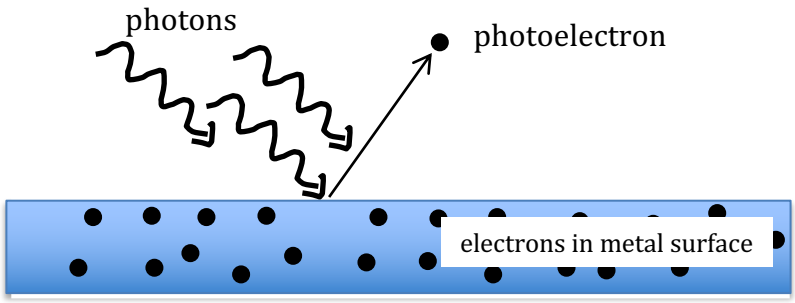
2.8.1 The photoelectric effect

videos

When certain metals are exposed to light of a certain frequency, they emit electrons. These are called photoelectrons (but are just normal electrons).

It is found that the photons of light are transferring energy to electrons in the metal surface, which gain enough energy to escape the metal surface. The minimum energy that the electrons need to escape the metal surface is called the work function (ϕ) of the metal, and varies depending on the metal.



One photon of light has an energy $E = hf$ (*where h = the Planck constant, and f = frequency of the light*). This energy is completely transferred to one electron in the metal surface. If this energy is larger than the work function, there is a chance that the electron will escape the surface of the metal. Most electrons actually require more energy than this to escape the surface.

(1) What do you think happens if the energy of the photons is smaller than the work function?

(2) What do you think happens if the energy of the photons is larger than the work function?

We can write an energy equation for the transfer of energy from a photon to an electron.

$$hf = \phi + E_{k(\max)}$$

where $E_{k(max)}$ is the maximum kinetic energy of the emitted electron

This shows that the energy provided by the photon (*hf*) goes into freeing the electron from the surface of the metal plus the kinetic energy of the emitted electron.

(3) Why is the kinetic energy in the equation the maximum kinetic energy a photoelectron can have?

(4) It is found that below a certain frequency of light, called the threshold frequency (f_{thresh}), no photoelectrons are emitted. Why do you think this is? (Hint: think about the energy of the photons).

At the threshold frequency, we just start to see electrons being emitted, because the photon energies are just enough the overcome the work function. Electrons are emitted with very little kinetic energy ($E_{Kmax}=0$).
Therefore, we can write:

$$hf_{thresh} = \phi + zero$$

$$\therefore \ f_{thresh} = \frac{\phi}{h}$$

(5) As the frequency is increased (above the threshold frequency), what will happen to the kinetic energy of the photoelectrons?

(6) What do you think will happen to the number of photoelectrons emitted?

When we increase the intensity of the light, what we are actually doing is increasing the rate at which photons 'hit' the surface of the metal. A high intensity – lots of photons per second, etc.

(7) What would you expect to observe if the frequency of light is above the threshold frequency and the intensity is increased?

Evidence for the particle nature of light

The photoelectric effect is evidence for the particle nature of light. The observations can only be explained by electromagnetic radiation coming in discrete energy packets called photons.