Chemistry - 101

Let’s continue the journey – day 2

HW 1

How many molecules of oxygen (O2) will be necessary to turn one molecule of aspirin into carbon dioxide (CO2) and water (H2O)?

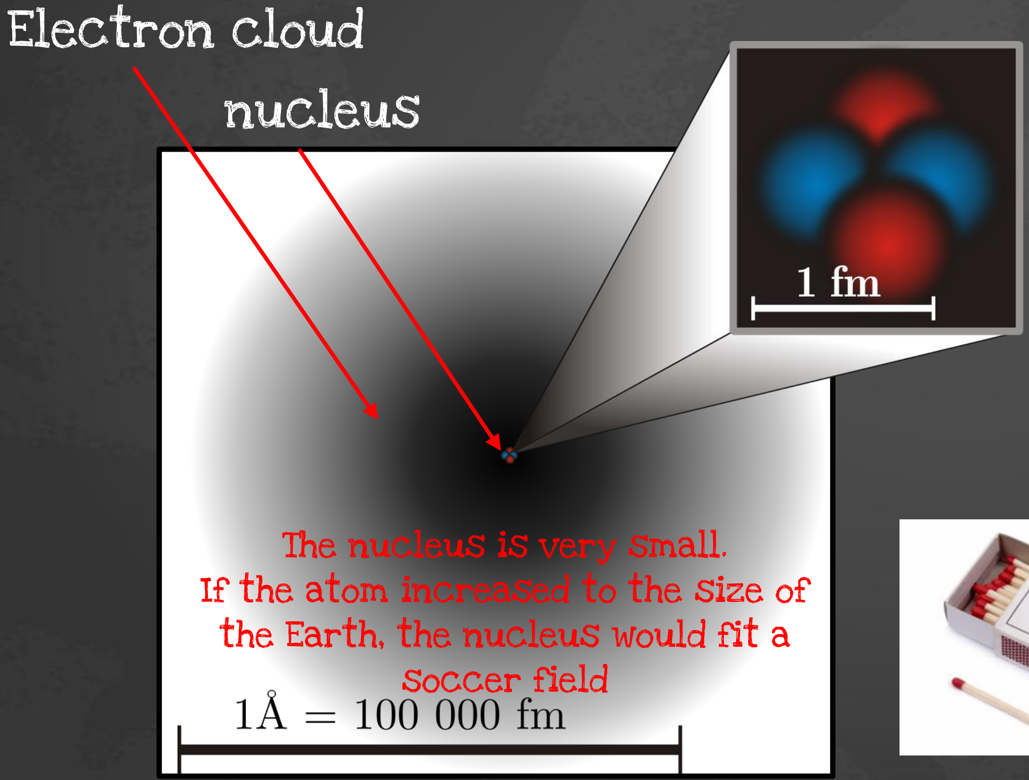
$$C_9H_8O_4 + O_2 \rightarrow CO_2 + H_2O$$

What are the building blocks and the building rules?

What is the difference between different atoms?
Why do the atoms connect the way they connect and not in some different way?
Why did the atoms of oxygen and nitrogen connect by two and argon stay alone in the air?
Can the carbon dioxide atoms be connected differently?
How do atom attach to each other?

Atomic composition

- Atoms are made up of even smaller particles, which define properties of elements
- If you change the arrangement of these particles or the number of these particles you will change the properties of the element or the element itself



- Almost all atomic mass is in the nucleus
- The density of matter in the nucleus is enormous - 10^{13}-10^{14} g/cm^3 (density of lead is 11.29 g/cm^3)
- The atoms are tiny, classical physics cannot accurately predict their behavior (quantum effects)

2.5x10^9 tons ~ 200 Egyptian pyramids

Atomic Composition

- Atoms are made of nucleus and an electron cloud around it
- The electron cloud has a negative charge, protons in the nucleus have positive charge.
- In each atom the number of protons is equal to the number of electrons so as a whole an atom is neutral
- (An atom can loose or acquire electrons, getting charged)
- In addition to protons a nucleus contains neutrons. The neutrons do not have any charge
- Electrons, protons and neutrons are subatomic particles

The Size of the atom

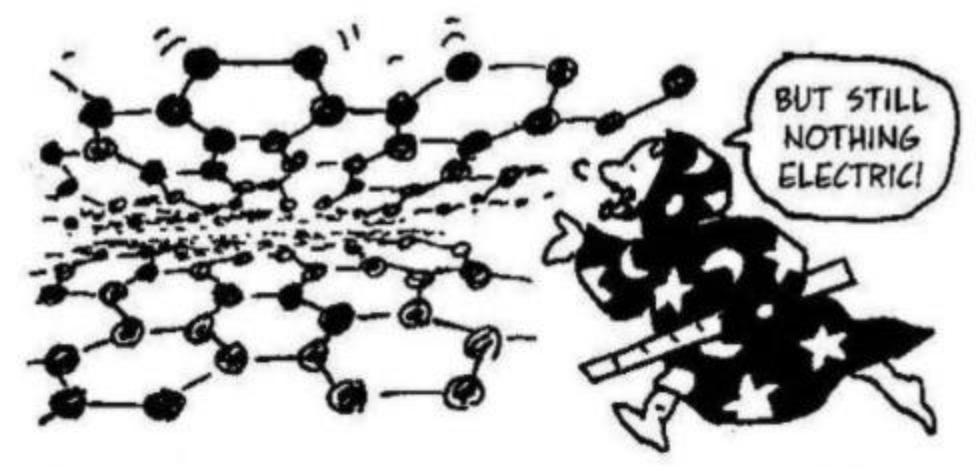
If we Shrink ***a million times***...

A human hair is now thirty stories thick...

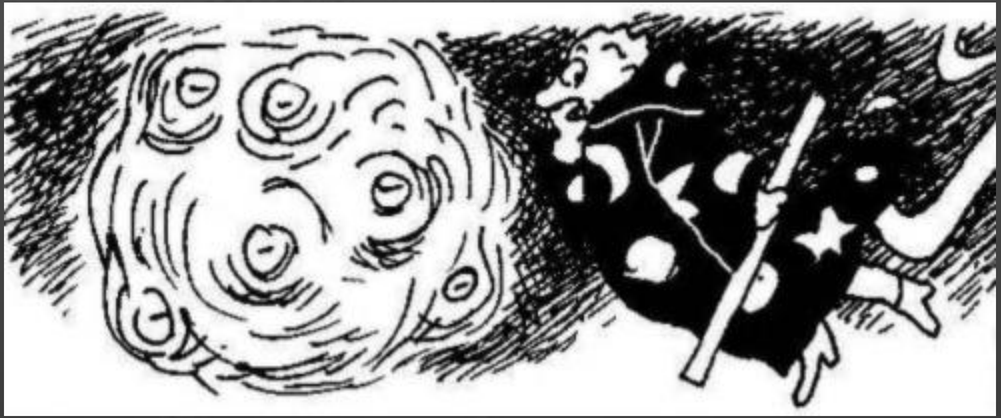
Bacteria are the size of torpedoes...

And atoms are just barely visible as tiny specks.

Shrink another thousand times brings us to NANOMETER (10^{-9} meter) scale. The little man is about 2 nm tall, and the atoms are about 1/10th of his size



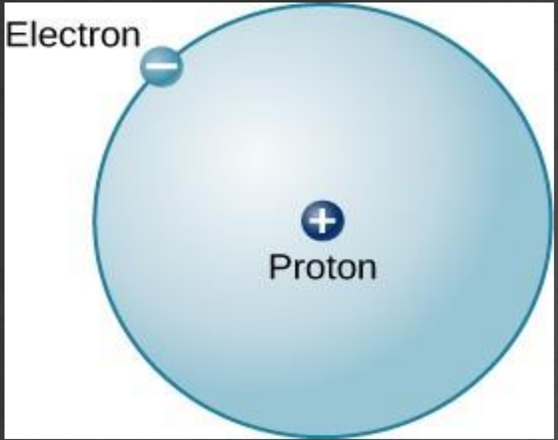
Let's shrink 10 more times to atomic size - 10^{-10} meter and look at a single carbon atom. Some electrons are humming around... but where are positive charges?

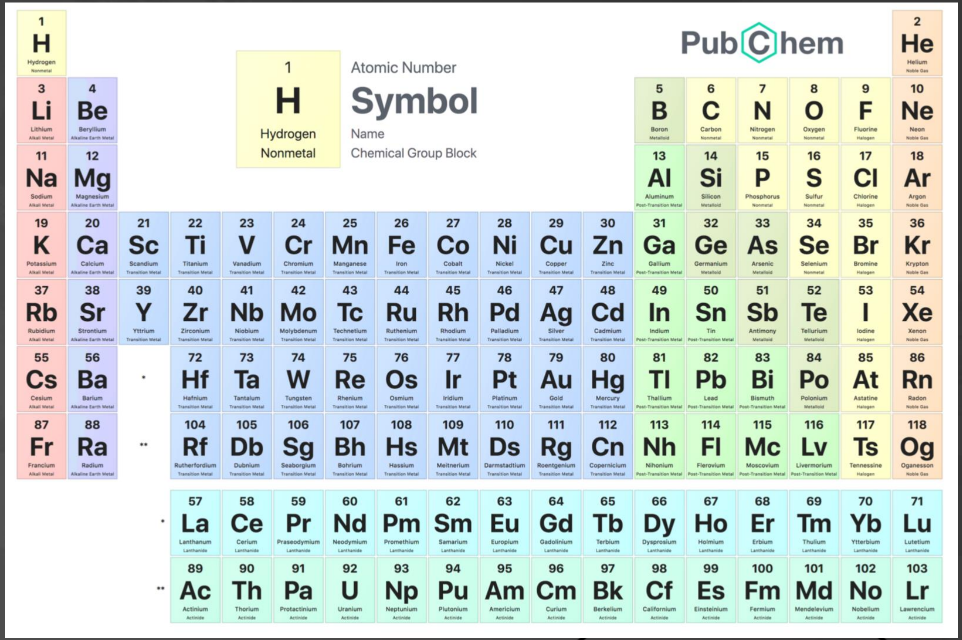


Now the man is a hundred times smaller, PICOMETER scale. That is a million of a millionth, or 10^{-12} actual size.

If the diameter of the atom were the length of a football field, then the nucleus would be smaller than a pea.

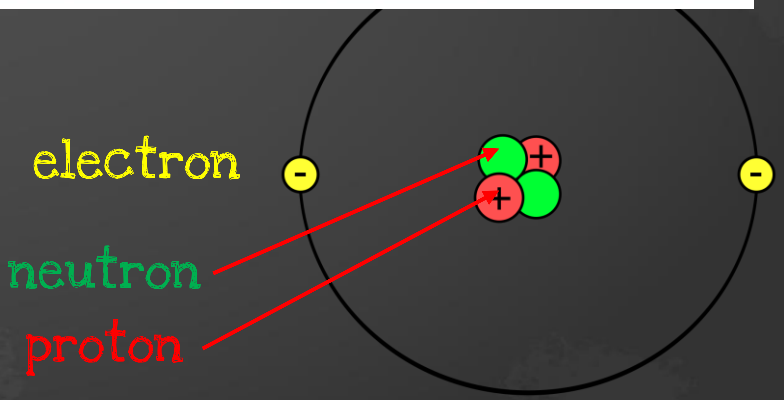
The atom is mostly empty space!





This is hydrogen atom

- The number of protons defines the element
- The elements in the periodic table are written in the order of their atomic numbers, which is the number of protons

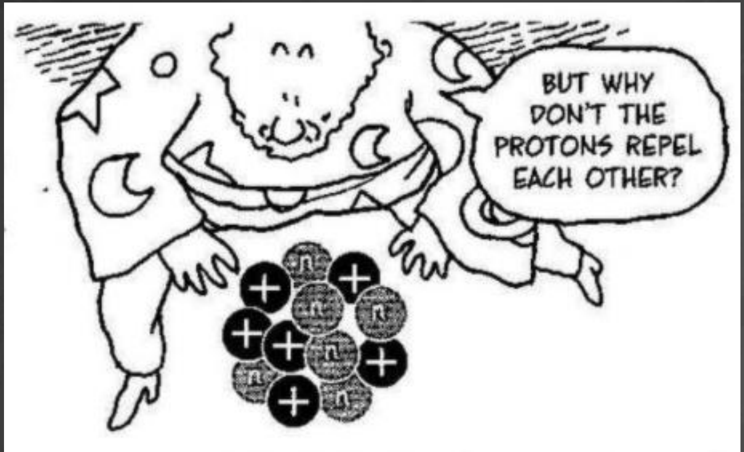


PubChem

1 H Hydrogen Nonmetal
Atomic Number **Symbol** Name Chemical Group Block

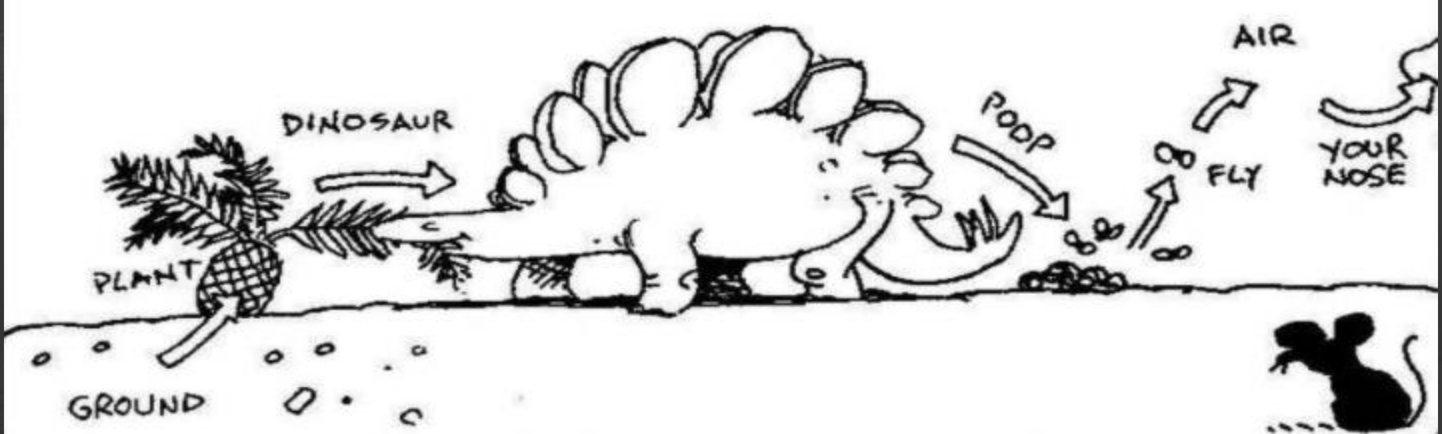
1 H Hydrogen Nonmetal																	2 He Helium Noble Gas
3 Li Lithium Alkali Metal	4 Be Beryllium Alkaline Earth Metal											5 B Boron Metalloid	6 C Carbon Nonmetal	7 N Nitrogen Nonmetal	8 O Oxygen Nonmetal	9 F Fluorine Halogen	10 Ne Neon Noble Gas
11 Na Sodium Alkali Metal	12 Mg Magnesium Alkaline Earth Metal											13 Al Aluminum Post-Transition Metal	14 Si Silicon Metalloid	15 P Phosphorus Nonmetal	16 S Sulfur Nonmetal	17 Cl Chlorine Halogen	18 Ar Argon Noble Gas
19 K Potassium Alkali Metal	20 Ca Calcium Alkaline Earth Metal	21 Sc Scandium Transition Metal	22 Ti Titanium Transition Metal	23 V Vanadium Transition Metal	24 Cr Chromium Transition Metal	25 Mn Manganese Transition Metal	26 Fe Iron Transition Metal	27 Co Cobalt Transition Metal	28 Ni Nickel Transition Metal	29 Cu Copper Transition Metal	30 Zn Zinc Transition Metal	31 Ga Gallium Post-Transition Metal	32 Ge Germanium Metalloid	33 As Arsenic Metalloid	34 Se Selenium Nonmetal	35 Br Bromine Halogen	36 Kr Krypton Noble Gas
37 Rb Rubidium Alkali Metal	38 Sr Strontium Alkaline Earth Metal	39 Y Yttrium Transition Metal	40 Zr Zirconium Transition Metal	41 Nb Niobium Transition Metal	42 Mo Molybdenum Transition Metal	43 Tc Technetium Transition Metal	44 Ru Ruthenium Transition Metal	45 Rh Rhodium Transition Metal	46 Pd Palladium Transition Metal	47 Ag Silver Transition Metal	48 Cd Cadmium Transition Metal	49 In Indium Post-Transition Metal	50 Sn Tin Post-Transition Metal	51 Sb Antimony Metalloid	52 Te Tellurium Metalloid	53 I Iodine Halogen	54 Xe Xenon Noble Gas
55 Cs Cesium Alkali Metal	56 Ba Barium Alkaline Earth Metal	*	72 Hf Hafnium Transition Metal	73 Ta Tantalum Transition Metal	74 W Tungsten Transition Metal	75 Re Rhenium Transition Metal	76 Os Osmium Transition Metal	77 Ir Iridium Transition Metal	78 Pt Platinum Transition Metal	79 Au Gold Transition Metal	80 Hg Mercury Transition Metal	81 Tl Thallium Post-Transition Metal	82 Pb Lead Post-Transition Metal	83 Bi Bismuth Post-Transition Metal	84 Po Polonium Metalloid	85 At Astatine Halogen	86 Rn Radon Noble Gas
87 Fr Francium Alkali Metal	88 Ra Radium Alkaline Earth Metal	**	104 Rf Rutherfordium Transition Metal	105 Db Dubnium Transition Metal	106 Sg Seaborgium Transition Metal	107 Bh Bohrium Transition Metal	108 Hs Hassium Transition Metal	109 Mt Meitnerium Transition Metal	110 Ds Darmstadtium Transition Metal	111 Rg Roentgenium Transition Metal	112 Cn Copernicium Transition Metal	113 Nh Nihonium Post-Transition Metal	114 Fl Flerovium Post-Transition Metal	115 Mc Moscovium Post-Transition Metal	116 Lv Livermorium Post-Transition Metal	117 Ts Tennessine Halogen	118 Og Oganesson Noble Gas
		*	57 La Lanthanum Lanthanide	58 Ce Cerium Lanthanide	59 Pr Praseodymium Lanthanide	60 Nd Neodymium Lanthanide	61 Pm Promethium Lanthanide	62 Sm Samarium Lanthanide	63 Eu Europium Lanthanide	64 Gd Gadolinium Lanthanide	65 Tb Terbium Lanthanide	66 Dy Dysprosium Lanthanide	67 Ho Holmium Lanthanide	68 Er Erbium Lanthanide	69 Tm Thulium Lanthanide	70 Yb Ytterbium Lanthanide	71 Lu Lutetium Lanthanide
		**	89 Ac Actinium Actinide	90 Th Thorium Actinide	91 Pa Protactinium Actinide	92 U Uranium Actinide	93 Np Neptunium Actinide	94 Pu Plutonium Actinide	95 Am Americium Actinide	96 Cm Curium Actinide	97 Bk Berkelium Actinide	98 Cf Californium Actinide	99 Es Einsteinium Actinide	100 Fm Fermium Actinide	101 Md Mendelevium Actinide	102 No Nobelium Actinide	103 Lr Lawrencium Actinide

Atoms



The nucleus is held together by a powerful short-range force attraction called THE STRONG FORCE, which overcomes electrical repulsion.

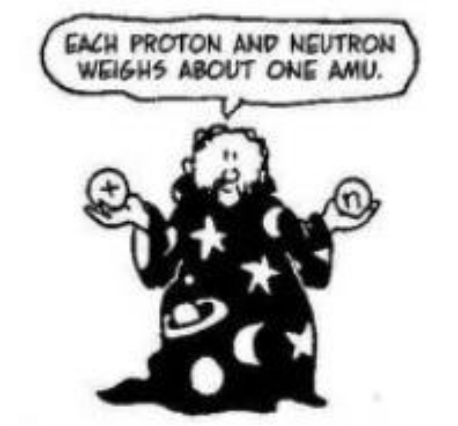
This intense pull makes most nuclei virtually indestructible.



Atomic mass

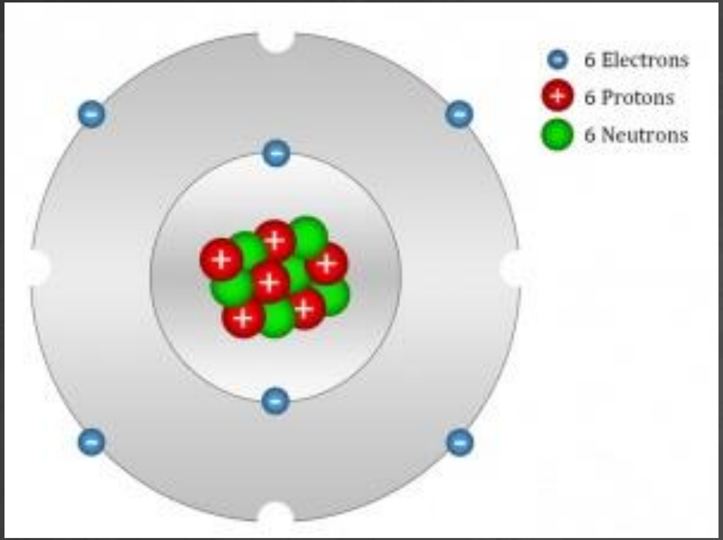
- **Atomic number** – is the number of protons in nucleus
  - Atomic number of C?
- **Atomic mass ? Each proton and neutron has 1840 times the mass of an electron**

Particle	Mass	
	kg	AMU
PROTON	$1.673x10^{-24}g$	1.00728
NEUTRON	$1.675x10^{-24}g$	1.00867
ELECTRON	$0.00091x10^{-24}g$	0.000549

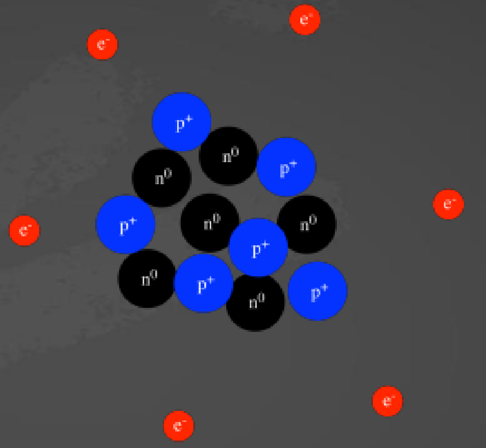


- **Chemists define an atomic mass unit, or AMU, to be precisely one-twelfth the mass of a ^{12}C atom. The common carbon atom has a mass of exactly 12.000000 AMU, by definition.**
- **All other atomic masses are computed relative to this reference.**

Isotopes



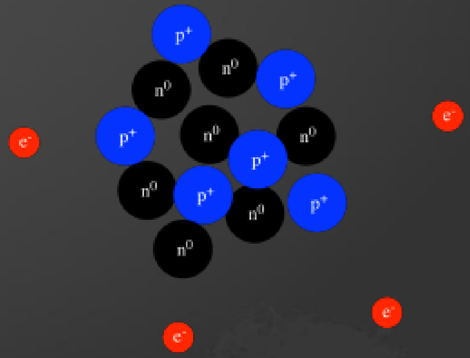
We can write it as ^{12}C

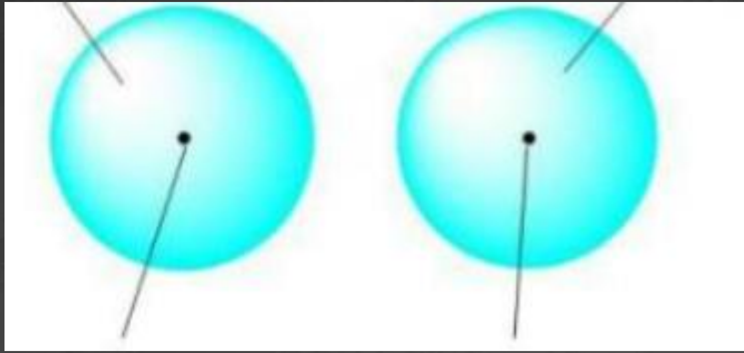


This atom has
6 protons
7 neutrons
6 electrons

This is carbon ("C") atom
It has :
6 protons
6 neutrons
6 electrons

It is still a carbon atom
We can write it as ^{13}C
In the natural carbon it is
present at ~1%





$^{12}_{6}C$ $^{13}_{6}C$

Atomic mass of C=
(0.989x12)+(0.011x13) = 12.011

$$\text{atomic mass of an element} = \left(\text{fractional abundance of isotope 1} \times \text{mass of isotope 1}\right) + \left(\text{fractional abundance of isotope 2} \times \text{mass of isotope 2}\right) + \ldots$$

Isotopes

Isotope - each of two or more forms of element that contain equal number of protons but different number of neutrons in their nuclei, and hence differ in relative atomic mass but no in chemical properties.

Most natural isotopes are stable
The unstable ones fall apart releasing subatomic particles and electromagnetic waves. This is called radioactivity

Element	Latin name	Atomic mass of the element in nature	Atomic mass of isotopes	% of isotope in the element in nature
Hydrogen	Hydrogenium	1.0079		
$^{1}_{1}H$			1.0078	99.984
$^{2}_{1}H$ (D)			2.0140	0.0156
Carbon	Carboneum	12.011		
$^{12}_{6}C$			12.000	98.892
$^{13}_{6}C$			13.00335	1.108
Nitrogen	Nitrogenium	14.0067		
$^{14}_{7}N$			14.00307	99.635
$^{15}_{7}N$			15.00011	0.365
Oxygen	Oxygenium	15.9994		
$^{16}_{8}O$			15.99491	99.759
^{17}O			16.9991	0.037
$^{18}_{8}O$			17.9992	0.204
Sodium	Natrium	22.9898		
$^{23}_{11}Na$			22.9898	100
Chlorine	Chlorium	35.453		
$^{35}_{17}Cl$			34.96885	75.53
^{37}Cl			36.9658	24.47

A Special element Hydrogenium

- Hydrogen is the only element that has different symbols and names for its isotopes:
  - ^{1}H – protonium
  - ^{2}D – deuterium
  - ^{3}T - tritium