• Chapter 11: Nuclear Physics

• 11.1. Basic Structure

- What is a nucleon?

- What do N, Z, and A signify?

- What varies between two isotopes of the same atom?

- What is the difference between stable and unstable nuclei?

- What is the atomic mass unit?

- What did Rutherford discover when he shot alpha particles at gold, and what did it prove?

- What is the rough formula for the size of a nucleus?

- How does the mass density of a nucleus depend on its atomic number?

• 11.2. Binding

- Why don't the protons inside a nucleus explode outward due to electrostatic repulsion?

- How does the strong force depend on distance between nucleons?

- How has the strong force's existence been proven?

- Why can a proton and a neutron bond together (into a deuteron), but two protons or two neutrons cannot?

- **Arbitrary Nucleon Number**
    - How does the strong force change as you increase the number of nucleons in the nucleus?

    - What effect does Coulomb repulsion have on the stability of nuclei?

    - Why must nuclei include protons? Why not neutrons only?

    - Why do smaller nuclei have equal numbers of protons and neutrons, but larger nuclei have more neutrons?

- **Stability: The Experimental Truth**
    - How do we calculate the binding energy of a nucleus"

    - What is the curve of stability?

    - Which element(s) has the largest binding energy per nucleon? Overall binding energy?

• 11.3 Nuclear Models

- **Liquid Drop Model**
    - Why is a water drop like an atomic nucleus?

    - What quantity does this model predict?

    Why does this model include a *volume term*? How does it depend on A? (Why doesn't it go as A^2?) Why is it positive?

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- Why does this model include a *volume term*? How does it depend on A? (Why doesn't it go as A^2?) Why is it positive?

- Why does it include a *surface* term? What does it look like?

- Explain the *Coulomb* term.

- Why is there an *asymmetry* term? How does it depend on N and Z?

- Where do the coefficients come from?

- Is the liquid drop model a good fit to experiment?

- How is the shell model different from the liquid drop model?

- What are *magic numbers*?

- What is the *pairing effect*?

11.5 Radioactivity
- What happens during radioactive decay?

- Why does an atom decay? How does it "benefit"?

- **Alpha Decay**
  - What is an alpha particle?

  - What happens to N, Z, and A during alpha decay?

  - Why do nuclei like to emit helium nuclei? Why not single protons, or lithium nuclei?

  - Why does the alpha particle end up with most of the kinetic energy created by the decay?

- **Beta Decay**
  - What is beta decay?

  - What happens to N, Z, and A during beta decay?

  - How can a *nucleus* emit an electron, if there are no electrons in the nucleus?

  - What is a *neutrino*, and why is it necessary to explain beta decay?

  - What happens in *electron capture?*

  - Are neutrons stable?

  - What kinds of nuclei prefer alpha decay? Beta- decay? Beta+ decay or electron capture?

  - What is a *decay series*?

- What is *gamma decay*, and why does it occur?

  What is *spontaneous fission*? What are the end-products?

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- What is *spontaneous fission*? What are the end-products?

11.6 Radioactive Decay Law
- Why do we say that radioactive decay is probabilistic?

- Derive the radioactive decay law

- What is the *decay constant* , the *decay rate*, and the *half-life*?

- How does radioactive dating work?

11.7 Nuclear Reactions
- What is a *nuclear reaction*, and how does it differ from radioactive decay?

- **Fission**
  - What is *nuclear fission*?

  - What kinds of nuclei will undergo it?

  - Why is it energetically favorable?

  - When does it occur?

  - How does a *chain reaction* occur? Why doesn't it occur in nature (very often)?

  - What is the difference between an uncontrolled and a controlled chain reaction? How is control maintained?

  - Why do countries that want to create nuclear fission need centrifuges?

  - What does a *moderator* do?

  - What is a *breeder reactor?*

- **Fusion**
  - What is *nuclear fusion*?

  - What kinds of nuclei will undergo it?

  - What is the *proton-proton cycle?*

  - What is the *carbon cycle*? Why is it faster than the proton-proton cycle?

  - Why can't fusion occur spontaneously? (i.e. Why is it so freaking hard to create controlled nuclear fusion on Earth?)

  - What two things does hydrogen need to fuse? How are these achieved?

  - What two things make fusion preferable to fission?