Energy and Work

Energy is the capacity to do work or to produce heat.

Internal energy is the sum of kinetic energy and the potential energy.

or... $$E = KE + PE$$

If one were to heat the sample what happens to the KE?

> The KE would increase because heating something causes an increase in temperature. Since the *kinetic energy* has increased the *internal energy* has also increased.

What happens when a gas is compressed; does a compressed gas have more *potential energy* than one that has not been compressed?

> Yes, compressed gasses can push soda out of soda fountains. When the pressure drops to low then the gas cannot push the soda out of the container. The potential energy of the gas was increased when it was compressed.

So the *internal energy* can be changed by heating the sample, or by doing work on the sample.

in math speak... $$\Delta E = q + w$$

This relationship is the one we will be using. When taking about energy we are talking about changes in energy.

When gasoline and oxygen when mixed together have a certain amount of internal energy, there is chemical PE and since the molecules are moving there is KE. When a reaction occurs, combustion, work is done and heat is released. We measure the amount of energy released. This energy is the change in energy from the initial state, gasoline and oxygen, to the final state.

The change in *internal energy* is equal to the sum of the *flow of heat* to the system and the *work* done to the system.

What is the **system**? What ever we say it is.

What are the **surroundings**? Everything else.

Since we will focus on the energy changes in the system, and not the surroundings...

Any energy transfer that augments the energy of the system is a positive number.

Any energy transfer that reduces the energy of the system is a negative number.

For us, if **heat** (q) flows into the system then **q** is **positive**.
If **heat** flows out of the system then **q** is **negative**.

The same is said for work. If **work** is **done to** the system then **w** is **positive**.
If the system **does work** then **w** is **negative**.

Lets first look at **work**

Work is defined as force times distance:

$$w = F \times \Delta x$$

Gases can do work. As a gas in a container expands it pushes against the atmosphere. The gas is doing work. The pressure the gas is pushing against is the atmosphere. The amount of work the gas did can be stated as follows:

$$w = P \times \Delta V$$

Why does is this work, I thought work was force time distance?

Well, in a piston what is ΔV? $\Delta V = V_{final} - V_{initial}$

What changes are made to the piston to make the volume is change?

h

the area of the piston stays the same...so...

$$\Delta V = A \times \Delta h$$

substituting for ΔV....

$$w = P \times A \times \Delta h$$

Ok, what is pressure? Pressure is Force per unit area so...

$$w = \frac{F}{A} \times A \times \Delta h$$

or...

$$w = F \times \Delta h$$

To fill a balloon work has to be done. How much work is done by a compressed air cylinder to fill a mylar balloon (this way we do not have to worry about the rubber in the balloon adding to the work we must do)? The balloon holds 7.5 L of air at 23 °C and 1.0 atm. Atmospheric pressure on this given day is 1 atm and the room is 23 °C.

$$w = - P \times \Delta V$$

Why the negative sign? If the volume is increasing then the gas is doing work, and work is leaving the system, and the system has less energy afterwards. If the volume decreases then work is being done to the gas and the gas (system) has more energy after the work was done.

$$w = - 1 \text{ atm} \times (7.5 - 0)\text{L}$$

$$w = -7.5 \text{ L} \bullet \text{atm}$$

But what is a L • atm?

We can use the gas law constants to compare L • atm to a more understandable energy unit.

R can be expressed as follows:

$$R = 0.08206 \text{ L} \bullet \text{atm} \bullet \text{K}^{-1} \bullet \text{mol}^{-1} \quad \text{or} \quad R = 8.314 \text{ J} \bullet \text{K}^{-1} \bullet \text{mol}^{-1}$$

so...

$$0.08206 \frac{\text{L}\bullet\text{atm}}{\cancel{\text{K}\bullet\text{mol}}} = 8.314 \frac{\text{J}}{\cancel{\text{K}\bullet\text{mol}}}$$

$$0.08206 \text{ L} \bullet \text{atm} = 8.314 \text{ J}$$

or...

$$1 \text{ L} \bullet \text{atm} = 101.3 \text{ J}$$

So,

$$w = -7.5 \text{ L} \bullet \text{atm} \times \frac{101.3 \text{ J}}{1 \text{ L} \bullet \text{atm}} = 760 \text{ J}$$

in calories...

$$759.75 \text{ J} \times \frac{1 \text{ cal}}{4.184 \text{ J}} = 180 \text{ cal}$$

Weird things about PV work....

Determining the work done when compressing a gas is more complicated because the pressure that is being pushed against changes as the gas is compressed, so not only is the volume a function of distance, but the pressure is also a function of distance.