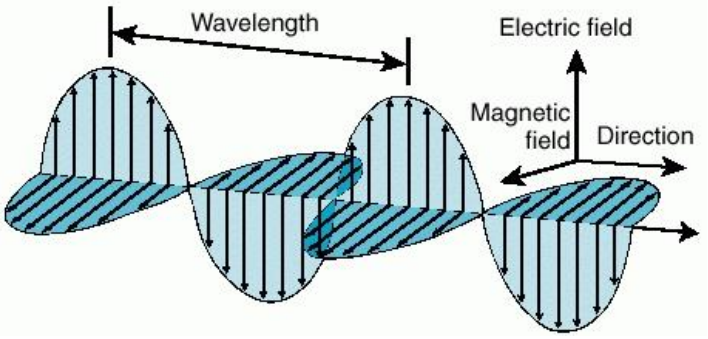
Introduction to Quantum Mechanics

Chem20, Elementary Chemistry

Wave-Particle Duality and the Nature of Light

Light is a form of *electromagnetic radiation,* meaning that it is both electricity and magnetism traveling as a perpendicular wave.



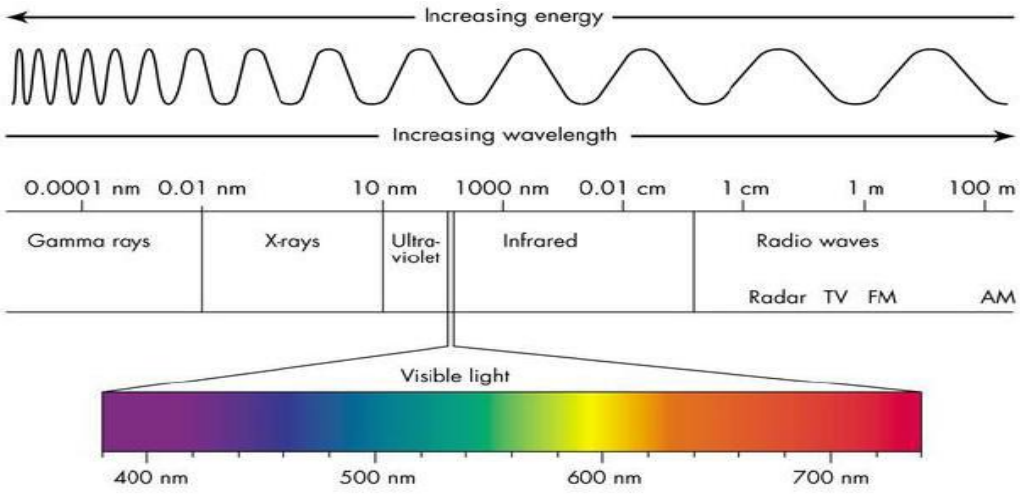
All electromagnetic radiation has a wavelength (λ), frequency (ν), and energy (E) that can all be related through two equations: $c = \lambda\nu$ and $E = h\nu$

speed of light (c, 2.998×10^{8} m/s) = wavelength (λ, m) x frequency (ν, s^{-1})

energy (E, J) = Planck's constant (h, 6.626×10^{-34} J·s) x frequency (ν, s^{-1})

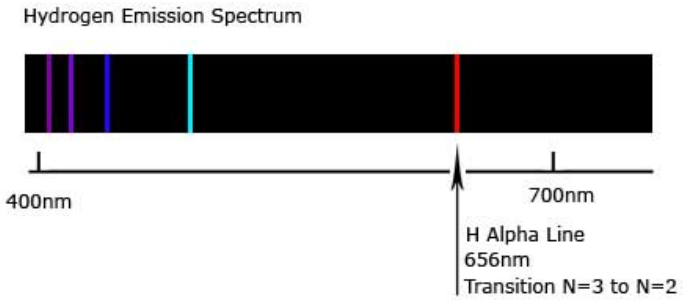
- Wavelength and frequency are <u>inversely</u> proportional.
- Wavelength and energy are <u>inversely</u> proportional.
- Energy and frequency are <u>directly</u> proportional.

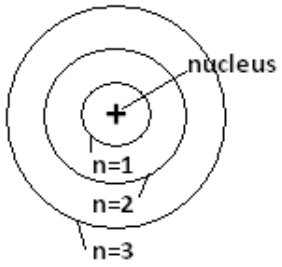
Electromagnetic radiation is classified into one of six categories based on wavelength, called the electromagnetic spectrum. Visible light is a subcategory between ultraviolet and infrared (400-750 nm).



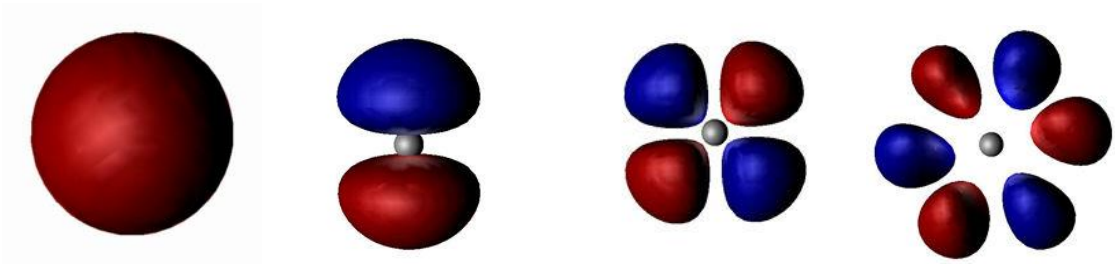
The Model of the Atom

Though white light will show every wavelength of electromagnetic radiation between 400 – 750 nm, elements, when charged with electricity, will only emit discrete lines at particular wavelengths. These emissions relate directly to quantized energy levels in the atom, or shells, like layers around an onion. These layers are numbered by the <u>principal quantum number</u>, **n** (n = 1, 2, 3,…∞)





Inside each shell reside a certain number of subshells, or orbitals, that have a variety of different shapes. These are defined by the <u>azimuthal quantum number</u>, ***l*** (l = 0, 1, 2, 3…n-1), which is dependent on the value of n. The value of *l* determines the type of the orbital. Each orbital can hold two total electrons.



If… *l = 0* → 1 s –orbitals *l = 1* → 3 p-orbitals *l = 2* → 5 d-orbitals *l = 3* → 7 f-orbitals

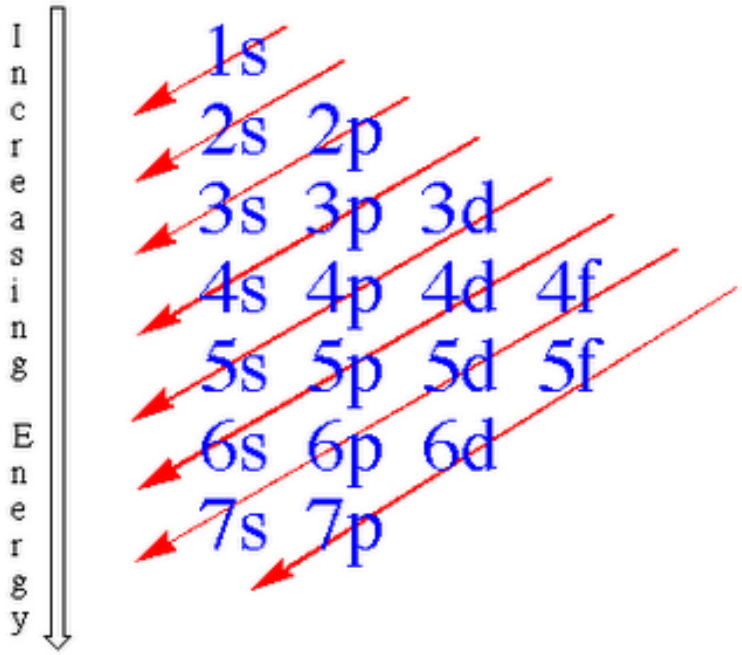
If n is equal to…	The orbitals available in that energy level are…	Maximum electron capacity in that energy level is…
1	s	2
2	s and p	8
3	s, p, and d	18
4	s, p, d, and f	32

Electrons and the Atom

The quantum numbers of n and *l* can be used to identify the location of an individual electron in an atom by listing the atom's *electron configuration*.

(numerical value of n)(letter designation for orbital shape)$^{\#\text{ of electrons in the orbital}}$

An atom will always fill its lowest energy levels and orbitals first and continue to fill from bottom-up until it has placed all its electrons in an orbital. For every element on the periodic table, it follows the same pattern of **1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p:**



Since there is only one s-orbital per energy level, only two total electrons can fill any given *ns* orbital. For three p-orbitals per energy level, six total electrons can fill a given set of *np* orbitals. For five d-orbitals, ten total electrons can fill a given set of *nd* orbitals and for seven f-orbitals, fourteen total electrons can fill a given set of *nf* orbitals.

Valence electrons are defined as electrons in the outermost energy level. *Core electrons* are electrons in the inner shells. Valence electrons are the easiest to reach and thus define the reactivity of a particular atom. All atoms wish to gain noble gas configuration – meaning a completely filled outermost energy level (valence shell).

The element's position on the periodic table can be used to determine the location of its valence shell. Its period number is equal to the number of its outermost energy level, and its region on the table corresponds to the orbital type in which its valence electrons are found.