

Radioactive Decay and Radiometric Dating

Extra credit: chapter 7 in Bryson
See online (link fixed) or moodle

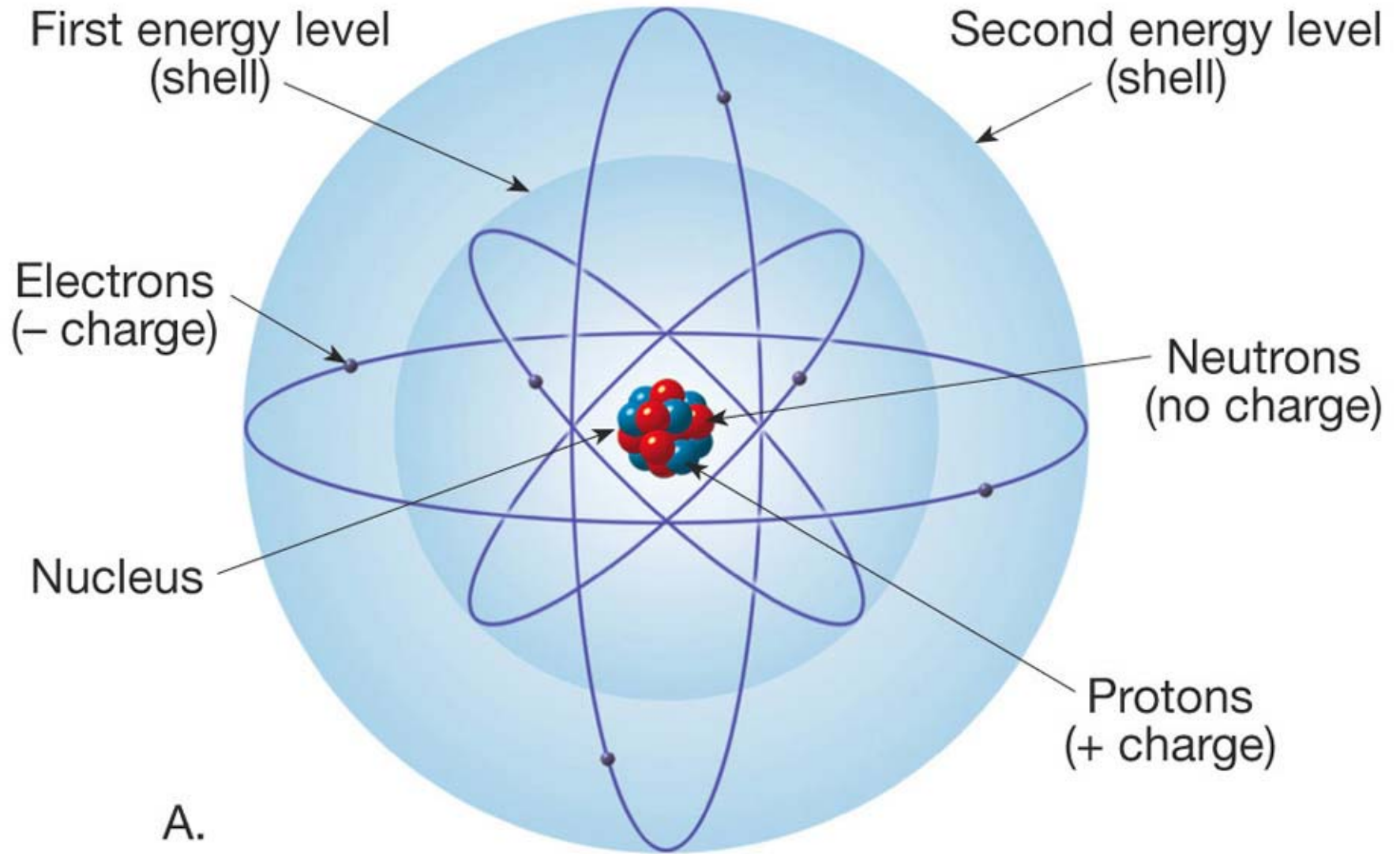
Radioactivity and radiometric dating

- Atomic nucleus
- Radioactivity
- Allows us to put numerical ages on geologic events

Atomic structure

- Nucleus—composed of protons and neutrons
- Orbiting the nucleus are electrons – negative electrical charges

Atom model



Atomic number

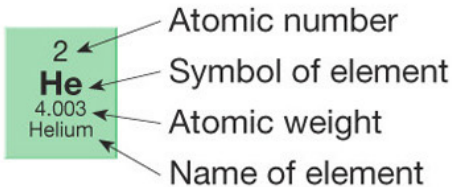
- Identifying number
- Number of protons
- Determines the properties

Mass number

- Protons + Neutrons
- Nucleons
- Not the same as Atomic Mass

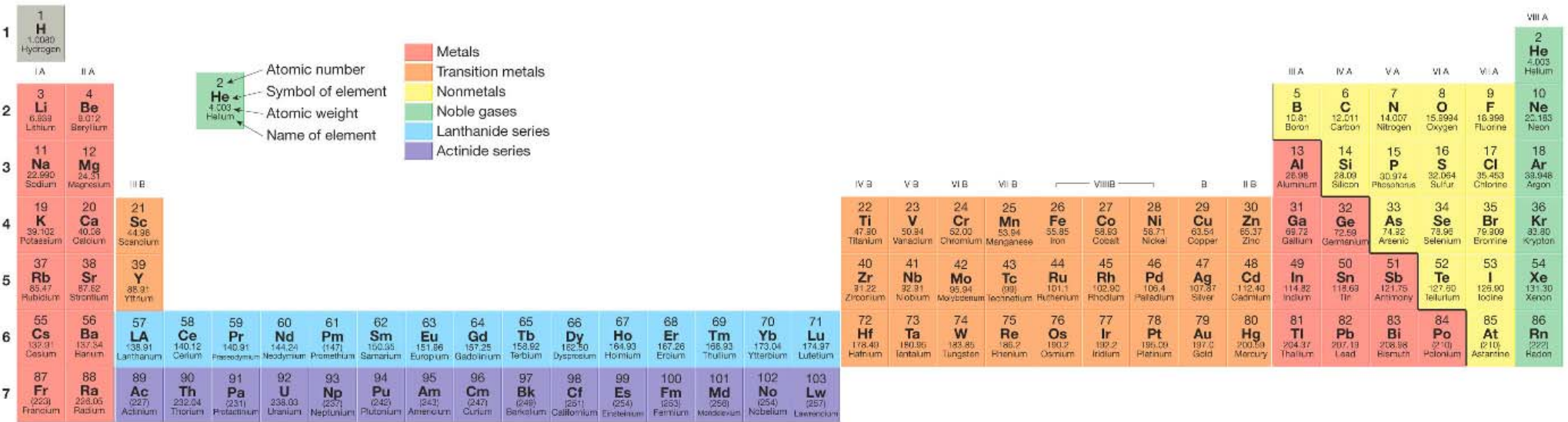
Periodic Table

1 H 1.0080 Hydrogen																	VIII A 2 He 4.003 Helium
IA	II A											III A	IV A	V A	VI A	VII A	
2 3 Li 6.939 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.011 Carbon	7 N 14.007 Nitrogen	8 O 15.9994 Oxygen	9 F 18.998 Fluorine	10 Ne 20.183 Neon
3 11 Na 22.990 Sodium	12 Mg 24.31 Magnesium	III B	IV B	V B	VI B	VII B	VIII B			B	II B	13 Al 26.98 Aluminum	14 Si 28.09 Silicon	15 P 30.974 Phosphorus	16 S 32.064 Sulfur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
4 19 K 39.102 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.90 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 53.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.71 Nickel	29 Cu 63.54 Copper	30 Zn 65.37 Zinc	31 Ga 69.72 Gallium	32 Ge 72.59 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.909 Bromine	36 Kr 83.80 Krypton
5 37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc (99) Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.90 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.87 Silver	48 Cd 112.40 Cadmium	49 In 114.82 Indium	50 Sn 118.69 Tin	51 Sb 121.75 Antimony	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.30 Xenon
6 55 Cs 132.91 Cesium	56 Ba 137.34 Barium	57 TO 71	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.85 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.09 Platinum	79 Au 197.0 Gold	80 Hg 200.59 Mercury	81 Tl 204.37 Thallium	82 Pb 207.19 Lead	83 Bi 208.98 Bismuth	84 Po (210) Polonium	85 At (210) Astatine	86 Rn (222) Radon
7 87 Fr (223) Francium	88 Ra 226.05 Radium	89 TO 103	57 La 138.91 Lanthanum	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm (147) Promethium	62 Sm 150.35 Samarium	63 Eu 151.96 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.92 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thullium	70 Yb 173.04 Ytterbium	71 Lu 174.97 Lutetium
			89 Ac (227) Actinium	90 Th 232.04 Thorium	91 Pa (231) Protactinium	92 U 238.03 Uranium	93 Np (237) Neptunium	94 Pu (242) Plutonium	95 Am (243) Americium	96 Cm (247) Curium	97 Bk (249) Berkelium	98 Cf (251) Californium	99 Es (254) Einsteinium	100 Fm (253) Fermium	101 Md (256) Mendelevium	102 No (254) Nobelium	103 Lw (257) Lawrencium



- Metals
- Transition metals
- Nonmetals
- Noble gases
- Lanthanide series
- Actinide series

Series in Periodic Table



Isotope

- Same number of protons
- Different number of neutrons
- Different mass number than another isotope of the same element
- Variant atom of the same element
- Say “Gold 188” for Au-188

Radioactivity

Spontaneous breaking apart
(decay) of atomic nuclei

Nucleus

- Very small— 10^{-15} to 10^{-14} m radius
- “Strong interaction” binds nucleons
- Protons repel one another
 - Neutrons counteract this
 - More neutrons than protons in larger atoms

Nuclear forces

- Very strong at small distances (10^{-15} m)
- Weakens at 10X that distance (10^{-14} m)
- Elements at. # 82 + are unstable, because they are big
- “Radioactive”

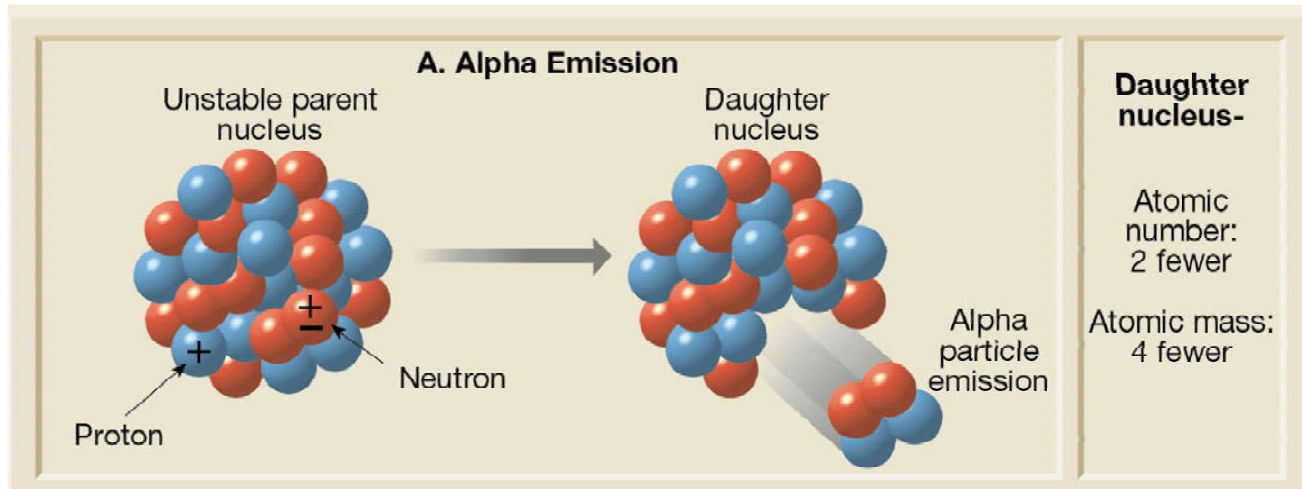
Radioactive decay

- Parent atom– an unstable isotope
- Daughter products
 - Formed from the decay of a parent atoms
 - Different element because of nuclear changes

Types of radioactive decay

- Alpha emission α
- Beta emission β
- Gamma radiation γ

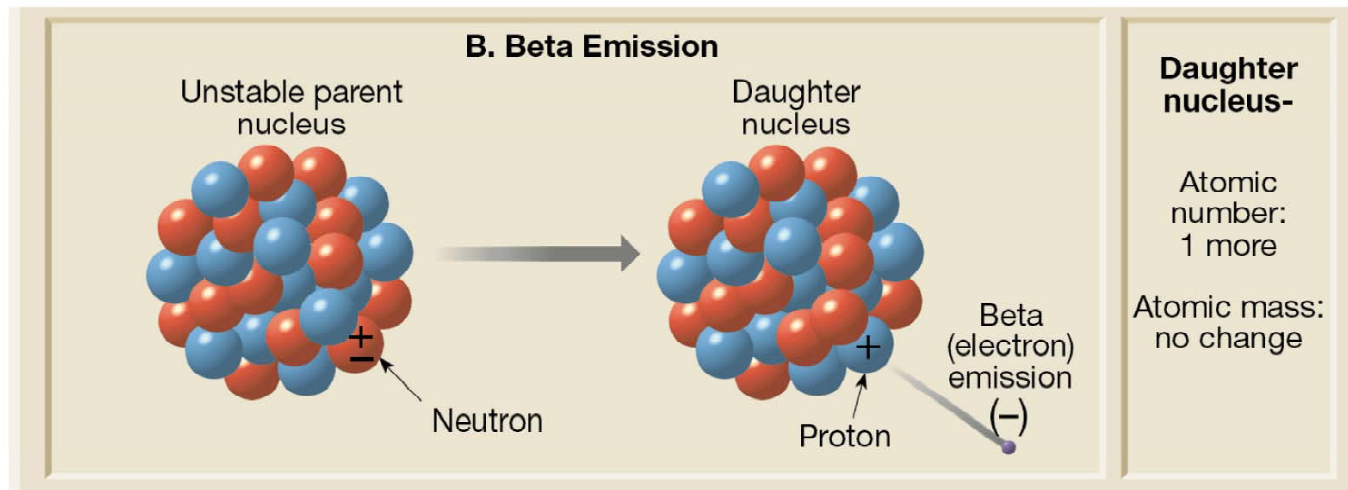
Alpha emission α



- $2 N + 2 P^+$
- Positive charge
- Large \rightarrow non-penetrating

Beta emission

β



- Negative charge—electron
- $N \rightarrow P^+ + e^-$
- Small, but low energy—minor penetration

Gamma radiation γ

- Penetrating, energetic photons
- Lower energy of excited daughter nucleus
- No charge, less mass than electron

Nuclear Decay Equation

Alpha Decay



Total nucleons stays same,
but on daughter (product) side

Alpha decay α removes 2N^0 and 2P^+

Nuclear Decay Equation

Beta Decay



Total nucleons stays same

Beta decay β $\text{N}^0 \rightarrow \text{P}^+ + \text{e}^-$

Balancing Nuclear Equations

- P^+ (protons) + e^- (electrons) = N^0 (neutrons)
- Keep track of protons: elemental symbol
- α decay decreases by two by releasing them with two neutrons...so atomic number goes down by 2, atomic mass goes down by 4
- β decay increases protons by releasing electron...so atomic number goes up by 1, atomic mass stays the same

Decay of U-238

NAMES--

Pa: protactinium

Th: thorium

Ra: radium

Rn: radon

Po: polonium

At: astatine

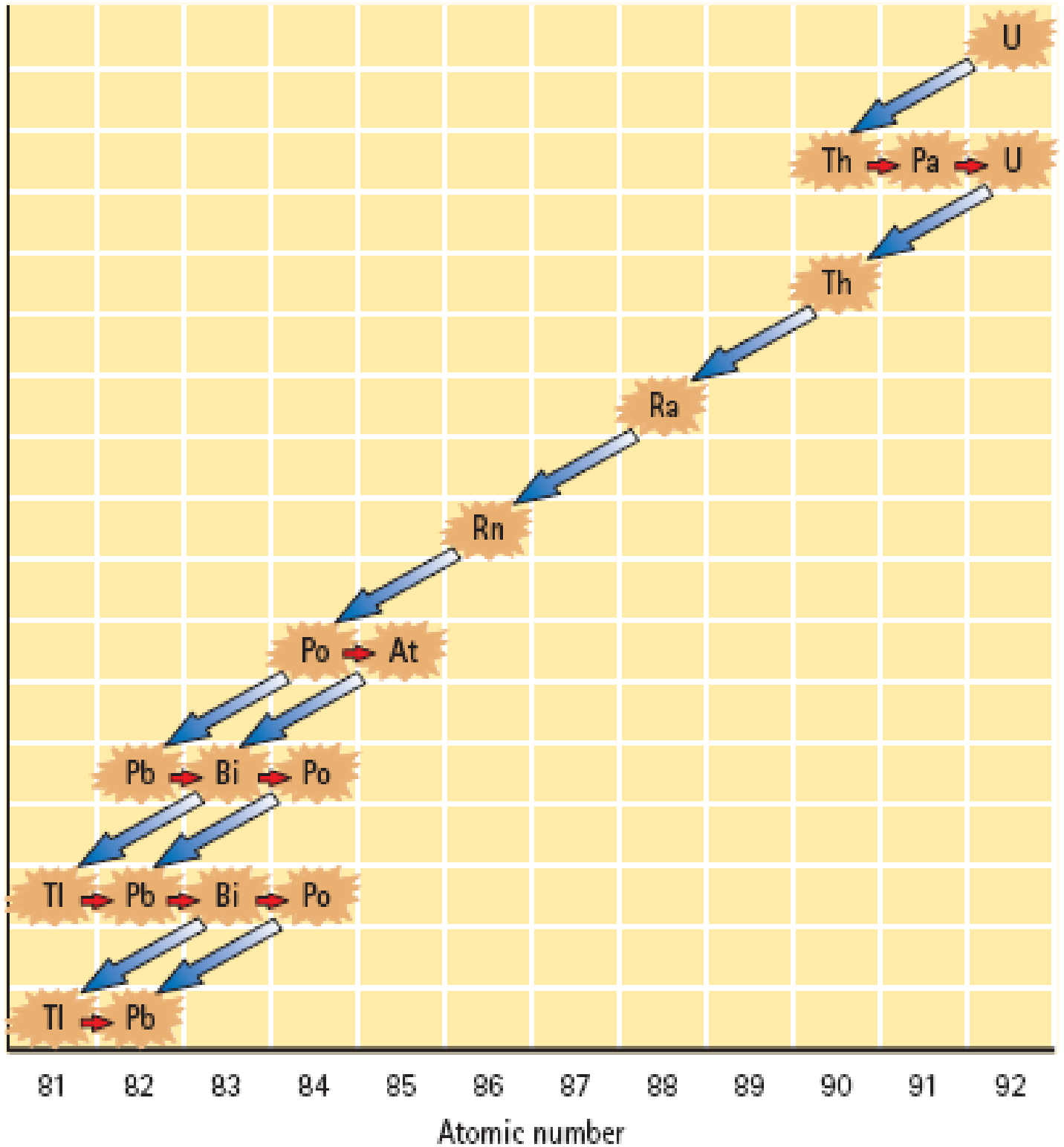
Pb: lead

Bi: bismuth

Tl: thallium

Atomic mass

238
234
230
226
222
218
214
210
206



Measuring Radioactivity

- Radioactive decay strips electrons from atoms
- Ions created
- Geiger counter--charged wire, results in 'clicks' of counter
- Others rely on visual reactions of ions



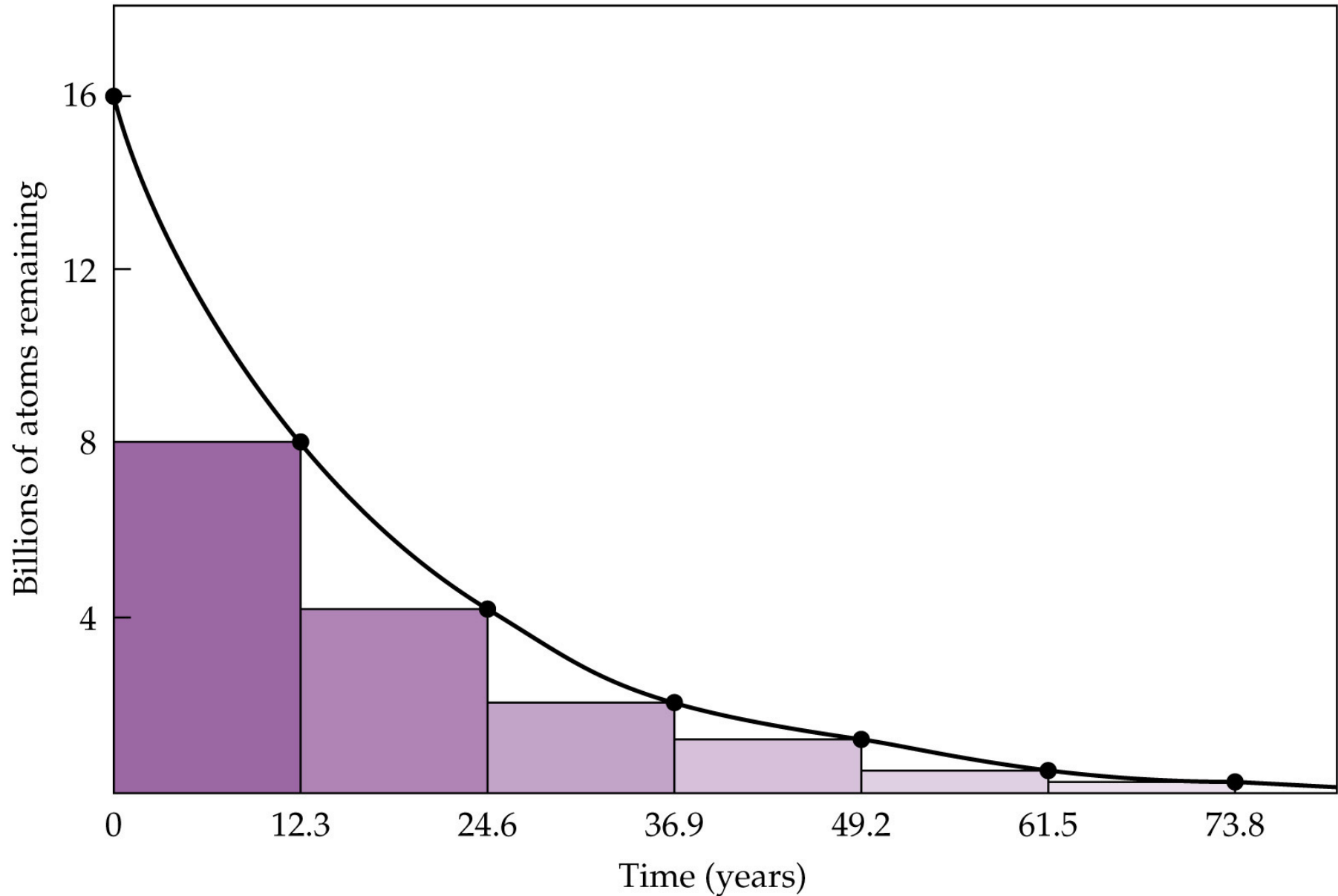
Half Life

Decay is random for any radioactive atom

BUT: Predictable for mass of material

- One half of unstable parent material →
daughter product: HALF LIFE: $T_{1/2}$
- Decay rate constant, unaffected by external conditions

Parent to daughter ratios of H-3



Half Life equation

Amount remaining can be calculated by

$$R = I \frac{1}{2^n}$$

R remaining I initial n number of half-lives

Calculate amount from half-life

- Start with 400 mg of Co-60
- Half life is 5.25 years
- How much is left after 15.75 years?
- To use equation at right,
- First calculate how many half lives
3 half-lives

$$R = I \frac{1}{2^n}$$

$$15.75 \text{ years} \div \frac{5.25 \text{ yr}}{\text{half-life}} = 3 \text{ half-lives}$$

Calculate amount from half-life

- 400 mg of Co-60
- Half life is 5.25 years
- How much is left after 3 half-lives?

- Calculate amount

$$R = (400mg) \cdot \frac{1}{2^3} = 50mg$$