Lecture 33
April 21. 2017.

Atoms

- Atoms are made up with a central nucleus of protons and neutrons surrounded by a number of electrons equal to the number of protons.
- The notation we use is ${}_2He^4$
- 2 is the atomic number = number of protons (and electrons)
- 4 is the mass number = number of protons + neutrons
- Note atomic mass is the actual mass of the nucleus in Atomic Mass Units (AMU) with Carbon set to be 12 AMU and atomic mass in general is not an integer

- H_2O gives the number of atoms required to make a molecule
- water = 2 Hydrogen plus 1 Oxygen
- In a nuclear reaction energy, charge, and atomic mass are conserved.

- Atoms can decay
- Atoms can join together to form new atoms or molecules
- Chemistry is determined by the electrons

3E-05 Cloud Chamber

According to P. M. Dirac (1928-1935):

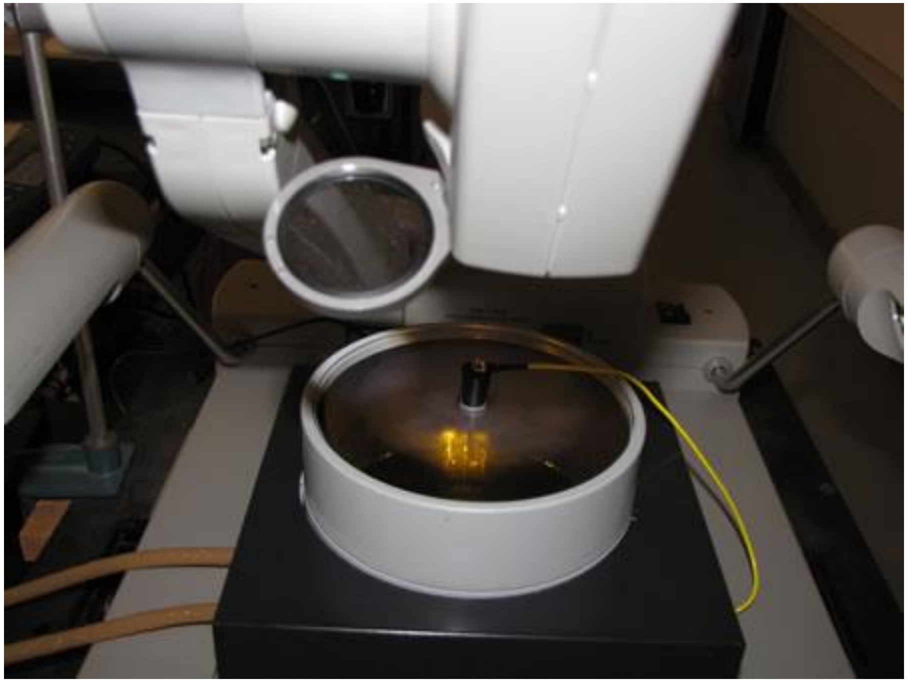
Every particle has an antiparticle: $e^{-} \rightarrow e^{+}$ $\qquad q_{particle} = -q_{antiparticle}$

$p \rightarrow \bar{p}$ $\qquad m_{particle} = m_{antiparticle}$

$notation : \bar{m},\ \bar{q}$

As charged particles pass through a gas electrons are knocked out of the atom and the ions produced can act as "seeds" for a super saturated liquid to condense. This leaves a visible track of bubbles of liquid. Cosmic rays are bombarding the earth continuously and radioactive decays also produce charged particles which can be observed in a cloud chamber. If the chamber is in a magnetic field the tracks are curved

The first observation of the positron (anti particle of the electron) was made by Anderson (1932) in a cloud chamber.



Major Detector Types

I. Scintillators

1. A plastic scintillator makes a flash when charge particle impinges on it. Used by Thompson and Rutherford (1897→till today)

2. Wavelength shifting scintillator → wave guide. Changes the wave-length so that the signal can be guided to a counter without loosing it. This physical process is causing climate change. Sun's radiation enters into the Earth's atmosphere, increases its wavelength and due to Air + CO_2 composition can not leave the earth's atmosphere. The radiation is trapped. (Similarly for Air + Methane and Air + Freon mixtures)

II. Cloud Chambers

3. Cloud Chamber: Water vapor tracks charge particles. It was used to discover e^+ the positron.

III. Bubble Chambers

4. Bubble Chambers: Super heated liquid hydrogen forms tracks along the path of a charged particle. Extremely successful to study multiparticle events like:

$$\pi^- + p \to \pi^+ + \pi^- + n, \quad \pi^+ + \pi^- + \pi^0 + n$$

$$K^0 + \bar{K}^0 + n$$

during the 1950-1980 time period (L. Alvarez, Berkeley 72″ B.C.)

IV. Drift Chambers

5. This is the modern electronic experimental tracking device to study high energy, charged multiparticle

$e^+ + e^-$ and $p + p$ collisions.

Isotopes

•For a given number of protons there is a nucleus that is most stable for a particular number of neutrons.

•Isotopes are when for the same number of protons the number of neutrons thus the mass is different from the most stable configuration.

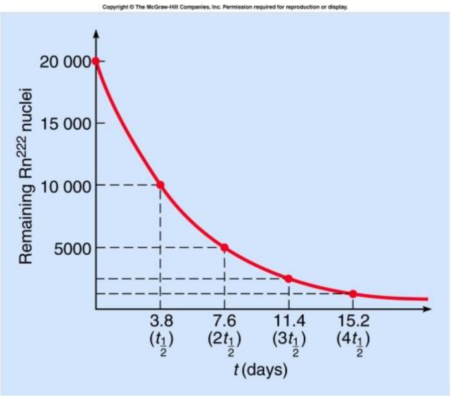
•Since the number of electrons is the same, for all isotopes, their chemical properties are "identical", but the nucleus can be unstable.

•The larger the mass difference between ideal nucleus and the isotope the more unstable the nucleus becomes.

•Nuclei have been made artificially that do not exist in nature.

Radioactive decay

•The general rule is that if a lower energy configuration exists for the same set of particles then they will try to change into that configuration.



$$N = N_0 e^{-t/\tau}$$

Each radioactive element has a characteristic half life, that is the time for half the sample to decay. Radioactive elements are clocks which tick at a specific rate.

Half lives vary from billions of years to a fraction of a second. Those in the range of greater than thousands of years are used to date objects on earth back to it's formation 4.6 billion years ago

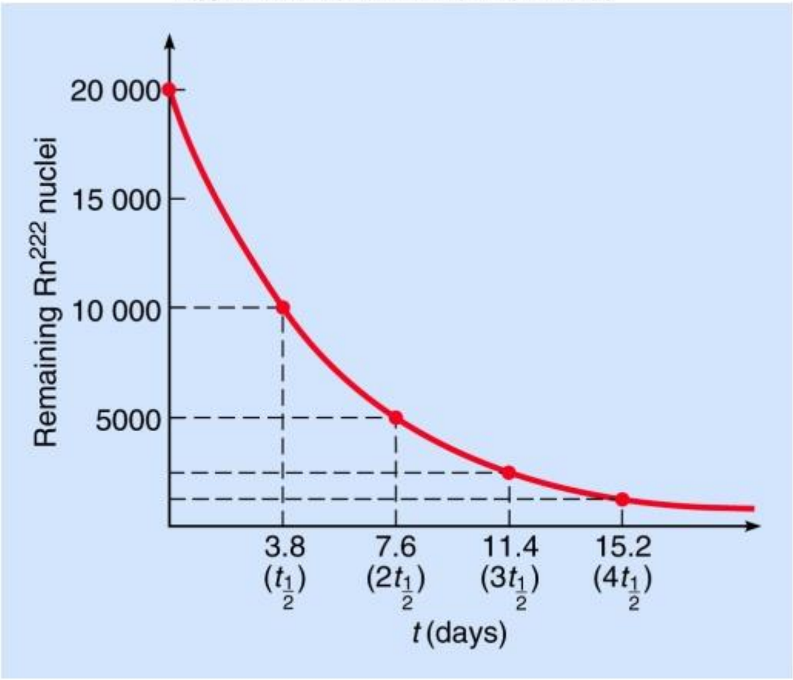
C^{14} 5730 years I^{129} 1.6 million

U^{238} 4.47 billion

The amount remaining after N half lives is ½ x ½ x ½ ………..

http://www.physics.purdue.edu/class/applets/phe/lawdecay.htm

Radioactive decay



- To obtain the figure on the left, we encounter a fundamental physical equation for most of decaying systems

$$\Delta N = -\lambda N \Delta t \qquad \text{Eq.1}$$

- The number of decaying atoms in small time interval *Δt* is proportional to the number of existing atoms (available for decay). Going to infinitesimal time *dt* and infinitesimal number *dN* we obtain

$$dN = -\lambda N\, dt \qquad \text{Eq.2}$$

- Rearranging we obtain $\frac{dN}{dt} = -\lambda N \qquad \text{Eq.3}$

- So far, we have done only algebraic rearrangement of the fundamental Eq.1
- To find the solution of this equation shown in the figure above, we have to solve this differential equation and obtain: $N = N_0 e^{-t\lambda}$ where it is customarily to write $\lambda = 1/\tau$ and τ is called lifetime. So, finally, we obtained the curve in the figure above using the solution of the fundamental differential form of Eq. 1

Types of nuclear decays

A proton can change into a neutron and emits a positron (anti particle of electron)

$$_{1}e^{0} = \bar{e} \text{ is a positron = antielectron } q_{\bar{e}} = +1\text{, mass = 0.51MeV}$$

Atomic number decreases by 1the mass number remains the same

A neutron can change into a proton and emits an electron

$$_{-1}e^{0} = e^{-}, \quad q_e = -1, \text{ mass = 0.51MeV}$$

Atomic number increases by 1 the mass number remains the same

A nucleus can emits an alpha particle which is 2 neutrons and 2 protons (actually a helium nucleus)

$$_{2}He^{4} = \alpha \quad \text{particle discovered by Thompson}$$

Atomic number decreases by 2 unit mass number decreases by 4 unit

Photons can be emitted .

No change in Atomic number or mass number.

What is the daughter?

- When an element decays it usually changes to a new element.

- The notation we use is $_3Li^7$ where 3 is the number of protons, called the atomic number, and 7 is the number of protons plus neutrons, called the mass number.

- Any decay or nuclear reaction conserves charge and mass number.

- $_2He^4 + {_7N^{14}} = {_8O^{17}} + {_1H^1}$ nuclear reaction
- $_{88}Ra^{226} = {_{86}Rn^{222}} + {_2He^4}$ nuclear decay

Energy and atoms

When we make atoms from the constituents energy is released. The sun's energy comes from fusion $E = Mc^2$

When we make molecules by joining atoms energy is released. Burning is Carbon plus oxygen making CO_2

Electrons in atoms have specific energy levels

When an electron is removed from an atom the atom will capture an electron and emit photons of specific energies

When many atoms are emitting photons we get spectral lines, that is electromagnetic radiation of specific wavelengths and colors. Each atom has it's own "fingerprint"