The Atomic Nature of Matter

Everything is made of ATOMS

Atoms are…

- Incredibly small
- Incredibly numerous
- In constant motion
- “Timeless”

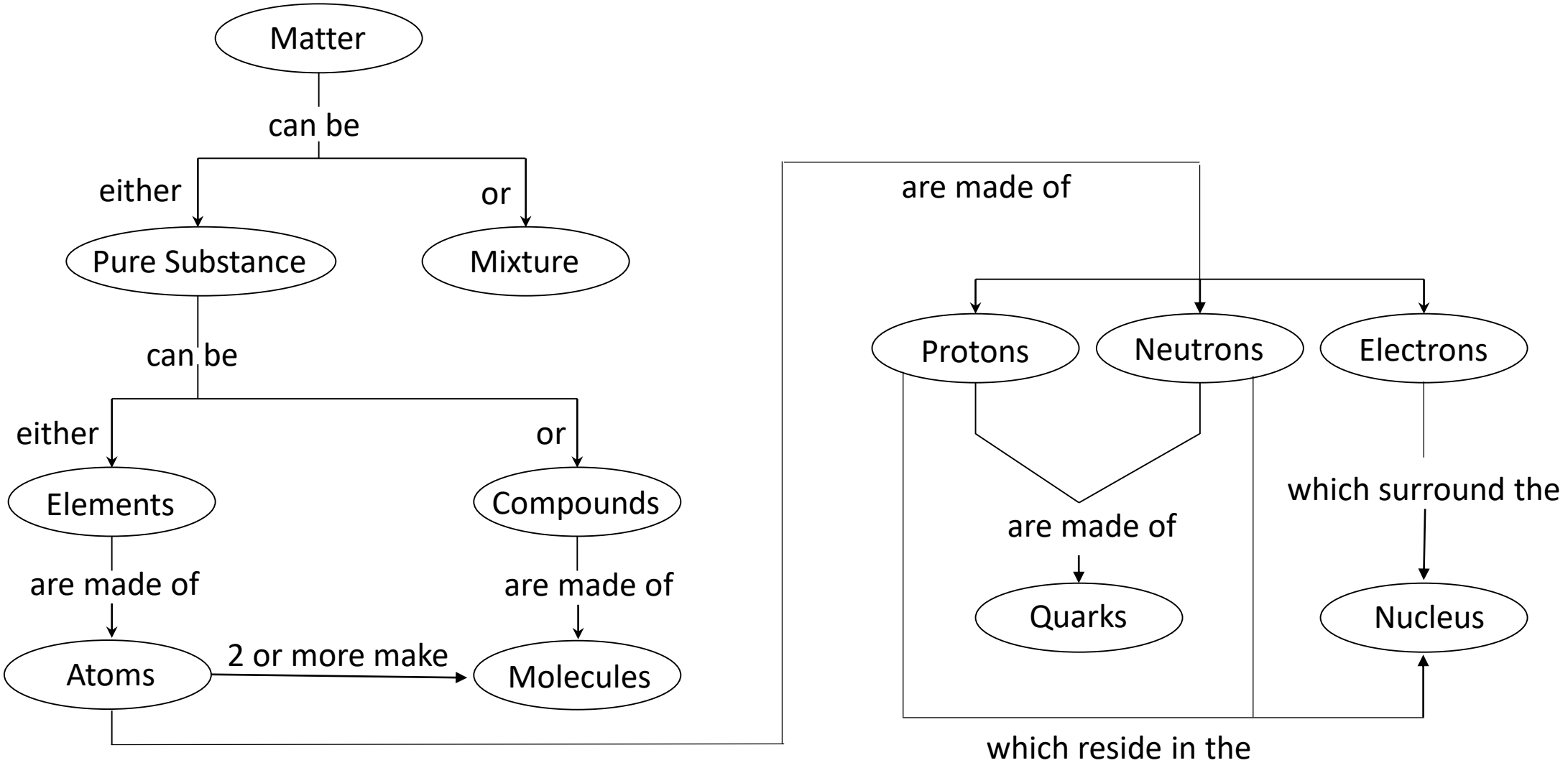
Evidence for the existence of atoms

- Brownian motion
  - The observance of the random motions of grain pollen and ash particles under a microscope caused by atomic bombardment.
- Chemical reactions
  - The law of definite proportions in chemistry demonstrating that compound substances form with specific mass ratios of elements.
- Electron micrographs
  - Electron scattering through crystalline substances producing regular patterns on photographic film.
- Scanning tunneling microscope (STM) photographs
  - Images produced by measured electric currents between adjacent atoms.
  - The ability to manipulate individual atoms with the STM.

Evolution of the Model of an Atom

- Democritus (c. 2000 B.C.) presupposed the existence of atoms.
  - The sensation of wind on his face and the smell of bread baking in a kiln.
  - Envisions atoms as incredibly small indivisible spheres
- John Joseph (J.J.) Thompson (1898) discovers the electron.
  - Small electrically charged particle appears to be a constituent of the atom.
  - Puts forth the “plum-pudding” model of the atom.
- Ernest Rutherford (1911) discovers the atomic nucleus.
  - Perform his famous “gold-foil” experiment of scattered radiation particles.
  - This discovery leads to the “planetary” model of the atom.
- Edwin Schrodinger et al. (1920’s & 30’s) develop quantum mechanics.
  - Electron forms “clouds of probability” around the nucleus of an atom.

Classification of Matter



Some terms and definitions

Atomic Number, Z: The number of protons in the nucleus of an atom.

The atomic number identifies the element. For example the atomic number of Carbon is $Z = 6$. Any atom that has 6 protons in its nucleus is a "carbon" atom.

Atomic Mass Number, A: The total number of protons plus neutrons in the nucleus of an atom. That is, $A = Z + N$.

The atomic mass number identifies the *isotope* of the element. Diffterent isotopes an element are atoms that have the same Z, but different N. For example, ^{14}C (Carbon-14) has 6 protons and 8 neutrons.

For an arbitrary element, "X," the an isotope of that element is written as ^{A}X.

Atomic Mass, *M*: The mass of an atom of a particular element averaged over the abundance of the naturally occurring isotopes of that element.

For example, Hydrogen has three naturally occurring isotopes:

^{1}H (protium), ^{2}H (deuterium), and ^{3}H (tritium).

Each has $Z = 1$ (1 proton—that's what makes it hydrogen!) but have 0, 1, and 2 neutrons respectively.

If you grab 1 billion H atoms at random from the universe, 999,800,000 will likely be ^{1}H. The remainder will likely be ^{2}H. (If you are extremely lucky—one chance in a billion grabs—you might get a single ^{3}H!)

When averaged, the atomic mass of hydrogen is $M = 1.0079$ mass units.

Electrically charged atoms (a.k.a. IONS)

The protons have “positive” electric charge and electrons have “negative” electric charge.

An electrically neutral atom has an equal number of protons and electrons.

An ION is an electrically charged atom.

If an atom has too few electrons it is a positive ion.

If an atom has too many electrons, it is a negative ion.

A sodium atom missing an electron would be written Na^{+}.

An oxygen atom missing two electrons would O^{2-} or O^{--}.

Question

How many protons, neutrons, and electrons does $^{56}Fe^{+++}$ have?

Answer:

Refer to the Periodic Table of Elements.

Fe is the chemical symbol for iron and has atomic number $Z = 26$.

So, 26 protons.

The isotope is 56Fe has atomic mass number $A = 56$ which is $Z + N$.

So, $N = A - Z = 56 - 26 =$ 30 neutrons.

Finally, 26 electron would make this atom electrically neutral. Since it is positively charge by missing 3 electrons, this ion has 23 electrons.

Exotic Forms of Matter

Antimatter:

Matter that that has the same mass as “ordinary” matter, but has opposite electrical charge. For example, an atom of “anti-hydrogen” consists of a *negatively* charged proton surrounded by a *positively* charged electron.

Dark Matter:

Unseen and unidentified matter whose existence is evidenced by the gravitational effect it has on matter we can see. For example, the rotational rates of galaxies is too fast to be consistent with the amount of matter visible. There must be more “stuff” out there to account for the observations.