ATOMIC STRUCTURE & PERIODICITY (Ch 7&8)
AP CHEM

The Wave Nature of Light -Electromagnetic Radiation
Light travels as a _____________

Draw/Define: Parts of a wave

Electromagnetic radiation - the way energy travels through space.
Wavelength (λ) - the distance between two consecutive peaks or troughs in a wave.
Frequency (ν) - the number of waves (cycles) per second that pass a given point in space.
Note Wavelength and frequency are inversely related.

Velocity-
Amplitude-

1******>

Visible light is a type of electromagnetic radiation, which is a form of energy that emits a wavelike behavior.

Light Equations
1. $\lambda\nu = c$
c = *speed of light* = 3.00×10^8 *m/s*

Quantitized Energy of Photons-
The Nature of Matter

How does matter behave? It acts like a _________________
But….

Enter Max Planck (1858-1947)

Planck's constant (h) - the quantity of energy that can be absorbed or emitted. h = 6.626 x 10-34 J•s
Now the energy of a system ΔE (as we learned thermodynamics chap) can be defined as

2. $\Delta E = h\nu$

h is Planck's constant and ν is the frequency of the electromagnetic radiation absorbed or emitted.

Energy is in fact quantized and can only occur in discrete units of size $h\nu$. Each of these small "packets" of energy is called a quantum (or a photon when we are talking about light).

Energy comes in small quantities called _______________

So what about light?
Light travels as a ___________________ and as a ________________
A particle of light is called a ____________________

2******>

Does light have mass?

3. Einstein at the same time came up with the idea that E (energy) has mass (*m*). Giving us the equation
$E = mc^2$

The Particle Nature of Light
p. 305 Photoelectric effect

PHOTOELECTRIC EFFECT: Experiments had shown that light shining on a clean metal surface causes the surface to emit electrons. Each metal has a minimum frequency of light below which no electrons are emitted. For ex., light with a frequency of $4.60 \times 10^{14} s^{-1}$ or greater will cause cesium metal to emit electrons, but light of lower frequency has no effect. To explain the photoelectric effect, Einstein assumed that the radiant energy striking the metal surface does not behave like a wave, but rather if it were a stream of tiny energy packets. Each packet is called a photon (tiny particle).
Einstein deduced that each photon must have an energy = to Planck's constant times the frequency of the light.
$E = h\nu$ h = planck's constant

Thus, radiant energy itself is quantized (restricted to certain quantities of energy). A photon (under the right conditions), can strike a metal surface and be absorbed. When this happens, the photon can transfer its energy to an electron in the metal. A certain amount of energy (work function) is required for an e- to overcome the attractive forces that hold it in the metal. If the photons of the radiation impinging on the metal have less energy than the work function, electrons do not acquire sufficient energy to escape from the metal surface, even if the light beam is intense. If the the photons have sufficient energy, e- are emitted from the metal.

Dual nature of light - phenomenon in which light acts like both a wave and a particle of matter. The previous two equations were used by deBroglie to form the following equation to help confirm this idea of duality electromagnetic radiation.

deBroglie Hypothesis: (Matter Waves)- He said that all matter has wave characteristics. This is important because sometimes the behavior of e-is better described in terms of waves than particles.

$\lambda = h/m\nu$

**mv = momentum*

His hypothesis is very useful for very small particles, such as electrons. For larger particles, the wavelength becomes too small to be of interest.

Conclusion - Energy is really a form of matter, and all matter shows the same types of properties. That is, all matter exhibits both particulate and wave properties. Large pieces of matter, such as baseballs, exhibit predominantly particulate properties. The associated wavelength is so small that it is not observed. Very small bits of matter, such as photons, while showing some particulate properties, exhibit predominantly wave properties. Pieces of matter *intermediate mass, such as electrons, show clearly both the particulate and wave properties of matter.*

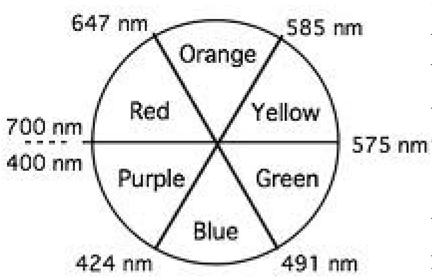
Line Spectra amd the Bohr Model -Atomic Spectrum of Hydrogen

A. How does a spectrum work? (p. 308)

1. Continuous spectrum - this spectrum results when white light passes through a prism, like the rainbow produced when sunlight is dispersed by raindrops, it contains all the wavelengths of visible light.

Diffraction and diffraction pattern - when light is scattered from a regular array of points or lines.

2. Line spectrum - in this spectrum , we see only a few lines, each of which corresponds to a discrete wavelength. The significance of the line spectrum is that it indicates that only certain energies are allowed for the electron in the atom.



Why do filters appear violet, blue, green yellow, orange, and red? They are each composed of different molecules – molecules that absorb different wavelengths of light. For ex, the red filter appears red to the human eye because it is transmitting red light. All non-red wavelengths are absorbed by the red filter to some extent, although green light will be absorbed the most. The green photons hit the filter and are absorbed by the molecules in the filter. They don't make it through the filter, so a green color is not seen from this filter. In contrast, red photons are not absorbed by the molecules in the red filter, so they pass right through the filter and a red color is observed.

Colors opposite each other on the color wheel are complementary colors: One is transmitted and the other absorbed. For example, the violet filter absorbs yellow light and transmits violet light. ------→spinach demo

B. Bohr's Model:
Classical physics says that an electron should lose energy and spin in a circular path continuously emitting electromagnetic radiation ---it should spiral into the positively charged nucleus.
Bohr adopted Planck's idea that energies are quantized.

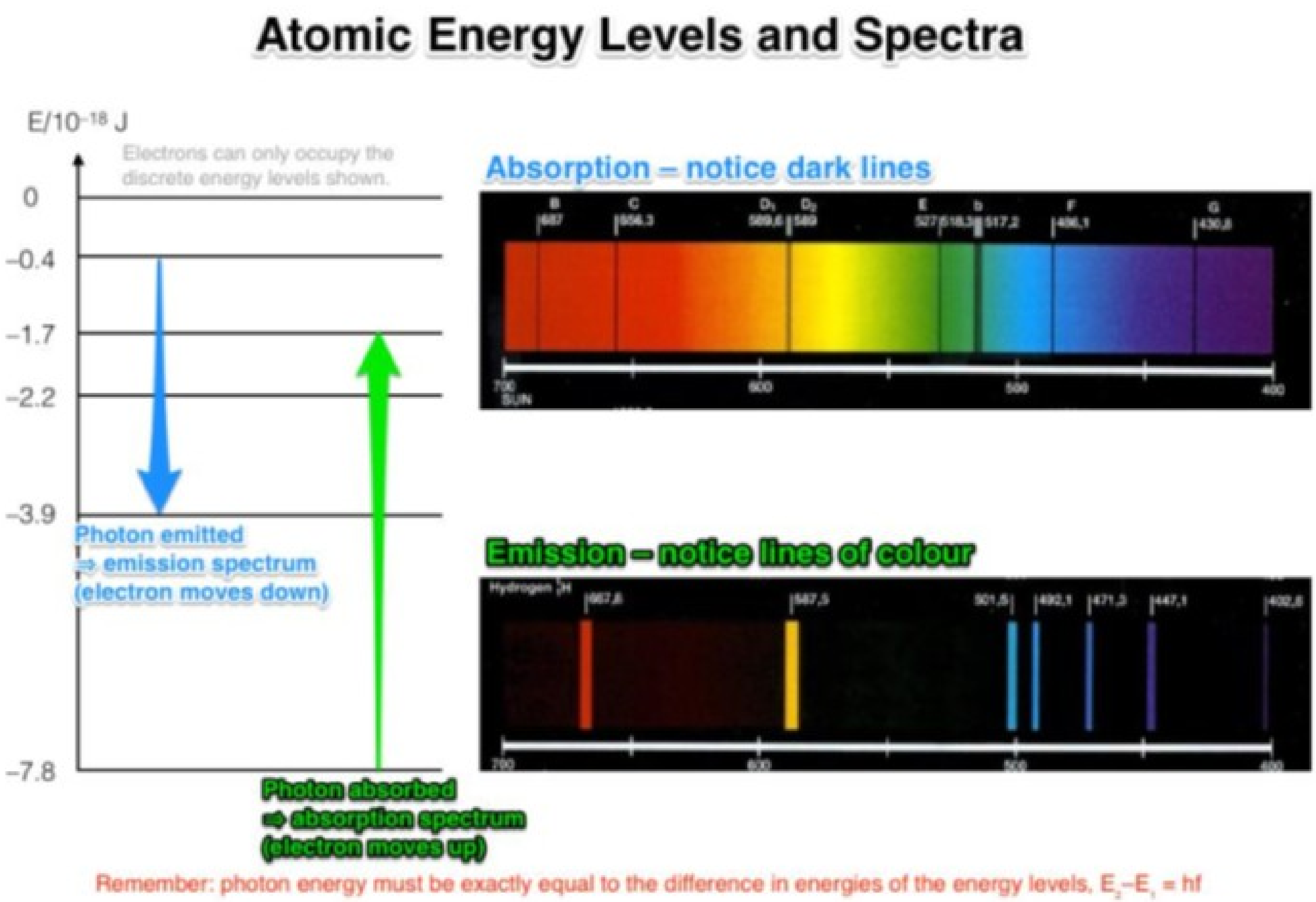
Rutherford built on Crooke's idea about the atom. However, time, a physical principle, said an atom could not be stable. e- & p+ are attracted and electrons would eventually fall into the nucleus. Bohr said there is energy from electrons that is quantized (restricted to a value). Electrons move about the nucleus in an orbit and centrifugal force counterbalanced the e- and nucleus attraction.

C. Pointers on Determining the excited state of an atom:
Excited state of a system (atom, molecules, or ions) is any configuration of the system that has a higher energy than the **ground state (**more energy than the absolute minimum).

The **ground state** of the hydrogen atom corresponds to having the atom's single e- in the lowest possible orbit (1s, which has the lowest possible quantum numbers). By giving the atom additional energy (for ex., by the absorption of a photon of an appropriate energy), the e- is able to move into an **excited state** (one or more quantum numbers greater than the min. possible). If the photon has too much energy, the electron will cease to be bound to the atom, and the atom will become

I O N I Z E D!!!

Once the e- is in its excited state, the hydrogen atom is EXCITED!! The atom may return to a lower excited state, or ground state, by emitting a photon with a characteristic energy. Emission of photons from atoms in various excited states leads to a spectrum showing a series of characteristic emission lines (Lyman and Balmer series)



Practice: Indicate whether each of the following electronic transitions emits energy or requires the absorption of energy: A) n=3 to n=1; B) n=2 to n=4

Mass spectrophotometer: Mass of each fragment (ion) can be determined. Higher the mass of a particle, then the more it will strike the detector

<u>Modern View of the Atom: Schrodinger, Heisenberg- Quantum Mechanics</u>

Where is the _____________ in the atom?

We can't say exactly where the atom is…
We can only say where we think it _________ be.

Developed by Werner Heisenberg (1901-1976), Louis De Broglie (1892-1987), Erwin Schrodinger (1887-1961)

Schrodinger made an equation from the hydrogen data. He explained e- movement by shapes.

Not lines. Those shapes were _______________ distributions & are pictured in 3 dimensions.

4 Quantum Numbers describing an electron in an atom:
n=
l=
m=
s=

Important Vocabulary #1

1. Quantum numbers - each of the orbitals are characterized by a series of numbers which describe various properties of the orbital.
2. Principal quantum number (n) - has integral values: 1, 2, 3, … related to the size and energy of the orbital.
3. Angular momentum quantum number (l) - has integral values from 0 to n - l for each value of n. Related to the shape of atomic orbitals. (subshell)
4. Magnetic quantum number (ml) - has integral values between l and - l including zero. Related to the orientation of the orbital in space relative to the other orbitals in the atom.
5. Electron spin (ms) - the fourth quantum number, developed by Goudsmit and Uhlenbeck, was necessary to account for the details of the emission spectra of atoms. The spectra indicated that the electron had a magnetic moment with two possible orientations. Has values of + ½ and - ½.

Important Vocabulary #2

1. Quantum Mechanics - broke away from the traditional particulate models and offered wave mechanics as the basis of describing electrons in an atom.
2. Standing wave - stationary waves, which do not travel along the length of the string. Like musical instruments.
3. Wave function (ψ) - a function of the coordinates (x, y, and z) of the electron's position in three-dimensional space.
4. Orbital - a specific wave function (we called it an area of high probability).
5. Heisenberg uncertainty principle - a fundamental limitation to just how precisely we can know both the position and momentum of a particle at a given time.

Polyelectronic Atoms

1. Polyelectronic atoms - atoms with more than one electron. A problem occurs when you apply Schrödingers equation to polyelectronic atoms, results cannot be solved exactly. Electron repulsion seems to be the problem. This is called the electron correlation problem. So approximations must be made to simplify the problem.
2. Outer electrons are not held as strongly to the nucleus do to shielding, the repulsion of the inner electrons on the outer electrons, causing weaker attraction to the nucleus. - Effective Nuclear Charge
3. Energy of the sublevels - energy increases in this manner.
$s < p < d < f$
4. Penetration effect - allows, for example, 2s electrons to be more strongly attracted to the nucleus than 2p electrons. Thus 2s electrons have lower energy than 2p electrons.

Ch 8 Periodic Table—History p.338

Originally elements were grouped only because of their similar properties:
Done by Dimtri _______________ (1834-1907)

Dimitri predicted that some elements would be discovered later due to gaps in his table.

Aufbau Principle and the Periodic Table
Electron Configurations

Practice: Write electron configurations of several elements

Exceptional Electron Configurations (Those that don't fit the pattern—exceptions)
Why?

Stable Orbital fulfills the octet rule and achieves the lowest possible energy.
Full Orbital's are the ____________ stable
½ full orbital's are also ____________

ENC & Zeff – (p. 342 & p. 353-354)

7.3: Periodic Trends in Atomic Properties
1. Atomic Size p. 355-356

Which atoms are larger than others?

Why?

2. IE, atomic size ionic size, & magnetic properties – p. 357

First Ionization Energy =
2nd Ionization Energy =
3rd Ionization Energy =

It all comes back to size!!
1. Why does the Energy increase as you increase the number of electrons removed from the atom?

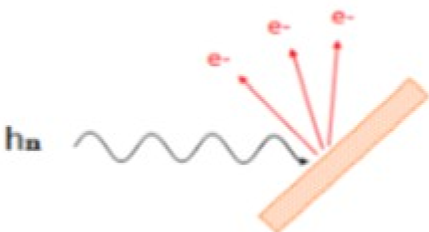
2. Why is there such a big jump in energies in certain portions of the table above?

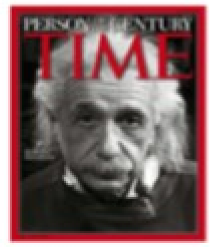
3. Why is the ionization energy of oxygen lower than that of nitrogen?

4. Why is the ionization energy of Aluminum lower than that of Magnesium?

Photoelectron Spectroscopy (PES)

Photoelectric Effect - Ionization occurs when matter interacts with light of sufficient energy (Heinrich Hertz, 1886)
(Einstein, A. Ann. Phys. Leipzig 1905, 17, 132-148.)





$E_{h\nu}$ = electron kinetic energy + electron binding energy

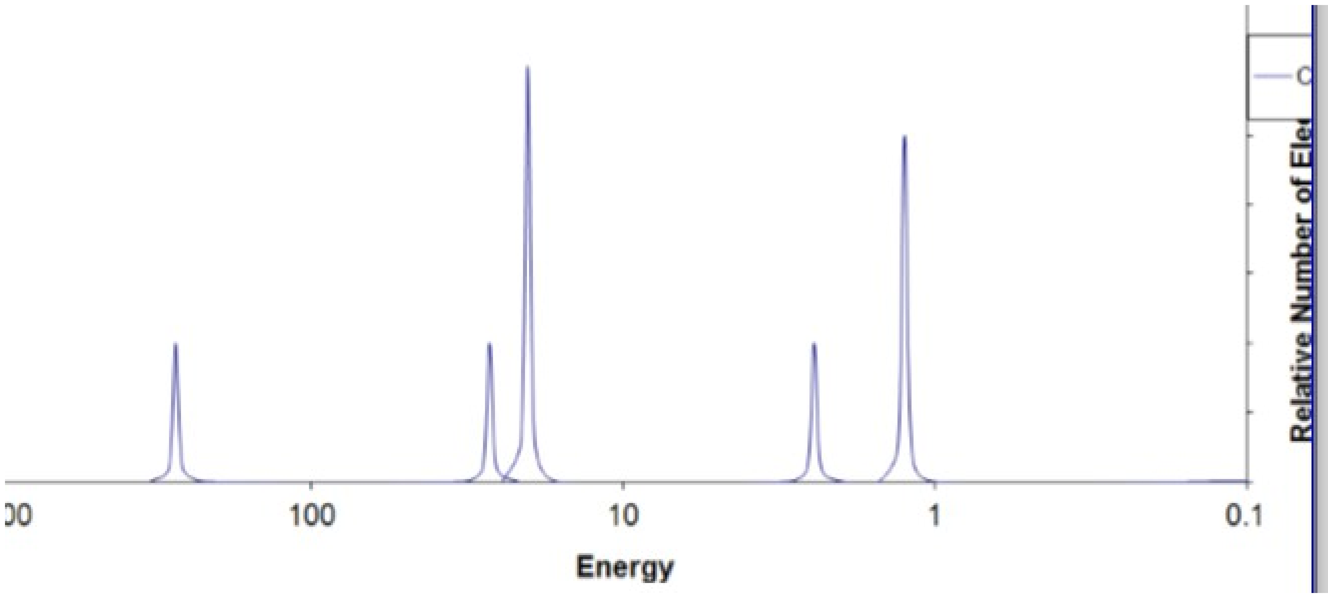
Photoelectron spectroscopy uses this phenomenon to learn about the electronic structure of matter

1

What is PES?

- www.pes.arizona.edu

  Good website with detailed info on pes
- Photon energy have enough energy to remove an electron (ionization energy, binding energy of electron to nucleus)
- The excess energy (KE of electron) goes to a detector
- Photon Energy = IE + KE
- IE = Photon Energy – KE
- A photoelectron spectrum is produced to show IE



Which element does this PES graph represent?________________

FR

Account for each of the following in terms of principles of atom structure, including the number, properties, and arrangements of subatomic particles.

(a) The second ionization energy of sodium is about three times greater than the second ionization energy of magnesium.

(b) The difference between the atomic radii of Na and K is relatively large compared to the difference between the atomic radii of Rb and Cs.

(c) A sample of nickel chloride is attracted into a magnetic field, whereas a sample of solid zinc chloride is not.

(d) Phosphorus forms the fluorides PF3 and PF5, whereas nitrogen forms only NF3.