Unit 3, Lesson 01: Introduction to Thermochemistry

Up until Grade 12, your studies of chemistry have focussed on the changes in ***matter*** during chemical reactions- how the atoms in the reactants are rearranged to form new products. It is now time to consider the ***energy*** changes that go along with chemical reactions. Changes in energy drive most chemical reactions.

Thermochemistry is the branch of chemistry that studies the energy changes in chemical reactions.

Energy: is defined as the ability to do work (to make things move).

- this is called an "operational definition" because it tells us what energy can ***do***, but it does not explain what energy ***is***. That is- we can recognize different forms of energy, we can measure energy, we can change energy from one form to another and we can use energy- but we do not know what energy actually is.
- the SI unit for measuring energy is the joule (J) or kilojoule (kJ). The British system unit for measuring energy is the calorie, where one calorie is equal to 4.18 joules.
- energy can be classified as either kinetic energy or potential energy.

a) **Kinetic Energy**: is the energy that an object has because of its motion. There are many different types of kinetic energy, depending on what type of object is moving:
eg. sound energy when air particles vibrate
mechanical energy when large objects move
thermal energy when particles (either atoms or molecules) move

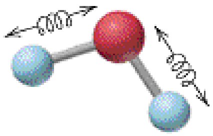
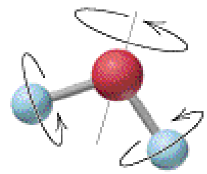
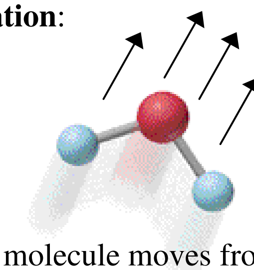
b) **Potential Energy**: is the energy that an object has because of its position relative to other objects and the level of its attraction to other objects. Potential energy is often thought of as "stored energy". There are many different types of potential energy, depending on what type of attraction exists between the two objects:
eg. magnetic attraction or repulsion
gravity, which is energy due to the force of attraction between objects because of their masses
elastic energy stored in a coiled or compressed spring
chemical energy due to the bonds between atoms in a molecule

The Law of Conservation of Energy states that energy can not be created or destroyed, but energy can be transferred from one object to another and energy can change form. That is, the total energy content of the Universe is constant. For example, chemical potential energy can be converted to thermal (kinetic) energy when a fuel is burned to heat a pot of water.

In thermochemistry, we are primarily concerned with thermal (kinetic) energy and chemical (potential) energy. We will look at both of these forms of energy in detail: what they are, how they can be measured, and how they can be inter-converted.

Thermal Energy: The Kinetic Energy of Moving Particles

There are three ways that particles can move (that is, there are three types of molecular motion):

Vibration:	**Rotation**:	**Translation**:
		
The movement of the atoms along the bonds in a molecule.	When an atom or molecule "spins" on its axis.	When a molecule moves from one place to another.

<u>Temperature</u> is defined as a measure of the ***average*** kinetic energy of the particles in a substance.

- temperature tells us how fast the particles in a substance, on average, are moving
- temperature is measured in ºC or K (Kelvins), where K = ºC + 273
- at absolute zero (0 K or –273 ºC) all molecular motion stops, so the kinetic energy of the particles in the substance at absolute zero is zero

<u>Thermal energy</u> is the ***total*** kinetic energy of the particles (either atoms or molecules) in a substance due to their motion.

The thermal energy in an object depends on two things:

1. how many particles there are (the mass or the number of moles). The more particles there are, the greater the thermal energy, and
2. how fast the particles are moving (their temperature). The faster the particles are moving, the greater the thermal energy. At absolute zero, thermal energy is zero

Let's look at an example:

- the molecules in a small Tim Horton's™ coffee are moving very fast, so they have a high temperature (about 85 ºC)
- but, there are not very many molecules (a small mass), so the total amount of thermal energy is low

- the molecules in an extra-large Tim Horton's™ coffee are moving very fast, so they have a high temperature (about 85 ºC), the same as the small coffee
- there are many more molecules (a larger mass), so there is much more total thermal energy

- the water molecules in a bathtub full of warm water are not moving very fast, so they have a low temperature (about 30 ºC)
- but, there are many, many times more molecules (a much, much larger mass) than in the coffee, so there is much, much more total thermal energy

When thermal energy is transferred from one object to another, it is called heat.

Heat can be defined as thermal energy in transit.

- heat is always transferred from the substance with higher temperature to the substance with lower temperature
- the symbol for heat is Q and its units are J or kJ (the same units as any energy term)

Basically, what happens when thermal energy is transferred is that the faster moving particles (higher temperature) collide with the slower moving particles (lower temperature). When the particles collide, some of the kinetic energy is transferred to the slower particles, so the slower particles start to move faster. Thermal kinetic energy has been transferred as heat between the objects.

A model may help illustrate the difference between thermal energy, temperature and heat:

Think about cars travelling on the 401. Each car represents a single molecule.

- the cars are translating (moving from one place to another)
- all of the cars are moving at different speeds. The average speed of all of the cars represents ***temperature***.
- If there are a lot of cars on the 401, even if they are moving slowly, there will be a lot of total movement. The total amount of movement represents ***thermal energy***. The more cars there are and the faster they are moving, the greater the thermal energy (or total movement).
- if a fast-moving car hits a slow-moving car, it will make the slower car speed up. Some of the kinetic energy of the fast car is transferred to the slow car. This represents ***heat*** (energy transfer).
- if the cars are not moving and have their engines turned off- they have no kinetic energy. This represents absolute zero.

In summary:

1. **Thermal energy** is the total amount of movement (kinetic energy) of the particles in a system. The total amount of thermal energy depends on how many particles there are (mass or # of moles) and their temperature (how fast, on average, they are moving).
2. **Temperature** (T) is the measure of the average speed (kinetic energy) of the particles in the substance.
3. **Heat** (Q) refers to the transfer of thermal energy from one object to another by the collisions of their particles.