7.3: Density Trivia

- Anything with a density less than 1 g/cm ^{3} will float on water; anything with a greater density will sink.
- Most substances are more dense in the solid state than they are in the liquid state, so that as they freeze, the frozen parts sink. An important exception is water, which has its maximum density at *4* ^{o}C in the liquid state. Frozen water (ice) is less dense that liquid water, so the frozen parts float. This has been important for life on Earth: aquatic life is able to survive freezing temperatures because ice floats to the top of bodies of water, forming a layer of ice that insulates the water below. If ice were more dense than water, lakes and rivers would freeze solid and destroy most aquatic life.
- The chemical element with the *lowest* density is hydrogen, with a density of 0.0899 g/cm^3 at standard temperature and pressure. But excluding gases, the lightest element is lithium, with a density of 0.534 g/cm^3. Lithium and potassium are the only two solid elements light enough to float on water (although they will also chemically react with water).

Caution

Don't try this!! Lithium and potassium will explosively burn in water!!

- The chemical element with the *highest* density is osmium. There has been some debate over the years about whether osmium or iridium is the densest element, and the densities of the two are very close. But calculations show that for a perfect crystalline sample of each element, the density of osmium is 22.59 g/cm^3, while that of iridium is 22.56 g/cm ^{3}, making osmium the winner by a small margin.[2] Either element is twice as dense as lead.
- Among the planets, Earth has the largest average density (5.515 g/cm^3). The least dense planet is Saturn, with a density of 0.687 g/cm^3. Saturn is the only planet in the Solar System that would float on water (given a large enough ocean).
- Why was the International Prototype Kilogram made of a 90/10 platinum-iridium alloy? Platinum was chosen because of its high density. Making the standard kilogram from a high-density material mini- mizes its size, which minimizes the surface area that is subject to contamination, and also minimizes the buoyant force of the surrounding air. Osmium and iridium are denser but much more difficult to machine; platinum is dense, yet fairly easy to work with. The addition of 10% iridium hardens the platinum somewhat to minimize wear (which would alter the mass).
- The lightest solids around are called *aerogels*. These are artificial materials that are essentially *very* light solid silica foams, and have the appearance of “solid smoke”. They are excellent thermal insu- lators, and have been used by NASA to capture small dust particles from a comet (because they can gradually decelerate the particles with minimal damage). Aerogels have been made with densities as low as 0.001 g/cm^3. If held up in the air and released, such an aerogel will remain almost stationary in the air, falling very slowly to the earth.
- Except for a black hole (which has, in a sense, infinite density), the densest object in Nature is a *neutron star*. Normally a star is in a state of equilibrium, with outward radiation pressure balancing the inward gravitational pressure. But when the star runs out of fuel, the outward radiation pressure is gone, and the star collapses under its own gravity. If the star is large enough, gravity can be strong enough to push the electrons of the atoms into the nucleus, forming a “neutron star”, which is essentially a giant ball of neutrons. A typical neutron star has a density of *10* ^{14} g/cm^3. To get an idea of how dense this is:
  - One pound of neutron star material would be about the size of a speck of dust.
  - A bit of neutron star material the size of a grain of sand would weigh as much as *two* fully fueled Saturn V Moon rockets.
  - 1/4 teaspoon of neutron star material would weigh as much as the borough of Manhattan.

- 1 teaspoon of neutron star material would weigh as much as 5000 *Gerald R. Ford*-class aircraft carriers.
- 1 cup of neutron star material would weigh as much as Mt. Everest.
- A cube of neutron star material occupying 1/2 the college campus would weigh more than the entire Earth.
