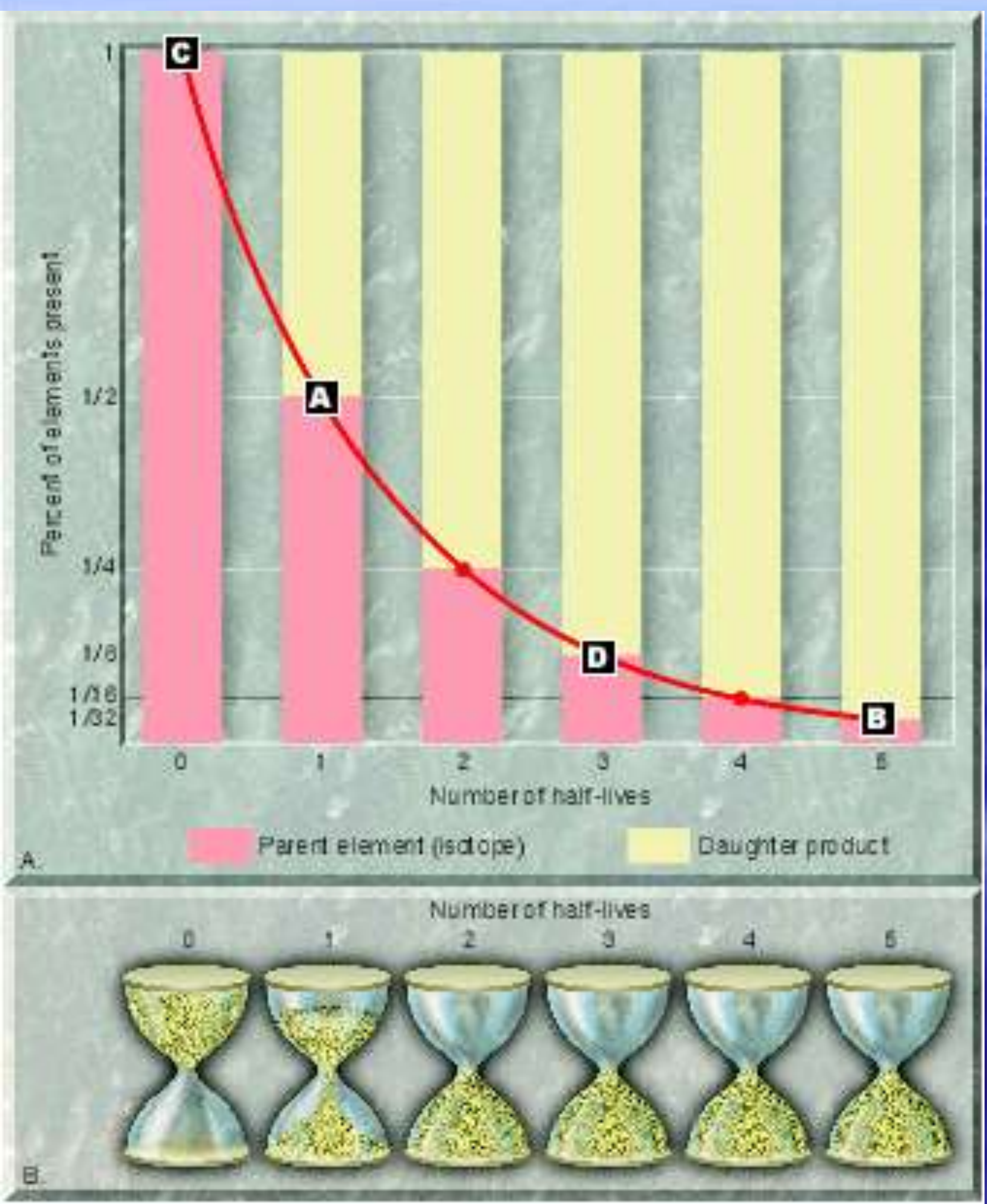
Earth Systems

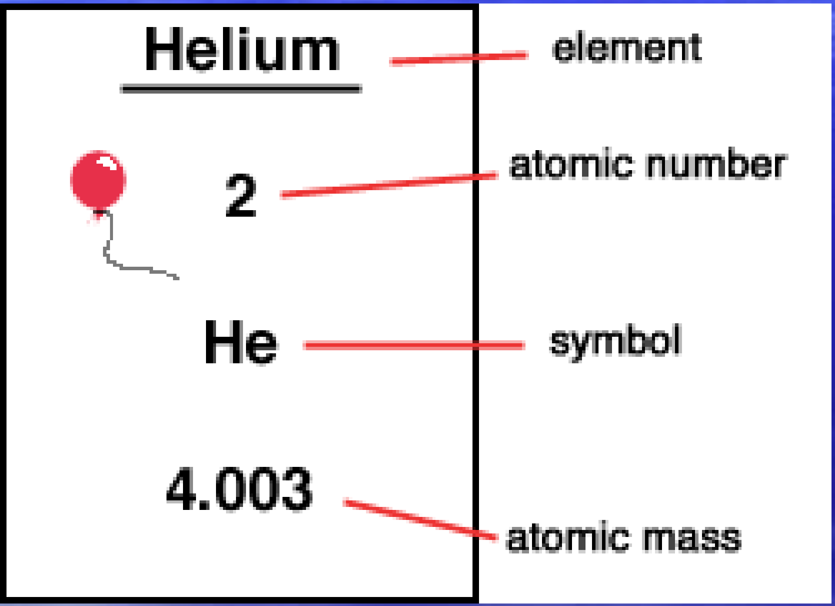
Lesson 3

Radioactive dating



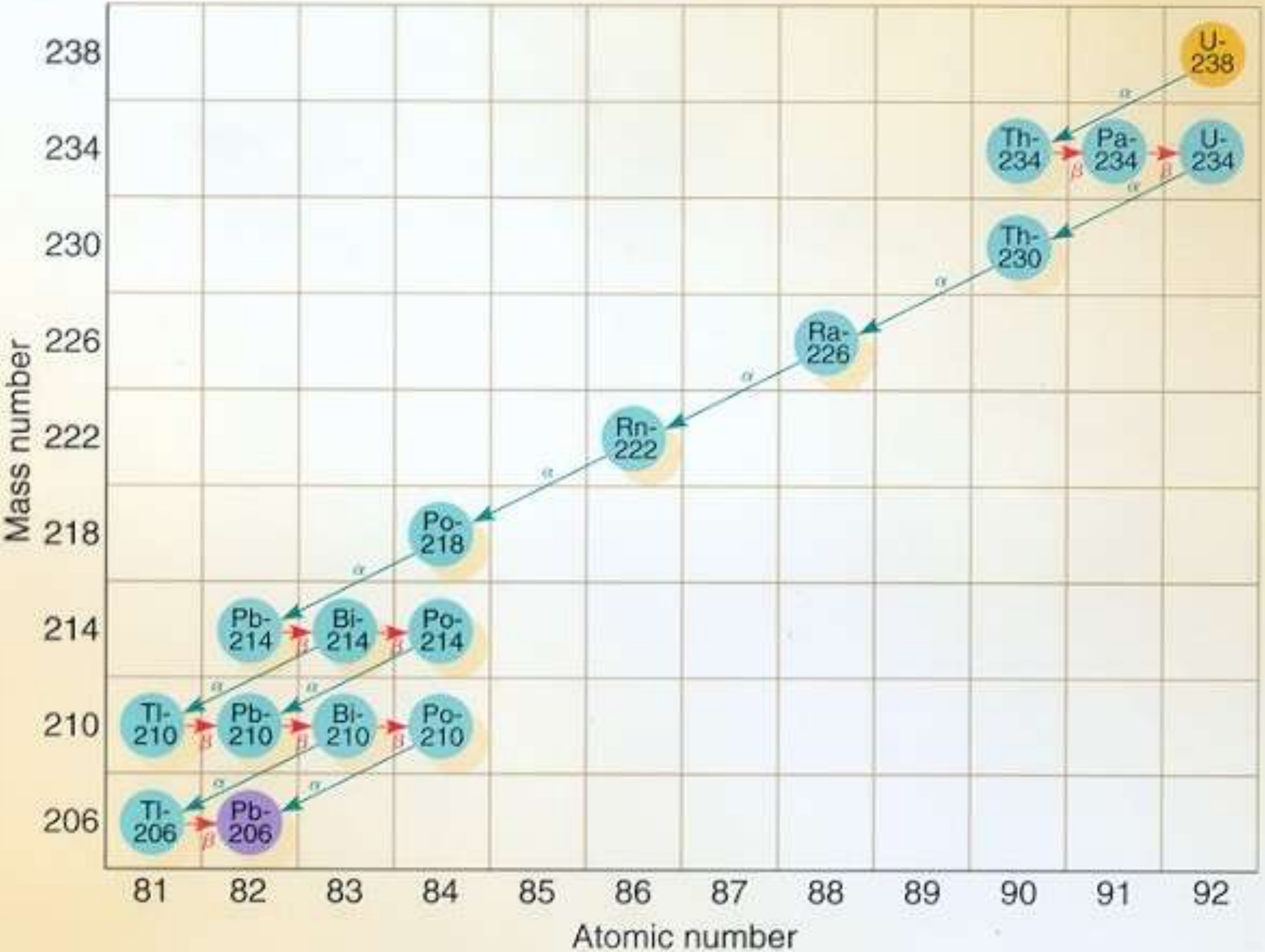
- Assume a radioactive isotope with a half-life of 1 million years.
- What percentage of ‘parent material’ is left after:
  - 1 million years?
  - 3 million?
  - 5 million?
  - 0?

Atomic breakdown



- Atomic number = # of protons = # of electrons
- Atomic mass = # of protons + # of neutrons
  - Ex: $^{238}_{92}U$

238 amu - 92 protons = 146 neutrons



Mass number
238
234
230
226
222
218
214
210
206
Atomic number
81
82
83
84
85
86
87
88
89
90
91
92
U-238
Th-234
Pa-234
U-234
Th-230
Ra-226
Rn-222
Po-218
Pb-214
Bi-214
Po-214
Tl-210
Pb-210
Bi-210
Po-210
Tl-206
Pb-206
α
β

- So, as $^{238}_{92}U$ decays, it loses:

10 protons, 10 electrons and 22 neutrons to make $^{206}_{82}Pb$

Half-Life

- Not all of the atoms in a sample of radioactive material break down or decay at the same time.
- This is a gradual process, but a rate can be determined.
- The process itself is measured in terms of the half-life, or the amount of time it takes for 1/2 of the total number of atoms present in a sample to decay.

- In Uranium, decay involves the changing of ***uranium*** atoms into ***lead*** atoms.
- The half-life of the *238 Isotope of Uranium* is *4.5 billion years*.
- So, if we find a sample of granite where the relationship of ***Uranium*** atoms and ***Lead*** atoms is ***50/50***, the rock will be ***4.5 billion years old.***
- Remember: The original radioactive material is called the "**parent material**" while the stuff it breaks down into is called the "**daughter**" or "**decay product**"

- Because ^{238}U has such a long half-life, its used to date only very old rocks.
- In younger rocks, the amount of ^{206}Pb is very small, and can't be measured accurately.
- Also, when we use Uranium to date rocks, we have to take into account that some of the lead may be naturally occurring and not formed from Uranium decay. This lead will make the rock look older than it actually is.

^{14}C (Radioactive Carbon)

- This is used to date relatively young organic based material.
- It is useful to a maximum of about 75,000 years ago.
- ^{14}C forms the upper part of the earths atmosphere when ^{14}N (nitrogen) is affected by high energy cosmic rays

- This ^{14}C can then combine with oxygen and form CO_2.
- The CO_2 is the absorbed by plants and used in the photosynthesis process, which then becomes part of the food chain and so on.
- ^{14}C breaks down to form N
- The half-life of ^{14}C is 5730 years
- The ratio of ^{12}C and ^{14}C will remain the same in a plant as the atmosphere above it.
- At this early stage none of the ^{14}C will have decayed.

- After 5730 years, only 1/2 the original material will remain.
- By the time ~ 75000 years pass, so little ^{14}C remains that the actual amount can't be measured accurately so there's a limit on its usage.
- So to use ^{14}C as a dating tool we compare the amount in organic material to the amount that should be there, assuming that the ^{14}C in the atmosphere remained constant over time.

Substances used in radioactive dating include

- ^{238}U (Uranium) - half life of 4.5 billion yrs and decays to form ^{206}Pb
- ^{14}C - half life of 5730 and decays to form ^{14}N
- ^{40}K (Potassium) - half life of 1.3 billion years and decays to form ^{40}Ar (Argon)
  - Note: Argon is a gas, so it can escape a rock making it look younger than it actually is. Geologists study the crystals of the rock, rather than a chunk of the rock itself.