Assignment #3- Lay Article

Sean Sutton
April 6, 2005

Back in 1905 there were some great advancements in the field of physics. One of these advancements came in Einstein s famous paper on the photoelectric effect. This paper can be very difficult and confusing for the average reader to understand, and so here is a summary of the last three chapters of his paper.

Before we begin looking at the actual sections of Einstein s paper however, we should introduce a few terms and concepts to make this easier to understand.

Photon- A particle of light. Imagine light as water. At times it s best for us to describe the movement of water by means of waves (water in a river). However sometimes we find it easier to describe it as droplets (falling rain). A photon is the rain drop equivalent of light.

Discrete- This means having a certain value. If we say light is made up of discrete particles , we mean that there are definite particles which make up the light.

Quantum- A quantum of light would be a photon. Quantum refers to a discrete value. The plural of this is quanta.

Frequency- How often a wave goes up and down. This is a very important feature, used to describe a wave. This can also describe the colour of the light wave. The energy of light is related directly to the frequency of its photons.

Wavelength- The length over which the wave completes one full cycle. The value is equal to 1 / (frequency)

Monochromatic- Refers to light that is made up of only one frequency. For example, red light is monochromatic because there is only the red frequency. However, white light is made up of a number of different frequencies and so it wouldn t be monochromatic.

Photoelectric effect- In this effect a photon of light strikes the surface of a plate which has an electrical charge on it. An electron is then ejected from the surface. This was used to prove the particle nature of light (i.e. Photons).

Work- The amount of energy we need to use to get something done.

Potential- The amount of work that is needed to get something to happen.

Electron- A particle in an atom. Electrons have a negative charge. They are the particles in the atom which take in the energy from photons of light.

Ionization Energy- The amount of energy needed to remove an electron from a molecule.

Incident and Emitted Light- Incident light refers to incoming light. Emitted light refers to outgoing light. For example and incident ray of light would be one that strikes and is absorbed by an electron. An emitted ray would be the light that is given of by the energetic electron.

Chapter 7- Concerning Stoke s Rule

Let s look at the case of incoming light of a specific colour (monochromatic light) which we will call *v*1, and let s assume that this light strikes a metal plate with an electrical charge on it. The light will be absorbed and then emitted at a frequency which we will call *v*2 (or it could be spit out at a different frequency as well at the same time by means of another photon, or even as other kinds of energy like heat).

If there is no outside energy coming into the system, then the energy of the light being spit out must be equal to, or less than the energy of the incoming light. Now since the energy of a quantum of light is dependant only on its frequency (as mentioned in the definition of frequency listed above), we can then say that in general

$$v2 <= v1$$

Which means that the frequency of the photon being spit out, has to be less than the frequency of the incoming photon.

Figure 1. *In the first picture we see a photon transferring it s energy to an electron in the atom. The second picture depicts the electron re-emitting it s energy in the form of a new photon. Stoke s law simply says that the energy of the original photon has the same amount of energy or more energy that the photon that is re-emitted. [1]*

The only time that the situation that we ve presented may change would be under the following conditions:

1- That there are enough photons of light coming in at the same time that, the photon being spit out can get its energy from multiple different sources.

2- That the incident light has a frequency that isn t valid under Wein s Law.

Chapter 8- Concerning the Emission of Cathode Rays Through Illumination of Solid Bodies.

Quanta of light can give all or part of their energy to the electrons which they strike. However, let s say for now that each quantum delivers all of its energy to a single electron.

We have to assume that the electron will have to do some extra work to leave the surface which the light is striking. Let s then say that we have the smallest possible positive potential on the plate, that still keeps the electrons from escaping.

If we then look at the relationship between the positive potential and the frequency of the light, we find that it is linear (meaning that if you make a graph of one versus the other, you will always get a straight line) no matter what material the plate is made from.

We can then note that, if each one of our photons delivers its energy to an electron, then the velocity of the electrons that are being spit out has nothing to do with the intensity of the incident light (meaning the number of incoming photons). Also, the number of electrons leaving the surface depends on the intensity of the incident light.

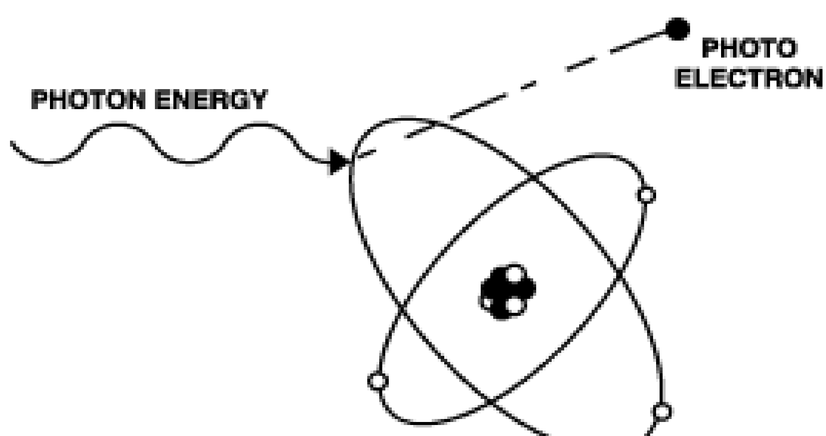

Figure 2. *The incoming photon transfers all of it s energy to the outgoing electron. We can see from this that each electron will need it s own photon in order to get excited.* [2]

This is a very powerful statement. A good analogy for this is to imagine shaking dust from a rug. You would assume that the harder you shook it (larger the amplitude of the wave), the faster the dust particles would escape from the surface. However this is saying that with light, the harder it s shaken (the greater the intensity), the more dust particles will come off, and also that the greater the frequency you shake it with, the faster the particles will come off.

Chapter 9- Concerning the Ionization of Gases by Ultraviolet Light Solid Bodies

Ionization is a process in which an electron is removed or added to a molecule. Let s just consider the case in which an electron is removed from a molecule, in this case by gaining enough energy from a photon that it can escape from the molecule. Let s also assume again that each quantum gives all of its energy to an individual gas molecule.

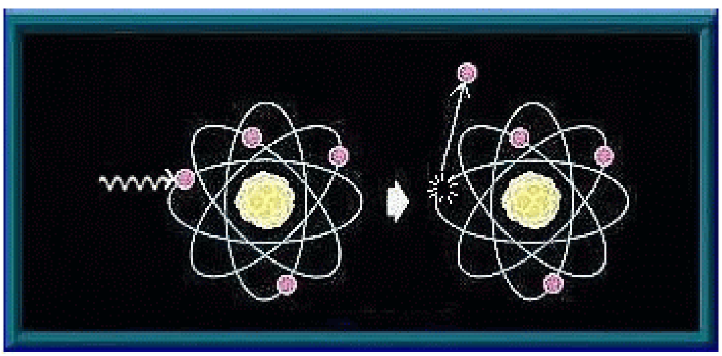

Figure 3. *In this example of ionization, we can see an incoming photon gives its energy to an atom, which then escapes the atom.*[4]

We can then say that the energy of a quantum which ionizes a molecule, must be greater than or equal to the ionization energy of the molecule which it is ionizing. This makes sense because if the quantum has less energy than the ionization energy, there will not be enough energy to ionize the molecule!

A good analogy for this would be trying to buy a chocolate bar. If you (the quantum of light) have $5.00 (this is your amount of energy), and the chocolate bar only costs $2.50 (the ionization energy), then you will be able to buy it (ionize it). It wouldn t matter how much money over $2.50 you had, you d still be able to buy it, and even with only $2.50 you d be able to make the purchase. However if you had anything less than $2.50 you would not be able to buy the chocolate bar (or in our case, ionize the molecule). It should also be noted that if there was money (energy) left over after the purchase, it would have to be used up as well. So it would be like paying with a $5.00 bill, and the clerk not being able to give you change back. The same thing happens with the transfer of energy to an electron. The extra energy will end up being spent as some other for of energy such as kinetic energy or heat.

References

[1] - picture taken from http://csep10.phys.utk.edu/astr162/lect/light/excitation.gif

[2]- picture taken from
http://www.nbc-med.org/SiteContent/MedRef/OnlineRef/FieldManuals/amedp6/PART_I/images/chapter2

[3] Analogy take from a lecture given by Dr. Gordon Drake.

[4] http://www.hko.gov.hk/education/dbcp/radiation/eng/image/ionization.jpg

[5] A. Einstein, *Considering an Heuristic Point of View Toward the Emmision and Transformation of Light* A.. Physik **17**,132 (1905)