# Chapter 24

Radioactivity and such

# Radioactivity – emit radiation

- Nuclear reactions – change an element into a new element!! Lots of energy involved!
  - Unlike a chemical reaction because we are doing more than rearranging – we CHANGE the identity.
  - Change in the atom's nucleus.
- UNSTABLE nuclei are unhappy and lose energy by emitting radiation – radioactive decay.
- They form STABLE atoms of a different element.

# Radioisotopes

- Isotopes of atoms with unstable nuclei.

- Undergo radioactive decay to attain stability.

Emit 3 types of radiation
  - alpha, $\alpha$
  - beta, $\beta$
  - gamma, $\gamma$

# Warm Up

- Name the three types of radioactive decay that we discussed Tuesday and their charges.
- Why do elements undergo radioactive decay?
- Complete this decay equation:

$^{210}_{84}Po \rightarrow ^{4}_{2}He +$ _______

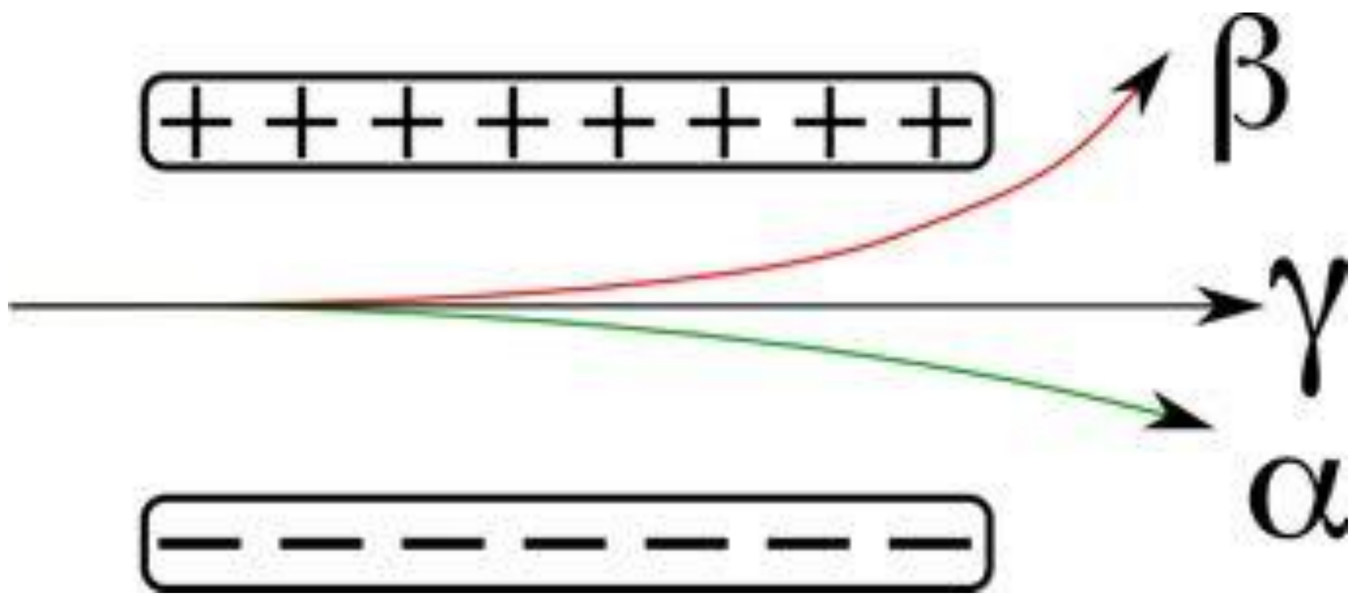
what type of decay is it?

# Today's Agenda

- Question for today: What are the ways that large elements decay? How harmful are these particles?

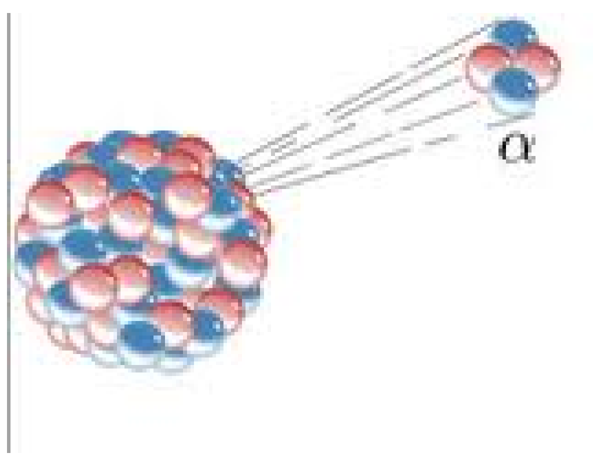
- Alpha, beta, gamma decay, positron emission and electron capture
- Nuclear forces
- Band of stability
- Quiz tomorrow! Final paper due tomorrow!
- Homework set due TUES. Test Ch 4&24 Thurs.

# What are the charges on radioactive particles?



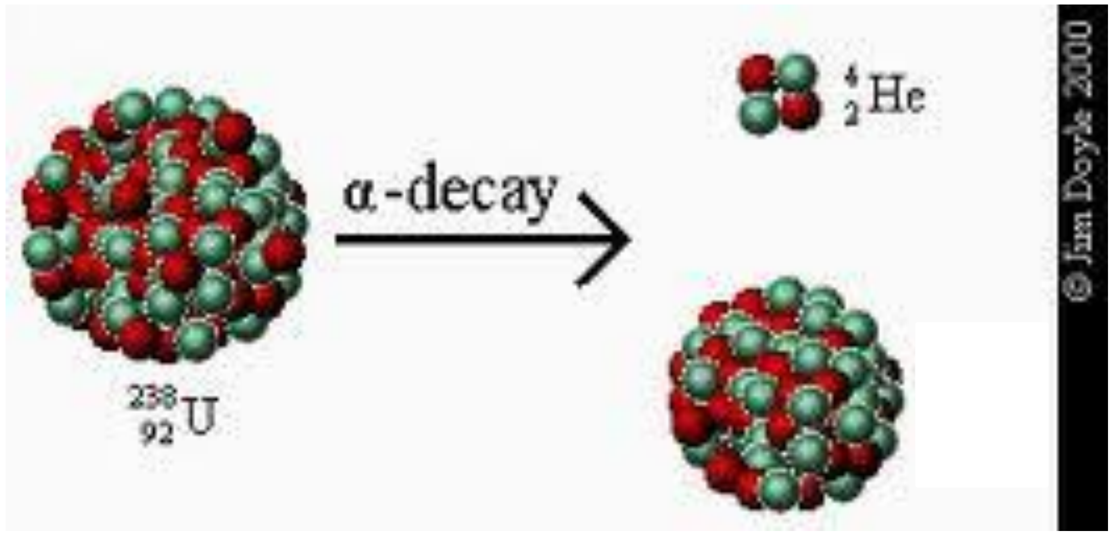
# Types of Radiation

- Alpha radiation – (remember the gold foil experiment?!?!) made up of POSITIVE "alpha particles".
- 2 protons and two neutrons (no electrons!)




$^{4}_{2}He^{2+}$ or $\alpha$

# Alpha decay



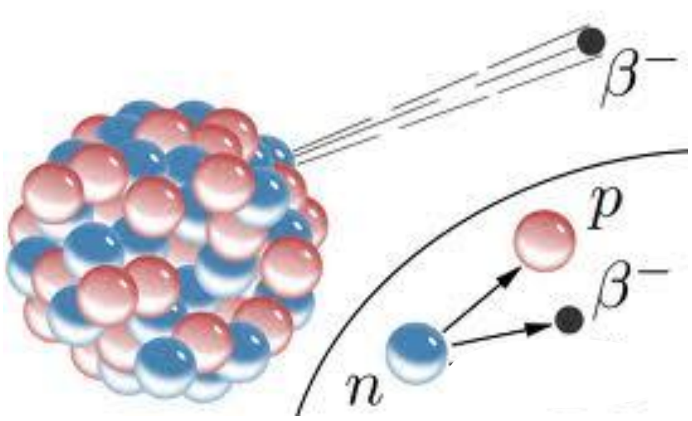

$$^{238}_{92}U \longrightarrow\ ^{4}_{2}He + \ ^{234}_{90}Th$$

$$^{226}_{88}Ra \longrightarrow\ ^{4}_{2}He + \ ^{222}_{86}Rn$$

$$^{247}_{96}Cm \longrightarrow\ ^{4}_{2}He + \ ^{243}_{94}Pu$$

# Types of Radiation

- Beta radiation – negatively charged beta particles
- Unstable neutron turns into a proton and ejects 1 electron




$e^-$ or $\beta$

# Types of Radiation

- Gamma radiation – emits gamma rays, high energy photon that has no mass nor charge.

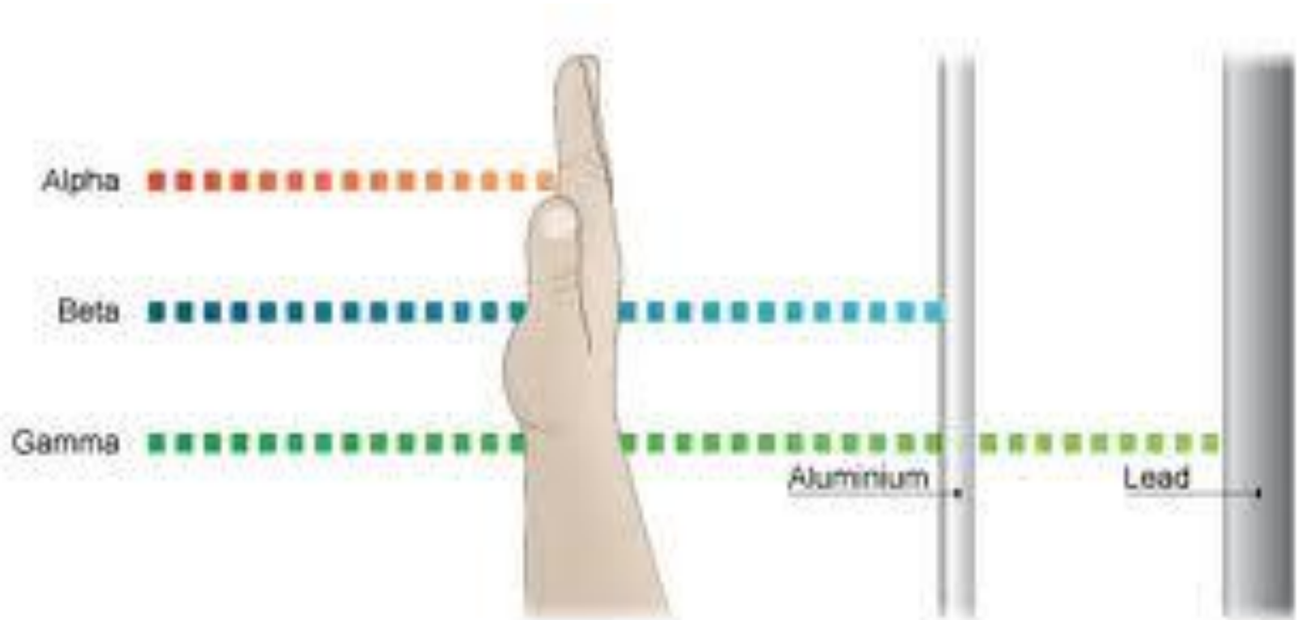
- Gamma rays almost always accompany alpha and beta radiation and account for the energy lost in the nucleus.

$\gamma$

Usually omitted from nuclear equations.

$$^{238}_{92}U \longrightarrow {}^{4}_{2}He + {}^{234}_{90}Th + 2\gamma$$

# Penetrating Power of Radiation



# Penetrating Power

Least

Alpha particles most mass and charge.

Isotopic mass → $^{4}_{2}He^{2+}$ ←

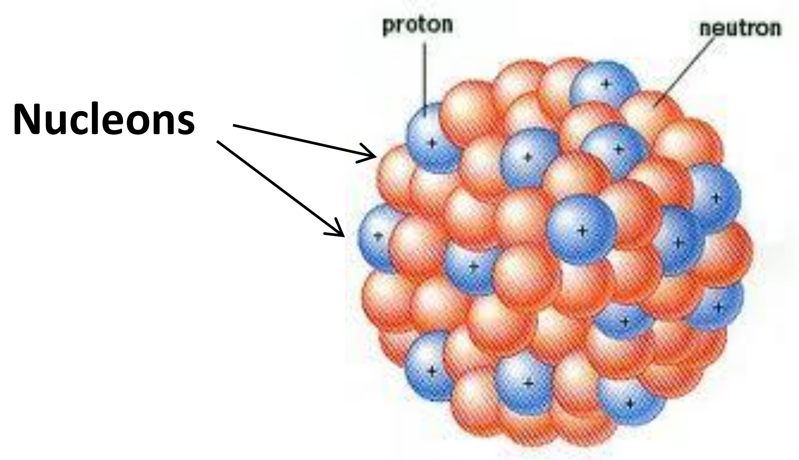
Beta particles less mass (only the mass of an electron) and a neg charge.

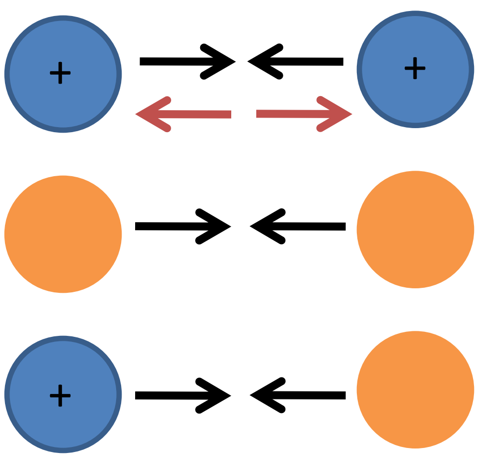
Gamma rays have no mass and no charge.

Most

# In the Nucleus

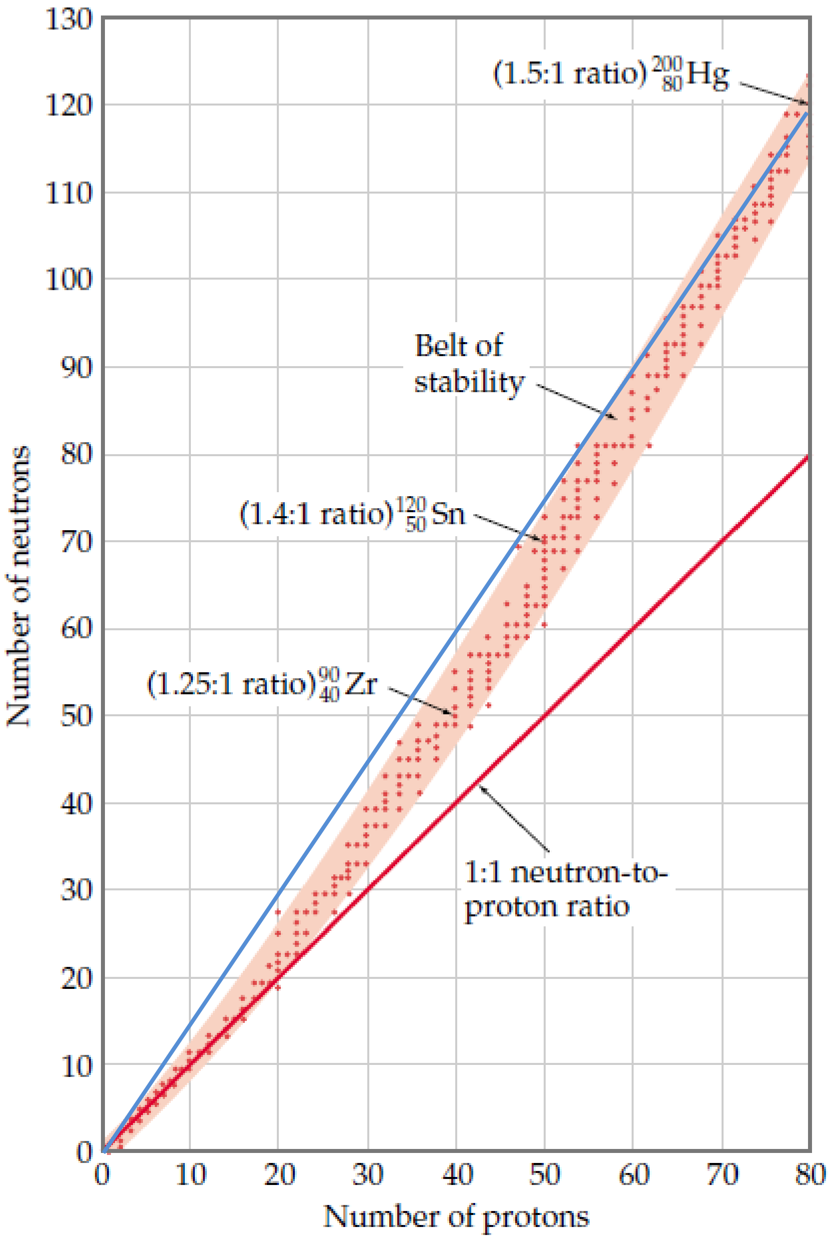
- Radioactive decay – **transmutation**
  - Atomic # is altered = identity of element changed



Strong nuclear force between all nucleons.
Repulsive force between 2 protons (electrostatic).
Neutron attraction have to overcome the repulsive forces – as atomic # increases we need more neutrons to stabilize the nucleus!!!

All nuclei with more than 82 protons are radioactive!




Low atomic #'s have a 1:1 neutron to proton ratio $^{4}_{2}He$

High atomic #'s are stabilized by a 1.5:1 ratio $^{200}_{80}Hg$

If atom is not in band (belt) of stability it undergoes radioactive decay to get there!

# Other types of decay…

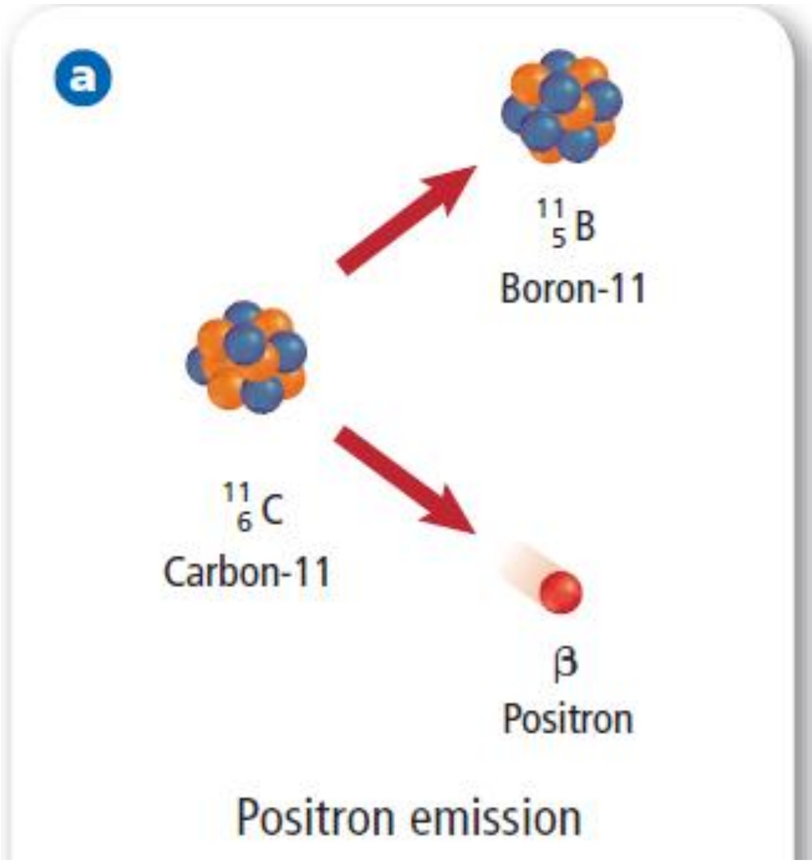
- Nuclei with low neutron to proton ratio undergo **positron emission** and **electron capture.**
- **Positron** – particle with same mass as an electron but opposite charge ($e^+$ or $\beta$).

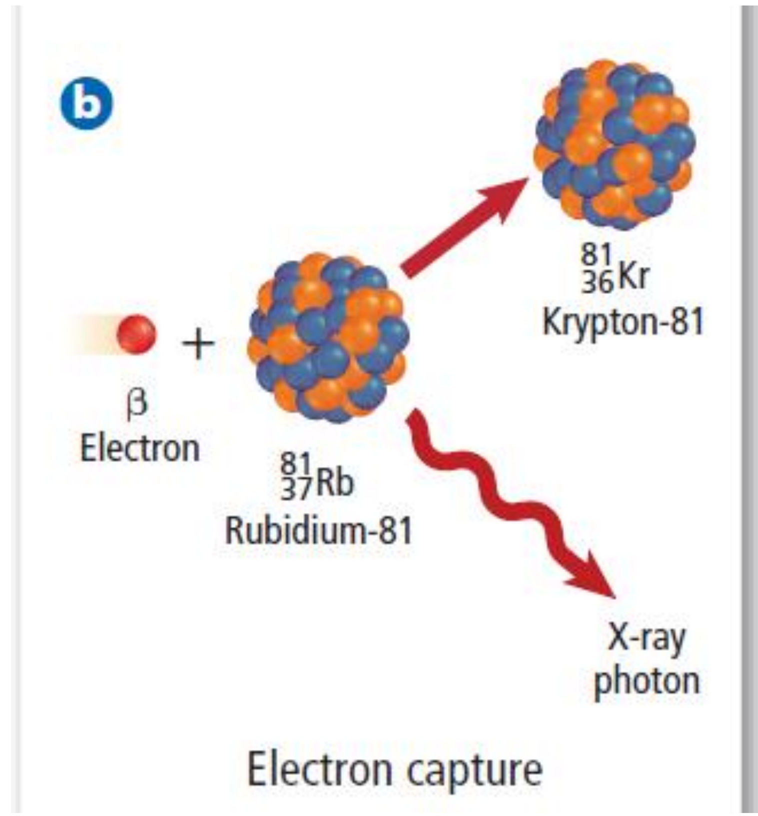
Positron emission = $p \rightarrow n + e^+$

Electron capture = $p + e^- \rightarrow n$

both processes decrease # protons to increase stability

# Positron Emission and e⁻ Capture



## Table 24.3 Summary of Radioactive Decay Processes

Interactive Table Explore radioactive decay processes at glencoe.com.

| Type of Radioactive Decay | Particle Emitted | Change in Mass Number | Change in Atomic Number |
|---|---|---|---|
| Alpha decay | $^{4}_{2}He$ | decreases by 4 | decreases by 2 |
| Beta decay | $\beta$ or $e^{-}$ | no change | increases by 1 |
| Positron emission | $\beta$ or $e^{+}$ | no change | decreases by 1 |
| Electron capture | X-ray photon | no change | decreases by 1 |
| Gamma emission | $\gamma$ | no change | no change |

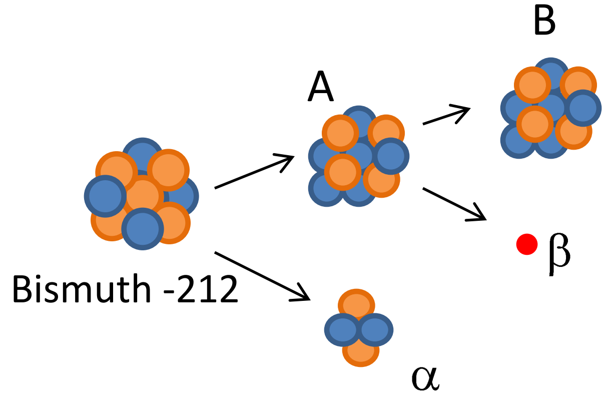
# Decay Practice

$\alpha$ decay $$^{238}_{94}Pu \longrightarrow ^{4}_{2}He + ^{234}_{92}U$$

Thorium-229 is used to increase the lifetime of fluorescent bulbs.
What type of decay occurs when thorium-229 decays to form radium-225?
Write out the nuclear equation.

$$^{229}_{90}Th \longrightarrow ^{4}_{2}He + ^{225}_{88}Ra$$

Write a balanced nuclear equation for the decay shown on the right.
Identify **A** and **B**




$$^{212}_{83}Bi \longrightarrow ^{4}_{2}He + ^{208}_{81}Tl \quad \mathbf{A}$$

$$^{208}_{81}Tl \longrightarrow \beta + ^{208}_{82}Pb \quad \mathbf{B}$$

# Nuclear Reactions

- Induced Transmutation – FORCE an element to change its identity by bombarding it with radioactive particles!

$$^{4}_{2}He + ^{14}_{7}N \longrightarrow ^{17}_{8}O + ^{1}_{1}H$$

- Particle accelerators move particles at extremely high speeds to overcome repulsive forces.

# Warm Up

Complete these reactions and indicate the TYPE of radioactive process:

$^{241}_{94}Pu \rightarrow ^{241}_{95}Am +$ ____

$^{214}_{83}Bi \rightarrow ^{210}_{81}Tl +$ ____

$^{85}_{37}Rb \rightarrow ^{85}_{36}Kr +$ ____

What is the optimal neutron to proton ratio for a large nucleus? What happens if n:p is not ideal?

# Today's Agenda

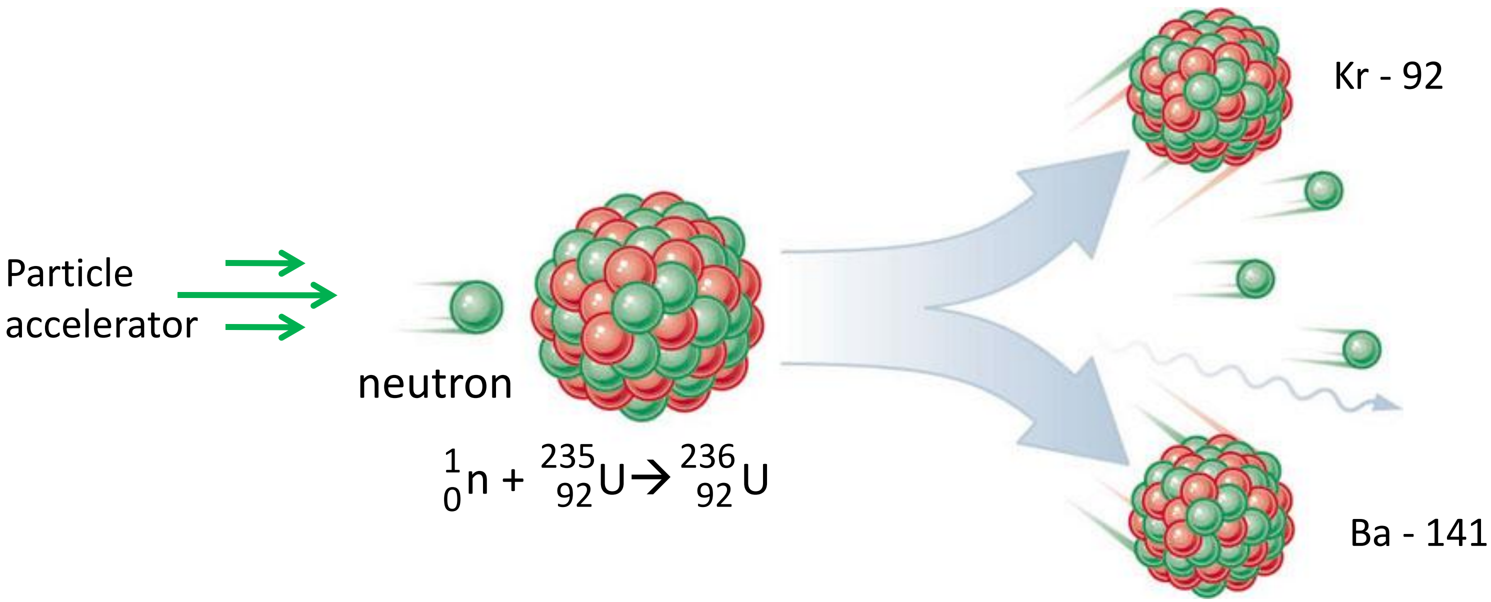
- Question for today: What is nuclear energy and why is it a possible alternative energy source?

- Nuclear reactions – Fission and Fusion
- Nuclear power – what it is and how it works
- Half life calculations.

- Lab Report due Today in my hand! Homework Set due Tues.
- Ch 4/24 Test Thurs.

# Nuclear Fission

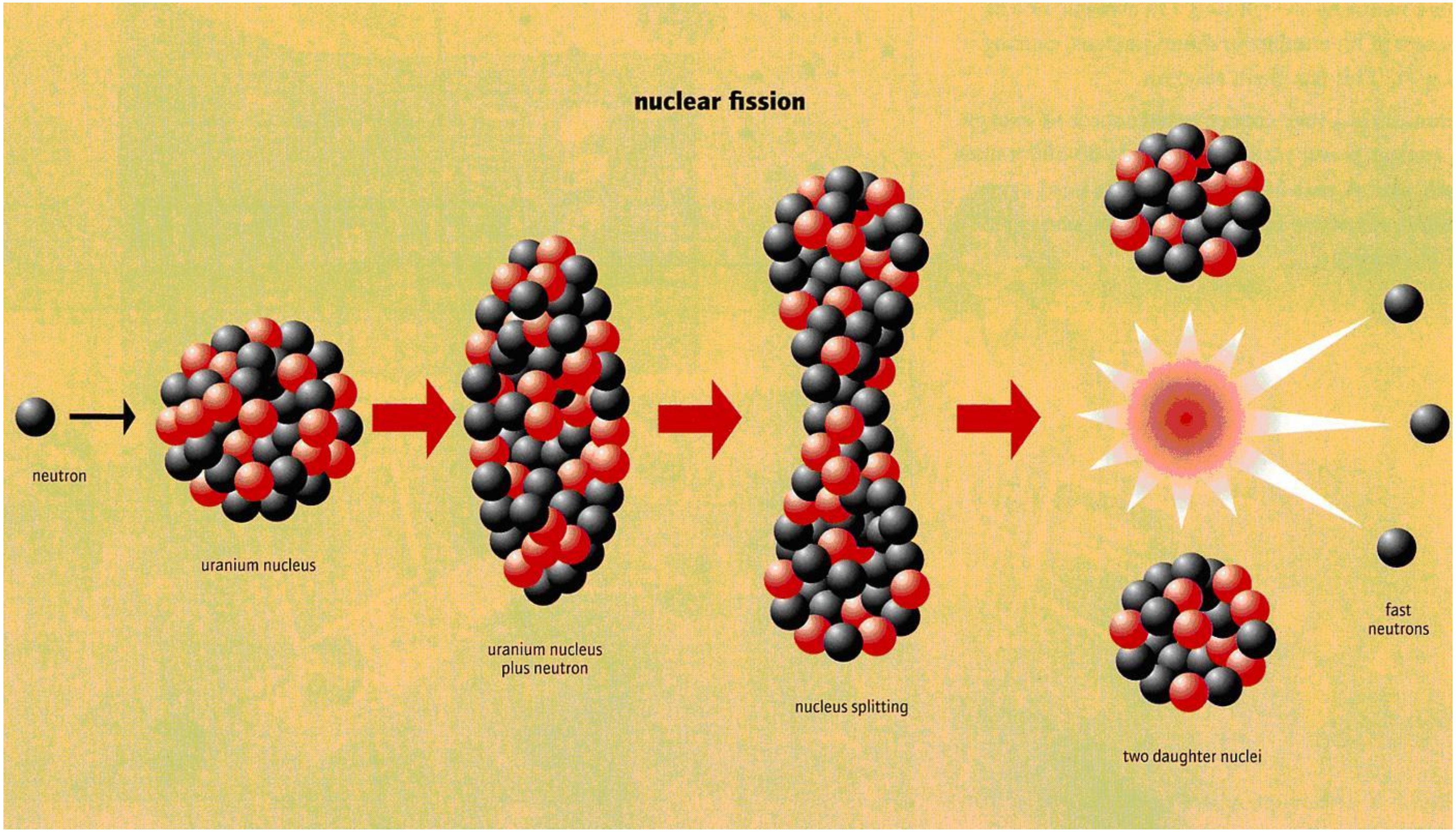
- Force a nucleus to split into fragments – resulting in a LARGE release of energy!



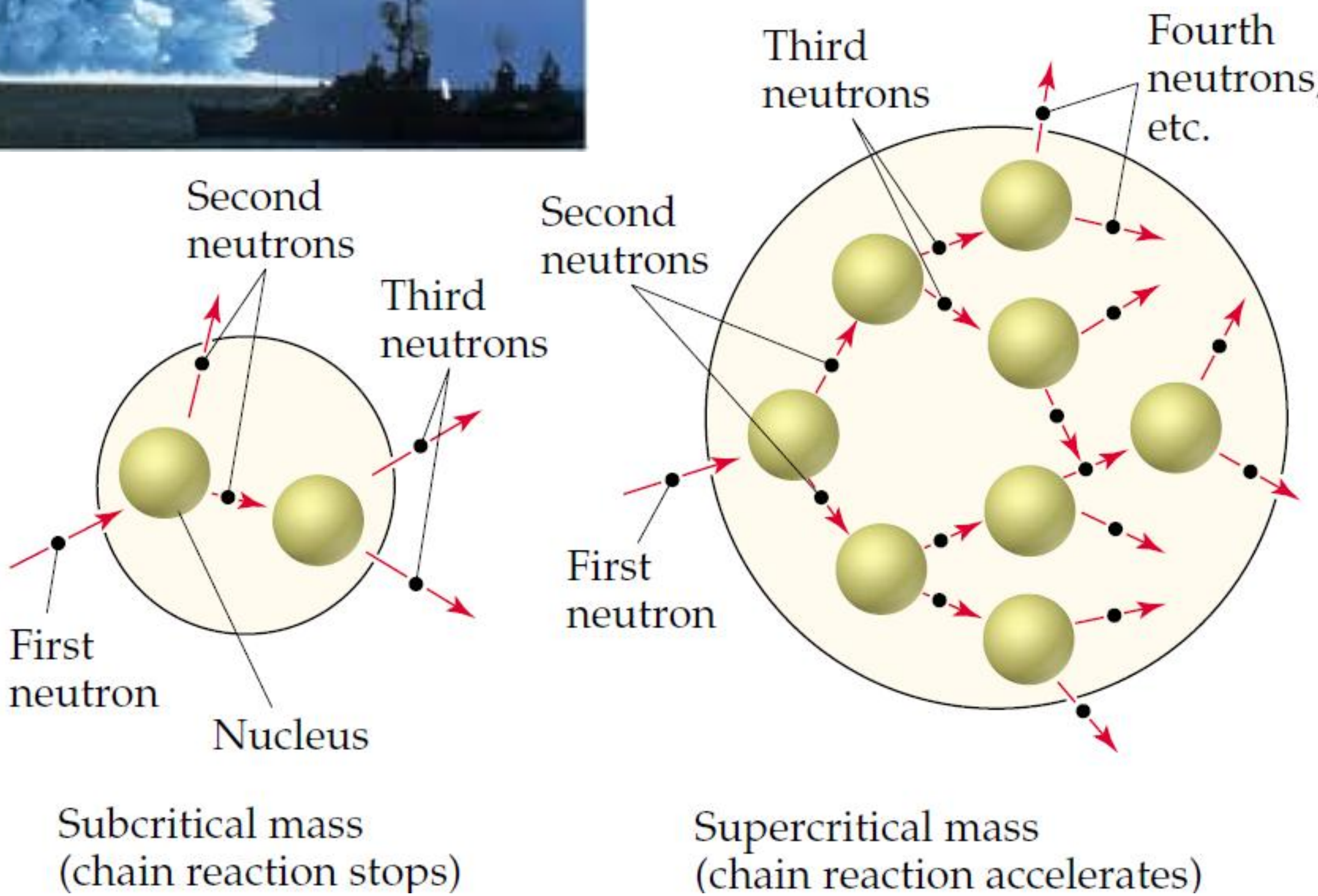

$${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{236}_{92}U$$

What products are formed?

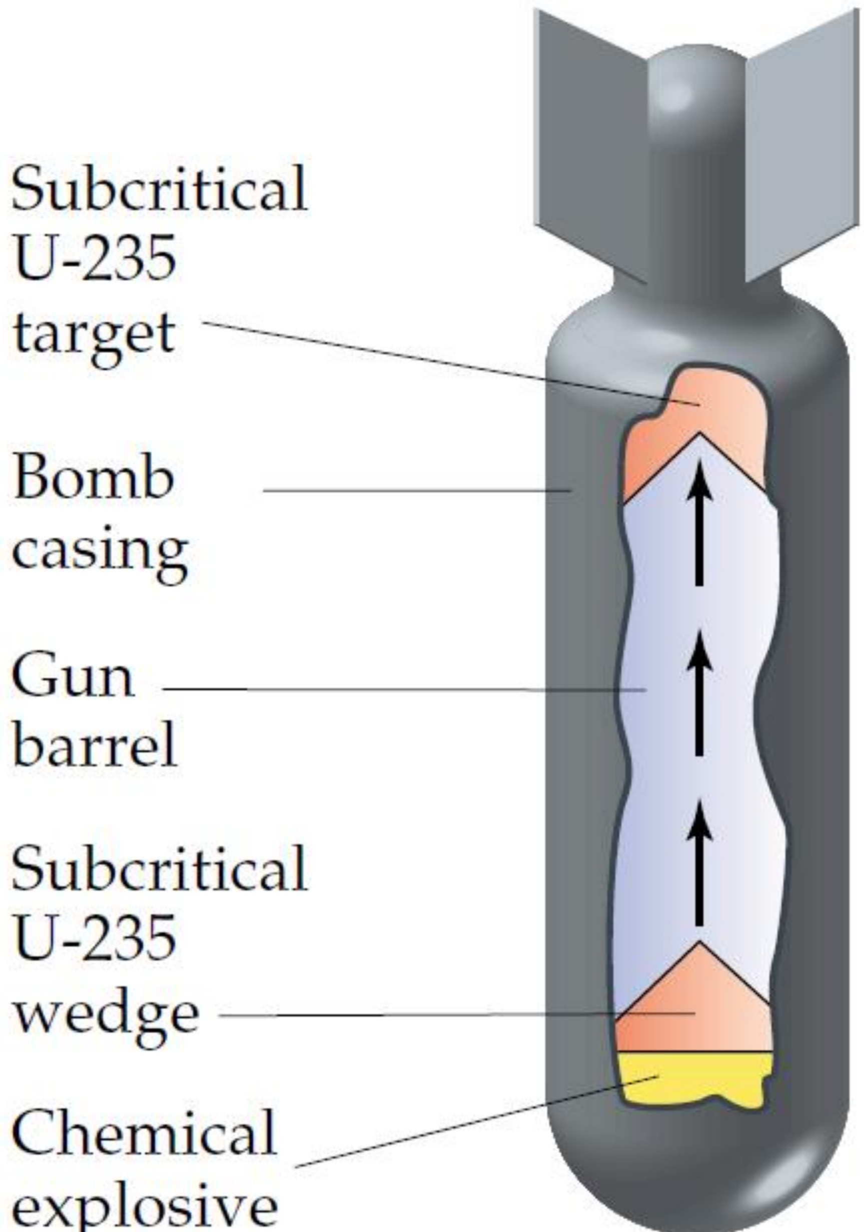
# Neutrons Perpetuate Fission



# Critical Mass



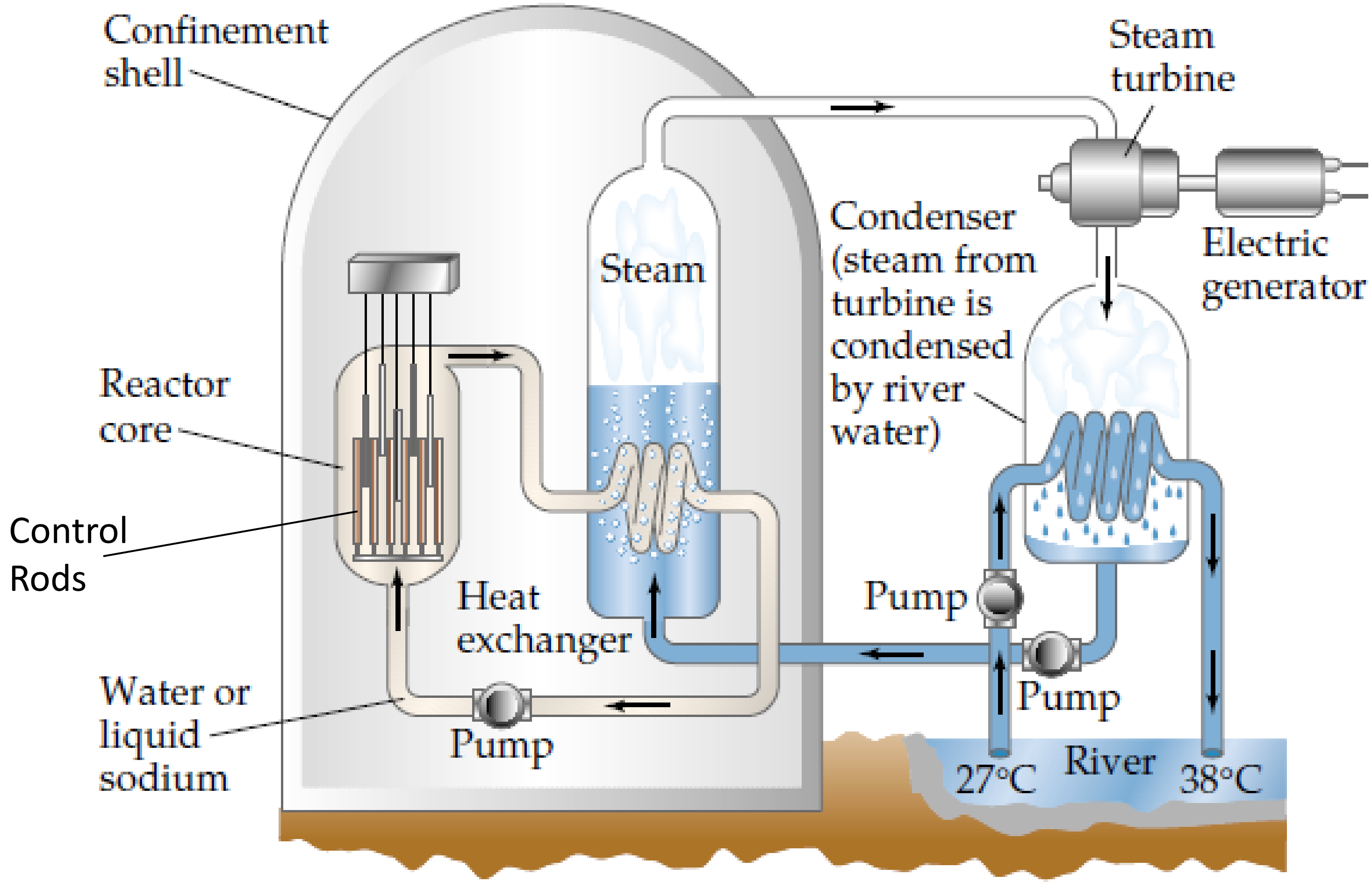
# Violent Nuclear Reactions




Subcritical masses that get together to form supercritical mass.

Equal to 20,000 tons of TNT

# Nuclear Reactors




Reactor core controlled by Cd or B to absorb neutrons
Current Events!

# Nuclear Fusion

- Bind low atomic mass (less than 60 because 60 is ideal) to form more stable atom.

- Combination of nuclei called fusion.
- How the sun works…

$$4\,{}^{1}_{1}H + 2\beta \longrightarrow \text{energy} + {}^{4}_{2}He$$

- Need very high energy to initiate and sustain.

# Nuclear Energy vs. Fossil Fuel

- Why is nuclear energy considered cleaner than fossil fuels with respect to greenhouse gases?

- Describe the process that occurs during a nuclear chain reaction and explain how to monitor a chain reaction in a nuclear reactor.

True/False

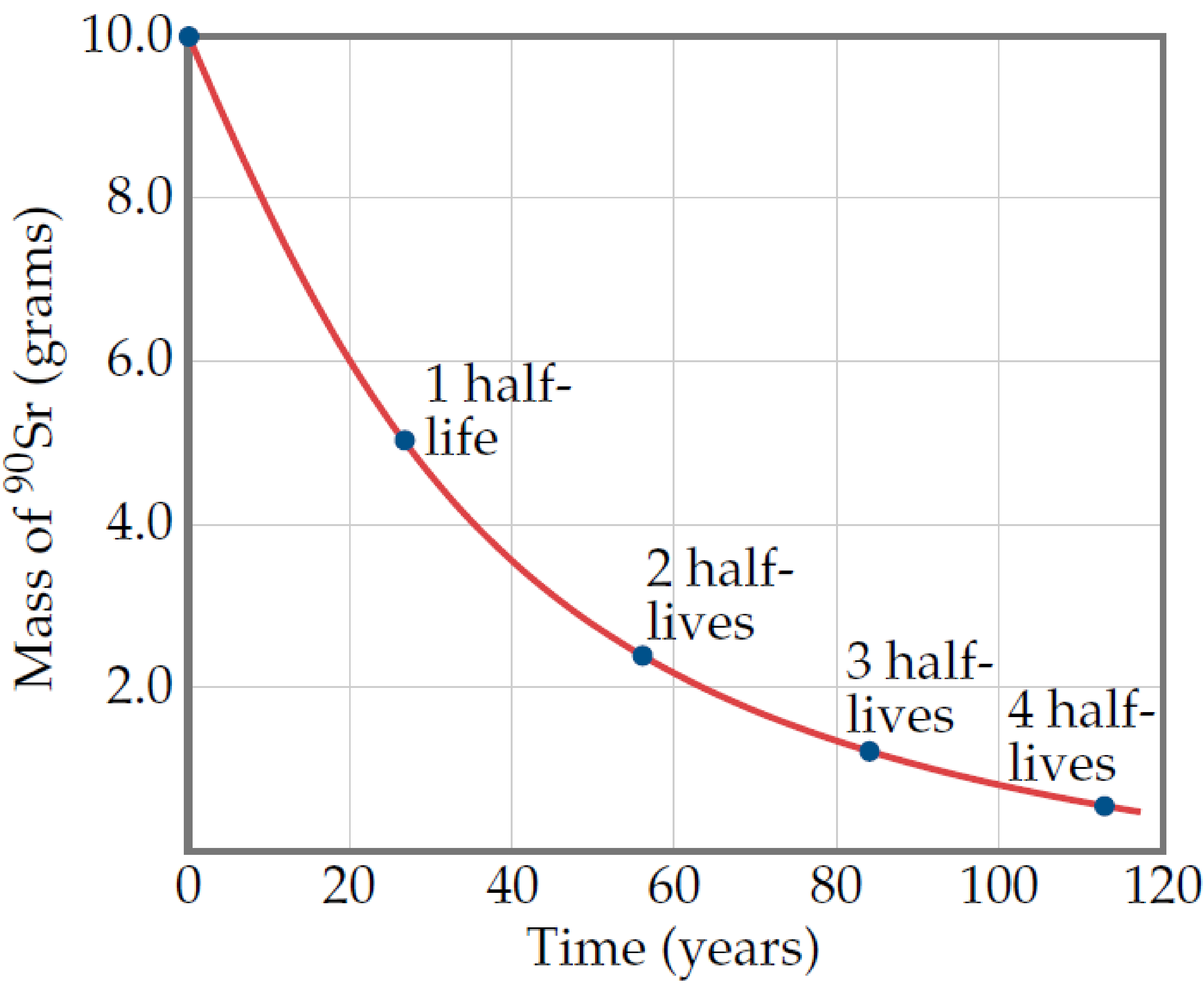
- Great amounts of energy can be liberated from small amounts of matter in a nuclear reaction.
- The amount of U-235 in a nuclear reactor should always be kept subcritical.
- Nuclear power plants do not contribute to air pollution.
- Nuclear power use is dangerous because plants are commonly are out of control.

# Half Life

- Time required for one half of the nuclei to decay into its products.

- Strontium-90 half life is 29 years.

If you had 10 g now, in 29 years you would have 5g.



10.0
8.0
6.0
4.0
2.0
Mass of $^{90}$Sr (grams)
0
20
40
60
80
100
120
Time (years)
1 half-life
2 half-lives
3 half-lives
4 half-lives

# Work together to solve…

Kr is used in indicator lights of appliances. Kr-85 has a half life of 11 years. If a refrigerator light contains 2.0 mg of Kr-85, after 33 years, how much is left?

# Half Life Formula

$$N = N_0 (½)^n$$

N – remaining amount of element

$N_0$ – initial amount of element

n – number of half lives that have passed

Kr-85 has a half life of 11 years. Kr is used in indicator lights of appliances. If a refrigerator light contains 2.0 mg of Kr-85, after 33 years, how much is left?

N = ?

$N_0$ = 2 mg

n = 33 years/11 years (years that have passed/half life)

Kr is used in indicator lights of appliances. Kr-85 has a half life of 11 years. If a refrigerator light contains 2.0 mg of Kr-85, after 33 years, how much is left?

$$N = 2.0\ \text{mg}\ (\tfrac{1}{2})^{(33/11)}$$

$$N = 2.0\ \text{mg}\ (\tfrac{1}{2})^{3}$$

$$N = 2.0\ \text{mg}\ (\tfrac{1}{8})$$

N = 0.25 mg left after 33 years

# Half Life Practice

- The half life of Ra-222 is 3.8 days. How much is left of a 10 mg sample after 15.2 days?

$$N = N_0 \left(\tfrac{1}{2}\right)^n$$

$$N = 10\text{mg} \left(\tfrac{1}{2}\right)^{(15.2/3.8)}$$

$$N = 10\text{mg} \left(\tfrac{1}{2}\right)^4$$

$$N = 10\text{mg} \,(1/16)$$

$$N = 0.625\text{mg}$$

# Half Life Practice

Bandages can be sterilized by exposure to gamma radiation from cobalt-60, which has a half life of 5.27 years. How much of a sample of cobalt-60 did we start with if after 10.54 years we have 0.75 mg?

$$N = N_0\,(½)^n$$

$$0.75\text{ mg} = N_0\,(½)^{26.35/5.27}$$

$$\frac{0.75\text{ mg}}{(½)^5} = N_0$$

# Half – Life Calculations

- Do the problem intuitively…

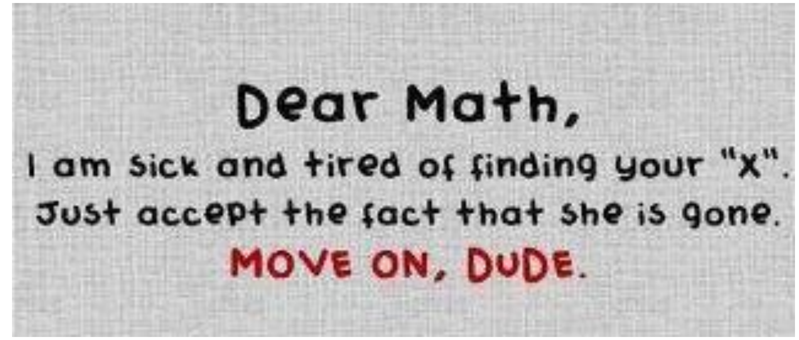
Think about how many half lives have passed and just do the math!

26.35 years/5.27 years in half life = five half lives

Multiply 0.75 mg by 2 five times

0.75 mg x 2 x 2 x 2 x 2 x 2 = 24 mg

# Solve!




- Americium-241 has a half life of 430 years. How much of a 15 mg sample is left after 2150 years?
- A radioisotope has a half life of 197 years. How much remains of a 2.0 g sample after 10 years?
- Strontium has a half life of 29 years. How long will it take for a 56 g sample to decay to 0.875 g?