MSE160 Lecture Notes

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Chapter 1

Course Information

Midterm is now Thursday February 28

Chapter 2

Molecular Chemistry

2.1 Lecture 2: Light and Electron Energies

2.1.1 Miscellaneous Facts

- Most metals are ductile (easy to make wires out of) and malleable (easy to flatten out)
- However, lead is ONLY malleable
- The reason for which all materials have different properties is because of differences in atomic structures and how it affects bonding with other atoms.

2.1.2 Characteristics of Light

- Wavelength is the distance between one crest to another (or trough to another), λ
- Frequency is the number of cycles per second a wave goes through, v
- $\lambda * v = c$ where c is the speed of light ($3.0 * 10^8 m/s$)
- Amplitude is the intensity of the wave.
- Visible light is just a small part of the EM spectrum.
  - Long radio waves
  - AM Radio
  - FM and TV Radio

- Radar
- Microwaves
- Infrared
- Visible Light
- UV
- X-Rays
- Gamma rays

2.1.3 Double Slit Experiment

This experiment showed that light can interfere with itself in a wave-like fashion. If a trough and a crest overlap, then they will destructively interfere. Two crests or two troughs will constructively interfere. The experiment showed this because, when light was shined through two slits, an interference pattern would be shown on a screen on the other side of the slits.

2.1.4 Photoelectric Effect

This experiment showed that light also has particle-like behavior. $E_{photon} = hv_{photon}$ where $h = 6.63 * 10^{-}34$. Surplus energy from photon goes directly into kinetic energy of the electron.

- When light is shines on metals, electrons are ejected.
- By the past model, higher amplitude should result in greater kinetic energy of ejected electrons.
- However, it seemed to depend on frequency instead.
- Even with low amplitude light, if it was of high enough frequency, the kinetic energy of the ejected electrons was the same. The only difference was the rate of ejections.
- Conclusion: Light comes in packets called "photons", and the energy of each photon is given by the equation above (linearly dependent on frequency).

Conclusion: light acts like a wave and a particle (wow!).

2.1.5 Further Information on Wave-Particle Duality

Generally speaking, light behaves like a wave when the scale of interraction is large (i.e. light going through a prism - the prism is orders of magnitude larger than the wavelength of light). Meanwhile, light behaves more like a particle when interracting with things like atoms (atoms are roughly on the same order of magnitude as the wavelength of most light).

2.1.6 Electron Energies

- Electrons have discrete energy states where higher energy states have higher potential energy and lower states have lower potential energies.
- Ground state is the lowest energy state that the electron can have in an atom, while excited state(s) are any states that are higher.
- Convention: free electrons not bound to atoms have 0 energy (like potential gravitational energy).
  - Electrons bound to atoms have $E < 0$, and ground state has $E << 0$.
- Photons can be absorbed to raise an electron to a higher energy state.
- Photons are emitted when electrons fall down to a lower energy state.

Atomic Spectra

When atoms are in a place where their electrons are constantly being excited to above the ground state and then are falling back down, they emit their own signature spectrum due to the differences in energies between that particular atom's energy levels. You can solve for the frequency of the light emitted by electrons falling from one energy level to the other with $E = hv$.

2.1.7 Models for Atoms

- Rutherford model had electrons randomly hovering/orbiting a nucleus.
- Due to the observation of distinct atomic spectra, Bohr predicted that there must be distinct energy levels that each atoms has.
- Massive step forward because it was the first time that we could predict the behavior of atoms.

- It had a lot of issues though!
  - It did not generalize well to non-hydrogen atoms.
  - Didn't add up with the fact that magnetic/static fields would mess up spectral lines
  - As well, it conflicted with Maxwell's theory (classical electromagnetic theory)
    * A moving charge should emit energy/light
    * Therefore, by classical electromagnetic theory, electrosn should lose energy until they crash into the nucleus.
    * Bohr did not realize that electrons don't really behave like particles.

2.1.8 Double-Slit Experiment with Electrons

When you shoot electrons through double slits, they ALSO show an interference pattern! This indicates that electrons have wave-like properties.

- De Broglie arrgued that all objects have a wavelength associated with them.
- Given by $\lambda_p article = \frac{h}{p} = \frac{h}{/}mv$
- The reason for which we don't see wave properties in large objects is because mass is in the denominator, so wavelength is unimaginably small for things larger than subatomic particles.

2.1.9 Equations

$$E = hv \tag{2.1}$$

$$E_{kinetic} = \frac{1}{2}mv^2 \tag{2.2}$$

$$\lambda = \frac{hc}{E} \tag{2.3}$$

$$\lambda = \frac{h}{mv} \tag{2.4}$$

$$c = 3.8 * 10^8 m/s \tag{2.5}$$

2.1.10 Applications

Electron Microscopes

- Since electrons have wave properties, we can use them to get images of very small things.
- Light microscopes have limited resolving power because wavelength of light is kind of big compared to atoms.
- So we can get really really nice images of really small objects with electron microscopes.

Quantum Technology

- Quantum dots are semiconductor molecules that have very large absorption spectra but very narrow emission spectrum.
- As well, we can tailor molecules to have practically any emission frequency
- With this, we can image where molecules go in the body.
- If we can attach ligands (side molecules) to the quantum dots, we can very specifically target things like cancer.

Chapter 3

Materials