Chem 103, Section F0F
Unit I - An Overview of Chemistry
Lecture 5

- Energy and matter
- Energy and change
- Enthalpy

Lecture 5 - Energy and Matter

This topic will be dealt with in some detail in Chem 104, however, it will be helpful for us to have some introduction to the topic in Chem 103.

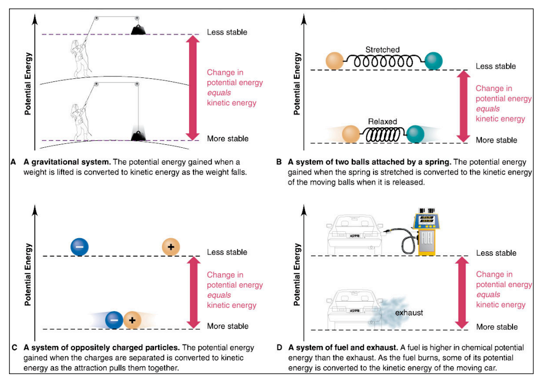
- Reading in Silberberg
  - Chapter 1, pp. 8-10 *The Importance of Energy in the Study of Matter*
  - Chapter 6, Section 1 *Forms of Energy and Their Interconversion*
  - Chapter 6, Section 2 *Enthalpy: Heats of Reaction and Chemical Change*

Lecture 5 - Energy and Matter

Both physical and chemical changes are accompanied by changes in energy.

- We have already looked at two forms of energy
  - Kinetic energy (K.E.)
  - Potential energy (P.E.)
- We have seen how these two forms of energy can transform from one to the other.

Lecture 5 - Energy and Matter



A A gravitational system. The potential energy gained when a weight is lifted is converted to kinetic energy as the weight falls.

B A system of two balls attached by a spring. The potential energy gained when the spring is stretched is converted to the kinetic energy of the moving balls when it is released.

C A system of oppositely charged particles. The potential energy gained when the charges are separated is converted to kinetic energy as the attraction pulls them together.

D A system of fuel and exhaust. A fuel is higher in chemical potential energy than the exhaust. As the fuel burns, some of its potential energy is converted to the kinetic energy of the moving car.

Lecture 5 - Energy and Change

In lab we saw how chemical changes can be accompanied by a change in energy that is manifested by either an absorption or a release of **heat**:

$$H_3C_6H_5O_7 + NaHCO_3 \xrightarrow{\text{heat absorbed (endothermic)}} NaH_2C_6H_5O_7 + CO_2 + H_2O$$

citric acid + sodium bicarbonate → sodium citrate + carbon dioxide + water

$$Mg + 2\,HCl \xrightarrow{\text{heat released (exothermic)}} MgCl_2 + H_2$$

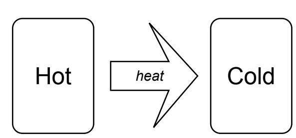
magnesium + hydrochloric acid → magnesium chloride + hydrogen

Lecture 5 - Energy and Change

Heat is one of the ways that energy can be transferred from one place to another

Heat and temperature are related.

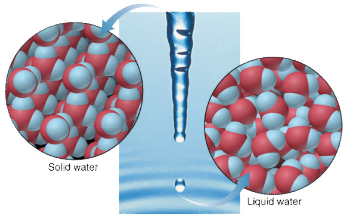
- Temperature is used to measure how hot or cold an object is
  - Heat flows spontaneously from hot regions to cold ones.
  - When an object absorbs heat, it gains energy
  - When a object release heat, it loses energy.



Lecture 5 - Energy and Change

Heat is also transferred along with physical changes

- For example, the melting of ice
- In this case the heat does not go to change the temperature by rather to change the physical state

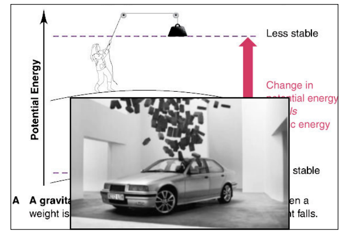


A Physical change: Solid form of water becomes liquid form; composition does *not* change because particles are the same.

Lecture 5 - Energy and Change

Another way that energy can be transferred from one region to another is through **work.**

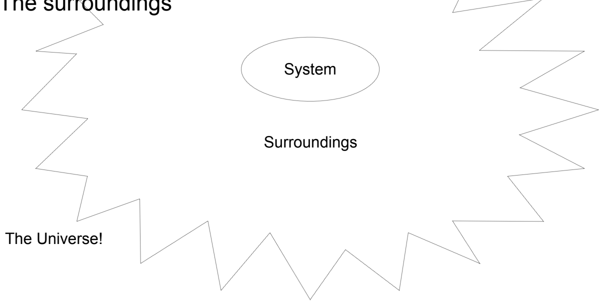
- One definition used for energy is *the ability to do work*.
- Example, when a heavy weight falls to the ground it does work by rearranging things on the ground:



Lecture 5 - Energy and Change

To study these transfers in energy in more detail, we divide the universe up into two regions

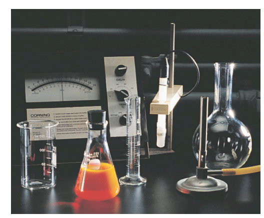
- The system
- The surroundings



Lecture 5 - Energy and Change

The system can be almost anything that defines a region of the universe

- a beaker
- a test tube
- the earth
- a human being
- ...



It represents what we are interested in studying.

Lecture 5 - Energy and Change

There are are different forms of energy that can be evaluated.

- One of these, is the internal energy (E)
  - E is the sum of all the kinetic and potential energies of all of the particles in a system.
- When a chemical or physical change occurs, the change in the internal energy, ΔE, is equal to the energy after the change, E_{final} minus the energy before the change $E_{initial}$.

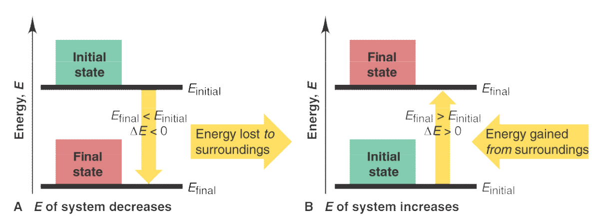
$$\Delta E = E_{final} - E_{initial}$$

- For a chemical reaction, this would be

$$\Delta E = E_{products} - E_{reactants}$$

Lecture 5 - Energy and Change

- If the energy of the system decreases, $\Delta E < 0$
- If the energy of the system increases, $\Delta E > 0$



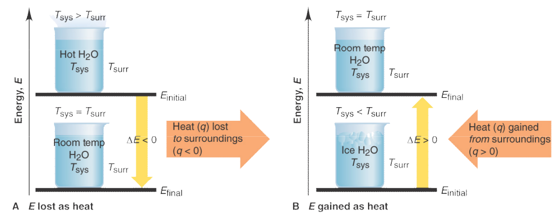
Lecture 5 - Energy and Change

When the energy of a system changes, heat and/or work flows into or from the system to the surroundings.

Lecture 5 - Energy and Change

The change in the internal energy for the system can be determined by adding together

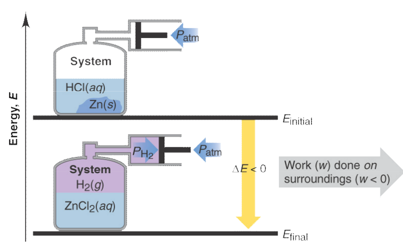
- the heat absorbed by the system (*q*)



Lecture 5 - Energy and Change

The change in the internal energy for the system can be determined by adding together

- the heat absorbed by the system (*q*) and
- the work done on the system (*w*).



Lecture 5 - Energy and Change

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$$\Delta E = q + w$$

Since the heat absorbed by the system is equal to the heat lost by the surrounding, and the work done on the system is equal to the work done by the surroundings,

$$\Delta E_{system} = q + w$$

$$\Delta E_{system} = -\Delta E_{surroundings}$$

$$\Delta E_{universe} = \Delta E_{system} + \Delta E_{surroundings} = 0$$

Lecture 5 - Energy and Change

Since $\Delta E_{universe}$ = 0, the energy of the universe is a constant.

This is a statement of the **First Law of Thermodynamics.**

- *The total energy of the universe is a constant; it an be neither created or destroyed.*

The laws of thermodynamics were worked out in the 1800's by studying the efficiency of steam engines.

Lecture 5 - Energy and Change

Efficiency comes with

- maximizing the work done while
- minimizing the amount of heat released

Example, the combustion of gasoline (octane):

$$2\ C_8H_{18}\ (\text{octane}) + 25\ O_2 \xrightarrow{\text{heat released}} 16\ CO_2 + 18\ H_2O$$

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Lecture 5 - Energy and Change

The work done can include:

- The mechanical work in moving the car down the highway and counteracting friction.
- The electrical work of running the headlights and the stereo system.
- The chemical work of charging the battery.

$$2\ C_8H_{18}\ (\text{octane}) + 25\ O_2 \xrightarrow[\text{work done}]{\text{heat released}} 16\ CO_2 + 18\ H_2O$$

Lecture 5 - Question 1

If the energy in the gasoline can be used to do all those things, where did the energy in the gasoline come from?

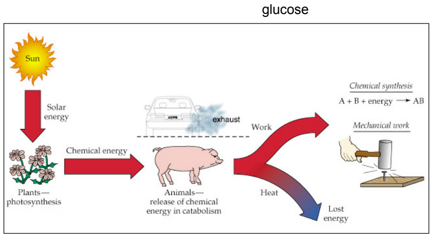
A) The ground
B) The oil refinery
C) The sun
D) A space alien put it there

Lecture 5 - Energy and Change

Where did the chemical energy in the gasoline come from?

- Ultimately, it came from the sun
  - In a process called photosynthesis:

$$6\ CO_2 + 6\ H_2O \xrightarrow{\text{light energy absorbed}} C_6H_{12}O_6\ (\text{glucose}) + 6\ O_2$$



Lecture 5 - Energy and Change

The units of energy that are commonly used are based on either mechanical work (*Joule*) or heat (*calorie*)

- The *Joule* comes from Newton's laws of mechanics
  - Work = Force x Distance ($w = F \times d$)
  - Force = mass x acceleration ($F = m \times a$)

Work = mass x acceleration x distance

$$kg \quad \left(\frac{m}{s^2}\right) \quad (m)$$

$$1\ Joule = 1\ \frac{kg \bullet m^2}{s^2}$$

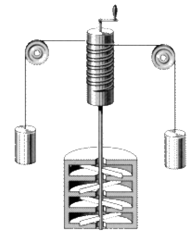
Lecture 5 - Energy and Change

The units of energy that are commonly used are based on either mechanical work (*Joule*) or heat (*calorie*)

- The calorie is defined as the quantity of heat required to raise the temperature of 1 g of water from 14.5°C to 15.5°C.

Lecture 5 - Energy and Change

James Joule (1818-1889) showed the equivalence of heat and mechanical work with a system of paddle wheels and weights:



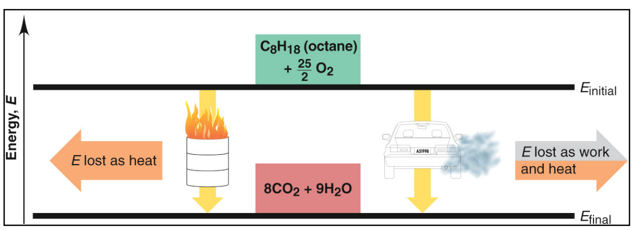
$$w = mgh\left\{\frac{kg\ m^2}{s^2}\right\}$$

$$1\ cal = 4.184\ \frac{kg\ m^2}{s^2}$$

$$1\ cal = 4.184\ Joule$$

Lecture 5 - Energy and Change

Quantities like Δ*E* are independent of how you get from the intial to the final state.



Lecture 5 - Enthalpy

In the chemistry lab we are usually working under conditions of constant pressure.

- Under these conditions, another useful quantity is the Enthalpy (*H*)

$$\Delta H = \Delta E + P\Delta V$$

- It can be shown that

$$\Delta H = q_P$$

Lecture 5 - Enthalpy

When no gases are produced or consumed, ($\Delta V = 0$)

$$\Delta H = \Delta E$$

Even when gases are produced,

$$\Delta H \approx \Delta E$$

- For chemical reactions,
  - Δ*H* is called the heat of reaction
- For freezing a liquid
  - Δ*H* is called the *heat of fusion*, ΔH_{fus}
- For boiling a liquid
  - Δ*H* is called the *heat of vaporization*, ΔH_{vap}

Lecture 4 - Problem

A system receives 425 J of heat and delivers 425 J of work to its surrounds. What is the change internal energy of the system (in J)

Lecture 4 - Problem

What is the change in internal energy (ΔE) energy (in J) of a system that absorbs 0.615 kJ of heat from its surroundings and has 0.247 kcal of work done on it?

Lecture 4 - Problem

“Hot packs” used by skiers, snowmobilers, and others for warmth are based on the oxidation of iron filings in the presence of charcoal.

A) What is the sign of ΔH for this reaction?

B) Is the reaction **exothermic** or **endothermic**?

Unit I - Up Next

Unit II - The Elements and the Structure of Their Atoms

- The nature of light and other formes of elctromagneti energy
- What happens when light interacts with matter
- Some behaviors that light and matter share

The End