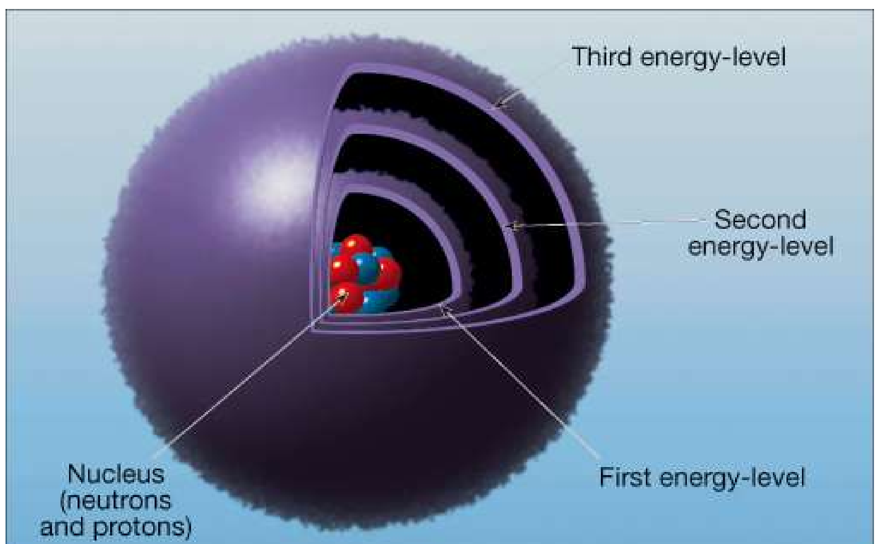
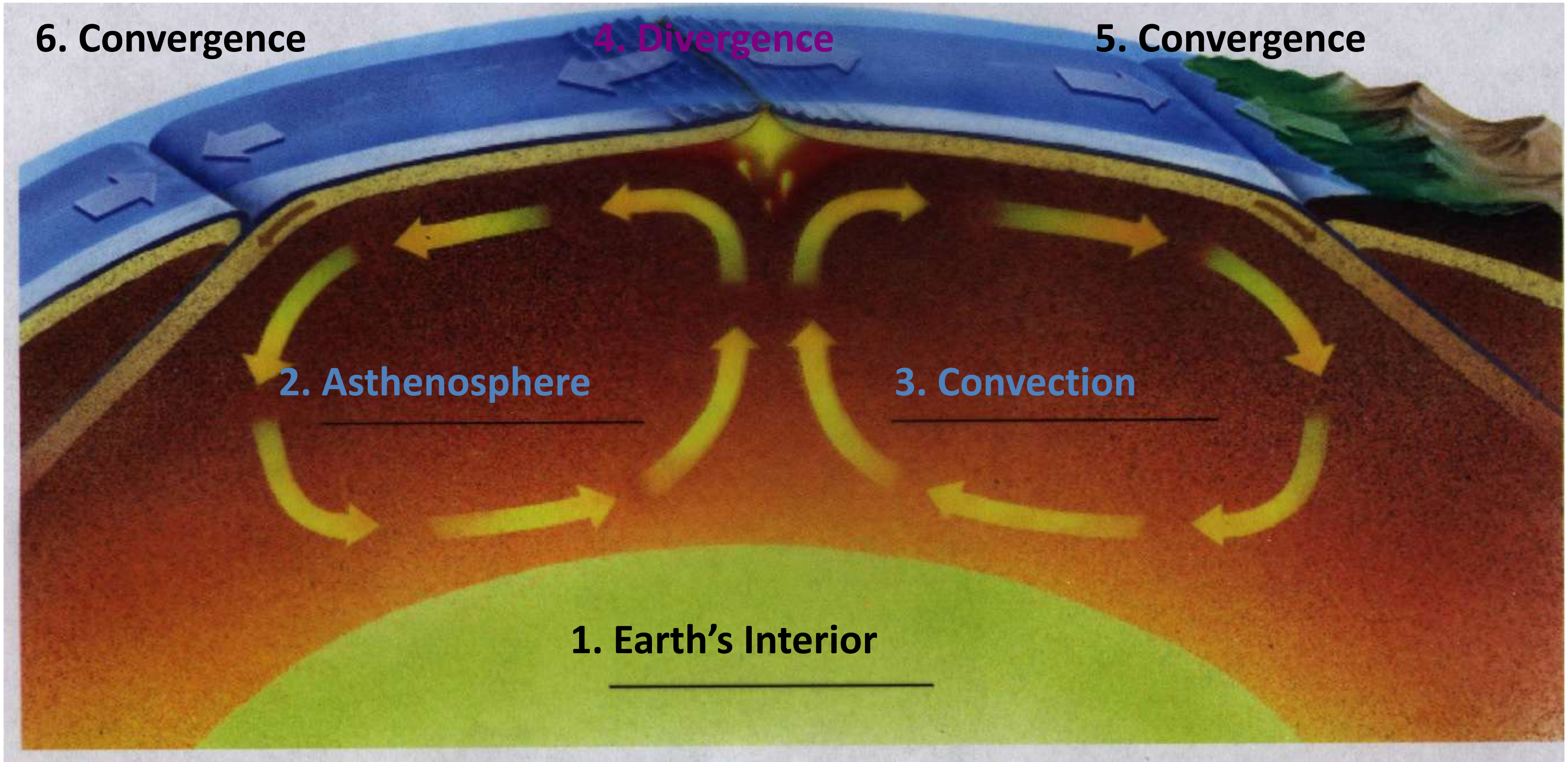
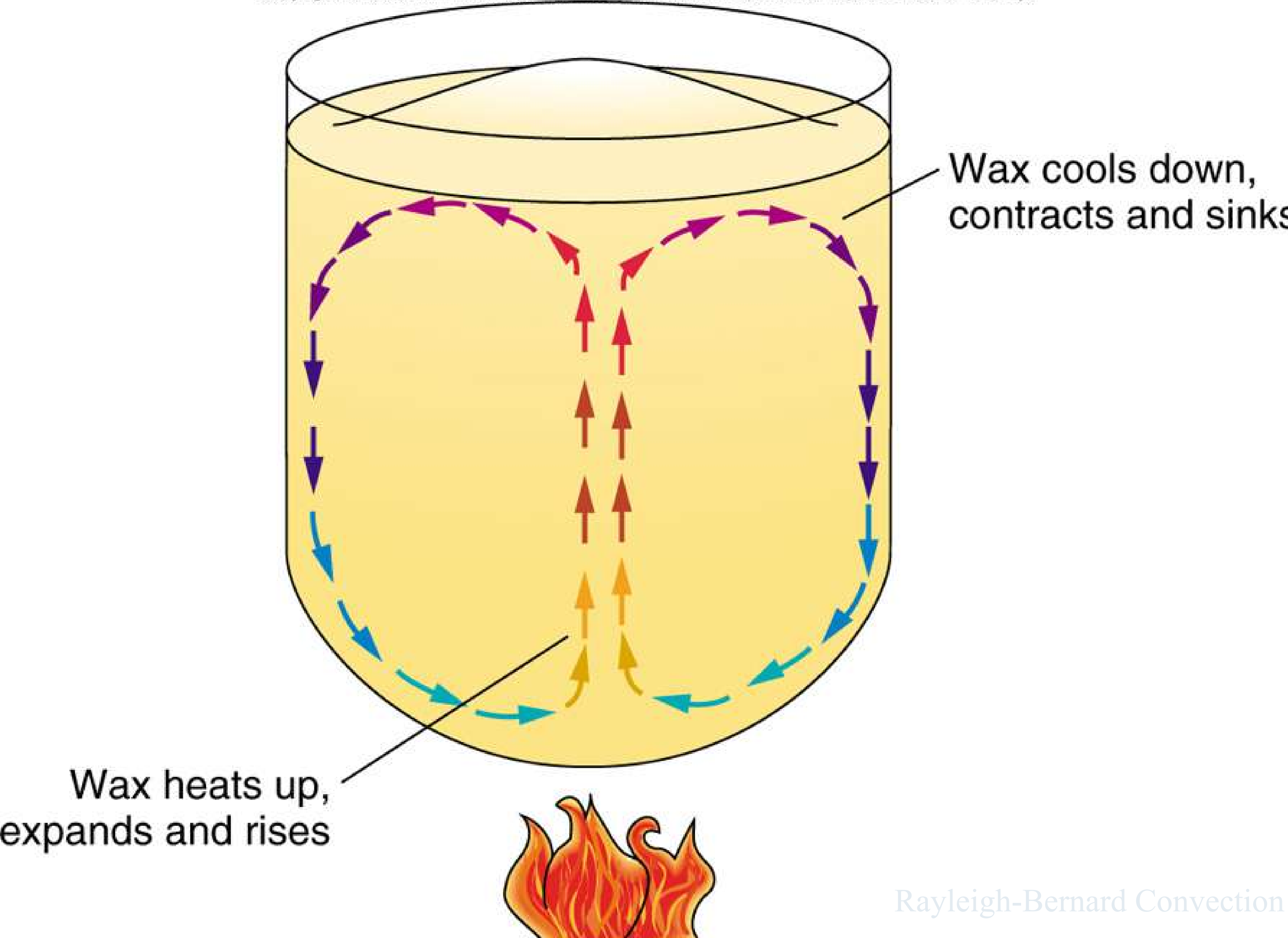
Earth’s Internal Heat, Isotopes & Radioactive Decay



EARTH'S INTERNAL HEAT ENGINE AND CONVECTION

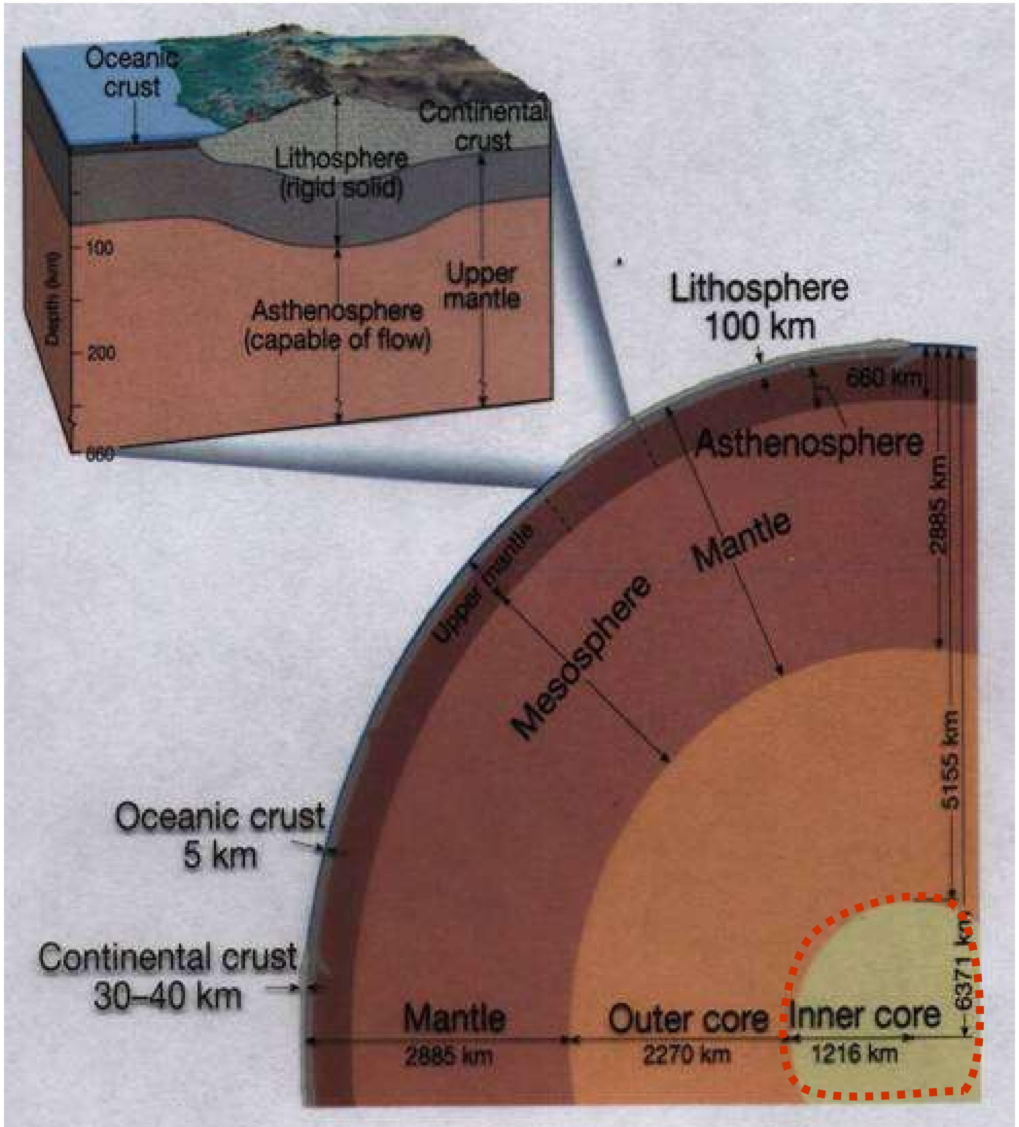
The diagram below shows a cross section of Earth to a depth of approximately 700 km (not to scale). Arrows show motion of Earth's interior due to heat generated motion.





Rayleigh-Bernard Convection

CROSS-SECTION VIEW OF EARTH'S INTERNAL STRUCTURE



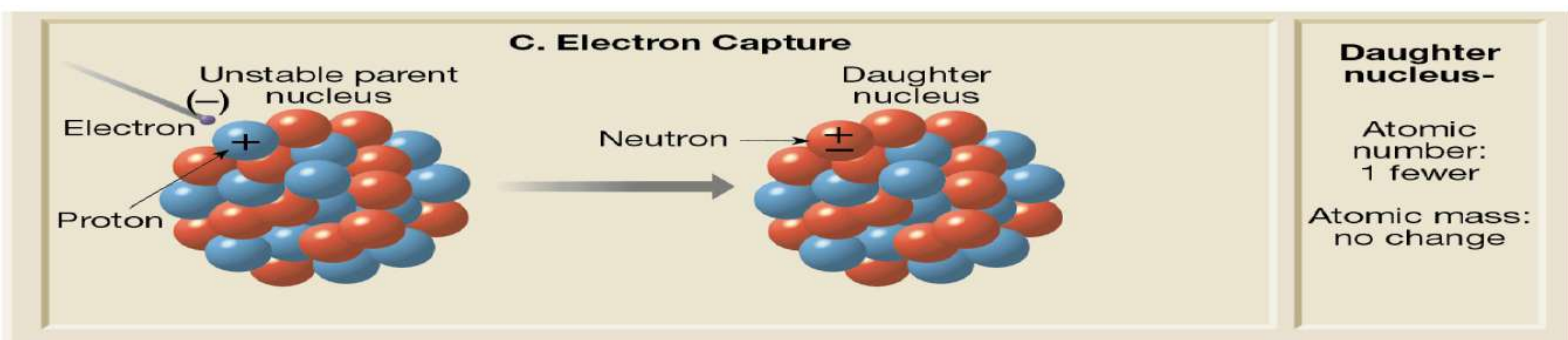
Since its formation, Earth has been giving off heat through two processes:

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

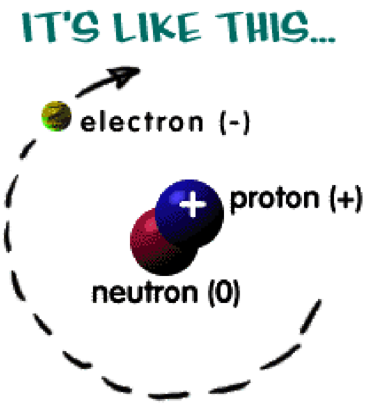
The phenomenon of radioactivity relates to our story about the age of the Earth in two ways:

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.

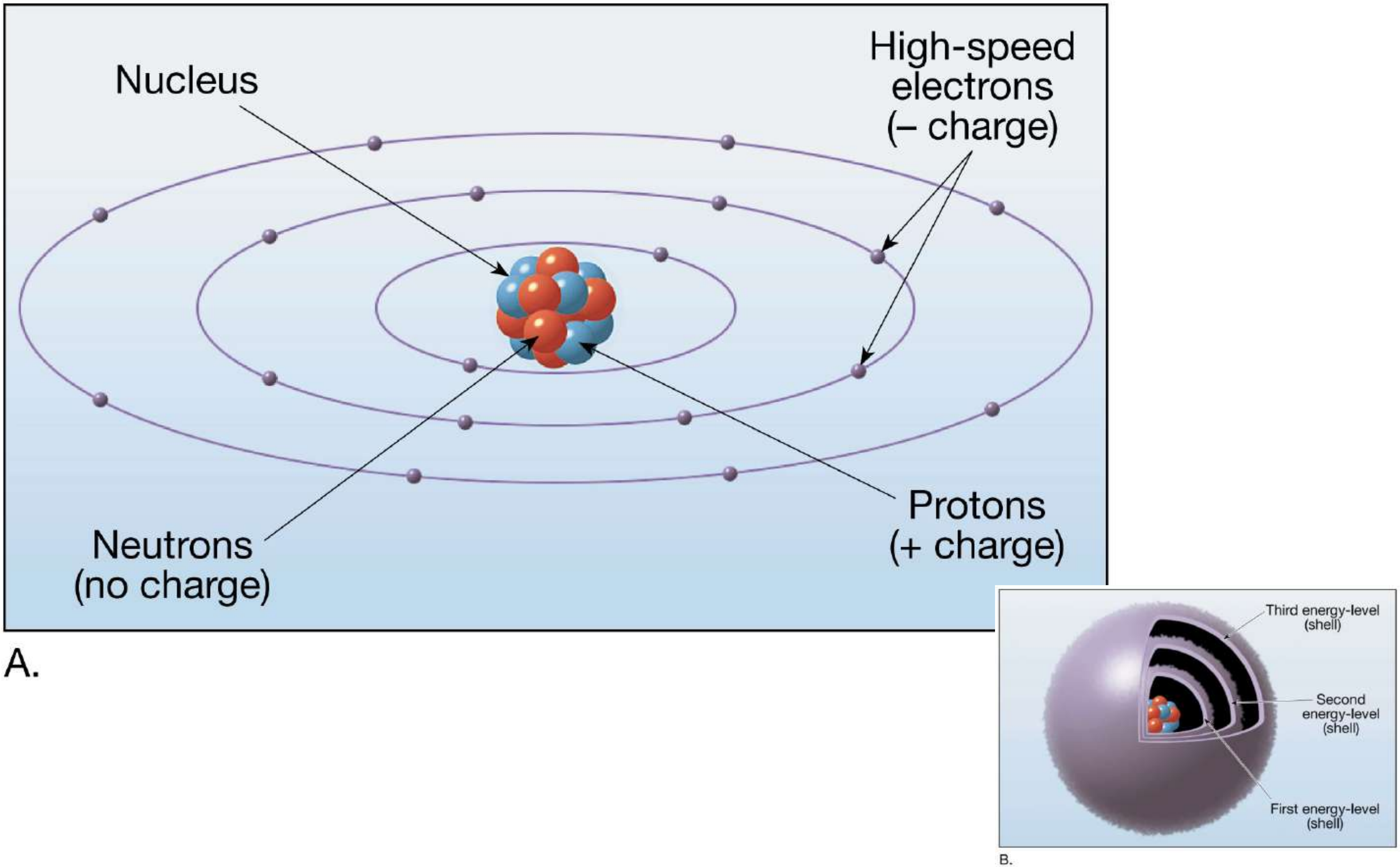
Nucleus (99% of atom's mass):

- uncharged **Neutrons**
- positively charged **Protons**
- Net charge of the nucleus is **POSITIVE**

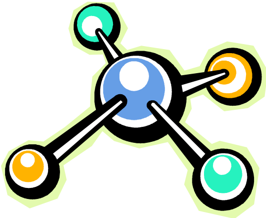
Electrons in constant motion create a "cloud" like a fan around the nucleus.

- Charge of an electron is **NEGATIVE**

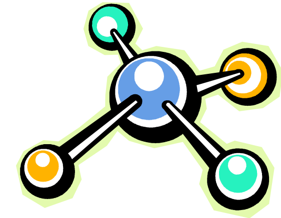
The Atom



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**.

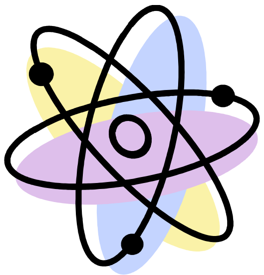
  Number of Neutrons = Mass # - # of protons

- 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	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.0079																	2 **He** 4.0026
2	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
3	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
4	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
5	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
6	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)
7	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**

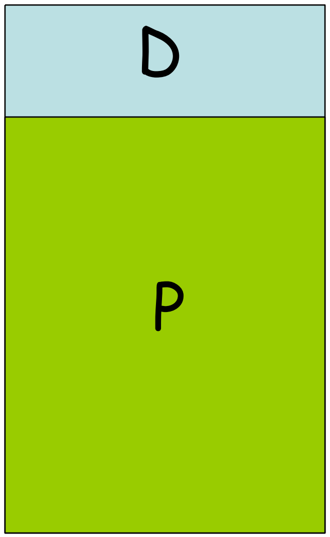
Group Legend

- Alkali Metal
- Alkali Earth
- Metal
- Trans. Met.
- Actinides
- Lanthanides
- Non-metal
- Halogen
- Noble Gas

To estimate the age of a rock:

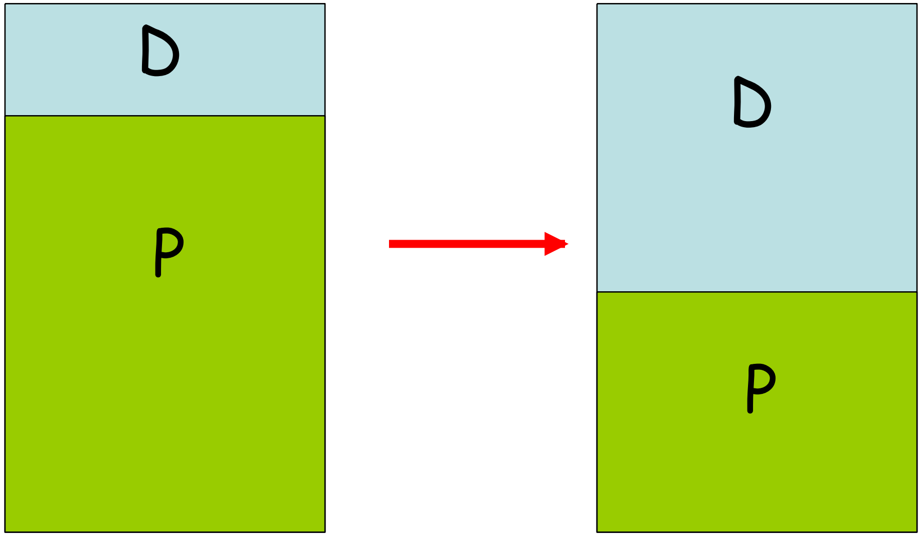
D = amount of daughter product.
P = amount of parent.

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

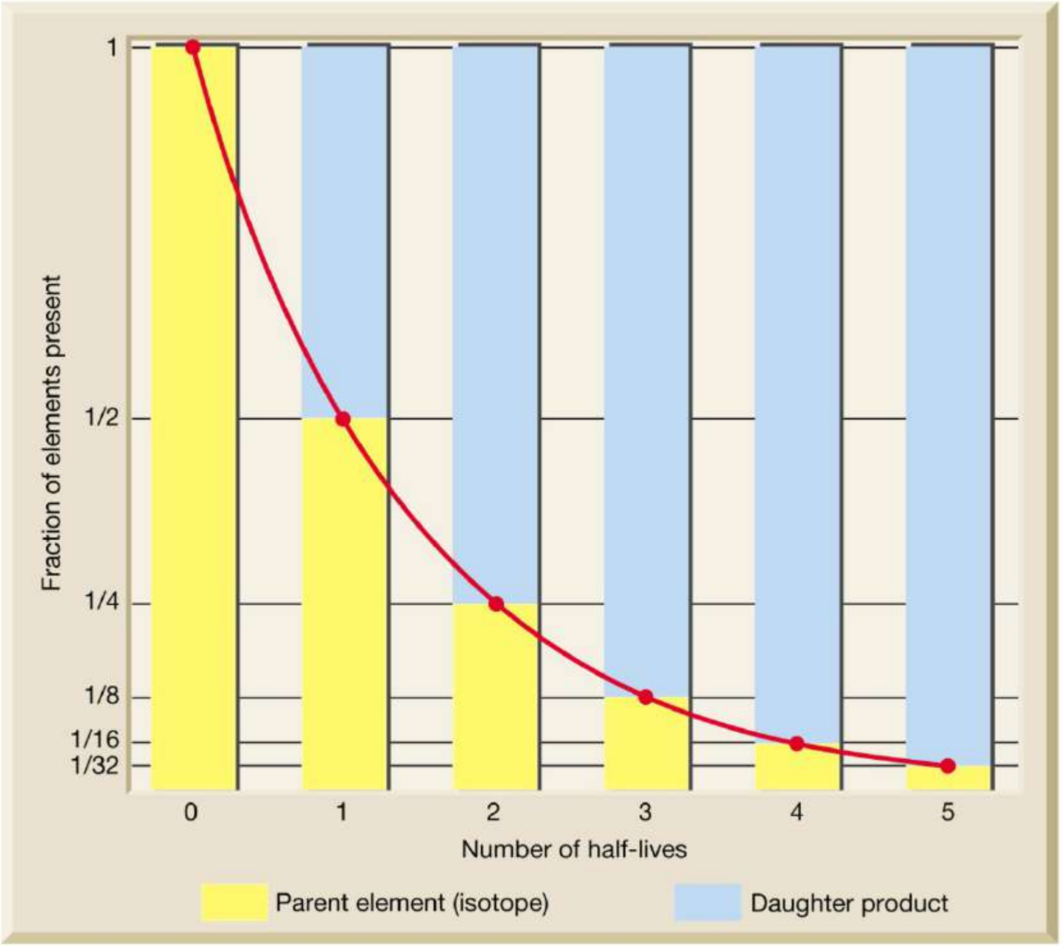


✓ Rate of decay (from theory and measurement)

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



As time passes, the amount of parent decreases, and the amount of daughter product increases. This provides a way of estimating the amount of time since the "clock" got started (i.e., since the rock solidified).



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

Half-Lives of Radioactive Isotpes

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