

Hess's Law and the Additivity of Heats

Hess's Law: The value of ΔH for any reaction that can be written in steps equals the sum of the values of ΔH for the individual steps.

Method 1: Additivity of Heats

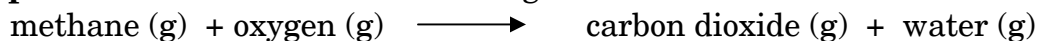
1. Identify the target equation and balanced it (if not given).
2. Identify the individual step equations. These are provided or are found on a Table of Heats of Formation.
3. Reverse any step equations so that the position of reactants/products matches that of the target equation. If an equation is reversed, also reverse the sign of ΔH for the step equation.
4. Multiply the step equations by the appropriate coefficient to match those in the target equation. Also multiply the ΔH by the same coefficient.
5. Add up the modified step equations and their ΔH values. The sum of the modified individual step equation should be identical to the target equation.

Heats (Enthalpy Change) of Formation

Elements	Formula	Name	ΔH (kJ/mol)
$\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$	$\rightarrow \text{H}_2\text{O}(\text{g})$	water vapour	- 241.8
$\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$	$\rightarrow \text{H}_2\text{O}(\text{l})$	water	- 285.8
$\text{S}(\text{s}) + \frac{1}{2} \text{O}_2(\text{g})$	$\rightarrow \text{SO}_2(\text{g})$	sulfur dioxide	- 296.8
$\text{S}(\text{s}) + \frac{3}{2} \text{O}_2(\text{g})$	$\rightarrow \text{SO}_3(\text{g})$	sulfur trioxide	-395.7
$\text{H}_2(\text{g}) + \text{S}(\text{s}) + 2\text{O}_2(\text{g})$	$\rightarrow \text{H}_2\text{SO}_4(\text{l})$	sulfuric acid	- 811.7
$\frac{1}{2} \text{N}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g})$	$\rightarrow \text{NO}(\text{g})$	nitric oxide	+ 90.25
$\frac{1}{2} \text{N}_2(\text{g}) + \text{O}_2(\text{g})$	$\rightarrow \text{NO}_2(\text{g})$	nitrogen dioxide	+ 33.18
$\frac{1}{2} \text{N}_2(\text{g}) + \frac{3}{2} \text{H}_2(\text{g})$	$\rightarrow \text{NH}_3(\text{g})$	ammonia	- 46.11
$\text{C}(\text{s}) + \frac{1}{2} \text{O}_2(\text{g})$	$\rightarrow \text{CO}(\text{g})$	carbon monoxide	- 110.5
$\text{C}(\text{s}) + \text{O}_2(\text{g})$	$\rightarrow \text{CO}_2(\text{g})$	carbon dioxide	- 393.5
$\text{C}(\text{s}) + 2\text{H}_2(\text{g})$	$\rightarrow \text{CH}_4(\text{g})$	methane	- 74.81
$2\text{C}(\text{s}) + 3\text{H}_2(\text{g})$	$\rightarrow \text{C}_2\text{H}_6(\text{g})$	ethane	- 84.68
$3\text{C}(\text{s}) + 4\text{H}_2(\text{g})$	$\rightarrow \text{C}_3\text{H}_8(\text{g})$	propane	- 103.8
$\frac{1}{2} \text{H}_2(\text{g}) + \frac{1}{2} \text{I}_2(\text{g})$	$\rightarrow \text{HI}(\text{g})$	hydrogen iodide	+ 25.9
$4\text{C}(\text{s}) + 4\text{H}_2(\text{g}) + \text{O}_2(\text{g})$	$\rightarrow \text{C}_3\text{H}_7\text{COOH}(\text{l})$	butyric acid	- 522.1
$2\text{C}(\text{s}) + 2\text{H}_2(\text{g}) + \text{O}_2(\text{g})$	$\rightarrow \text{CH}_3\text{COOH}(\text{l})$	acetic acid	- 486.6

Method 1: Additivity of Heats (continued)

Example: Determine ΔH for the following reaction:

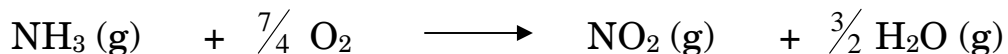
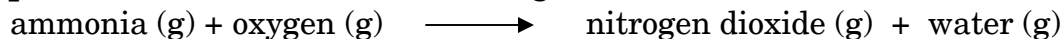


Method 2: Summation of Heats

Identify the $\Delta H_{\text{formation}}$ for each product and reactant and solve using the equation:

$$\Delta H = \sum (n\Delta H_{\text{form}}(\text{products})) - \sum (n\Delta H_{\text{form}}(\text{reactants}))$$

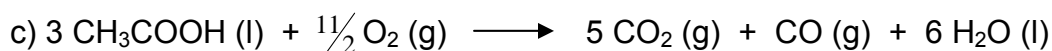
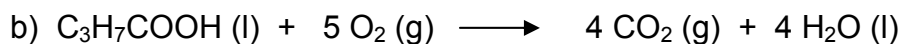
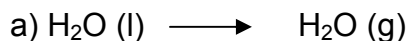
Example: Determine ΔH for the following reaction:



Hess's Law and Additivity of Heats

Complete these questions using the Additivity of Heats method. Refer to the Table of Heats of Formation for the individual step equations.

1. Calculate ΔH for each of the following:



2. a) Write a balanced equation for the combustion of propane gas (C_3H_8) to produce carbon dioxide and water vapour.

b) Add equations and heats of formation to calculate the ΔH for the combustion of 1.00 mol of propane.

Answers: 1 a) 44.0 kJ/mol
 b) -2195 kJ/mol
 c) -2333 kJ/mol
 2 -2044 kJ

Do the following problems using the Summation of Heats method.

1. Predict the heat of reaction for:

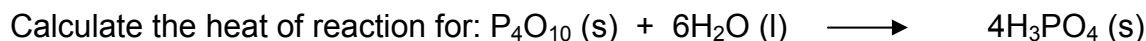


2. Given that ΔH_{form} for $\text{SiO}_2 (\text{s})$ is -856.9 kJ/mol , what is the ΔH for:



3. What is the heat of formation of $\text{H}_2\text{SO}_4 (\text{l})$ from $\text{H}_2\text{O} (\text{l})$ and $\text{SO}_3 (\text{g})$?

4. Given: ΔH_{form} for $\text{P}_4\text{O}_{10} (\text{s}) = -3009.5 \text{ kJ/mol}$
 ΔH_{form} for $\text{H}_3\text{PO}_4 (\text{s}) = -1266.5 \text{ kJ/mol}$



Answers: 1. - 802.3 kJ/mol
 2. + 463.4 kJ/mol
 3. - 130.2 kJ/mol
 4. - 342 kJ/mol