

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

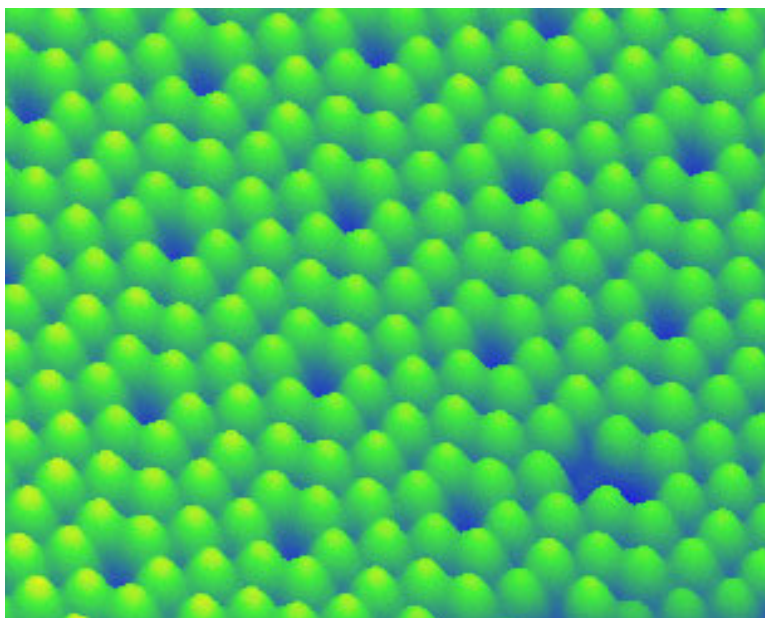
After about 1700 the idea of “atoms” gained ground, becoming the accepted theory of chemistry around 1850

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) 63-5
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) 108-5
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	Cesium 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) 197-0
11	—	Gold Au 197-2	Mercury Hg 200-0	Thallium Tl 204-1	Lead Pb 206-9	Bismuth Bi 208	—	—	—	—	—	—
12	—	—	Radium Ra 224	—	Thorium Th 232	—	Uranium U 239	—	—	—	—	—

HIGHER SALINE OXIDES
 | R | R₂O | RO | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ | RO₂ | R₂O₃ |

HIGHER GASEOUS HYDROGEN COMPOUNDS
 | RH₄ | RH₃ | RH₂ | RH |

Modern Periodic Table

Atomic number

Symbol

Atomic weight

Metal

Semimetal

Nonmetal

1	2											13	14	15	16	17	18
1 H 1.008												5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3 Li 6.941	4 Be 9.012											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209.0	85 At 210.0	86 Rn 222.0
87 Fr 223.0	88 Ra 226.0	103 Lr 262.1	104 Rf 261.1	105 Db 262.1	106 Sg 263.1	107 Bh 264.1	108 Hs 265.1	109 Mt 268	110 Uun 269	111 Uuu 272	112 Uub 277	113 Uut	114 Uuq 289	115 Uup	116 Uuh 289	117 Uus	118 Uuo 293
		57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 146.9	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0		
		89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.0	94 Pu 244.1	95 Am 243.1	96 Cm 247.1	97 Bk 247.1	98 Cf 251.1	99 Es 252.0	100 Fm 257.1	101 Md 258.1	102 No 259.1		

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Kremer Paul



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)

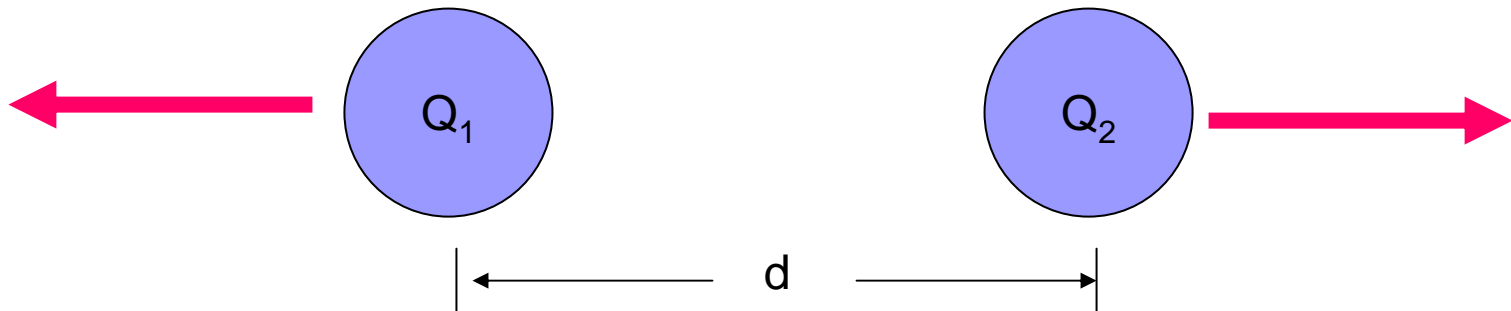
Charge is *conserved* – in any reaction, the total charge must not change

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”

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

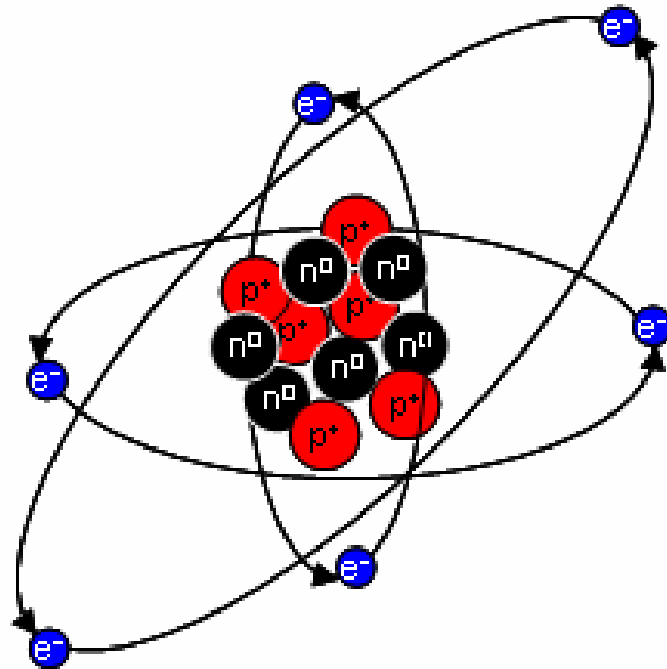




Tape demo

Van de Graff demo

Cartoon picture of an atom:



Electric force:

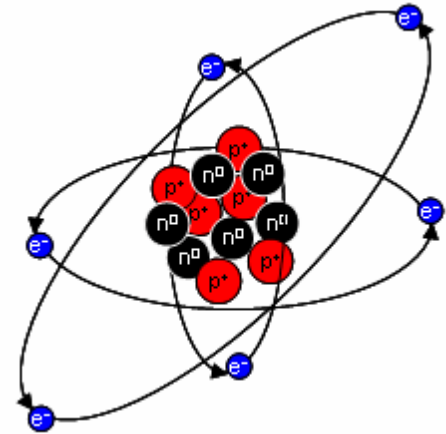
- protons in nucleus attract electrons
- protons in nucleus repel each other

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



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), $Z = 79$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012																
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 98.91	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209.0	85 At 210.0	86 Rn 222.0
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

6	12.01	C	6
Atomic number			Symbol
			Atomic weight

Metal	Semimetal	Nonmetal
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But complete specification requires knowing number of neutrons as well

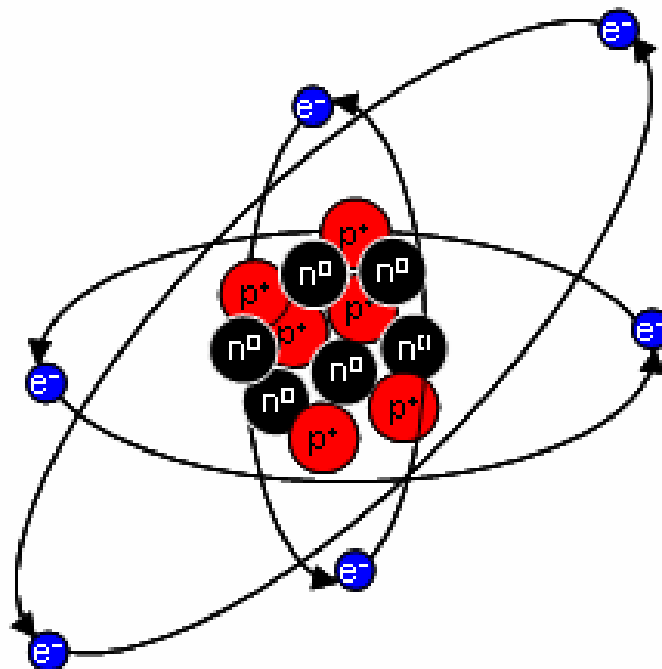
Number of neutrons (N) = 6

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: ${}^{12}_{6}\text{C}$

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:

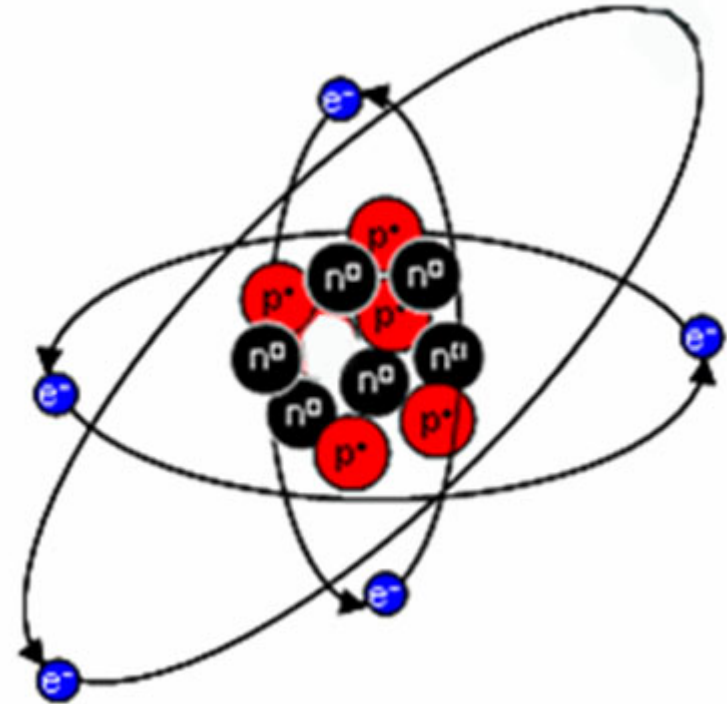
$Z = 5$

Element? **B (boron)**

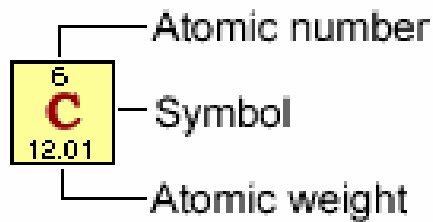
$N = 6$

$A = 11$

Symbol? **$\overset{11}{5}\text{B}$**



1	1	2
H		
1.008		
2	3	4
Li	Be	
6.941	9.012	
3	11	12
Na	Mg	
22.99	24.31	



- Metal
- Semimetal
- Nonmetal

13	14	15	16	17	18
B	C	N	O	F	Ne
10.81	12.01	14.01	16.00	19.00	20.18
13	14	15	16	17	18
Al	Si	P	S	Cl	Ar
26.98	28.09	30.97	32.07	35.45	39.95

Another example:

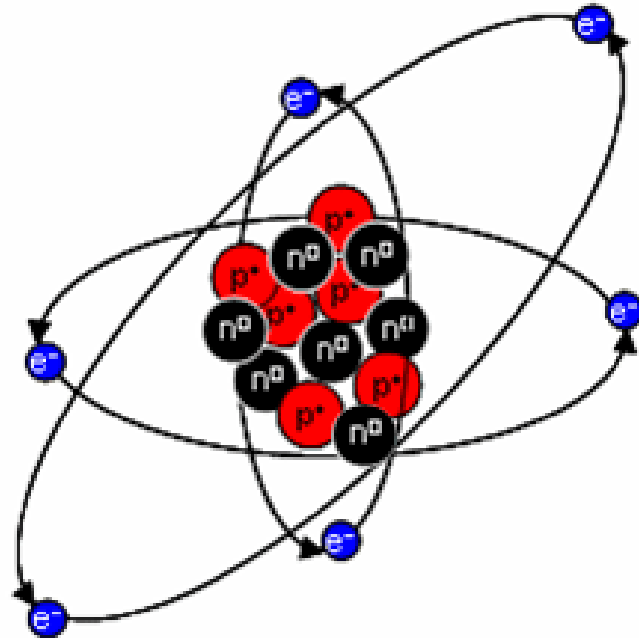
$Z = 6$

Element? *C (carbon)*

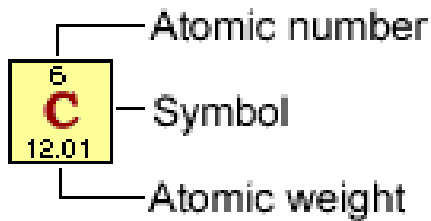
$N = 7$

$A = 13$

Symbol? *¹³₆C*



1	1	2
1	H	
1.008		
2	3	4
Li	Be	
6.941	9.012	
3	11	12
Na	Mg	
22.99	24.31	



- Metal
- Semimetal
- Nonmetal

13	14	15	16	17	18
5	6	7	8	9	10
B	C	N	O	F	Ne
10.81	12.01	14.01	16.00	19.00	20.18
13	14	15	16	17	18
Al	Si	P	S	Cl	Ar
26.98	28.09	30.97	32.07	35.45	39.95

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.”

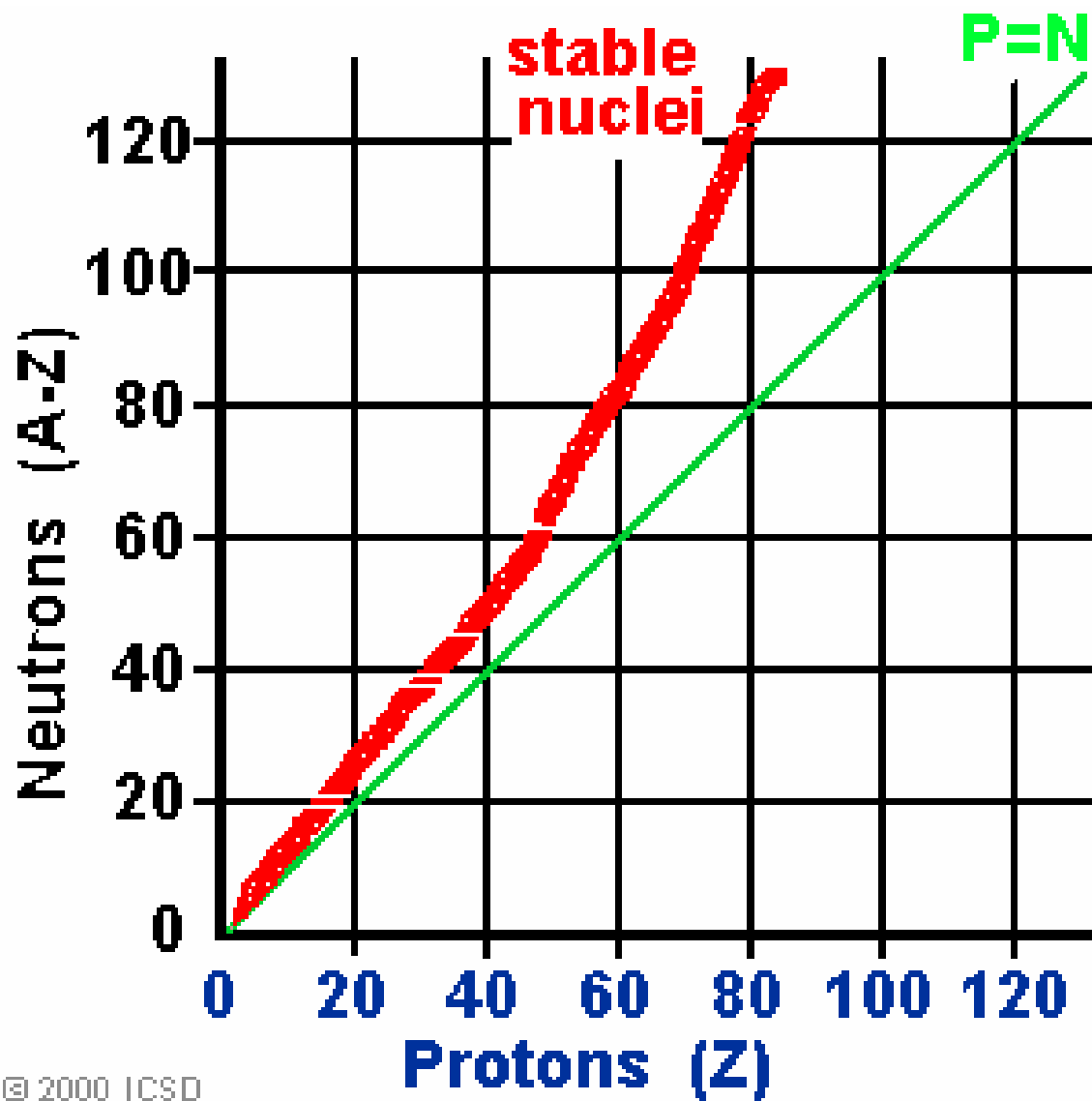
How many protons in ${}_{92}^{238}\text{U}$? 92

How many electrons? 92

How many nucleons? 238

How many neutrons? 146

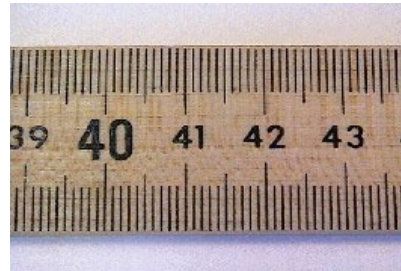
How many neutrons in ${}_{92}^{239}\text{U}$? 145



1 m



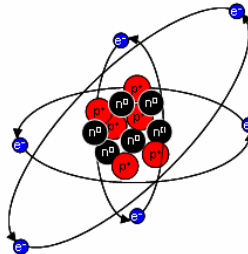
0.001 m or 10^{-3} m
or 1 mm



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



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



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

