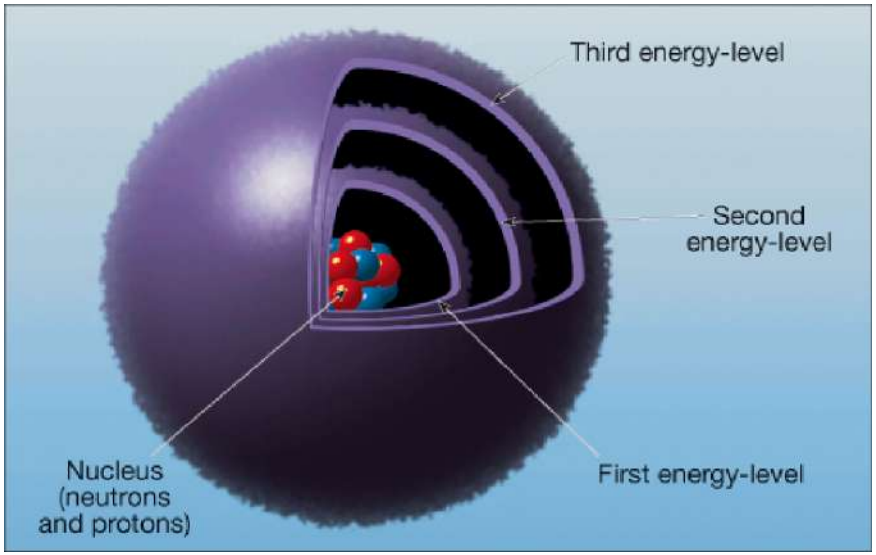
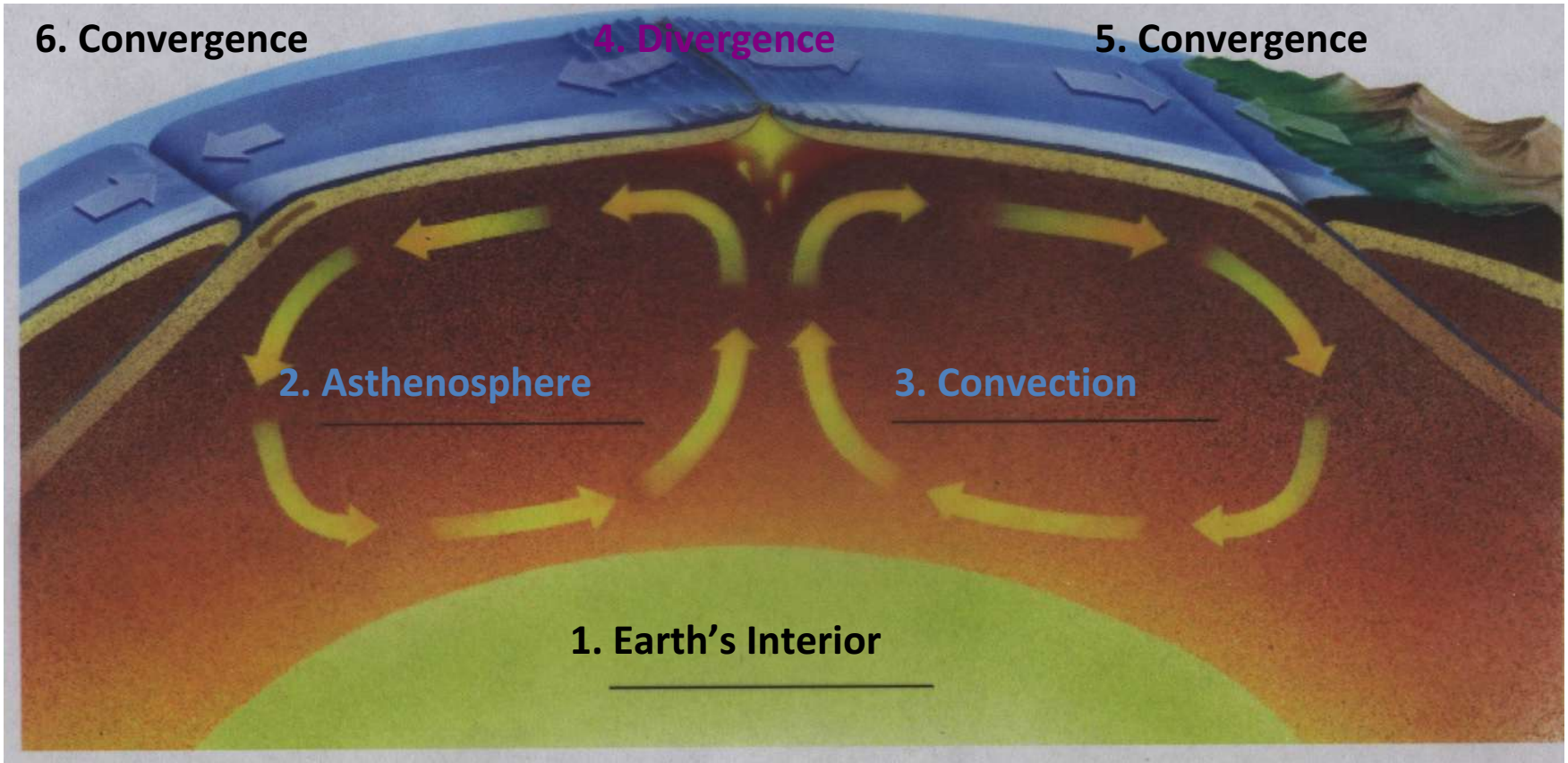
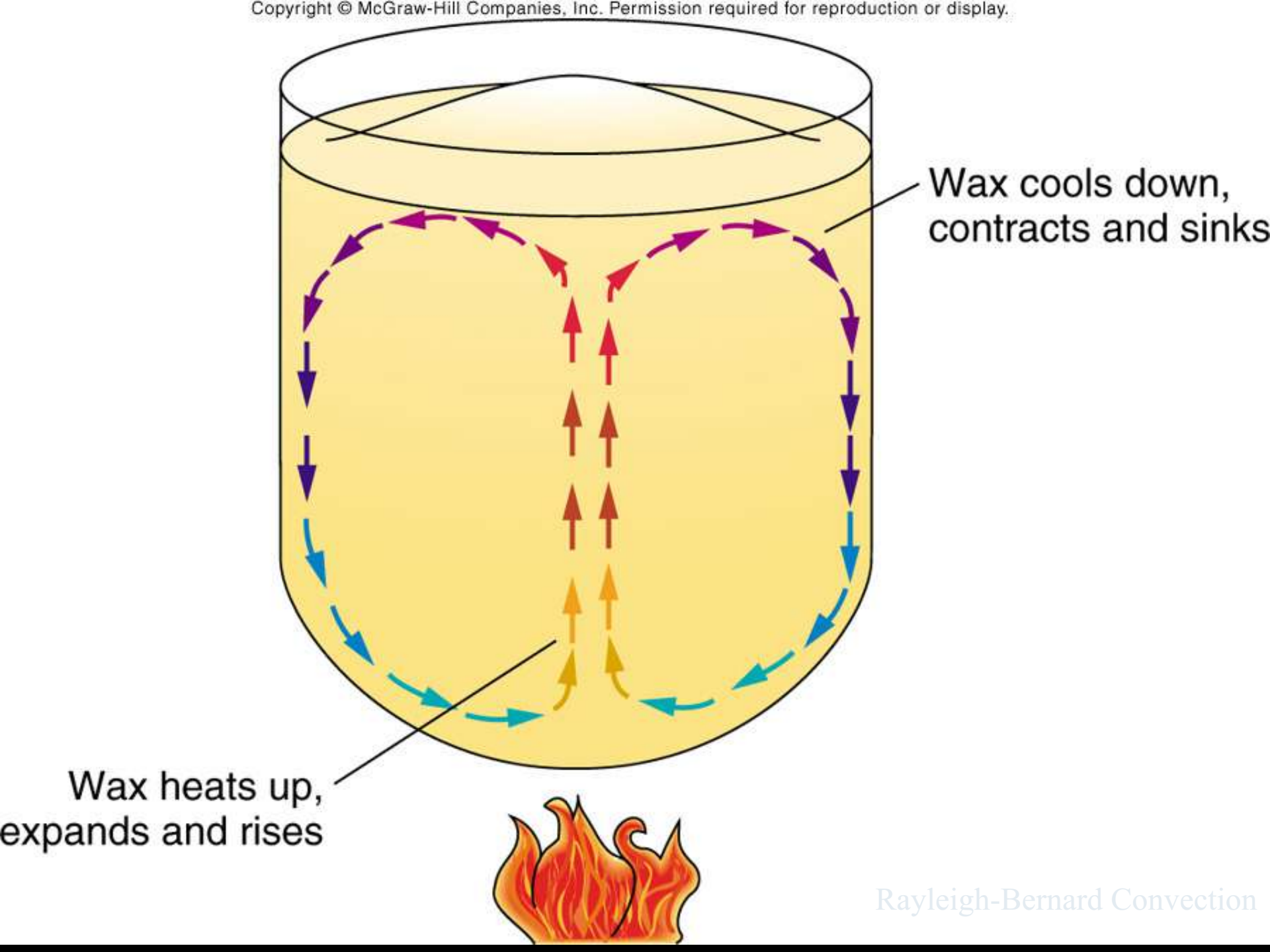
Earth's Internal Heat, Isotopes & Radioactive Decay



EARTH'S INTERNAL HEAT ENGINE AND CONVECTION

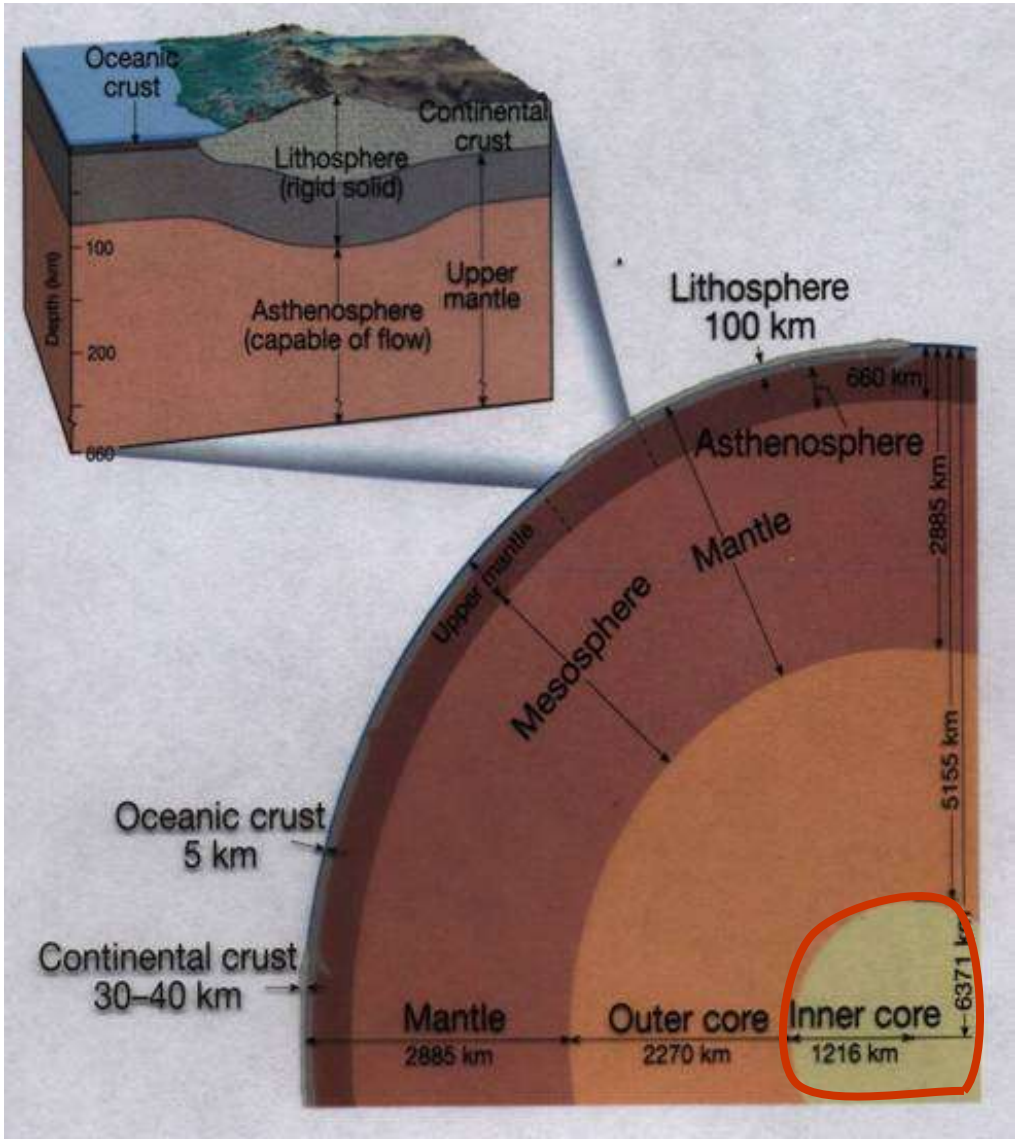
The diagram below shows a cross section of Earth to a depth of approximately 700 km (not to scale). Arrows show motion of Earth's interior due to heat generated motion.





Rayleigh-Bernard Convection

CROSS-SECTION VIEW OF EARTH'S INTERNAL STRUCTURE



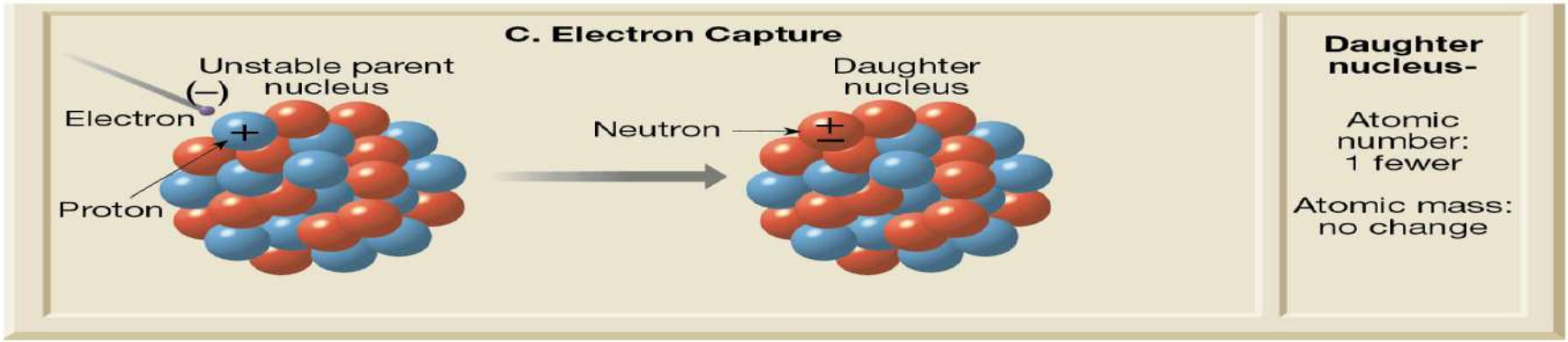
Since its formation, Earth has been giving off heat through two processes:

1. **Decay of radioactive materials**
2. **Residual heat from Earth's formation**

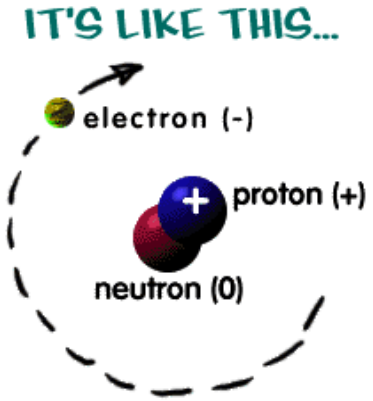
The phenomenon of radioactivity relates to our story about the age of the Earth in two ways:

(1) As radioactive elements decay in the Earth, they heat up the surrounding rocks.

(2) Radiometric Dating

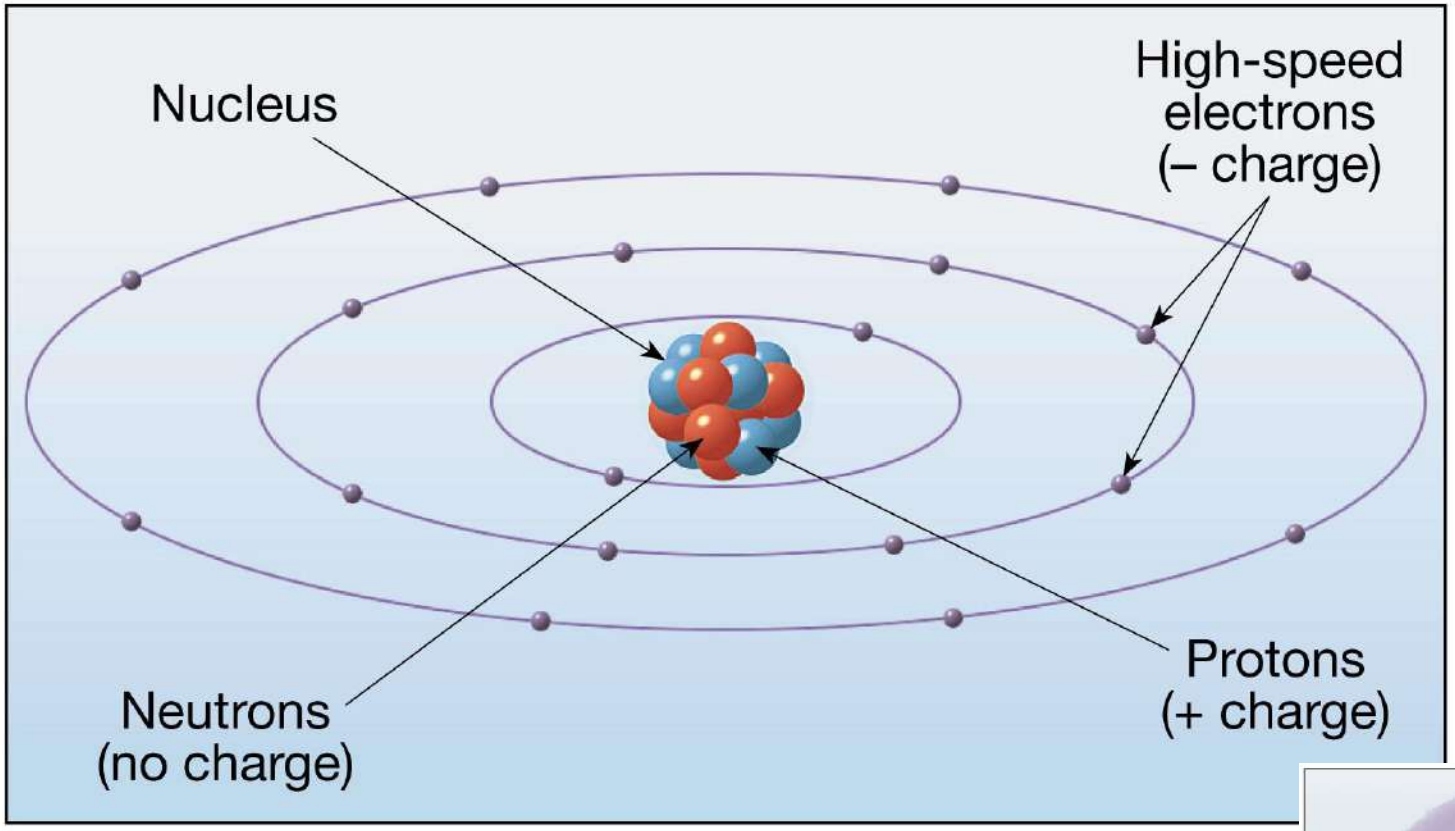


ATOM BASICS

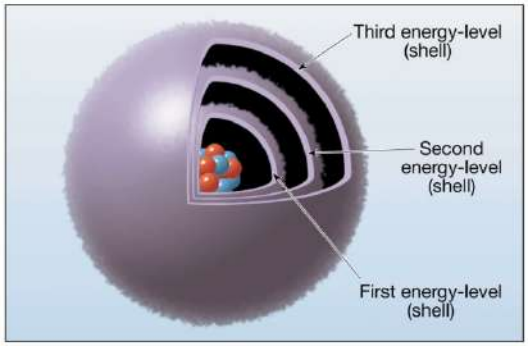


- **ATOM**: the smallest particle that has the properties of an element.
  - Nucleus (99% of atom's mass):
    - uncharged **Neutrons**
    - positively charged **Protons**
    - Net charge of the nucleus is **POSITIVE**
  - **Electrons** in constant motion create a "cloud" like a fan around the nucleus.
    - Charge of an electron is **NEGATIVE**

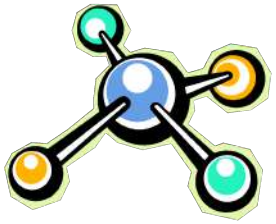
The Atom


Nucleus
High-speed electrons (– charge)
Neutrons (no charge)
Protons (+ charge)

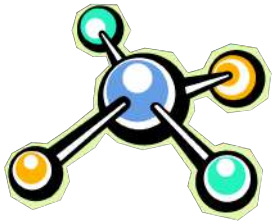
A.


Third energy-level (shell)
Second energy-level (shell)
First energy-level (shell)

B.



ISOTOPES



- **Isotopes** are atoms that have the same # of **protons**, but a different # of **neutrons**.

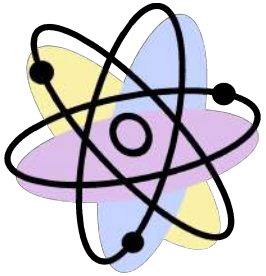
Number of Neutrons = Mass # - # of protons

- The difference in the number of neutrons cause isotopes to have different mass numbers

Mass Number = protons + neutrons

- Isotopes are unstable and fall apart releasing atomic particles – they are radioactive, release energy

Example of an Isotope



- Example:

  Carbon-12 (NORMAL) vs. Carbon-14 (ISOTOPE)

  ^{12}C

  Mass # = 12; Atomic # = 6

  (6P, 6E, 6N)

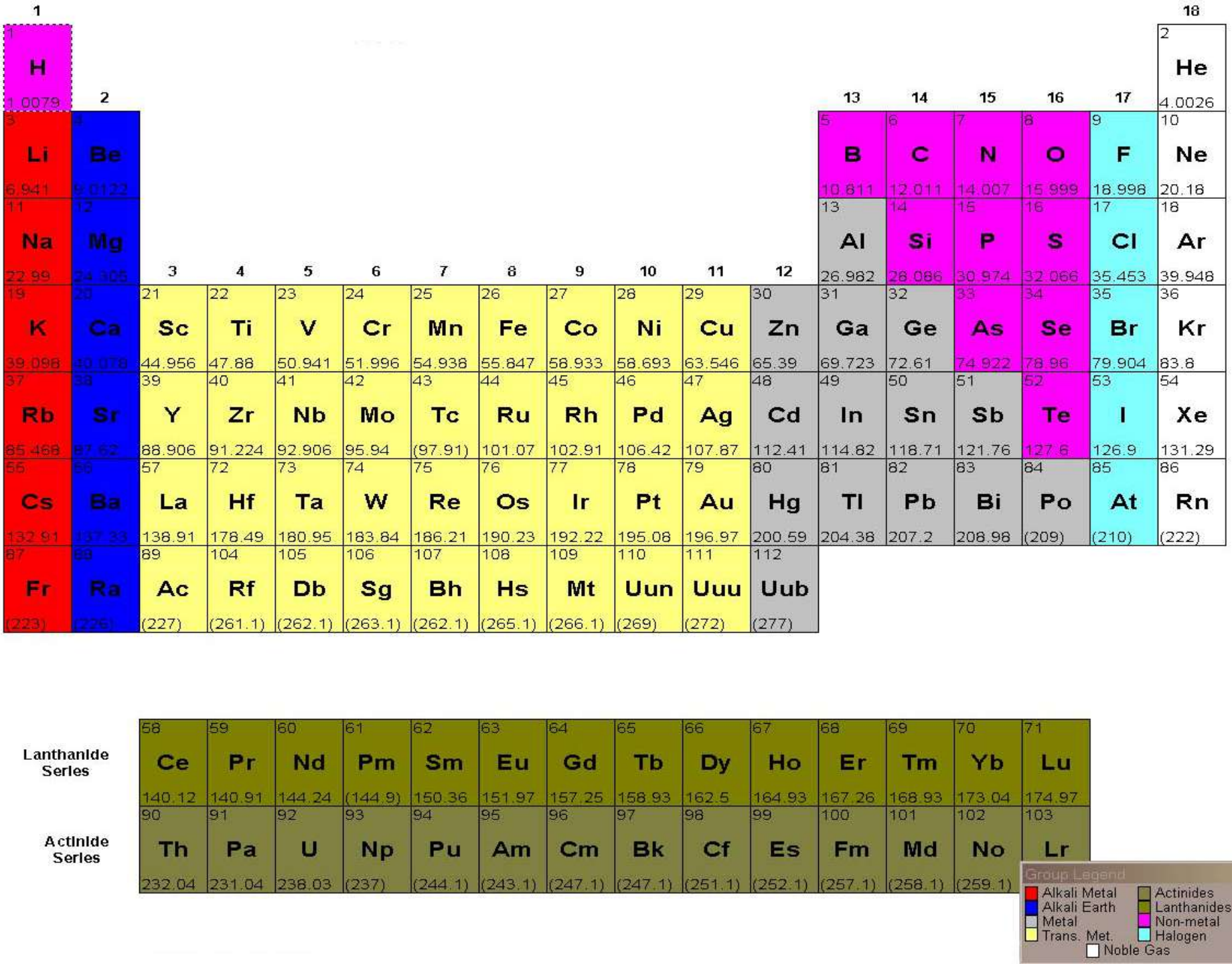
  How did we determine there were 6 neutrons?

  ^{14}C

  Mass # = 14; Atomic # = 6

  (6P, 6E, 8N)

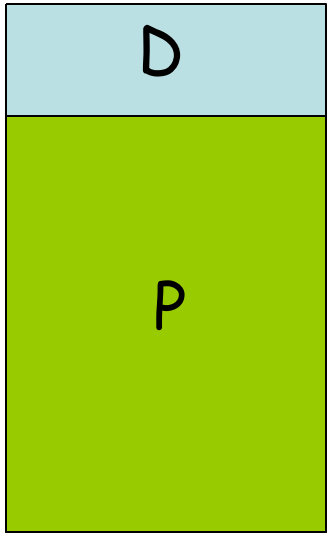
  How did we determine there were 8 neutrons?


1 H 1.0079
2 He 4.0026
3 Li 6.941
4 Be 9.0122
5 B 10.811
6 C 12.011
7 N 14.007
8 O 15.999
9 F 18.998
10 Ne 20.18
11 Na 22.99
12 Mg 24.305
13 Al 26.982
14 Si 28.086
15 P 30.974
16 S 32.066
17 Cl 35.453
18 Ar 39.948
19 K 39.098
20 Ca 40.078
21 Sc 44.956
22 Ti 47.88
23 V 50.941
24 Cr 51.996
25 Mn 54.938
26 Fe 55.847
27 Co 58.933
28 Ni 58.693
29 Cu 63.546
30 Zn 65.39
31 Ga 69.723
32 Ge 72.61
33 As 74.922
34 Se 78.96
35 Br 79.904
36 Kr 83.8
37 Rb 85.468
38 Sr 87.62
39 Y 88.906
40 Zr 91.224
41 Nb 92.906
42 Mo 95.94
43 Tc (97.91)
44 Ru 101.07
45 Rh 102.91
46 Pd 106.42
47 Ag 107.87
48 Cd 112.41
49 In 114.82
50 Sn 118.71
51 Sb 121.76
52 Te 127.6
53 I 126.9
54 Xe 131.29
55 Cs 132.91
56 Ba 137.33
57 La 138.91
72 Hf 178.49
73 Ta 180.95
74 W 183.84
75 Re 186.21
76 Os 190.23
77 Ir 192.22
78 Pt 195.08
79 Au 196.97
80 Hg 200.59
81 Tl 204.38
82 Pb 207.2
83 Bi 208.98
84 Po (209)
85 At (210)
86 Rn (222)
87 Fr (223)
88 Ra (226)
89 Ac (227)
104 Rf (261.1)
105 Db (262.1)
106 Sg (263.1)
107 Bh (262.1)
108 Hs (265.1)
109 Mt (266.1)
110 Uun (269)
111 Uuu (272)
112 Uub (277)
Lanthanide Series
58 Ce 140.12
59 Pr 140.91
60 Nd 144.24
61 Pm (144.9)
62 Sm 150.36
63 Eu 151.97
64 Gd 157.25
65 Tb 158.93
66 Dy 162.5
67 Ho 164.93
68 Er 167.26
69 Tm 168.93
70 Yb 173.04
71 Lu 174.97
Actinide Series
90 Th 232.04
91 Pa 231.04
92 U 238.03
93 Np (237)
94 Pu (244.1)
95 Am (243.1)
96 Cm (247.1)
97 Bk (247.1)
98 Cf (251.1)
99 Es (252.1)
100 Fm (257.1)
101 Md (258.1)
102 No (259.1)
103 Lr
Group Legend
Alkali Metal
Alkali Earth
Metal
Trans. Met.
Actinides
Lanthanides
Non-metal
Halogen
Noble Gas

To estimate the age of a rock:

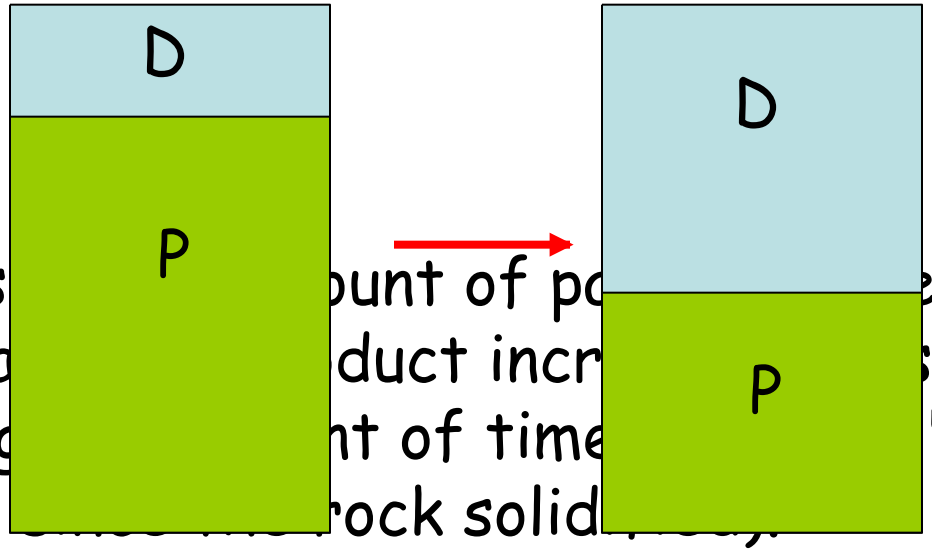
D = amount of daughter product.
P = amount of parent.

For a particular radioactive element in a rock, determine the present ratio = D/P.

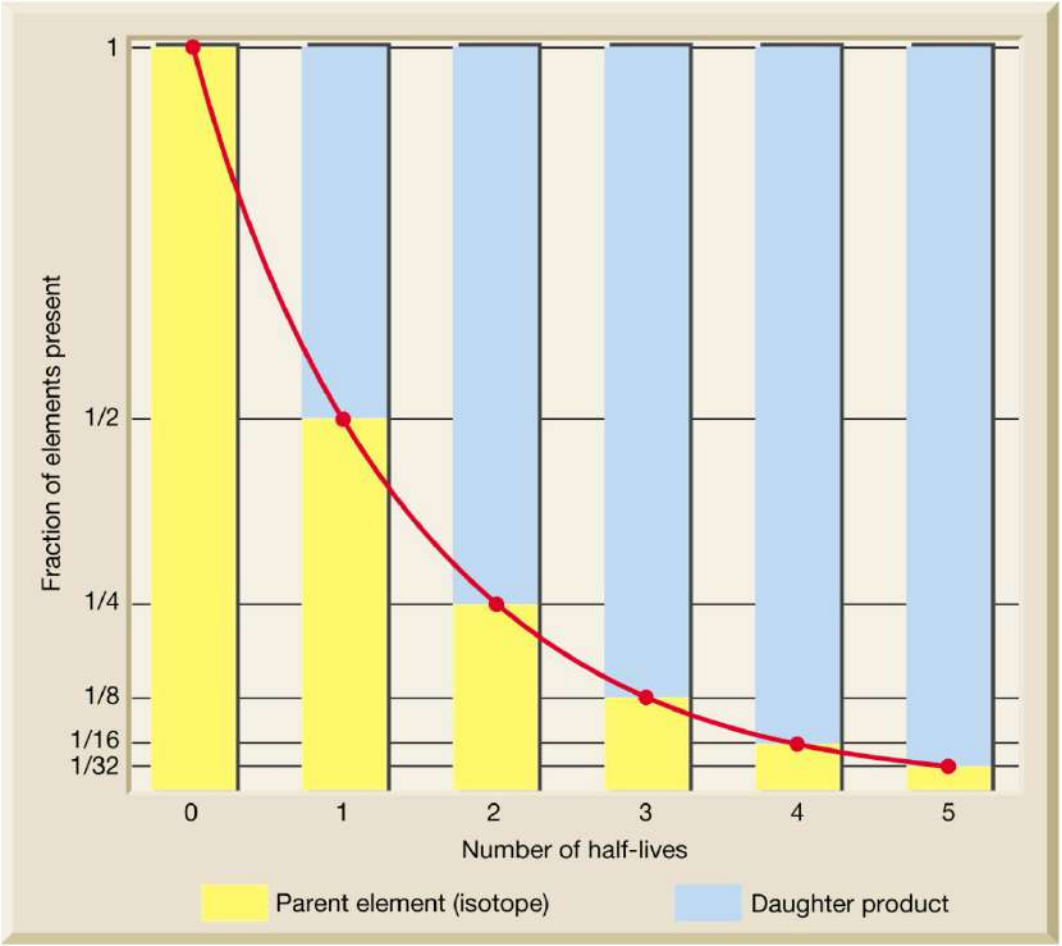


✔ Rate of decay (from theory and measurement)

✔ Make assumptions about original ratios (from theory of geochemistry).



As time pass ount of p eases, and the amount of da duct incr provides a way of estimating nt of time "clock" got started (i.e., rock solid).



Half Life = Number of years for 1/2 of the original number of atoms to decay from U to Pb

Half-Lives of Radioactive Isotopes

Table 10.1 Radioactive isotopes frequently used in radiometric dating.

Radioactive Parent	Stable Daughter Product	Currently Accepted Half-Life Values
Uranium-238	Lead-206	4.5 billion years
Uranium-235	Lead-207	713 million years
Thorium-232	Lead-208	14.1 billion years
Rubidium-87	Strontium-87	47.0 billion years
Potassium-40	Argon-40	1.3 billion years