

Definitions

I. Energy ():

II. Heat ():

III. Reaction perspectives:

A. System:

B. Surroundings:

IV: Heat changes:

A. Exothermic: Energy is . The of the while the of the

B. Endothermic: Energy is The of the while the of the

Property	Exothermic	Endothermic
Energy		
System temp.		
Surr. temp.		

V. Units:

A.

VI. State function:

A. The property of a system determined by

B. Independent of how the system reached that state.

C. Examples:

D. These are measured using the change from a system's initial and final states.



Measuring Heat Flow

I. Heat capacity (C):

()

A. Units: or

B. Specific heat ():

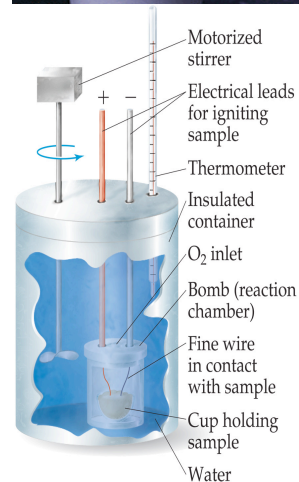
C. Molar heat capacity (Cmolar):

II. Calorimetry:

A. Equation: or

1.

2.



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3.

4.

C. First law of thermodynamics ()::

D. $c_{\text{water}} =$ or

III. Measured using a

A. Coffee cup calorimeter ()

B. Bomb calorimeter ()

C. In calorimetry calculations, always take the
(unless noted).

Example

(a) How much heat is needed to warm 250 g of water (about 1 cup) from 22°C (about room temperature) to near its boiling point, 98°C? The specific heat of water is 4.18 J/g-K.

(b) What is the molar heat capacity of water?

Practice (a) Large beds of rocks are used in some solar-heated homes to store heat. Assume that the specific heat of the rocks is 0.082 J/g-K. Calculate the quantity of heat absorbed by 50.0 kg of rocks if their temperature increases by 12.0°C. **(b)** What temperature change would these rocks undergo if they emitted 450 kJ of heat?

Answers: **(a)** 4.9×10^4 J, **(b)** 110 K = 110°C decrease

Enthalpy

I. Enthalpy (H) :

A. State function: we care about change in H (ΔH), not H because

B. At constant pressure,

1. Sign of ΔH ()

a.

b.

2.

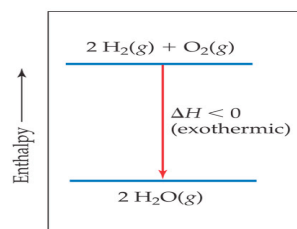
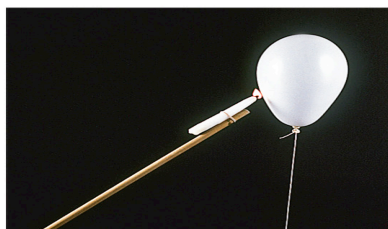
3. It is () (1st law).

(2nd law).

C. A change of state involves a . $\text{H}_2\text{O}(s) \rightarrow \text{H}_2\text{O}(l)$ $\Delta H =$

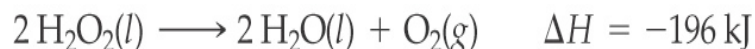
D. Enthalpy of reaction: measures the ΔH of a reaction.

1.

**Example:**

How much heat is released when 4.50 g of methane gas is burned in a constant-pressure system?

Hydrogen peroxide can decompose to water and oxygen by the following reaction:



Calculate the value of q when 5.00 g of $\text{H}_2\text{O}_2(l)$ decomposes at constant pressure.

Answer: -14.4 kJ

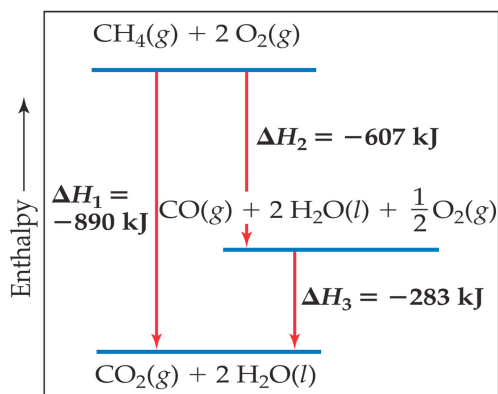
II. Hess's Law (3rd Law)

A. States that the

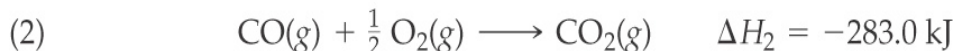
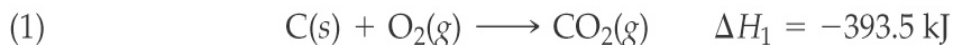
B. Thus,

C. When calculating...

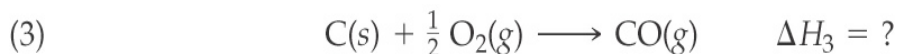
1. ()!
2. ()!

**Example!**

1. The enthalpy of reaction for the combustion of C to CO₂ is -393.5 kJ/mol C , and the enthalpy for the combustion of CO to CO₂ is -283.0 kJ/mol CO :



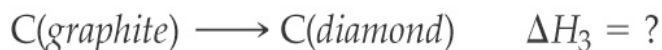
Using these data, calculate the enthalpy for the combustion of C to CO:

**Example!**

Carbon occurs in two forms, graphite and diamond. The enthalpy of the combustion of graphite is -393.5 kJ/mol and that of diamond is -395.4 kJ/mol :



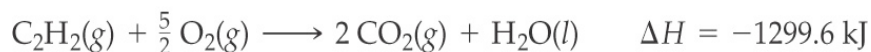
Calculate ΔH for the conversion of graphite to diamond:



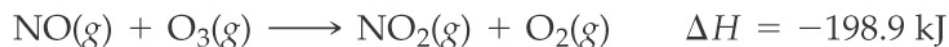
Answer: $\Delta H_3 = +1.9 \text{ kJ}$

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2. Calculate ΔH for the reaction $2\text{C}(s) + \text{H}_2(g) \longrightarrow \text{C}_2\text{H}_2(g)$ given the following chemical equations and their respective enthalpy changes:



Calculate ΔH for the reaction $\text{NO}(g) + \text{O}(g) \longrightarrow \text{NO}_2(g)$ given the following information:



Answer: -304.1kJ

III. Enthalpy of formation ()

A. MEMORIZE:

B. Dependent on

C. New thermo standard!!!

1. Standard state ():

2. If "standard state" is mentioned,

3. Standard enthalpy of formation ():

D. Many ΔH_f° values have been measured so you can find ΔH° using ΔH_f° values and Hess's Law.

E. REMEMBER:

F. NOTE: the ΔH_f° for

(ex.)

G. Mind your

H. Note: an equation of formation needs to have r

I. Refer to p. 635-636

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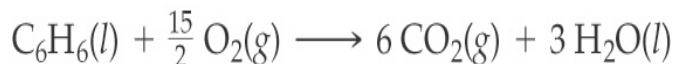
TABLE 5.3 Standard Enthalpies of Formation, ΔH_f° , at 298 K

Substance	Formula	ΔH_f° (kJ/mol)	Substance	Formula	ΔH_f° (kJ/mol)
Acetylene	$C_2H_2(g)$	226.7	Hydrogen chloride	$HCl(g)$	-92.30
Ammonia	$NH_3(g)$	-46.19	Hydrogen fluoride	$HF(g)$	-268.60
Benzene	$C_6H_6(l)$	49.0	Hydrogen iodide	$HI(g)$	25.9
Calcium carbonate	$CaCO_3(s)$	-1207.1	Methane	$CH_4(g)$	-74.80
Calcium oxide	$CaO(s)$	-635.5	Methanol	$CH_3OH(l)$	-238.6
Carbon dioxide	$CO_2(g)$	-393.5	Propane	$C_3H_8(g)$	-103.85
Carbon monoxide	$CO(g)$	-110.5	Silver chloride	$AgCl(s)$	-127.0
Diamond	$C(s)$	1.88	Sodium bicarbonate	$NaHCO_3(s)$	-947.7
Ethane	$C_2H_6(g)$	-84.68	Sodium carbonate	$Na_2CO_3(s)$	-130.9
Ethanol	$C_2H_5OH(l)$	-277.7	Sodium chloride	$NaCl(s)$	-410.9
Ethylene	$C_2H_4(g)$	52.30	Sucrose	$C_{12}H_{22}O_{11}(s)$	-2221
Glucose	$C_6H_{12}O_6(s)$	-1273	Water	$H_2O(l)$	-285.8
Hydrogen bromide	$HBr(g)$	-36.23	Water vapor	$H_2O(g)$	-241.8

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Example!

Calculate the standard enthalpy change for the combustion of 1 mol of benzene, $C_6H_6(l)$, to $CO_2(g)$ and $H_2O(l)$.



Example!

The standard enthalpy change for the reaction $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ is 78.1 kJ. From the values for the standard enthalpies of formation of $CaO(s)$ and $CO_2(g)$ given calculate the standard enthalpy of formation of $CaCO_3(s)$.

IV. Enthalpy of combustion ()

A. MEMORIZE:

B. Also dependent on

C. Standard enthalpy of combustion ():

D. Conceptually,

E. ΔH_c involves

F. You will need to remember how to write combustion reactions: Ex...

V. Bond enthalpies (units:)

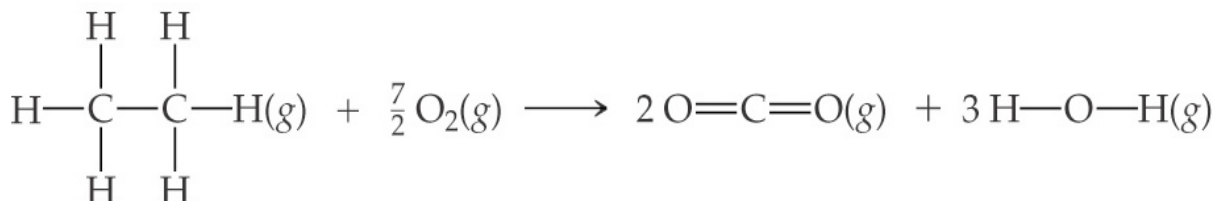
A. Definition:

B. Refer to Table 8.4 on p. 211.

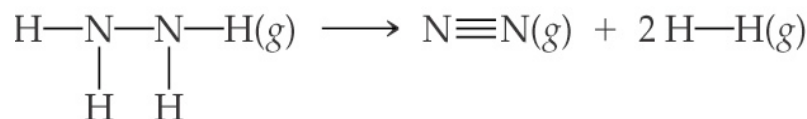
C. Same concept:

D. Example:

Estimate ΔH for the following reaction (where we explicitly show the bonds involved in the reactants and products):



Estimate ΔH for the reaction



Answer: -86 kJ

VI. Born-Haber Cycle (a neat summary...)

A. Thermochemical cycle used to analyze stability of ionic compounds.

B. Consider: $\text{Na}(\text{s}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{NaCl}(\text{s}) \quad \Delta H = -411 \text{ kJ}$

C. FYI: $\text{Na}(\text{s}) \rightarrow \text{Na}(\text{g}) \quad \Delta H = 108 \text{ kJ}$

$\frac{1}{2}\text{Cl}_2(\text{g}) \rightarrow \text{Cl}(\text{g}) \quad \Delta H = 122 \text{ kJ}$

$\text{Na}(\text{g}) \rightarrow \text{Na}^+(\text{g}) + \text{e}^- \quad \Delta H = 496 \text{ kJ}$ (1st IE)

$\text{Cl}(\text{g}) + \text{e}^- \rightarrow \text{Cl}^-(\text{g}) \quad \Delta H = -349 \text{ kJ}$ (EA)

D. What is $\Delta H_{\text{lattice}}$? $\text{Na}^+(\text{g}) + \text{Cl}^-(\text{g}) \rightarrow \text{NaCl}(\text{s})$

