# The Atom

It's the smallest unit of a chemical element that still has the properties of that chemical element

## The Atom consists of 2 elements

- **Nucleus** consists of

  **+ Protons** are positively charged and make up the cell's atomic number, they are the main factor in differentiating between cells, it has the charge of 1e, which is $1.602 \times 10^{-19}$

  **± Neutrons** are neutrally charged

  And they define the isotope of the element, It has the mass of $9.1 \times 10^{-31}$g

- **- Electrons** surround the nucleus by an electromagnetic bound cloud, they have a negative charge if their count equals the atomic proton count, then the atom is neutrally charged

**Commented [H1]:** Isotope is a variable of the chemical that has the same number of protons but different in nuetrons, which means that they have the same atomic number but a different mass number, same elements with different isotopes have different physical properties

The atom is the basic particle of chemical elements, they can attach to one or more other atoms by chemical bonds to form chemical compounds like crystals or molecules, the

ability of atoms to attach and detach like that is the reason for most physical changes observed in nature, atoms are extremely small with a diameter of around 100 picometers, the nucleus is around 10 femtometers

Imagine the atom is a solar system where the sun is the positive nucleus, and the planets are negatively charged electrons orbiting the nucleus/sun

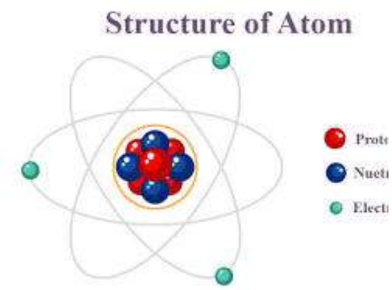
The sun in itself is composed of two materials, just like how the nucleus is composed of protons and neutrons

The neutron is like dark matter so it doesn't affect any charge because of the neutral charge

The cool thing about atoms is that they can differ rapidly like how solar systems work, because when we change our positively charged protons, the nucleus/sun will change the whole solar system's structure giving us a new whole atom/ solar system

## Atoms

Atoms are the smallest units of matter that still have the properties of that chemical element. They are made up of two main parts: the nucleus and the electrons.

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## The nucleus

The nucleus is a tiny, dense region at the center of the atom. It contains protons and neutrons. Protons have a positive charge, while neutrons have no charge. The number of protons in the nucleus determines the atom's atomic number, which is what distinguishes one element from another. For example, all carbon atoms have 6 protons in their nuclei.

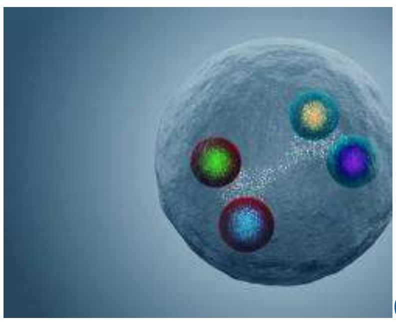
## Electrons

Electrons are negatively charged particles that orbit the nucleus. They are arranged in energy levels, with each level holding a certain number of electrons. The outermost

energy level is called the valence shell. The number of electrons in the valence shell determines the atom's chemical properties. For example, all carbon atoms have 4 electrons in their valence shells.

## Quarks

Quarks are the fundamental building blocks of matter. Protons and neutrons are made up of three quarks each. There are six flavors of quarks: up, down, charm, strange, top, and bottom.



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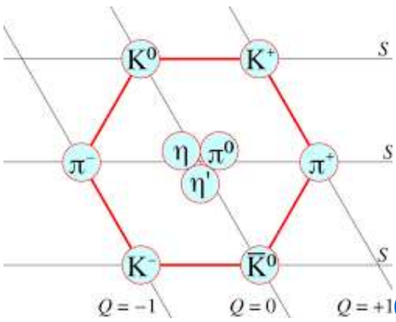
Quarks have a fractional charge, meaning that they can have a charge of +2/3, -1/3, or 0. Protons and neutrons have a charge of +1 and 0, respectively. This is because the charges of the quarks inside them add up to those values.

Quarks are never found alone. They are always bound together in groups of two or three. Groups of two quarks are called mesons. Groups of three quarks are called baryons. Protons and neutrons are baryons.



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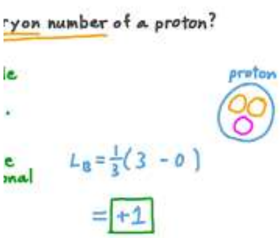

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## How atoms were created

Atoms were created after the Big Bang, about 13.7 billion years ago. As the universe cooled, protons and neutrons formed. These particles then combined to form the first atoms. The earliest atoms were hydrogen and helium. Heavier atoms were formed later in stars, and are still being formed today.

# THE ATOMIC STRUCTURE

It represents the structure of an atom, which means that there is a nucleus in the middle with electrons orbiting around it, and there are two variables we get from it

**Atomic number** = proton count

**Mass number** = proton count + neutron number

Neutral atoms have an equilibrium between + protons and – electrons, however, atoms will increase/decrease their electron count using chemical reactions to stabilize themselves, and the result of the increase/decrease is called an ion

**Commented [H2]:** Ion is a positively or negatively charged electron, aka electron that changed it's default electron acount

That's the reason atoms have different structures because they have a different amount of protons and electrons

## Atomic Mass Number

The atomic mass number of an element is the total number of protons and neutrons in the nucleus of its atom. It is denoted by the symbol A. The atomic mass number is typically written as a superscript to the left of the chemical symbol of the element. For

example, the atomic mass number of carbon is 12, which is written as C-12.

Isotopes of an element have the same number of protons but different numbers of neutrons. Therefore, isotopes have different atomic mass numbers. For example, carbon has two stable isotopes: carbon-12 and carbon-13. Carbon-12 has 6 protons and 6 neutrons, while carbon-13 has 6 protons and 7 neutrons.

The atomic mass number of an element is a useful quantity in chemistry. It can be used to calculate the average mass of an element, which is known as the atomic mass. The atomic mass is used in many chemical calculations, such as calculating the molar mass of compounds and the stoichiometric coefficients of chemical reactions.

Examples

Here are some examples of atomic mass numbers:

- Hydrogen: 1
- Helium: 4
- Carbon: 12
- Oxygen: 16
- Sodium: 23
- Chlorine: 35
- Iron: 56
- Silver: 108
- Gold: 197
- Uranium: 238

# Isotopes

Imagine you have multiple twins that are the same, but they differ in weight, one is fat as fuck, and one is just right 😩 because they have different weights, they try to get to the right weight, because having more weight, will make you unstable, these twins are isotopes

For example

Carbon 12, carbon 13, and carbon 14 are all just carbon atoms with the same atomic number of 6 protons, carbon 12 and 13 are stable with their weight, but carbon 14 will try to lose its weight and go back to the mass number of 12/13

Unstable isotopes often called **radioisotopes** will go through a process called radioactive decay to get rid of the excess neutrons and their energy

Radioactive decay has multiple types

- **Alpha decay** will emit alpha particles, this occurs in heavier elements
- **Beta decay** will emit beta particles, this happens when the nucleus has too few protons, it can convert a proton to a neutron and emit a positron
- **Positron emission** they will emit positrons, this happens when the nucleus has too many protons, it will convert a proton to a neutron and emit a positron
- **Gamma decay** they will emit gamma rays, this happens when the nucleus emits alpha/beta particles and they still have energy
- **Electron capture** will capture an electron and combine it with a proton to create a neutron, this happens when too many protons are in the nucleus
- **Spontaneous fission** when the nucleus is very heavy it will split into two releasing a large amount of energy, it happens to the nucleus with over 230 mass number

## Isobars

It represents atoms with the same mass number but with a different atomic number

For example, Ar, K, Ca have the mass numbers of 40, but the atomic numbers of 18, 19, 20 respectfully

**Commented [H3]:** Helium nucleus

**Commented [H4]:** electrons

**Commented [H5]:** known as an anti electron, is a subatomic particle with the mass of an electron but a positive charge, when it collides with electrons, they produce two or more photos

it was theorized by paul irac in 1928 and discovered by carl d

**Commented [H6]:** high energy photons

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It's like a family where you have all these different cousins "different in atomic number" but they have the same weight "mass number"

## Isotones

It represents atoms with the same neutron count but different proton counts, so Boron12 and carbon13 have different proton counts but they have the same neutron count of 20

It's like when there are multiple different people with **"different proton counts"** but they all same height and **"same neutron count"**

### Alpha particles

it is normally called "alpha ray/alpha radiation", and it consists of two protons and two neutrons, it's like the nucleus of a helium-4, they are a highly ionizing form of particle radiation, although that might sound scary, they have two types

- **Low penetration depth** results from radioactive alpha decay and they will typically be stopped by a few centimeters of air or skin
- **High penetration depth** results from ternary fission is as 3x as energetic and will penetrate 3x as far

You should always think of alpha particles as little helium particles

Without their electrons

## Beta particles

Often called “beta rays or beta radiation”, they are very energetic and fast electrons or positrons emitted by the radioactive decay in the process of beta decay, they have the symbol (β), and they have two types

- **β-** when a neutron is converted into a proton, it shoots a very fast electron, how?
- β+ When a proton is converted into a neutron, it shoots a positron and an electron neutrino, how?
- When the neutron: proton ratio is too low for stability

## Gamma Radiation

also known as gamma rays and has the symbol (γ), it’s a penetrating form of radiation with the shortest wavelength of all electromagnetic waves, gamma rays have frequencies above 30 exahertz

they are emitted during nuclear fission or nuclear explosions, they are high-energy photons that can ionize atoms and they are very dangerous to living cells, they are like the Hulk or rays, they have a lot of energy capable of destroying and mutating living tissues, they are like little superpowered light particles

**Commented [H7]:** The neutron turns into a proton through the emission of a virtual W− boson1. At the quark level, W− emission turns a down quark into an up quark, turning a neutron (one up quark and two down quarks) into a proton (two up quarks and one down quark)1.

**Commented [H8]:** An elemantry particle with 0 electric charge and the spin 1/2, it forms leptons with electrons

**Commented [H9]:** When the binding energy in the daughter nucleus is greater than the parent nucleus

## Problems of Alpha beta gamma

A negative beta particle has a mass of 0, and a charge of -1, basically an electron

$${}^{0}_{-1}\beta$$

A positive beta particle has a mass of 0, and a charge of 1, basically a positron

$${}^{0}_{1}\beta$$

A proton has a mass of 1 and a charge of 1

$${}^{1}_{1}P$$

An alpha particle a mass of 4 and a charge of +2 (aka proton count)

$${}^{4}_{2}\alpha \qquad {}^{4}_{2}He$$

a neutron has a mass of 1 and a charge of 0

$${}^{1}_{0}n$$

the gamma

$${}^{0}_{0}\gamma$$

**BETA DECAY :** let's say you have nitrogen 13 and it produces a beta particle, what is the missing element

$$^{13}_{7}N \longrightarrow {}^{0}_{-1}e +$$

Now the law of conservation of mass tells us that the masses have to be the same, so the missing mass has to be 13

$$^{13}_{7}N \longrightarrow {}^{0}_{-1}e + {}^{13}$$

now for the charge, what number does -1 need to produce 7, obviously the answer is 8

$$^{13}_{7}N \longrightarrow {}^{0}_{-1}e + {}^{13}_{8}$$

Now we need to add an element with the atomic number of 8, which is oxygen

$$^{13}_{7}N \longrightarrow {}^{0}_{-1}e + {}^{13}_{8}O$$

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OBSERVATION : beta decay does not change the **mass** but it increases the **atomic number**, aka the **number of protons**, and decreases the number of **neutrons**

**Which means that**

**in beta decay**, a neutron in the nitrogen atom got turned into a proton and an electron

$$n \longrightarrow p + e^-$$

**Example of positron production**

$$6n \quad {}^{13}_{7}N \longrightarrow {}^{0}_{1}\beta + {}^{13}_{6}C$$

$$7n$$

$${}^{1}_{1}p \longrightarrow {}^{1}_{0}n + {}^{0}_{1}e$$

**What happens when a positron meets an electron**

$${}^{0}_{1}\beta + {}^{0}_{-1}\beta \longrightarrow {}^{0}_{0}\gamma$$

**Electron capture**

When a nucleus captures one of its electrons

Electron Capture

$$^{73}_{33}As + ^{0}_{-1}e \rightarrow ^{73}_{32}Ge$$

40n 41n

$$^{1}_{1}p + ^{0}_{-1}e \rightarrow ^{1}_{0}n$$

**Alpha particle production**

$$^{210}_{84}Po \rightarrow ^{4}_{2}He + ^{206}_{82}Pb$$

## The three atomic laws are:

- **Law of conservation of mass:** Mass can neither be created nor destroyed.
- **Law of definite proportions**: the ratio of mass of the elements in any compound is fixed, so every $H2O$ will always have the same ratio with any the $H2O$

- **Law of multiple proportions:** When two elements form more than one compound, the masses of one element that combine with a fixed mass of the other element are in a simple whole-number ratio or كسور نضيفه .

These laws were developed in the early 19th century by John Dalton, and they are among the most fundamental laws in chemistry.

### Examples of the three atomic laws:

- **Law of conservation of mass:** When you burn a piece of paper, the paper disappears, but the mass of the ashes and the gases produced is the same as the mass of the original paper.
- **Law of definite proportions**: When you combine hydrogen and oxygen to form water, the hydrogen and oxygen always combine in a ratio of 2:1 by mass.
- **Law of multiple proportions:** Carbon and oxygen can form two compounds: carbon monoxide and carbon dioxide. In carbon monoxide, the ratio of carbon to oxygen is 1:1 by mass, while in carbon dioxide, the ratio of carbon to oxygen is 1:2 by mass.

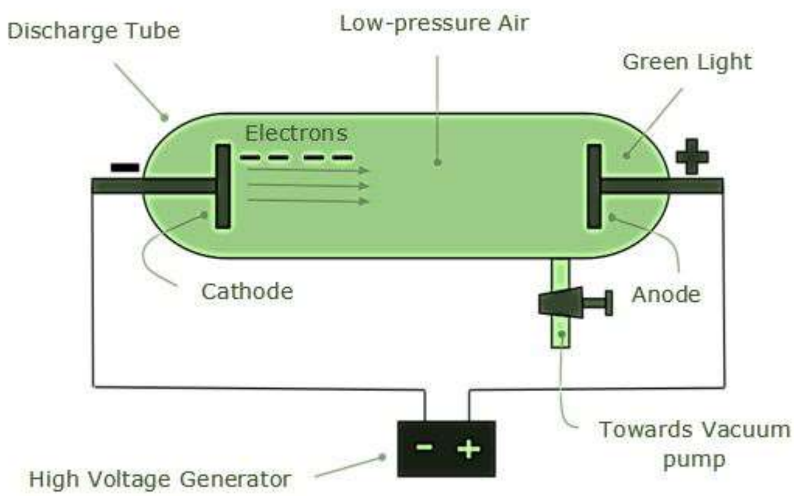
### Cathode Ray Experiment

In the late 19th century, scientists began to study cathode rays, which are streams of electrons that are emitted from a cathode when a voltage is applied to it. Cathode rays can be deflected by electric and magnetic fields, which indicates that they are charged particles.

In 1897, J.J. Thomson conducted a series of experiments on cathode rays to determine their mass and charge. In one experiment, Thomson passed a beam of cathode rays through a chamber with two electrically charged plates. The cathode rays were deflected by the electric field, and the amount of deflection was measured. Thomson then used the amount of deflection to calculate the mass-to-charge ratio of the cathode rays.

In another experiment, Thomson passed a beam of cathode rays through a chamber with a magnetic field. The cathode rays were deflected by the magnetic field, and the amount of deflection was measured. Thomson then used the amount of deflection to calculate the charge-to-mass ratio of the cathode rays.

By combining the results of these two experiments, Thomson was able to calculate the mass and charge of the electron. He found that the electron has a mass of about 9.109×10−31 kilograms and a charge of about −1.602×10−19 coulombs.




**Discovery of Electrons**

## Gold Foil Experiment

In 1909, Ernest Rutherford conducted a series of experiments on the scattering of alpha particles by thin sheets of gold foil. Alpha particles are doubly charged helium nuclei that are emitted by some radioactive atoms.

Rutherford expected that the alpha particles would pass through the gold foil undeflected. However, he found that a small number of alpha particles were deflected at large angles. This led Rutherford to conclude that the atom must have a small, dense nucleus surrounded by a cloud of electrons.

Rutherford's experiment was the first experiment to provide direct evidence for the existence of the atomic nucleus. It also showed that the atom is mostly empty space.

## Facts

- Atoms are the smallest unit of matter that retains all of the chemical properties of an element.
- Atoms are composed of particles called protons, electrons, and neutrons.
- Protons carry a positive electrical charge, electrons carry a negative charge, and neutrons carry no electrical charge.
- The atomic number of an element is determined by the number of protons in the nucleus of its atom.
- The mass number of an element is determined by the total number of protons and neutrons in the nucleus of its atom.
- Isotopes of an element have the same number of protons but different numbers of neutrons.
- Ions are atoms or molecules that have lost or gained electrons.
- Atoms can combine to form molecules and compounds.
- The properties of an element are determined by the number and arrangement of its electrons.

## HISTORY OF FIGURING OUT ATOMS

Ancient Greece

- 460-370 BC: Democritus, a Greek philosopher, proposed the idea of atoms. He believed that atoms were the smallest possible particles of matter, and that they were indivisible and indestructible.

18th Century

- 1766-1844: John Dalton, an English chemist, developed the first modern atomic theory. Dalton's theory was based on the following observations:
    - Elements can combine to form compounds in fixed, whole-number ratios.
    - All compounds of a given element have the same proportion of that element by mass.
    - Atoms of a given element are identical in mass and properties.
    - Atoms of different elements have different masses and properties.

Dalton also proposed that atoms were indivisible and indestructible.

19th Century

- 1832-1919: William Crookes, an English physicist and chemist, discovered cathode rays. Cathode rays are streams of electrons that are emitted from a cathode when a voltage is applied to it. Crookes found that cathode rays could be deflected by electric and magnetic fields, and that they had a mass that was much smaller than the mass of any known atom.

- 1856-1940: J.J. Thomson, an English physicist, conducted a series of experiments on cathode rays in the late 19th century. Thomson found that cathode rays could be deflected by electric and magnetic fields, and that they had a mass that was much smaller than the mass of any known atom. Thomson concluded that cathode rays were made up of tiny, negatively charged particles called electrons.
- 1871-1937: Ernest Rutherford, a New Zealand physicist, conducted the gold foil experiment in 1909. In this experiment, Rutherford bombarded a thin sheet of gold foil with alpha particles, which are positively charged helium nuclei. He found that most of the alpha particles passed through the gold foil undeflected, but a small number of alpha particles were deflected at large angles. Rutherford concluded that the atom must have a small, dense nucleus surrounded by a cloud of electrons.

20th Century

- 1885-1962: Niels Bohr, a Danish physicist, developed a quantum mechanical model of the atom in 1913. Bohr's model proposed that electrons orbit the nucleus in discrete energy levels, and that they can only move between energy levels by absorbing or emitting photons of light.

- 1891-1974: James Chadwick, an English physicist, discovered the neutron in 1932. The neutron is a subatomic particle that has no electrical charge and is slightly heavier than the proton.
- 1888-1969: Otto Stern, a German physicist, and Otto Frisch (1904-1979), an Austrian-born British physicist, discovered nuclear fission in 1939. Nuclear fission is the splitting of a heavy atom into two lighter atoms, releasing a large amount of energy.
- 1901-1994: Linus Pauling, an American chemist, proposed the alpha helix model of DNA in 1951. The alpha helix is a spiral structure that DNA molecules take on.
- 1928-present: James Watson, an American molecular biologist and geneticist, and Francis Crick (1916-2004), a British molecular biologist and physicist, discovered the structure of DNA in 1953. DNA is the genetic material that is found in all living organisms.
- 1918-2013: Frederick Sanger, a British biochemist and chemist, sequenced the first human genome in 2003. The human genome is the complete set of genetic information that is found in humans.

21st Century

- Scientists are continuing to study atoms and atomic structure, and they are making new discoveries all the time. For example, in recent years, scientists have discovered new types of atoms and new ways to manipulate atoms.

Dalton also proposed that atoms were indivisible and indestructible. |

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| 1879 | J.J. Thomson | Discovered the electron | Thomson was an English physicist who conducted a series of experiments on cathode rays in the late 19th century. Thomson found that cathode rays could be deflected by electric and magnetic fields, and that they had a mass that was much smaller than the mass of any known atom. Thomson concluded that cathode rays were made up of tiny, negatively charged particles called electrons. |

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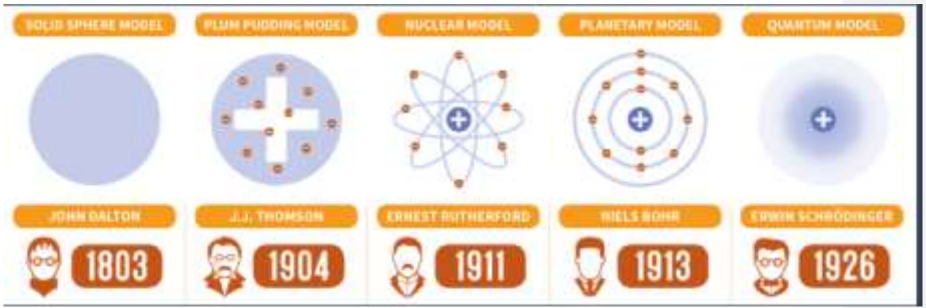
| 1939 | Otto Stern and Otto Frisch | Discovered nuclear fission | Stern and Frisch were physicists who discovered nuclear fission in 1939. Nuclear fission is the splitting of a heavy atom into two lighter atoms, releasing a large amount of energy. |

| 1951 | Linus Pauling | Proposed the alpha helix model of DNA | Pauling was an American chemist who proposed the alpha helix model of DNA in 1951. The alpha helix is a spiral structure that DNA molecules take on. |

| 1953 | James Watson and Francis Crick | Discovered the structure of DNA | Watson and Crick were molecular biologists and physicists who discovered the structure of DNA




## ATOMS VS SOLAR SYSTEMS

| SIMILARITIES | DIFFERENCES |
|---|---|
| • They both have something in the center<br>• They both have smaller stuff that orbits the center | • They are affected by different forces (electromagnetic field, gravitinial pull)<br>• Electrons orbit around in a zone, planets go in a fixed orbit |

# CAPSTONE

- Knowing atoms will help with materials
- Radioactive materials will be avoided cuz isotopes
- Knowing rays like alpha, beta, gamma will help with safety standards

# NOTES

- An atom is the smallest unit of matter that retains all of the chemical properties of an element.

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- Atoms are composed of particles called protons, electrons, and neutrons.
- Protons carry a positive electrical charge, electrons carry a negative charge, and neutrons carry no electrical charge.
- The atomic number of an element is determined by the number of protons in the nucleus of its atom.
- Isotopes are variants of a particular chemical element which differ in neutron number, and consequently in nucleon number.
- Isobars are atomic species that have the same mass number but different atomic numbers.
- The term “isobar” was first used by Alfred Walter Stewart in 1918.
- Isotones are nuclides of different chemical elements that have the same neutron number.
- The term “isotone” was formed by the German physicist K. Guggenheimer.
- Alpha particles, also known as alpha radiation, are emitted by certain types of radioactive substances. They consist of two protons and two neutrons bound together.
- Alpha particles were discovered by Ernest Rutherford in 1899.
- Beta particles, also known as beta radiation, are high-energy, high-speed electrons or positrons emitted by certain types of radioactive substances during beta decay.
- Beta particles were discovered by Ernest Rutherford in 1899.
- Gamma rays are a form of electromagnetic radiation that arises from the radioactive decay of atomic nuclei. They consist of the shortest wavelength electromagnetic waves and typically have higher energy than X-rays.
- Gamma rays were discovered by Paul Villard in 1900.
- John Dalton was an English chemist, physicist, and meteorologist who is best known for introducing the atomic theory into chemistry.
- Dalton’s atomic theory proposed that all matter is composed of atoms, indivisible and indestructible building blocks. Different atoms combine in simple whole-number ratios to form compounds.

- The size of an atom is typically around 100 picometers (a ten-billionth of a meter).
- The size of a proton is about 0.84–0.87 femtometers (fm), which is equivalent to $0.84–0.87 \times 10^{-15}$ meters.
- The size of a neutron is similar to that of a proton with a radius of about 0.8 fm ($0.8 \times 10^{-15}$ meters).
- Electrons are much smaller than protons and neutrons with their size being less than $10^{-18}$ meters or 0.000000000000000001 meters.
- The mass of a proton is approximately $1.67262192 \times 10^{-24}$ grams. The mass of a neutron is slightly larger than that of a proton, approximately $1.67492749804(95) \times 10^{-24}$ grams.
- Electrons are much lighter than protons and neutrons with their mass being approximately $9.10938356 \times 10^{-28}$ grams.
- Protons carry a positive charge equal to +1e, where e is the elementary charge (approximately equal to $1.602176634 \times 10^{-19}$ coulombs).
- Neutrons carry no charge, they are neutral particles.
- Electrons carry a negative charge equal to -1e (approximately equal to $-1.602176634 \times 10^{-19}$ coulombs).
- Alpha particles carry a positive charge because they consist of two protons and two neutrons.
- Beta particles can either be negatively charged (if they are electrons) or positively charged (if they are positrons).
- Gamma rays do not carry any charge as they are electromagnetic waves…
- The atomic mass unit, often abbreviated as AMU, is a unit of mass used to express atomic and molecular weights. It is defined as one-twelfth of the mass of an unbound neutral atom of carbon-12 in its nuclear and electronic ground state and at rest.
- The AMU is used in atomic physics, chemistry, and related fields to measure masses extremely precisely. When the mass of an atom is expressed in AMU, it roughly equals the sum of the number of protons and neutrons in the atomic nucleus (electrons contribute negligibly to the overall mass). The symbol for the unit is "u" (unified atomic mass unit) or "Da" (Dalton), although "AMU" may still be used.

- The concept of an atomic mass unit was first introduced by the Italian chemist Stanislao Cannizzaro in 1826–1910. He initially used hydrogen as a reference standard for atomic weight. However, the current definition based on carbon-12 was adopted by the international scientific community much later in 1961. This standardization allows scientists worldwide to compare their measurements accurately.
- The atomic mass unit is measured to be 1/12 of a carbon12 atom which is approx. 1.66 x 10^-24 grams
- Protons are composed of two up quarks with charge +2/3e each and one down quark with charge -1/3e. The rest masses of quarks contribute only about 1% of a proton's mass.
- The neutron is composed of two down quarks each with -1/3e charge and one up quark with +2/3e charge.
- Electrons are elementary particles and not made up of smaller components .
- The quark model was independently proposed by physicists Murray Gell-Mann and George Zweig in 1964 .
- The mass-to-charge ratio (m / Q) is a physical quantity relating the mass (quantity of matter) and the electric charge of a given particle, expressed in units of kilograms per coulomb (kg/C).
- The mass-to-charge ratio is used in the electrodynamics of charged particles, e.g. in electron optics and ion optics.
- The importance of the mass-to-charge ratio, according to v electrodynamics, is that two particles with the same mass-to-charge ratio move in the same path in a vacuum, when subjected to the same electric and magnetic fields.
- Some disciplines use the charge-to-mass ratio (Q / m) instead, which is the multiplicative inverse of the mass-to-charge ratio.

The CODATA recommended value for an electron is Qm = −1.758 820 010 76(53) × 1011 C·kg−1.

- The discovery of quarks was first theorized in 1964 in the work of two physicists, Murray Gell-Mann and George Zweig, who were both at the California Institute of Technology (CalTech) but who came to the conclusion that quarks exist independently of one another . 40-In 1968, a series of electron-proton scattering experiments by the MIT-SLAC collaboration at the Stanford Linear Accelerator Center (SLAC) in the US revealed the first signs that nucleons have an inner structure .
- In numerous experiments at CERN including those at the Large Hadron Collider (LHC), physicists are measuring the properties of Gell-Mann and Zweig's particles with ever-greater precision
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