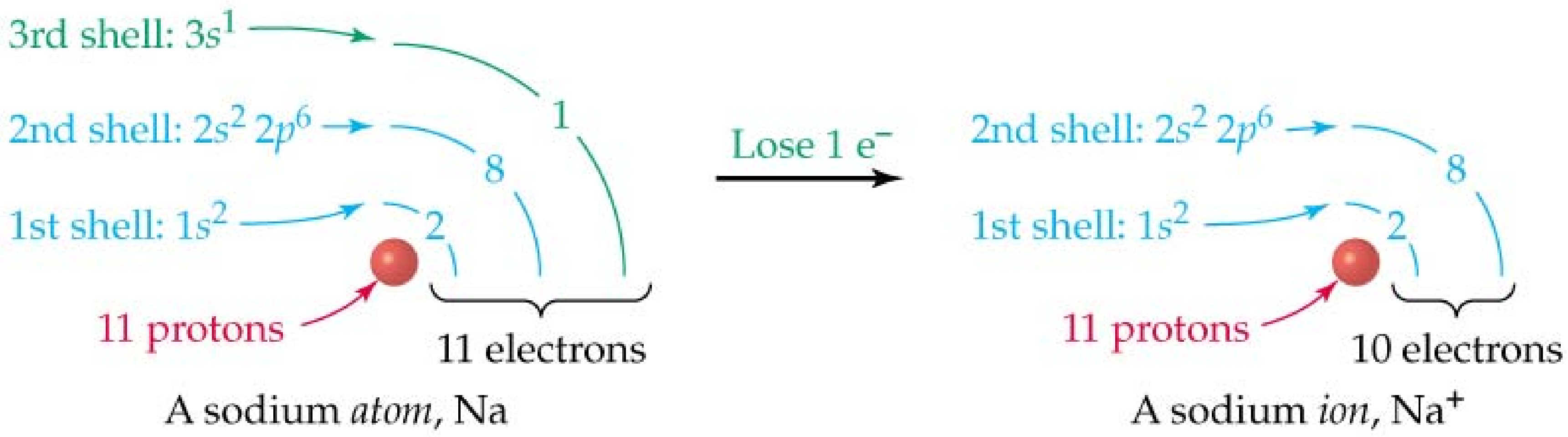
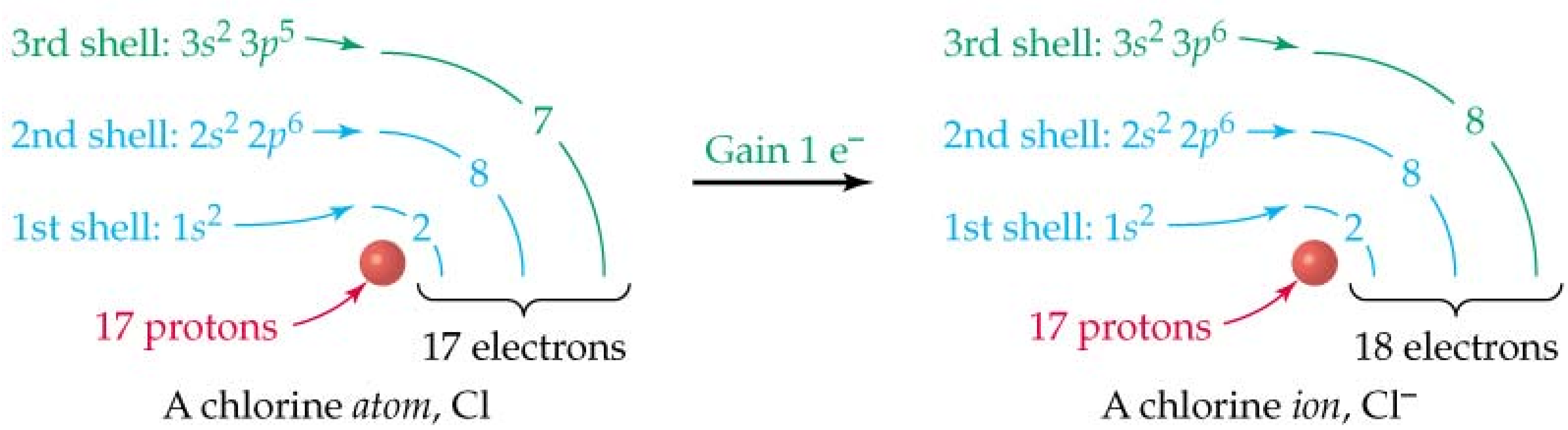
4.1 Ions

- Atoms are electrically neutral because they contain equal number of protons and electrons. By gaining or losing electrons an atom can be converted into a charged particle called an ***ion***.
- Loss of one or more electrons from a neutral atom gives a positively charged ion called a ***cation***.

The symbol for cation is written by adding a positive charge as a superscript to the symbol for the element. For example, by losing an electron Na metal is converted to the sodium cation (Na^+).



- Gain of one or more electrons by a neutral atom gives a negatively charged ion called a ***anion***. The symbol for the anion is written as by adding a negative charge as a superscript to the symbol for the element. For example, by gaining an electron chlorine atom becomes chloride ion, Cl^-.



4.2 Periodic Properties and Ion Formation

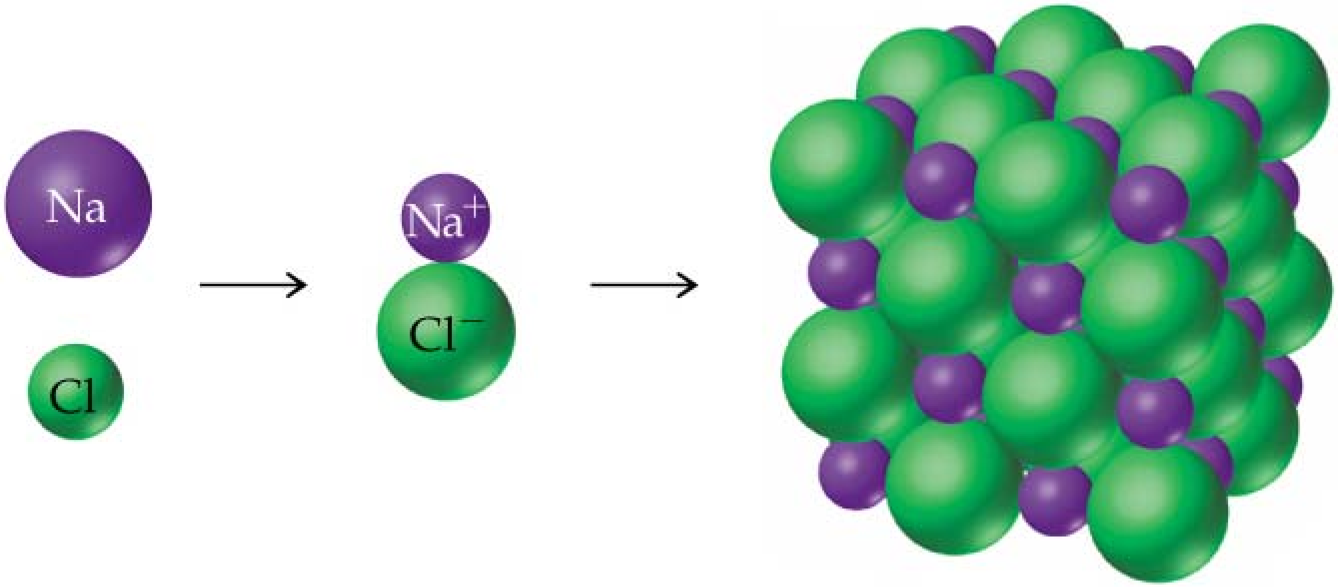
- ***Ionization energy***: *The energy required to remove an electron from a single atom in the gaseous state.* The ease with which an atom loses an electron to form a ***cation***.
- ***Electron affinity***: *The energy released on adding an electron to a single atom in the gaseous state.*

  The ease with which an atom gains an electron to form an anion. Small ionization energy – electron easily lost; small electron affinity – electron not easily gained – formation of cation is favored.

4.3 Ionic Bonds

- Opposite electrical charges attract each other.
- When sodium combines with chlorine, sodium transfer electron to chlorine forming Na^+ and Cl^- ions.
- The oppositely charged Na^+ and Cl^- ions are held together by a ionic bond.
- In three dimensional crystals, all nearby oppositely charged ions attract each other. We can not separate attraction between only two oppositely charged ions-we speak of the whole crystal and crystal as being an ***ionic solid* or *ionic compound***.

- In NaCl crystal, each sodium ion is surrounded by 6 chloride ions, and each chloride ion is surrounded by 6 sodium ions.



4.4 Some Properties of Ionic Compounds

- Ionic compounds are usually crystalline solids.
- Different ions vary in size and charge.
- Ions packed together in crystals in different ways.
- The crystal pattern ensures that ions efficiently fills space and maximizes ionic bonding.
- Ionic compounds have high melting and high boiling points.

- An ionic compound will dissolve in water if the attraction between water and the ions overcome the attraction between the ions in an ionic compound. Example, NaCl is soluble in water.
- An ionic compound will not dissolve in water if the attraction between water and the ions can not overcome the attraction between the ions in an ionic compound.

4.5 Ions and the Octet Rule

Octet Rule: Main group elements tend to undergo reactions that leaves them with 8 valence electrons or noble gas configuration. All noble gases, except helium (He), has 8 electrons in their valence shell. For example, in NaCl, Na^+ and Cl^- have the following electron configuration

$$\underset{1s^2\,2s^2\,2p^6\,3s^1}{\mathrm{Na}} \;+\; \underset{1s^2\,2s^2\,2p^6\,3s^2\,3p^5}{\mathrm{Cl}} \;\longrightarrow\; \underset{\underbrace{1s^2\,2s^2\,2p^6}_{\text{Neon configuration}}}{\mathrm{Na}^+} \;+\; \underset{\underbrace{1s^2\,2s^2\,2p^6\,3s^2\,3p^6}_{\text{Argon configuration}}}{\mathrm{Cl}^-}$$

4.6 Electron-Dot Symbol

- *Electron-Dot Symbol*: Dots are placed around the atomic symbol to indicate the number of valence electron present.
- A group 1A atom such as sodium, has a single dot, a group 2A atom such as magnesium has 2 dots, and so on.
- Helium differs from other noble gases in having only two valence electrons rathar than eight. Neverthe less, helium is considered a member of group 8A because its properties resemble those of the other noble gases.

4.7 Ions of Some Common Elements

The metals of group 1A and 2A form only +1 and +2 ions only. Ions of these elements all have noble gas configuration as a result of electron loss from their outermost shell. Group 6A and 7A elements attain noble gas configuration by gaining 1 or 2 electrons. For example

Group 6A:

$$\cdot\underset{\cdot\cdot}{\ddot{\mathrm{O}}}\cdot + 2\,e^- \longrightarrow :\underset{\cdot\cdot}{\ddot{\mathrm{O}}}:^{2-}$$

$$\cdot\underset{\cdot\cdot}{\ddot{\mathrm{S}}}\cdot + 2\,e^- \longrightarrow :\underset{\cdot\cdot}{\ddot{\mathrm{S}}}:^{2-}$$

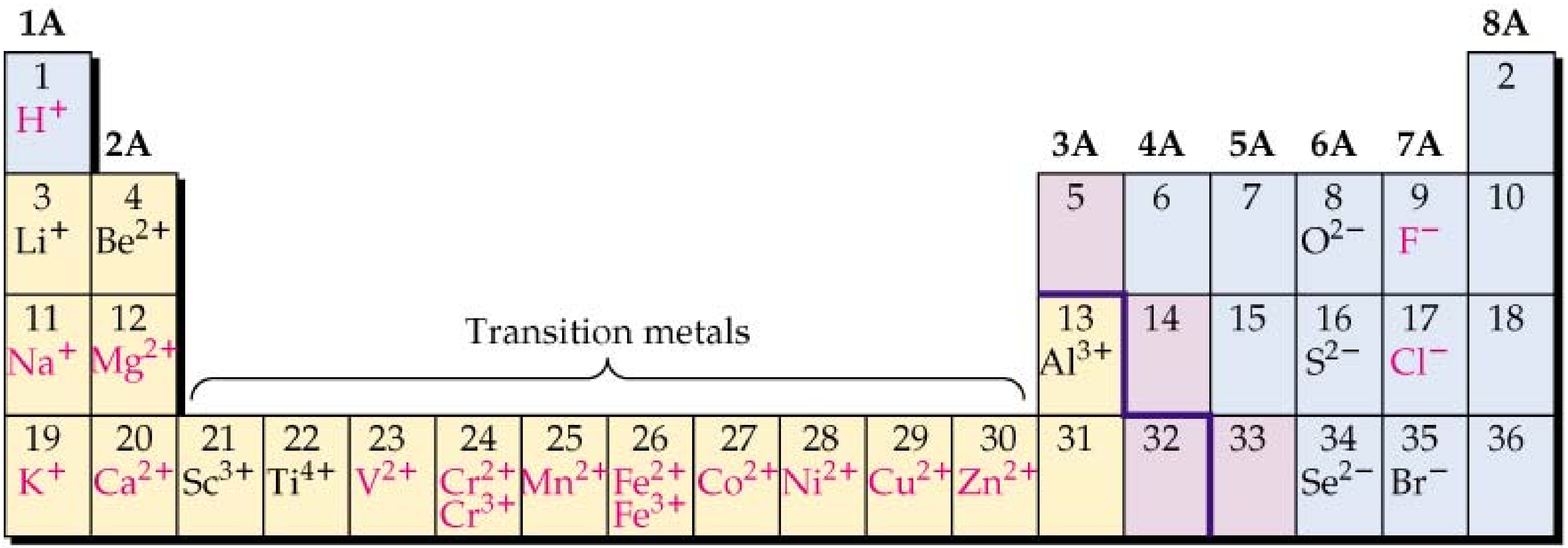


Fig 4.4 Common ions formed by elements in the first four periods

4.8 Naming Ions

Main group metal cations in group 1A, 2A, and 3A are named by identifying the metal, followed by the word “ion” as shown below:

K^+	Potassium ion
Mg^{2+}	Magnesium ion
Al^{3+}	Aluminum ion

For transition metals such as iron or chromium which can form more than one type of cation the following two methods are used:

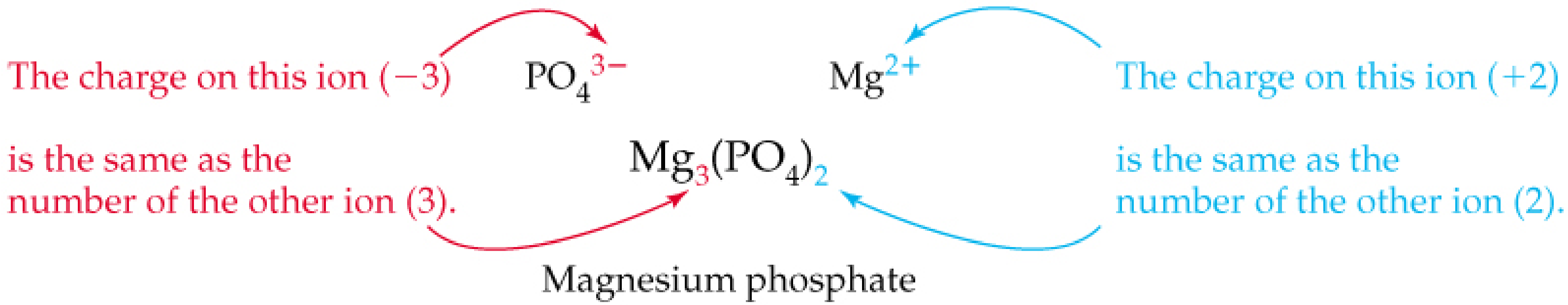
	Cr^{2+}	Cr^{3+}
Old name	Chromous ion	Chromic ion
New name	Chromium (II) ion	Chromium (III) ion

4.9 Polyatomic Ions

- *Polyatomic ion*: Ions composed of more than one atom.
  - Most polyatomic ions contain oxygen and another element.
  - Formula for polyatomic ions show by subscripts how many each type of atom are combined.
  - For example, SO_4^{2-} ion is composed of one sulfur atom and four oxygen atoms.
- The atoms in a polyatomic ion are held together by covalent bond (discussed in the next chapter) and the entire group of atoms act as a single unit.

4.10 Formulas of Ionic Compounds

The formula of an ionic compound shows the lowest possible ratio of atoms in the compound.



4.11 Naming Ionic Compounds

- Ionic compounds are named by citing first the cation and then the anion with a space between the words. For example,

  $MgSO_4$ – Magnesium sulfate

  $SnCl_2$ - Stannous chloride or Tin (II) chloride

  $SnCl_4$ – Stannic chloride or Tin (IV) chloride

4.12 H^+ and OH^- Ions: An Introduction to Acids and Bases

- *Hydrogen cation* (H^+): Since hydrogen atom contains a proton and an electron, a hydrogen cation contains only a proton.
- *Hydroxide anion* (OH^-): A polyatomic ion in which a oxygen atom is covalently bonded to a hydrogen atom.

- *Acid*: A substance that provides H^+ ion in water; for example, HCl, H_2SO_4, HNO_3.

  HCl dissolved in water → $H^+ + Cl^-$

- *Base*: A substance that provides OH- ions in water; for example, NaOH, KOH, $Ba(OH)_2$.

  NaOH dissolved in water → $Na^+ + OH^-$