Hello in this video will discuss about Compton effect in brief and the concept of the particle nature of radiation. Here is the outline of this talk. Learners will be able to understand the experimental arrangement and results of Compton effect and understand the equation of content shift.  Einstein using his concept of photons was able to explain the observation of the photoelectric effect, but not many physicists took this seriously, concept of photons, except maybe Niel Bohr. But after Compton's experiment it was confirmed that light does have particle nature. Arthur Holly Compton 1923 assumed that the photon not only carries an energy E is equal to h nu, but also has a certain momentum like a material particle. So  what is the Compton effect? If a photon of energy h nu  strikes an electron, some of the energy is transferred to the electron and the scattered photon will have less energy than the incident photon or will have larger wavelength then the incident photon. The observed change in frequency or wavelength is called content shift. In this slide, we'll talk about the experimental demonstration of Compton effect. As you can see in this setup you have an X ray tube which produces monochromatic X Rays, that is X Rays of single wavelength, and the X Rays are incident onto a carbon foil and we measure intensity for different scattering angles. So these plots as you see here are the plots of intensity distribution versus wavelength. Let's look at the first example. For unscattered radiation, that is scattering angle is zero, we just have one peak here. So the wavelength corresponding to this peak Is equal to the wavelength of the incident radiation. Now let's look at the scattering angle of 45 degrees. So in this case you have two peaks instead of one peak. The first peak has a wavelength that is equal to wavelength of the incident radiation, but along with that you also have a second peak which has wavelength which is larger than the incident radiation and the separation between these two peaks is the Compton shift and we observe here as the angle increases the Compton shift also increases. According to classical wave theory, the existence of first peak could be explained. According to the wave theory you have radiation coming in and it interacts with the electron. The electron oscillates with the same frequency as the incident radiation and now the electron is oscillating and the oscillating charged particle emits radiation. So it also emits radiation with the same frequency as the incident radiation. So the existence of the 1st peak could be explained but classical wave theory could not explain the existence of the second peak over here. To explain the discrepancy. Compton also independently  Debye assumed that X Rays are not radiation, they are photons. So when X Ray photon comes in it interacts with the electron just like a two billiard ball collision. If initial energy is h nu of the photon, so the X ray photon comes in and  interacts with electron, some of the energy is transferred to the electron.As can be seen in the figure, the electron is moving in this direction and the scattered X Ray will have less energy compared to the initial X Rays or the scattered X ray will have a greater wavelength compared to the incident radiation. Theta here is the scattering angle.. So using conservation of energy and conservation of Momentum, Compton arrived at the equation of Compton shift, that is delta lambda, which is a Compton shift,  is equal to lambda prime minus lambda is equal to h by m_0 c into 1- cos theta. Theta as I mentioned is the scattering angle and h by m_0 c has units of meters, so it is called Compton wavelength. If the angle theta is zero, that is un-scattered radiation, so as cos 0 is 1 Delta Lambda will be equal to 0. Hence you just see one peak over here.

When theta is equal to 90 degrees, cos 90 is 0,  the compton shift is h by m_0 c. So if you plug in this values you should get a value  that is equal to the difference between these two wavelengths and the maximum scattering, that is maximum shift, is when the photon backscatters from the electron, that is photon coming in it interacts with electron and  backscatters with an angle of 180 degrees. In that case cause 180 is minus one, so the Compton shift will be 2 h by m_0 c. So using the compton shift formula compton was able to explain the existence of the second peak as you can see here. But now these X rays are getting scattered, so how can you explain the existence of the first peak is the question. Compton in derivation had assumed that the electron is free and stationary. X Ray coming in interacts with the carbon foil, so it is carbon atoms, so it can interact with electrons that are lightly bound  or electrons that are tightly bound. So as I mentioned here, we had assumed that the electrons are free but they are actually bound. But this is a good assumption if the electron is  lightly bound, that is the kinetic energy of the X ray photon is large enough, larger than the binding energy, so the electron will be free, and this assumption will be valid. But what about the X ray photon interacting with the tightly bound electrons? In that case it may not have enough energy to remove the electron from the atom. So in that case, the interaction between X Ray and electron will be like interaction between X Ray and the entire atom. So the entire atom will recoil. In this case the mass of the electron should be replaced by the mass of the carbon atom. Mass of the carbon atom is around 22,000 times greater than the mass of the electron. So there's this Compton shift that will be very, very less, so we really cannot detect the company shift. This first peak, as you see,  is because of the interaction of X Ray photons with tightly bound electrons. As I said, Compton had assumed that electrons are free and stationary, but electrons in a carbon atom have random velocities. They're not actually stationary, but they maybe rest on average. If they were actually stationary if velocity is  zero then we would expect the intensity distribution curve, which looks like this. As you have monochromatic X Ray, if the X Ray gets scattered off a tightly bound electron, you have this peak Lambda, the X Ray collides with an electron that  is lightly bound and we will have a peak Lambda prime. But you can see that realistically speaking, we have this broad distribution of intensity versus wavelength.

This is because electrons may have some slight  velocity, so scattered X Ray photons may not actually exactly have wavelength lambda prime. It may be Lambda prime plus a small value. Hence you have this broad distribution. In this slide, I'll explain Rayleigh scattering and Compton scattering and the difference between them. So Rayleigh  scattering is a process where a photon scatters without changing its wavelength, and that scattered photon will have the same wavelength as the incident photon. If the incident radiation is in radio, visible or microwave region, the wavelength Lambda. Is much greater than the constant shift. So in this case the scattered radiation will look like it has the same wavelength as the incident radiation. So in this region Rayleigh scattering dominates. Compton scattering can get important for low Z atoms where electrons are very lightly bound, so it is easier to free them. As Lambda goes to Infinity the quantum and classical results they merge. On the other hand, in the gamma region where lambda goes to zero, the photon energy is large enough to remove any tightly bound electrons.

So you will always observe Compton shift and in this case, the Compton scattering dominates.

In this slide I will discuss the contrasting behavior of classical and quantum physics, so we consider a system that is oscillating so classically the oscillator can have any energy values. You have a continuous range of energy values, as shown in this figure over here, but according to Planck's postulate that energy transfer between radiation and oscillator is quantized. The oscillator only can have discrete energy values that is E is equal to the integral multiple of h nu. So a quantum harmonic oscillator, as per Planck can have the energy values h nu, 2 h nu, 3 h nu and so on, and the spacing between these two energy levels is h nu.

So in the high frequency region as we saw, the classical results fail to explain the scattering of radiation in the gamma ray region. Why is that? See the spacing between these energy levels is h nu and the value of h is very small that is 6.626 into 10 to the power minus 34 Joules sec. So if the frequency is also small then the spacing between energy levels will be small and it will be like the classical system. So if the frequency is large, and then the spacing between the energy levels will be large and then quantum effects will start to come out. That means to test Planck's postulate the frequency should be large. If you remember the. Ultraviolet catastrophe the radiancy versus frequency plot, classical physics was not able to explain the plot at high frequencies. Similarly, here for high frequency region classical results failed to explain the scattering of radiation. So one final comment I want to make here. The value of h has a lot of significance. If the value of h is zero, then quantum and classical systems merge, that is results. If the value of h is 0, then quantum and classical results merge and if the value of h it is large enough then you would actually see quantum effects in your day-to-day life or your lab experiments. The reason why we don't actually detect quantum effects in your day to day life and experiments is because the value of h is so small. In conclusion, the classical wave theory of light failed to explain the scattering of X Rays from electrons. Compton by assuming the particle nature of light and applying conservation of energy and momentum to the collision between the photons and electron obtained the equation of Compton shift that explained the experimental results. The results of Compton effect further confirmed the particle nature of light. After this there was no doubt that light has particle nature. Again, some useful references, thank you.