Section Summary

22.1 The Structure of the Atom

- Rutherford's gold foil experiment provided evidence that the atom is composed of a small, dense nucleus with electrons occupying the mostly empty space around it.
- Analysis of emission spectra shows that energy is emitted from energized gas in discrete quantities.
- The Bohr model of the atom describes electrons existing in discrete orbits, with discrete energies emitted and absorbed as the electrons decrease and increase in orbital energy.
- The energy emitted or absorbed by an electron as it changes energy state can be determined with the equation $\Delta E = E_i - E_f$, where $E_n = \frac{Z^2}{n^2} E_o (n = 1, 2, 3, ...)$.
- The wavelength of energy absorbed or emitted by an electron as it changes energy state can be determined by the equation $\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$, where $R = 1.097 \times 10^7 \mathrm{m}^{-1}$.
- Described as an electron cloud, the quantum model of the atom is the result of de Broglie waves and Heisenberg's uncertainty principle.

22.2 Nuclear Forces and Radioactivity

- The structure of the nucleus is defined by its two nucleons, the neutron and proton.
- Atomic numbers and mass numbers are used to differentiate between various atoms and isotopes. Those numbers can be combined into an easily recognizable form called a *nuclide*.
- The size and stability of the nucleus is based upon two forces: the electromagnetic force and strong nuclear force.
- Radioactive decay is the alteration of the nucleus through the emission of particles or energy.
- Alpha decay occurs when too many protons exist in the nucleus. It results in the ejection of an alpha particle, as described in the equation X Z A N → Y Z−2 A−4 N + H 2 4 e .
- Beta decay occurs when too many neutrons (or protons) exist in the nucleus. It results in the transmutation of a neutron into a proton, electron, and neutrino. The decay is expressed through the equation X Z A N → Y Z+1 A N−1 +e+v . (Beta decay may also transform a proton into a neutron.)
- Gamma decay occurs when a nucleus in an excited state move to a more stable state, resulting in the release of a photon. Gamma decay is represented with the equation X Z A N → X N + .
- The penetration distance of radiation depends on its energy, charge, and type of material it encounters.

22.3 Half Life and Radiometric Dating

- Radioactive half-life is the time it takes a sample of nuclei to decay to half of its original amount.
- The rate of radioactive decay is defined as the sample's activity, represented by the equation $R = \frac{\Delta N}{\Delta t}$.
- Knowing the half-life of a radioactive isotope allows for the process of radioactive dating to determine the age of a material.
- If the half-life of a material is known, the age of the material can be found using the equation $N = N_O e^{-\lambda t}$.
- The age of organic material can be determined using the decay of the carbon-14 isotope, while the age of rocks can be determined using the decay of uranium-238.

22.4 Nuclear Fission and Fusion

- Nuclear fission is the splitting of an atomic bond, releasing a large amount of potential energy previously holding the atom together. The amount of energy released can be determined through the equation $E = mc^2$.
- Nuclear fusion is the combining, or fusing together, of two nuclei. Energy is also released in nuclear fusion as the combined nuclei are closer together, resulting in a decreased strong nuclear force.
- Fission was used in two nuclear weapons at the conclusion of World War II: the gun-type uranium bomb and the implosion-type plutonium bomb.
- While fission has been used in both nuclear weapons and nuclear reactors, fusion is capable of releasing more energy per reaction. As a result, fusion is a well-researched, if not yet well-controlled, energy source.

22.5 Medical Applications of Radioactivity: Diagnostic Imaging and Radiation

- Medical imaging occurs when a radiopharmaceutical placed in the body provides information to an array of radiation detectors outside the body.
- Devices utilizing medical imaging include the Anger camera, SPECT detector, and PET scan.
- Ionizing radiation can both cure and cause cancer through the manipulation of DNA molecules.
- Radiation dosage and its effect on the body can be measured using the quantities radiation dose unit (rad), relative biological effectiveness (RBE), and the roentgen equivalent man (rem).