Thermochemistry Vocabulary

Energy

Matter

Heat

Work

System

Surroundings

Open System

Closed System

Isothermal System

Adiabatic System

Exothermic

Endothermic

QUANTIFIED

Heat

Heat Capacity

Specific Heat

Don't confuse calorie with Calorie

Work

A joule is a unit of energy also.

Energy
We talk about two types

Kinetic Energy

Potential Energy

State Function

1. What is the heat involved when 250.0 grams of water are heated from 25ºC to 75ºC?

2. What is the temperature change when 75.0 g of Aluminum (heat capacity 0.900 joule/gram degree) absorbs 250 joules of heat?

3. What is the work when a gas is expanded from 10.0 to 100.0 liters at a pressure of 1.50 atm?

4. If a piston does 50.0 joules of work at 2.00 atm applied pressure how much can you expand a gas?

5. A baseball weighing 0.14 kg is dropped from a building top. When it is 25.0 m from the ground it is moving 15m/s. What is its total energy at this point?

6. An empty swimming pool is 3.5 m deep. A kid on a skateboard (total mass 50 kg) rides down the side of the pool. If he moves with no friction what is his potential energy before he starts to ride down? What is his kinetic energy at the bottom assuming 100% energy transfer? What is his speed at the bottom of the pool?

The First Law of Thermodynamics

We use these ideas to develop and define Enthalpy:

What do the silly little circles mean? "NOT"

State Functions can all be calculated by tabulated data. This is known as products minus reactants.

$$\Delta H^o = \sum_{i=1}^{n} \nu_i H_i^o$$

In English:

Calculate the Enthalpy change associated with the following reaction:

$Fe_2O_3(s)$ +	$3CO(g) \leftrightarrows$	$2Fe(s)$ +	$3CO_2(g)$
−825.5 kJ	−110.5 kJ	0 kJ	−393.5 kJ

Hess' Law- Heats of reaction are additive.
1. Given:

$N_2O_4\ (g) \leftrightarrows 2NO_2(g)$ $\Delta H° = 57.20$ kJ
$2NO(g) + O_2(g) \leftrightarrows 2NO_2(g)$ $\Delta H° = -114.14$ kJ

Find the enthalpy change for the following reaction:
$2NO(g) + O_2(g) \leftrightarrows N_2O_4\ (g)$

2. Use the following equations to calculate the enthalpy change for the following:

$H_2(g) + Cl_2(g) \leftrightarrows 2HCl(g)$ $\Delta H° =?$

$NH_3(g) + HCl(g) \leftrightarrows NH_4Cl(s)$ $\Delta H° = -176.0$ kJ
$N_2(g) + 3H_2(g) \leftrightarrows 2NH_3(g)$ $\Delta H° = -92.22$ kJ
$N_2(g) + 4H_2(g) + Cl_2(g) \leftrightarrows 2NH_4Cl(s)$ $\Delta H° = -628.86$ kJ

3. Use the following equations to calculate the enthalpy change for the following:

$C_2H_2(g) + 2H_2(g) \leftrightarrows C_2H_6(g)$ $\Delta H° = ?$

$2C_2H_2(g) + 5O_2(g) \leftrightarrows 4CO_2(g) + 2H_2O(l)$ $\Delta H° = -2600$ kJ
$2C_2H_6(g) + 7O_2(g) \leftrightarrows 4CO_2(g) + 6H_2O(l)$ $\Delta H° = -3120$ kJ
$H_2(g) + 1/2\ O_2(g) \leftrightarrows H_2O(l)$ $\Delta H° = -286$ kJ

4. Use the following equations to calculate the enthalpy change for the following:

$CH_4(g) + 2O_2(g) \leftrightarrows CO_2(g) + 2H_2O(l)$ $\Delta H^\circ = ?$

$2H_2(g) + C(s) \leftrightarrows CH_4(g)$ $\Delta H^\circ = 74.81 KJ$
$2H_2(g) + O_2(g) \leftrightarrows 2H_2O(l)$ $\Delta H^\circ = -571.66 KJ$
$C(s) + O_2(g) \leftrightarrows CO_2(g)$ $\Delta H^\circ = -393.52 KJ$

5. Use the following equations to calculate the enthalpy change for the following:

$2NH_3(g) + 3N_2O(g) \leftrightarrows 4N_2(g) + 3H_2O(l)$ $\Delta H^\circ =$

$2NH_3(g) + 3/2O_2(g) \leftrightarrows N_2(g) + 3H_2O(l)$ $\Delta H^\circ = -765.5$ kJ/mole
$3N_2O(g) + 3H_2(g) \leftrightarrows 3N_2(g) + 3H_2O(l)$ $\Delta H^\circ = -1102.2$ kJ/mole
$3H_2O(l) \leftrightarrows 3H_2(g) + 3/2O_2(g)$ $\Delta H^\circ = 857.7$ kJ/mole

6. Use the following equations to calculate the enthalpy change for the following:

$2C(s) + H_2(g) \leftrightarrows C_2H_2(g)$ $\Delta H^\circ =$

$C_2H_2(g) + 5/2O_2(g) \leftrightarrows 2CO_2(g) + H_2O(l)$ $\Delta H^\circ = -1229.6$ kJ/mole
$C(s) + O_2(g) \leftrightarrows CO_2(g)$ $\Delta H^\circ = -393.5$ kJ/mole
$H_2(g) + 1/2O_2(g) \leftrightarrows H_2O(l)$ $\Delta H^\circ = -285.9$ kJ/mole

Phase Changes
What are the six phase changes?

Latent Heat

Heat of Fusion

Heat of Vaporization

Heat Capacities for common materials:

Substance	Specific Heat	Substance	Specific Heat
H_2O (s)	2.06 J/g °C	Aluminum (s)	0.900 J/g °C
H_2O (g)	2.02 J/g °C	Benzene (l)	1.74 J/g °C
H_2O (l)	4.18 J/g °C	Ethanol (l)	2.42 J/g °C

Phase Change Data

Substance	Heats of Fusion (Hf):	Heats of Vaporization (Hv):	Boiling Points	Melting Points
H_2O	6.01 kJ/mol	40.7 kJ/mol	373.2 K	273.2 K
Benzene	10.59 kJ/mol	30.8 kJ/mol	353.2 K	278.6 K
Ethanol	4.60 kJ/mol	43.5 kJ/mol	351.5 K	158.7 K
Acetone	5.72 kJ/mol	29.1 kJ/mol	329.4 K	179 K

Some useful data:
Benzene = C_6H_6 Ethanol = C_2H_5OH Acetone = CH_3COCH_3

1. How much heat is required to melt 50.0 g of ice at 0°C?

2. How much heat is required to melt 75.0 g of Benzene at 278.6 K?

3. You have a sample of H_2O with a mass of 25.0 g at a temperature of –30.0 °C. How many kilojoules of heat energy are necessary to:

a) heat the ice to 0°C?

b) melt the ice?

c) heat the water from 0°C to 100°C?

d) boil the water?

e) heat the steam from 100°C to 130°C?

4. How much heat is required to raise 250.0 g of ice at a temperature –50.0°C to125.0°C?

Heat of Formation:

Lets practice from tabulated data:
Calculate the enthalpy change for the following reactions from standard data tables.

1. __$Br_2(g)$ + __$I^-(aq)$ ⇆ __$I_2(s)$ + __Br^-aq)

2. __$CH_4(g)$ + __$O_2(g)$ ⇆ __$CO_2(g)$ + __$H_2O(g)$

3. __$NO_2(g)$ ⇆ __$N_2O_4(g)$

4. __Zn(s) + __HCl(aq) ⇆ __$Zn^{2+}(aq)$ + __$H_2(g)$ + __$Cl^-(aq)$

5. __ $Na_2CO_3(s)$ + __HCl (aq) ⇆ __$CO_2(g)$ + __$H_2O(g)$ + __NaCl(s)

Calorimetry

The first law says that energy can not be created or destroyed, therefore any heat going in has to be accounted for going out!

1. To a calorimeter (whose heat capacity is 195 J/K) containing 100. grams of water at 25.0°C is added 50.0 grams of aluminum (heat capacity of 0.900 J/gK) at 100.0°C. What is the final temperature?

2. You start with 100 grams of cold water (15°C) in a calorimeter whose heat capacity is 50 cal/K. To it you add some hot water (80°C). The final temperature is 30°C. What mass of hot water did you add?

3.A calorimeter contained 60.0 g of water at 20.00° Celsius. A 100.0 g sample of iron at 100.00° Celsius was added giving the mixture a final temperature of 29.68° Celsius. Calculate the heat capacity of the calorimeter. The specific heat of iron is 0.450 J/gK.

4.Suppose you have a coffee cup calorimeter whose heat capacity is 50 J/K that holds 200 mL's of water at 22° Celsius. To this you drop in a 100.0gram chunk of aluminum that has a specific heat of 0.900 J/gK. If the metal was at 95° Celsius what was the final temperature of the mixture?

Lattice Energy:

Bond Energy
Where is the energy stored in a chemical reaction?

Find the energy in a Carbon-Hydrogen bond in methane CH_4.

C(graphite) + $2H_2$(g) $\leftrightarrows$ CH_4(g)	$\Delta H^o = -74.85$ kJ
C(graphite) $\leftrightarrows$ C(gas)	$\Delta H^o = 718.38$ kJ
$1/2H_2$(g) $\leftrightarrows$ H(gas)	$\Delta H^o = 217.94$ kJ

How about the Carbon-Carbon bond in Ethane? The heat of formation of ethane is -84.7 kJ.

Bond Energies can also be used to estimate the enthalpy change in a reaction using the idea that energy goes in and out:

Bond Energies:

H-H	432 KJ/mol	Cl-Cl	239 KJ/mol	F-F	154 KJ/mol
I-I	149 KJ/mol	H-I	259 KJ/mol	Br-Br	193 KJ/mol
H-Cl	427 KJ/mol	H-Br	363 KJ/mol	H-F	565 KJ/mol

Use bond energy values from the table to calculate the enthalpy change for the following reaction:

$$H_2(g) + F_2(g) \leftrightarrows 2HF(g)$$

Use bond energy values from the table to calculate the enthalpy change for the following reaction:

$$H_2(g) + Cl_2(g) \leftrightarrows 2HCl(g)$$

Use bond energy values from the table to calculate the enthalpy change for the following reaction:

$$H_2(g) + Br_2(g) \leftrightarrows 2HBr(g)$$