

Subatomic Particles

protons (p^+)

1. positively charged subatomic particle located in nucleus of an atom
2. mass = $1.673 \text{ E} - 24 \text{ g}$ or 1.0073 u
3. always moving (atomic vibration)

neutrons (n)

1. subatomic particle located in nucleus that has no electrical charge
2. mass = $1.675 \text{ E} - 24 \text{ g}$ or 1.0087 u
3. free neutron decays into proton, electron, and electron anti-neutrino
4. half-life of free neutron is about 890 seconds
5. from Standard Model theory, the neutron is composed of 3 quarks (one Up and 2 Down quarks = UDD), the weak force converts one of the Down quarks into an Up quark, turning the neutron into proton (UUD). A third particle, known as W boson is emitted as a result of the conversion process. This W boson decays into an electron and the electron-antineutrino.
6. The amount of time that a neutron survives before it decays plays a role in determining which elements were created during the Big Bang. It has a strong influence on the amount of Helium-4 in the universe.

electron (e^-)

1. very small negatively charged subatomic particle found in orbit around nucleus
2. mass = $1.1 \text{ E} - 29 \text{ g}$ or $0.000 549 \text{ u}$
3. mass is $1/1836$ that of proton
4. moves very rapidly and is rather easily accelerated

Nucleus has a diameter of about $1 \text{ E} - 14 \text{ m}$, atom has a diameter of about $1 \text{ E} - 10 \text{ m}$ or a difference of 10 000 to 100 000.

Imagine the atom as the size of a professional baseball stadium (in 3D). The size of the nucleus would be about the size of a baseball in proportion. Ants would be far too big to represent as the electrons.

Leptons: particles with no perceptible internal structure (and spin $1/2$) include the electron neutrino, electron, muon neutrino, muon, tau neutrino, and tau.

Quarks: particles that make up hadrons. The 6 quarks in order of increasing size: up, down, charm, strange, top, bottom.

Hadrons: particles made up of quarks; examples: protons, neutrons, anti-protons, lambda, and omega

Matter and Antimatter: for every particle there is a corresponding antiparticle. These particles and antiparticles have identical mass and spin but opposite charges.

Definitions

Atomic Number (Z) - the number of protons in the nucleus, in electrically balanced atom, it is also the number of electrons

Atomic Mass (M) - the cumulative average of the following: the average of the mass numbers of all the isotopes of that element with their natural abundances factored in, along with mass defect and the understanding that the number 1 (1 u) is a comparison to 1/12 of the mass of a carbon-12 atom.

Mass Number (A) - the sum of the protons and neutrons that make up that nucleus (or sum of nucleons)

Nucleons - particles (of hadron nature) making up the nucleus of atoms (protons and neutrons)

Element - a pure form of a substance, made up of one kind of atom, elements are simple substances that cannot be decomposed or transformed into another element by chemical means (you must use physical means such as radiation exposure or particle accelerators)

Atom - the smallest particle of an element which possesses the properties of that element

Molecule - a substance made up of 2 or more atoms bonded chemically together, has a definite, invariable composition and structure

Ions and Isotopes

Ions

1. atoms that have lost or gained electrons
2. example: calcium atoms tend to lose 2 electrons in reactions
calcium starts with 20 protons and 20 electrons so that by losing 2 electrons it now is
an ion and is written as Ca^{2+} (it has 2 more protons than electrons)
3. example: oxygen tends to gain 2 electrons in reactions
oxygen starts with 8 protons and 8 electrons and when it gains those 2 electrons it becomes an ion that is written as: O^{2-} (2 more electrons than protons)

Isotopes

1. these are atoms of the same element that have different numbers of neutrons in the nucleus
2. their mass numbers will be different but atomic number is the same
3. example: boron has an atomic mass of 10.81 which is an average of boron-11 that exist in nature 80% of the time and boron-10 that only exist in 20% of the cases.

4. Hydrogen has 3 forms: natural hydrogen with 1 proton and 1 electron, deuterium with 1 proton, 1 neutron, and 1 electron, and tritium with 1 proton, 2 neutrons, and 1 electron.

Bromine-79 and bromine-81 has atomic mass (M) of 79.904 there is no bromine 80

Boron-11 (80 % abundant) and boron -10 (20 % abundant) has $M = 10.81$ (abundance shifts average mass)

Cobalt-60 and gold-181 are used in cancer research, both are man-made

Carbon-13 and oxygen-18 used to find pathways of photosynthesis

Rubidium-87 used in archeological dating

Compounds

Compounds are 2 or more elements chemically joined (meaning held together by chemical bonds)

There is a fixed proportion of these elements by weight.

The properties of the compound are different from those of the component elements.

Compounds can be separated into parts only by chemical means

Mixtures

Mixtures are 2 or more substances (elements or compounds or both) that do not combine chemically during the mixing. The parts are not chemically combined. There is a variable proportion of components and the properties of these components remains the same as before the mixing. The parts can be separated by physical means. Examples: ice tea, concrete, granite

Types:

1. **heterogeneous** -> can divide this type mixture in half and not get 2 identical halves (can see at least 2 parts) examples: concrete, ice tea, wood
2. **homogeneous** -> 2 or more components so evenly distributed that if its divided in half you can't tell the difference between them examples: quartz, glass
3. **emulsion** -> a mixture of of 2 immiscible liquids (liquids that do not mix), may separate back out in time and emulsifiers may be used to keep droplets small example: oil & vinegar, paint, hand creme

4. **alloy** -> a mixture of 2 or more metals melted together having new and different properties from the individual metals example: brass, bronze, pewter
5. **amalgam** -> alloy that contains mercury example: dental filings
6. **solutions** -> typically a liquid homogeneous mixture containing a dissolved substance
 - solvent** -> component in largest concentration
 - solute** -> component in smallest concentration
 - aqueous** -> solvent is water (example: Kool-Aid)
 - tincture** -> solvent is alcohol
7. **colloids** - click to see page of information

Notes on Colloidal Suspensions

The formal study of colloids began in the latter part of the 19th century with the studies of Thomas Graham. The first colloids studied were gelatins and glues, and so Graham used the Greek word *kolla*, meaning glue, as the root for his newly coined term. Colloidal particles may be gaseous, liquid, or solid. They may occur in various types of suspensions, e.g., solid/gas (aerosol), solid/solid, liquid/liquid (emulsion), gas/liquid (foam). It may be useful to observe that a suspension is any system in which small solid or liquid particles are more or less evenly dispersed in a second medium, typically a gas or a liquid. Some sources do not regard colloidal suspensions as suspensions at all, instead reserving this latter term for systems involving particles larger than colloidal size, but we will not adhere to this distinction.

In the size range of colloidal particles, the surface area of the particle is so much greater than its volume that some unusual behavior is observed, e.g., the particles do not settle out by gravity (i.e., they neither float nor sink). Many macromolecules are at the lower limit of this size range (a nanometer). The upper limit to colloidal particle size is commonly taken to be the size at which the particles become visible in an optical (i.e., light) microscope (about 1 micrometer). Natural colloidal systems include rubber latex, milk, blood, and egg-white.

Aerosols are suspensions of liquid or solid particles in a gas. The particles are often in the colloidal size range, making many aerosols colloidal suspensions. Fog (water/air) and smoke (C/air) are common examples of natural aerosols. Fine sprays such as those used with perfumes, insecticides, inhalants, anti-per spirants, and paints are man-made aerosols.

An emulsion is a stable mixture of two or more immiscible liquids held in suspension by small amounts of substances called emulsifiers. Proteins or small carbohydrate polymers (which are themselves colloidal in size) often act as emulsifiers by coating the surfaces of the dispersed phase and thus preventing coalescence. Such emulsifying agents are called protective colloids as they protect the dispersed phase from coalescence and subsequent separation. Long-chain alcohols and fatty acids can also act as emulsifiers by "solubilizing" the dispersed phase by virtue of the former's solubility in the dispersing medium (often water). These emulsifying agents are called detergents. Commercial polymerization reactions are often carried out in emulsion form. Floor and glass waxes, many drugs, photographic coatings, and paints are all examples of emulsion systems.

Foams are dispersions of gases in liquids or solids. If the gas globules are of colloidal size, the foam is a colloidal foam. Yeast breads are examples of solid foams. Shaving cream and whipped

cream are good examples of liquid foams. Useful foams for automobile seats and mattresses are made from natural and synthetic (e.g., polystyrene, polyurethane) latexes. Metal and concrete foams are also possible.

The Tyndall effect can be used to differentiate a true solution from a colloidal suspension in cases where a beam of light can be passed through the material. In a true solution, the light will pass through relatively unimpeded and so not be visible from side view. In a colloidal suspension, the colloid particles are sufficiently large to significantly scatter the light and so make the beam visible from side view.

In closing, it should be noted that true solutions are distinct from colloids in that the dispersed agents in true solutions (i.e., the solutes) are typically atoms, ions, or fairly small molecules.

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Methods to separate mixtures:

1. **filtration**
2. **distillation** -> must know boiling points of two liquids
3. **recrystallization** -> must know melting points and crystal structures (example: ice berg)
4. **use of centrifuge** -> differences in densities
5. **solubility** -> know nature of substances (example: polar molecules and ionic compounds dissolve in polar solvents)
6. **size**
7. **magnetic attraction**
8. **electrical attraction**
9. **chromatography** -> separate due to differences in affinity to surface versus their affinity to solvent

Definitions:

1. **dilute solution**: small amount of solute compared to amount of solvent
2. **concentrated solution**: contains more solute than a dilute solution
3. **saturated solution**: when solvent cannot hold any more solute at that temperature
4. **solubility**: maximum amount of solute that can be dissolved in a given amount of solvent at a specified temperature
5. **suspension**: heterogeneous mixture in which one of the parts is a liquid (visible particles will settle out of any suspension - example = oil and vinegar)
6. **colloids**: particles small enough that they do not settle out (particles do not sink to bottom of containers and usually are too small to be visible (example = gelatin, cold cream, lipstick, shaving cream)
7. **gels**: colloid in which liquid particles are spread out in a solid (example: gelatin, jelly, stick deodorant)
8. **emulsion**: colloid of 2 liquids (example: mayonnaise, hand cream, milk, salad dressing)

9. **aerosol:** colloid in which either solid or liquid particles are suspended in a gas (example = fog or smoke)

Law of Conservation of Mass/Energy

1. In the Universe there is a finite amount of matter and energy. We cannot create any new matter or energy nor can we destroy any of the matter or energy we have for the Universe as a whole.
2. We can change matter to energy and energy to matter without gaining or losing any of either to the Universe. Examples:
3. Energy can be changed in form, from one to another, without any loss to the Universe. Examples:
4. Matter can be changed in form, or state, without any loss of matter to the Universe. Examples:

First Law of Thermodynamics: Conservation of Energy

Second Law of Thermodynamics: Entropy increases in all natural processes

Third Law of Thermodynamics: We cannot reach absolute zero temperatures

Zeroth Law of Thermodynamics: If $T_a = T_b$ and $T_b = T_c$, then $T_a = T_c$, (shows thermal equilibrium in balance)

ENTROPY - entropy is a measure of the randomness of molecular motion - in all natural processes entropy increases - in every energy transformation some of the original energy is changed to heat energy that is not available for any future use -the amount of free energy available for use decreases - heat flows from hotter areas to cooler areas - random motion of molecules increases - can't add heat to system and turn it entirely into work (you always have some heat loss) - no perpetual motion machines can exist -can't take heat from cold object and make hot object hotter without you doing some extra work - example: you have a cup of water at 0°C and another at 100°C , you mix them together in a larger container that will hold 2 cups. The water is now at 50°C . Entropy says that this water will not divide itself back up into 2 cups of 0 and 100°C water unless you do some amount of work to make this happen.

4 Forces in Nature

1. gravity -- this force is dependent on mass and the distance between the objects
2. electromagnetism -- affects all electrically charged particles
3. strong nuclear force -- binds together the particles of the nucleus
4. weak nuclear force -- responsible for nuclear decay (radioactivity)

Mass Defect - When scientist found the actual mass of an atom they found it to be less than what it should have been. This missing mass had been converted into energy to hold the nucleus together. This is called binding energy (an example of the strong nuclear force).

- Magnify a letter on a type written page one million times and you can see the molecules the ink is made of. This is CHEMISTRY.

- Magnify it a billion times more and you see the atoms that make up the molecules. This is ATOMIC PHYSICS.

- Select one atom, magnify it 10 000 times and you are inside the nucleus. This is NUCLEAR PHYSICS.

- Smash the nucleus, disintegrating it into smaller particles. This is PARTICLE PHYSICS.

LEPTONS = particles with no perceptible internal structure (electrons, muons, neutrinos, etc.)

HADRONS = particles composed of quarks (protons, neutrons, pions, etc.)

Quarks (in order of ascending mass) Up, Down, Strange, Charmed, Bottom, Top

1. Quarks form protons, neutrons, but not electrons or positrons
2. Gluons bind together particles these quarks
3. Gluons are similar to photons. Both are massless, move at the speed of light, and neither has an electrical charge.
4. The strength of the gluon is so strong that a quark cannot be separated from a proton, but the quark making up part of the proton may emit a gluon if the conditions are acceptable.
5. The gluon force is called the strong force or color force.
6. Quarks have colors (red, blue, green) and corresponding antiquarks with antired, antiblue, and antigreen.
7. Gluons can interact with other gluons, but when a quark emits a gluon, the color of the quark is changed.
8. If electrons and positrons collide they are both annihilated to form pure energy from which a quark and an antiquark can materialize (of opposite colors of course). These particles have a high kinetic energy which will cause the emission of a gluon, which changes the color of the quark but the total color of the quark, antiquark, and gluon will still cancel to zero.
9. The annihilation of these electrons and positrons form jets of particles, which were first predicted and then actually found. These are called Mercedes Jets.
10. Protons and neutrons are thought to be clouds of particles called mesons which are made up of quarks