Introduction

The chemical reactions we've done in the lab so far showed several signs that a reaction was actually happening. We observed things like the formation of a precipitate, the formation of gas bubbles, change in color, and **evolution of heat**. We will now discuss heat. Heat is a form of **energy**, and chemical reactions may either take in or give off energy while reacting.

We will first discuss some of the basic terminology and definitions of thermodynamics - the study of heat transfer.

The energy content of substances

Heat is a form of energy. What is energy, though? **Energy** is defined as the capacity to **do work**. The only kind of "work" that matters in thermodynamics is the motion of matter, so energy is essentially the capacity to move matter.

If you've had a physics or physical science course, you're probably familiar with energy. In a basic physical sciences course, you'd learn that energy comes in two basic "flavors": kinetic and potential. **Kinetic energy** is defined as the energy of an object in motion. Say you threw a tennis ball - you'd be giving it kinetic energy. **Potential energy** is defined as the energy an object has because it's being acted on by some force. The typical example is gravity. If you hold a tennis ball up in the air, you give it potential energy.

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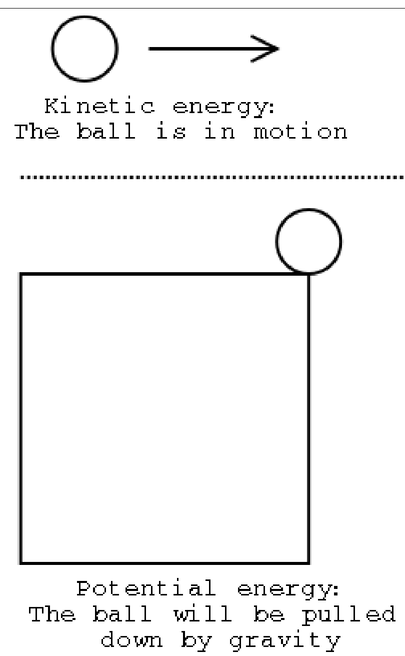

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- The moving ball possesses kinetic energy.
- The stationary ball is being acted on by the force of gravity. Giving the ball a slight nudge will cause it to roll off the edge and start moving downwards, converting the potential energy to kinetic energy.

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<td>Illustration 1 - Kinetic vs. potential energy</td>
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How does this relate to the energy content of chemical compounds? The kinetic theory tells us how molecules in the gas phase are in constant motion. This is also true for the solid and liquid phases (though the molecules don't have as much **freedom** to move as they do in a gas). So, molecules have **kinetic energy**. Molecules also have **potential energy**, in the sense that they can be acted on by forces like gravity and the fact that they can be acted on by forces from other molecules in chemical reactions. This energy in the molecules of an object or substance is called the **internal energy** and is abbreviated as **U**. It is this **internal energy** that we will be concerned with when we discuss the heat of chemical reactions, as different substances at different conditions have different amounts of internal energy.

Heat and chemical reactions

In the language of thermodynamics, **heat** is a **transfer of energy** between one substance and another because of a **difference in temperature**. Heat, abbreviated as **Q**, is measured in energy units. These are the same units used for kinetic, potential, or internal energy.

Here are two common units of energy.

- The **joule** (J) is the metric unit of energy. A joule is a $kg \cdot m^2/s^2$. This makes the joule a derived unit. If you look at the equation for kinetic energy ($E_k = ½mv^2$), you can see where the terms come from.
- The **calorie** (cal) is another unit of energy. It is defined as the amount of energy required to raise the temperature of a gram of water by 1 °C. 1 calorie = 4.184 joules. The calorie that weight-conscious people count is the kcal (1000 calories). The kcal (which is often called "Calorie" on food labels) is a common way of describing the energy content of foods.

To actually measure heat transfer, we have to clearly define what we actually want energy transfer information about. In the language of thermodynamics, we must specify the **system** and the **surroundings**. The **system** is the substance(s) under study, and we investigate heat transfer into or out of the system. The **surroundings** are everything else. Practically speaking, the surroundings are everything else in the immediate vicinity of the system.

As an example, let's pretend we're studying the cooling of hot tea in a cup. We might want to know if, say, how strong the tea was influenced how fast it cooled. So, we might define a system this way:

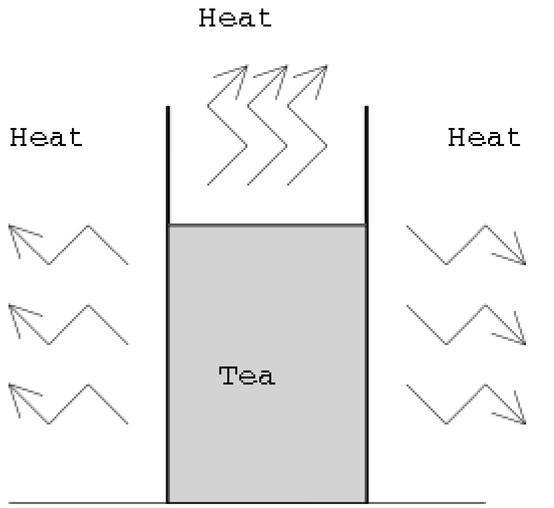

Illustration 2: A system and its surroundings

- The hot tea is defined as the **system**, since that's what we're studying.
- The cup and the air around the cup are the **surroundings**.
- Heat flows from the tea to the cup and air because the tea is at a higher temperature. Or, heat flows from the system to the surroundings.
- This process is **exothermic**, because heat is given off by the system.

The mathematical sign of the heat transfer (Q) is also significant. The sign of Q has been defined to be **negative** if the system under study **releases heat**, and **positive** if the system under study **absorbs heat**. If we were to calculate the heat change of the tea (using equations we'll discuss later), we would find that the heat change was negative.

A system that loses heat is **exothermic**, while a system that gains heat is **endothermic**. As shown in Illustration 2, the cooling of tea is an **exothermic** process - heat is released, the temperature of the cup and the air surrounding the tea goes up, and the sign of Q is negative. To sum up,

The system ...	***Sign of Q***	***Type of process***	***Surroundings***
... loses heat (releases heat)	negative	exothermic	temperature increases
... gains heat (absorbs heat)	positive	endothermic	temperature decreases

<u>Summary</u>

In this note pack, you have been briefly introduced to the basic concepts and terminology of thermodynamics. You should know that heat is a transfer of energy from a substance of greater temperature to a substance of lesser temperature. Since (from kinetic theory) we know that temperature relates to the energy of the atoms in matter, heat transfer can be viewed much like a transfer of kinetic energy.

We also discussed the terminology of heat transfer. Q represents heat, and its sign represents whether substances gain or lose heat. An object undergoing an exothermic process loses heat, while an object undergoing an endothermic process gains heat.

Next, we will discuss how we measure heat changes and how these heat changes relate to chemical reactions.