s)}$ is a product in equation (2) with the same coefficient

And $H_2O_{(\ell)}$ is a product in equation (1) with the same coefficient

To change $Na_2O_{(s)}$ and $H_2O_{(\ell)}$ from products side to reactants side

we need to change their sign from (+) to (-)

by multiplying equations (1) and (2) by (-) sign to becomes:

$- H_{2(g)} - {}^{1}/_{2}\ O_{2(g)} \longrightarrow - H_2O_{(\ell)}$ $\triangle H_1 = -(-286$ KJ)

$- 2Na_{(s)} - {}^{1}/_{2}\ O_{2(g)} \longrightarrow - Na_2O_{(s)}$ $\triangle H_2 = -(-414$ KJ)

While the product we need is $2\ NaOH_{(s)}$

NaOH is a product in equation (3) but with different coefficient

So we need to change the coefficient of NaOH by

multiplying equation (3) by (2) to becomes:

$2\ [\ Na_{(s)} + {}^{1}/_{2}\ O_{2(g)} + {}^{1}/_{2}\ H_{2(g)} \longrightarrow NaOH_{(s)}$ $\triangle H_3 = -425$ KJ]

$2\ Na_{(s)} + O_{2(g)} + H_{2(g)} \longrightarrow 2NaOH_{(s)}$ $\triangle H_3 = 2\ (-425$ KJ)

$\triangle H_3 = -850$ KJ

Then we adding the three equations $-$(1) and $-$(2) and (3)(after multiplying by 2)

$$-\ H_{2\,(g)} - \tfrac{1}{2}\,O_{2\,(g)} \longrightarrow -\ H_2O_{(\ell)} \qquad \triangle H_1 = -\,(-286\ KJ)$$

$$-\ 2Na_{(s)} - \tfrac{1}{2}\,O_{2\,(g)} \longrightarrow -\ Na_2O_{(s)} \qquad \triangle H_2 = -\,(-414\ KJ)$$

$$2\,Na_{(s)} + O_{2\,(g)} + H_{2\,(g)} \longrightarrow 2NaOH_{(s)} \qquad \triangle H_3 = -\,850\ KJ$$

$$-\ H_{2\,(g)} - \tfrac{1}{2}\,O_{2\,(g)} - 2Na_{(s)} - \tfrac{1}{2}\,O_{2\,(g)} + 2\,Na_{(s)} + O_{2\,(g)} + H_{2\,(g)}$$
$$\longrightarrow -\ H_2O_{(\ell)} - Na_2O_{(s)} + 2NaOH_{(s)}$$

$$\triangle H = -\,(-286\ KJ) - (-414\ KJ) - 850\ KJ$$
$$= +\,286 + 414 - 850 = -\,150\ KJ$$

$$\ldots\ldots\ldots \longrightarrow -\ H_2O_{(\ell)}\ -\ Na_2O_{(s)} + 2NaOH_{(s)}$$

$$H_2O_{(\ell)} + Na_2O_{(s)} \longrightarrow 2NaOH_{(s)} \qquad \triangle H = -\,150\ KJ$$

This is the thermochemical equation represents the formation of $NaOH_{(s)}$

The bird who dare to fall
is the bird who learn to fly