The Atomic Nucleus

The atom and it's discovery

- Atoms are the smallest unit of matter with sub-atomic particles.
- Democritus coined the term 'atom' meaning indivisible.
- John Dalton proposed elements are composed of tiny, indivisible atoms.
- Ernest Rutherford discovered the nucleus of an atom.
- All matter is composed of atoms with protons, neutrons, and electrons.
- The Standard Model includes elementary and composite particles.

Isotopes

- Isotopes are nuclear species of the same element with different numbers of neutrons
- They have the same atomic number and chemical properties but different masses
- The term "isotope" comes from Greek roots meaning "the same place" on the periodic table
- Coined by Margaret Todd and popularized by Frederick Soddy in 1913.

Discovery of the Constituent Particles

- Subatomic particles are units of matter or energy
- Atom composed of electrons, protons, and neutrons
- Nucleus contains quarks and leptons
- Bosons transmit forces
- 200+ subatomic particles found with antiparticles

Discovery of Electrons

- Faraday studied electrical discharge in cathode ray tubes in the 1850's.
- J. J. Thompson furthered Faraday's work and discovered electrons.
- Cathode ray tubes contain electrodes and gases that can be adjusted for pressure.
- High voltage causes current to flow through the tube, producing cathode rays.
- Cathode rays were the first subatomic particles to be discovered.

Discovery of Protons

- 1815: William Prout proposed all atoms are made of hydrogen atoms
- 1886: Eugen Goldstein observed high charge-to-mass ratio of hydrogen ion
- 1917: Ernest Rutherford used cathode ray tube in experiment
- Rutherford observed alpha particles detecting hydrogen nuclei
- Rutherford found hydrogen nuclei from nitrogen atoms
- Firing alpha particles into nitrogen gas increased hydrogen nuclei
- Concluded nitrogen must be made of hydrogen particles
- Hydrogen nucleus named 'proton' as atomic building block

Discovery of Neutrons

- Alpha particles from heavy elements hit light elements, causing penetrating radiation.
- Radiation observed was unaffected by electric fields, believed to be gamma radiation.
- High-energy radiation led to Majorana and Rutherford proposing neutral particles.
- Chadwick discovered neutral particles with mass slightly greater than protons, naming them neutrons.

"The nucleus is the heart of an atom, holding its secrets within."

Bohr’s Model of the Atom

- Bohr's model: nucleus surrounded by electrons, farther electrons have more energy
- Atom consists of protons, electrons, neutrons
- Electrons move in energy levels around nucleus in fixed paths
- Postulates: electrons revolve in orbits, each with fixed energy
- Limitations: fails to explain Zeeman Effect, Stark Effect, violates Heisenberg Uncertainty Principle

Quantum Numbers and Rules

- Quantum numbers describe the state of an electron in an atom.
- There are four quantum numbers: n, l, m_l, m_s.
- n determines energy level, ranging from 1.
- l defines orbital shape, ranging from 0 to (n-1).
- m_l specifies orbital orientation, ranging from -l to +l.
- m_s describes electron spin, with values of +1/2 or -1/2.

The Strong and Weak Nuclear Forces

- Big Bang Theory: Matter broken down into sub-atomic particles
- Strong nuclear force forms protons and neutrons
- Enables creation of stars, galaxies, and planets
- Necessary for the existence of our Universe

The Strong and Weak Nuclear Forces

- Strong Nuclear Force: Overcomes electromagnetic repulsion between protons in the nucleus of atoms. Breaking this force releases high-energy photons.

- Weak Nuclear Force: converts neutron to proton in nuclear decay, releasing sub-atomic particles at near the speed of light.

Binding Energy

- Binding energy measures energy to disassemble nucleus into nucleons
- Strong nuclear force holds protons and neutrons together in nucleus
- Overcomes electrostatic repulsion between protons
- Much stronger than electromagnetic force at nuclear distances
- Weak nuclear force responsible for certain types of radioactive decay processes
- Nucleus mass less than sum of constituent masses due to binding energy
- Binding energy calculated using formula: $E\ (MeV) = (Zm + Nm - M) \times 931.494\ MeV/u$
- Shows force between nucleons binding them together in nucleus

Nuclear Stability

- Nucleus stability requires energy to change
- Around 250 out of thousands of nuclides are stable
- Band of stability is where stable isotopes fall on neutron vs. proton plot
- Lighter nuclei have equal protons and neutrons, heavier have more neutrons
- Quantum rules, nuclear forces, and charge govern nuclear stability
- Unstable nuclei decay to other isotopes
- Even numbers of protons and neutrons are generally stable
- Magic numbers of protons and neutrons can make nuclei stable
- Superheavy elements near atomic number 126 may be stable in nature.

Thank you all