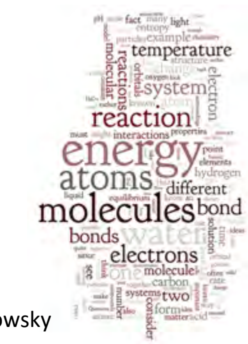
Origins of Atoms

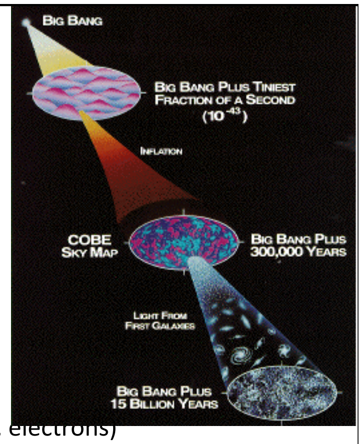


Chemistry, Life, the Universe & Everything – Cooper & Klymkowsky

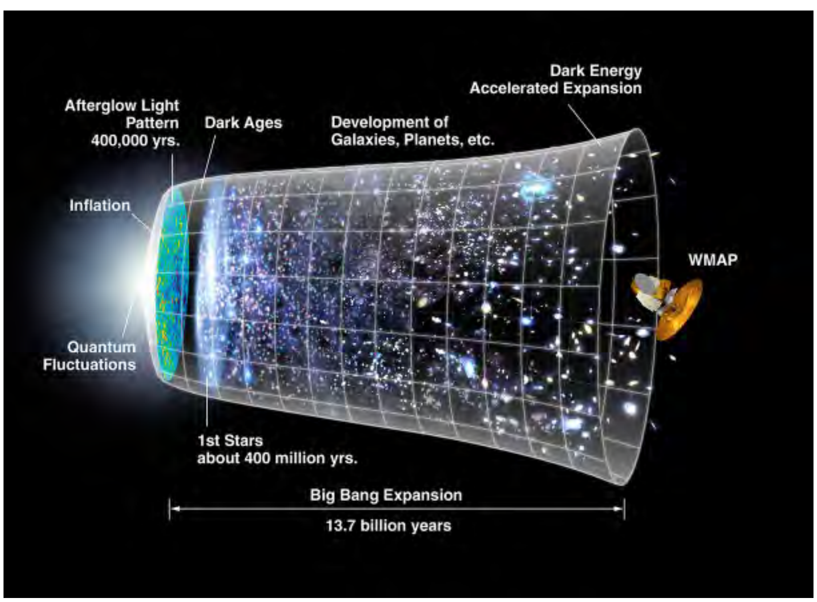
How old are the atoms in your body?

A. ~20 years
B. ~600 years
C. ~60,000 years
D. ~10,000,000,000 years
E. ageless (eternal)

Where do atoms come from?



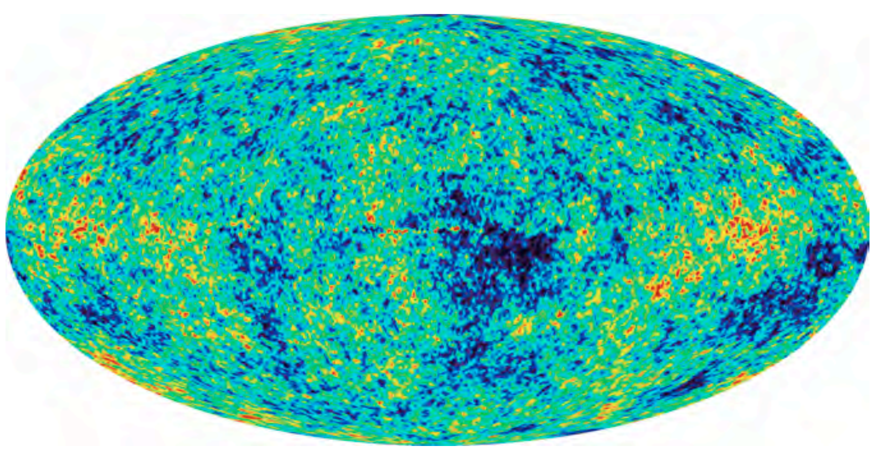
- In the beginning …..
- Big Bang
  - 13.73 Billion years ago –
  - Singularity
  - 1 pico second after - no only leptons (quarks, electrons)
  - 1 micro second – protons and neutrons
  - Few minutes – H^+ D^+ He^{2+} Li^{3+} (density of air)
  - For 400K years temp dropped – no further fusion
  - the big bang
  - Before the Big Bang
  - http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/



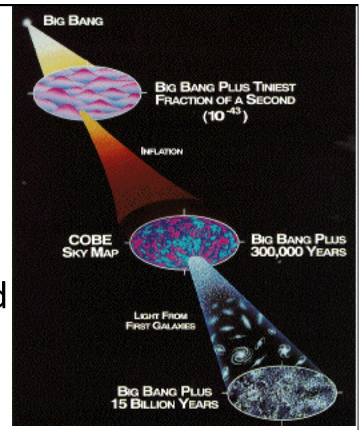
How do we know?

- Universe is expanding (red shift)
- Computer Models
- CMBR (Cosmic background microwave radiation)
  - 1.9mm (microwave) – relic of early universe that was a plasma of protons

Background radiation from 380,000 yrs after the big bang



A billion years later



- Clumping (universe is not homogeneous)
- Gravitational attraction – raised temperature
- Fusion restarted
- Stars formed
- Hydrogen burning
  - $4\ {}^{1}H^{+} \rightarrow {}^{4}He^{2+} + 2e^{+}$ + energy
- Helium burning
  - $3\ {}^{4}He^{2+} \rightarrow {}^{12}C^{6+}$ + (lots of) energy

Solar system

- 3rd generation star
- Formation triggered by shockwave from a supernova “nearby”
- Sun contains heavy elements not found in 1st generation
- Earth - 4.5 billion years - accreted from proto-star disc
- “We are stardust”

Nuclear Reactions

- Involve nucleus (not electrons)
- Often result in change in element (since element is defined by the number of protons)

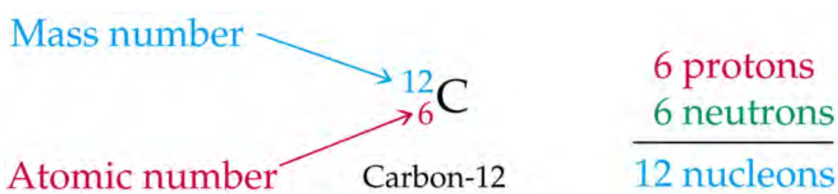
Chemical Reactions

- Involve rearrangements (sharing, donating or accepting) of valence electrons
- The element undergoing a chemical reaction does not change (EVER)

Nuclear reactions

- Fusion (adding two nuclei together)
- Fission (breaking apart)
- Decay (emitting particles, α, β, γ etc)

The Atomic number defines the element



Isotopes have same # protons and a different # of neutrons

Which is an isotope of ^{12}C?

A. ^{13}C

B. ^{12}N

C. ^{12}Mg

How many protons and neutrons does ^{12}N have?

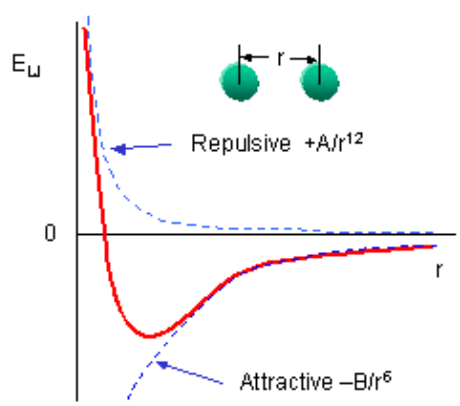
A. 6p, 6n
B. 7p, 5n
C. 5p, 7n
D. 7p, 7n

Fusion

At close range there is a strong repulsion between the nuclei.

It must be overcome by adding energy to the system.

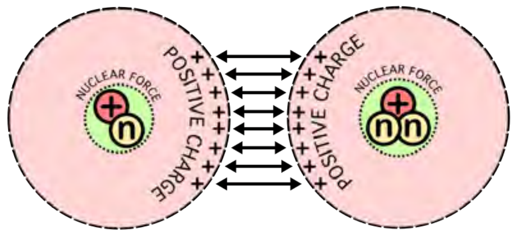
When nuclei get close enough they fuse together – and release energy ($E=mc^2$)



Repulsion increases energy required to cause fusion

Barrier to fusion is high (electrostatic)

If nuclei can get close enough the strong nuclear force can come into play (only at distances of about one nucleon – proton or neutron)



Fusion

Hydrogen burning

$4\ {}^{1}H^{+} \rightarrow {}^{4}He^{2+} + 2e^{+}$ + energy

Helium burning

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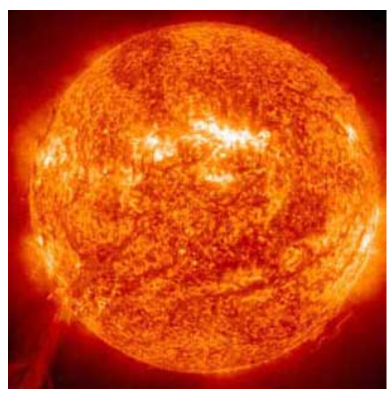
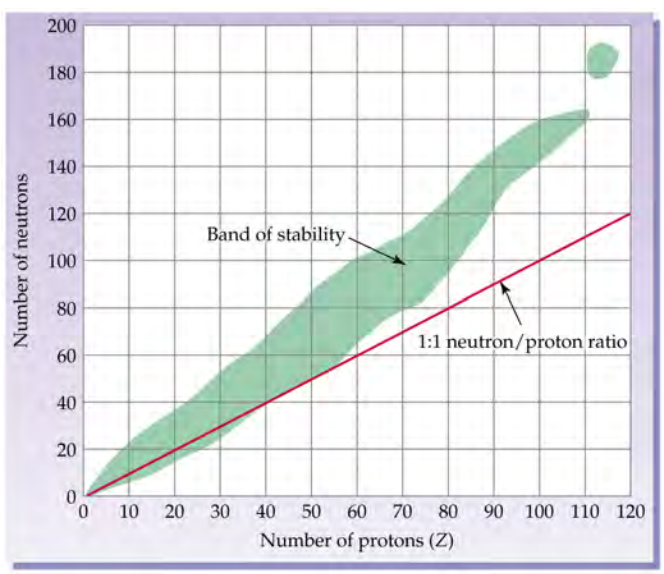


Stable nuclei

- Typically # neutrons (N) > # protons (P) for heavier elements (strong nuclear force overcomes p+↔p+ repulsion)
- Have “magic numbers” of nucleons (P or N or both)
  - 2, 8, 20, 28, 50, 82, 126
- Have < 92 protons

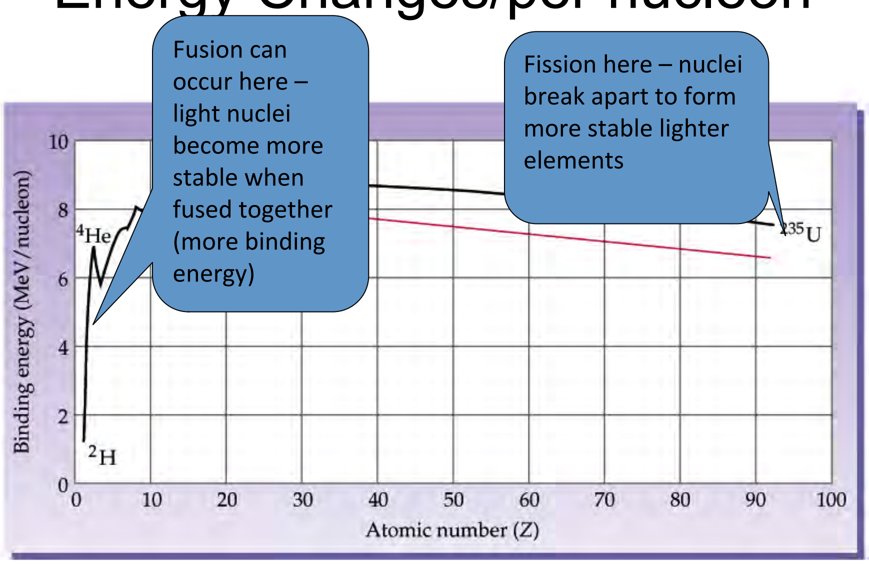
Why do some nuclei decay?



Nuclear reactions and energy changes

- Nuclear reactions are accompanied by changes in mass!
- Mass-energy equivalence
- $E=mc^2$

Energy Changes/per nucleon



Nuclear Fission

- **Nuclear Fission** is the fragmentation of heavy nuclei to form lighter, more stable ones.