Hewitt/Lyons/Suchocki/Yeh

Conceptual Integrated Science

Chapter 9

THE ATOM

The Elements

Atoms:

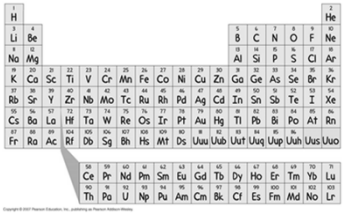
- make up all matter around us
- to date, 115 distinct kinds of atoms
- made up of protons, neutrons and electrons

Element:

any material consisting of only one type of atom

The Periodic Table

The Periodic table is a list of chemical elements:



Atoms Are Ancient, Tiny, and Empty

- Ancient – the origin of most atoms goes back to birth of universe
- tiny – even a small amount of substance contains billions upon billions of atoms
- mostly empty space (football field analogy)

Protons and Neutrons

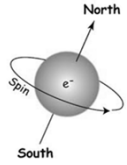
Protons:

- carry a positive charge
- are about 1800 times more massive than an electron
- The Atomic Number is the number of protons in the nucleus of an atom.

Protons and Neutrons

Electrons:

- are negatively charged
- have electrical repulsion that prevents atomic closeness



Protons and Neutrons

Neutrons:

- accompany protons in the nucleus
- have about the same mass as protons but no charge, so are electrically neutral

Both protons and neutrons are *nucleons*.

Isotopes and Atomic Mass

Isotopes are atoms of the same element that contain the same number of protons but different numbers of neutrons in the nucleus.

Mass number = protons + neutrons in a nucleus.

$^{4}_{2}He$

Isotopes and Atomic Mass

Atomic mass:

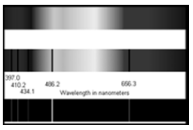
- total mass of the atom [protons, neutrons, and electrons]

One atomic mass unit is equal to
1.661×10^{-24} gram or 1.661×10^{-27} kg

Atomic Spectra

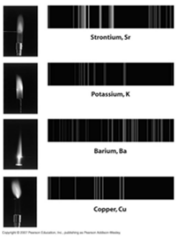
A Spectroscope is an instrument that separates and spreads light into its component frequencies.

Each element emits a distinctive glow when energized and displays a distinctive spectrum.



Atomic Spectra

Spectral Lines of Various Elements



Atomic Spectra

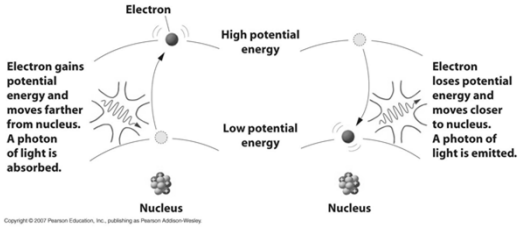
An atomic spectrum is an element's fingerprint - a pattern of discrete (distinct) frequencies of light.

Discoveries of atomic spectrum of hydrogen:

- In the 1800s: noted that hydrogen has a more orderly atomic spectrum than others.
- Johann Balmer expressed line positions by a mathematical formula.
- Johannes Rydberg noted that the sum of the frequencies of two lines often equals the frequency of a third line.

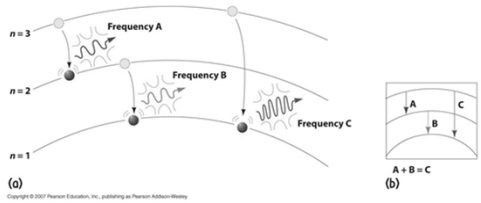
Atomic Spectra

Atomic Excitation



Atomic Spectra

Three transitions in an atom. The sum of the energies (and frequencies) for jumps A and B equals the energy (and frequency) of jump C.



The Quantum Hypothesis

Max Planck, a German physicist, hypothesized that warm bodies emit radiant energy in discrete bundles called *quanta*.

Energy is proportional to the frequency of radiation.

Albert Einstein stated that light itself is quantized and consists of a stream of energy bundles called *photons*.

The Quantum Hypothesis

Is light a wave, or a stream of particles?

Light can be described by both models - it exhibits properties of both a wave or a particle, depending on the experiment.

The amount of energy in a photon is directly proportional to the frequency of light:

$$E \sim f$$

The Quantum Hypothesis

Danish physicist Niels Bohr explained the formation of atomic spectra as follows:

1. The potential energy of an electron depends on its distance from the nucleus.
2. When an atom absorbs a photon of light, it absorbs energy.
3. When an electron in any energy level drops closer to the nucleus, it emits a photon of light.

The Quantum Hypothesis

Bohr reasoned that there must be a number of distinct energy levels within the atom.

Each energy level has a principal quantum number *n,* where *n* is always an integer. The lowest level is $n = 1$ and is closest to the nucleus.

Electrons release energy in discrete amounts that form discrete lines in the atom's spectrum.

The Quantum Hypothesis

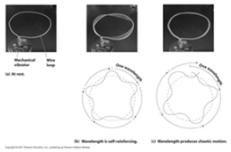
Bohr's model explains why atoms don't collapse:

- Electrons can lose only specific amounts of energy equivalent to transitions between levels.
- An atom reaches the lowest energy level called the *ground state,* where the electron can't lose more energy and can't move closer to the nucleus.

Electron Waves

An electron's wave nature explains why electrons in an atom are restricted to particular energy levels.

The orbit for $n = 1$ consists of a single wavelength, $n = 2$ is of two wavelengths, and so on.



Probability Clouds and Atomic Orbitals

- Erwin Schrödinger, Austrian scientist, formulated an equation from which intensities of electron waves in an atom can be calculated.
- The Schrödinger wave equation describes the probability of finding the electron at various locations in the atom.

Probability Clouds and Atomic Orbitals

The densest regions correspond to where the electron's wave intensity is greatest.

The probability cloud is a close approximation to the actual shape of an electron's three-dimensional wave.

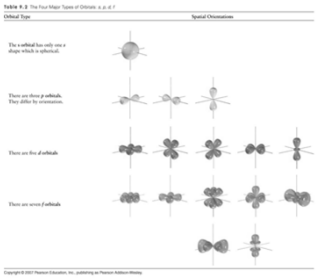
Probability Clouds and Atomic Orbitals

Atomic orbitals:

- Are a volume of space within which an electron may reside.
- Each orbital represents a different region in which an electron of a given energy is most likely to be found.
- They are classified by letters *s*, *p*, *d*, and *f* and come in a variety of shapes.
- Electron energies are quantized, and the sizes of atomic orbitals are quantized.

Probability Clouds and Atomic Orbitals

s, *p*, *d*, and *f* Orbitals



s Orbital

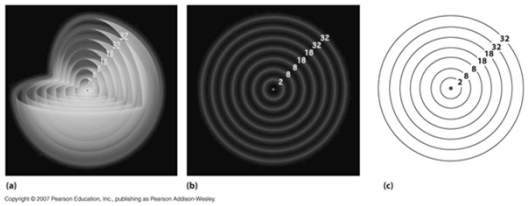
p Orbitals

d Orbitals

f Orbitals

Probability Clouds and Atomic Orbitals

Cutaway view of shells in the shell model of the atom



Probability Clouds and Atomic Orbitals

Shell model showing the first three periods of the periodic table