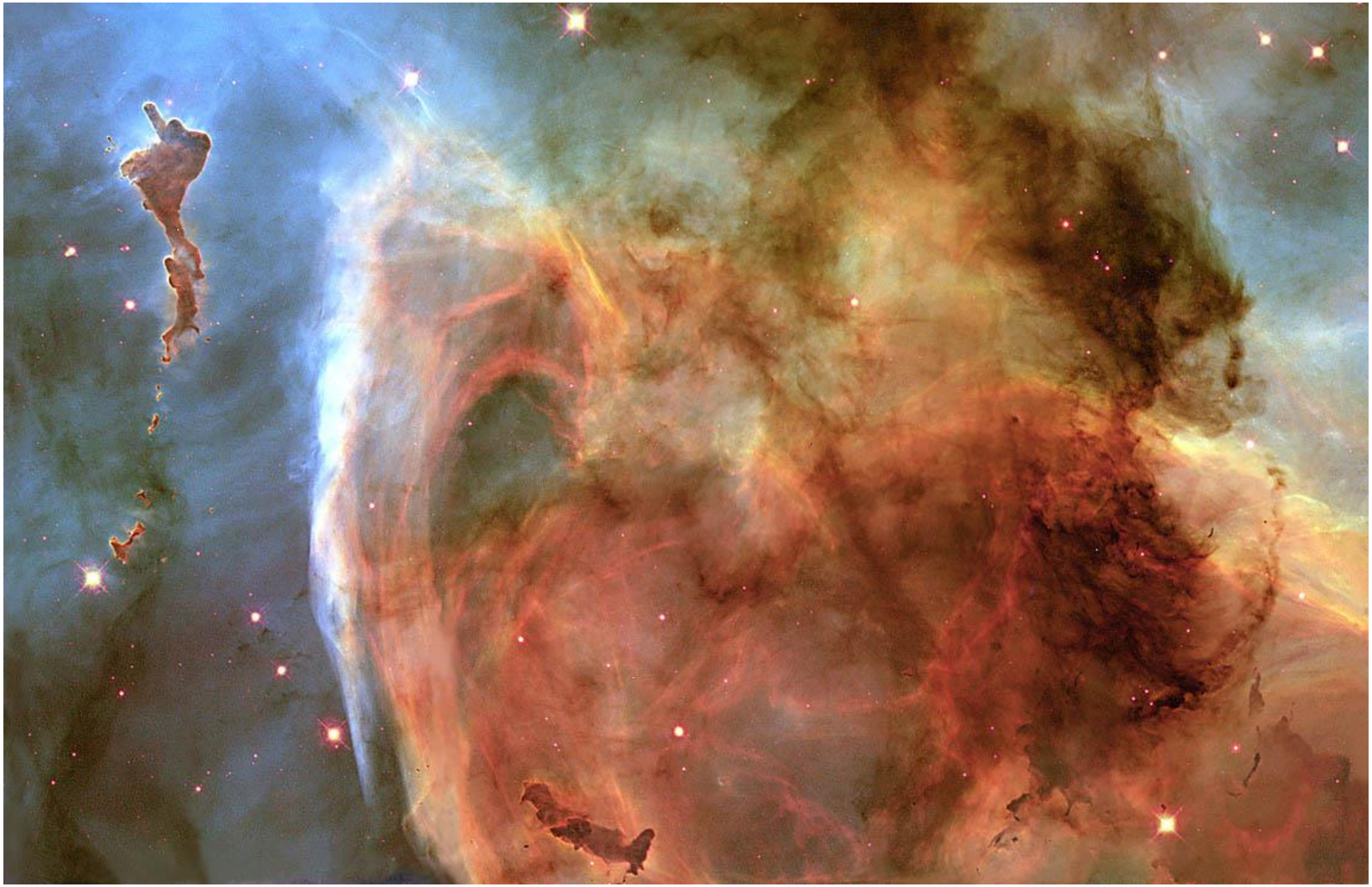
Chapter 2: Atoms and Elements



Early Ideas about the structure of Matter

- Ancient Greece
  - Leucippus and Democritus: Proposed that there were many types of atoms, different in shape and size.
  - Aristotle: Substances have no “smallest part”, but were made of earth, air, fire, and water.
  - Aristotle wins because of his influence, and the idea of atoms is tabled for nearly 2000 years.

Early Ideas about the structure of Matter

– Lavoisier: Law of Conservation of Mass

In a chemical reaction, matter is neither created nor destroyed.

– Proust: Law of Definite Proportions

All samples of a given compound, regardless of their source or how they were prepared, have the same proportions of their constituent elements.

– Dalton: Law of Multiple Proportions

When two elements (A and B) form two different compounds, the masses of element B that combine with element A can be expressed as a ratio of small whole numbers.

Dalton: Atomic Theory of Matter

Matter is composed of atoms

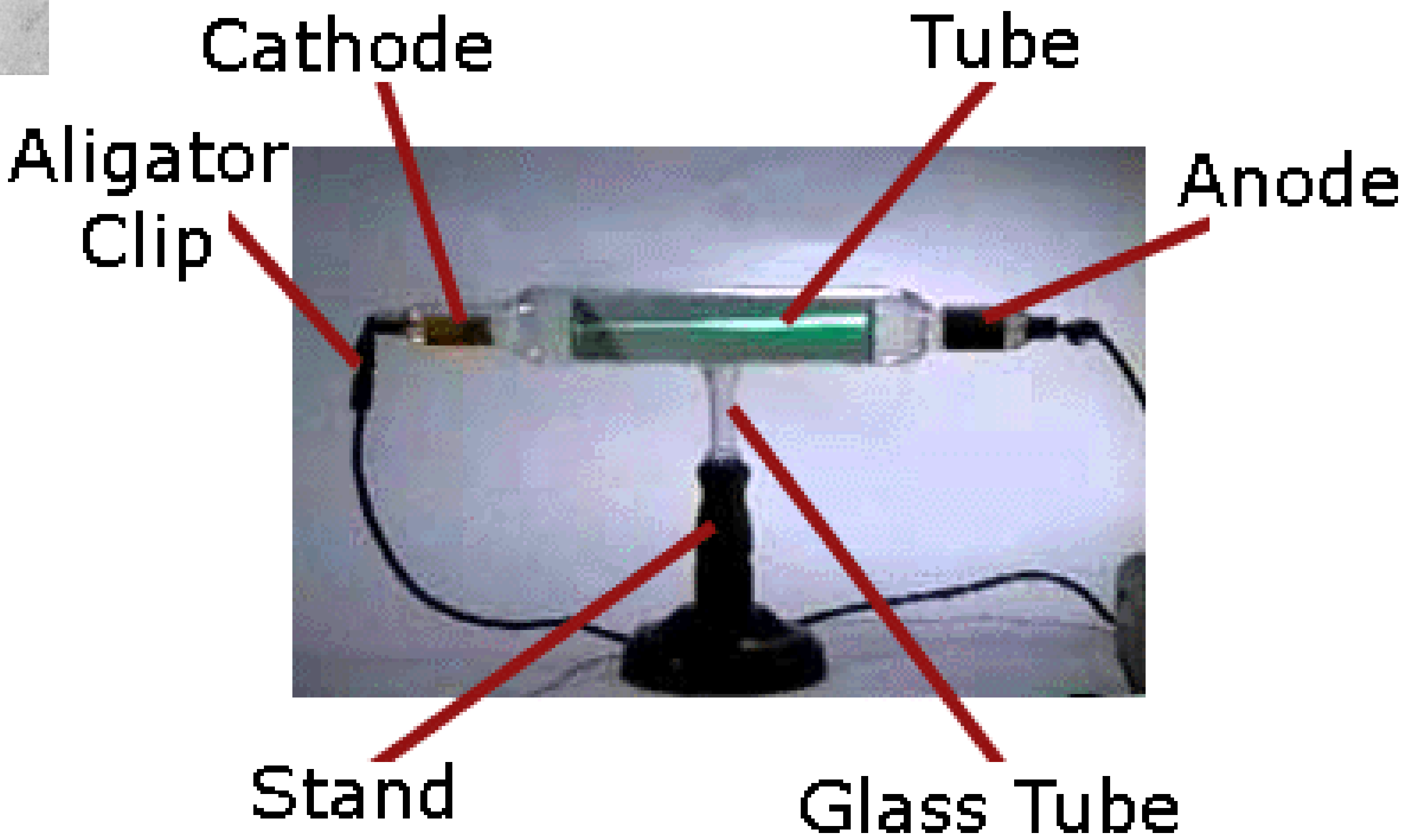
Atoms of given element have identical properties

Different elements have different properties

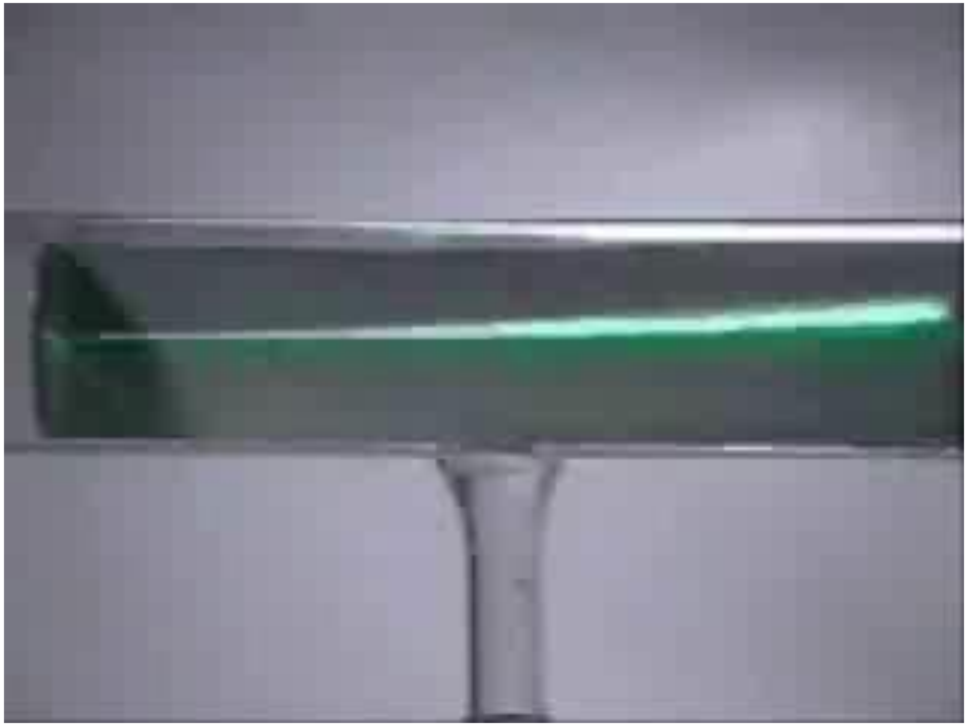
Atoms combine in *whole number* ratios

Cathode Ray Tube

J. J. Thomson
Charge to Mass
Ratio of electrons



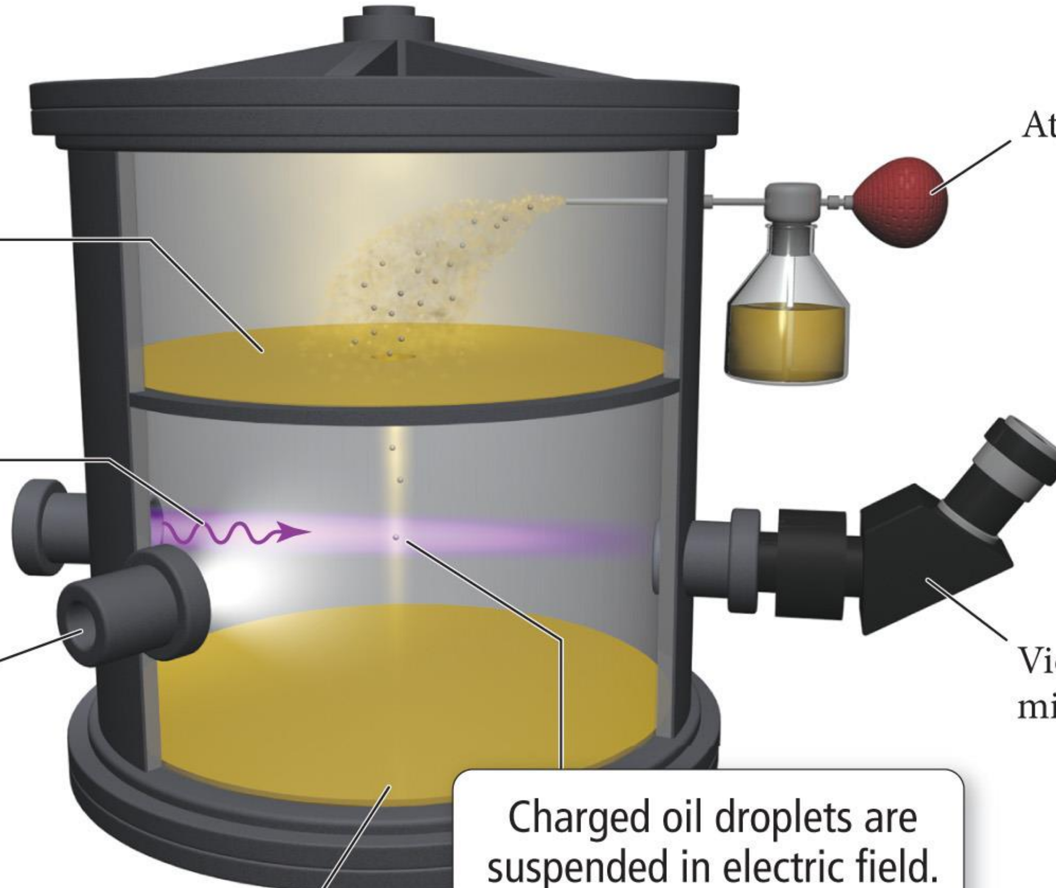
Cathode Ray Tube

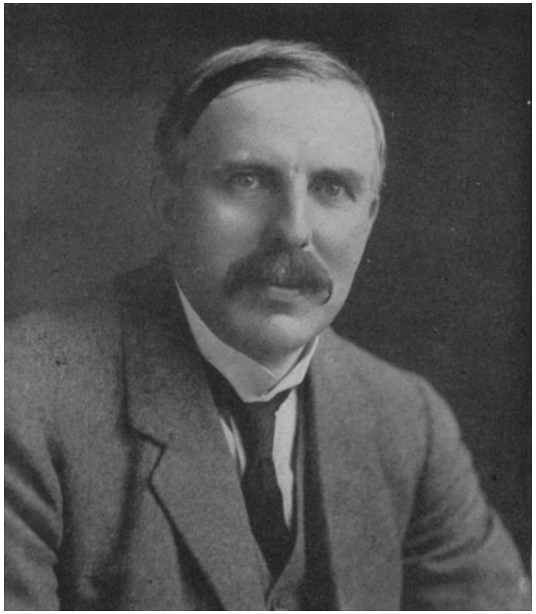


- http://www.chem.uiuc.edu/clcwebsite/video/Cath.wmv

Oil Drop Experiment

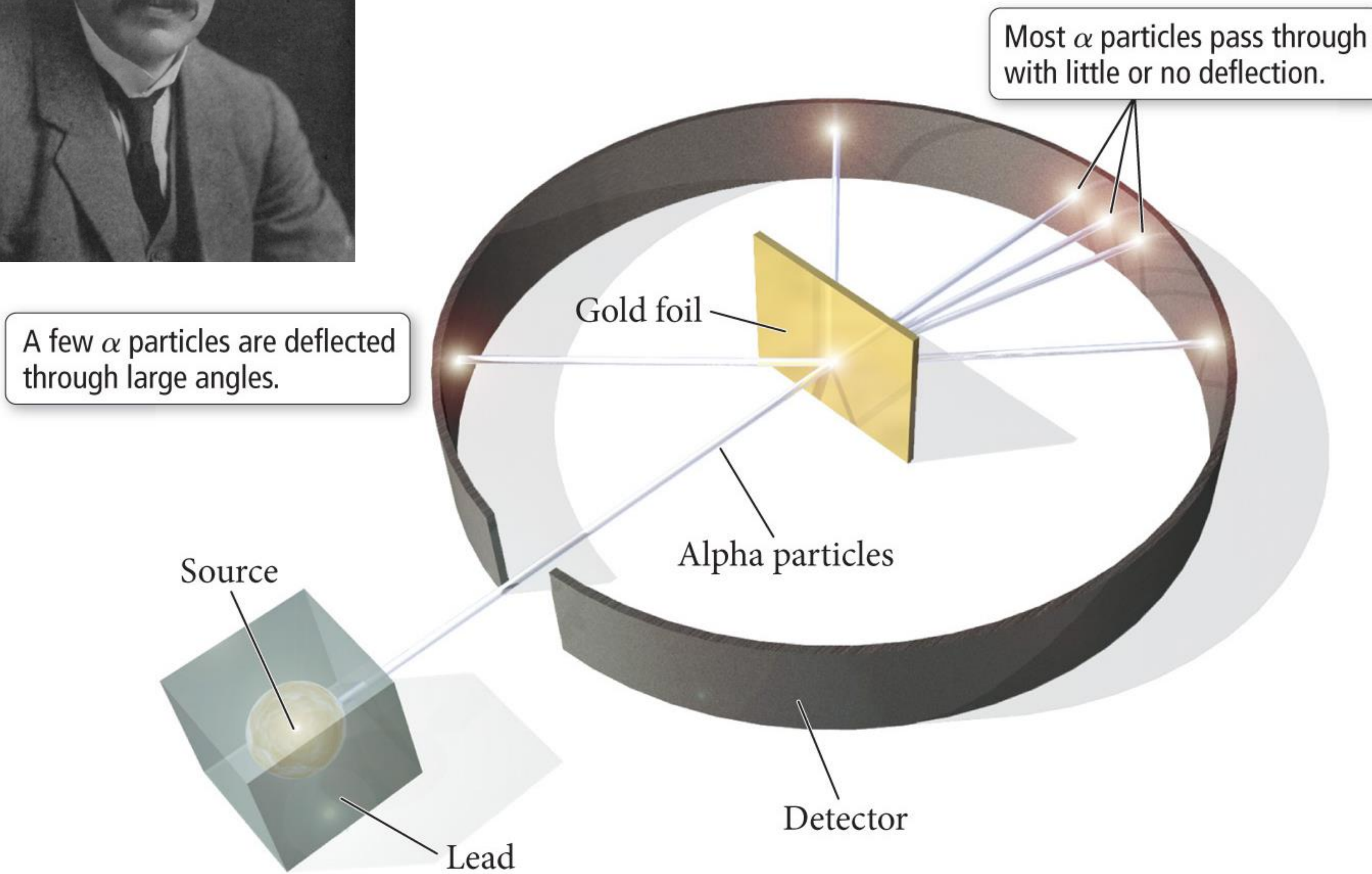
Robert
Millikan
Charge *and* Mass
of electrons





Ernest Rutherford

The structure of the atom



Composition of Atoms

Atoms contain protons, neutrons, and electrons

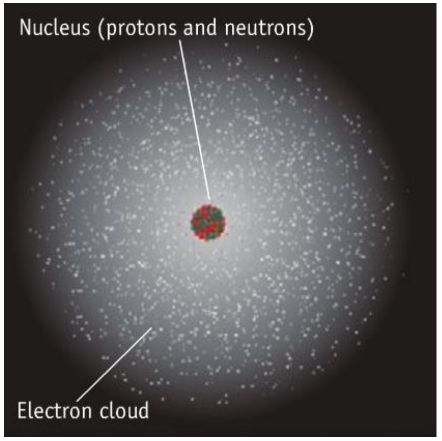
The nucleus includes protons and neutrons

Electrons surround the nucleus

Protons have positive (+) charge

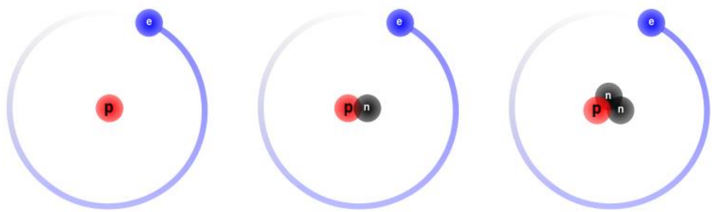
Electrons have negative (–) charge

Neutrons have no charge



Isotopes

Atoms with the same atomic number but different masses are called isotopes

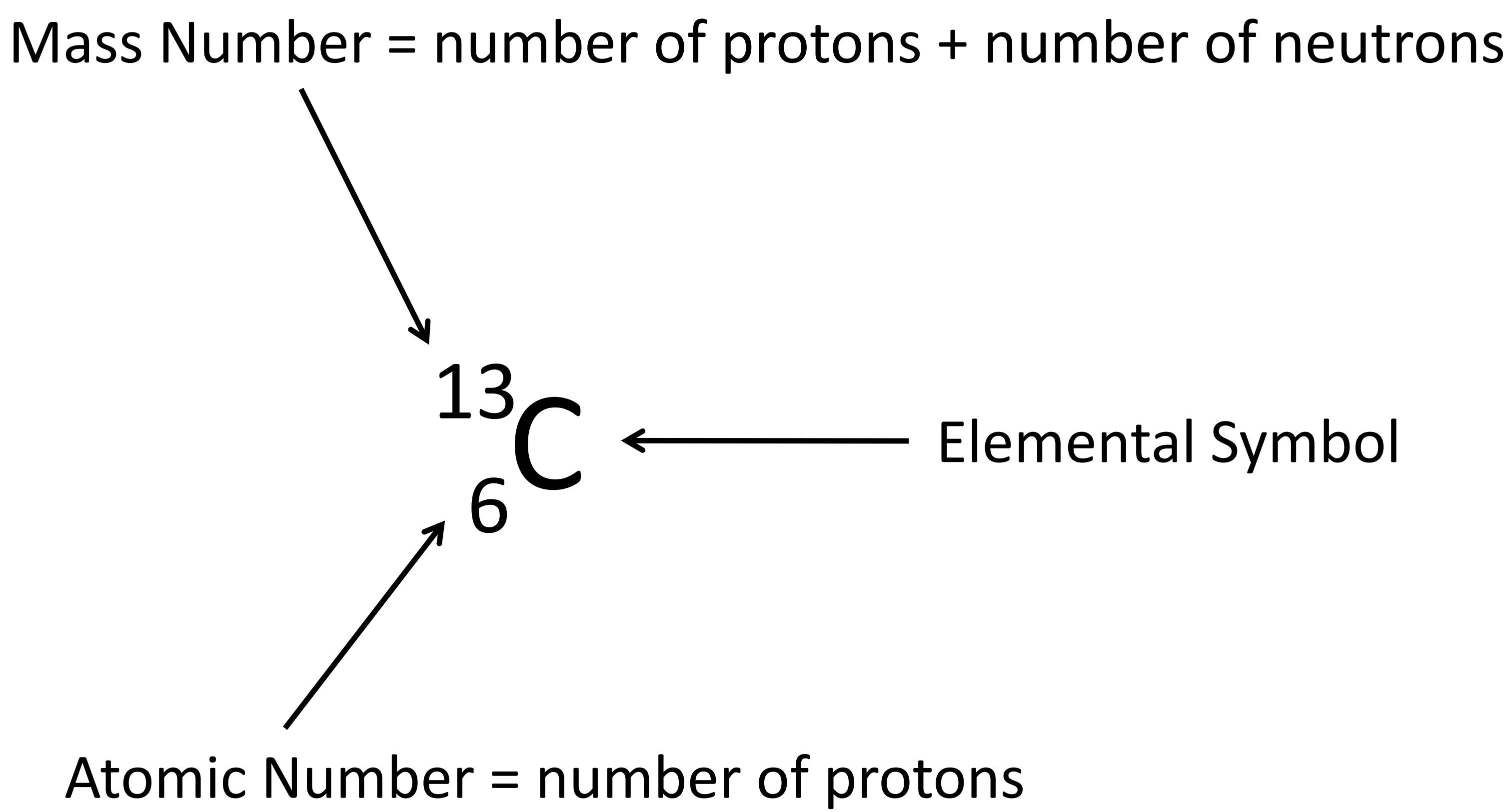


$^{1}_{1}\mathrm{H}$ $^{2}_{1}\mathrm{H}$ $^{3}_{1}\mathrm{H}$

Since the chemical behavior of atoms is determined by electrostatic attraction between the nuclei and the electrons, atoms with the same number of protons (Z) behave identically

^{81}Br and ^{79}Br not ^{81}Kr and ^{81}Br

Isotope Symbol



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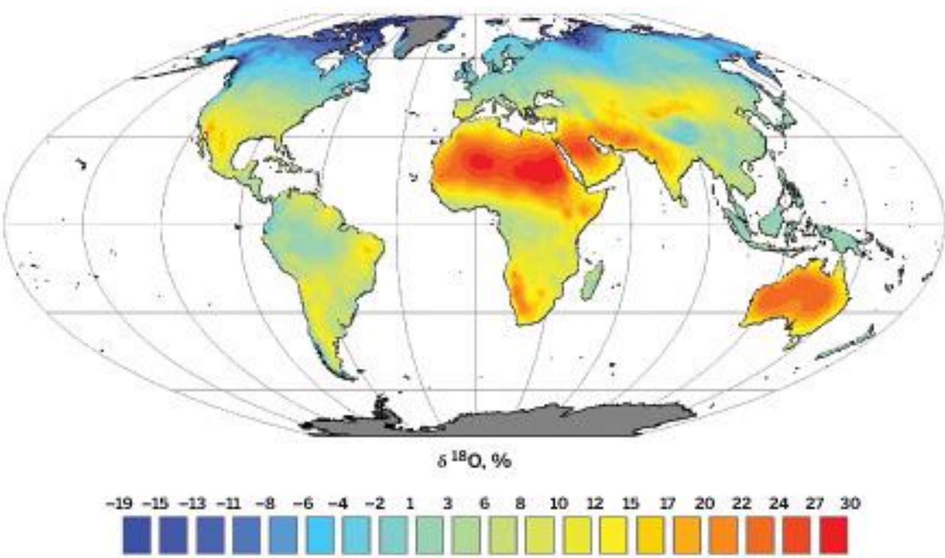
Isotopes Mark The Spot

Ratios of stable isotopes help locate the origin of corpses, follow migration routes, and authenticate items as different as bottled water and expensive cheese



The term isoscapes was first coined by Jason West, now an ecologist at Texas A&M University. (pubs.acs.org/cen/science/89/8926sci1.html)

Atomic Mass

Atoms have measureable masses

The Atomic Mass of an element is the *average mass* of an atom of the element

Units:
1 amu = 1.66 x10^{-27} kg

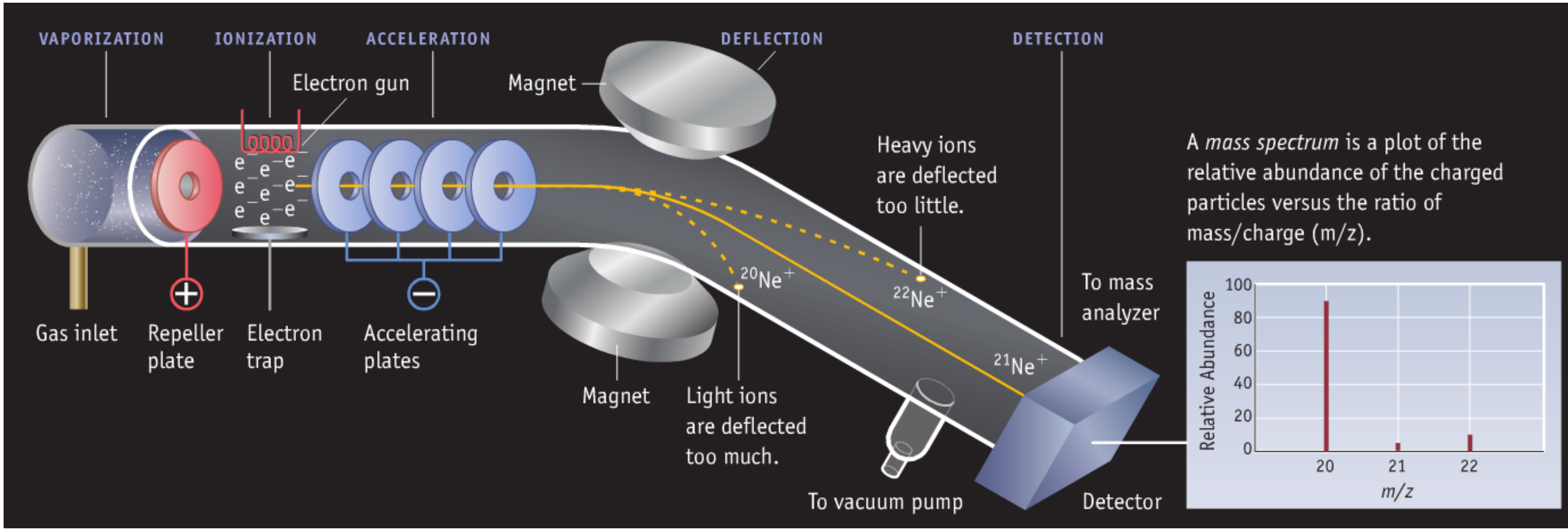
$$\text{Atomic Mass} = \left[\frac{\text{\% abundance of isotope 1}}{100}\right] \times \text{mass of isotope 1} + \left[\frac{\text{\% abundance of isotope 2}}{100}\right] \times \text{mass of isotope 2} \;\ldots\ldots + $$

Example

76. An element has four naturally occurring isotopes with the masses and natural abundances given here. Find the atomic mass of the element and identify it.

Isotope	Mass (amu)	Abundance (%)
1	135.90714	0.19
2	137.90599	0.25
3	139.90543	88.43
4	141.90924	11.13

Isotopes and Mass Spectrometry



Atomic mass and isotopic abundance can be experimentally measured using mass spectrometer – highly accurate mass/charge ratio measurement allows the accurate identification of atom or molecules

Example

- Use the abundances and masses of the isotopes from the previous example to predict what the mass spectrum of that element would look like:

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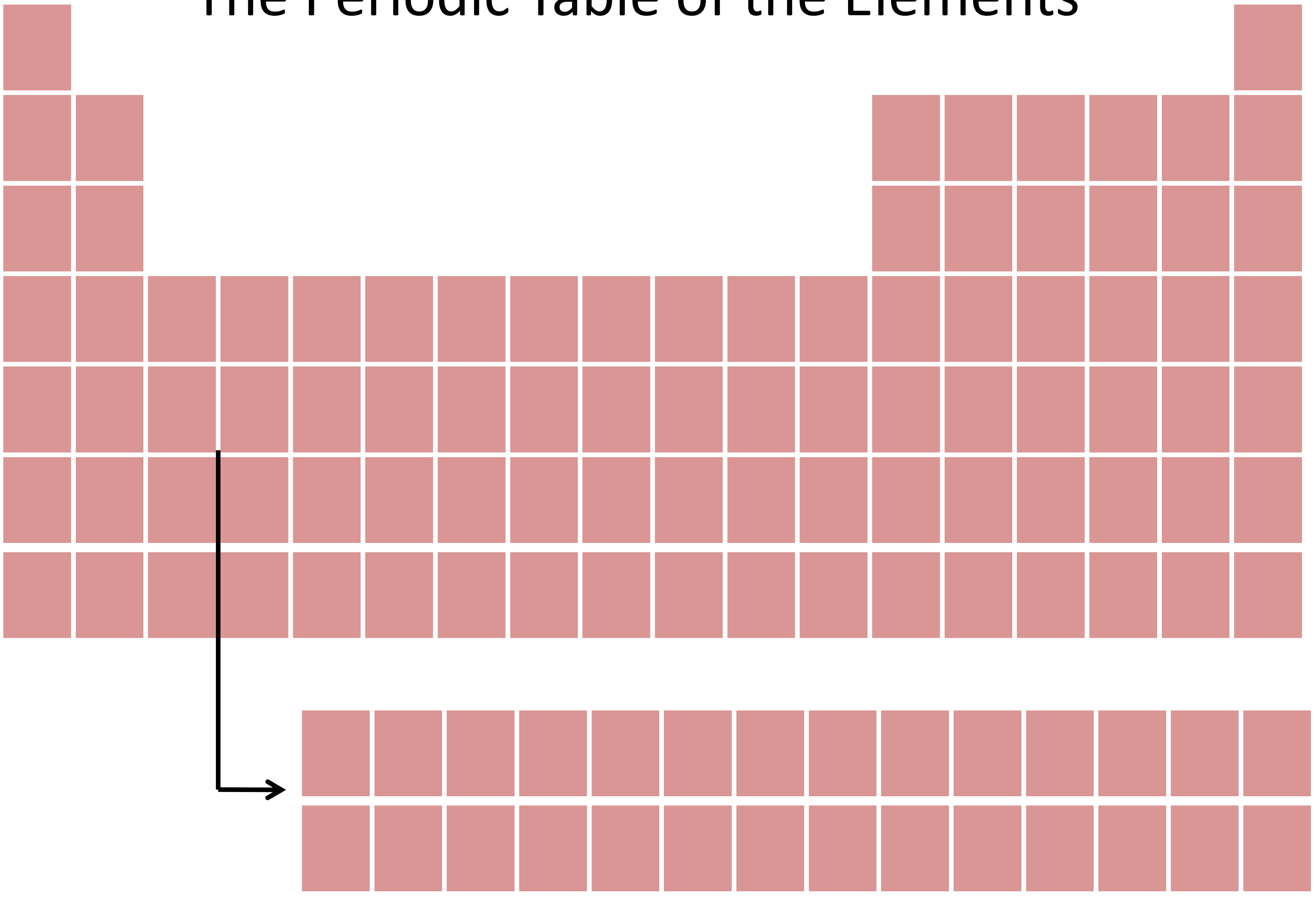
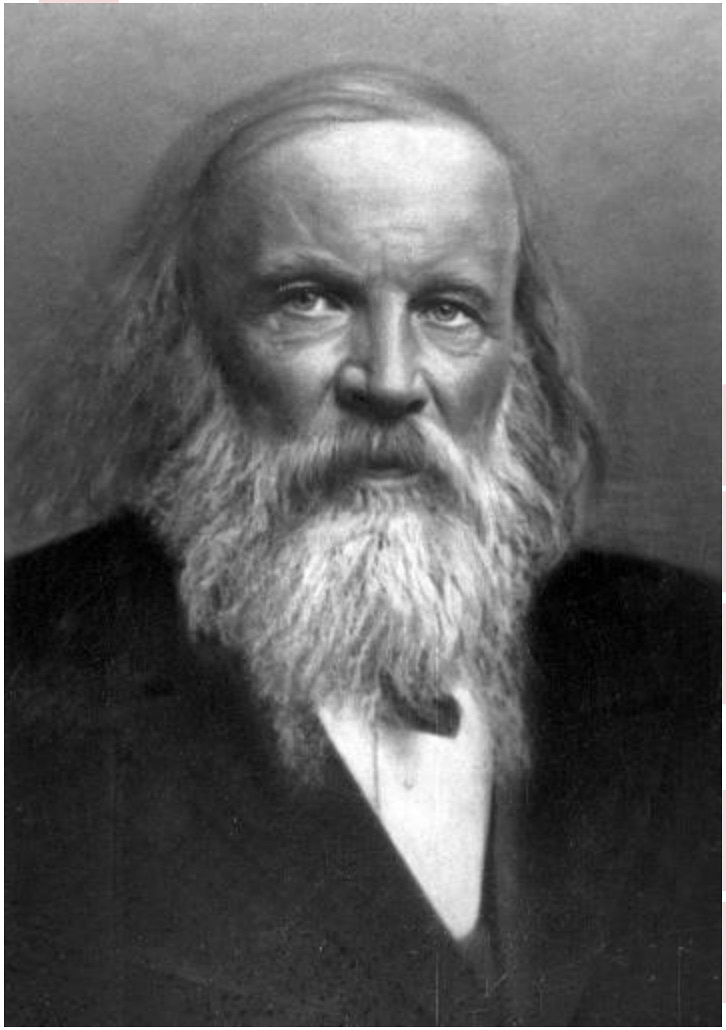
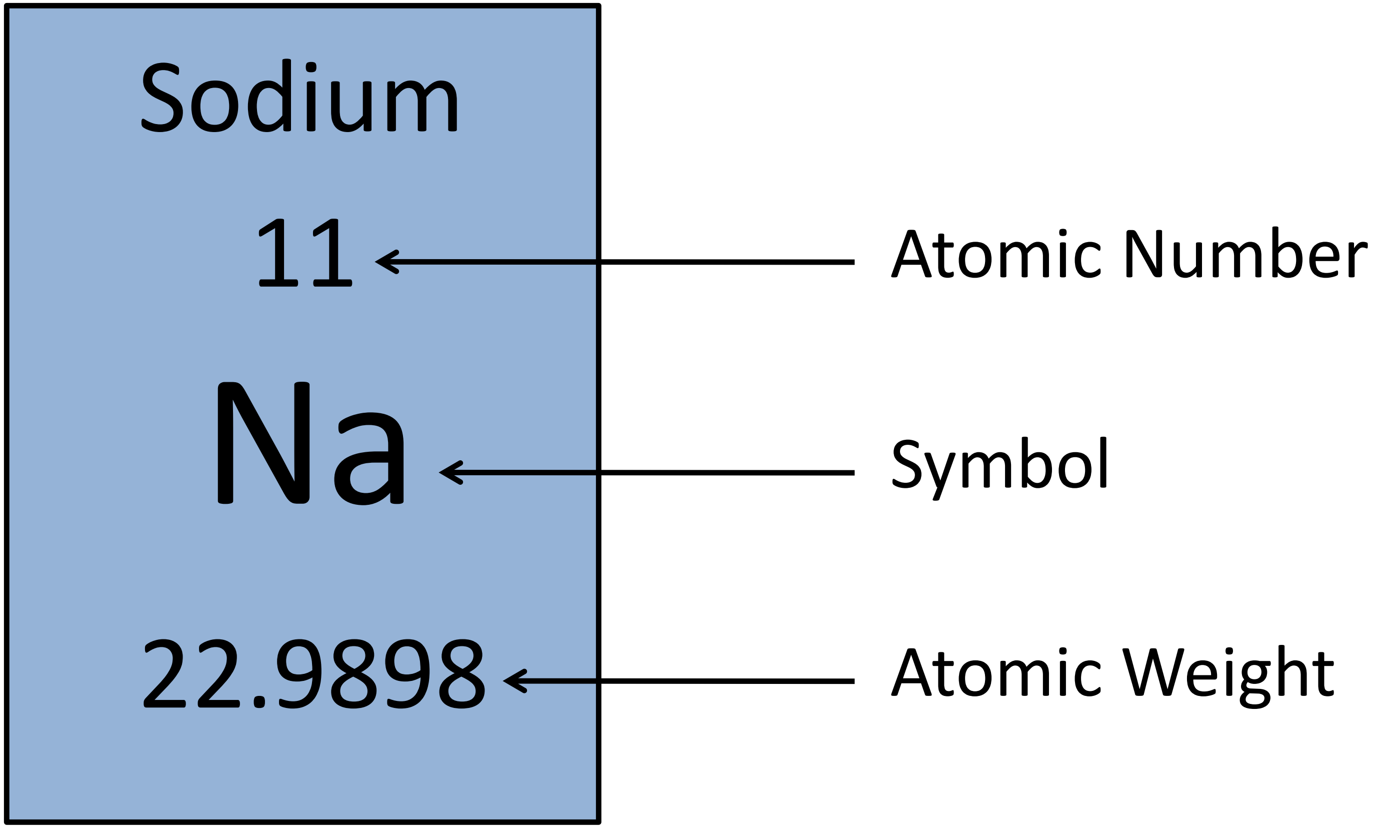
The Periodic Table of the Elements

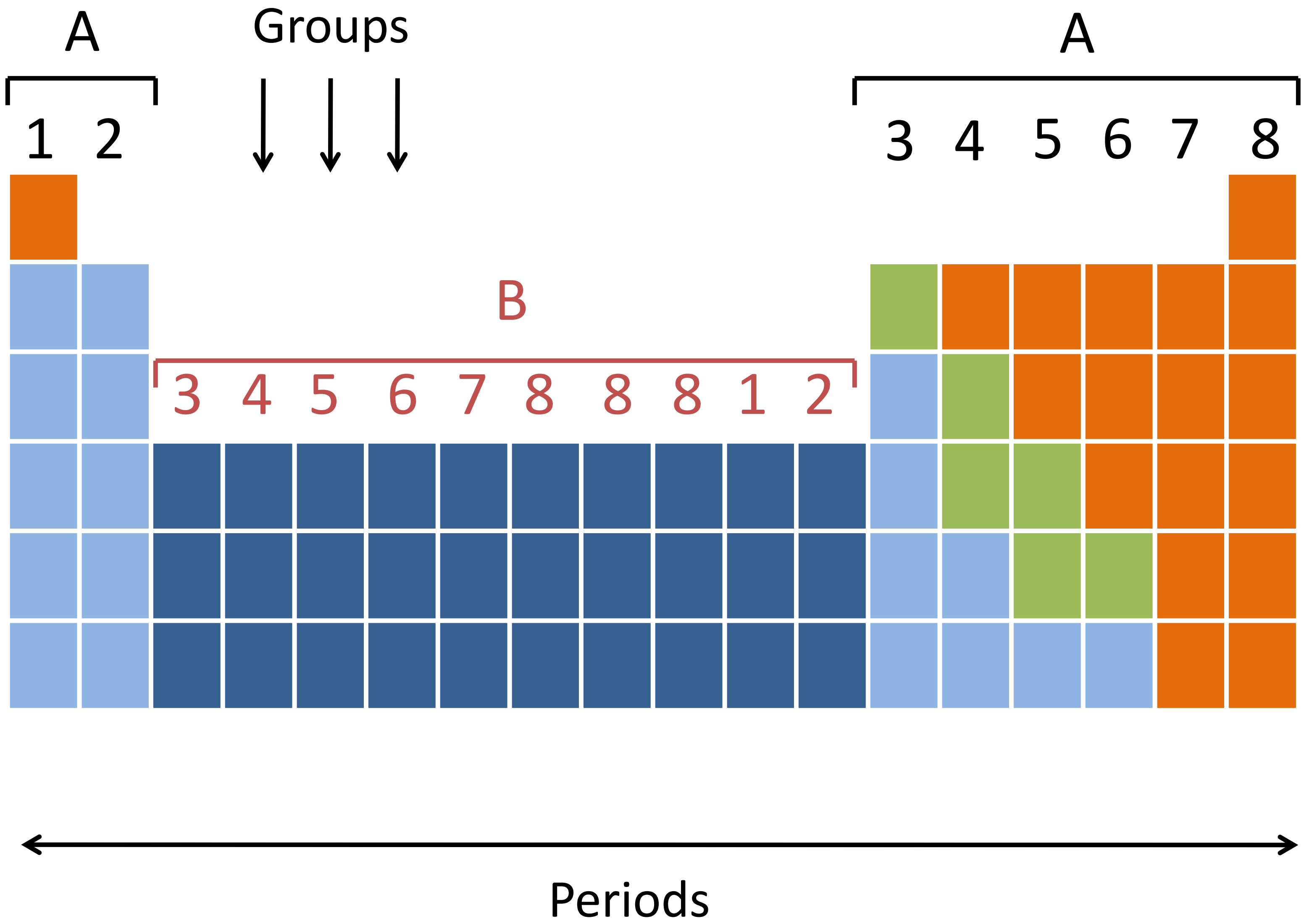


The Periodic Table of the Elements

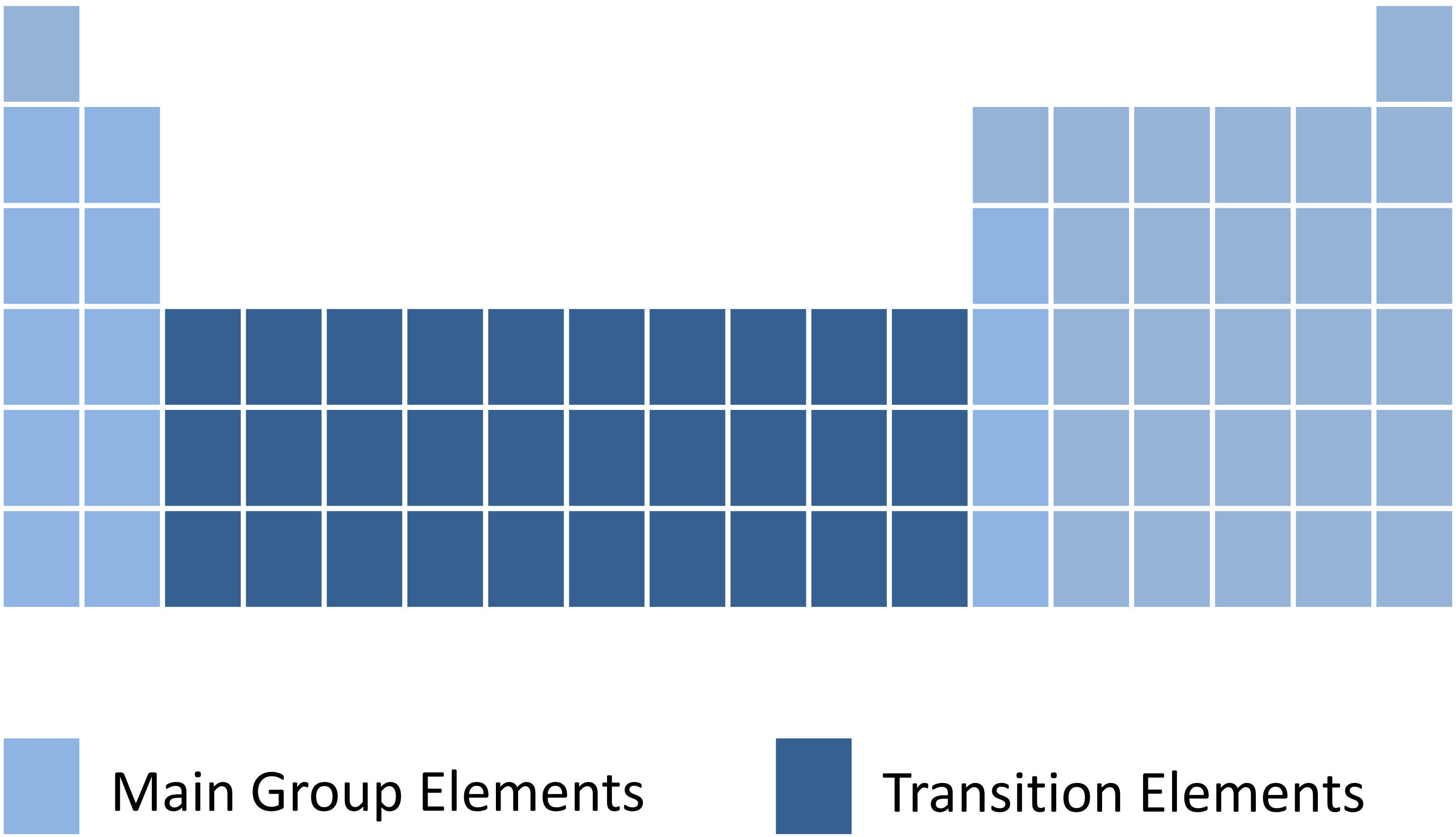


Dmitri Mendeleev

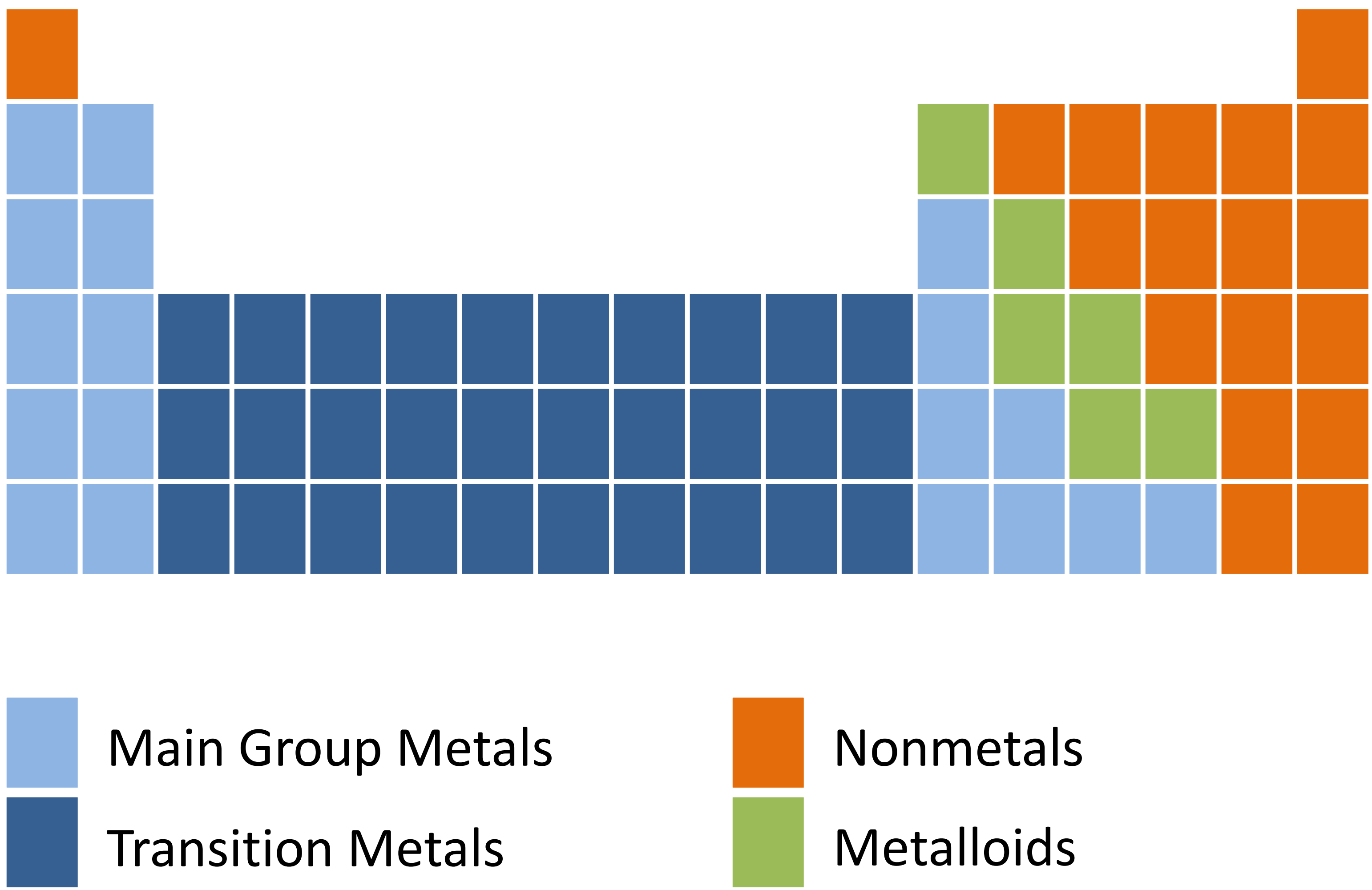

Sodium
11
Na
22.9898
Atomic Number
Symbol
Atomic Weight


A
Groups
A
1 2
3 4 5 6 7 8
B
3 4 5 6 7 8 8 8 1 2
Periods

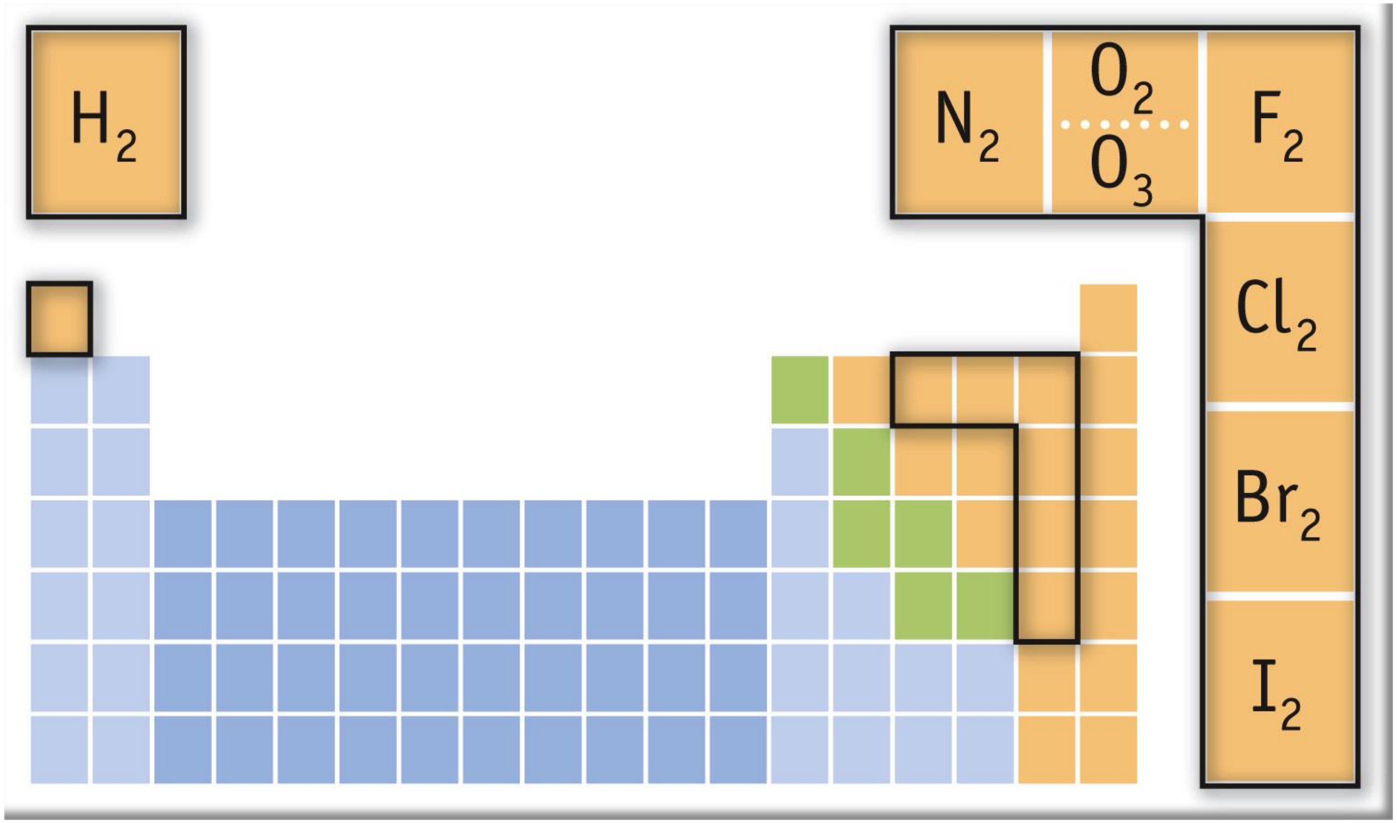
The Periodic Table of the Elements



The Periodic Table of the Elements



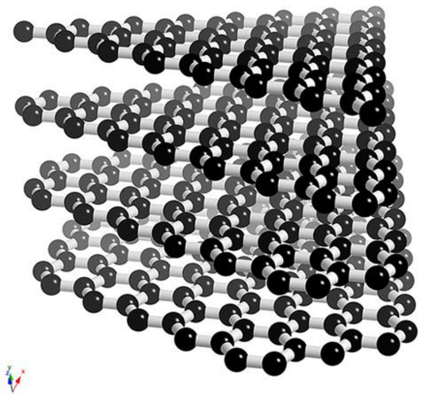
Elements that Exist as Diatomic or Triatomic Molecules

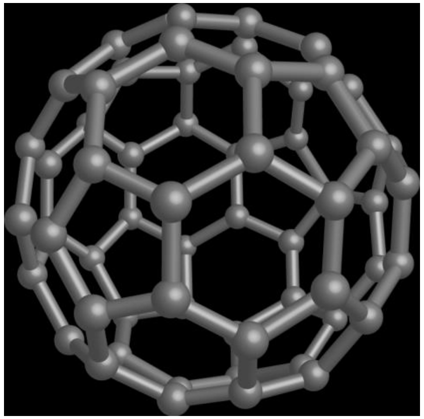


Allotropes

One interesting aspect of the nonmetals (like carbon) is that an element of this type can often exist in several different and distinct forms, called allotropes.

Each allotrope has its own physical and chemical properties.





Ions

Ions are atoms or groups of atoms with electric charge

Cations have positive charge

Anions have negative charge

Monatomic Cations

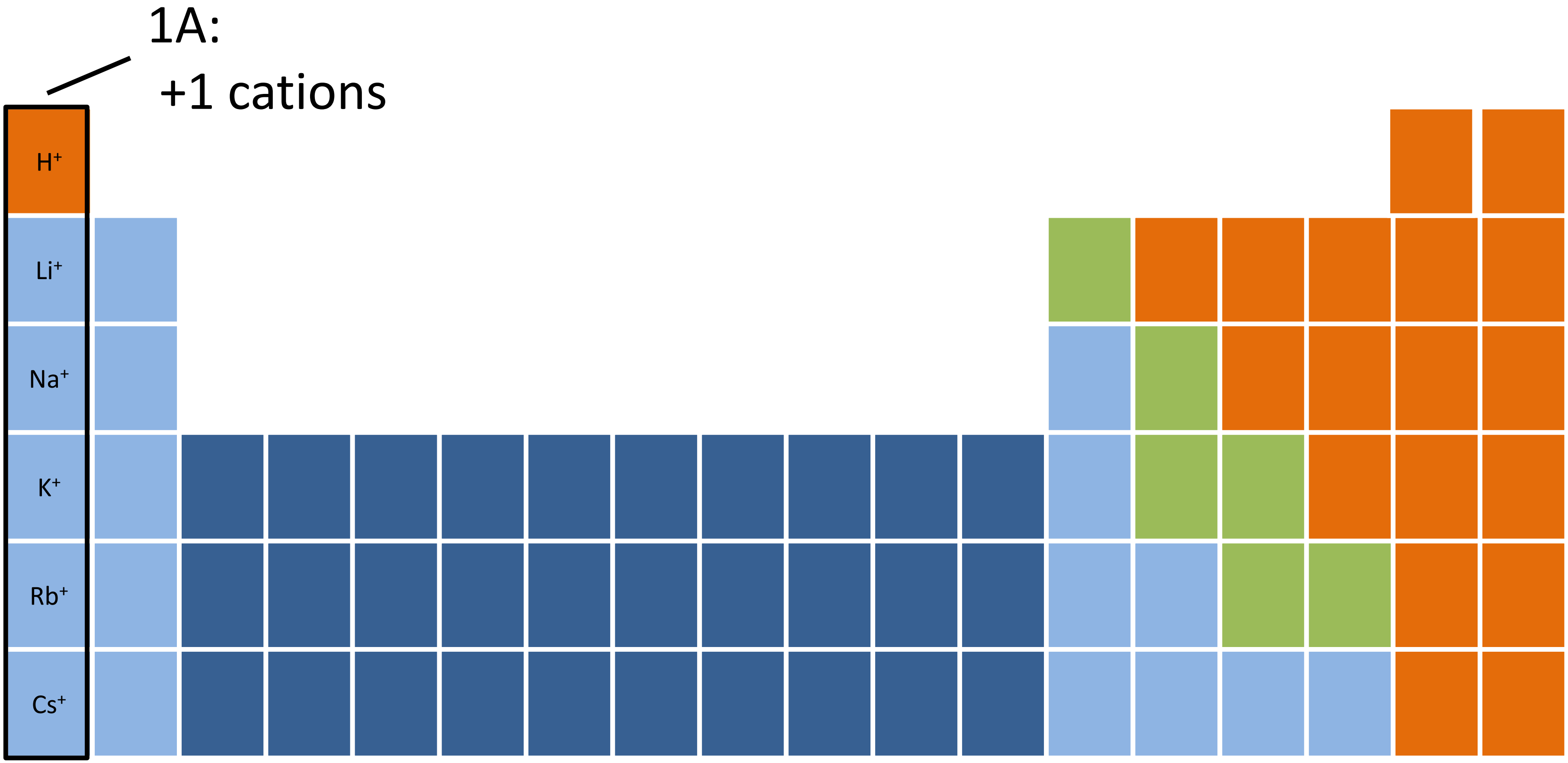
Formed from neutral atoms by removing one or more electrons

Metals, often from the first 2 columns of the periodic table

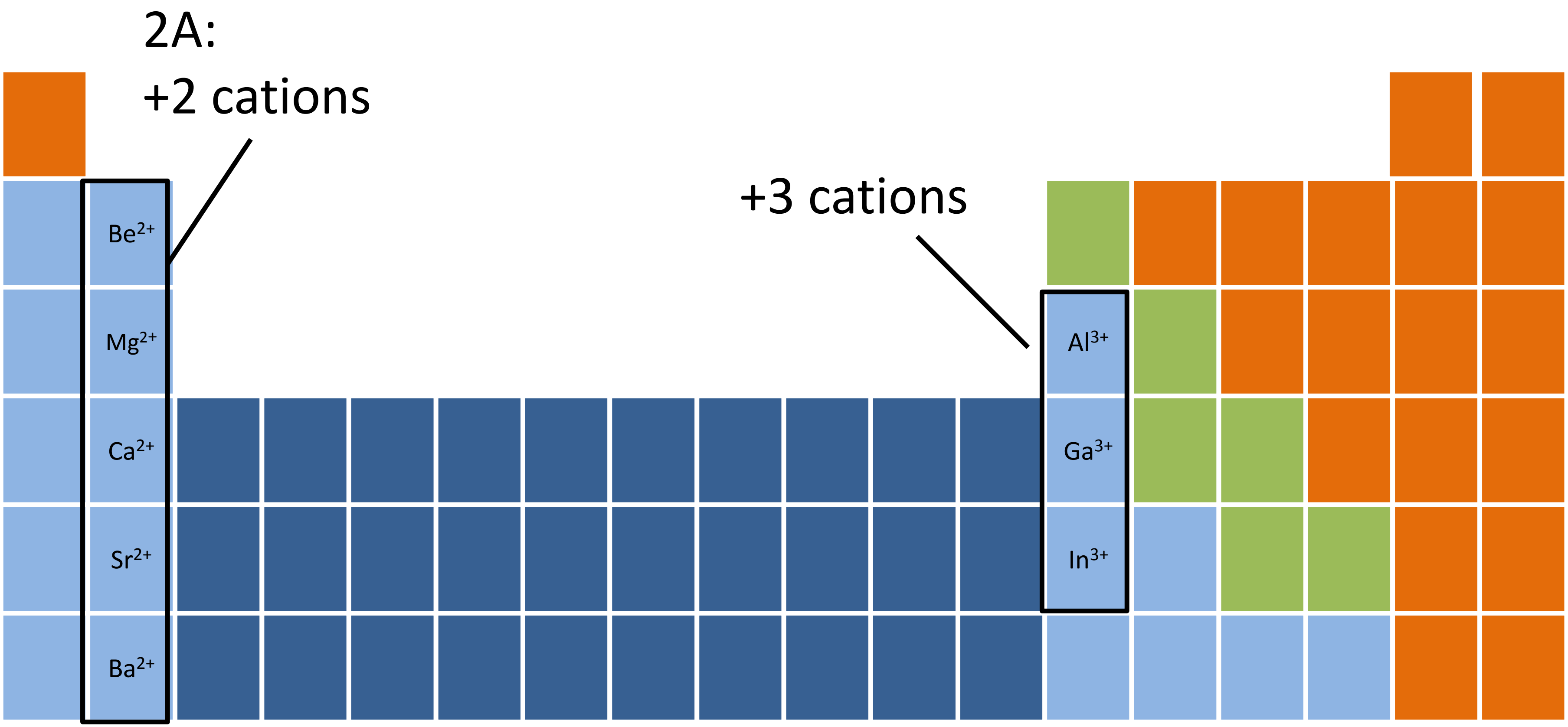
$$Na \longrightarrow Na^{+} + e^{-}$$

$$Mg \longrightarrow Mg^{2+} + 2e^{-}$$

Monatomic Ions



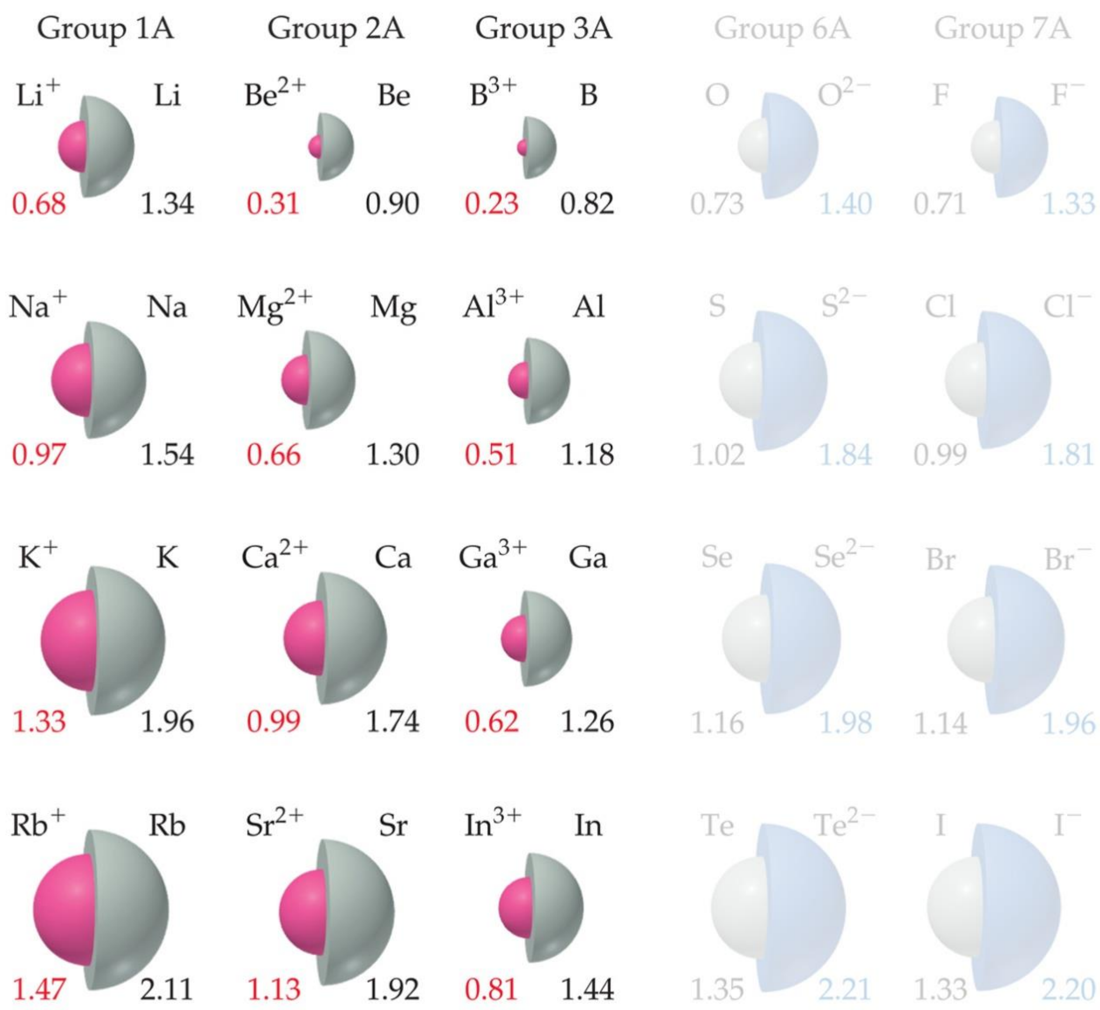
Monatomic Ions



Main Group 1A, 2A M^{n+} where n=group number

Naming: Element + ‘cation’

Monatomic Cations



Cations are smaller than their parent atoms.

Monatomic Anions

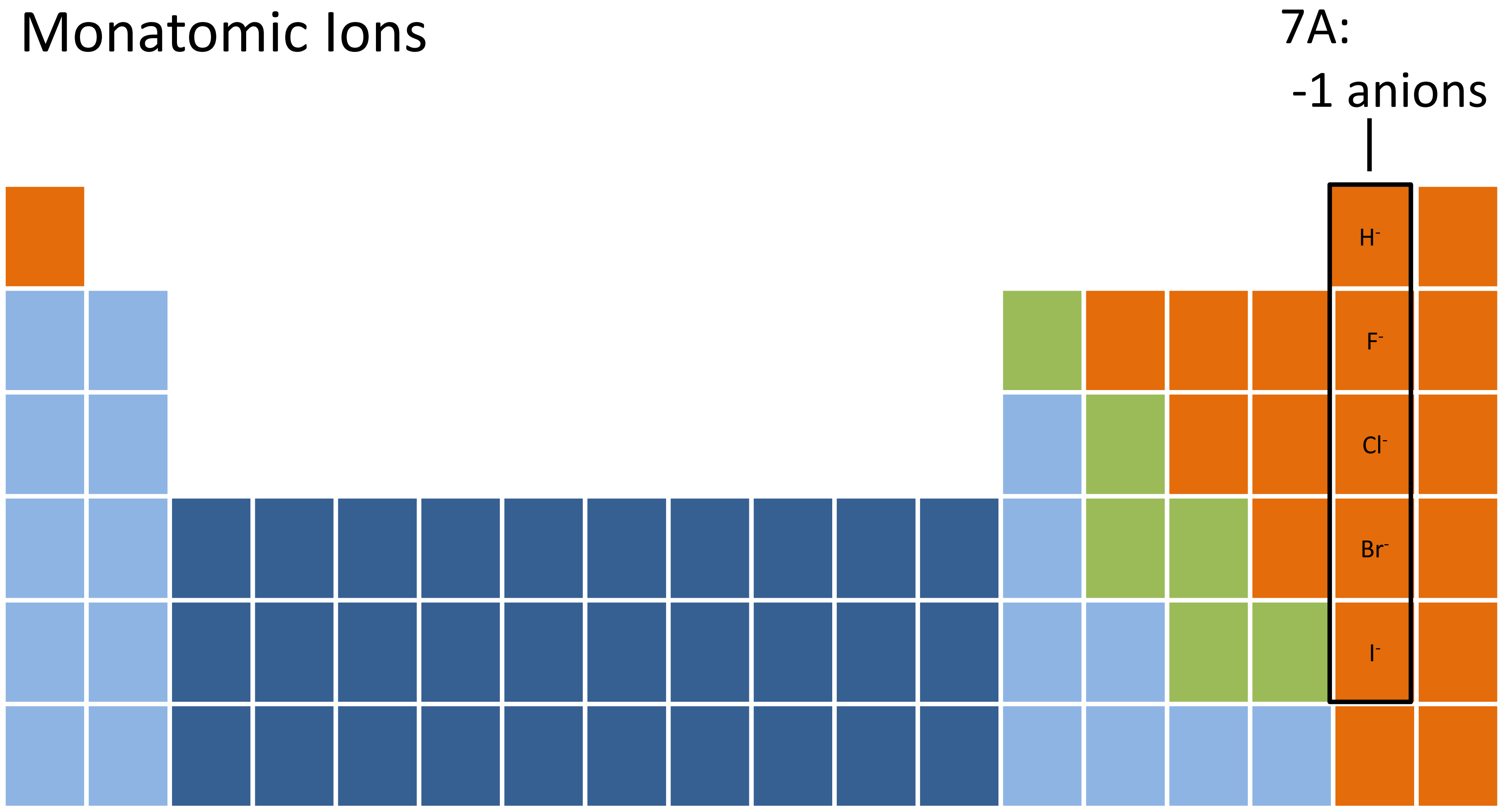
Formed from neutral atoms by adding one or more electrons

Nonmetals, often halogens from the last 2 columns of the periodic table

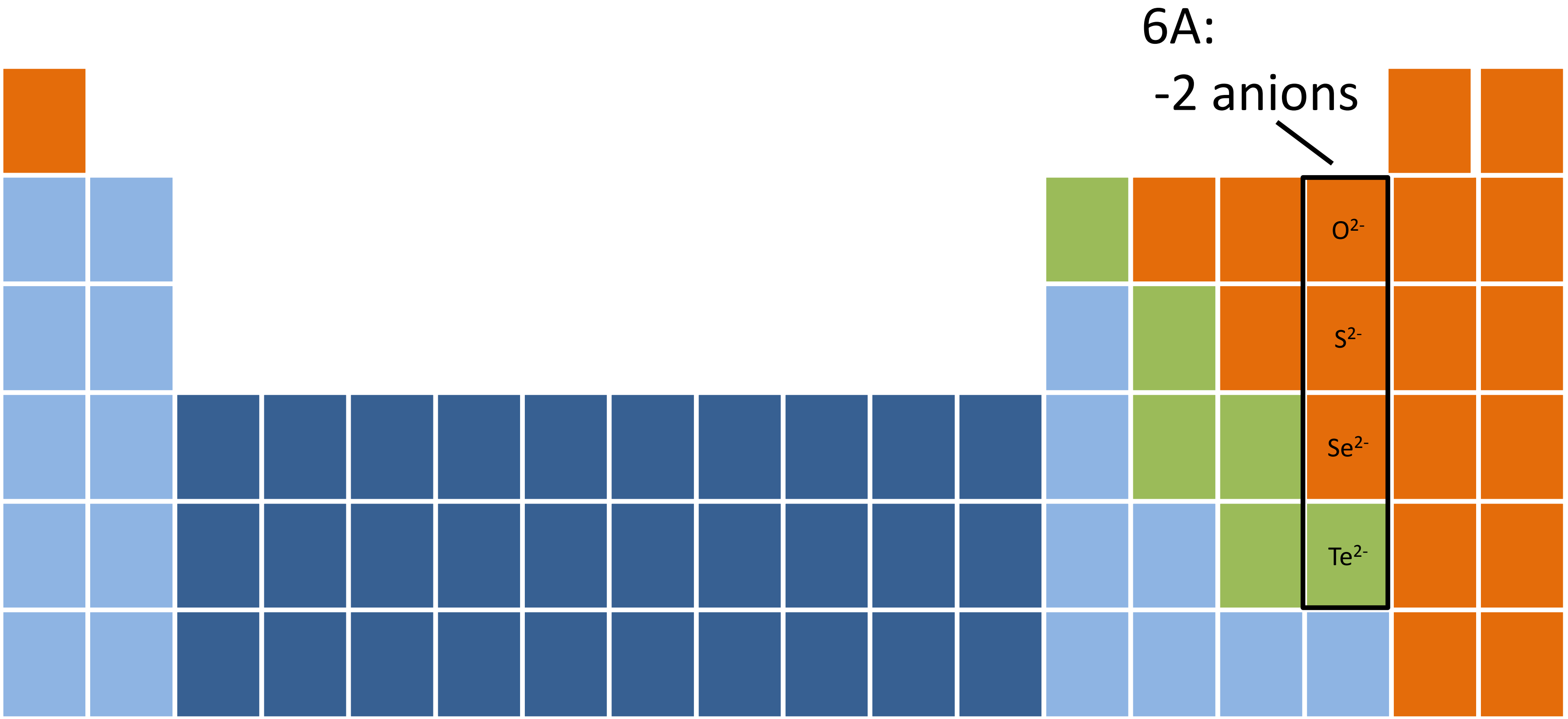
$$Cl + e^{-} \longrightarrow Cl^{-}$$

$$O + 2e^{-} \longrightarrow O^{2-}$$

Monatomic Ions



Monatomic Ions



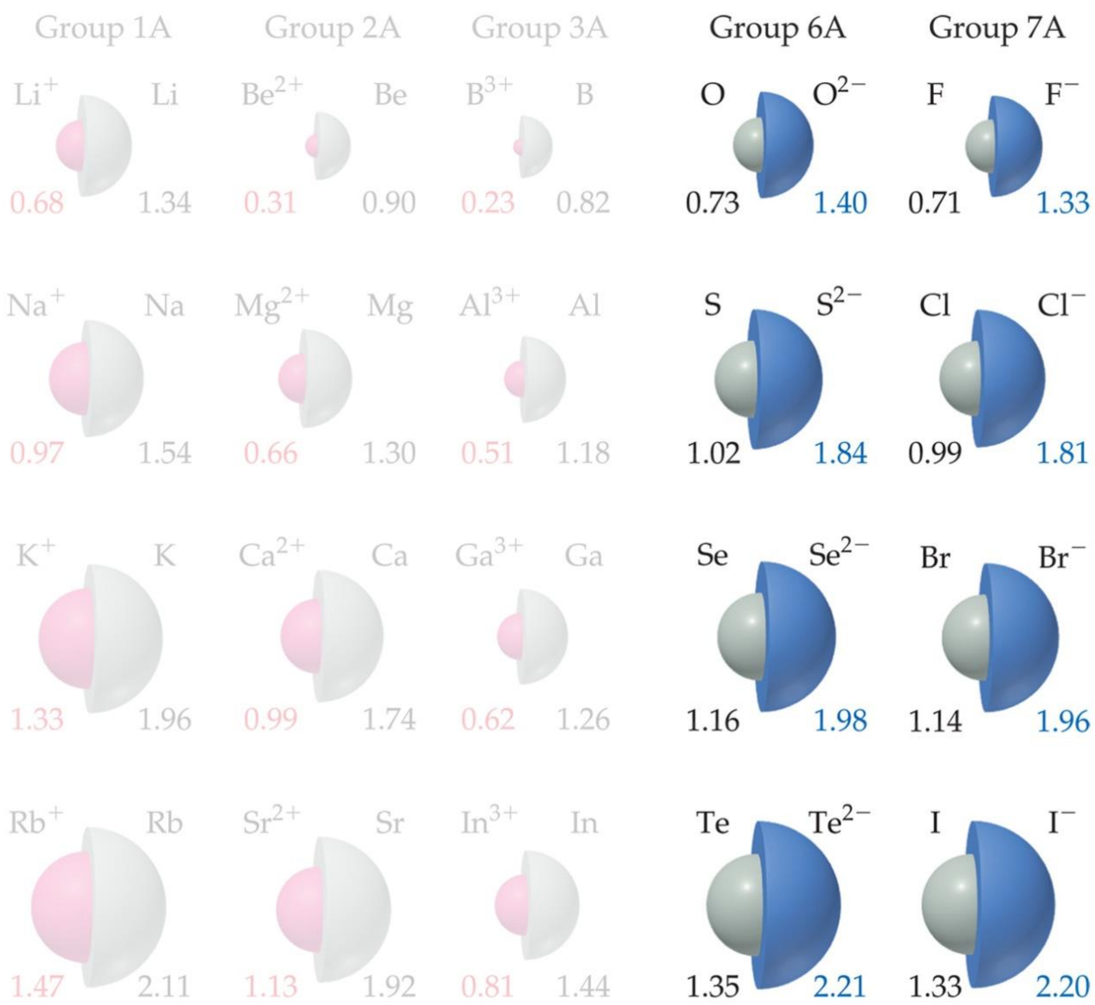
Monatomic Ions

Naming Monatomic Anions

C^{4-},carbide	N^{3-}, nitride	O^{2-}, oxide	F^{-}, fluoride
		S^{2-}, sulfide	Cl^{-}, chloride
			Br^{-}, bromide
			I^{-}, iodide

Name derived by adding “ide” suffix.

Monatomic Anions



Anions are larger than their parent atoms.

The Mole

1 mol items = 6.022 x 10^{23} items

- Avogadro's number is the number of ^{12}C atoms in exactly 12 grams.

Atomic Mass:

1 atom of H = 1.01 amu
1 mol of H = 1.01 grams

CONVERSION FACTOR ALERT!

The periodic table is full of conversion factors that take us from mass to moles of ANY atom.

Example

- Which sample has the most atoms?

20 grams of Pt　　　　or　　　　10 grams of Cu