AP FaSTudy: NUCLEAR PHYSICS

Nuclear Notation
Z = atomic number (protons)
A = mass number ($Z + N$)
N = number of neutrons

Units
1 eV = 1.6×10^{-19} J
1 u = 1.66×10^{-27} kg

Standard representation of the nucleus of element X, followed by actual isotope examples.

$${}^{A}_{Z}\mathrm{X} \qquad {}^{1}_{1}\mathrm{H} \qquad {}^{4}_{2}\mathrm{He} \qquad {}^{12}_{6}\mathrm{C} \qquad {}^{238}_{92}\mathrm{U} \qquad {}^{235}_{92}\mathrm{U}$$

Decays occur when nucleus is unstable
α (alpha) Nucleus ejects an α-particle (helium nucleus). Reduces Z by 2 and A by 4. Alpha particles have low penetrating power; can be stopped by cardboard.

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Z} + {}^{4}_{2}\mathrm{He} \qquad {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Z} + {}^{4}_{2}\alpha$$

β (beta) A neutron decays to a proton by ejecting an electron: $n^0 \rightarrow p^+ + e^-$ Increases Z by 1; leaves A unchanged. The ejected electron is called a β-particle. Beta particles can be stopped by metal foil.

$${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Z} + {}^{0}_{-1}\mathrm{e} \qquad {}^{A}_{Z}\mathrm{X} \rightarrow {}^{A}_{Z+1}\mathrm{Z} + {}^{0}_{-1}\beta$$

γ (gamma) A nucleus emits a high-energy photon (aka an electromagnetic wave called a gamma ray) instead of a nuclear particle. Neither Z nor A is changed; nucleus loses energy only. A gamma ray has the highest penetrating power and can be stopped by a thick layer of lead.

$${}^{A}_{Z}\mathrm{X}^{*} \rightarrow {}^{A}_{Z}\mathrm{X} + \mathrm{Energy} \qquad {}^{A}_{Z}\mathrm{X}^{*} \rightarrow {}^{A}_{Z}\mathrm{X} + {}^{0}_{0}\gamma$$

Half Life is the time it takes half a radioactive sample to decay.

Mass-Energy Equivalence. Mass can be converted to energy: $E = mc^2$.

Binding Energy. A given nucleus has less mass than the equivalent group of nucleons unbound. This difference in mass is called the *mass defect*.

Fission is the separation of a larger "parent" nucleus into two smaller "daughter" or "fragment" nuclei. Energy is released if the daughter nuclei are more tightly bound than the parent. The example shows the fission of a uranium nucleus into two fragments (barium and krypton). The fission was triggered by a neutron and released three neutrons (which can then trigger further fissions to create a chain reaction).

$${}^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{141}_{56}\mathrm{Ba} + {}^{92}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n}$$

Fusion is the coalescence of two smaller nuclei into a single larger nucleus. The example shows the fusion of deuterium and tritium nuclei to create a helium nucleus and release a neutron.

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

Read: *Essentials of College Physics* (Serway & Vuille) X!

Nuclear Decay

Read Chapter 29, Sections 2 through 6
Answer Chapter 29 Conceptual Questions 1-4, 6, 8, 11
Solve Chapter 29 Problems 23-26 (Appendix B is your friend)

Nuclear Fission and Fusion

Read Chapter 30, Sections 1 and 2
Solve Chapter 30 Problems 1, 2, 10
1996.5
1991.5

Answers to even-numbered textbook items (odds are in the book)

Ch. 29 CQ
2. The alpha particle will have more KE. It has the same momentum, but with less mass it most have more speed. KE depends more on speed than momentum does.
4. Alpha particle is doubly pos. charged, massive, and is a poor penetrator; beta particle is singly neg charged, light, and a slightly better penetrator; gamma is uncharged, high-energy; best penetrator
6. Betas penetrate better than alphas
8. Alpha is about 7000 times more massive than beta

Ch. 29 P
24. ${}^{12}_{6}C$, ${}^{4}_{2}He$, ${}^{14}_{6}C$
26. 4.28 MeV

Ch. 30 P
2. 192 MeV
10. 5.49 MeV