PHYS 111
1ST semester 1439-1440

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Lecture 26

Chapter 44

Nuclear Structure

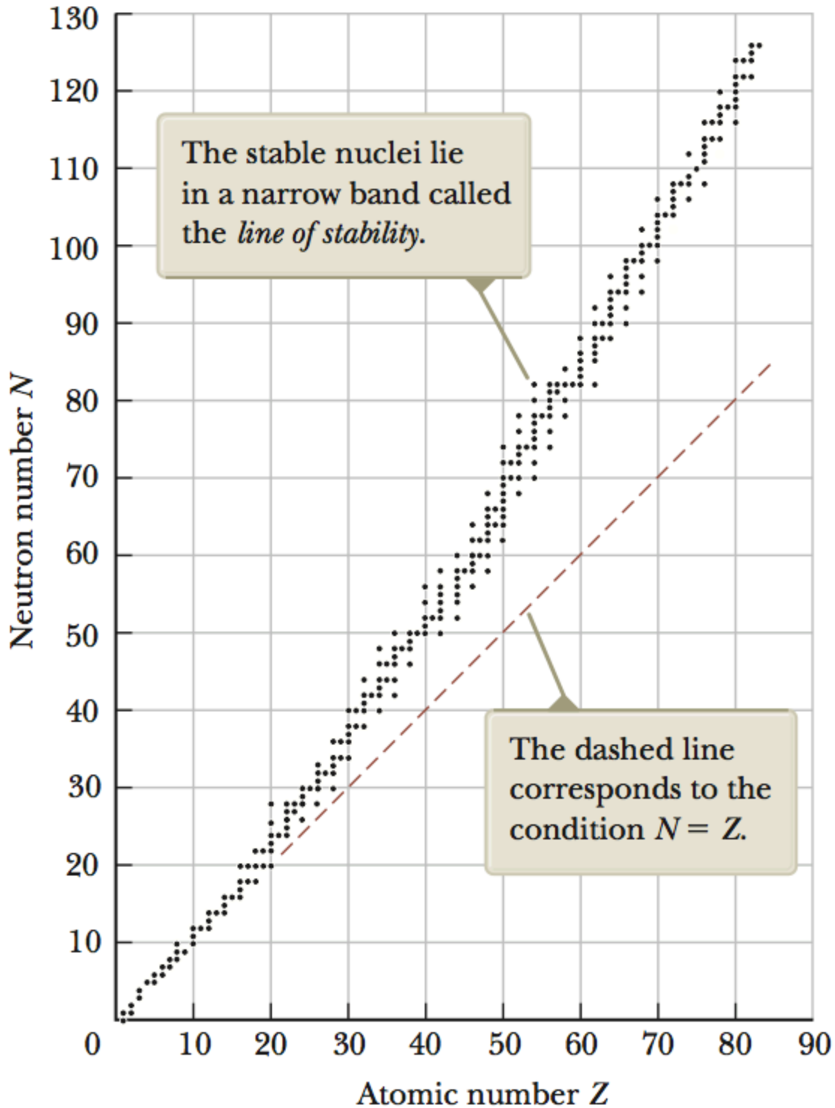
- **44.1** Some Properties of Nuclei
- **44.2** Nuclear Binding Energy
- **44.4** Radioactivity
- **44.5** The Decay Processes
- **44.6** Natural Radioactivity
- **44.7** Nuclear Reactions

Nuclear Stability

- You might expect that the very large repulsive Coulomb forces between the protons in a nucleus should cause the nucleus to fly apart. Because that does not happen, there must be a attractive force.
- The **nuclear force** is a very short range (about 2 fm) attractive force that acts between all nuclear particles.
- The protons attract each other by means of the **nuclear force**, and, at the same time, they repel each other through the **Coulomb force**.
- The nuclear force also acts between pairs of neutrons and between neutrons and protons.
- The nuclear force is independent of charge. In other words, the forces associated with the proton–proton, proton–neutron, and neutron–neutron interactions are the same.

Neutron number *N* versus atomic number *Z* for stable nuclei

- The **stable nuclei** are represented by the black dots, which lie in a narrow range called the *line of stability.*
- The **light stable nuclei** contain an equal number of protons and neutrons; that is, $N = Z$.
- In **heavy stable nuclei**, the number of neutrons exceeds the number of protons: above $Z = 20$, the line of stability deviates upward from the line representing $N = Z$.
- This deviation can be understood by recognizing that as the number of protons increases, the strength of the Coulomb force increases, which tends to break the nucleus apart.
- As a result, more neutrons are needed to keep the nucleus stable because neutrons experience only the attractive nuclear force.



44.2 Nuclear Binding Energy

- The total mass of a nucleus is less than the sum of the masses of its individual nucleons.
- Therefore, the rest energy of the bound system (the nucleus) is less than the combined rest energy of the separated nucleons.
- This difference in energy is called the **binding energy** of the nucleus and can be interpreted as the energy that must be added to a nucleus to break it apart into its components.
- Therefore, to separate a nucleus into protons and neutrons, energy must be delivered to the system.

44.2 Nuclear Binding Energy

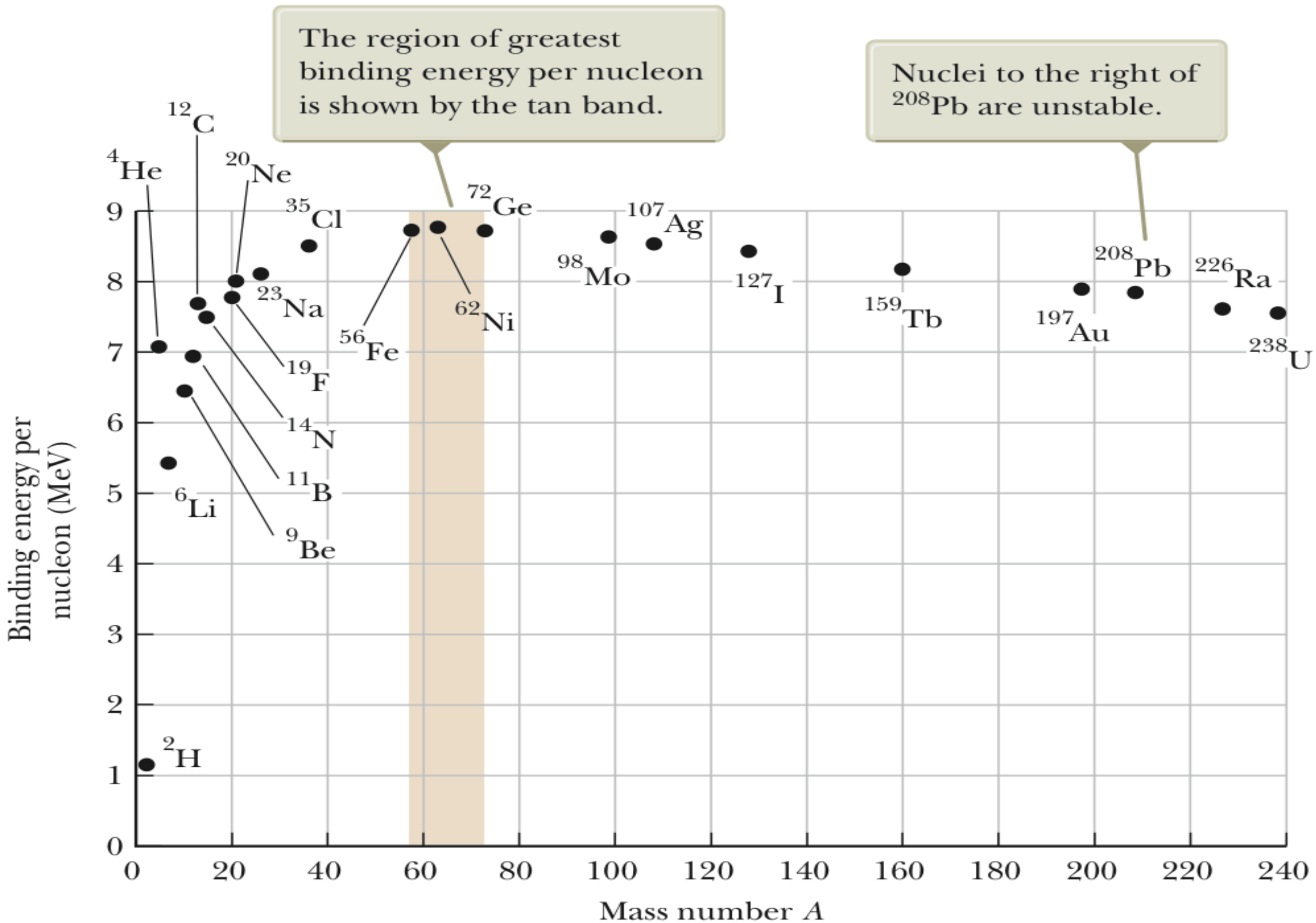
- The binding energy E_b in MeV of any nucleus is

$$E_b = [ZM(\mathrm{H}) + Nm_n - M(^{A}_{Z}\mathrm{X})] \times 931.494 \text{ MeV/u}$$

- where M(H) is the atomic mass of the neutral hydrogen atom, m_n is the mass of the neutron, $M(^{A}_{Z}\mathrm{X})$ represents the atomic mass of an atom of the isotope $^{A}_{Z}\mathrm{X}$, and the masses are all in atomic mass units.

44.2 Nuclear Binding Energy

- Binding energy per nucleon E_b/A as a function of mass number A for various stable nuclei.



44.4 Radioactivity

- In 1896, Becquerel accidentally discovered that uranyl potassium sulfate crystals emit an invisible radiation that can darken a photographic plate even though the plate is covered to exclude light.
- This process of spontaneous emission of radiation by uranium was soon to be called **radioactivity.**
- Additional experiments, including Rutherford’s famous work on alpha-particle scattering, suggested that radioactivity is the result of the ***decay***, or disintegration, of unstable nuclei.