ATOM, MOLECULES AND SUBATOMIC PARTICLES

- MATTER MADE FROM ELEMENTS.
- ELEMENTS CONSIST OF ATOMS. THE ATOMS OF A GIVEN ELEMENT IS THE SMALLEST PARTICLE OF AN ELEMENT THAT CAN EXIST AND STILL HAVE THE PROPERTIES OF THE ELEMENT
- COMPOUNDS ARE COMBINATIONS OF ATOMS. THE PROPERTIES OF COMPOUNDS ARE VERY DIFFERENT FROM THOSE OF ATOMS.

ATOMIC THEORY OF MATTER

1. ALL MATTER IS MADE OF ATOMS.

   118 DIFFERENT TYPES OF ATOMS KNOWN.

2. ALL ATOMS OF A GIVEN TYPE WILL BE SIMILAR TO ONE ANOTHER AND DIFFERENT FROM ALL OTHERS.

3. RELATIVE NUMBER AND ARRANGEMENT OF DIFFERENT TYPES OF ATOMS IN A PURE SUBSTANCE DETERMINE ITS IDENTITY.

4. CHEMICAL CHANGE IS A UNION, SEPARATION OR REARRANGEMENT OF ATOMS TO GIVE NEW SUBSTANCES.

5. ONLY WHOLE ATOMS CAN PARTICIPATE IN OR RESULT FROM ANY CHEMICAL CHANGE. FOR OUR PURPOSES ATOMS ARE CONSIDERED INDESTRUCTIBLE DURING SUCH CHANGES.

MOLECULES

- MOLECULES ARE MADE FROM 2 OR MORE ATOMS COVALENTLY BOUND TOGETHER WHICH FUNCTION AS A SINGLE ENTITY.
  - THESE ARE CALLED MOLECULAR COMPOUNDS.
  - THE RELATIVE NUMBER AND ARRANGEMENT OF DIFFERENT TYPES OF ATOMS CONTAINED IN A PURE SUBSTANCE DETERMINE ITS IDENTITY.
  - THE MOLECULE IS THE LIMIT OF PHYSICAL SUBDIVISION.
  - THE ATOM IS THE LIMIT OF CHEMICAL SUBDIVISION.

MOLECULES

- MOLECULE MUST CONTAIN TWO OR MORE ATOMS.
- DIATOMIC MOLECULE: A MOLECULE THAT CONTAINS TWO ATOMS.
- POLYATOMIC MOLECULE: A MOLECULE THAT CONTAINS MORE THAN TWO ATOMS.
- *HOMOATOMIC MOLECULE:* THE ATOMS IN THE MOLECULES ARE THE SAME KIND.
- *HETEROATOMIC MOLECULE:* THE ATOMS IN THE MOLECULES ARE OF TWO OR MORE DIFFERENT KINDS.
- THERE ARE 7 ELEMENTS THAT EXIST DIATOMIC MOLECULES – H_2, N_2, O_2, F_2, CL_2, Br_2, I_2
- PHOSPHORUS IS A QUAD – SULFUR IS AN OCTET

MOLECULES

- MOLECULES CONTAINING CARBON ARE CALLED “ORGANIC.”
- MOLECULES CONTAINING JUST CARBON, HYDROGEN AND OXYGEN ARE CALLED CARBOHYDRATES.
- THOSE WITH JUST CARBON AND HYDROGEN ARE HYDROCARBONS.

MOLECULES

- THERE IS ONLY ONE KIND OF MOLECULE FOR ANY GIVEN MOLECULAR SUBSTANCE.
- MOLECULES HAVE THEIR OWN PROPERTIES WHICH WILL BE DIFFERENT FROM THOSE OF THE INDIVIDUAL ATOMS.
- MILLIONS OF MOLECULES EXIST – BOTH NATURALLY AND MAN-MADE (SYNTHETIC).

ATOMS

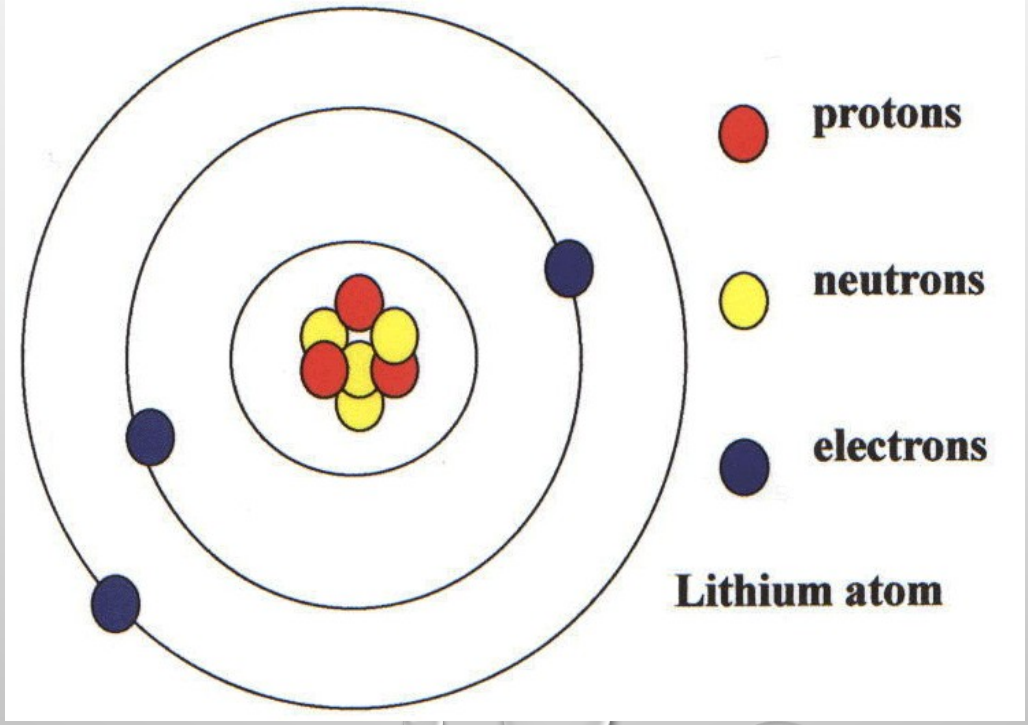
- ATOMS ARE NEUTRAL
  - ATOMS WILL HAVE THE SAME NUMBER OF PROTONS AND ELECTRONS. A BALANCED CHARGE MEANS THEY ARE NEUTRAL.
  - IONS ARE NOT NEUTRAL.
- ATOMS MAKE UP *ELEMENTS AND COMPOUNDS;* ELEMENTS ARE PURE SUBSTANCES WITH ALL THE SAME ATOMIC NUMBER.
- COMPOUNDS CHEMICAL ARE COMBINATIONS OF ATOMS.

ATOMS

- SIZE OF ATOMS
  - NOT EASILY DEFINED.
  - SMALLER THAN THE WAVELENGTH OF LIGHT SO CAN'T BE SEEN WITH OPTICAL MICROSCOPE.
  - MASS OF ATOM IS IN THE NUCLEUS; NUCLEUS IS SMALL COMPARED TO ELECTRON CLOUD. ELECTRON CLOUD IS MAJOR CONTRIBUTOR TO ATOMIC SIZE.
  - THE RATIO OF THE SIZE OF THE HYDROGEN ATOM TO ITS NUCLEUS IS ABOUT 100,000:1. IF AN ATOM WERE THE SIZE OF A STADIUM, THE NUCLEUS WOULD BE THE SIZE OF A MARBLE.

ATOMS

- THIS MODEL OF A LITHIUM ATOM SHOWS THE ELECTRONS (BLUE), THE PROTONS (RED), AND THE NEUTRONS (YELLOW).



SUBATOMIC PARTICLES

- **ATOMS ARE MADE UP OF SMALLER FUNDAMENTAL PARTICLES CALLED SUBATOMIC PARTICLES.**
- **SUBATOMIC PARTICLES:** BUILDING BLOCKS FOR ATOMS.
  - **PROTONS**: A SUBATOMIC PARTICLE WITH A POSITIVE CHARGE; WEIGHS SLIGHTLY LESS THAN A NEUTRON
  - **NEUTRONS**: A SUBATOMIC PARTICLE THAT IS NEUTRAL; NO CHARGE; HEAVIEST OF SUBATOMIC PARTICLES
  - **ELECTRONS**: A SUBATOMIC PARTICLE WITH A NEGATIVE CHARGE. SMALLEST OF SUBATOMIC PARTICLES. ABOUT 1800 TIMES LIGHTER THAN PROTON OR NEUTRON.

SUBATOMIC PARTICLES

- **NUCLEUS**:
  - SMALL, DENSE CENTER OF THE ATOM;
  - CONTAINS PROTONS AND NEUTRONS;
  - ALWAYS CARRIES A POSITIVE CHARGE.
- **NUCLEON**:
  - ANY SUBATOMIC PARTICLE IN THE NUCLEUS. FOR THIS CLASS THAT MEANS PROTONS AND NEUTRONS.

SUBATOMIC PARTICLES

- **ELECTRON CLOUD**:
  - OUTER REGION OF AN ATOM WHERE ELECTRONS MOVE RAPIDLY AROUND THE NUCLEUS.
  - LARGE AREA COMPARED TO SIZE OF NUCLEUS.
  - HAS NO FIRMLY DEFINED AREA.
  - CONTAINS SHELL LEVELS, WHICH HAVE SUBSHELL LEVELS WHICH CONTAIN ORBITALS FOR THE ELECTRONS.
  - CARRIES A NEGATIVE CHARGE.

- **ATOMIC NUMBER**: THE NUMBER OF PROTONS IN THE NUCLEUS OF AN ATOM.
  - ATOMS ARE DEFINED BY THEIR NUMBER OF PROTONS.
  - #1-92 (EXCEPT Tc AND Pm) ARE NATURALLY OCCURRING, REST ARE SYNTHETIC (MAN-MADE).
  - NUMBER OF ELECTRONS WILL EQUAL THE ATOMIC NUMBER IN AN ATOM. THIS GIVES A NEUTRAL ATOM.
  - ATOMIC NUMBER IS DENOTED BY Z

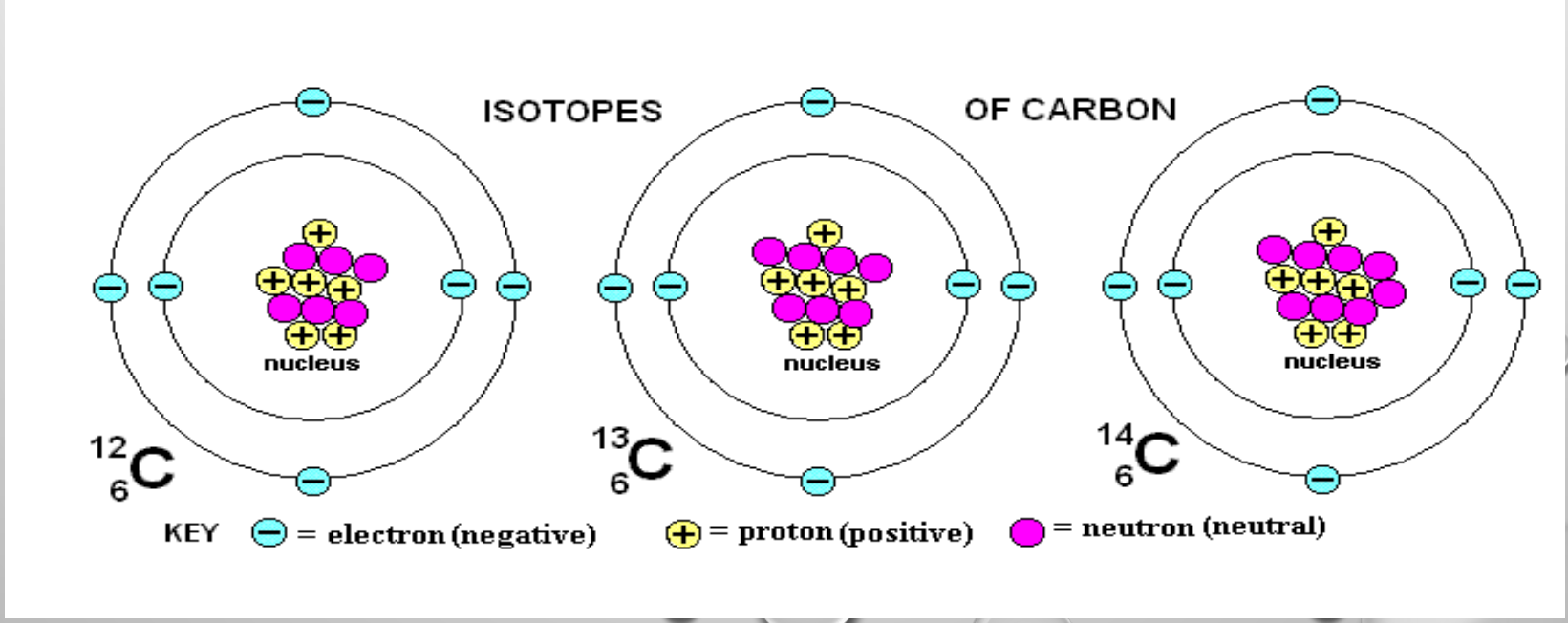
- **MASS NUMBER**:
  - SUM OF THE PROTONS AND NEUTRONS IN THE NUCLEUS OF AN ATOM.
  - THIS NUMBER IS A COUNT – NOT AN ATOMIC MASS.

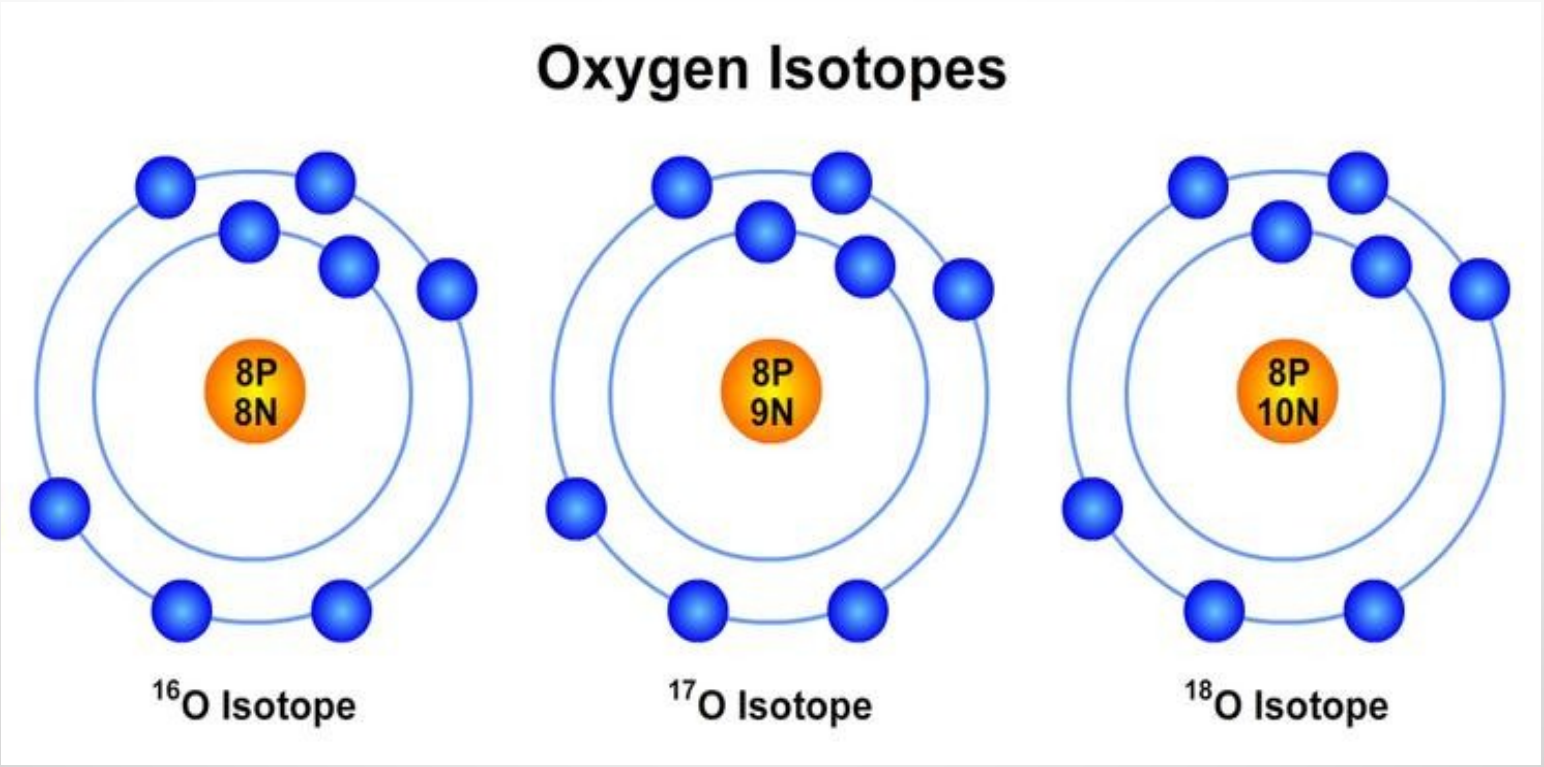
  EXAMPLE: ALUMINUM HAS 13 PROTONS AND 14 NEUTRONS SO THE MASS NUMBER IS 27.

- **NUCLEAR NOTATION**: USED TO INDICATE THE ATOMIC NUMBER AND MASS NUMBER OF AN ATOM OR ISOTOPE
  - NUCLEAR NOTATION IS FORMED BY WRITING AN ELEMENTAL SYMBOL PRECEDED BY A SUBSCRIPT INDICATING ITS ATOMIC NUMBER (Z) AND A SUPERSCRIPT INDICATING ITS MASS NUMBER (A).
- **NUCLIDE**:
  - AN ATOM WITH A SPECIFIC ATOMIC NUMBER AND A SPECIFIC MASS NUMBER.

ISOTOPES

- ISOTOPES ARE ATOMS OF AN ELEMENT THAT HAVE SAME NUMBER OF PROTONS AND ELECTRONS BUT DIFFERENT NUMBER OF NEUTRONS.
  - TYPE OF ELEMENT DETERMINED BY SAME NUMBER OF PROTONS.
  - NUCLEUS CAN HAVE DIFFERENT NUMBERS OF NEUTRONS.
  - DIFFERENT NUMBER OF NEUTRONS MEANS A DIFFERENT MASS NUMBER; NOT A DIFFERENT ATOMIC NUMBER.
  - CAN HAVE SLIGHTLY DIFFERENT PHYSICAL PROPERTIES.
  - SIMILAR CHEMICAL PROPERTIES




Oxygen Isotopes
8P
8N
8P
9N
8P
10N
^{16}O Isotope
^{17}O Isotope
^{18}O Isotope

ISOTOPES

- WE OFTEN REFER TO AN ISOTOPE BY STATING THE NAME OF THE ELEMENT FOLLOWED BY THE MASS NUMBER.
  - COBALT-60 IS
  - CARBON-14 IS
- HOW MANY PROTONS AND NEUTRONS DOES AN ATOM OF LEAD-206 HAVE?
  - THE ATOMIC NUMBER OF Pb IS 82, SO IT HAS 82 PROTONS.
  - Pb-206 HAS MASS NUMBER 206 SO,

Mass number - Atomic Number = Number of Neutrons

206 - 82 = 124 NEUTRONS.

- CALCULATE MASS NUMBER OF AN ELEMENT WITH 14 ELECTRONS AND 14 NEUTRONS ?

- CALCULATE THE NUMBER OF NEUTRONS OF ELEMENT WITH 9 PROTONS AND 19 MASS NUMBER ?

EXAMPLES OF ISOTOPES

1	Hydrogen		
$^{1}_{1}H$	1.008 amu	99.985%
$^{2}_{1}H$	2.014 amu	0.015%
$^{3}_{1}H$	3.016 amu	trace

2	Helium		
$^{3}_{2}He$	3.016 amu	trace
$^{4}_{2}He$	4.003 amu	100%

3	Lithium		
$^{6}_{3}Li$	6.015 amu	7.42%
$^{7}_{3}Li$	7.016 amu	92.58%

4	Beryllium		
$^{9}_{4}Be$	9.012 amu	100%

5	Boron		
$^{10}_{5}B$	10.013 amu	19.6%
$^{11}_{5}B$	11.009 amu	80.4%

6	Carbon		
$^{12}_{6}C$	12.000 amu	98.89%
$^{13}_{6}C$	13.003 amu	1.11%
$^{14}_{6}C$	14.003 amu	trace

7	Nitrogen		
$^{14}_{7}N$	14.003 amu	99.63%
$^{15}_{7}N$	15.000 amu	0.37%

8	Oxygen		
$^{16}_{8}O$	15.995 amu	99.759%
$^{17}_{8}O$	16.999 amu	0.037%
$^{18}_{8}O$	17.999 amu	0.204%

9	Fluorine		
$^{19}_{9}F$	18.998 amu	100%

10	Neon		
$^{20}_{10}Ne$	19.992 amu	90.92%
$^{21}_{10}Ne$	20.994 amu	0.26%
$^{22}_{10}Ne$	21.991 amu	8.82%

11	Sodium		
$^{23}_{11}Na$	22.990 amu	100%

12	Magnesium		
$^{24}_{12}Mg$	23.985 amu	78.70%
$^{25}_{12}Mg$	24.986 amu	10.13%
$^{26}_{12}Mg$	25.983 amu	11.17%

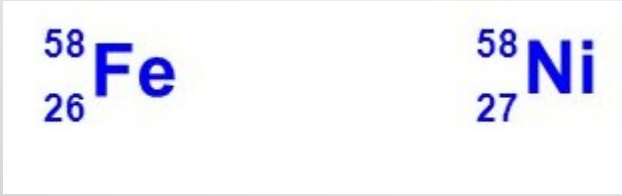
ISOBARS

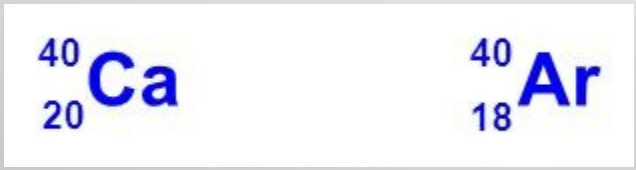
- **ISOBARS**:

ISOBARS ARE ATOMS (NUCLIDES) OF DIFFERENT CHEMICAL ELEMENTS THAT HAVE THE SAME NUMBER OF NUCLEONS.

- ATOMS THAT HAVE THE SAME MASS NUMBER.
- THEY WILL HAVE DIFFERENT ATOMIC NUMBERS.

EXAMPLES-





Using the information below, indicate if the pairs of atoms are isotopes, isobars or neither.

	Protons	Neutrons	Electrons
Atom A	9	10	9
Atom B	10	9	10
Atom C	10	10	10
Atom D	9	9	9

Atom A and Atom B

Atom A and Atom C

Atom C and Atom D

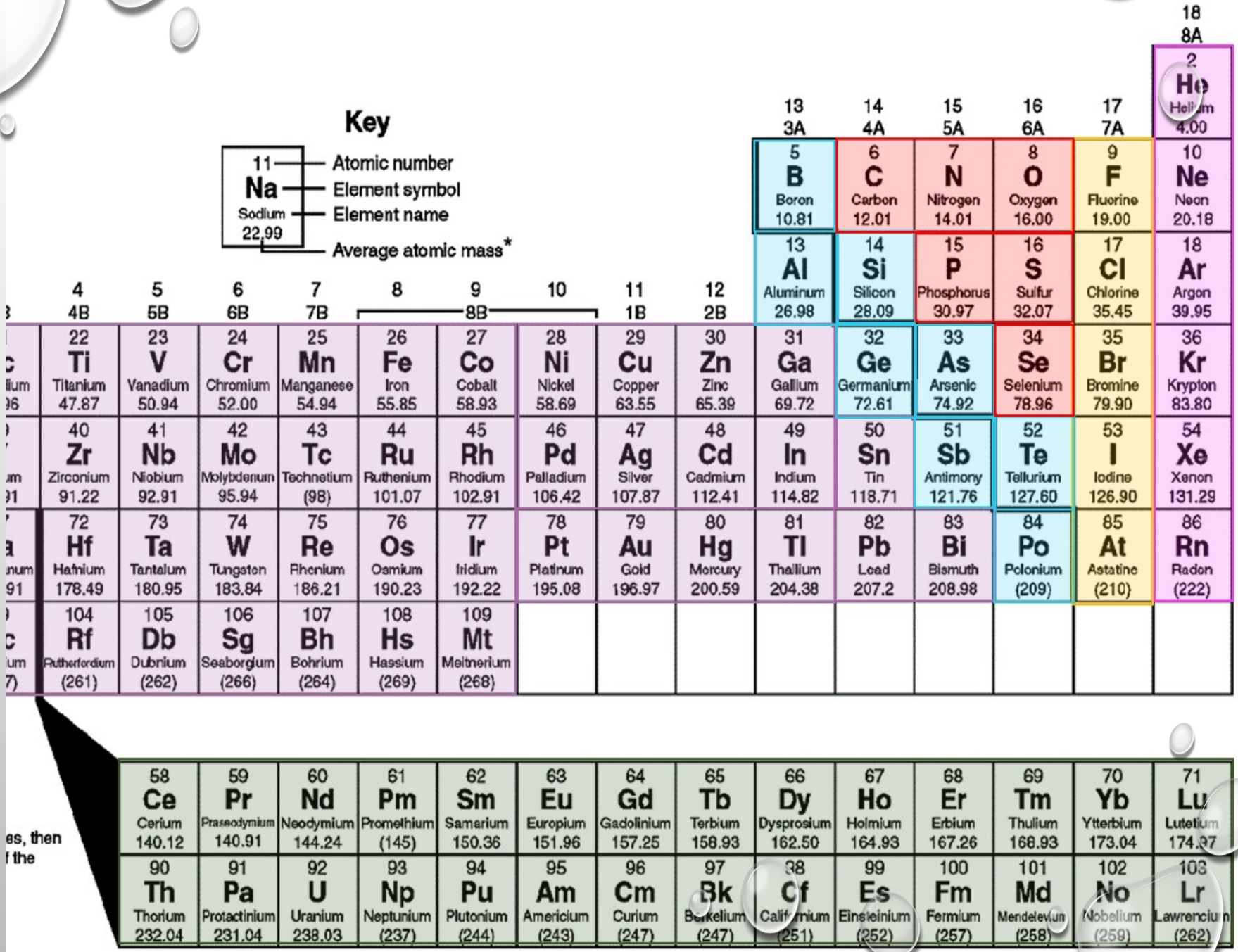
Atom C and Atom B

Atom A and Atom D

Atom B and Atom D

MASS NUMBER AND ATOMIC MASS

- MASS NUMBER = SUM OF PROTONS AND NEUTRONS
- ATOMIC MASS = WEIGHTED AVERAGE MASS THAT ACCOUNTS FOR:
  - THE NUMBER OF ISOTOPES FOR THE ELEMENT.
  - PERCENT ABUNDANCE OF EACH ISOTOPE.
  - THE *RELATIVE MASS* OF EACH ISOTOPE USING CARBON -12 AS THE REFERENCE POINT.


Key
11
Na
Sodium
22.99
Atomic number
Element symbol
Element name
Average atomic mass*
18
8A
13
3A
14
4A
15
5A
16
6A
17
7A
2
He
Helium
4.00
5
B
Boron
10.81
6
C
Carbon
12.01
7
N
Nitrogen
14.01
8
O
Oxygen
16.00
9
F
Fluorine
19.00
10
Ne
Neon
20.18
13
Al
Aluminum
26.98
14
Si
Silicon
28.09
15
P
Phosphorus
30.97
16
S
Sulfur
32.07
17
Cl
Chlorine
35.45
18
Ar
Argon
39.95
4
4B
5
5B
6
6B
7
7B
8
9
8B
10
11
1B
12
2B
22
Ti
Titanium
47.87
23
V
Vanadium
50.94
24
Cr
Chromium
52.00
25
Mn
Manganese
54.94
26
Fe
Iron
55.85
27
Co
Cobalt
58.93
28
Ni
Nickel
58.69
29
Cu
Copper
63.55
30
Zn
Zinc
65.39
31
Ga
Gallium
69.72
32
Ge
Germanium
72.61
33
As
Arsenic
74.92
34
Se
Selenium
78.96
35
Br
Bromine
79.90
36
Kr
Krypton
83.80
40
Zr
Zirconium
91.22
41
Nb
Niobium
92.91
42
Mo
Molybdenum
95.94
43
Tc
Technetium
(98)
44
Ru
Ruthenium
101.07
45
Rh
Rhodium
102.91
46
Pd
Palladium
106.42
47
Ag
Silver
107.87
48
Cd
Cadmium
112.41
49
In
Indium
114.82
50
Sn
Tin
118.71
51
Sb
Antimony
121.76
52
Te
Tellurium
127.60
53
I
Iodine
126.90
54
Xe
Xenon
131.29
72
Hf
Hafnium
178.49
73
Ta
Tantalum
180.95
74
W
Tungsten
183.84
75
Re
Rhenium
186.21
76
Os
Osmium
190.23
77
Ir
Iridium
192.22
78
Pt
Platinum
195.08
79
Au
Gold
196.97
80
Hg
Mercury
200.59
81
Tl
Thallium
204.38
82
Pb
Lead
207.2
83
Bi
Bismuth
208.98
84
Po
Polonium
(209)
85
At
Astatine
(210)
86
Rn
Radon
(222)
104
Rf
Rutherfordium
(261)
105
Db
Dubnium
(262)
106
Sg
Seaborgium
(266)
107
Bh
Bohrium
(264)
108
Hs
Hassium
(269)
109
Mt
Meitnerium
(268)
58
Ce
Cerium
140.12
59
Pr
Praseodymium
140.91
60
Nd
Neodymium
144.24
61
Pm
Promethium
(145)
62
Sm
Samarium
150.36
63
Eu
Europium
151.96
64
Gd
Gadolinium
157.25
65
Tb
Terbium
158.93
66
Dy
Dysprosium
162.50
67
Ho
Holmium
164.93
68
Er
Erbium
167.26
69
Tm
Thulium
168.93
70
Yb
Ytterbium
173.04
71
Lu
Lutetium
174.97
90
Th
Thorium
232.04
91
Pa
Protactinium
231.04
92
U
Uranium
238.03
93
Np
Neptunium
(237)
94
Pu
Plutonium
(244)
95
Am
Americium
(243)
96
Cm
Curium
(247)
97
Bk
Berkelium
(247)
98
Cf
Californium
(251)
99
Es
Einsteinium
(252)
100
Fm
Fermium
(257)
101
Md
Mendelevium
(258)
102
No
Nobelium
(259)
103
Lr
Lawrencium
(262)