Phys 112 2019

Lecture 38

Mon: Warm Up 15 (D2L)

Tues: Usual moved to Weds

Weds: Discussion /quiz

Matter and electromagnetic interactions

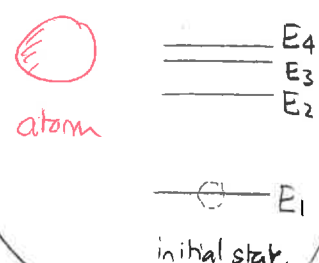
Quantum theory describes how light interacts with matter as follows

Light - consists of photons

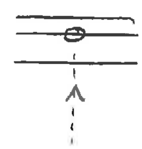
single photon energy

$E_{photon} = hf = hc/\lambda$

Matter - quantized energy levels

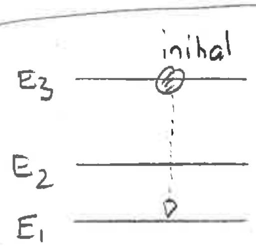


Matter: can only absorb or emit photon if photon energy exactly matches a jump in energy levels



$E_{ph} = E_3 - E_1$

The same applies for emission of photons



$E_{ph} = \Delta E_{atom}$

→ Only possibilities in this case

$\Delta E_{atom} = E_3 - E_2$

$\Delta E_{atom} = E_3 - E_1$

$\Delta E_{atom} = E_2 - E_1$

Quiz 1

Note that if the system energy during absorption or emission changes by ΔE_{system} then

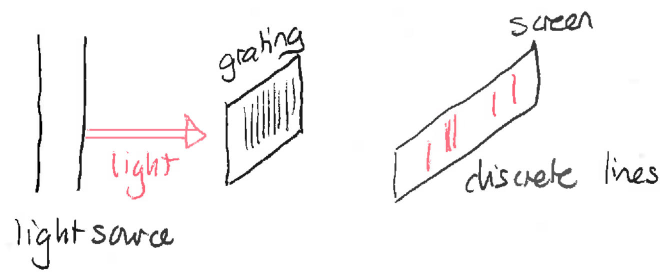
$$E_{photon} = |\Delta E_{system}| \Rightarrow \frac{hc}{\lambda} = |\Delta E_{system}| \Rightarrow \boxed{\lambda = \frac{hc}{|\Delta E_{system}|}}$$

Energy quantization for the system implies that only certain discrete system energy changes are possible. Thus a system can only absorb or emit certain discrete wavelengths of light. The emitted light will therefore produce a discrete 'spectrum' and this spectrum depends entirely on the energy level structure of the system/matter/molecule/atom.

Spectroscopy

Is the technique by which light that is emitted from various objects /atoms is decomposed into constituent colors and the wavelengths or frequencies of these are analyzed. Usually the decomposition is done by some type of diffraction grating.

Demo: * H_2 (He, Ne) discharge tubes
* Diffraction gratings



Spectroscopy was developed in the early 19th century and the patterns of lines for various elements were charted. This enabled the identification of the presence of elements and the discovery of new elements. Examples include Cesium (Bunsen + Kirchoff, 1860), Rubidium (Bunsen + Kirchoff, 1861), Helium (Rayet, Haig, Pogson, Herschel, 1868)

Demo: Emission Spectra
SE La Univ

There are two types of spectroscopy:

1) emission spectroscopy - describes spectrum of light emitted by a substance

2) absorption " - describes " " " absorbed by a substance

We focus on emission spectroscopy. Classical physics could not explain:

1) the discrete nature of the emission spectra of various materials

2) the particular values of the wavelengths emitted.

An empirical rule was determined for hydrogen by the late 1800s. This is

> The emitted wavelengths satisfy
>
> $$\lambda = \frac{91.1\text{nm}}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)}$$
>
> where $m = 1, 2, 3, \ldots$ and $n = m+1, m+2, \ldots$

What physical theory could predict this?

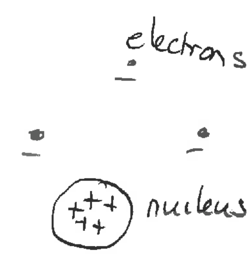
Quiz 2

Atomic structure

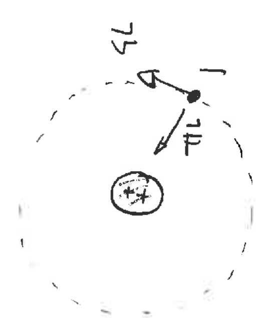
The explanation for the spectrum requires a model of the atomic structure of atoms. The current picture results from a series of experiments done in the late 19th century and early 20th century. The main conclusions are:

1) nearly all of the mass of an atom is concentrated in a small region at the atom's center. – the nucleus of the atom.
2) the nucleus is positively charged
3) the electrons inhabit regions significantly far from the nucleus, compared to the dimensions of the nucleus.

Demo PhET Rutherford Scattering
- show Plum Pudding Models – traces
- show Rutherford Atom – traces



The resulting model is as illustrated.
The question was how an atom could remain in a stable state. Classical physics and classical electromagnetism could explain that the Coulomb force could provide a centripetal force which keeps the electron in a circular orbit. Then classical physics could address remaining aspects of the electron motion:



1) acceleration
2) energy

Quiz 3

Classical physics predicts that the electron accelerates. Classical electromagnetism predicts:

1) an accelerating charge radiates electromagnetic waves
2) the frequency of the waves is determined by the orbital frequency
3) the energy of the orbiting electron.

explains how an atom can produce light and how to determine frequencies

Unfortunately if the charge radiates electromagnetic waves then these waves carry energy away and the energy of the atom/electron must decrease. This is only possible if the orbital radius decreases. One can determine the rate at which it decreases. By classical physics this predicts that a hydrogen atom will have a lifespan of 10^{-11} s. This is not consistent with observations.

PhET: Hydrogen atom molecules

– classical solar system in prediction