UBC Physics 102

Lecture 1

Rik Blok

Outline

- Isotopes
- Size of the nucleus
- Review: Atomic mass
- Binding energy
- End

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$
  - $X =$ element (symbol)

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$
  - $X =$ element (symbol)
  - $A =$ atomic mass (# protons + neutrons)

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$
  - $X =$ element (symbol)
  - $A =$ atomic mass (# protons + neutrons)
  - $Z =$ atomic number (# protons, redundant if X given)

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$
  - $X =$ element (symbol)
  - $A =$ atomic mass (# protons + neutrons)
  - $Z =$ atomic number (# protons, redundant if X given)
- **Definition:** *Isotope*
  - A nucleus with a specific atomic mass, A.

Isotopes [Text: Sect. 42-1]

- **Notation:** ${}^{A}_{Z}X$
  - $X =$ element (symbol)
  - $A =$ atomic mass (# protons + neutrons)
  - $Z =$ atomic number (# protons, redundant if X given)
- **Definition:** *Isotope*
  - A nucleus with a specific atomic mass, A.
- **Example:**
  - ${}^{11}C$ and ${}^{12}C$ are the same element but different isotopes.

Size of the nucleus [Text: Sect. 42-1]

- **Discussion: Nuclear radius**

Size of the nucleus [Text: Sect. 42-1]

- **Discussion: Nuclear radius**
  - Nuclei are very small.

Size of the nucleus [Text: Sect. 42-1]

- **Discussion: Nuclear radius**
  - Nuclei are very small.
  - Nucleus with atomic mass A can be roughly described as sphere with radius

$$r \approx (1.2\times10^{-15}\ \mathrm{m})A^{1/3}.$$

Size of the nucleus [Text: Sect. 42-1]

- **Discussion: Nuclear radius**
  - Nuclei are very small.
  - Nucleus with atomic mass A can be roughly described as sphere with radius

$$r \approx (1.2\times10^{-15}\ \mathrm{m})A^{1/3}.$$

  - (All boxed equations and constants will be provided on formula sheet, http://www.zoology.ubc.ca/~rikblok/phys102/formula/.)

Size of the nucleus, contd

- **Example: Ch. 42, Prob. 61**
  - A neutron star consists of neutrons at approximately nuclear density. Estimate, for a $10\ \mathrm{km}$ diameter neutron star, (*a*) its mass number, (*b*) its mass (kg), and (*c*) the acceleration of gravity at its surface.

Size of the nucleus, contd

- **Example: Ch. 42, Prob. 61**
  - A neutron star consists of neutrons at approximately nuclear density. Estimate, for a $10\ \mathrm{km}$ diameter neutron star, (*a*) its mass number, (*b*) its mass (kg), and (*c*) the acceleration of gravity at its surface.
- **Solution:**

Size of the nucleus, contd

- **Example: Ch. 42, Prob. 61**
  - A neutron star consists of neutrons at approximately nuclear density. Estimate, for a $10\ \mathrm{km}$ diameter neutron star, (*a*) its mass number, (*b*) its mass (kg), and (*c*) the acceleration of gravity at its surface.
- **Solution:**

(*a*) The star has a radius $r = 5\ \mathrm{km}$ so its mass number is

$$A = \left[\frac{r}{1.2\times10^{-15}\ \mathrm{m}}\right]^3 = 7.2\times10^{55}.$$

Size of the nucleus, contd

- **Solution: contd**

Size of the nucleus, contd

- **Solution: contd**

(*b*) A is the number of neutrons in the star. Each neutron has a mass of $m_{\rm n} = 1.7{\times}10^{-27}$ kg so its mass M is

$$M = Am_{\rm n} = 7.2{\times}10^{55} \cdot 1.7{\times}10^{-27}\ {\rm kg} = 1.2{\times}10^{29}\ {\rm kg}.$$

Size of the nucleus, contd

- **Solution: contd**

(*b*) A is the number of neutrons in the star. Each neutron has a mass of $m_{\rm n} = 1.7\times10^{-27}$ kg so its mass M is

$$M = Am_{\rm n} = 7.2\times10^{55}\cdot 1.7\times10^{-27}\ {\rm kg} = 1.2\times10^{29}\ {\rm kg}.$$

(*c*) Recall, the acceleration due to gravity at the surface of a massive sphere is

$$\begin{aligned} g &= G\frac{M}{r^2} = 6.67\times10^{-11}\ {\rm m}^3/{\rm kg}\cdot{\rm s}^2 \times \frac{1.2\times10^{29}\ {\rm kg}}{(5000\ {\rm m})^2} \\ &= 3.2\times10^{11}\ {\rm m/s}^2. \end{aligned}$$

Size of the nucleus, contd

- **Solution: contd**

(*b*) A is the number of neutrons in the star. Each neutron has a mass of $m_{\rm n} = 1.7{\times}10^{-27}$ kg so its mass M is

$$M = Am_{\rm n} = 7.2{\times}10^{55} \cdot 1.7{\times}10^{-27}\ {\rm kg} = 1.2{\times}10^{29}\ {\rm kg}.$$

(*c*) Recall, the acceleration due to gravity at the surface of a massive sphere is

$$\begin{aligned} g &= G\frac{M}{r^2} = 6.67{\times}10^{-11}\ {\rm m}^3/{\rm kg}\cdot{\rm s}^2 \times \frac{1.2{\times}10^{29}\ {\rm kg}}{(5000\ {\rm m})^2} \\ &= 3.2{\times}10^{11}\ {\rm m/s}^2. \end{aligned}$$

- So the pull of gravity would be about 30 billion times stronger than on earth!

Review: Atomic mass [Text: Sect. 17-1]

- **Definition:** *Atomic mass unit*

$$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$$

Review: Atomic mass [Text: Sect. 17-1]

- **Definition:** *Atomic mass unit*

$$1 \text{ u} = 1.66 \times 10^{-27} \text{ kg}$$

  - Is approximate mass of a neutron or proton.

Review: Atomic mass [Text: Sect. 17-1]

- **Definition:** *Atomic mass unit*

$$1\ \mathrm{u} = 1.66\times10^{-27}\ \mathrm{kg}$$

  - Is approximate mass of a neutron or proton.
  - Periodic table lists masses of each element in atomic mass units (per atom).

Review: Atomic mass [Text: Sect. 17-1]

- **Definition:** *Atomic mass unit*

$$1\ \mathrm{u} = 1.66\times10^{-27}\ \mathrm{kg}$$

- Is approximate mass of a neutron or proton.
- Periodic table lists masses of each element in atomic mass units (per atom).
- Can use to convert mass to number of molecules/atoms.

Review: Atomic mass, contd

- **Example:**
  How many atoms are there in a $3.4\ \mathrm{g}$ copper penny?

Review: Atomic mass, contd

- **Example:**
  How many atoms are there in a $3.4\ \mathrm{g}$ copper penny?
- **Solution:**
  - Atomic mass of copper$= 63.5\ \mathrm{u}$ per atom (from Periodic Table).

Review: Atomic mass, contd

- **Example:**
  How many atoms are there in a $3.4\ \mathrm{g}$ copper penny?
- **Solution:**
  - Atomic mass of copper$= 63.5\ \mathrm{u}$ per atom (from Periodic Table).

$$\begin{aligned} \#\ \text{atoms} &= 3.4\times10^{-3}\ \mathrm{kg}\left(\frac{1\ \mathrm{u}}{1.66\times10^{-27}\ \mathrm{kg}}\right)\left(\frac{1\ \text{atom}}{63.5\ \mathrm{u}}\right) \\ &= 3.23\times10^{22}\ \text{atoms.} \quad \square \end{aligned}$$

Review: Atomic mass, contd

- **Example:**
  How many atoms are there in a $3.4\ \mathrm{g}$ copper penny?
- **Solution:**
  - Atomic mass of copper$= 63.5\ \mathrm{u}$ per atom (from Periodic Table).

$$\begin{aligned} \#\ \text{atoms} &= 3.4\times10^{-3}\ \mathrm{kg}\left(\frac{1\ \mathrm{u}}{1.66\times10^{-27}\ \mathrm{kg}}\right)\left(\frac{1\ \text{atom}}{63.5\ \mathrm{u}}\right) \\ &= 3.23\times10^{22}\ \text{atoms.} \quad \square \end{aligned}$$

- **Interactive Quiz: PRS 01a**

Binding energy [Text: Sect. 42-2]

- **Definition:** *Strong nuclear force*

Binding energy [Text: Sect. 42-2]

- **Definition:** *Strong nuclear force*
  - An attractive force between nucleons (protons and neutrons).

Binding energy [Text: Sect. 42-2]

- **Definition:** *Strong nuclear force*
  - An attractive force between nucleons (protons and neutrons).
  - Counteracts repulsive electric force to hold nucleus together.

Binding energy [Text: Sect. 42-2]

- **Definition:** *Strong nuclear force*
  - An attractive force between nucleons (protons and neutrons).
  - Counteracts repulsive electric force to hold nucleus together.
- **Principle: Energy minimization**

Binding energy [Text: Sect. 42-2]

- **Definition:** *Strong nuclear force*
  - An attractive force between nucleons (protons and neutrons).
  - Counteracts repulsive electric force to hold nucleus together.
- **Principle: Energy minimization**
  - Systems in nature tend to reduce their potential energy.

Binding energy [Text: Sect. 42-2]

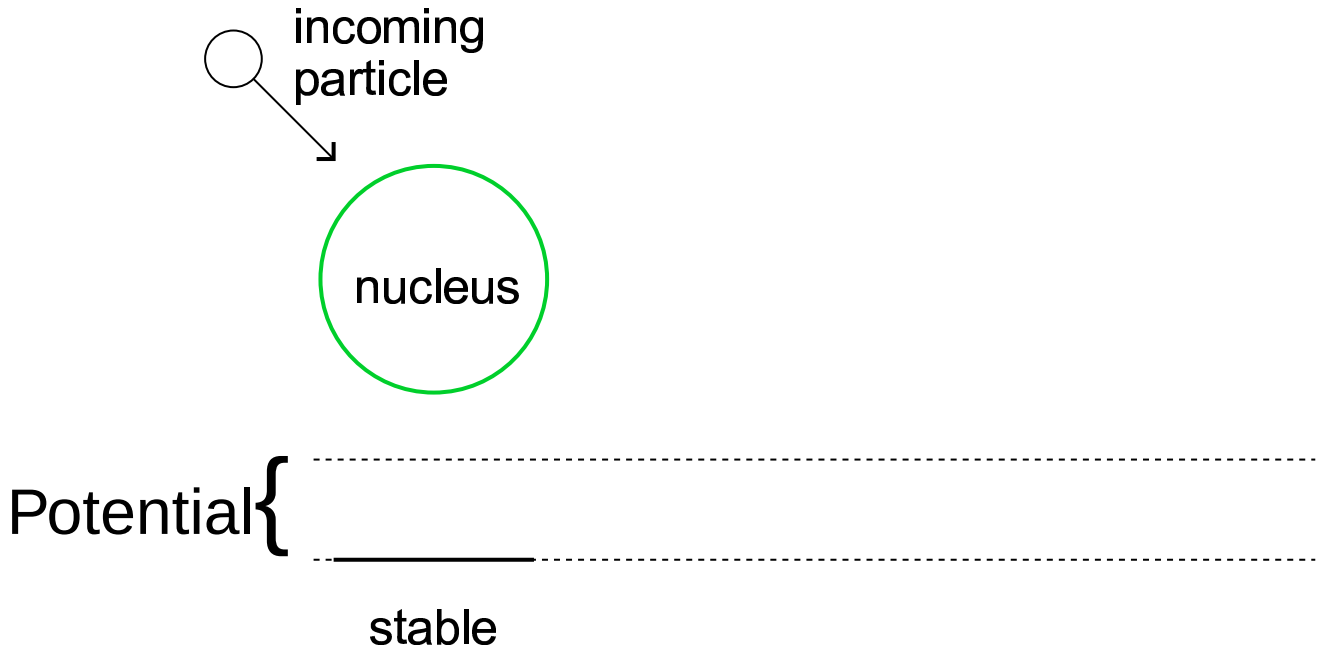
- **Definition:** *Strong nuclear force*
  - An attractive force between nucleons (protons and neutrons).
  - Counteracts repulsive electric force to hold nucleus together.
- **Principle: Energy minimization**
  - Systems in nature tend to reduce their potential energy.
  - If a nucleus has excess energy it may reduce its potential energy by emitting a particle.

Binding energy, contd

- **Definition:** *Unstable nucleus*
  - A nucleus that can reduce its potential energy by emitting a particle.

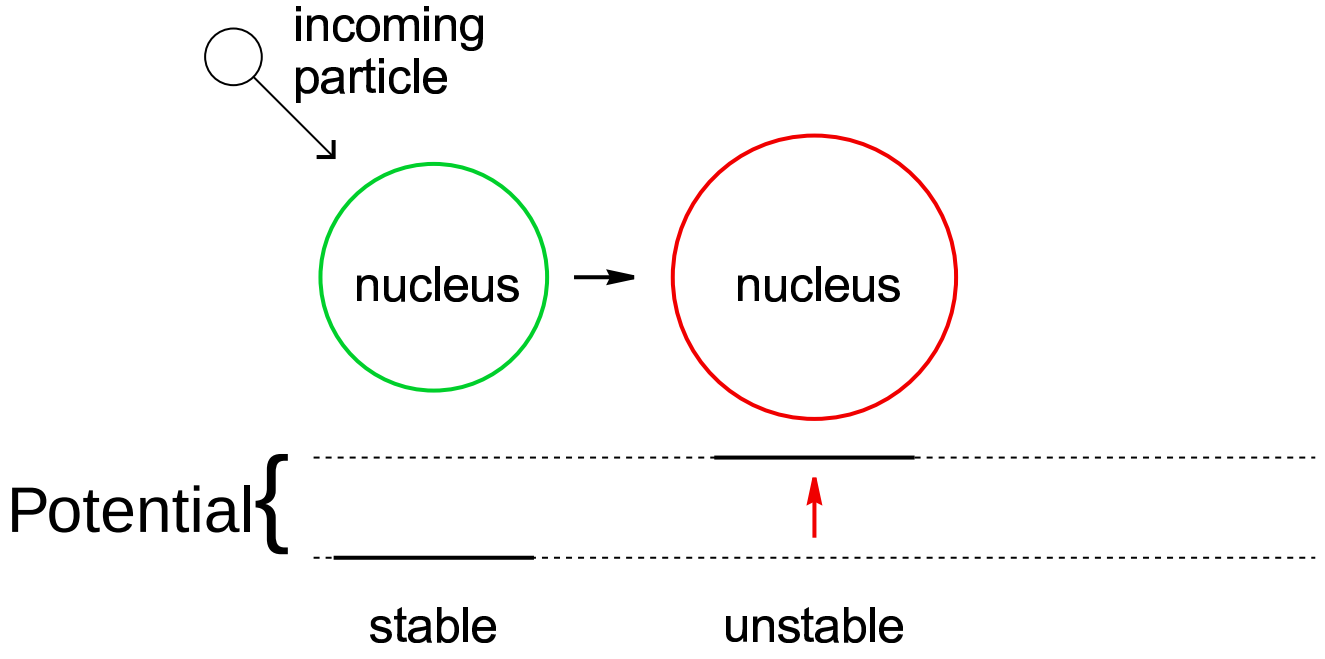
Binding energy, contd

- **Definition:** *Unstable nucleus*
  - A nucleus that can reduce its potential energy by emitting a particle.
- **Demonstration: Potential energy**



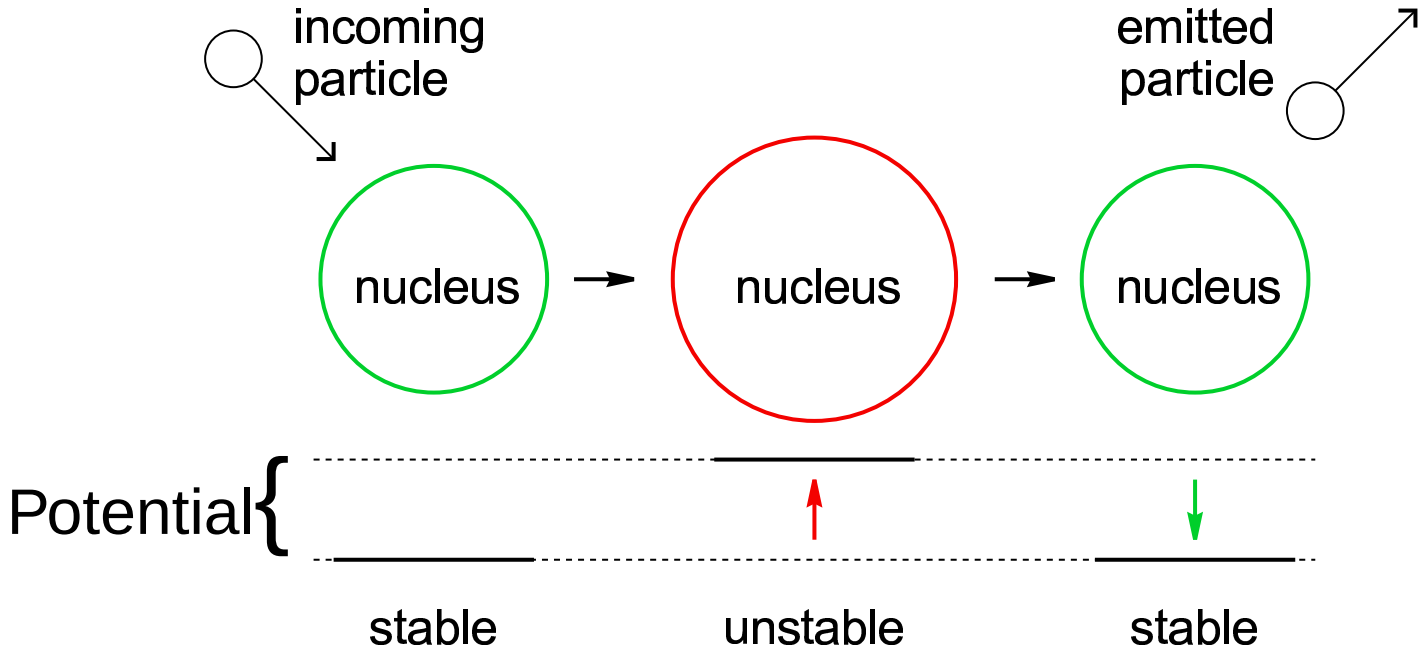
Binding energy, contd

- **Definition:** *Unstable nucleus*
  - A nucleus that can reduce its potential energy by emitting a particle.
- **Demonstration: Potential energy**



Binding energy, contd

- **Definition:** *Unstable nucleus*
  - A nucleus that can reduce its potential energy by emitting a particle.
- **Demonstration: Potential energy**



End

- **Practice Problems:**
  - (These problems are not for marks. They are the kinds of problems you can expect to find on tests.)
  - Ch. 17: Q. 1, 21; P. 1
  - Ch. 42: Q. 1, 3, 5; P. 3, 5, 57
  - Also, be able to identify the greek letters α, β and γ for next class.

End

- **Practice Problems:**
  - (These problems are not for marks. They are the kinds of problems you can expect to find on tests.)
  - Ch. 17: Q. 1, 21; P. 1
  - Ch. 42: Q. 1, 3, 5; P. 3, 5, 57
  - Also, be able to identify the greek letters α, β and γ for next class.
- **Interactive Quiz: Feedback**

End

- **Practice Problems:**
  - (These problems are not for marks. They are the kinds of problems you can expect to find on tests.)
  - Ch. 17: Q. 1, 21; P. 1
  - Ch. 42: Q. 1, 3, 5; P. 3, 5, 57
  - Also, be able to identify the greek letters α, β and γ for next class.
- **Interactive Quiz: Feedback**
- **Tutorial Question: tut01**
  - (Hand in your solution to a TA when you are done, for grading.)