CHM1051 Notes

Week 1

$$^{12}_{6}C$$

- **Atomic Number** (Z) – Number of protons in the nucleus of an atom
- **Mass Number** (A) – Number of protons and neutrons in the nucleus of an atom

Light and Matter

- The speed of light (c) is $3.00 x 10^8$ m/s
- The relationship between the **frequency** (f) and **wavelength** (λ) of light is $f\lambda = c$
- Wavelength is measured in metres
- Frequency is measured in Hertz (Hz) or s^{-1}
- Einstein and Max Planck used the idea of light "quanta" to explain certain properties of light (such as the photoelectric effect)
    - This assumes that light comes in small packets called "quanta" or **photons**
- Photons have energy (E) proportional to $E = hf$ (v is sometimes used in place of f)
    - h is Planck's constant, and is equal to $6.63 x 10^{-34}$ Js

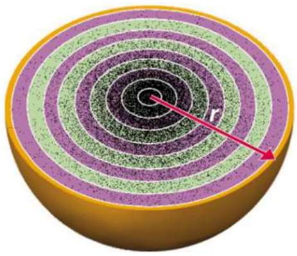
The Photoelectric Effect

- Only light above a certain frequency has enough energy to eject electrons from a metal
- Light is composed of photons, the energy of which must be entirely absorbed by the electrons in the metal
- The **work function** (E_0) of a metal is the energy required for an electron to escape the metal
- When a photon is absorbed by an electron, leftover energy from the photon, after the electron overcomes the work function of the metal, is translated into the kinetic energy (K) of the electron
    - $K = E_{photon} - E_0$

Atomic Spectra

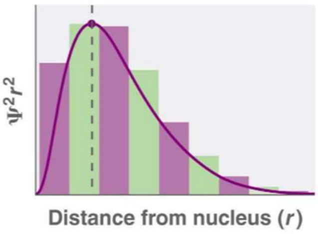
- Atoms of different elements only emit specific colours (wavelengths) of light, known as an **atomic spectrum**
- Niels Bohr explained atomic spectra by assuming electrons can only move between certain allowed orbits (or **energy levels**), corresponding to certain energies, by absorbing photons of specific energies
- The **Rydberg equation** is used for calculating the wavelength of light emitted by an electron jumping down energy levels in a hydrogen atom
    - $\frac{1}{\lambda} = 1.097x10^7\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where n_1 and n_2 are the two energy levels the electron is jumping between

Quantum Mechanics

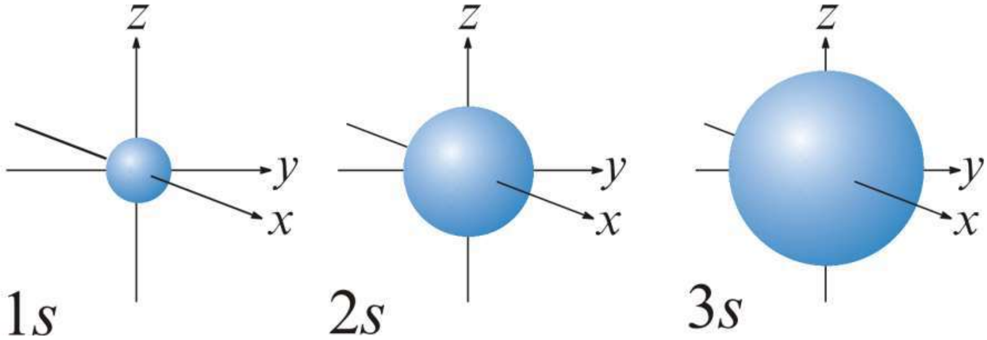


- In 1927 Davisson & Germer demonstrated that electrons also act like waves
- The **Heisenberg Uncertainty Principle** demonstrates that there is an uncertainty surrounding the location of an electron around an atom
- The **probability density** (ψ^2 or $\mathrm{R(r)}^2$) describes the probability of finding an electron a certain distance from the nucleus of an atom
- The **radial distribution function** describes the probability of finding and electron within a spherical shell a certain distance from the nucleus

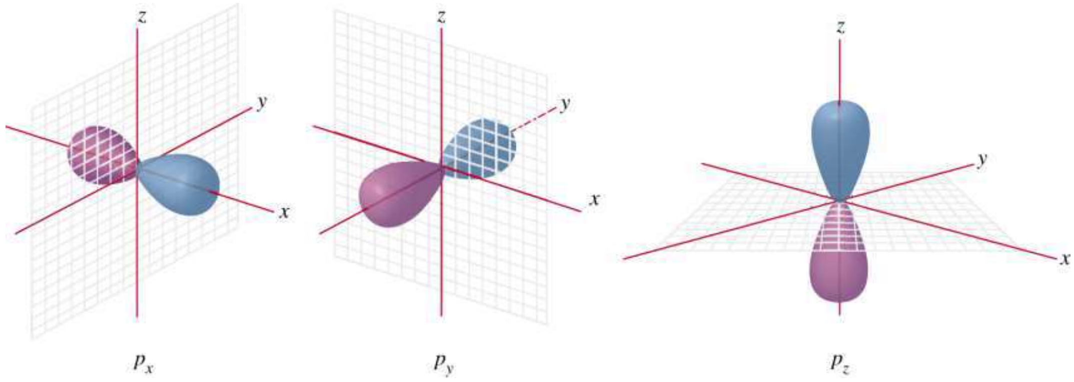
Quantum Numbers



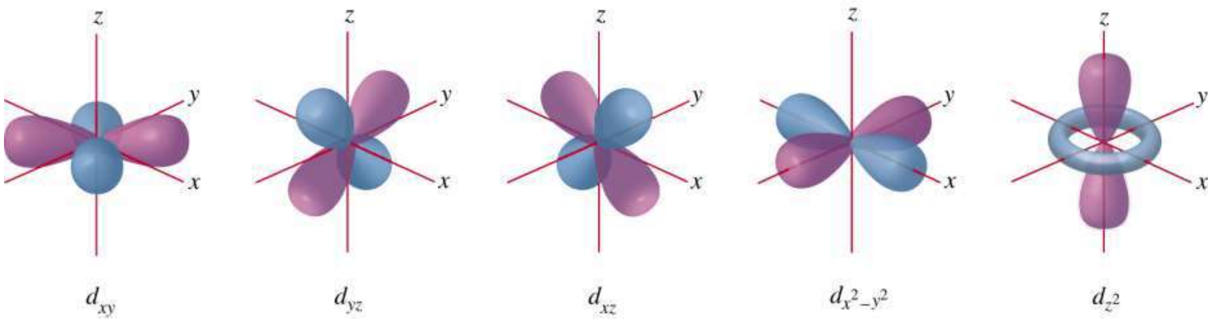
- **Quantum numbers** are like a directory system that describe where an electron is most likely to be found around an atom
  - These areas are called **orbitals**, and the shape of an orbital describes where an electron is likely to be found 95% of the time
- The **principal quantum number** (n) is allowed positive integer values and determines the orbital energy/size
- The **angular momentum/azimuthal quantum number** (l) is allowed integer values from 0 to $\mathrm{n} - 1$, and determines the orbital shape
- The **magnetic quantum number** (m_l) is allowed integer values from $-\mathrm{l}$ to l and determines orbital orientation
- Each atomic orbital can contain two electrons, each with a different **spin quantum number** (m_s) of either ½ or – ½
- A series of letters are used to describe the angular momentum quantum number
  - When $\mathrm{l} = 0$ the orbital is s
  - When $\mathrm{l} = 1$ the orbital is p
  - When $\mathrm{l} = 2$ the orbital is d
  - When $\mathrm{l} = 3$ the orbital is f
- Each orbital has a unique shape and is described by a different set of quantum numbers
  - e.g. $\mathrm{n} = 2$ and $\mathrm{l} = 0$ describes a 2s orbital
- Orbitals increase in size as n increases
- s orbitals have a spherical shape



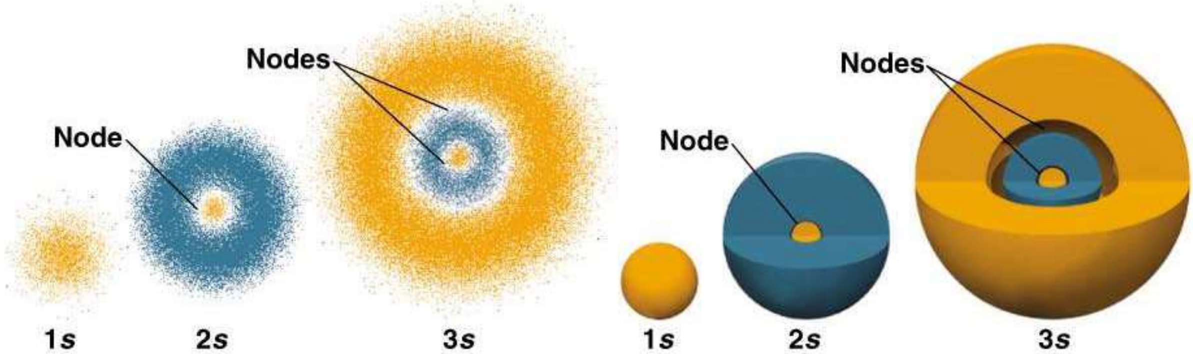
- p orbitals have a dumbbell shape and have three different orientations (along the x, y and z axes)



- There are five different types of d orbitals



- **Nodes** are regions of zero probability density/amplitude, meaning that there is zero probability of finding an electron in that region
- s orbitals have $n - 1$ spherical nodes



- A **nodal plane** is a plane across which an orbital has a zero probability amplitude
- p orbitals have a single nodal plane, which dissects the orbital along an axis
- d orbitals have two nodal planes