Chapter 3: Elements and Compounds

3.1 Elements

- An element is a fundamental substance that cannot be broken down by chemical or physical methods to simpler substances. The 118 known elements are nature's building blocks.

- An atom is the smallest particle of an element that can exist.
  - An atom is the smallest unit of an element that can chemically react.
  - An element is a substance in which all the atoms are the same.

- Elements tend to be reactive, so that most substances in nature are compounds or mixtures.
  - Some elements are unreactive and are found in their pure form in nature; these are sometimes referred to as noble.
  - At room temperature,
    - Two elements are liquids (Br, Hg),
    - Twelve are gases (H, N, O, F, Cl, He, Ne, Ar, Kr, Xe, Rn, Og?),
    - 104 elements are solids.

- The elements are not uniformly distributed in nature.
  - Hydrogen is the most abundant element in the universe (75% of all atoms are H, 90% of all mass is H).
  - Other measures of abundance are presented in your text.

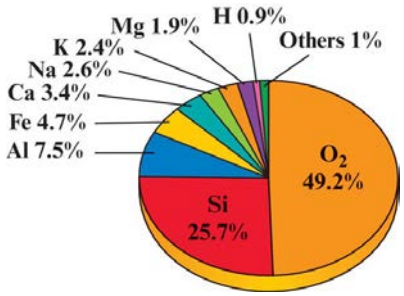


TABLE 3.1 Mass Percent of the Most Abundant Elements in the Earth's Crust, Oceans, and Atmosphere

Element	Mass percent	Element	Mass percent
Oxygen	49.2	Titanium	0.6
Silicon	25.7	Chlorine	0.19
Aluminum	7.5	Phosphorus	0.11
Iron	4.7	Manganese	0.09
Calcium	3.4	Carbon	0.08
Sodium	2.6	Sulfur	0.06
Potassium	2.4	Barium	0.04
Magnesium	1.9	Nitrogen	0.03
Hydrogen	0.9	Fluorine	0.03
		All others	0.49

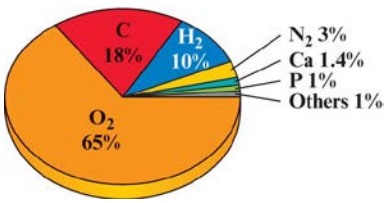


TABLE 3.2 Mass Percent of the Elements in the Human Body

Element	Mass percent
Oxygen	65
Carbon	18
Hydrogen	10
Nitrogen	3
Calcium	1.4
Phosphorus	1
Magnesium	0.5
Potassium	0.34
Sulfur	0.26
Sodium	0.14

Names and Symbols of the Elements

- Many element names are derived from Greek, Latin, or German words used to describe some property of the element.
  - Most recent artificial elements are named for people or places.

- Each element also has a symbol as an abbreviation.
  - Symbols are used in the periodic table.
  - Symbols are used in chemical formulas.

RULES FOR SYMBOLS OF ELEMENTS

1. Symbols have either one or two letters.
2. If one letter is used, it is capitalized.
3. If two letters are used, only the first is capitalized.

3.2 Introduction to the Periodic Table

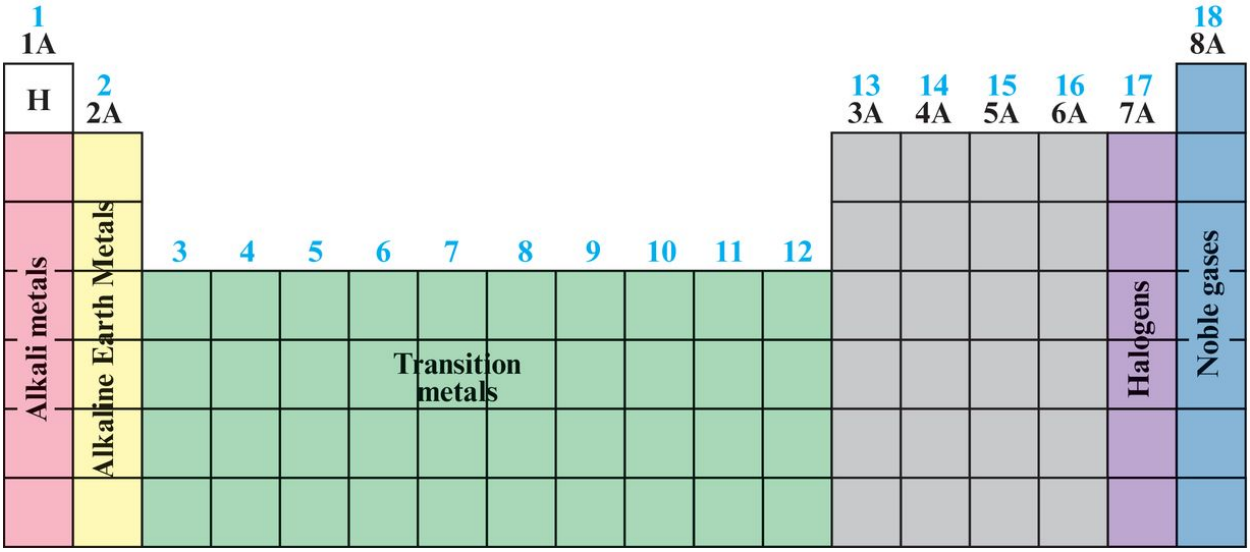
TABLE 3.5 | The Periodic Table

1 1A	2 2A	3	4	5	6	7	8	9	10	11	12	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac†	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
												Nh		Mc		Ts	Og

Metals
Metalloids
Nonmetals

*	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
†	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

- Key terms related to the Periodic Table:
  - Group (vertical), Period (horizontal)
  - Metal, Metalloid, Nonmetal (left to right)
  - Subdivisions
    - Representative elements
    - Transition metals
  - Families
    - Alkali metals
    - Alkaline earth metals
    - Halogens



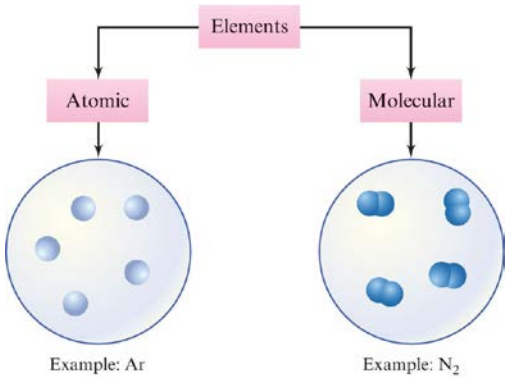
- Metals:
  - Typically are solid at RT (except Hg), have high luster, are good conductors of heat and electricity, are malleable, and are ductile.
  - Most have high melting points and high densities.
  - Tend not to form compounds with each other, but readily form compounds with nonmetals ('salts').
  - Form homogenous mixtures with each other called alloys.

- Nonmetal properties are generally opposite those of metals:
  not lustrous, low melting points and densities, poor conductors of heat and electricity, not malleable, and not ductile.
  - Nonmetals readily form compounds with each other.

- Metalloids have properties that are intermediate between those of metal and nonmetals; also called semimetals.
  - These elements are fund along the stair step border between metals and nonmetals.

- Seven elements are found free in nature as diatomic molecules.

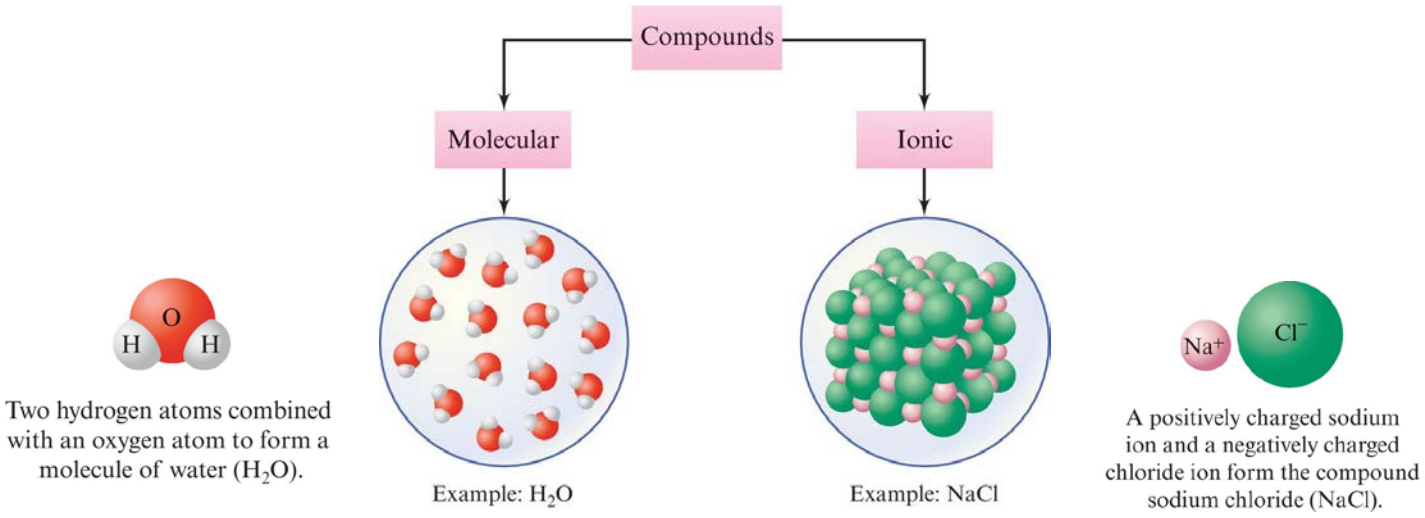
Element	Symbol	Molecular formula	Normal state
Hydrogen	H	H_2	Colorless gas
Nitrogen	N	N_2	Colorless gas
Oxygen	O	O_2	Colorless gas
Fluorine	F	F_2	Pale yellow gas
Chlorine	Cl	Cl_2	Greenish-yellow gas
Bromine	Br	Br_2	Reddish-brown liquid
Iodine	I	I_2	Bluish-black solid



3.3 Compounds and Formulas

- There are two general types of compounds:
  - Molecular in which the elements are held together by covalent bonds.
    - A molecule is the smallest uncharged individual unit.
    - A molecule is the ultimate particle of the compound.

  - Ionic in which ions of the elements are held together by attraction between the positive ions and the negative ions.
    - A positively charged atom or group of atoms is called a cation.
    - A negatively charged atom or group of atoms is called an anion.

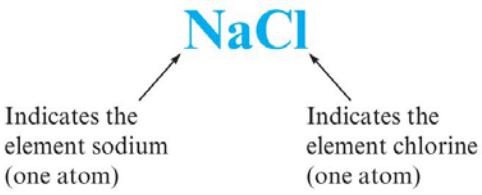


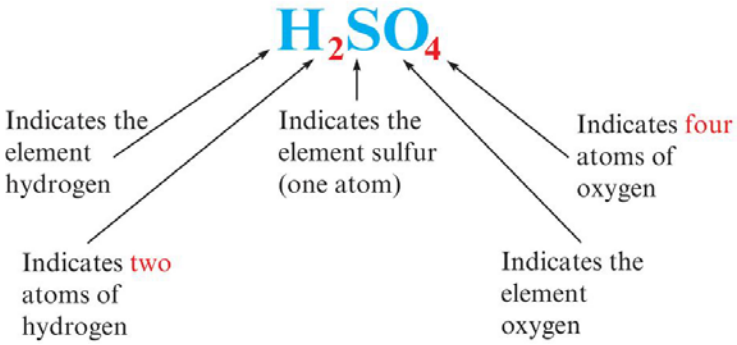
- A chemical formula shows the symbols and the ratios of the atoms of the elements in a compound.
  - Chemical formulas are used to represent compounds.
  - Sometimes the element symbols are grouped to reflect the underlying structure of the compound.
  - The chemical formula of an ionic compound represents the simplest ratio of the ions such that the overall charge is zero (the number of positive charges equals the number of negative charges).

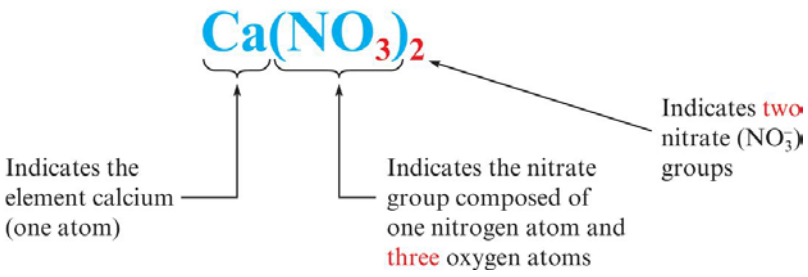
Characteristics of chemical formulas are as follows:

1. The formula of a compound contains the symbols of all the elements in the compound.
2. When the formula contains one atom of an element, the symbol of that element represents that one atom. The number 1 is not used as a subscript to indicate one atom of an element.
3. When the formula contains more than one atom of an element, the number of atoms is indicated by a subscript written to the right of the symbol of that atom. For example, the 2 in H_2O indicates two atoms of H in the formula.

4. When the formula contains more than one of a group of atoms that occurs as a unit, parentheses are placed around the group, and the number of units of the group is indicated by a subscript placed to the right of the parentheses. Consider the nitrate group, NO_3^-. The formula for sodium nitrate, $NaNO_3$, has only one nitrate group, so no parentheses are needed. Calcium nitrate, $Ca(NO_3)_2$, has two nitrate groups, as indicated by the use of parentheses and the subscript 2. $Ca(NO_3)_2$ has a total of nine atoms: one Ca, two N, and six O atoms. The formula $Ca(NO_3)_2$ is read as "C-A [pause] N-O-three taken twice."
5. Formulas written as H_2O, H_2SO_4, $Ca(NO_3)_2$, and $C_{12}H_{22}O_{11}$ show only the number and kind of each atom contained in the compound; they do not show the arrangement of the atoms in the compound or how they are chemically bonded to one another.







Composition of Compounds
(It's the Law!)

- Several hundred year ago, some laws were proposed concerning the composition of compounds. While we do not frequently reference these laws, they are a part of the fabric of chemistry, and we still rely on them today.

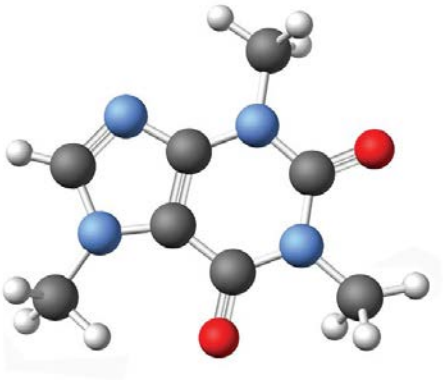
  - Law of Definite Composition: Compounds are formed from elements combined in definite proportion by mass.
    - Corollary: A water molecule is always H_2O.

  - Law of Multiple Proportions: Elements may combine in different ratios to produce different compounds.

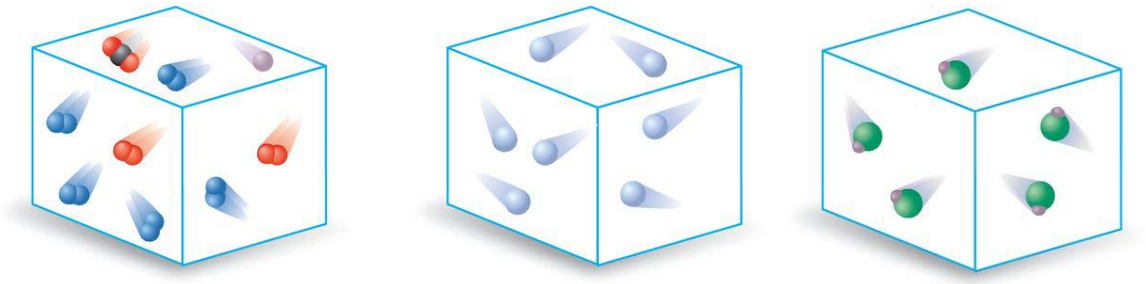
    CO and CO_2

    H_2O and H_2O_2

Use this model of caffeine to write the chemical formula for the compound. (C = gray, N = blue, O= red, H = white).



Element, Compound, or Mixture?



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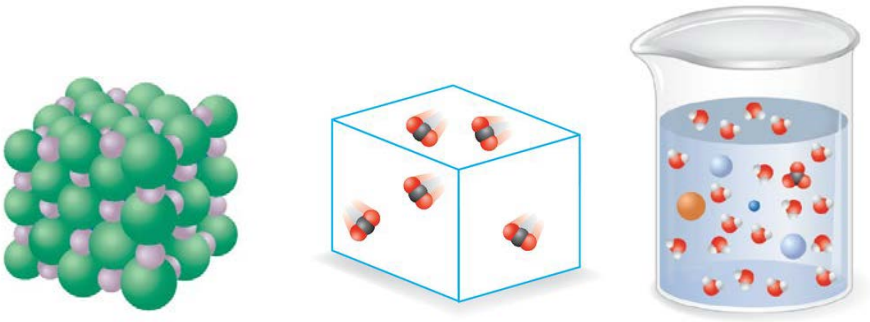
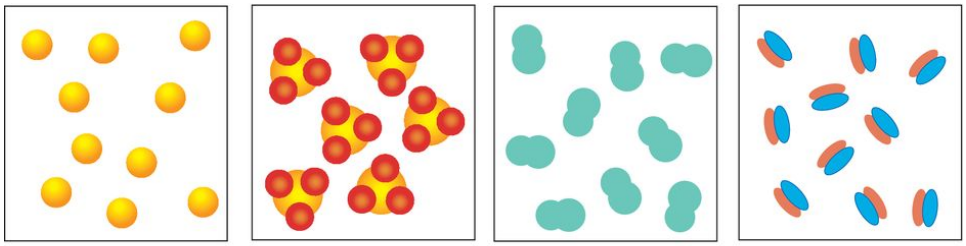


Which of the following pictures best represents fluorine gas?

Which other elements could this picture also represent?

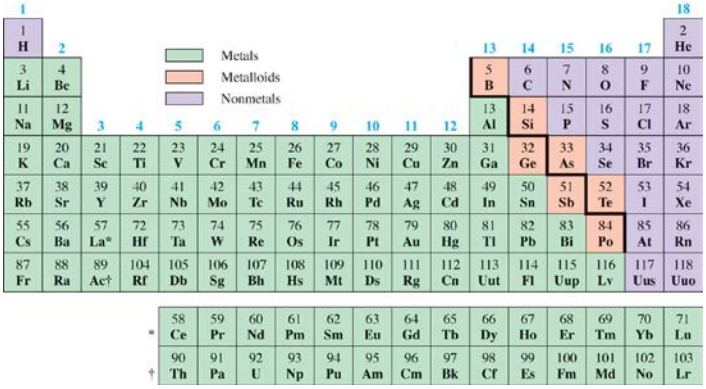
Which picture represents SO_3 gas?



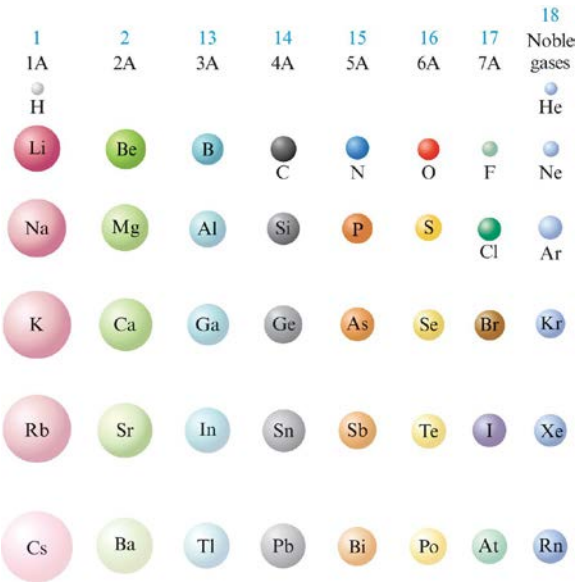
Periodic Trends in Atomic Properties (11.1 and 11.6)

- When a property gradually changes across a period, and there is a tendency for this change to repeat at regular intervals, we say that the property exhibits a Periodic Trend.

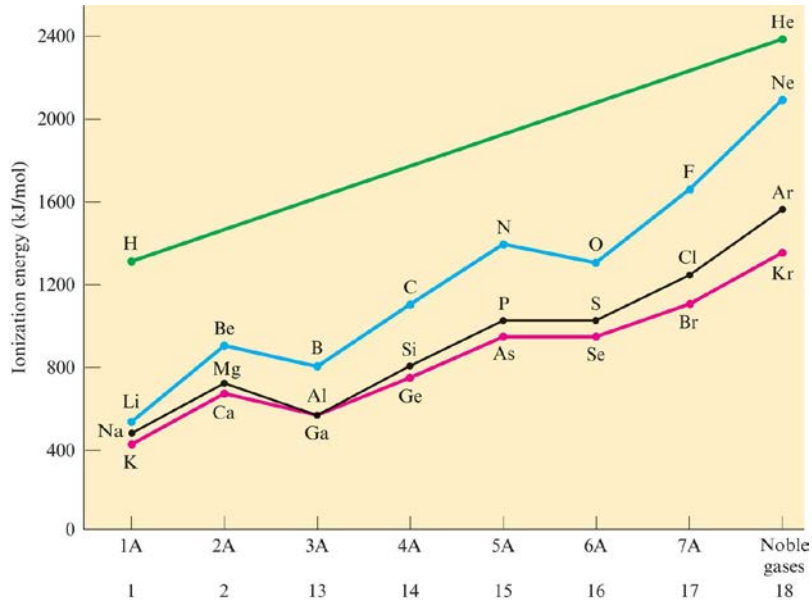
  - Elements get less metallic from left to right in a period.



- Atomic radius decreases from left to right in a period (more protons attracting electrons in the same shell).



- (First) Ionization energy is the energy required to remove the first electron from a neutral atom. Ionization energy increases from left to right in a period.
  - After removing valence electrons, subsequent IE's jump as electrons are removed from the core.



Electronegativity

- Electronegativity is the attraction that an atom of an element has for electrons.
  - Electronegativity exhibits a periodic trend.

Electronegativities

H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.7	Ba 0.9	La 1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.0