Phyx 320
Modern Physics

April 19, 2021

Reading: 42.1-42.4

Homework #12 Due Next Next Tuesday

Nuclear Structure

Atoms are made of electrons orbiting a nucleus

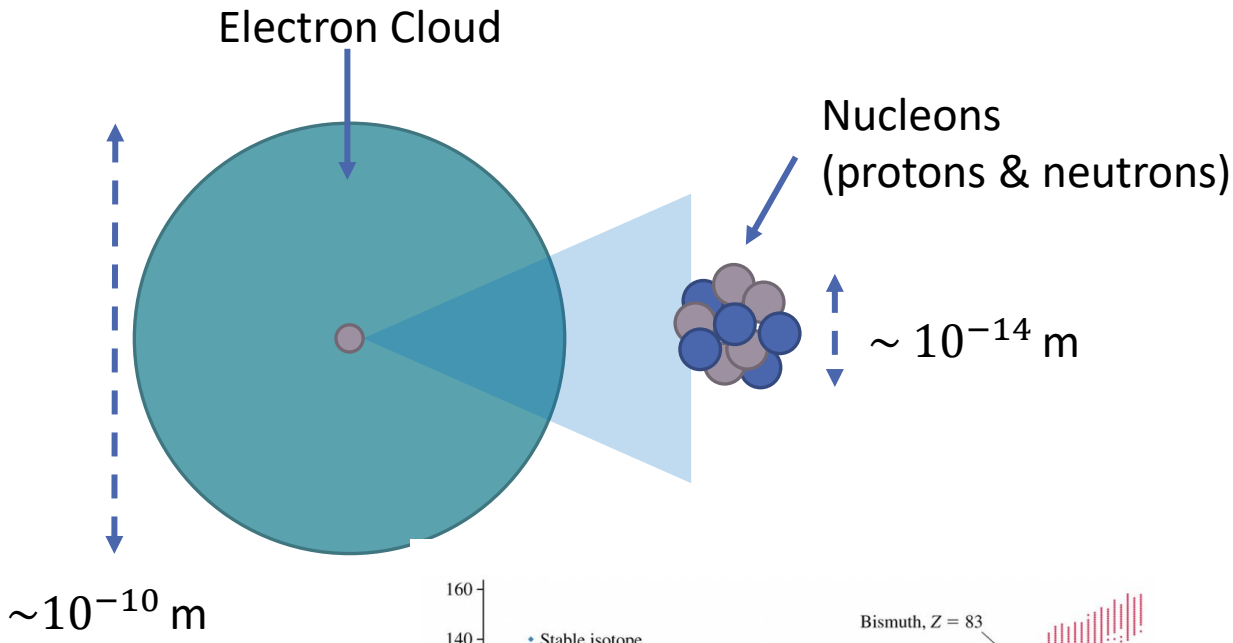
Nucleus is made up of nucleons:

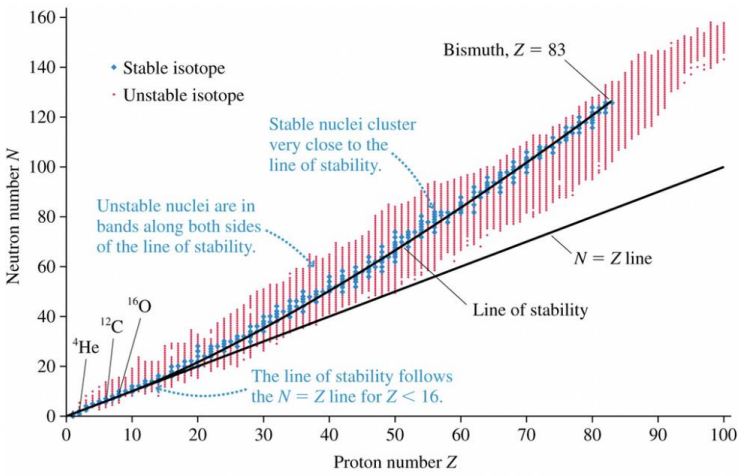
- Proton – number: Z, charge: +e, spin: ½, mass: 938.3 MeV
- Neutron - number: N, charge: 0, spin: ½, mass: 939.6 MeV

Proton and neutrons also obey the Pauli exclusion principle

As you go higher in the periodic table you need more neutrons to glue nucleus together

Nucleus held together by strong force





Shell Model

Like the atom, accounting for all the forces in a nucleus is a difficult problem

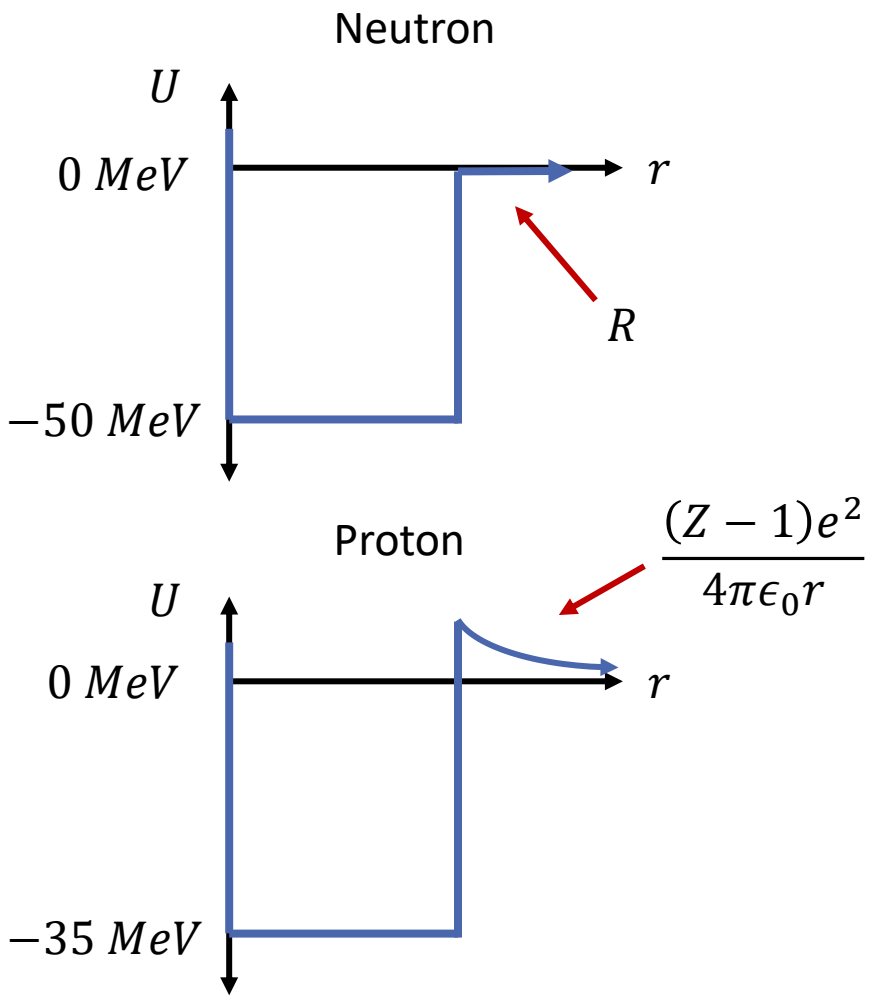
For many situations, the simplified shell model gives accurate results

Invented by Maria Goeppert-Mayer in 1949 (Nobel Prize in 1963)

Consists of a finite potential well below the radius of the nucleus

Protons also feel the electrostatic potential which rises the well and adds large distance tail to potential

Since the strong force is short-range, the depth of the well is $\approx -50\ MeV$ for all nuclei



Low-Z Nuclei

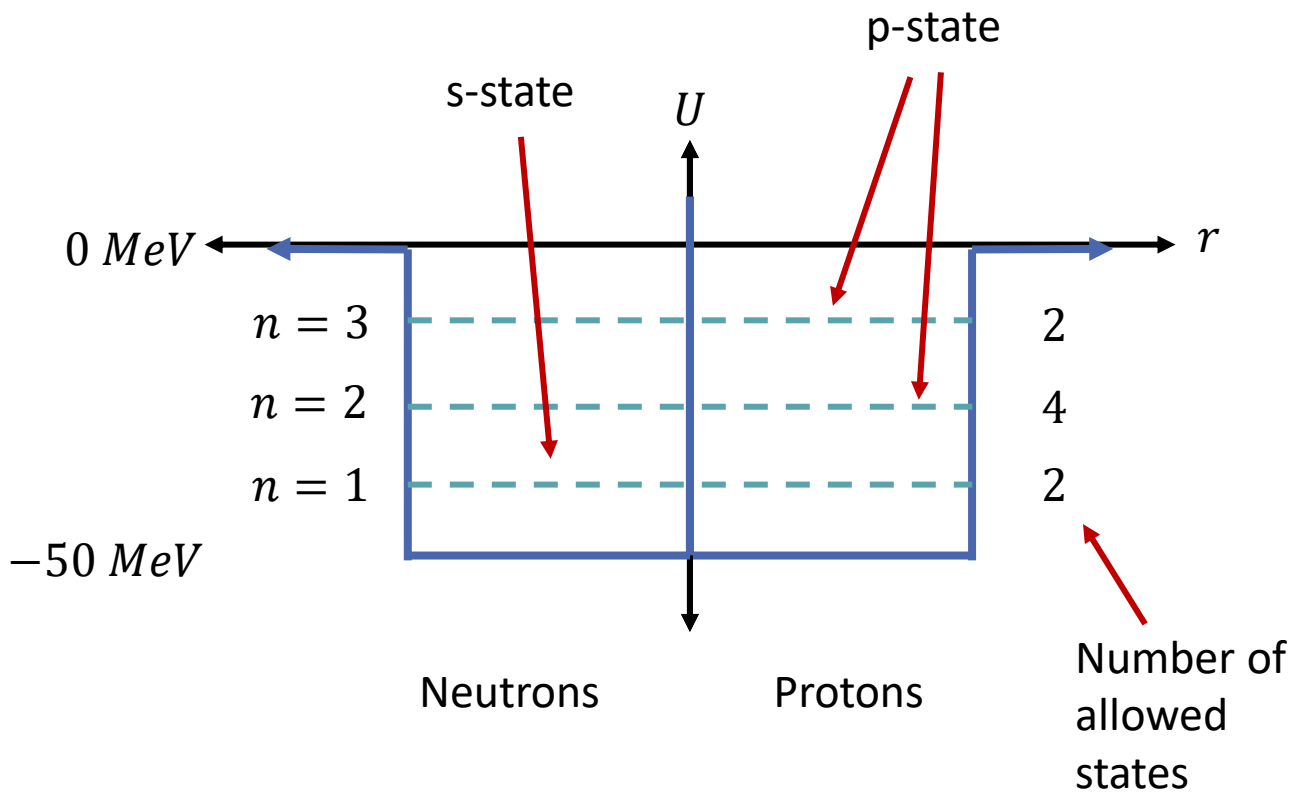
For low-Z nuclei (Z<8) the electrostatic potential can be ignored

Protons and neutrons feel the same potential which means they have the same energy states

As we showed in the past, the finite potential has a discrete set of energy states

But also remember that nuclei are 3-dimensional, so we have similar angular momentum states as atoms

Angular momentum states are split due to spin-orbit interactions



Low-Z Nuclei

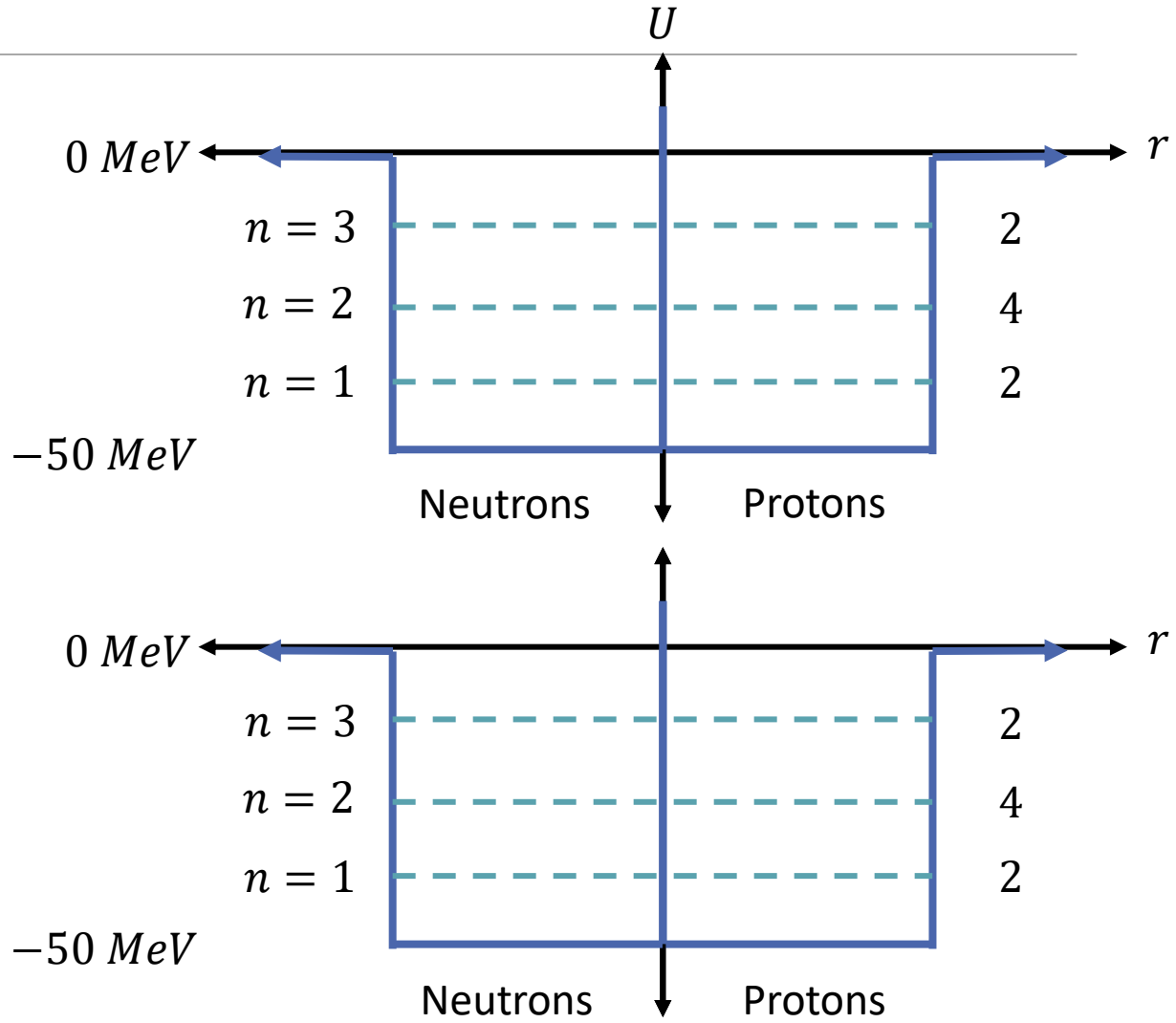
We fill in the energy levels just like we did with electrons

Remember, protons and neutrons are spin-1/2 particles so we can have either spin up or spin down

Many isotopes could be lower energy if they could swap a proton with a neutron or vice versa

This happens in a process called beta decay

Nature wants to keep neutron and protons energy levels filled to about the same level



Radiation

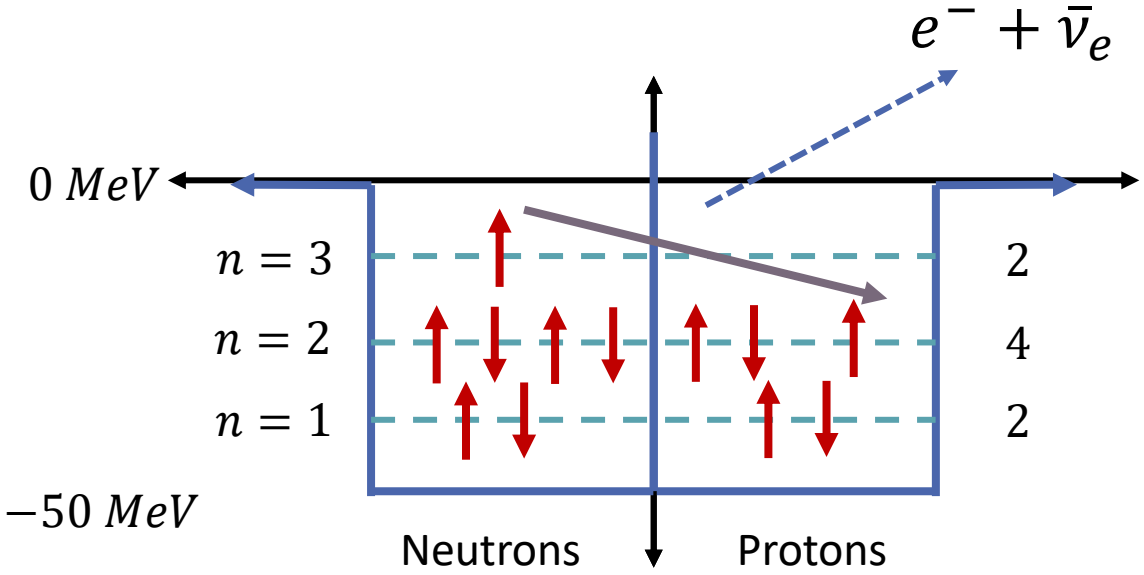
When nuclei transition from a higher energy state to a lower one, they can emit three types of radiation:

- Alpha – ^{4}He nucleus, 2 protons and 2 neutrons, +2e charge, stopped by a sheet of paper
- Beta – electron (or positron), -e charge, stopped by a few mm of aluminum
- Gamma – high-energy photon, 0 charge, stopped many cm of lead

This process is called radioactive decay

For example, boron-12 beta decays to carbon-12, emission of electron is needed to conserve charge

$$^{12}B \rightarrow {}^{12}C + e^- + \bar{\nu}_e$$



Ionizing Radiation

Radiation describes any non-contact (radiative) flow of energy, examples: sunlight, thermal glow, microwave,…

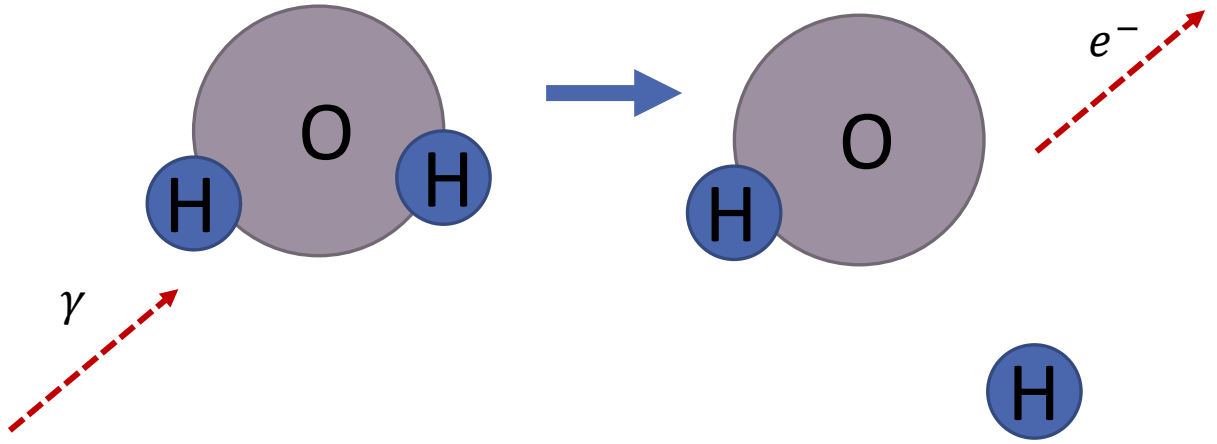
Most radiation is absorbed by materials and becomes heat

What makes nuclear radiation unique (and more dangerous) is that it can high enough energy to be ionizing radiation

Ionizing radiation strips electrons off atoms which can break molecular bonds

This is how radiation can damage tissue and materials

Since radiation many interacts with the electrons, the irradiated material does not itself become radioactive



Homework Questions

Homework Questions

Homework Questions