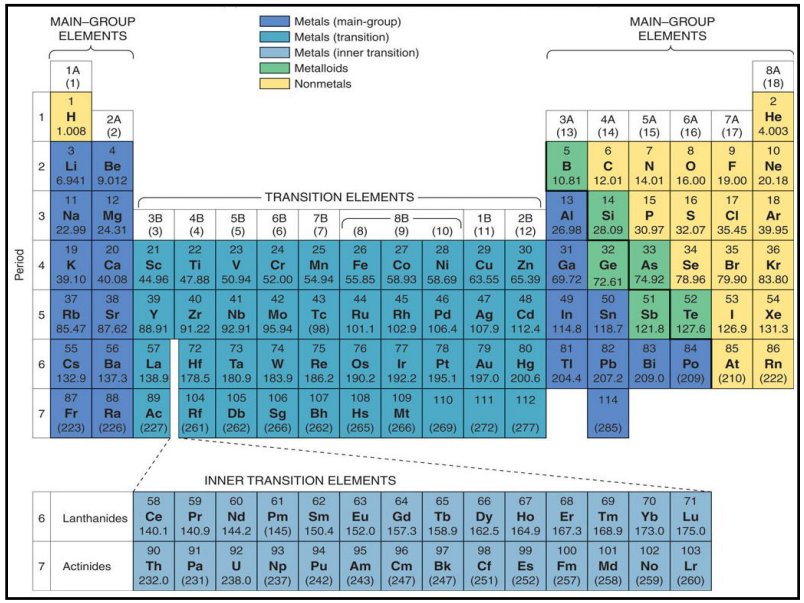
2.6 Elements and the Periodic Table

- Periodicity in the properties of the elements
  - Mendeleev's table, 1871 – arrangement by atomic mass
  - Modern version of the table – arrangement by atomic number
- **Groups** – vertical columns in the table
  - ***A*** groups (1, 2, 13-18) – representative elements
  - ***B*** groups (3-12) – transition elements
  - Inner transition elements – lanthanides & actinides
- **Periods** – horizontal rows in the table

- Elements in a group have similar properties
- Elements in a period have different properties
- **Metals**
  - good electrical and heat conductivity, malleable, ductile
- **Nonmetals**
  - poor electrical and heat conductivity, neither malleable nor ductile, often gases or liquids
- **Metalloids**
  - semiconductors, intermediate properties



- Properties change gradually down in a group
  - Group 1A (1) - **alkali metals** (Li, Na, K, Rb,...)
    - soft, easy melting metals; react violently with water
    - reactivity increases down in the group
  - Group 2A (2) - **alkaline earth metals** (Be, Mg, ...)
    - similar but less reactive than Group 1
    - reactivity increases down in the group
  - Group 7A (17) - **halogens** (F, Cl, Br, I,...)
    - very reactive - reactivity increases up in the group
    - gradual change in physical properties - F, Cl (yellow gases), Br (red-brown liquid), I (purple-black solid)
  - Group 8A (18) - **noble gases** (He, Ne, Ar,...)
    - very low reactivity - inert gases
    - colorless, odorless gases

2.7 Compounds

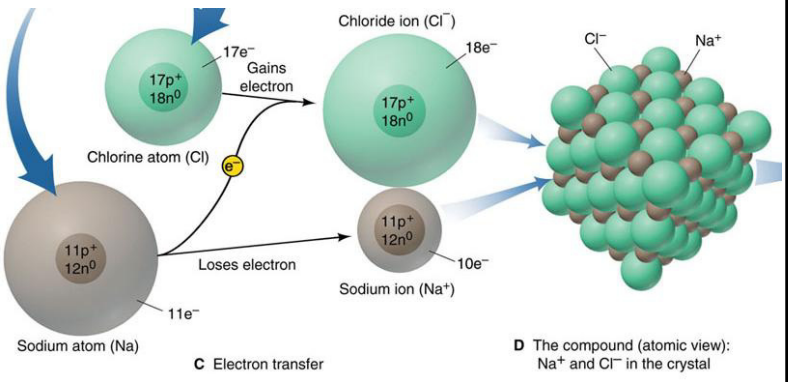
- Combination of two or more elements in some definite proportion
- **Chemical bonds** – the forces that hold the atoms of elements together in compounds
  - **Ionic bonding** – results from transfer of electrons from one atom to another
  - **Covalent bonding** – results from sharing of electrons between atoms
- **Ions** – el. charged atoms or groups of atoms
- **Molecules** – el. neutral groups of atoms covalently bonded together

- **Ionic compounds** – consist of positive and negative ions held together by electrostatic attraction (NaCl, CaO, ...)
  - Positive ions (**cations**) – often produced when metals lose electrons (Na^+, Ca^{2+}, ...)
  - Negative ions (**anions**) – often produced when nonmetals gain electrons (Cl^-, O^{2-}, ...)
- Binary ionic compounds – composed of just 2 elements (typically a metal and a nonmetal)
- Monatomic ions – formed through gain or loss of e^- by single atoms

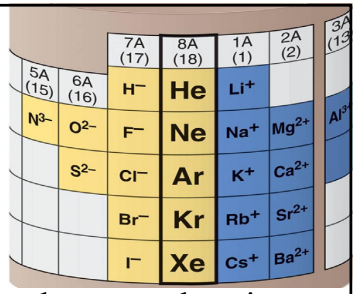
- Formation of binary ionic compounds

Example: NaCl

  - The electrons lost by Na are gained by Cl



- Charges of monoatomic ions can be predicted from the periodic table



  - Typically metals loose e^- and nonmetals gain e^- until they reach the same number of e^- as in the nearest noble gas (high stability)
  - Groups **1A–3A** form cations with charges equal to the **group#** (only the lighter members of 3A)
  - Groups **5A–7A** - anions with charges equal to the **group# - 8** (only the lighter members of 5&6A)

- The strength of ionic bonds depends on the charges and sizes of the ions
  - Potential energy of interaction between two ions with charges q_1 and q_2 separated by a distance r_{12}

$$E_p = \frac{q_1 \times q_2}{r_{12}}$$

$\Rightarrow$Ions with higher charges and smaller sizes attract each other stronger

- Ionic compounds are neutral $\rightarrow$ the # of positive charges must equal the # of negative charges (charge balance)

Problems:

1. What are the charges of the monatomic ions formed by Al and Br?

Al $\rightarrow$ Group 3A $\rightarrow$ 3+ $\rightarrow$ Al^{3+}
(loss of $3e^-$ $\rightarrow$Ne)

Br $\rightarrow$ Group 7A $\rightarrow$ 7 – 8 = -1 $\rightarrow$ Br^-
(gain of $1e^-$ $\rightarrow$ Kr)

2. What is the ratio of **Al^{3+}** to **Br^-** ions in the binary ionic compound of these elements?

Al^{3+} : Br^- $\rightarrow$ 1 : 3 $\leftarrow$ $1(+3) + 3(-1) = 0$

- **Covalent compounds** – typically consist of molecules in which atoms are bonded together through sharing of electrons $\rightarrow$ **molecular compounds** (H_2O, NH_3, …)
  - Formed usually between nonmetals
  - Some elements occur in nature in a molecular form (H_2, O_2, N_2, F_2, Cl_2, Br_2, I_2, P_4, S_8, …)
- **Polyatomic ions** – consist of two or more covalently bonded atoms with a net overall charge (NH_4^+, SO_4^{2-}, …) $\rightarrow$ participate in ionic bonding

2.9 Mixtures

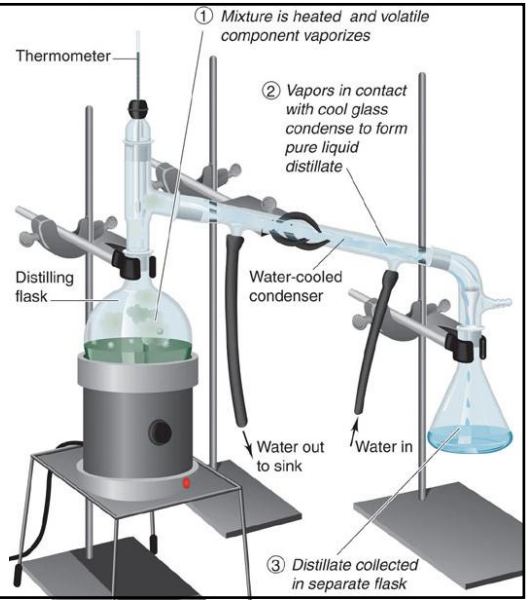
- Contain more than one pure substances
- **Heterogeneous mixtures** - composition changes from one part to another (soil, blood, milk, dust, fog, ...)
- **Homogeneous mixtures** - composition is uniform throughout (sea water, air, gasoline, vinegar, brass, ...)
- **Solutions** - homogeneous mixtures
  - solvent - present in the larger amount
  - solute - the dissolved substance
- Aqueous solutions - the solvent is water

- Differences between mixtures and compounds

Mixture	Compound
Components can be separated by using physical techniques.	Components cannot be separated by using physical techniques.
Composition is variable.	Compositon is fixed.
Properties are related to those of its components.	Properties are unlike those of its components.

- Separation of mixtures (relies on differences in the physical properties of the components)
  - **Extraction** - differences in the solubility
  - **Filtration** - differences in particle size

- **Distillation** - differences in the volatility (boiling point)



- **Chromatography** - differences in the ability to adsorb on surfaces or absorb into liquids
  - Stationary and mobile phases
  - GC
  - LC