ECE 30
Day 20 Notes

Elijah Hantman

Agenda

- Review Q.7 of Quiz 3
- Struction of the Atom
  - Rutherford Orbital Model
  - The Bohr Model
  - De Broglie Waves

Review

- The current is clockwise. I was correct last time I think. turns out it depends on the face we are looking at, could be solved with "parity" but whatever.

Structure of the Atom

- Rutherford said that the nucleus must be tiny since some alpha particles were deflected, but most weren't.
- Since alpha particles are positively charged the nucleus must have a very strong positive charge.
- Therefore Rutherford postulated that the atom was electrons orbiting a positively charged nucleus.

If the atom is an orbital then the following holds true.

$$F_c = F_e$$

The centripedal force balances out

$$F_c = m_e \frac{v^2}{r}$$

And from Coulombs law

$$F_e = k\frac{e^2}{r^2}$$

Where e is the charge of an electron.

From the first equality we know:

$$m_e \frac{v^2}{r} = k\frac{e^2}{r^2}$$

Therefore

$$m_e v^2 = k\frac{e^2}{r}$$

We can therefore calculate velocity:

$$v = \frac{e}{\sqrt{4\pi\epsilon_0 m_e r}}$$

The total energy is:

$$E = \frac{1}{2}mv^2 - \frac{e^2}{4\pi\epsilon_0 r}$$

In other words, it is the velocity minus the potential energy of the electron. The negative comes from the fact the electron and proton have opposite charges. The e is the magnitude of the charge not the sign.

If we substitude for v

$$E = \frac{e^2}{8\pi\epsilon_0 r} - \frac{e^2}{4\pi\epsilon_0 r}$$

$$E = \frac{-e^2}{8\pi\epsilon_0 r}$$

Since the energy is negative it means that orbiting an atom the electron is stable. It requires energy to break an electron away from an atom and it releases energy to bring an atom into orbit around an atom.

This also implies:

$$r = \frac{-e^2}{8\pi\epsilon_0 E}$$

Since we can ionize hydrogen we can measure E directly. Since the other constants are also measurable we can calculate the size of a hydrogen atom.

$$r = 5.3 \times 10^{-11}\mathrm{m}$$

This derivation matched experimental measurements.

Problems

If electron is moving around an atom it should be generating electro magnetic waves. It should slowly be losing energy until it collapses in on itself.

Gasses held at low pressure release a spectrum of light when heated.

French Physicist De Broglie proposed that all matter was made of waves. To test this he shot electrons through two small slits. It was well known that waves will create interferece patterns when passed through a similar setup.

When firing electrons and protons through these slits they form interference patterns, both when fired one at a time and en masse.

When we detect which slit the electron passed through the interference patterns disappeared.

This seemed to imply that particles move as waves until they are measured.

At a similar time Albert Einstein was working on the Photoelectric effect, in which light dislodges electrons from around atoms. He could only explain this if light came in discrete particles "photons".

All of this implies that matter is both a wave and a particle at the same time.

Hydrogen's spectra had a band at 6,536 Angstroms,

An Angstrom is defined:

$$A = 10^{-10}\mathrm{m}$$

There are other bands of increasing density up to 3,646 Å.

Light appeared to only be emittable in specific bands.

In 1928 De Broglie proposed that particles have the properties of waves, and that they obey the same wave properties as light:

$$\lambda = \frac{h}{P}$$

Where h is planck's constant and P is momentum. This is the same equation as for electromagnetic waves.

$$h \triangleq \text{Planck's Constant } 6.625 \times 10^{-34}\text{Jhz}$$

$$P \triangleq \text{Momentum } m \times v$$

Planck Postulated that:

1. An oscillating entity at atomic dimensions can only have energies given by:

   $$E = nhf$$

   Where f is the oscillating frequency, n is a positive integer (quantum number), and h is Planck's Constant.

2. Oscillators only radiate energy in discrete quanta if n changes:
   If n changes by 1 :

   $$\Delta E = \Delta nhf$$

   for $\Delta n = 1$:

   $$\Delta E = hf$$

   This means that hf is the smallest change in energy possible.

Danish scientist Nils Bohr used these observations by Planck to revise the model of the Atom. His model is called The Bohr Model.

De Broglie: wavelength is $\lambda_e = \frac{h}{mv_e}$

We know from Rutherford:

$$v = \frac{e}{\sqrt{4\pi\epsilon_0 mr}}$$

Therefore:

$$\lambda_e = \frac{h}{e}\sqrt{\frac{4\pi\epsilon_0 r}{m}}$$

But $r = 5.3 \times 10^{-11}\text{m}$ (from Rutherford).

Therefore we know all the constants on the left side of the equation. We then get that:

$$\lambda_e = 33 \times 10^{-11}\text{m}$$

The circumference of a Hydrogen Atom is $2\pi r \approx 33 \times 10^{-11}\text{m}$

So the wavelength of an electron at energy level $n = 1$ is equal to the circumference of it's orbit.

This implies an electron in an atom is a standing wave.