Thermochemistry Ch. 8

Definitions

I. Energy (__): _____
II. Heat (__): _____
A. Heat is not a substance. Objects do not contain heat, they _____ _____
B. Molecules _____ with each other.
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. Work: _____ an object a certain _____.
A. Can be converted to heat energy.
B. Includes all forms of energy transfer other than heat transfer.
VI. Units:
A. _____
VII. 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 (_____): _____
II. Calorimetry: _____
A. Equation: _____ or _____
1.
2.
3.
4.
C. First law of thermodynamics (_____): _____

D. c_{water} = _____ or _____

III. Measured using a _____

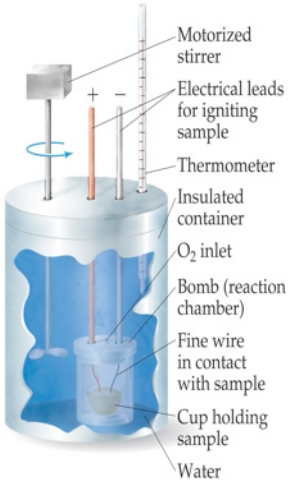
A. Coffee cup calorimeter (_____)

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 = 110ºC decrease

Enthalpy

I. Enthalpy (H) : _____

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

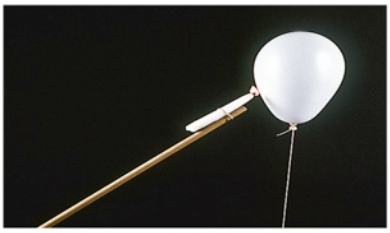
B. At constant pressure, _____

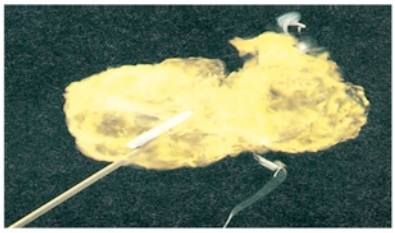
1. Sign of ΔH (_____)
   a. _____
   b. _____
2. _____ (2nd law).
3. It is _____ (_____) (1st law).

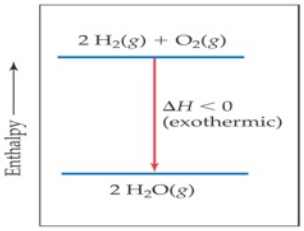
C. A change of state involves a _____. $H_2O(s)$ --> $H_2O(l)$ ΔH=_____

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?

$$\text{CH}_4\,(\text{given}) \rightarrow \text{moles CH}_4 \rightarrow \text{kJ}$$

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

Calculate the value of *q* when 5.00 *g* of H2O2(*l*) decomposes at constant pressure.

$$2\,H_2O_2(l) \longrightarrow 2\,H_2O(l) + O_2(g) \qquad \Delta H = -196\ \text{kJ}$$

Answer: –14.4 kJ

II. Hess's Law (3rd Law)

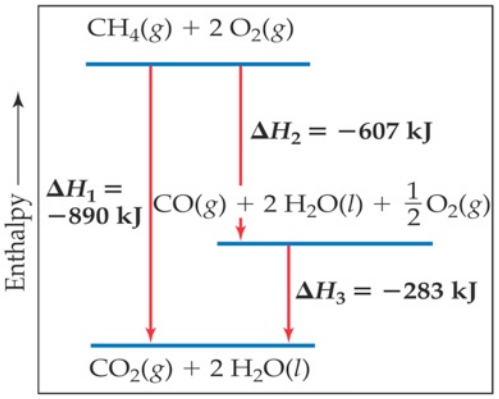
A. States that the _____
_____

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:

$$(1) \qquad C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_1 = -393.5 \text{ kJ}$$

$$(2) \qquad CO(g) + \tfrac{1}{2} O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_2 = -283.0 \text{ kJ}$$

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

$$(3) \qquad C(s) + \tfrac{1}{2} O_2(g) \longrightarrow CO(g) \qquad \Delta H_3 = ?$$

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:

$$C(\textit{graphite}) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_1 = -393.5 \text{ kJ}$$

$$C(\textit{diamond}) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H_2 = -395.4 \text{ kJ}$$

Calculate Δ*H* for the conversion of graphite to diamond:

$$C(\textit{graphite}) \longrightarrow C(\textit{diamond}) \qquad \Delta H_3 = ?$$

Answer: Δ*H*3 = +1.9 kJ

2. Calculate Δ*H* for the reaction $2\,C(s) + H_2(g) \longrightarrow C_2H_2(g)$ given the following chemical equations and their respective enthalpy changes:

$$C_2H_2(g) + \tfrac{5}{2} O_2(g) \longrightarrow 2\,CO_2(g) + H_2O(l) \qquad \Delta H = -1299.6 \text{ kJ}$$

$$C(s) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H = -393.5 \text{ kJ}$$

$$H_2(g) + \tfrac{1}{2} O_2(g) \longrightarrow H_2O(l) \qquad \Delta H = -285.8 \text{ kJ}$$

Calculate ΔH for the reaction $NO(g) + O(g) \longrightarrow NO_2(g)$ given the following information:

$$NO(g) + O_3(g) \longrightarrow NO_2(g) + O_2(g) \qquad \Delta H = -198.9 \text{ kJ}$$
$$O_3(g) \longrightarrow \tfrac{3}{2} O_2(g) \qquad \Delta H = -142.3 \text{ kJ}$$
$$O_2(g) \longrightarrow 2\,O(g) \qquad \Delta H = 495.0 \text{ kJ}$$

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 _____

_____

I. Refer to p. 635-636

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

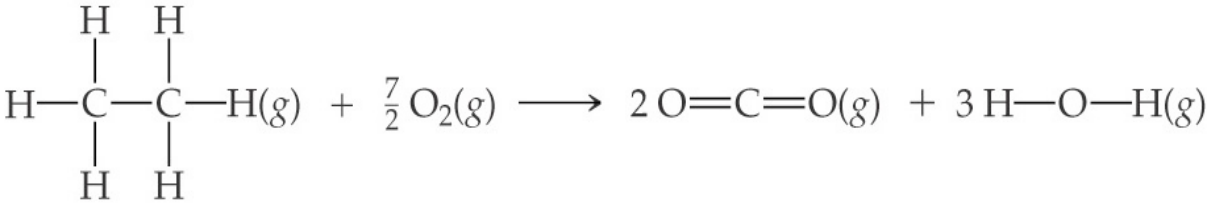
Substance	Formula	ΔH_f° (kJ/mol)	Substance	Formula	ΔH_f°(kJ/mo
Acetylene	$C_2H_2(g)$	226.7	Hydrogen chloride	HCl(g)	−92.30
Ammonia	$NH_3(g)$	−46.19	Hydrogen fluoride	HF(g)	−268.60
Benzene	$C_6H_6(l)$	49.0	Hydrogen iodide	HI(g)	25.9
Calcium carbonate	$CaCO_3(s)$	−1207.1	Methane	$CH_4(g)$	−74.80
Calcium 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	$Na_2CO_3(s)$ 1	− 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

Example!

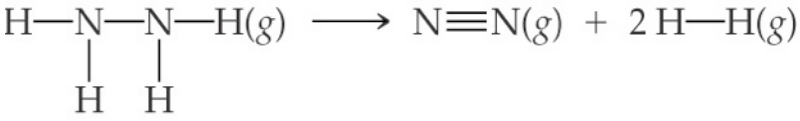
Calculate the standard enthalpy change for the combustion of 1 mol of benzene, $C_6H_6(l)$, to $CO_2(g)$ and $H_2O(l)$. $C_6H_6(l) + \frac{15}{2} O_2(g) \longrightarrow 6\,CO_2(g) + 3\,H_2O(l)$

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. ΔH_c involves _____
E. 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. _____
E. Example:
Estimate ΔH for the following reaction (where we explicitly show the bonds involved in the reactants and products):

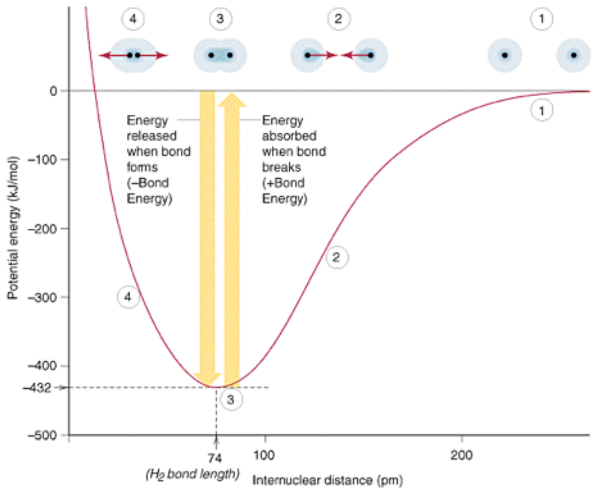


Estimate ΔH for the reaction



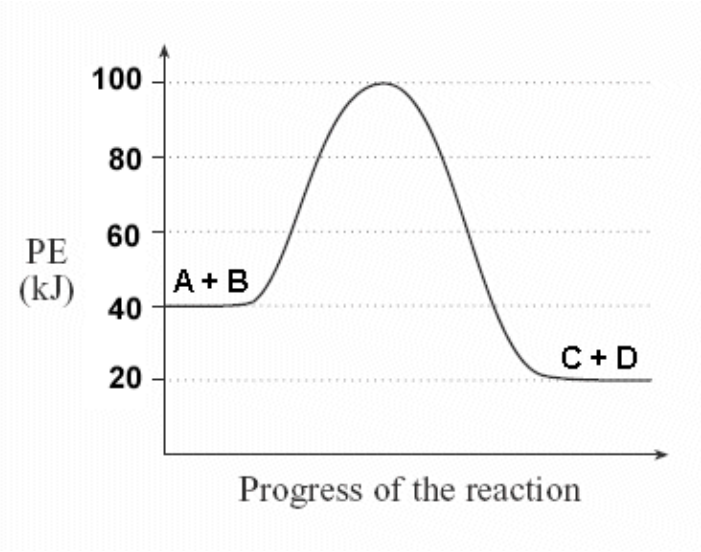
Answer: –86 kJ

F. Bond length revisited
1. You can find the bond length and bond energy using the graph on the right.



VI. Potential Energy Diagrams

1. Remember that potential energy and kinetic energy are related. (_____ _____)
2. Let's analyze the diagram below.



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

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

B. Consider: Na(s) + ½Cl_2 (g)-->NaCl(s) ΔH=-411kJ

C. FYI: Na(s) --> Na(g) ΔH=108kJ

½Cl_2 (g) --> Cl(g) ΔH=122kJ

Na(g) --> $Na^+(g) + e^-$ ΔH=496kJ (1st IE)

$Cl(g) + e^-$ --> $Cl^-(g)$ ΔH=-349kJ (EA)

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