Transcript
09-110-PVT

A few introductory words of explanation about this transcript.

This transcript includes the words sent to the narrator for inclusion in the latest version of the associated video. Occasionally, the narrator changes a few words on the fly in order to improve the flow. It is written in a manner that suggests to the narrator where emphasis and pauses might go, so it is not intended to be grammatically correct.

The Scene numbers are left in this transcript although they are not necessarily observable by watching the video.

There will also be occasional passages in blue that are NOT in the video but that might be useful corollary information.

There may be occasional figures that suggest what might be on the screen at that time.

105-Intro

What is the temperature of outer space? …way out there… between galaxies… where there is only about one hydrogen atom per cubic meter?

Can an individual atom be hot or cold? Can it even HAVE a temperature? It sounds a little silly to say an atom is 27 degrees Fahrenheit or something.

110-ParticleTemperature

But temperature is really a measure of the motion energy of an atom… if the atom is motionless then it is at zero Kelvin – we don't say "degrees" Kelvin any more. Now it can never be really motionless so it can never be at EXACTLY zero Kelvin.

And it moves pretty fast pretty fast as the temperature rises. At a tiny fraction of a degree above absolute zero, (700 nK (1 nK = 10^{-9} K)) the atom is already moving at about 1 centimeter per second.

For subatomic particles the energy is often measured in MeV or GeV. An electron with 1 GeV of energy is moving close to the speed of light. And that corresponds to a temperature of… 11 thousand billion kelvins.

E_{Total} = E_{Rest} X Gamma; Gamma = 1/SQRT(1-v^2/c^2)); v=.99999975c;

(And to use the electronvolt as a unit of temperature.... The conversion to Kelvins is defined by using k_b, the boltzman constant --
$K = 1eV/k_b = (1.6 \times 10^{-19}\ J) / (1.38 \times 10^{-23}\ J/K) = 11{,}600$ Kelvins.)

115-AverageTemperature

For a collection of atoms or molecules like a gas or a crystal lattice, the temperature of the collection is just the average temperature of the group. But of course because of collisions and interactions at the molecular level, a group of atoms or molecules will distribute the total motion energy pretty evenly among the individuals in the collection.

120-HeatFlow

And if two or more systems are brought together, some motion energy from the hotter system will flow to the colder system until they are both at the same temperature.

When you measure your body temperature using a thermometer, your body cools down a tiny bit and the thermometer heats up until the two are at the same temperature. Then reading the thermometer's temperature also reveals your body temperature since the two are the same.

125-Pressure and Volume

If we take a quantity of gas and enclose it in a container, the individual molecules in the gas constantly bang into the walls of the container creating a pressure on the walls. We can do three different things to increase the number of wall-collisions:

-- Increase the number of atoms in the container by adding more gas.

-- or increase the motion energy of the atoms already in the container by heating the gas. This makes them go faster and increases the number of times that each atom hits the wall.

-- or we can make the container smaller – decrease the volume – so that individual atoms have shorter distances to go to collide with the wall.

This leads directly to the ideal gas law relating temperature, volume, pressure, and quantity of gas:

$$p = nRT/V$$

Snuck that one in on you didn't we :)