Chemical Principles 2

Professor Dr. Arnab Mukherjee
Department of Chemistry
Indian Institute of Science Education and Research, Pune

Microscopic Definition of Temperature Part 2

Now let us see how do we measure a distal object or w have talked about the gaseous systems, gas particles having Maxwell-Boltzmann distribution. But let us say when we talk about solids or liquids, then they are not really moving from their own positions, right. So solid items are fixed in the particular position they move around that from a centre. So how do we actually measure temperature for that will it be kinetic energy for that or it will be something different.

Yes, some of you know the answer already from chemical principles 1 course, but I am going to repeat that little bit here.

(Refer Slide Time: 0:56)

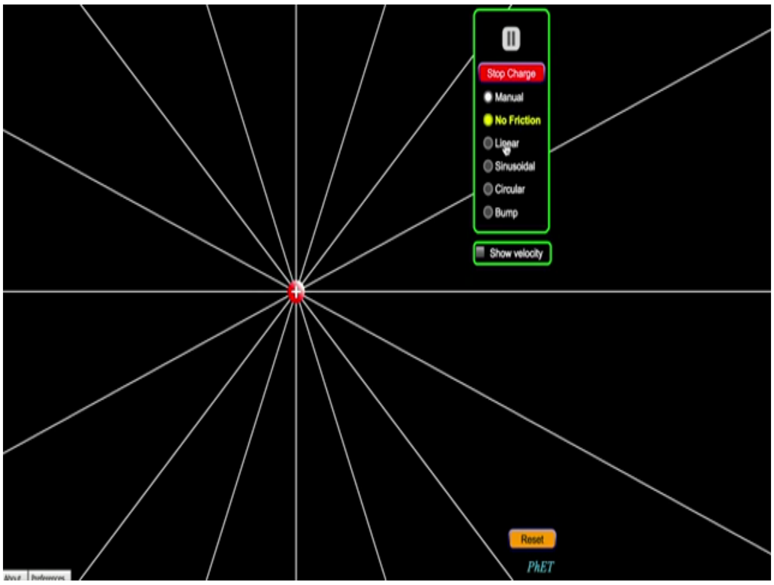
So let us say we want to calculate the temperature of this particular lava, how do you do that? We are not going to measure by a thermometer because looks like it will be very hot and thermometer will break. So what is the microscopic basis of temperature in that particular solid? And how do we measure the temperature of the distal object?

(Refer Slide Time: 1:18)

So in order to answer these two particular questions that we have to understand that thermal equilibration in solid also leads to a particular distribution of frequencies of the emitted electromagnetic radiation which is known as blackbody radiation, so in this case now similar to our kinetic theory of gases we have talked about Maxwell-Boltzmann velocity distribution, here we are going to talk about distributions of frequencies of electromagnetic radiation emitted from the particular object.

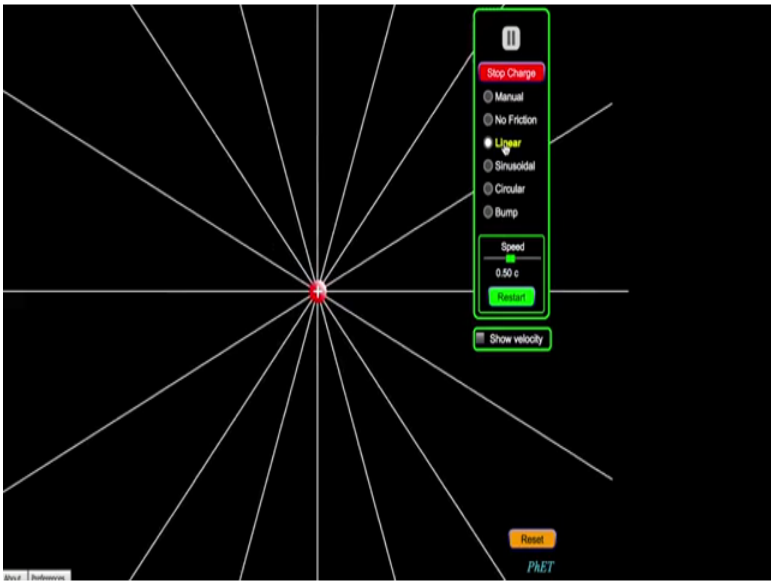
Now what we mean by that? We mean by that when an object a solid object is in thermal equilibrium then the atoms of that object will fluctuate or rather charges present in that particular object will fluctuate giving rise to electromagnetic radiation.

(Refer Slide Time: 2:04)



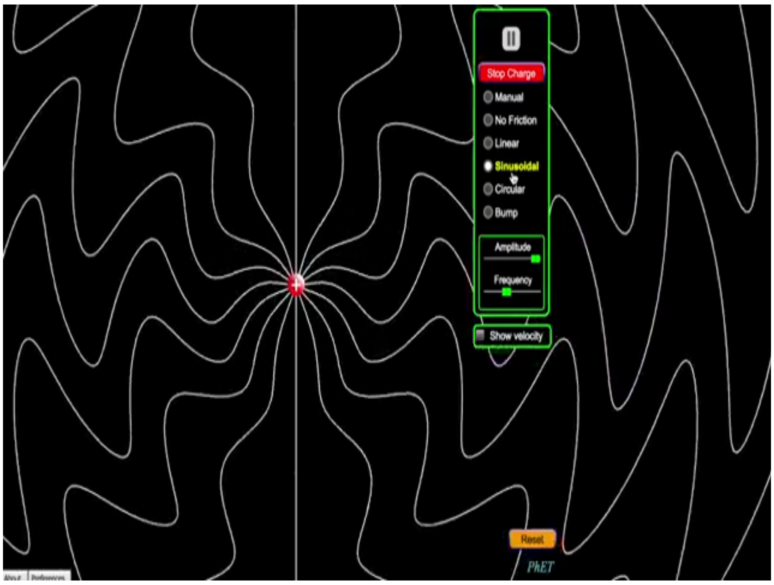
So we are going to show a demo of that a charge positive charge is kept somewhere and these are the fields associated with the charge.

(Refer Slide Time: 2:16)



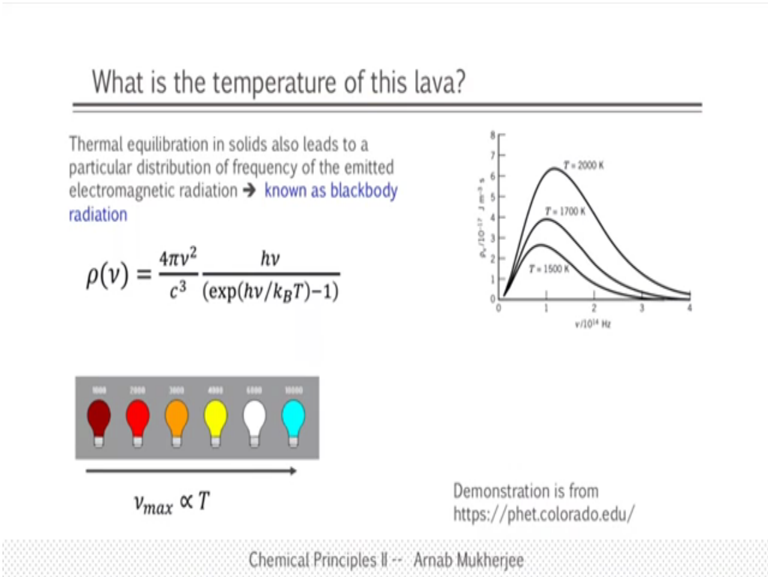
(So when we use a linear velocity) when you move the charge with the linear velocity does not actually give any electromagnetic radiation.

(Refer Slide Time: 2:22)



However, when you move it in a sinusoidal manner such that the charge oscillates it will give rise to an electromagnetic radiation corresponding with the frequency of movement of the particular charge. So now imagine that in solid objects which is kept at a very high temperature for example a very hot iron rod items in that rod will actually fluctuate and the charges within the atom of the rod will fluctuate giving rise to electromagnetic radiation.

(Refer Slide Time: 3:08)

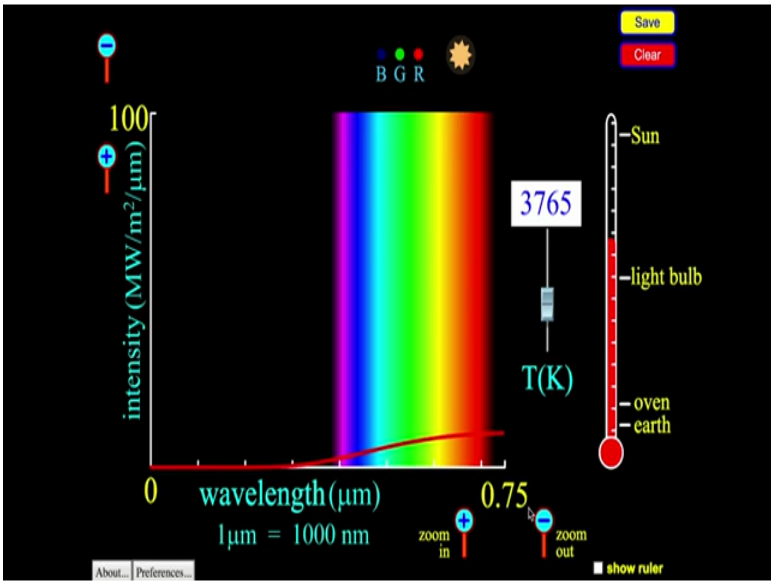


Now it turns out that just like velocities that all the particles will not have same velocities, similarly the emitted electromagnetic radiation will not be of same frequency, there will be a range of frequencies in which the radiation will happen and that is given by law called blackbody spectrum and that also in a surprising looks very similar to Maxwell-Boltzmann in the sense that if we plot it you will see an increasing and then decreasing behaviour so the new square here increases with the frequency and this particular part decreases with the frequency giving rise to this particular distribution and as you can see here that at different temperature it will give different type of blackbody spectrum.

Here also the temperature is fixed, the macroscopic variable which is temperature is fixed. However, individual frequencies are not having the same value just like our gas particles whether you get the analogy with the gas particles, the gas particles of same temperature or the microscopic value of the temperature having different velocities similarly the solid object having the same microscopic value of temperature giving rise to different frequencies of electromagnetic radiation.

And overall those frequencies will shift towards the higher frequency or rather we can say that the peak of the distribution will shift to the higher values as the temperature increases. And that is shown here as you can see that you know the frequency of red light is less compared to the blue light, so as we go from low frequency to the high frequency you can see that the colour changes. So by looking at the colour of an object which is emitting electromagnetic radiation we can figure out the temperature of that particular object.

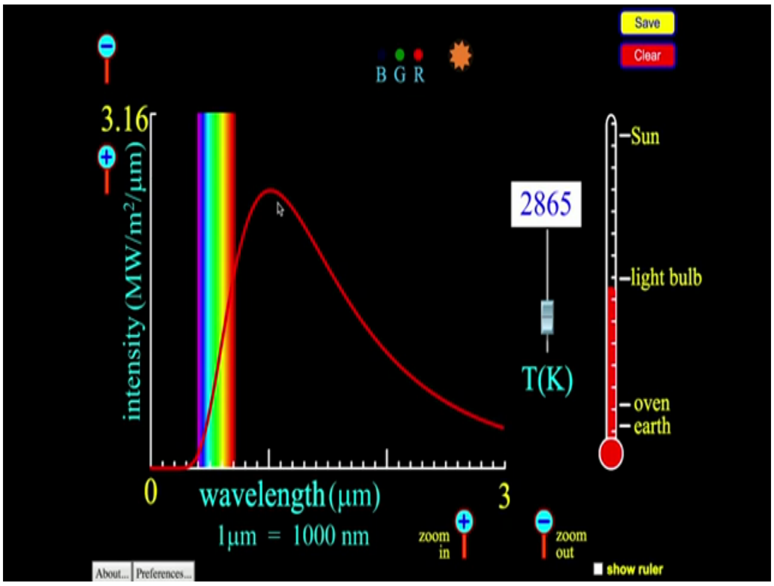
(Refer Slide Time: 4:48)



So I will show you a demonstration of that here and this demonstration has been taken from (())(4:50) Colorado, so this is the typical blackbody spectrum and in which this region is the visible range. So as you can see that right now the temperature is around 5000 kelvin almost the temperature of the sun and major portion of the peak of the distribution falls in the visible range therefore one can see that object.

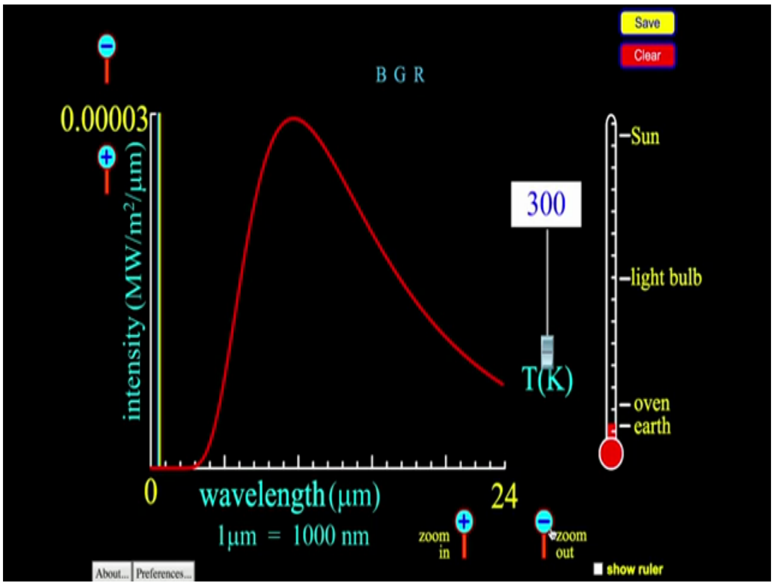
So if something has higher temperature or emitting radiation in the visible region then we will be able to see that. For example when a hot iron rod is emitting radiation we can see that it is red hot we call that red hot, now it becomes even hotter then it will become from red to yellow and finally if it is super-hot then it will adapt a bluish colour.

(Refer Slide Time: 5:44)



So however, as the temperature goes down if I go down the temperature decrease the temperature then what happens is that it will shift towards more and more lower frequencies so as you can see I am decreasing the temperature to 3000 and it is shifting to higher wavelength here which means the lower frequency.

(Refer Slide Time: 6:06)



And if we go down to as low as the normal human temperature which is 300 kelvin, so I am now at 1200 I have to go even lower, even lower so at 300 kelvin as you can see that the peak of the distribution is in the micrometre region and that is the region that is associated with IR radiation. So our body we are also kind of a blackbody which is emitting radiation some electromagnetic radiation, but we are radiating a distributions of frequencies, but all those frequencies are in the range of in the IR region and therefore our normal eyes we cannot detect anything that is beyond our visible spectrum therefore we cannot see the radiation coming out of our body so what kind of radiation it is?

We call that heat and heat is nothing but IR, so we are emitting IR radiation that is perceived by something called you know heat you know what is that camera called so it is called infrared camera where or heat sensor camera which senses the heat and then you know one can find out the presence of an object and also we can see that when you look at that body will see that although our temperature when you measure our temperature of the body it is one value, right but when you measure through a heat sensor you will see a distribution, you will not have the same value, you know some portions will be like hotter, some portions colder. So it is like that all the bodies are interacting with each other however, one gets a microscopic sense of the temperature.

(Refer Slide Time: 8:10)

So similar principle of using the blackbody radiation has been you know it is used in something called infrared thermometer, so we have one infrared thermometer here and we are going to measure temperature through that. So let us see what is temperature of this particular water which is still hot and that time we measure to be (50 degree) 40 degree, let us see how much it is, 40.9 if you want to see, do you want to try? You try it and tell the temperature and tell us that what is the temperature you are getting?

Student is answering: 40.5.

40.5, try this one.

Student is answering: 21.

21, so it is almost same as our thermometer however, is much easier and one can measure that.

(Refer Slide Time: 8:54)

So for example I can measure your body temperature it is supposed to be how much? 37 degree, yes the head gives 34, this particular infrared thermometer (goes) works in the lower range up to let us say 100 or something.

(Refer Slide Time: 9:11)

But we have a better one, we have this one it is called pyrometer which again follows similar things called Stefan–Boltzmann law which actually measures the energy density here and that works beyond 200 degree centigrade.

(Refer Slide Time: 9:28)

So looking at that yellow lights since we know that yellow falls in the range of you know 1000 something so we can actually measure the temperature of that, so let us measure that and see what you get. So we have to focus that light and it really does not matter whether there is a vial outside it or not, 1165 it fluctuates around it, but typically you can say 1104, 1136 something like that is.

(Refer Slide Time: 10:16)

And the temperature of this light which we saw yesterday around 300 degree you can say it fluctuates around that, okay.

[Processor-Student conversation starts]

Student: We cannot feel that high temperature, such high temperature.

Professor: If you touch that, you will of course feel that temperature, this is used to measure the electromagnetic radiation that is coming out of that. So since we are at a distance, we are not feeling the temperature however, if you touch the object of course you will feel the heat. So this light, let us say if you go to the source of the light you will have that

Student: If you touch the filament of that…

Student: What is the range of that?

Professor: This range, the range of this particular one I know the lower range 200, but I do not know the higher range I do not know how high it can go. The point of like you know when people try to calculate the temperature of the lava, they are not going to really go and measure it, right so we can do it from far away, but although we may not feel that but if you actually touch that source then you will see that the temperature is high, okay.

[Processor-Student conversation ends]

So we have seen that many different ways of measuring temperature that we can measure the temperature by volume of expansion of gases, solids or liquids through resistance, through blackbody radiations you know all possible ways we can actually measure the temperature of a particular system, but again the temperature is a quantity then which gives you when the temperature is at equilibrium then it gives you a distribution a particular distributions of gas molecules or frequency of electromagnetic radiation of the solid.

So it will give you a fixed distribution, so in a microscopic label things are not going to have one particular value, it will be always having a distribution and we are going to learn later on that why that is such? Why we always have a distribution in a microscopic label rather than one particular value?

(Refer Slide Time: 12:36)

We need to talk about I explain to you before, right we need to talk about 1 litre of volume in a microscopic sense it does not mean that it will always have 1 litre, it will fluctuate around that and that fluctuation is due to the motions of molecules that are there in that class (all those) and you will see that all the microscopic variables like temperature, pressure, and volume that you are going to measure later on they are nothing but averages of all those measurements, they are not fixed values, they are just average values.

And in the same way the Maxwell-Boltzmann distribution is giving you an average effect as temperature as one value, although it has many possible temperatures for individual molecules. Now if you go in the individual molecules and let us say what is the temperature of that molecule you calculate the kinetic energy of that molecule and that will be the corresponding temperature.

So that is why it is interesting that when you take out that high energy molecules what will happen? What do you think will happen that from let us say given N molecules which is having Maxwell-Boltzmann distribution, you take out the molecules which are having the higher velocities that is from the tale you take out something, what is going to happen, what do you think is going to happen?

So what is going to happen is that when you take out that so you are reducing the overall energy of the system. So now it is going to redistribute it, the velocities are going to be redistributed again having a different temperature and the distribution will shift to the left and same is true for if you take out the cold items cold molecules and then it will distribution will shift to the right.