Isotopes

Basics

- Isotopes are variants of atoms. An atom is a tight little system, about 0.3 nm large, consisting of an extremely small nucleus and a "cloud" of *electrons* that hang around the nucleus.
  - The nuclei itself is once more a tight *very* little system of z *protons* and $z \pm \Delta z$ *neutrons*. It is far smaller than its atom, say about a millionth of a nanometer or **10^{-6} nm**
    Protons and neutrons are extremely tight very little systems consisting of *quarks* and *gluons* (some of the stranger elementary particles).
    Quarks and gluons are ... no they ain't. They are, like electrons, truly fundamental or real "elementary" particles that cannot be divided into something even more fundamental (we think). Look up the link for more.
  - The **atomic number z**, the number of protons in the nucleus, spans the range from **z = 1 .... 104** and defines the type of atom. Hydrogen (H) has **$z_H = 1$**, silicon (Si) comes in at **$z_{Si} = 14$**, our beloved iron (Fe) is found at **$z_{Fe} = 26$**, and so on. Check the periodic table for more.

    All elements beyond polononium (Po) with **$z_{Po} = 84$** are radioactive and eventually decay into some lighter atoms. This radioactive decay might be very fast or very slow. It is always characterized by the **half-life**, the time during which 50 % of some bunch of radioactive atoms has split asunder.

Advanced Link

Elementary particles

- The atomic number z thus defines completely the type of atom and thus also its general behavior. Since the number of neutrons in the nucleus of an atom is variable to some extent, all atoms come in variants that we call isotopes.
  - We characterize an isotope of some element by writing the *total* number of protons and neutrons on the upper left of the chemical symbol, For iron (Fe) we have, for example: **^{54}Fe**, **^{56}**Fe, **^{57}Fe**, and **^{58}Fe**. Since the iron has the atomic number **$z_{Fe} = 26$**, we have **54 - 26 = 28** neutrons in **^{54}Fe**, and **30**, **31**, and **32** neutrons, respectively, in the other three isotopes given.
- Isotopes come in two basic variants:

  1. **Radioactive isotopes**, decaying eventually into some other kind of atom.
  2. **Stable isotopes**, existing forever (or until the end oft time, whichever comes first).
  - The iron isotopes given above are stable. Since the early suns (long extinct by now) that bred all the iron now found throughout the universe made all kinds of iron isotopes, the iron we find on *our* planet actually consists of a mix of those four types (details here)
    The early suns also made radioactive isotopes of iron and pretty much anything else. But those non-stable guys have long since decayed, except if their half-life is billion of years. That's why we still have, for example, some uranium (U) around. **^{238}U**, to give one number, has a half-life of **$4,5 \cdot 10^9$** years or roughly one third of the age of the universe.
  - That means that we must make radioactive isotopes if we need them. Typically this is done by bombarding suitable stable isotopes with neutrons in some nuclear reactor. More than 1000 radioactive isotopes are made in this way because isotopes are very useful in all kinds of fields, ifor example medicine, and not just in Materials Science.