Thermodynamics Lecture

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March 7, 2014

1 Introduction

Thermodynamics is the study of collections of particles. However, including many particles leads to certain assumptions. Real world atoms behave differently from the point masses in thermodynamics. Nonetheless, the theories of thermodynamics provide insight into the concepts of energy and heat.

2 The Ideal Gas Law

The ideal gas law relates the pressure, volume, and temperature. Most problems will require using this law only to set up ratios. The ideal gas law makes the assumption of an ideal gas – one with point masses as particles. From the ideal gas law comes an equation giving the energy of a gas at a certain pressure and volume.

$$PV = nRT \text{ (R = 8.3144 J/mol K)}$$

$$U = \frac{3}{2}PV = \frac{3}{2}nRT$$

3 The First Law of Thermodynamics

Simply stated, this law says that you cannot have energy from nowhere. Mathematically, the law states that to change the energy, you must add heat energy or let the system do work.

$$\Delta U = \Delta Q - \Delta W$$

4 The Second Law of Thermodynamics

This law states that the entropy of a system never decreases. What is the entropy? Entropy is a bit hard to define – basically, it measures the disorder of a system. Entropy arose when physicists theorized about perfect engines and created entropy as a by-product. Entropy is not usually measured directly, but the change in entropy is important.

$$\Delta S = \Delta Q / T$$

$$S = k_B \ln \Omega \text{ (k = Boltzmann constant, omega is number of microstates)}$$

$$\Delta S \geq 0 \text{ (Second Law of Thermodynamics)}$$

5 The Third Law of Thermodynamics

The third law says that if the temperature is 0 degrees Kelvin, the entropy of a system will be 0. This gives a point from which to measure entropies.

$$at\ T = 0, S = 0$$

6 Practice Problems

At a pressure of 30 Pascals, a cube-shaped container with a side length of 1 meter has a temperature of 25 degrees **Celsius**. What will be the temperature when the gas is compressed to 50 Pascals in the same box?

What is the energy of an ideal gas in a 1 meter cubed box with a pressure of 10 Pascals? If all of that energy were to be transferred to a 1 kg ball that was thrown upwards with this energy, how high would it go?

If a system's entropy were to double from 5000 Joules per Kelvin at 25 degrees Celsius, by how much would the heat energy have had to change?

A ball of mass 1 kg fell from 5 meters and transferred all the energy it had when it touched the ground into a piston (crashing into it), changing the volume of the cylinder holding the piston from 1 meter cubed to 0.5 meters cubed. The initial pressure of the cylinder was 10 Pascals. What is the pressure now? (Hint: find the initial energy and add on the energy from the ball)

A system (magically) starts at absolute zero. If 20 Joules of heat energy were added and the temperature rose to 10 degrees Kelvin, what is the entropy now? If the internal heat energy then doubled, but the temperature remained constant, what is the entropy now?

A balloon has volume 0.6 meters cubed. If its pressure was 20 Pascals at 25 degrees Celsius, how many molecules of the gas are there? (Note: PV = nRT gives n as the number of moles of the gas – one mole is $6.022*10^{23}$ molecules) What is the average energy of each of these molecules?