Radioactive Dating

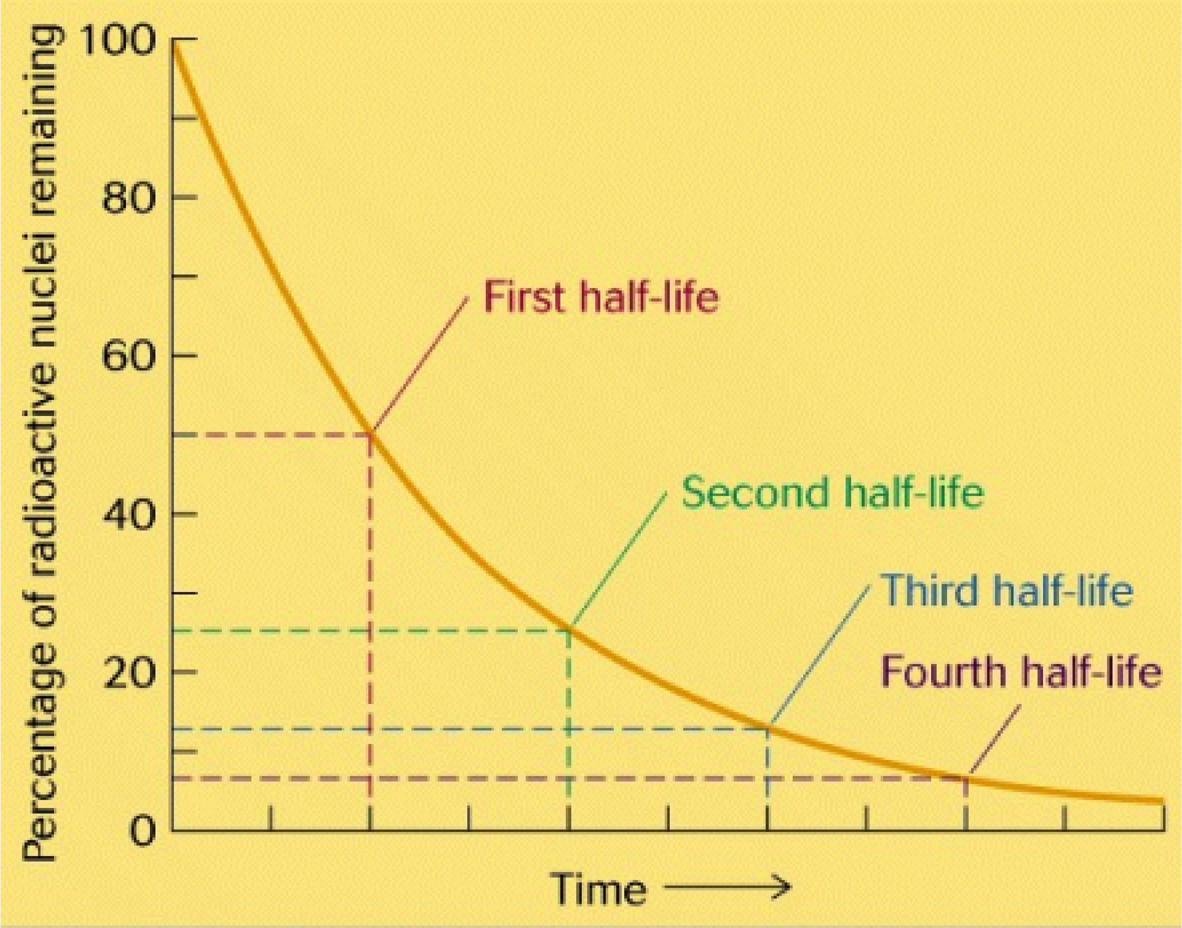
Many chemical elements are radioactive. They are not stable and decay with a characteristic half-life. A half-life is the time for half of the material to disappear. If you know how much of a radioactive element was present initially and you know how much is present now, you can calculate how old the material is.

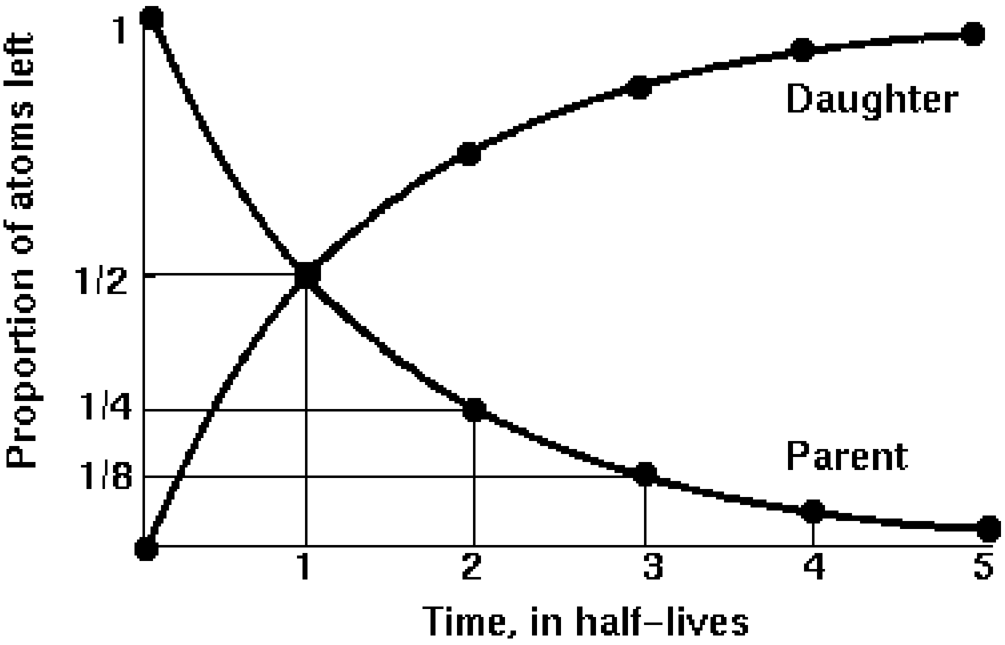
β Emission

$$^{14}_{6}\mathrm{C} \longrightarrow {}^{0}_{-1}\mathrm{e} + {}^{14}_{7}\mathrm{N}$$

Half-Life-1

Half-life ($t_{1/2}$) The time required for a substance to Be reduced by one-half its original amount




Proportion of atoms left
1
1/2
1/4
1/8
Daughter
Parent
1
2
3
4
5
Time, in half-lives

Radioactive Dating

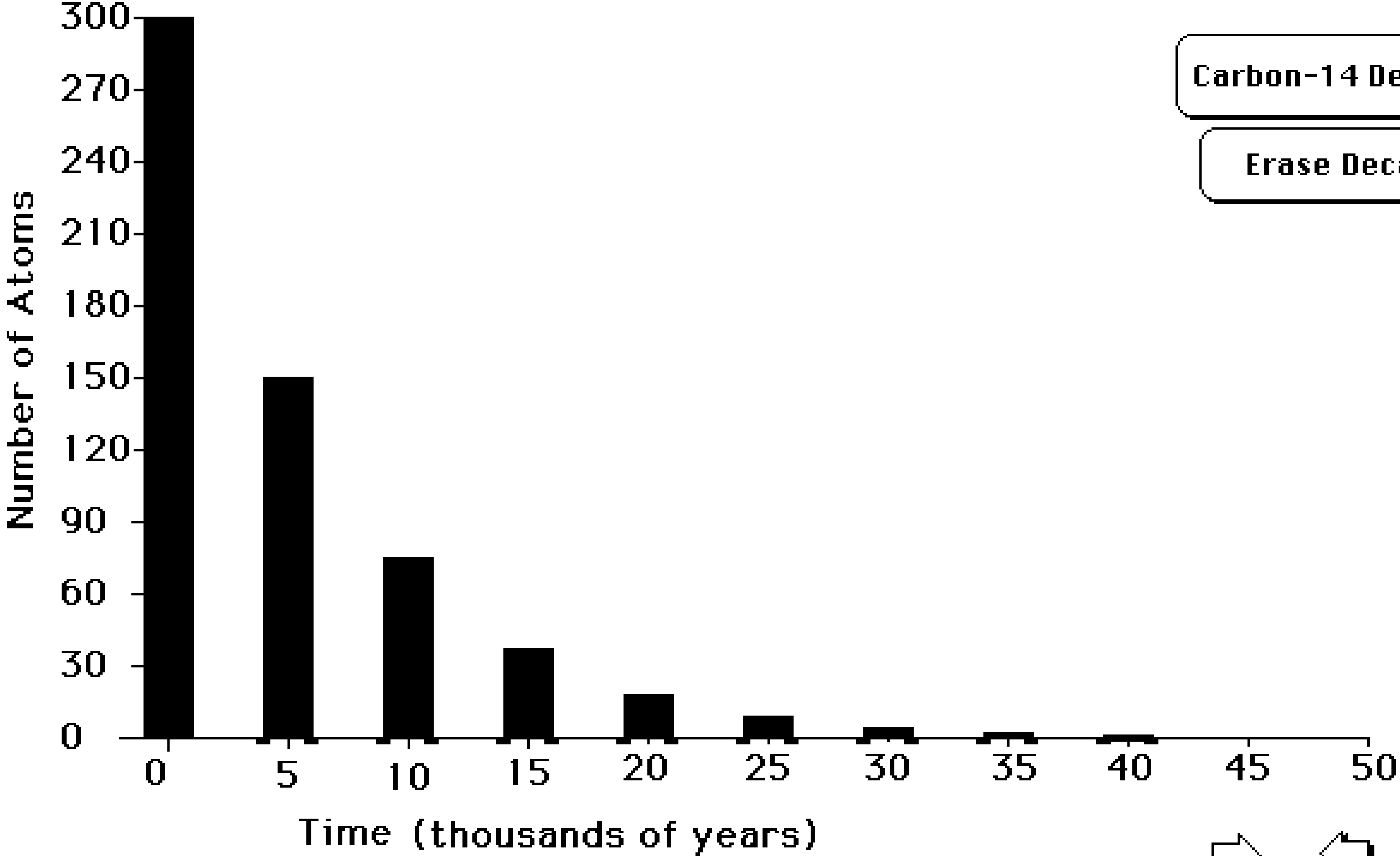
Carbon-14 has a **Half Life** of 5730 years

One-half of it decays every 5730 years. Since Carbon-14 is continually being made in the upper atmosphere by γ irradiation, the remaining carbon-14 in a substance can be used for dating. This method is good for objects up to 50,000 years old.

β Emission

$${}^{14}_{6}C \longrightarrow {}^{0}_{-1}e + {}^{14}_{7}N$$

Consider an object which initially has 300 counts of carbon-14: ○



Carbon-14 Decay

Erase Decay

$$ {}_{92}U^{238} \rightarrow \underset{\substack{\uparrow \\ \alpha\text{ Particle}}}{{}_{2}He^{4}} + {}_{90}Th^{234} \rightarrow \rightarrow {}_{82}Pb^{206} $$

Half life = 4.5×10^{9} years

Potassium-Argon dating is a very important method of dating Fossils. A significant amount of Ar-40 will accumulate in a few hundred thousand years. Lucy was dated by this method.

Electron Capture

$$ {}_{19}K^{40} + {}_{-1}e \longrightarrow {}_{18}Ar^{40} $$

Half life = 1.3×10^{9} years

Potassium-Argon Dating

Potassium-Argon Dating

This is a technique which is used to date volcanic rocks that are found adjacent to fossils allowing the age of the fossil to be deduced from the age of the rock layer that it is embedded in. The technique takes advantage of the fact that naturally occurring K-40decays to Ar-40 with a half-life of 1.3 billion years. As long as the Ar-40 remains trapped in the sample, it can be measured. From an analysis of the rock for K, the original amount of K-40 can be determined.

$$_{19}\mathrm{K}^{40} \quad + \quad _{-1}e \longrightarrow \quad _{18}\mathrm{Ar}^{40}$$

Half life = 1.3×10^{9} years

⇨ ⇦

The Evolution of the Elements

$$4\ {}_{1}H^{1} \longrightarrow {}_{2}He^{4} + 2\ {}_{+1}e^{0}$$

$$2\ {}_{1}H^{2} \longrightarrow {}_{2}He^{3} + {}_{0}n^{1}$$

$${}_{2}He^{3} + {}_{2}He^{3} \longrightarrow {}_{2}He^{4} + 2\ {}_{1}H^{1}$$

$$3\ {}_{2}He^{4} \longrightarrow {}_{6}C^{12}$$

$${}_{6}C^{12} + {}_{2}He^{4} \longrightarrow {}_{8}O^{16}$$

The Evolution of the Elements

Hydrogen Burning Produces Helium

$$4\,{}_{1}H^{1} \longrightarrow {}_{2}He^{4} + 2\,{}_{+1}e^{0}$$

$$2\,{}_{1}H^{2} \longrightarrow {}_{2}He^{3} + {}_{0}n^{1}$$

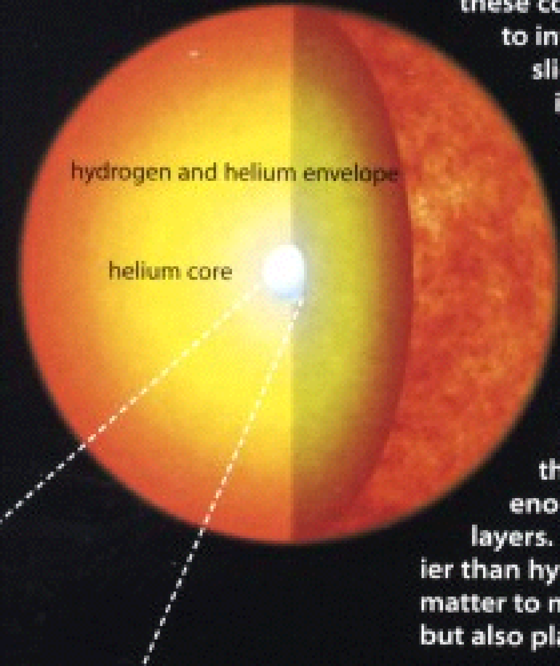
$${}_{2}He^{3} + {}_{2}He^{3} \longrightarrow {}_{2}He^{4} + 2\,{}_{1}H^{1}$$

Helium Burning Gives Carbon and Oxygen

$$3\,{}_{2}He^{4} \longrightarrow {}_{6}C^{12}$$

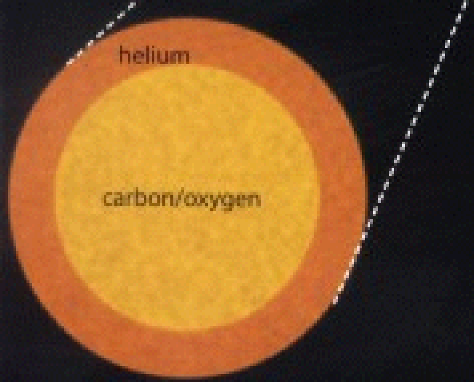
$${}_{6}C^{12} + {}_{2}He^{4} \longrightarrow {}_{8}O^{16}$$

Alchemy by Supernova



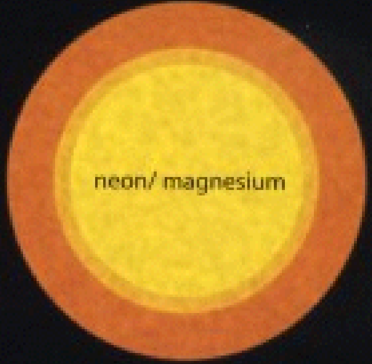
From the study of hundreds of supernovas in distant galaxies, scientists have identified two main varieties of these cosmic cataclysms. Type I supernovas are thought to involve gravitationally bound pairs of stars. The slightly more common Type II explosion typically involves a single high mass star—anywhere from eight to 20 times the mass of our Sun. Fusing hydrogen atoms at the rate of some 20 trillion tons per second, such a star reaches the end of its supply in only about 10 million years.

As long as fusion lasts at the core, its outward pressure counteracts the inward gravitational pull exerted by the star's enormous mass. As soon as fusion ends, however, the countdown to the explosion begins. Illustrated here and on the following page is the process known as core collapse, which frees enough nuclear energy to blow up the star's outer layers. The process also creates all the elements heavier than hydrogen and helium, seeding the universe with matter to make up not only the next generation of stars, but also planets, moons, comets, and all living things.



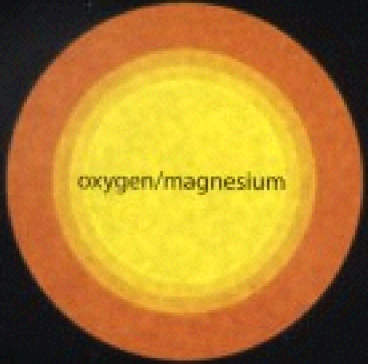
One Million Years to Blast Off

Gravitational collapse in the core pushes temperatures over 170 million degrees. Helium atoms fuse to form carbon and oxygen.



A Thousand Years to Go

Once helium in the inner shell is used up, the core begins to contract again, in alternating cycles of fusion and contraction. Carbon fuses to neon and magnesium.

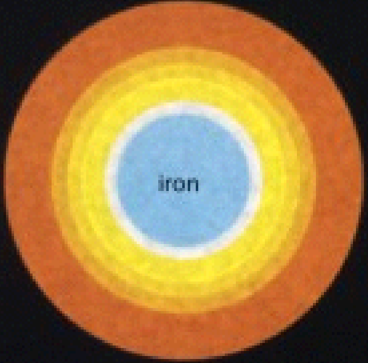


Seven Years Left

As temperatures reach 1.5 billion degrees in the stellar core, neon atoms fuse to form more oxygen and magnesium.

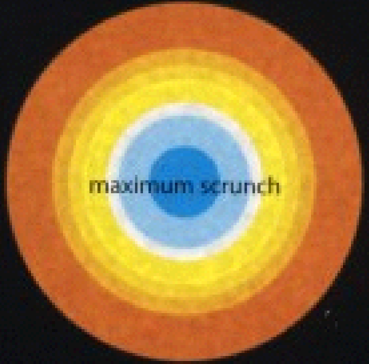
A Year to Go

Temperatures in the collapsing core top 2 billion degrees. Compressed oxygen atoms fuse to form silicon and sulfur.



A Few Days Left

At 3 billion degrees, silicon and sulfur fuse to form a compressed ball of iron. This is the last reaction that can take place.

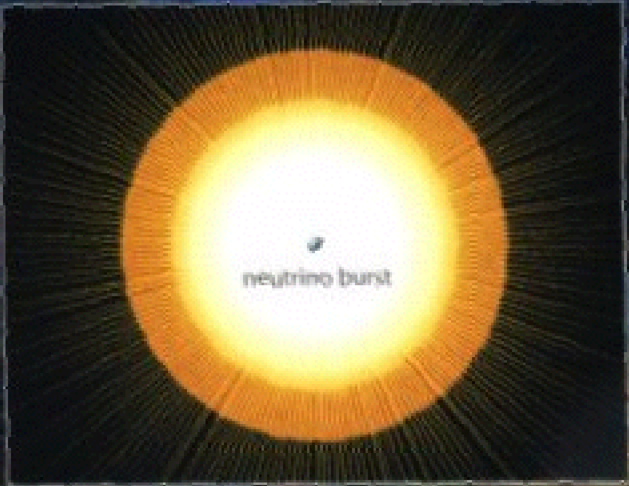


Only Tenths of a Second Left

At nearly 45,000 miles per second, the iron core crushes in on itself, packing an Earth-sized object into a ball 10 miles across. Astrophysicists call this "maximum scrunch."

The Explosion Has Begun

Repulsive force between the nuclei overcomes gravity and the iron core rebounds. The explosive shock wave blasts through the layers, creating new heavy elements as it goes.



Seconds into the Explosion

Neutrinos trapped in the core stream out through the star's layers, driving the shock wave to blast off the star's outer layers. The neutrino burst is the first detectable sign of the star's demise.


neutron star