Fundamental Forces of the Universe

There are four fundamental forces, or interactions in nature.

- Strong nuclear
- Electromagnetic
- Weak nuclear
- Gravitational

Strongest

↓

Weakest

Strong nuclear force

- Holds the nuclei of atoms together
- Very strong, but only over very, very, very short distances (within the nucleus of the atom)

Electromagnetic force

- Causes electric and magnetic effects
  - Like charges repel each other
  - Opposite charges attract each other
  - Interactions between magnets
- Weaker than the strong nuclear force
- Acts over a much longer distance range than the strong nuclear force

Weak nuclear force

- Responsible for nuclear decay
- Weak and has a very short distance range

Gravitational force

- Weakest of all fundamental forces, but acts over very long distances
- Always attractive
- Acts between any two pieces of matter in the universe
- Very important in explaining the structure of the universe

Remember…

- The weak nuclear force is NOT the weakest of the fundamental forces.
- GRAVITY is the weakest force, but most important in understanding how objects in the universe interact.

Nuclear Reactions

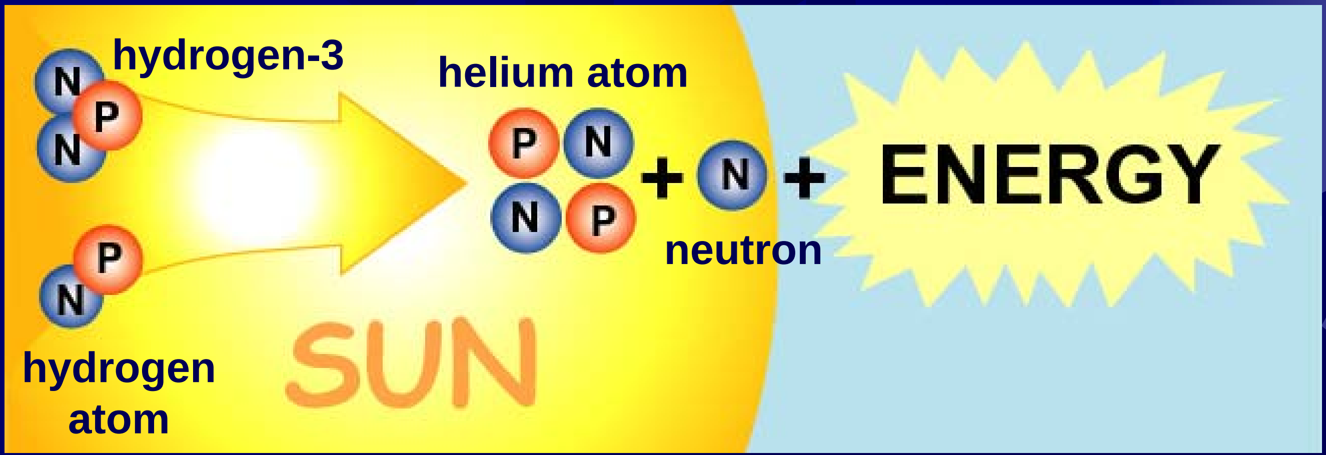
- There are two kinds of nuclear reactions:
  - Fusion
  - Fission
- Protons and neutrons are the two most important subatomic particles in the nucleus and participate in these reactions.

Fusion

- Fusion is the process of combining nuclei of atoms to make different atoms.
- This reaction is going from SMALL to LARGE particles.
- Think of fusing two things together.

Fusion

- Nuclear fusion happens at the sun.
- One atom of hydrogen-3 and one atom of hydrogen combine to form a helium atom, a neutron and lots of energy!!!



Fusion

- Where does the energy come from?
- Energy is gained when the two hydrogen atoms break apart.
- Some of this energy is used up to create the helium atom, but the rest is given off as light.
- Mass is converted to energy!
  - $E = mc^2$ $(c = 3.0 \times 10^8 \text{ m/s})$
  - Since the speed of light is so large even a small mass will be converted to a very large energy.

Fission

- Fission is the process of breaking up the nucleus of an atom.
- This reaction is going from LARGE to SMALL particles.
- Think of breaking two things apart.

Fission

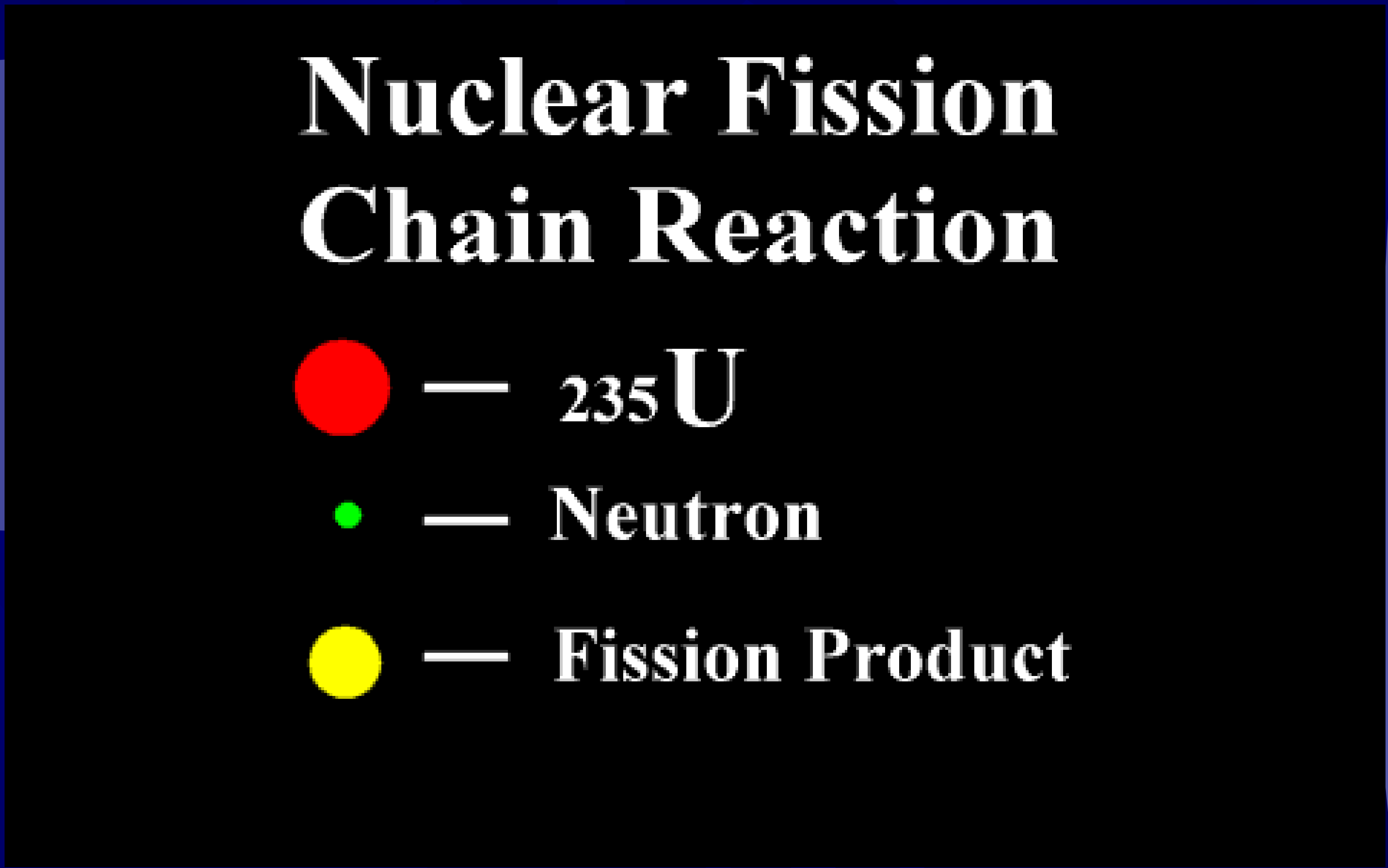
- Nuclear fission happens on earth.
- Nuclear fission begins when a neutron hits the nucleus of large atom.
- Adding this neutron makes the nucleus unstable and it splits into two smaller nuclei and two neutrons.

Fission

Chain Reactions

- If there are other $_{235}U$ atoms nearby, the neutrons that came from splitting the first $_{235}U$ nucleus can hit other atoms.
- The nuclei of these other atoms will release more neutrons and split more $_{235}U$ atoms.
- This is called a *chain reaction*.

Chain Reactions



Radioactivity

- Radioactivity is the process where the nucleus emits particles or energy.
- There are three types of radioactive decay:
  - Alpha decay
  - Beta decay
  - Gamma decay

Alpha decay

- A particle with 2 protons and 2 neutrons is released from an unstable nucleus.
- Alpha decay can be stopped by clothing, skin, a few centimeters of air, or cardboard.

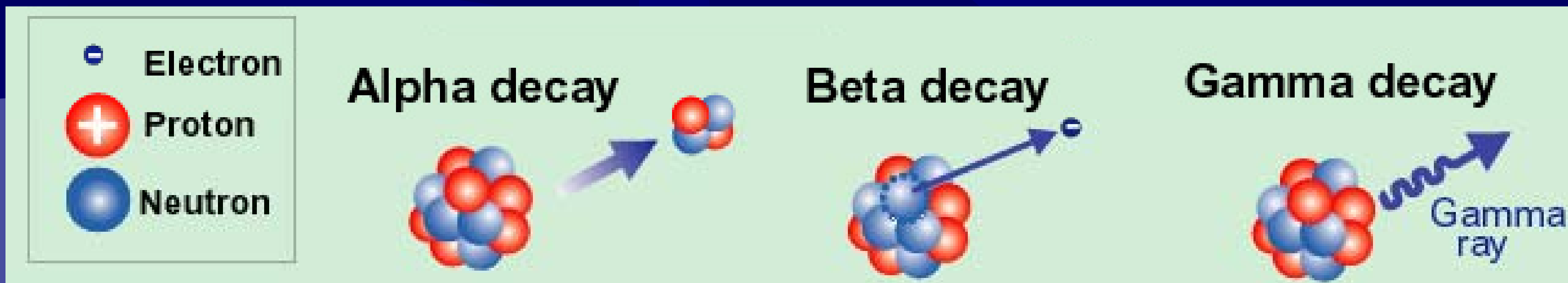
Beta decay

- This occurs when a neutron in the nucleus of a radioactive isotope splits into a proton and an electron.
- The electron is emitted.
- Beta decay can be stopped by dense clothing or wood.

Gamma decay

- This involves the release of high-energy, electromagnetic radiation from the nucleus of the atom.
- Gamma rays have even more energy than X-rays.
- It can only be stopped with thick walls of concrete or lead.

Radioactive Decay



# of Protons			
# of Neutrons			
What is released?			

Half-Life

Time (years)	Fraction of element left	Amount left (g)	Half-life
0	1	80	0
1000	1/2	40	1
2000	1/4	20	2
3000	1/8	10	3

Half-Life

- The half-life of a radioactive element is the <u>*TIME*</u> it takes for <u>*HALF*</u> of the radioactive atoms to decay to stable ones.

- If there are 80 grams of a radioactive element that has a half-life of 1000 years, then after 1000 years half of the element, or 40 grams of the element, will remain.

- Now that there are only 40 grams left, how many grams will be left after another 1000 years has passed?
  - There will be only 20 grams remaining.

Half-Life

- The number of half-lives that occur for an element is found by dividing the *total time* by the *half-life* of a radioactive element.
- Half-life ÷ total time = # of half-lives
- An element has a half-life of 1000 years. How many half-lives have occurred after 2000 years has passed?
  - Two half-lives because 2000 years ÷ 1000 years = 2

Half-Life

- To find the fraction of the original amount think of the original amount as 1 and then divide by 2.
  - 1 ÷ 2 = 1/2, one-half is how much remains after one half-life occurs.
- If two half-lives occur then divide the original amount by 2 twice.
  - 1 ÷ (2×2) = 1 ÷ 4 = 1/4, one-fourth is how much remains after two half-lives occur.
- What do you do if three half-lives occur?
  - 1 ÷ (2×2×2) = 1 ÷ 8 = 1/8, one-eighth is how much remains after three half-lives occur.

Half-Life Practice Problem #1

- The radioactive isotope Fluorine-11 has a half-life of 11.0 s. How many half-lives occur in 11.0 s for Fluorine-11?
  - Only one half-life occurs because the half-life of Fluorine-11 is 11.0 s.
- If you started with 30 g, how many grams are left after 11.0 s?
  - Since one half life occurs, 30 g is divided by 2 and there are 15 g left.
- What fraction of the original amount is left?
  - One-half of the original amount is left.

Half-Life Practice Problem #2

- The radioactive isotope Carbon-15 decays very fast and has a half-life of 2.5 s. How many half-lives occur in 5.0 s for Carbon-15?
  - Two half-lives occur because 5.0 s ÷ 2.5 s = 2.
- If you started with 100 g, how many grams are left after 5.0 s?
  - Since 2 half-lives occur, the 100 g must be divided by 2 twice: 100 g ÷ 4 = 25 g.
- What fraction of the original amount is left?
  - 1 ÷ (2×2) = 1 ÷ 4 = 1/4, one-fourth remains.

Half-Life Practice Problem #3

- Neon-15 has a half-life of 30 s. How many half-lives occur in 1.5 min?
  - Three half-lives occur because 1.5 min = 90 s and 90 s ÷ 30 s = 3.
- If you started with 56 g, how many grams are left after 1.5 min?
  - Since 3 half-lives occurred, the 39 g must be divided by 2 three times: 56 g ÷ 8 = 7 g.
- What fraction of the original amount is left?
  - 1 ÷ (2×2×2) = 1 ÷ 8 = 1/8, one-eighth is left