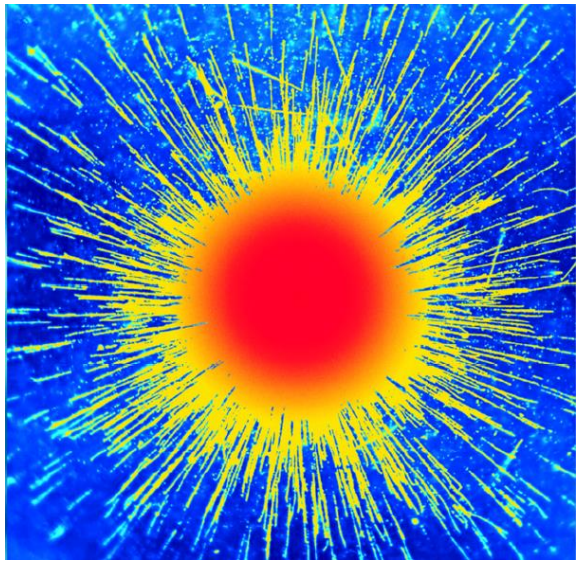
Atoms, Molecules and Ions

Chapter 2



Dalton's Atomic Theory (1808)

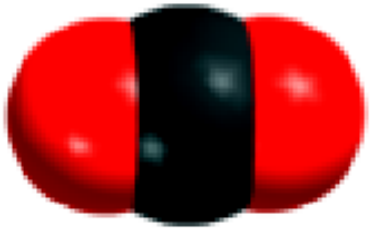
1. Elements are composed of extremely small particles called ***atoms***.
2. All ***atoms*** of a given element are identical, having the same size, mass and chemical properties. The atoms of one element are different from the atoms of all other elements.
3. ***Compounds*** are composed of atoms of more than one element. In any compound, the ratio of the numbers of atoms of any two of the elements present is either an integer or a simple fraction.
4. A ***chemical reaction*** involves only the separation, combination, or rearrangement of atoms; it does not result in their creation or destruction.

Dalton's Atomic Theory

Carbon monoxide

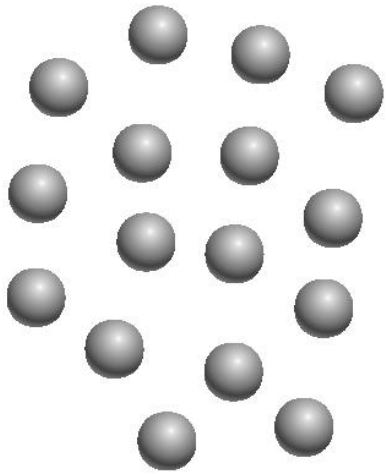
$$\frac{O}{C} = \frac{\text{●}}{\text{●}} = \boxed{\frac{1}{1}}$$

Carbon dioxide

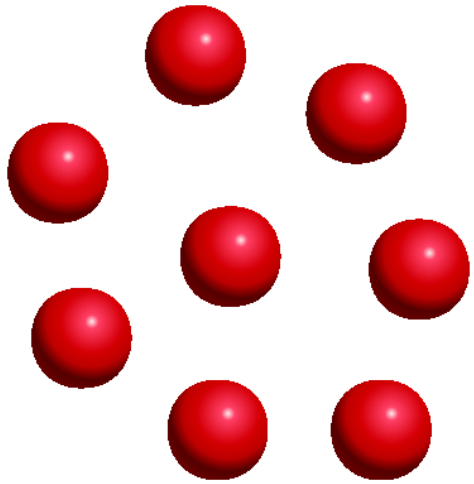


$$\frac{O}{C} = \frac{\text{● ●}}{\text{●}} = \boxed{\frac{2}{1}}$$

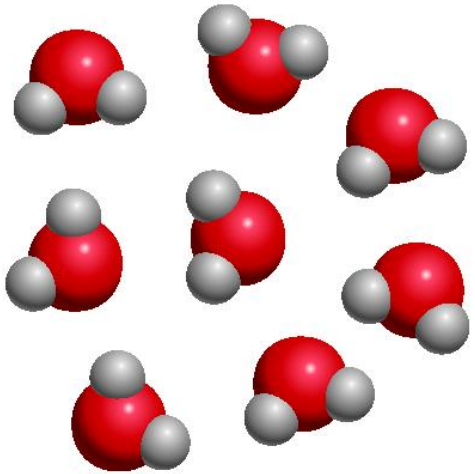
Law of Multiple Proportions



Atoms of element X



Atoms of element Y



Compounds of elements X and Y

$16\ X + 8\ Y \longrightarrow 8\ X_2Y$

Law of Conservation of Mass

TABLE 2.1 Mass and Charge of Subatomic Particles

Particle	Mass (g)	Charge	
		Coulomb	Charge Unit
Electron*	9.10938×10^{-28}	-1.6022×10^{-19}	-1
Proton	1.67262×10^{-24}	$+1.6022 \times 10^{-19}$	$+1$
Neutron	1.67493×10^{-24}	0	0

*More refined measurements have given us a more accurate value of an electron's mass than Millikan's.

mass p ≈ mass n ≈ 1840 x mass e^-

Atomic number, Mass number and Isotopes

Atomic number (Z) = number of protons in nucleus

Mass number (A) = number of protons + number of neutrons

= atomic number (Z) + number of neutrons

Isotopes are atoms of the same element (X) with different numbers of neutrons in their nuclei

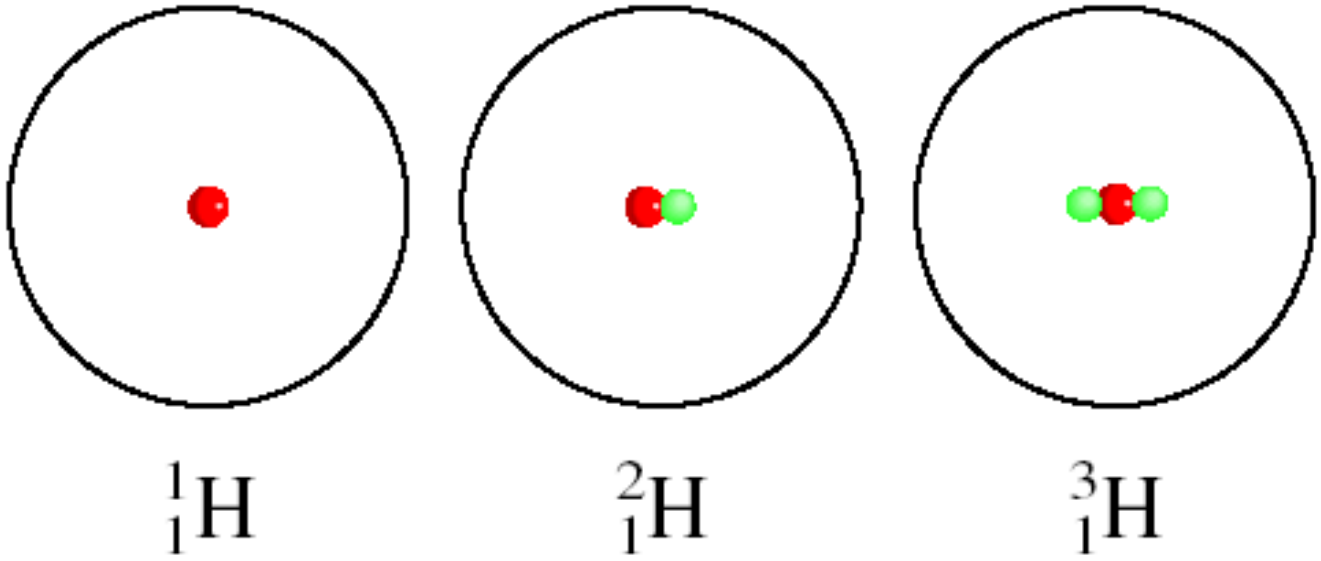
Mass Number → $^{A}_{Z}X$ ← Element Symbol

Atomic Number →

$^{1}_{1}H$ $^{2}_{1}H$ (D) $^{3}_{1}H$ (T)

$^{235}_{92}U$ $^{238}_{92}U$

The Isotopes of Hydrogen



$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

How many protons, neutrons, and electrons are in $^{14}_{6}C$?

6 protons, 8 (14 - 6) neutrons, 6 electrons

How many protons, neutrons, and electrons are in $^{11}_{6}C$?

6 protons, 5 (11 - 6) neutrons, 6 electrons

Examples

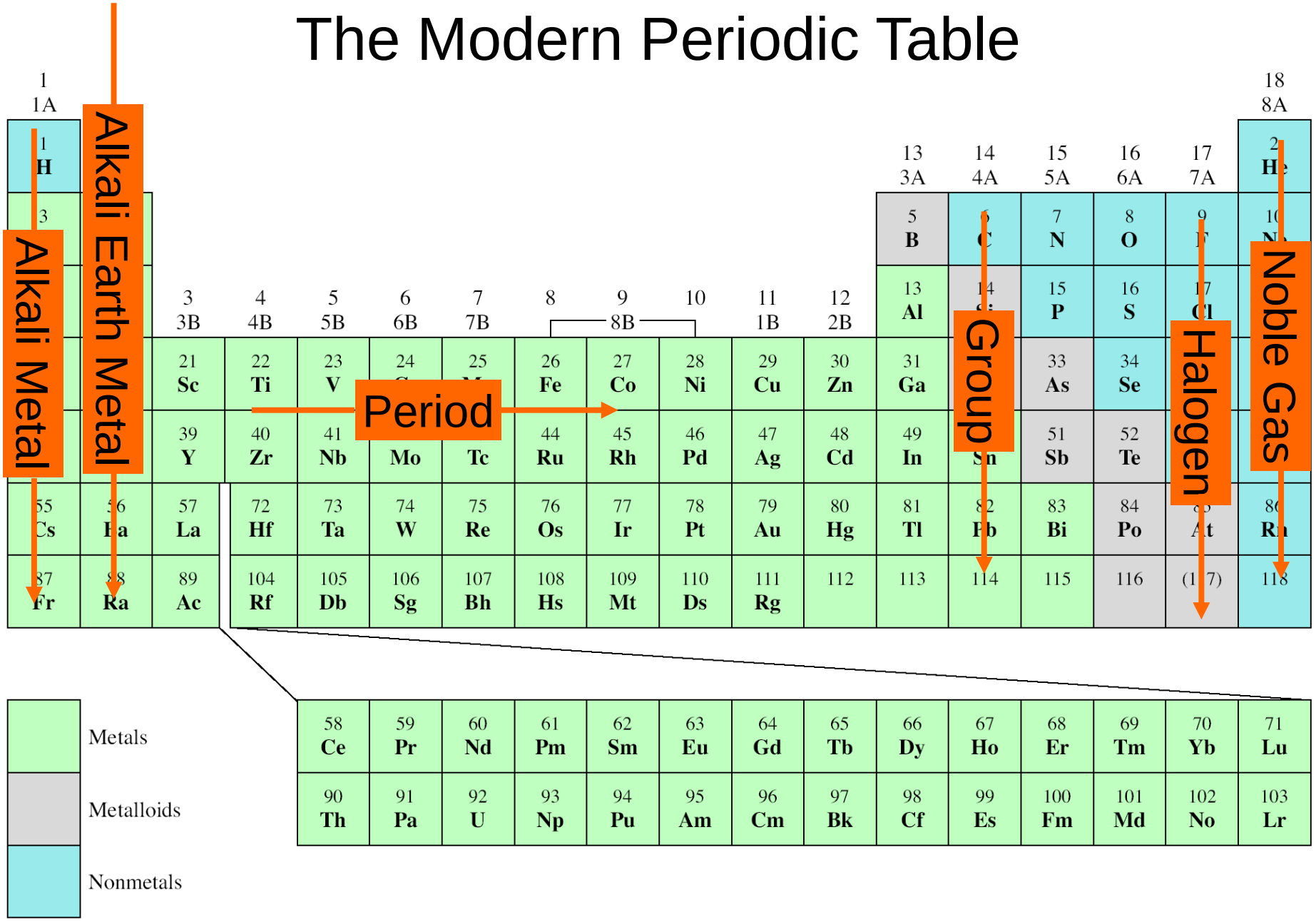
Ex: O Atom

$^{16}_{8}O$	
X	O
A	16
Z	8
$\#p^+$	8
$\#e^-$	8
$\#n^0$	8

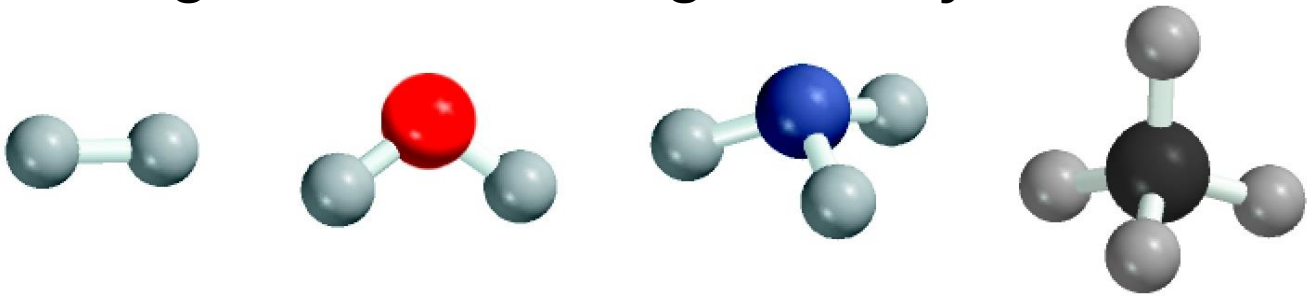
Ex: Cl atom

$^{35}_{17}Cl$	
X	Cl
A	35
Z	17
$\#p^+$	17
$\#e^-$	17
$\#n^0$	18

The Modern Periodic Table



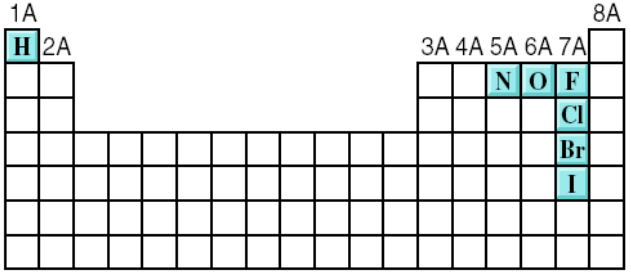
A ***molecule*** is an aggregate of two or more atoms in a definite arrangement held together by chemical forces



H_2 H_2O NH_3 CH_4

A ***diatomic molecule*** contains only two atoms

H_2, N_2, O_2, Br_2, HCl, CO



diatomic elements

A ***polyatomic molecule*** contains more than two atoms

O_3, H_2O, NH_3, CH_4

An ***ion*** is an atom, or group of atoms, that has a net positive or negative charge.

cation – ion with a positive charge

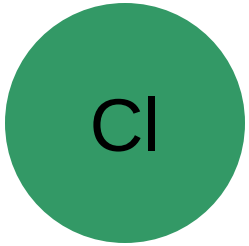
If a neutral atom **loses** one or more electrons it becomes a cation.

11 protons
11 electrons

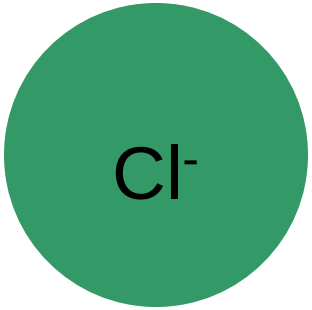
11 protons
10 electrons

anion – ion with a negative charge

If a neutral atom **gains** one or more electrons it becomes an anion.



17 protons
17 electrons



17 protons
18 electrons

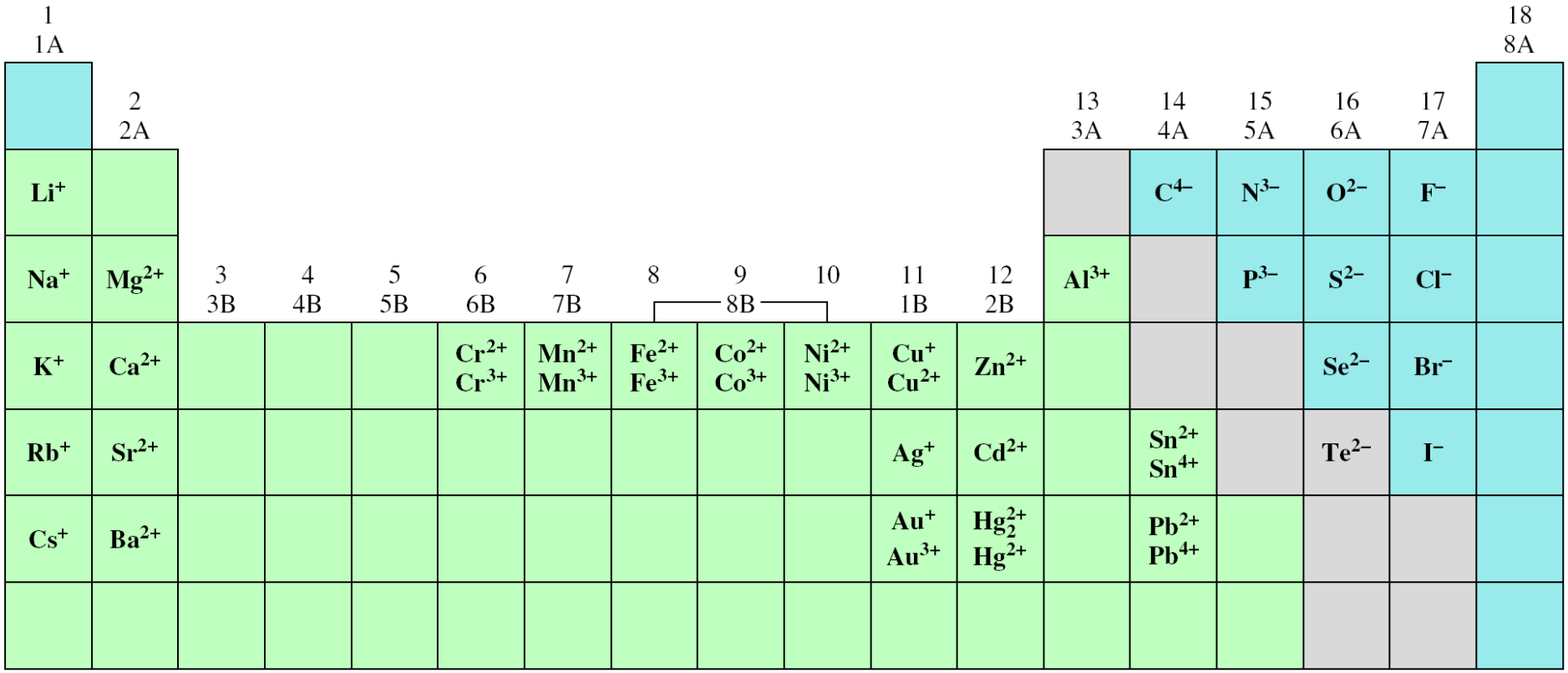
A ***monatomic ion*** contains only one atom

Na^{+}, Cl^{-}, Ca^{2+}, O^{2-}, Al^{3+}, N^{3-}

A ***polyatomic ion*** contains more than one atom

OH^{-}, CN^{-}, NH_4^{+}, NO_3^{-}

Common Ions Shown on the Periodic Table



Note: The mass number, no. of protons, and no. of neutrons will not change for the ions. The only thing that will change for the ion is the *number of electrons*.

For Ions:

- Atomic number (Z) = no. of protons (p^+)
- Mass number (A) = no. of protons (p^+) + no. of neutrons (n^0)
- No. of neutrons (n^0) = Mass number (A) – no. of protons (p^+)
- No. of protons (p^+) = Mass number (A) – no. of neutrons (n^0)

How many protons and electrons are in $^{27}_{13}Al^{3+}$?

13 protons, 10 (13 – 3) electrons

How many protons and electrons are in $^{78}_{34}Se^{2-}$?

34 protons, 36 (34 + 2) electrons

Number of electrons for ions

$$\boldsymbol{no.of\ electrons\ (e^-) = atomic\ number\ (Z) - charge}$$

or

$$\boldsymbol{e^-\ = no.of\ protons\ (p^+) - charge}$$

Examples

- $Na^{+1}(Z = 11; \#p^{+} = 11\ ):\quad \#electrons = 11 - (+1) = 10\ electrons$
- $Mg^{+2}(Z = 12;\ \#p^{+} = 12):\quad \#electrons = 12 - (+2) = 10\ electrons$
- $Sr^{+2}(Z = 38;\ \#p^{+} = 38):\quad \#electrons = 38 - (+2) = 36\ electrons$
- $S^{-2}(Z = 16;\ \#p^{+} = 16):\quad \#electrons = 16 - (-2) = 18\ electrons$
- $I^{-1}(Z = 53;\ \#p^{+} = 53):\quad \#electrons = 53 - (-1) = 54\ electrons$
- $N^{-3}(Z = 7;\ \#p^{+} = 7):\quad \#electrons = 7 - (-3) = 10\ electrons$

Examples

Ex: O^{-2} ion

$^{16}_{8}O^{-2}$	
X	O
A	16
Z	8
#p^+	8
#e^-	10
#n^0	8
Charge	-2
Cation/Anion/Atom	Anion

Ex: Na^{+1} ion

$^{23}_{11}Na^{+1}$	
X	Na
A	23
Z	11
#p^+	11
#e^-	10
#n^0	23
Charge	+1
Cation/Anion/Atom	Cation

Examples

Ex: Ba^{+2} ion

$^{137}_{56}Ba^{+2}$	
X	Ba
A	137
Z	56
#p^+	56
#e^-	54
#n^0	81
Charge	+2
Cation/Anion/Atom	Cation

Ex: Cl^{-1} ion

$^{35}_{17}Cl^{-1}$	
X	Cl
A	35
Z	17
#p^+	17
#e^-	18
#n^0	18
Charge	-1
Cation/Anion/Atom	Anion