11.S: Nuclear Chemistry (Summary)

- In most atoms, a nucleus containing an "excess" of neutrons (more neutrons than protons) is unstable and the nucleus will decompose by **radioactive decay**, in which particles are emitted until a stable nucleus is achieved. Common particles emitted during radioactive decay include:
  - **Alpha particles**, consist of *two protons* and *two neutrons.* This is equivalent to a *helium nucleus* and an alpha particle has a charge of **2+**. Because it is positive, it will be attracted towards a negative charge in an electric field. The atomic symbol for an alpha particle is ^4_2He, or sometimes $^4_2\alpha$. Alpha particles are slow-moving and are easily absorbed by air or a thin sheet of paper. When an element ejects an alpha particle, the identity of the element changes to the element with an atomic number that is *two less* than the original element. The mass number of the element *decreases by four units.*
  - **Beta particles** are electrons, are considered to have negligible mass and have a *single negative charge.* They will be attracted towards a *positive* charge in an electric field. The atomic symbol for a beta particle is $^0_{-1}\beta$, or sometimes $^0_{-1}e$. Beta particles have "intermediate" energy and typically require thin sheets of metal for shielding. A beta particle is formed in the nucleus when a neutron "ejects" its negative charge (the beta particle) leaving a *proton* behind. When an element ejects a beta particle, the identity of the element changes to the *next higher atomic number,* but the mass number does not change.
  - **Gamma particles** (gamma rays) are high-energy photons. They have no mass and can be quite energetic, requiring thick shielding.
  - **Positrons** are anti-electrons, are considered to have negligible mass and have a *single positive charge.* They will be attracted towards a *negative* charge in an electric field. The atomic symbol for a positron is symbol $^0_{+1}\beta$. Positrons have "intermediate" energy and typically require thin sheets of metal for shielding. A positron is formed in the nucleus when a proton "ejects" its positive charge (the positron) leaving a *neutron* behind. When an element ejects a positron, the identity of the element changes to the *next lower atomic number*, but the mass number does not change.
- In a **nuclear equation**, elements and sub-atomic particles are shown linked by a reaction arrow. When you balance a nuclear equation, the sums of the mass numbers and the atomic numbers on each side must be the same.
- Radioactive elements decay at rates that are *constant* and *unique* for each element. The rate at which an radioactive element decays is measured by its **half-life**; the time it takes for one half of the radioactive atoms to decay, emitting a particle and forming a new element. The amount of an original element remaining after *n* half-lives can be calculated using the equation:

$$R = I\left(\frac{1}{2}\right)^n$$

  where ***I*** represents the initial mass of the element and ***R*** represents the mass remaining.
- In nuclear **fission**, a nucleus captures a *neutron* to form an unstable intermediate nucleus, which then splits (undergoes fission) to give nuclei corresponding to lighter elements. Typically, *neutrons* are also ejected in the process. For heavy isotopes, the process of fission also releases a significant amount of energy. A nuclear equation for a classical fission reaction is shown below:

$$^{235}_{92}U + ^1_0n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^1_0n$$

- In nuclear **fusion**, nuclei *combine* to form a new element. For light isotopes, the process of fusion also releases a significant amount of energy. A nuclear equation for the fusion cascade that typically occurs in stars the size of our sun is shown below:

$$2^1_1\rho \rightarrow ^0_{+1}\beta + ^3_2He$$

$$2^3_2He \rightarrow 2^1_1\rho + ^4_2He$$