Edgenuity

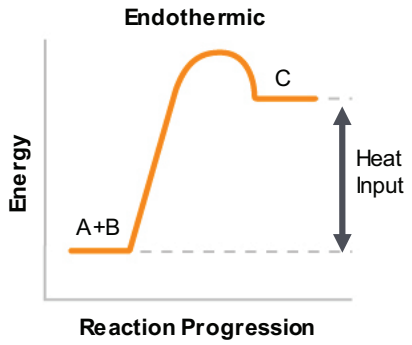
Warm-Up | Thermochemical Equations

Endothermic and Exothermic Reactions

- ***endo-***: into or inside
- exo- : out of or outside
- therm- : of or relating to heat

So:

- **endothermic**: input/absorption of heat



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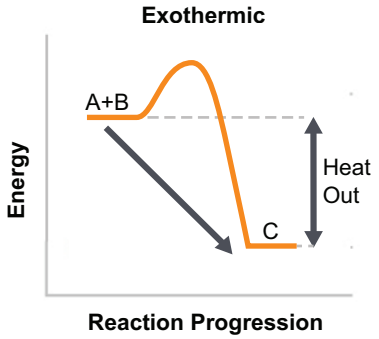
- ***therm-***: of or relating to heat

So:

- **endothermic**: input/absorption of heat
- **exothermic**: output/ release of heat



Lesson Objectives

By the end of this lesson, you should be able to:

- Understand the use of enthalpy in thermochemistry .
- Use thermochemical equations to calculate energy changes (i.e., enthalpy changes) that occur in a chemical reaction.
- Use thermochemical equations to calculate energy changes (i.e., enthalpy changes) that occur in a combustion reaction.

Science Practice: Examine books and other sources of information to find standard enthalpies of formation to solve thermochemical problems.

Warm-Up | Thermochemical Equations

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

B	enthalpy of combustion (ΔH_{comb})	A. a measure of heat and internal energy in a system
C	state function	B. the enthalpy of reaction for a combustion reaction, typically of a hydrocarbon
A	enthalpy (H)	C. a quantity whose change in magnitude during a process depends only on the beginning and end points of the process, not on the path taken between them
G	enthalpy of formation (ΔH_f)	D. the chemical equation that shows the state of each substance involved and the energy change involved in a reaction
F	enthalpy of reaction (ΔH_{rxn})	E. the natural state of an element at 1 atm and 25°C
D	thermochemical equation	F. the energy absorbed or released during a chemical reaction
E	standard state	G. the energy absorbed or released when a pure substance forms from elements in their standard states

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Lesson Question

How can the amount of heat absorbed or released in a chemical reaction be calculated and expressed?

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Enthalpy

- Bonds contain [potential] energy.
- Breaking and forming [bonds] involve energy.
- Reactants and products contain energy.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

Reactants: high energy

Products: low energy

- **Enthalpy (*H*)** is a measure of heat and internal [energy] in a system.

State Functions

- A **state function** is a quantity whose change in magnitude during a process depends only on the beginning and end points of the process, not on the [path] taken between them.
- [Enthalpy] change during reaction depends only on the identity of [reactants] and products and their initial and final conditions.

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Slide 2

Enthalpy of Formation

- **Enthalpy of formation (ΔH_f)** is energy absorbed or released when a [pure] substance forms from [elements] in their standard states.
  - Units: kJ/mol, kcal/mol
- **Standard state** is the natural state of an element at [1 atm] and 25°C.
  - ΔH_f for a pure element in its standard state is [0 kJ/mol].
  - Locate ΔH_f for other substances in the chart.

Element	Standard State
H	$H_2(g)$
N	$N_2(g)$
O	$O_2(g)$
F	$F_2(g)$
Cl	$Cl_2(g)$
Br	$Br_2(l)$
Hg	Hg(l)
noble gases	gaseous

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Enthalpy of Reaction

- **Enthalpy of reaction (ΔH_{rxn})** is energy absorbed or released during a [chemical] reaction.
- ΔH_{rxn} [negative]: exothermic reaction
- ΔH_{rxn} positive: endothermic reaction
- Hess's Law:

$$\Delta H_{rxn} = \sum\left(\Delta H_{f,\,products}\right) - \sum\left(\Delta H_{f,\,reactants}\right)$$

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Enthalpy of Reaction

Thermochemical **equation** is a chemical equation that shows the state of each substance involved and the energy change involved in a reaction.

Calculating Enthalpy of Reaction

Iron (III) oxide (Fe_2O_3 (s), $\Delta H_f = -826$ kJ/mol) can react with aluminum powder to form aluminum oxide (Al_2O_3 (s), $\Delta H_f = -1675.7$ kJ/mol) and iron according to this equation:

$$Fe_2O_3(s) + 2\,Al(s) \rightarrow Al_2O_3(s) + 2\,Fe(s)$$

What is ΔH_{rxn} for this reaction?

- Calculate the total enthalpy of formation of the reactants.

$1(-826\text{ kJ/mol } Fe_2O_3(s)) + 2(0\text{ kJ/mol } Al(s)) =$ −826 kJ

- Calculate the total enthalpy of the products.

$1(-1675.7\text{ kJ/mol}) + 2(0\text{ kJ/mol}) =$ −1675.7 kJ

- Calculate the enthalpy of reaction.

$-1675.7 - (-826) =$ −849.7 kJ

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Slide 7

Manipulating Equations

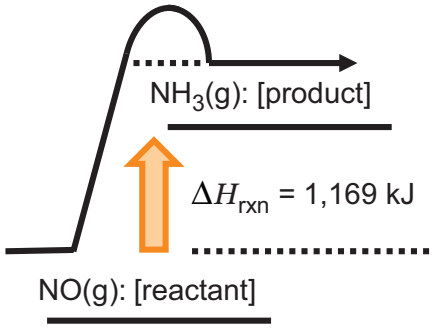
$4NO(g) + 6H_2O(l) \rightarrow 4NH_3(g) + 5O_2(g)$

$NO(g)$: $\Delta H_f = 90.37$ kJ/mol

$H_2O(l)$: $\Delta H_f = -285.8$ kJ/mol

$NH_3(g)$: $\Delta H_f = -46.19$ kJ/mol

$O_2(g)$: $\Delta H_f = 0$ kJ/mol



$4(90.37) + 6(-285.8) \rightarrow 4(-46.19) + 5(0)$

Products $\rightarrow$ -184.76 kJ

$-$Reactants $\rightarrow$ -1353.32 kJ

1169 kJ

Manipulating Equations

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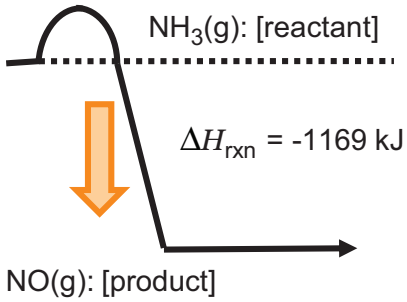
- Reverse equation: reverse sign of ΔH_{rxn}



$4(-46.19) + 5(0) \rightarrow 4(90.37) + 6(-285.8)$

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Instruction | Thermochemical Equations

Slide 7

Manipulating Equations

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$ $\Delta H_{rxn} = -1{,}170$ kJ

- Multiply equation by [coefficient]: multiply [ΔH_{rxn}] by same coefficient

$2NH_3(g) +$ [2.5] $O_2(g) \rightarrow 2NO(g) + 3H_2O(l)$ $\Delta H_{rxn} = -584.5$ kJ

$8NH_3(g) + 10O_2(g) \rightarrow$ [8] $NO(g) + 12H_2O(l)$ $\Delta H_{rxn} = -2{,}340$ kJ

Slide 10

Enthalpy of Combustion

- **Enthalpy of combustion (ΔH_{comb})** is the enthalpy of reaction for a combustion reaction, typically of a [hydrocarbon].
  - Values are tabulated.
- Units: kJ/mol, [kcal/mol]

Calculating Enthalpy of Combustion

What is the enthalpy of combustion for ethane ($C_2H_6(g)$, $\Delta H_f = -84.68$ kJ/mol)? The enthalpies of formation for $CO_2(g)$ and $H_2O(g)$ are –393.5 kJ/mol and –241.82 kJ/mol, respectively.

- Write the [balanced] chemical equation.

$2C_2H_6 + 7O2 \rightarrow$ [4] $CO_2 +$ [6] H_2O

Instruction | Thermochemical Equations

Slide 10

Calculating Enthalpy of Combustion

- Calculate the total [enthalpy] of formation of the reactants.

$$\Delta H_{\text{f, reactants}} = 2(-84.68\ \text{kJ/mol}) + 7(0\ \text{kJ/mol})$$
$$= [-169.36]\ \text{KJ/mol}$$

- Calculate the total enthalpy of the [products].

$$\Delta H_{\text{f, products}} = 4(-393.5\ \text{kJ/mol}) + 6(-241.82\ \text{kJ/mol})$$
$$= [-3024.92]\ \text{KJ/mol}$$

- Calculate the enthalpy of reaction.

$$\Delta H_{\text{comb}} = \sum\left(\Delta H_{\text{f, products}}\right) - \sum\left(\Delta H_{\text{f, reactants}}\right)$$
$$= [-3024.92]\ \text{KJ/mol} - [-169.36]\ \text{KJ/mol}$$
$$= 2{,}855.56\ \text{kJ/mol}$$

- Convert to a value for [1 mol] C_2H_6.

$$-2855/2 = 1{,}428\ \text{kJ/mol}$$

Summary | Thermochemical Equations

Lesson Question

How can the amount of heat absorbed or released in a chemical reaction be calculated and expressed?

Answer

(Sample answer) Enthalpy is defined as the measure of the total energy of the system and is represented by the symbol capital *H*. It is a state function. Enthalpy of reaction is calculated by having the sum of ΔH for all the products minus the sum of ΔH of formation for all of the reactants.

Slide 2

Enthalpy

- Enthalpy is a measure of the total energy of a system. It is represented by the symbol [H].
- Enthalpy is a state function, which means the change in enthalpy during a process depends only on the initial and final states of the system, not on the path taken between them.
- Enthalpy of formation (ΔH_f) is the energy absorbed or released when a substance forms from pure elements in their standard states.
- Standard state is the natural form of an element at 1 atm and [25°C].
- The enthalpy of formation of an element in its standard state is defined as zero.

Summary | Thermochemical Equations

Slide 2

Enthalpy of Reaction

- Enthalpy of reaction (ΔH_{rxn}) is the total energy absorbed or released during the reaction.
- Enthalpy of reaction is calculated using the following equation:

$$\Delta H_{rxn} = \Sigma\left(\Delta H_{f,\,products}\right) - \Sigma\left(\Delta H_{f,\,reactants}\right)$$

- When $\Delta H_{rxn} > 0$, the reaction is endothermic.
- When $\Delta H_{rxn} < 0$, the reaction is exothermic.
- Enthalpy of combustion (ΔH_{comb}) is the enthalpy of reaction for the complete combustion of 1 mol of a substance, typically a hydrocarbon.

Use this space to write any questions or thoughts about this lesson.