Not only is the Universe stranger than we imagine, it is stranger than we can imagine.

- Sir Arthur Eddington

Humanity is acquiring all the right technology for all the wrong reasons.

- R. Buckminster Fuller

The objects in our world are made of “substances” with different properties

- gases, liquids, solids
- clear, colored, soft, hard, stiff, flexible, acidic, basic, viscous

Substances undergo transformations

- phase changes
- chemical reactions
- mixing of substances

Before about 1700, the predominant view was that substances were mixtures of four “elements”: earth, air, fire, and water

Properties of substances were explained by postulating different amounts of each element in that substance

Transformations were explained by elements entering or leaving the substance

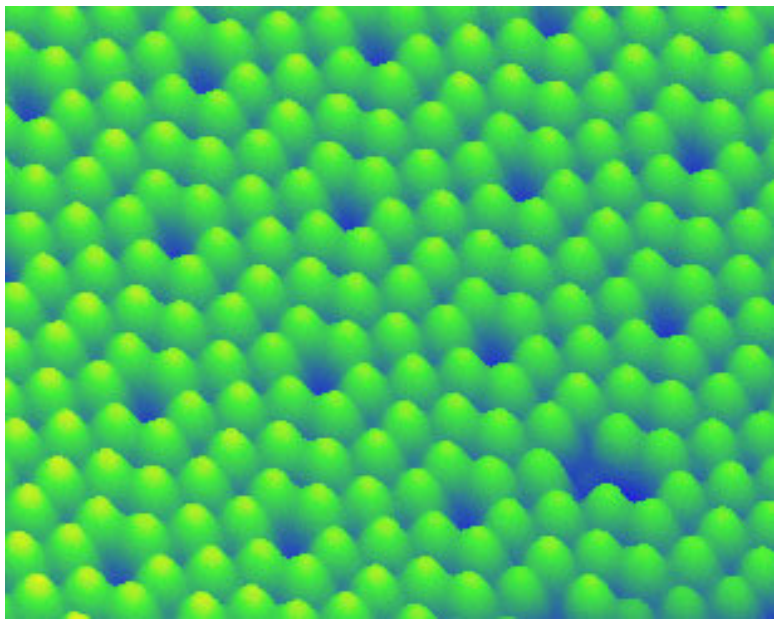
After about 1700 the idea of “atoms” gained ground, becoming the accepted theory of chemistry around 1850

Atom comes from Greek “a” – “tome”, roughly “can’t cut” or indivisible

Key observation was “the law of definite proportions”

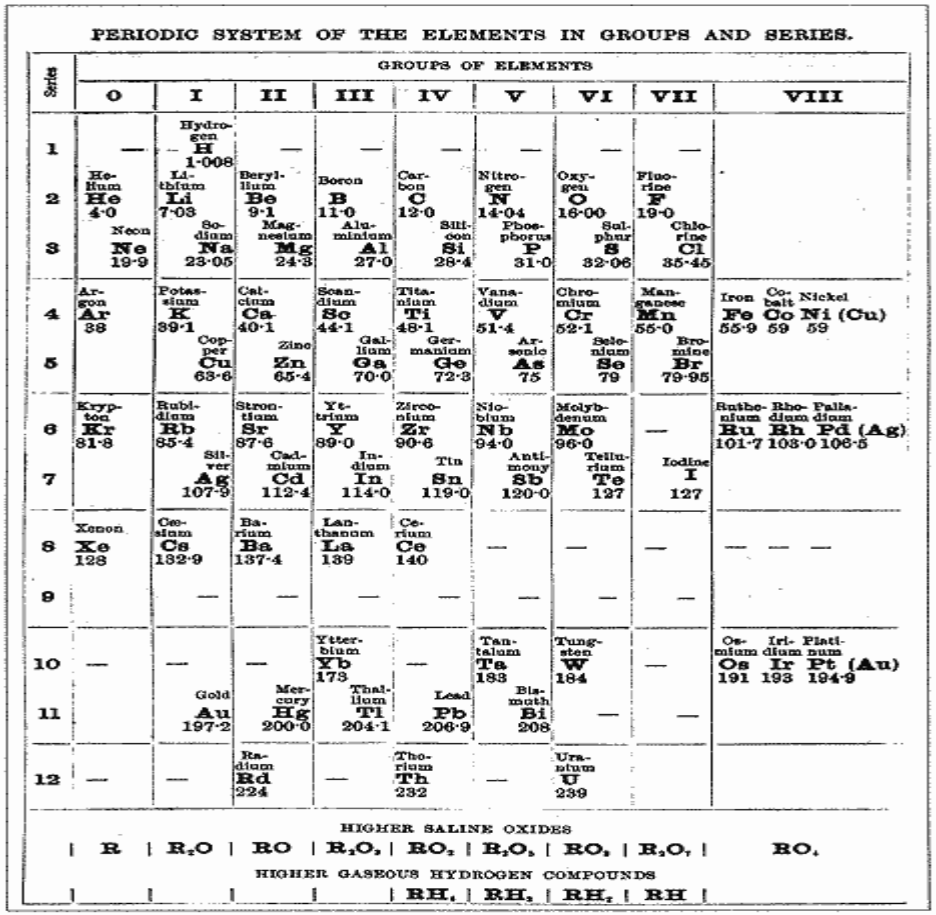
substances contained fixed, integer proportions of different elements

e.g., H_2O



Many more elements than four! (though many not yet discovered in 1850)

Periodic arrangement also not yet known (Mendeleev, 1870)



PERIODIC SYSTEM OF THE ELEMENTS IN GROUPS AND SERIES.

Series	GROUPS OF ELEMENTS								
	0	I	II	III	IV	V	VI	VII	VIII
1	—	Hydrogen H 1·008	—	—	—	—	—	—	
2	Helium He 4·0	Lithium Li 7·03	Beryllium Be 9·1	Boron B 11·0	Carbon C 12·0	Nitrogen N 14·04	Oxygen O 16·00	Fluorine F 19·0	
3	Neon Ne 19·9	Sodium Na 23·05	Magnesium Mg 24·3	Aluminium Al 27·0	Silicon Si 28·4	Phosphorus P 31·0	Sulphur S 32·06	Chlorine Cl 35·45	
4	Argon Ar 38	Potassium K 39·1	Calcium Ca 40·1	Scandium Sc 44·1	Titanium Ti 48·1	Vanadium V 51·4	Chromium Cr 52·1	Manganese Mn 55·0	Iron Fe 55·9 / Cobalt Co 59 / Nickel Ni 59 (Cu)
5		Copper Cu 63·6	Zinc Zn 65·4	Gallium Ga 70·0	Germanium Ge 72·3	Arsenic As 75	Selenium Se 79	Bromine Br 79·95	
6	Krypton Kr 81·8	Rubidium Rb 85·4	Strontium Sr 87·6	Yttrium Y 89·0	Zirconium Zr 90·6	Niobium Nb 94·0	Molybdenum Mo 96·0	—	Ruthenium Ru 101·7 / Rhodium Rh 103·0 / Palladium Pd 106·5 (Ag)
7		Silver Ag 107·9	Cadmium Cd 112·4	Indium In 114·0	Tin Sn 119·0	Antimony Sb 120·0	Tellurium Te 127	Iodine I 127	
8	Xenon Xe 128	Cæsium Cs 132·9	Barium Ba 137·4	Lanthanum La 139	Cerium Ce 140	—	—	—	— — —
9		—	—	—	—	—	—	—	
10	—	—	—	Ytterbium Yb 173	—	Tantalum Ta 183	Tungsten W 184	—	Osmium Os 191 / Iridium Ir 193 / Platinum Pt 194·9 (Au)
11		Gold Au 197·2	Mercury Hg 200·0	Thallium Tl 204·1	Lead Pb 206·9	Bismuth Bi 208	—	—	
12	—	—	Radium Rd 224	—	Thorium Th 232	—	Uranium U 239		

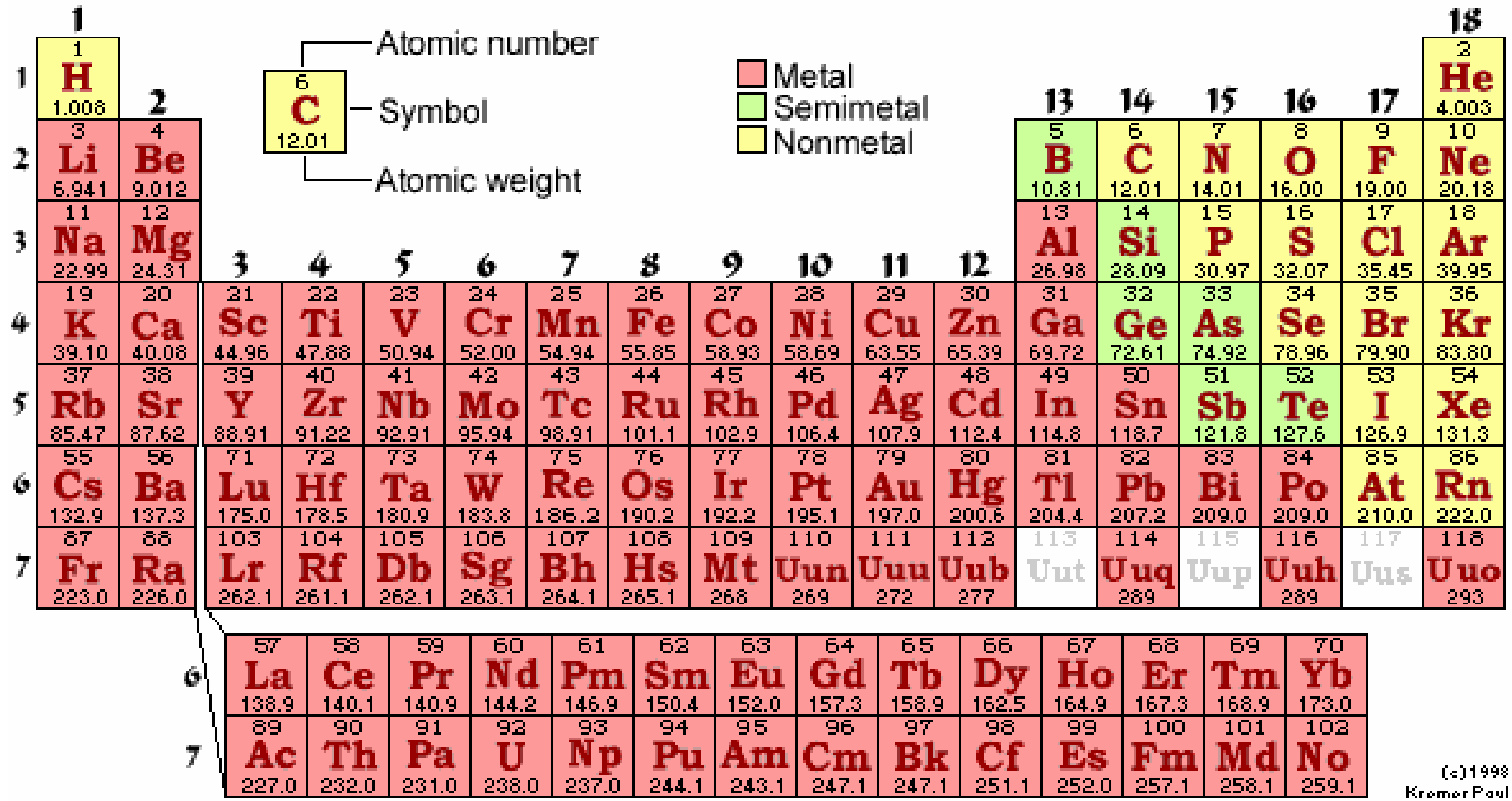
HIGHER SALINE OXIDES

R	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4

HIGHER GASEOUS HYDROGEN COMPOUNDS

				RH_4	RH_3	RH_2	RH

Modern Periodic Table



Brownian Motion demo

Crooke’s Tube demo

The Principle Players

The electron: e^-, negatively charged, very small mass (1/2000 of proton mass)

The proton, p^+, positively charged, feels strong force

The neutron, n^0, no charge, about same mass as proton, feels strong force

Charge is *quantized* – only integer multiples of charge of electron (or proton)

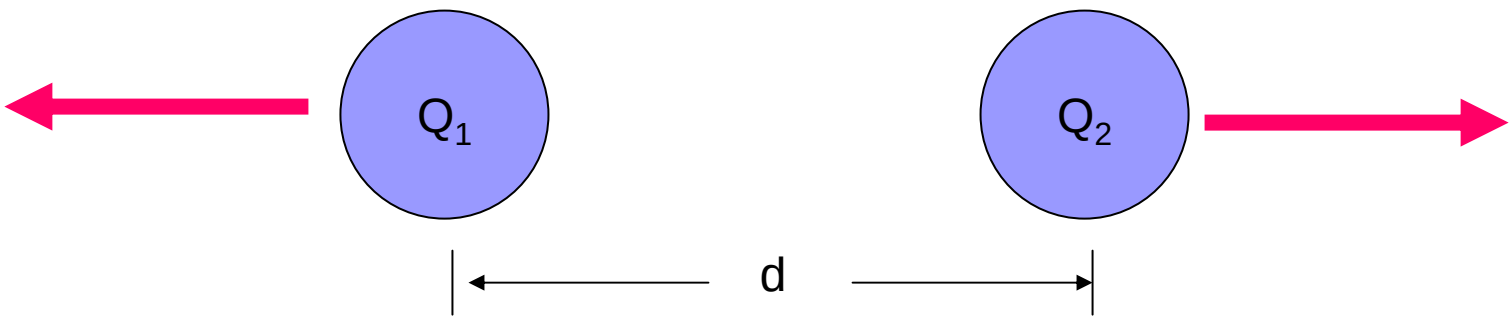
Charge is *conserved* – in any reaction, the total charge must not change

The electric force is proportional to the product of the charges and inversely proportional to the square of the distance apart

Like charges *repel*, unlike charges *attract*

"Coulomb's Law"

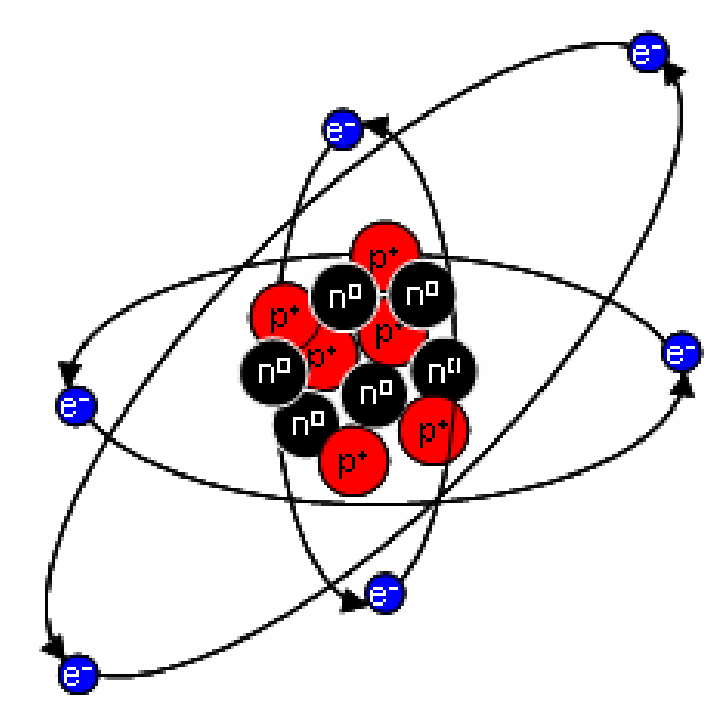
$$F_{electric} = k\frac{Q_1 Q_2}{d^2}$$



Tape demo

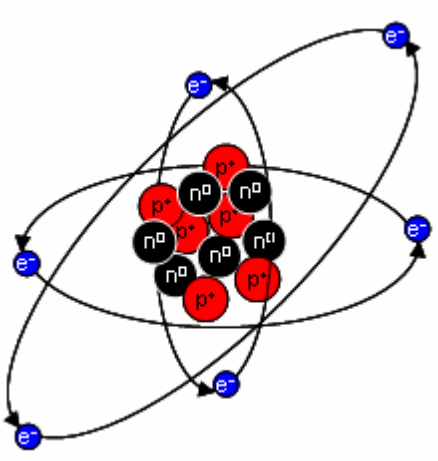
Van de Graff demo

Cartoon picture of an atom:



Electric force:

- protons in nucleus attract electrons
- protons in nucleus repel each other



Strong force:

- always attractive
- only acts between nucleons, not electrons
- nucleons must be “touching”

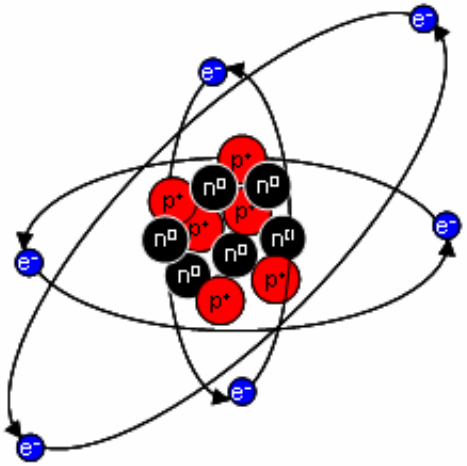
Note:

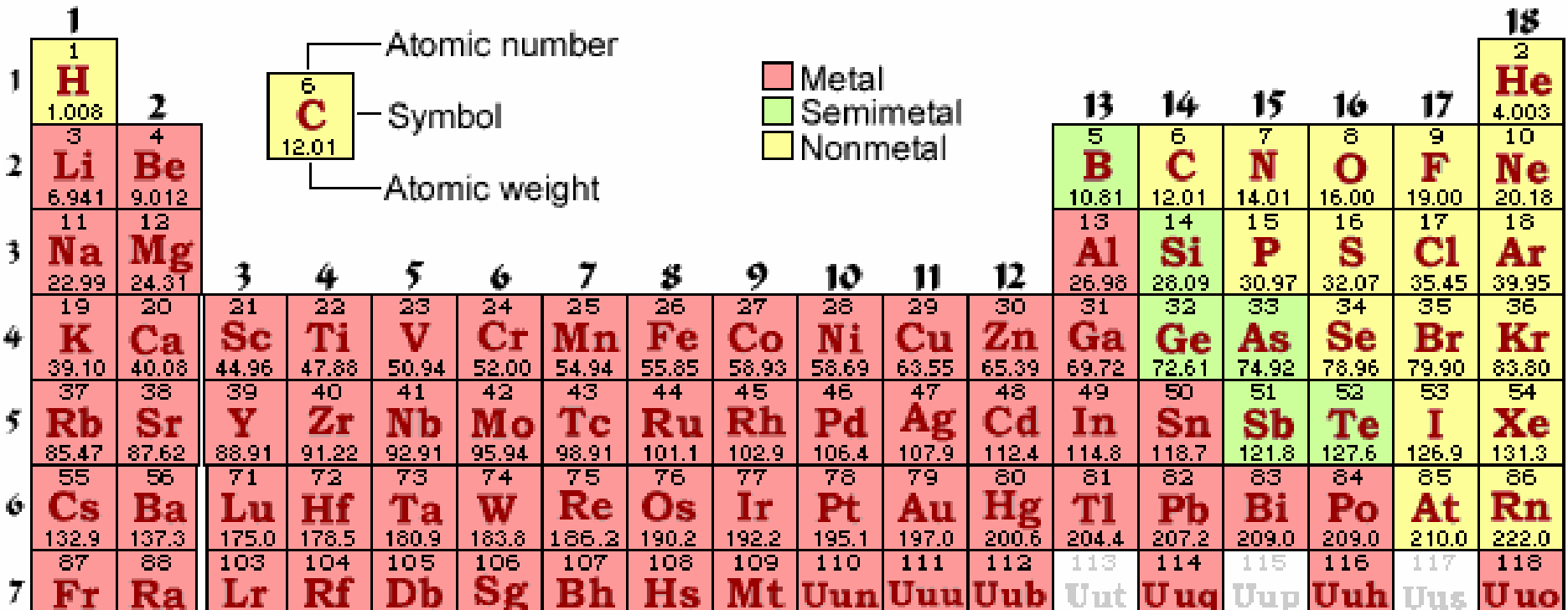
- virtually all the mass is in the nucleus
- mass approximately integer number of proton (or neutron) masses
- equal number of protons and electrons

What element is this?

Number of protons = number of electrons = 6

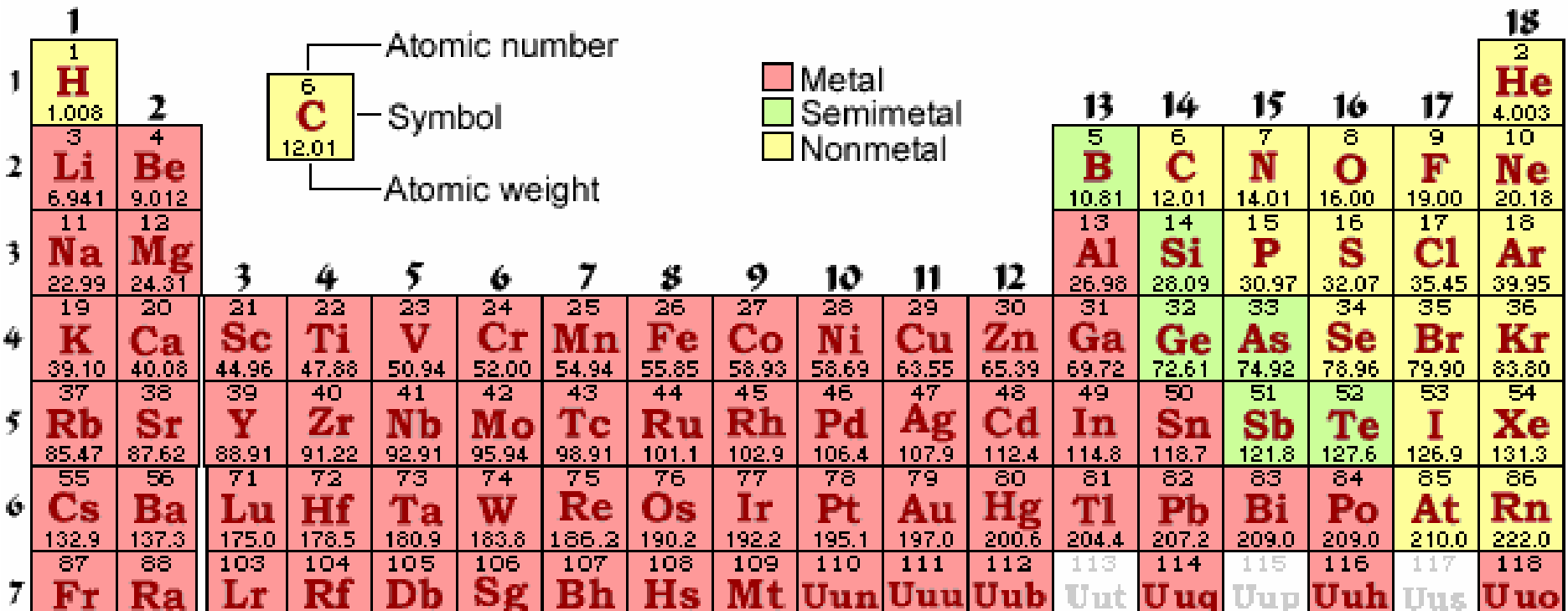
Look up 6th element – *carbon* - C





In general, the number of protons (or electrons) determines which element it is (hence, its chemical properties). This is also called the *atomic number.*

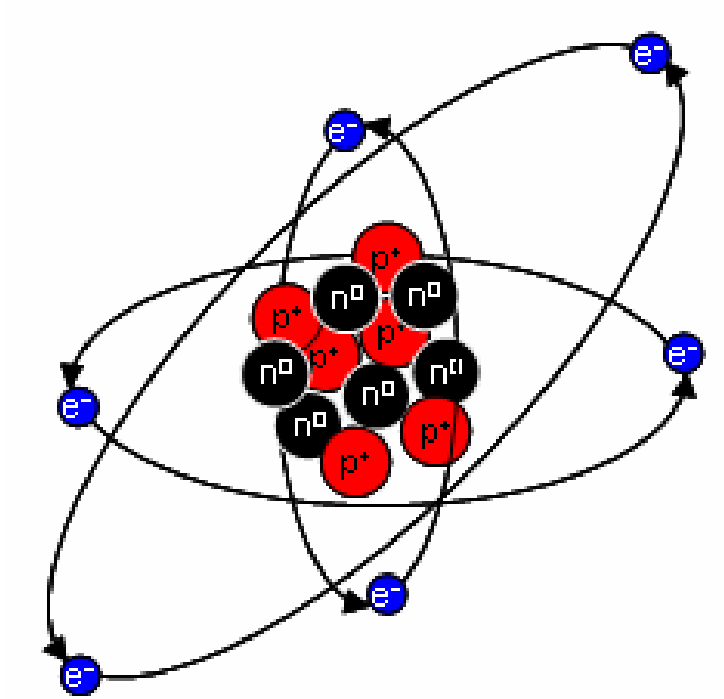
The number of protons (or electrons) is often symbolized by *Z.* So, for example, for carbon, $Z = 6$. For gold (Au), $Z = 79$



But complete specification requires knowing number of neutrons as well

Number of neutrons (*N*) = 6

Customarily, don't usually specify *N*. Instead, specify the total number of nucleons: $A = Z + N$. This is also called the *mass number.* Here, $A = 12$.



Symbolically: $^{12}_{6}\mathrm{C}$

Alternatively, carbon-12

Note: Chemists can generally omit both the atomic number and the mass number since it doesn't effect the chemistry (much).

Another example:

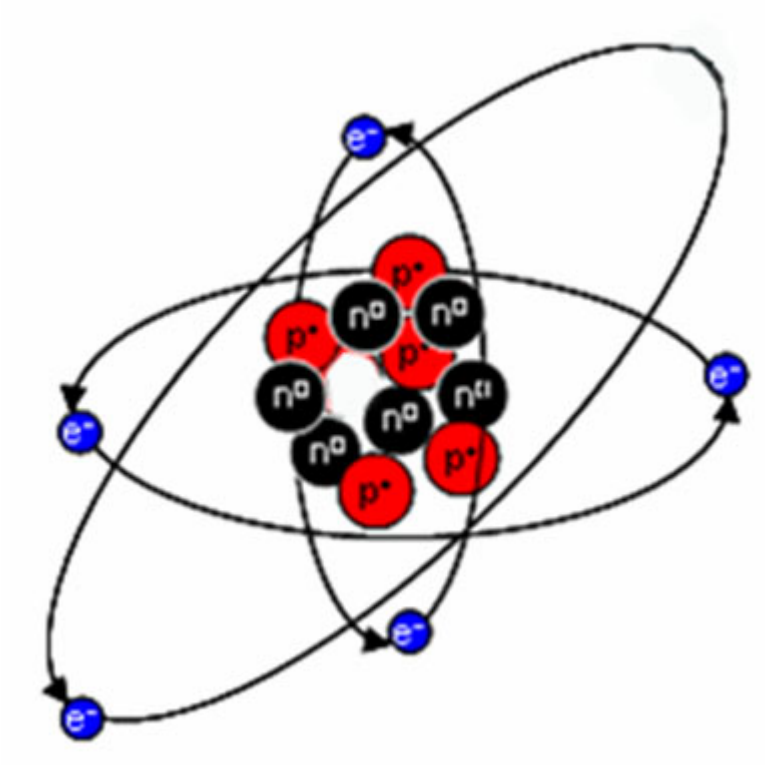
Z = 5

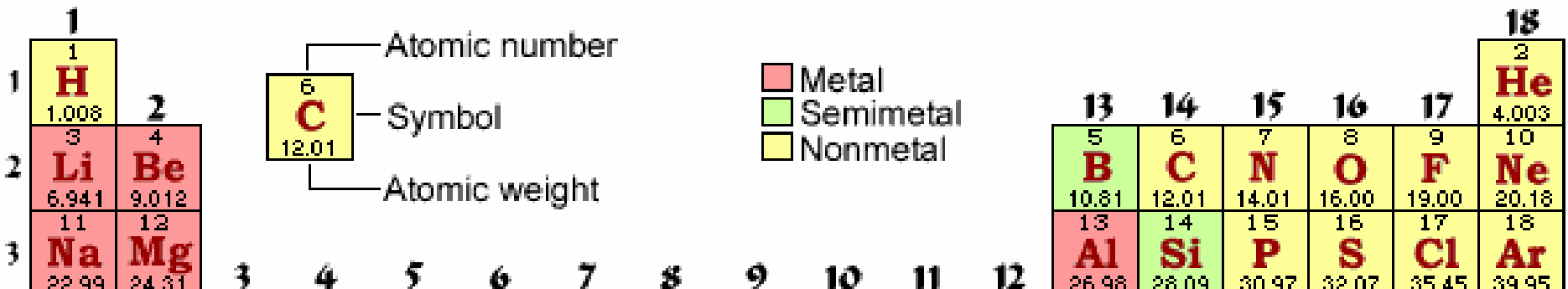
Element? B (boron)

N = 6

A = 11

Symbol? $^{11}_{5}B$





Another example:

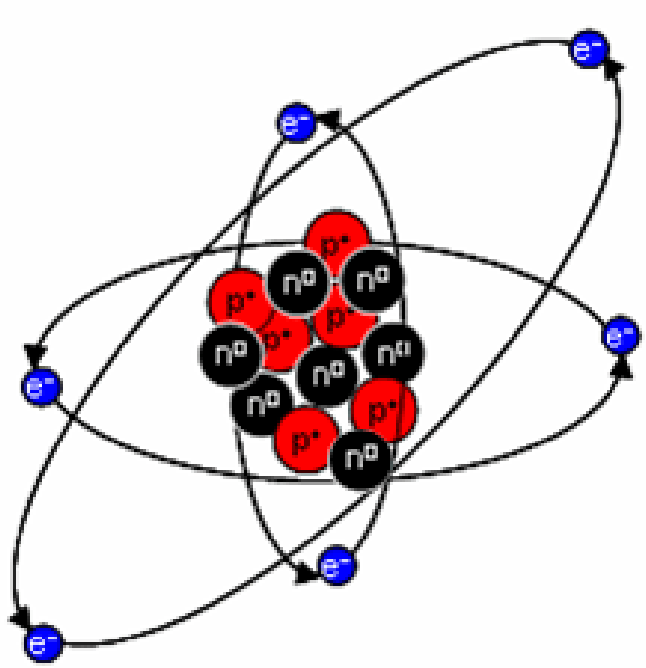
Z = 6

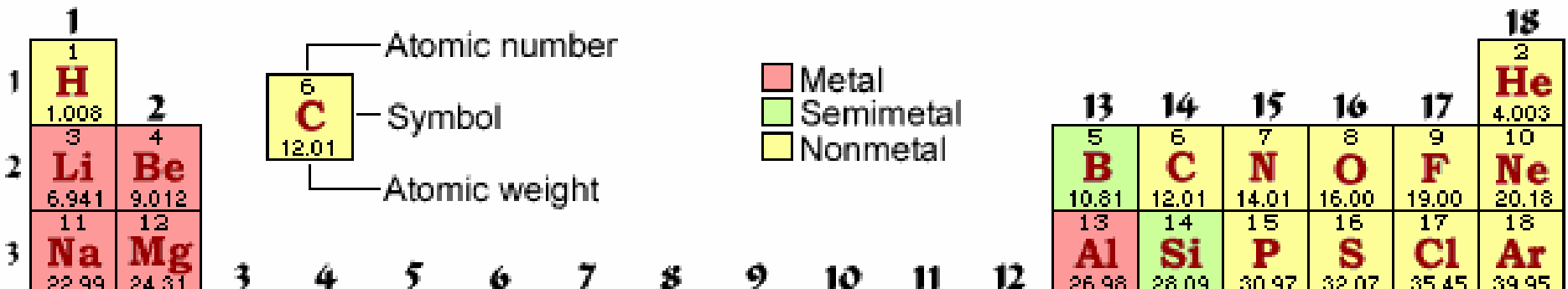
Element? C (carbon)

N = 7

A = 13

Symbol? $^{13}_{6}C$





Atoms or nuclei with same atomic numbers *Z (i.e.,* the same chemical element) but different mass numbers *A* are called *isotopes.*

Example usage: “Uranium-238 and uranium-239 are both isotopes of uranium and hence cannot be separated by using chemical reactions.”

How many protons in $^{238}_{92}\mathrm{U}$? 92

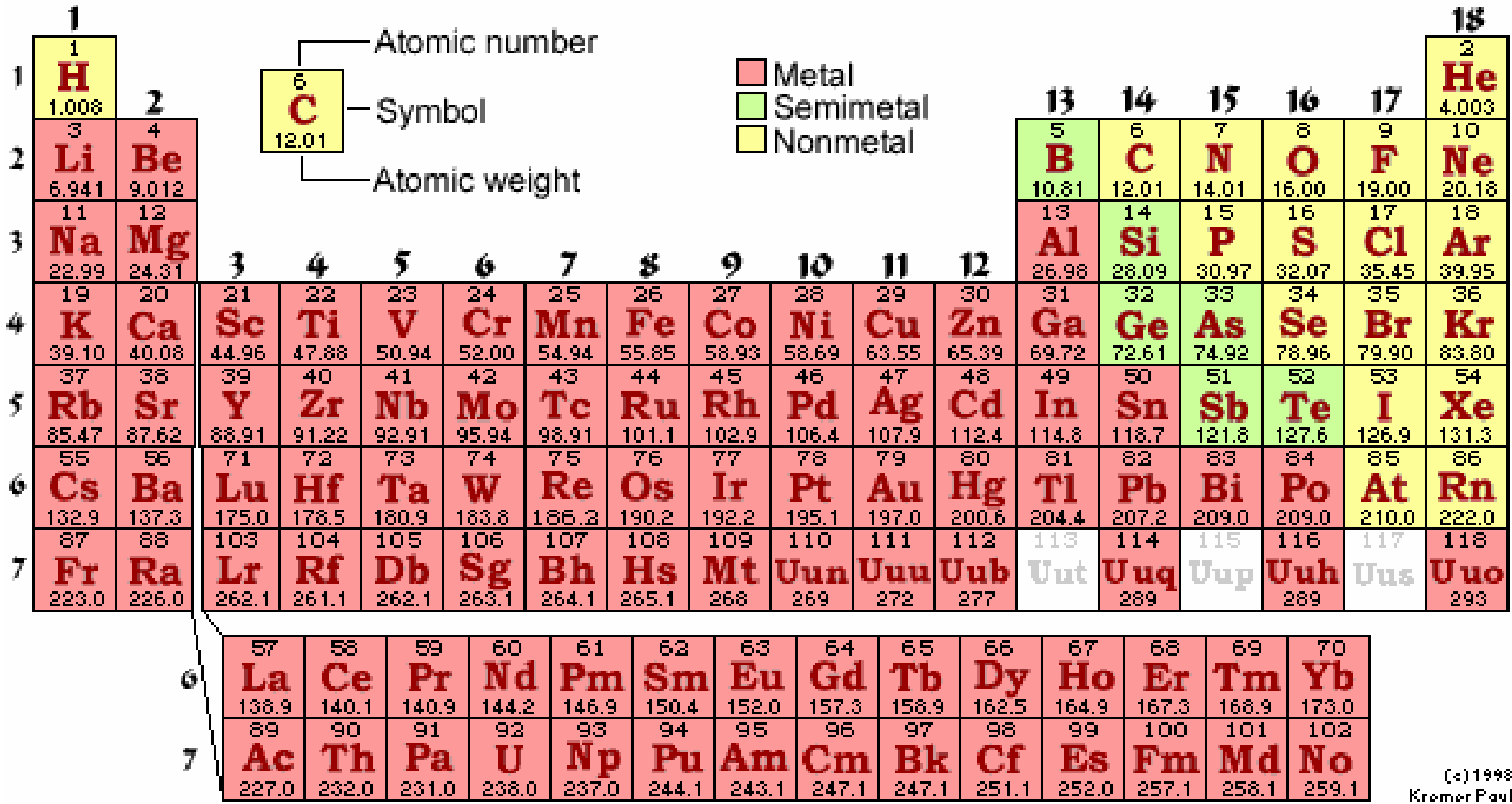
How many electrons? 92

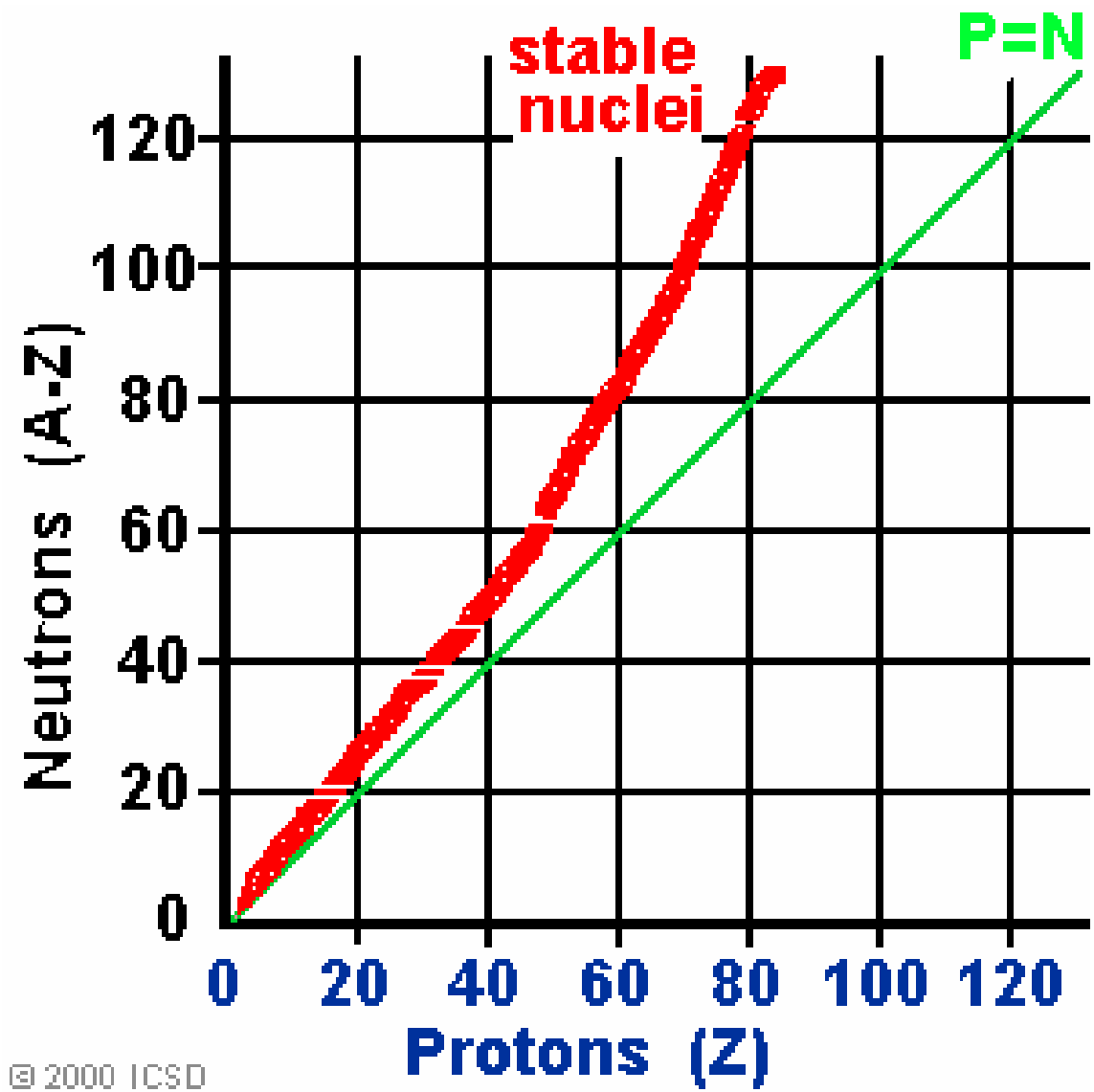
How many nucleons? 238

How many neutrons? 146

How many neutrons in $^{239}_{92}\mathrm{U}$? 145

Note how often atomic weights are near integers




stable
nuclei
P=N
120
100
80
60
40
20
0
Neutrons (A-Z)
0
20
40
60
80
100
120
Protons (Z)
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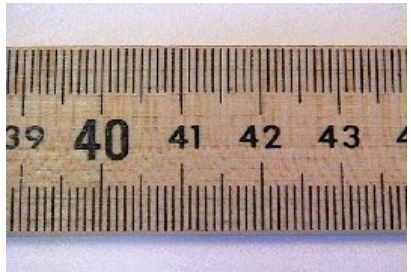
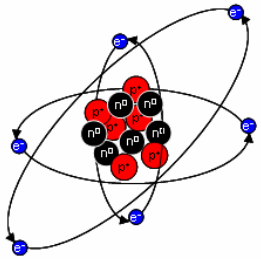
1 m

0.001 m or 10^{-3} m
or 1 mm



0.000001 m or 10^{-6} m
or 1 μm or 1 micrometer or
1 micron

10^{-10} m or 0.1 x 10^{-9} m
or 0.1 nanometer or 0.1 nm



10^{-13} m or 100 x 10^{-15} m
or 100 femtometer or
100 fermis

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