$^{18}\text{F}$

$\frac{1}{2} t = 110 \text{ min} \quad \beta^+ \text{ emitter}

- used in **Positron Emission Tomography (PET scan)**
  - choose molecule with high concentration in part of body of interest
  - synthesize compound, attach $^{18}\text{F}$
  - administer to patient
  - detect reaction of positrons with electrons in surrounding matter
    
    $+\,^0_1\beta + -\,^0_1\text{e} \rightarrow 2\,^0_0\gamma \quad \text{“annihilation”}$

  - images metabolic activity very clearly (e.g., Alzheimer’s, epilepsy, CP, stroke)
  - PET scans still relatively uncommon: $^{18}\text{F}$ short half-life: need to make onsite. Need a particle accelerator. Cost > $10^6$ (scanner not included).
  - $^{62}\text{Cu}$ also used in PET scans (blood flow).

- **Contrast to Computerized Axial Tomography (CAT scan)**
  - X-rays passed through body in thin slices.
  - Based on different densities of matter/tissue
  - No radioactive nuclide involved
  - Nothing radioactive administered to patient

- **Contrast to Magnetic Resonance Imaging (MRI)**
  - Patient inserted into huge magnet
  - Based on relaxation of spinning of hydrogen nuclei when magnetic field turned off
  - Excellent for imaging soft tissues (e.g., plaque from MS)
  - No radioactive nuclide involved
  - Nothing radioactive administered to patient

**Binding Energy**

Mass of atom $\leq$ Sum of masses of particles that make up atom

The “missing” mass (mass defect) was converted to energy, called binding energy

$$E = mc^2$$

$$\left(1.0 \times 10^{-3} \text{ kg}\right) \left(3.00 \times 10^8 \text{ m/s}\right)^2 = 9.0 \times 10^{13} \text{ J}$$

1 gram of mass = $9 \times 10^{10}$ kJ of energy!

To allow for fair comparison, the mass defect and corresponding binding energy are recorded on a per nucleon basis.

**largest binding energy**: $^{56}\text{Fe}$

Both fission and fusion have the goal of producing nuclides with higher binding energies per nucleon. (more stable). Both fission and fusion therefore release energy.
Fission Power Plants
1. Fuel—a fissionable nuclide
   e.g., $^{235}$U, $^{239}$Pu
   - In USA, typically pellets of $\text{U}_2\text{O}_8$ enriched to about 3% $^{235}$U. (Naturally occurring U contains about 0.7% $^{235}$U. Uranium-238 doesn’t fission nearly as effectively.)
   - Pellets contained in hundreds of tubes (“fuel rods”).

2. Moderator
   - Surrounded by fuel rods; slows down neutrons
   - In USA, typically water (can also be liquid sodium)
   - Does NOT absorb or react with neutrons

3. Coolant
   - Carries heat produced to external turbine to produce electricity
   - Typically water

4. Control Rods
   - Absorb neutrons
   - Control number of neutrons colliding with fuel
   - Full power: rods up all the way
   - Shut down: rods down all the way

5. Containment System

USA: ~20% of electricity from nuclear power
France: > 75% of electricity from nuclear power

Nuclear power plants are NOT potential nuclear bombs in and of themselves. The fuel isn’t nearly pure enough. (~90% fissionable fuel needed for a bomb.)

“Dirty bombs” contain lower levels of radioactive materials than new fuel but enough to cause some biological harm and lots of psychological harm. Spent nuclear reactor fuel/waste security is a great concern!

The major problem of fission reactors: the WASTE ~200 nuclides, ~35 elements

Fusion Power Plants?
Advantages: (lack of) waste
(practically) unlimited fuel ($^2$H)

Problems: high temperatures required (~$10^8$ K)
containment

$^2_{13}\text{Cs} / ^{137}\text{Ba}$
The “main groups” are the “A” groups in the American labeling of the periodic table—the groups corresponding to filling of valence $s$ and $p$ orbitals. The transition metals (the “B” groups; $d$ orbital filling) were discussed in Chapter 17. We’ll find that we can review a number of topics from throughout 3150:151 and 153 as we look at some highlights of main-group elements.

**Hydrogen**

3 isotopes: $^1$H (99.98%), $^2$H (0.02%), $^3$H (trace; radioactive—produced by cosmic rays in atmos.)

Hydrogen can lose its electron ($IE_1 = 1310 \text{ kJ} \cdot \text{mol}^{-1}$), gain an electron ($EA = -74.5 \text{ kJ} \cdot \text{mol}^{-1}$), or form a covalent bond.

**Preparation**

1. reactions of active metals (best: Group 1A) with water, acids, or bases

\[2\text{Na} + 2\text{H}_2\text{O} \rightarrow \text{H}_2 + 2\text{NaOH}\]

2. electrolysis of water

\[2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2\]

3. reaction of metal hydrides with water

\[\text{NaH} + \text{H}_2\text{O} \rightarrow \text{H}_2 + \text{NaOH}\]

**Reactions/Compounds**

- main group metal hydrides: generally ionic (contain H in $-1$ oxidation state)

\[2\text{Na} + \text{H}_2 \rightarrow 2\text{NaH}\]

- transition metal hydrides: primarily interstitial (non-stoichiometric)

- nonmetal hydrides: covalent (contain H in $+1$ oxidation state)

\[\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3\]

- as we have learned, transfer of $\text{H}^+$ is the basis for Brønsted-Lowry acid base reactions.

- $\text{H}_2$ commonly used in reduction of inactive metal oxides

\[\text{CuO} + \text{H}_2 \rightarrow \text{Cu} + \text{H}_2\text{O}\
"ore"\]