THERMOCHEMISTRY: Introduction

Therme - Greek for *heat*
Thermochemistry:
Study of the (heat) energy transfer in chemical reactions

Thermodynamics: *dynamo* - Greek for power or strength

Key Terms in this Unit:

Kinetic and Potential Energy	Law of Conservation of Energy
Heat	Temperature
Endothermic Changes	Endothermic Changes
Specific Heat and Heat Capacity	Calorimetry
Adiabatic and Isothermal Change	Enthalpy and Enthalpy Change
State Functions	Hess's Law of Heat Summation
Heats of Formation	Standard States

Energy - definition: Capacity to do work   Work = Force X Distance

Two ways matter can have energy:
Kinetic and Potential Energy
Total Energy = Kinetic Energy + Potential Energy
$Energy_{universe} = K.E. + P.E.$

Kinetic and Potential Energy

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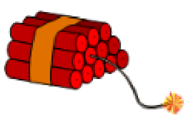
Kinetic Energy + Potential Energy = Total Energy
Energy of Motion ***Stored Energy***

K.E. Kinetic Energy - The Energy of Motion

What are some forms of kinetic energy?
Mechanical, electrical, thermal, sound, etc (Motion)

P.E. Potential Energy - Stored Energy

What are some forms of potential energy?

Chemical  **Positional** 

When objects that attract each other are pulled apart, ***PE increases***.
When move toward each other, ***PE decreases***.
When objects that repel are pushed toward each other, ***PE increases***.
When objects that repel are moved apart, ***PE decreases***.

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Energy Units:

In Chemistry the two most common units of energy are the calorie (cal) and the Joule (J).

1 calorie (cal) is *defined* as the quantity of heat needed to raise the temperature of 1 gram of pure water by 1°C.

1 calorie is different from a common **Food Calorie (Cal)**. There are 1000 calories in 1 Food Calorie. In other words, a Food Calorie is 1 ***kilo***calorie

1 Calorie (Food) = 1 kilocalorie = 1000 calories
1 C̲al = 1 kcal = 1000 c̲al (***Be careful about capitalization here!***)

The **Joule (J)** is commonly used in calculations and this SI unit is derived from kinetic energy calculations:

note that velocity is squared

Kinetic Energy - K.E. = 1/2 mv^2

mass in kilograms **velocity = distance/time meters/seconds**

1 Joule = 1 J = 1 **kg · m^2/s^2**

Conversion Factor between Energy units:
1 calorie (exact) = 4.182 Joules

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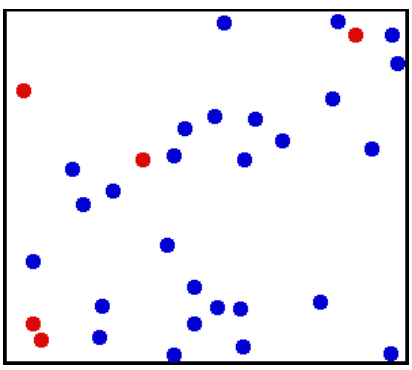
Absolute Temperature (in Kelvin): Directly proportional to the average kinetic energy of atoms/molecules. Therefore, Temperature is a measure of mol motion!

Interactive Temp Scale

Absolute Zero: 0 K is the theoretical absence of all molecular motion

PBS Timeline of Cold Research

Heat: The actual Kinetic Energy of atoms and molecules



Temperature Units:
Kelvin (K) - no negative temperature

Celsius (°C) °C = K + 273.15

Fahrenheit is not generally used in chemistry is not tested and may be utilized for conversion practice only.

NOVA Absolute Zero Program

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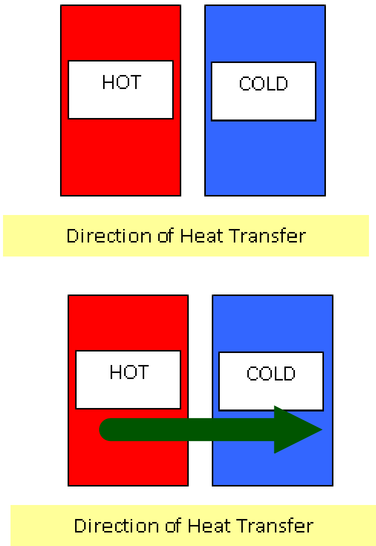
Direction of Heat Transfer:



The most common form of energy change involves heat.
The energy transfer as a result of a Temperature difference is Heat.

Heat always flows from object of higher Temperature to lower temperature because lower Potential Energy is more stable.

If undisturbed, the two objects will continue to transfer heat energy until the Temperature of the objects are equal.

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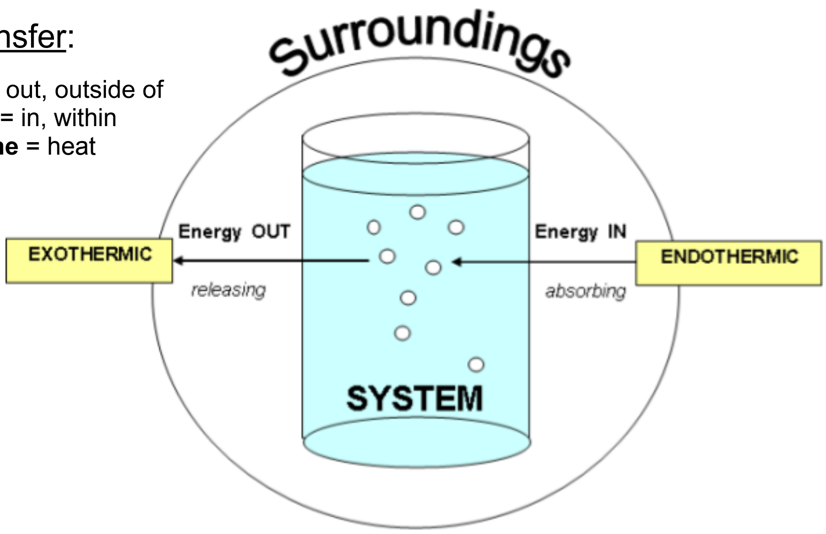
Energy Transfer:

Greek: **exo** = out, outside of
endo = in, within
therme = heat



Exothermic Change: Releases Energy to the surroundings (T increases)
If two reactants at the same Temperature are mixed and the resulting solution gets warmer = exothermic

Endothermic Change: Absorbs Energy from the surroundings (T drops)
If two reactants at the same T are mixed with resulting solution getting colder = endothermic

Both endothermic and exothermic reactions require a certain minimum energy to get started. This activation energy is required otherwise reaction will not occur (no product wil formed).

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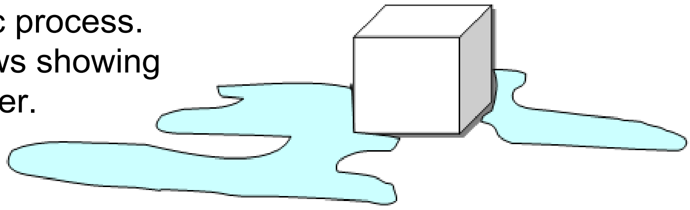
Determine if a melting ice cube is an endothermic or exothermic process. Draw a diagram with Arrows showing the direction of heat transfer.



Determine if an ice cube tray containing water is placed into the refrigerator freezer whether the freezing of the water is an endothermic or exothermic process. Draw a diagram with Arrows showing the direction of heat transfer.

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Specific Heat - Specific Heat Capacity

Specific Heat or Specific Heat Capacity (Cp): The Heat **energy** needed to raise the temperature of **one gram** of substance by **one degree Celsius**.

$$C_p \text{ of } H_2O = 4.184 \text{ J/g °C or } 1 \text{ cal/g °C}$$

Specific heat used to be called **specific heat capacit**y. It can be thought of as a measure of how well as substance resists changing its temperature when it absorbs or releases heat.

- Different materials have different capacities to store energy. The sand at the beach feels hotter to a bare foot than the boardwalk even though both are in the sun. Sand and wood have different specific heats.
- Each substance has its own specific heat.

Liquid water has one of the largest specific heat values which means water absorbs more heat than most substances. By warming up only a few degrees, a large body of water can absorb and store a huge amount of heat from the sun during daytime and summer. At night and during winter, the gradually cooling water can warm the air. This is the reason coastal areas generally have milder climates than inland regions and is also the basis for home solar energy heating.

The high specific heat of water also makes ocean temperatures quite stable, creating a favorable environment to marine life. Because of its high specific heat, the water that covers most of this planet keeps temperature fluctuations within limits that permit life.
Just think how different our environment would be if the surface of the plant was covered with a liquid of lower specific heat - less resistant to temperature changes.

In the body, water absorbs large amounts of heat without causing fluctuations in body temperature. It serves as our personal thermostat.

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When materials with small specific heats absorb energy, they attain high temperatures rapidly. Consider a frying pan often made of aluminum or copper. These materials heat quickly and transfer the heat to the food. The handles are made of materials such as wood with large specific heat so the pans can be picked up when the food is hot.

The amount of heat necessary to change the temperature of a given substance depends on three factors: mass, specific heat and temperature change (Δ T).

The Energy Equation is: $\mathbf{Q = m\,C\,\Delta T}$

Q = Energy (in Joules or calories)

m = mass in grams

ΔT = change in Temperature in °C

C = Specific Heat Capacity J/g°C or cal/g°C

$$Q = m \times C \times \Delta T$$

$$J = \cancel{g} \times \frac{J}{\cancel{g}\,°\cancel{C}} \times °\cancel{C}$$

notice how units will cancel

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EXAMPLE PROBLEM:

How much energy, in Joules, would be required to raise the temperature of 15.0 grams of water by 15° C ?
(The specific heat of water is 4.184 J/g° C)

Energy Equation: Q = m x C x ΔT

Q= ? (Joules)
m = 15.0 grams
C = 4.184 J/g °C
ΔT = 15 °C

Q =	15.0 g x	<u>4.184 J</u> x	15 °C
		g °C	

Q = 15.0 x 4.184 J x 15 Q = 941 J

Convert this energy to calories: 1 calorie = 4.184 J

$$941\text{ J} \times \frac{1\text{ calorie}}{4.184\text{ J}} = 225\text{ calories}$$

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Practice

1. Convert the following units:
   a. 356 Joules to calories
   b. 270 calories to Joules

2. How many calories of energy would be required to raise 35 grams of water 10 °C?
   (The specific heat of water is 1 cal/g°C)

3. How many Joules of Energy are needed to change the temperature of 550 grams of water from 50°C to 100°C?
   (The specific heat of water is 4.184 J/g°C)

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1. a. 356 Joules - ? calories

$$356 \text{ J} \times \frac{1 \text{ calorie}}{4.184 \text{ J}} = \boxed{85.1 \text{ cal}}$$

b. 270 calories = ? Joules

$$270 \text{ cal} \times \frac{4.184 \text{ J}}{1 \text{ calorie}} = \boxed{1100 \text{ J}}$$

NOTE:
Do NOT use Temperature as a guide for significant digits as theoretically this value could be converted to Kelvin.

2. **Q = m C** ΔT (C_P H_2O = 1 cal/g°C)

Q = ? cal
m = 35 g
ΔT = 10°C

$$Q = (35 \text{ g}) \left(\frac{1 \text{ cal}}{\text{g°C}}\right) (10°C)$$

$$\boxed{Q = 350 \text{ cal}}$$

3. **Q = m C** ΔT (C_P H_2O = 4.184/g°C)

Q = ? cal
m = 550 g
ΔT = 100 - 50°C = 50°C

$$Q = (550 \text{ g}) \left(\frac{4.184 \text{ J}}{\text{g°C}}\right) (50°C)$$

$$\boxed{Q = 120{,}000 \text{ J}}$$

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Attachments

- Kinetic and Potential Energy
- Timeline of Cold Research
- states of matter
- Interactive Temp Scale
- NOVA Absolute Zero Program