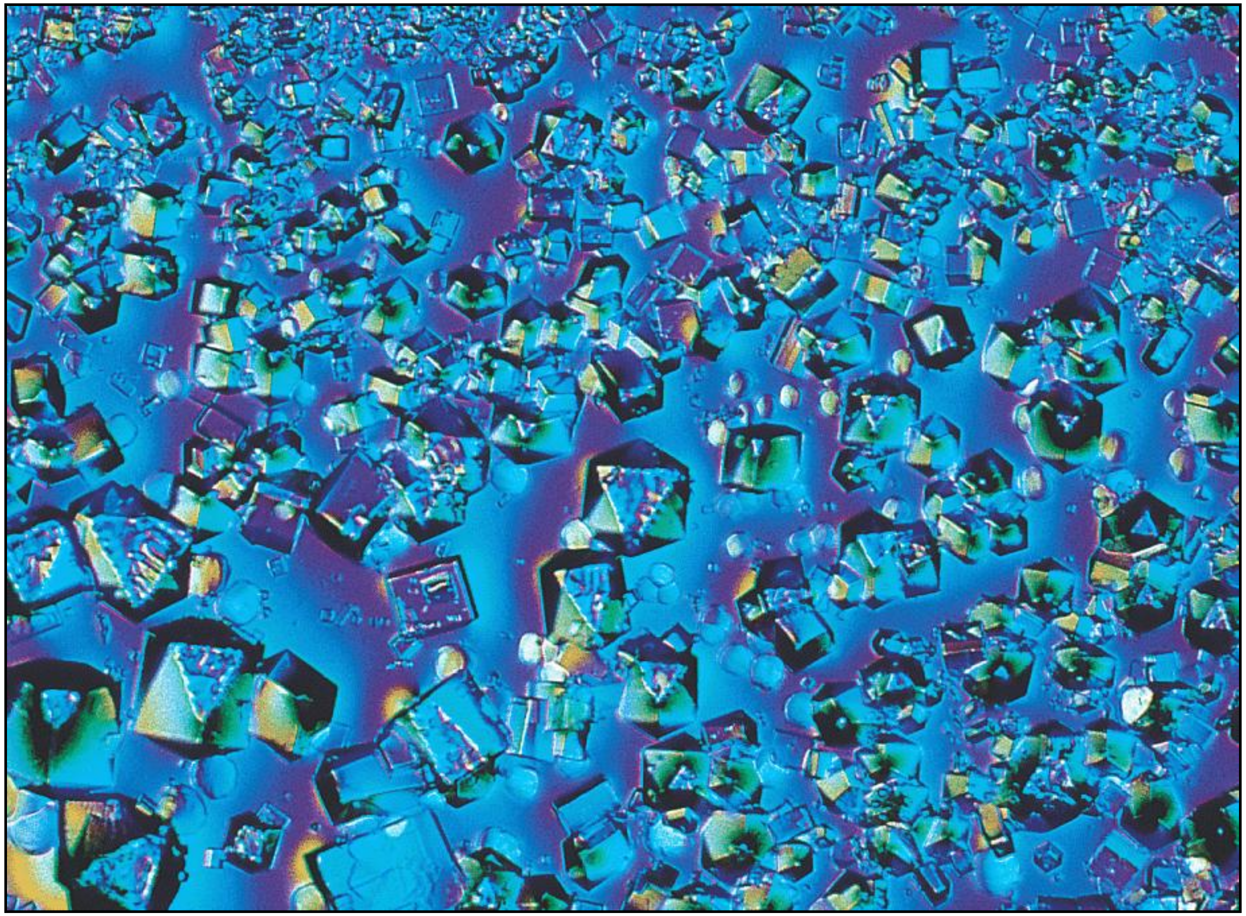
Chapter Four

Chemical Bonding: The Ionic Bond Model

The Ionic Bond in NaCl

→ **CO 4.1**
Magnification of crystals of sodium chloride.



M. S. Davidson/Photo Researchers

Copyright © Houghton Mifflin Company. All rights reserved.

Lewis Symbols of Main Group Elements

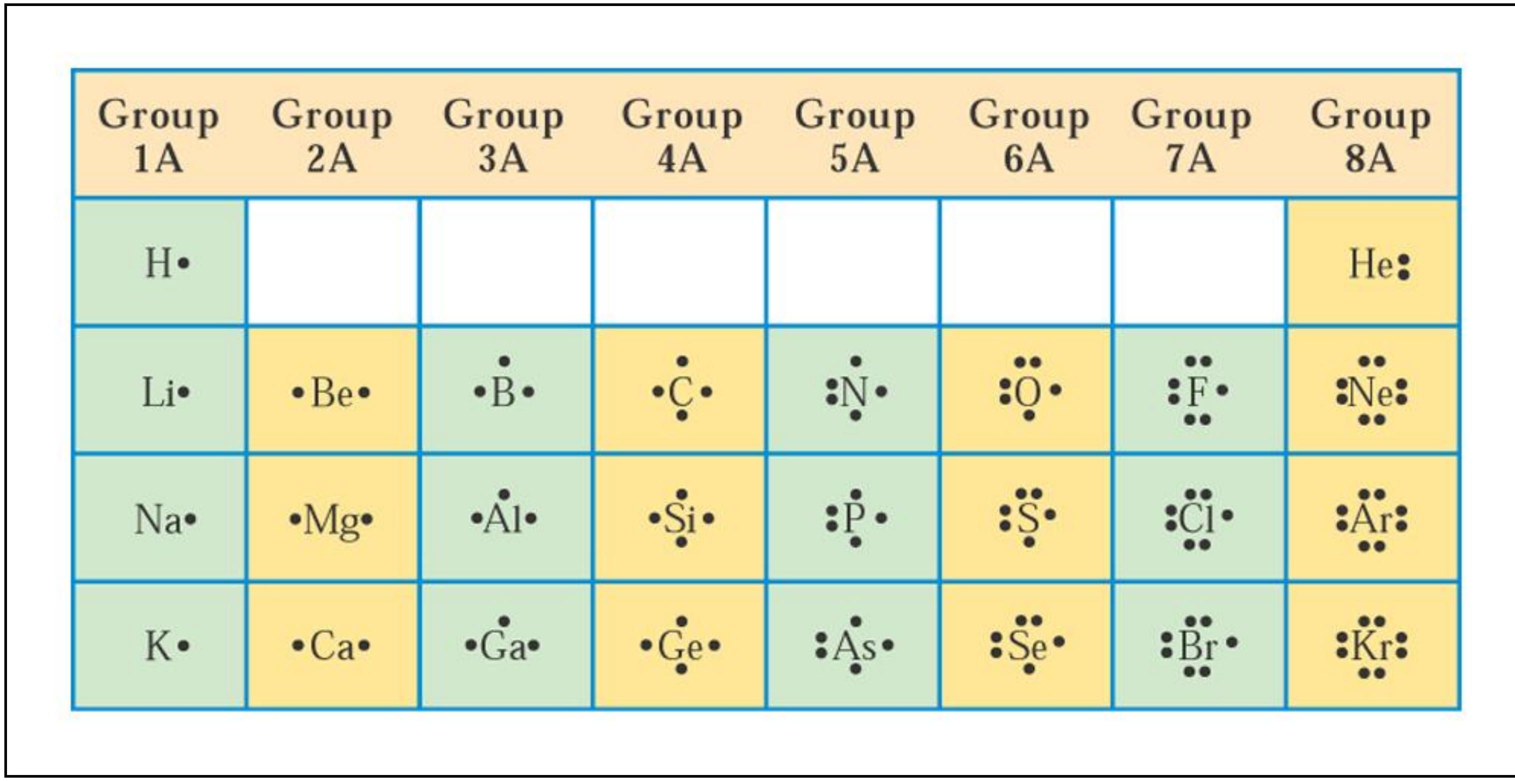
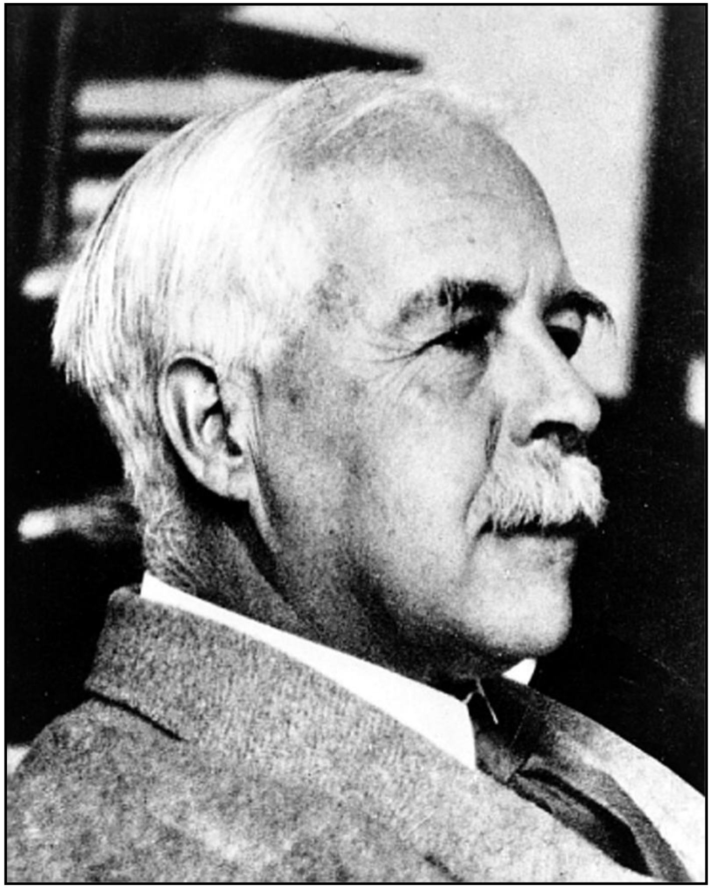


Fig. 4.1

Lewis structures for selected representatives and noble-gas elements

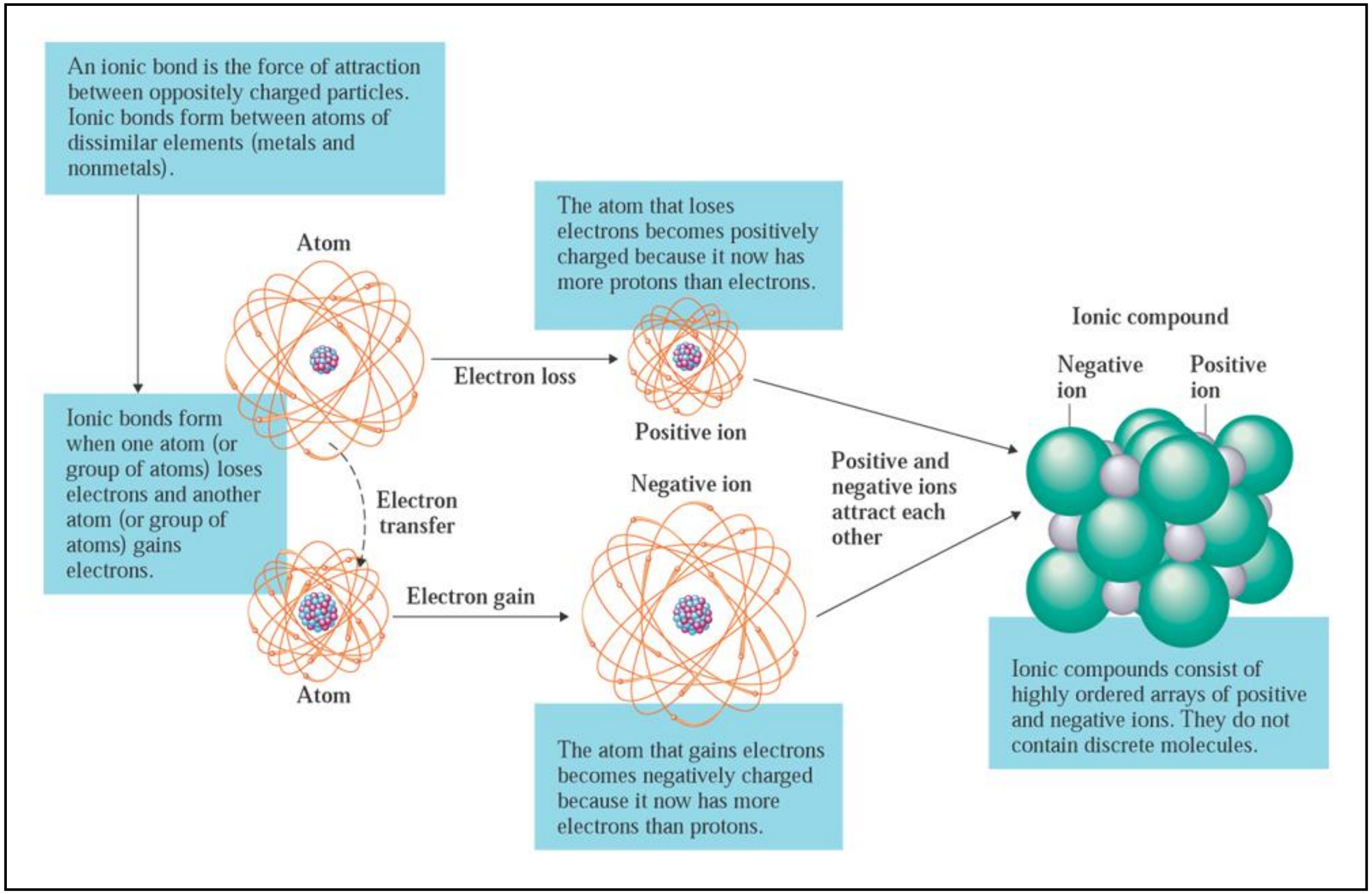
Lewis Explained the Chemical Bonding

→ ***Fig. 4.2*** ***Gilbert Newton Lewis was one of the foremost chemists of the 20th century.***



Edgar Fahs Smith Collection, University of Pennsylvania Library

The Ionic Bond Formation



← **Fig. 4.3**

Loss of an electron from a sodium atom leaves it with one more proton than electrons, so it has a net electrical charge of +1.

Matter of Ions

CC 4.1 A Matter of Ions

Water is the most abundant compound on the face of Earth. We encounter it everywhere we go: as water vapor in the air; as a liquid in rivers, lakes, and oceans; and as a solid (ice and snow) both on land and in the oceans.

All water as it occurs in nature is impure in a chemical sense. The impurities present include suspended matter, microbiological organisms, dissolved gases, and dissolved minerals. Minerals dissolved in water produce ions. For example, rock salt (NaCl) dissolves in water to produce Na^+ and Cl^- ions.

The major distinction between *fresh water* and *seawater* (salt water) is the number of ions present. On a relative scale, where the total concentration of ions in fresh water is assigned a value of 1, seawater has a value of approximately 500; that is, seawater has a concentration of dissolved ions 500 times greater than that of fresh water.

The dominant ions in fresh water and seawater are not the same. In seawater, Na^+ ion is the dominant positive ion and Cl^- ion is the dominant negative ion. This contrasts with fresh water, where Ca^{2+} and Mg^{2+} ions are the most abundant positive ions and HCO_3^- (a polyatomic ion; Section 4.10) is the most abundant negative ion.

When fresh water is purified for drinking purposes, suspended particles, disease-causing agents, and objectionable odors are removed. Dissolved ions are not removed. At the concentrations at which they are normally present in fresh water, dissolved ions are not harmful to health. Indeed, some of the taste of water is caused by the ions present; water without any ions present would taste "unpleasant" to most people.

Hard water is water that contains Ca^{2+}, Mg^{2+}, and Fe^{2+} ions. The presence of these ions does not affect the drinkability of water, but it does affect other uses for the water. The hard-water ions form insoluble compounds with soap (producing scum) and lead to the production of deposits of scale in steam boilers, tea kettles, and hot water pipes.

The most popular method for obtaining *soft water* from hard water involves the process of "ion exchange." In this process, the offending hard-water ions are exchanged for Na^+ ions. Sodium ions do not form insoluble soap compounds or scale. People with high blood pressure or kidney problems are often advised to avoid drinking soft water because of its high sodium content.

What's in NaCl Crystals

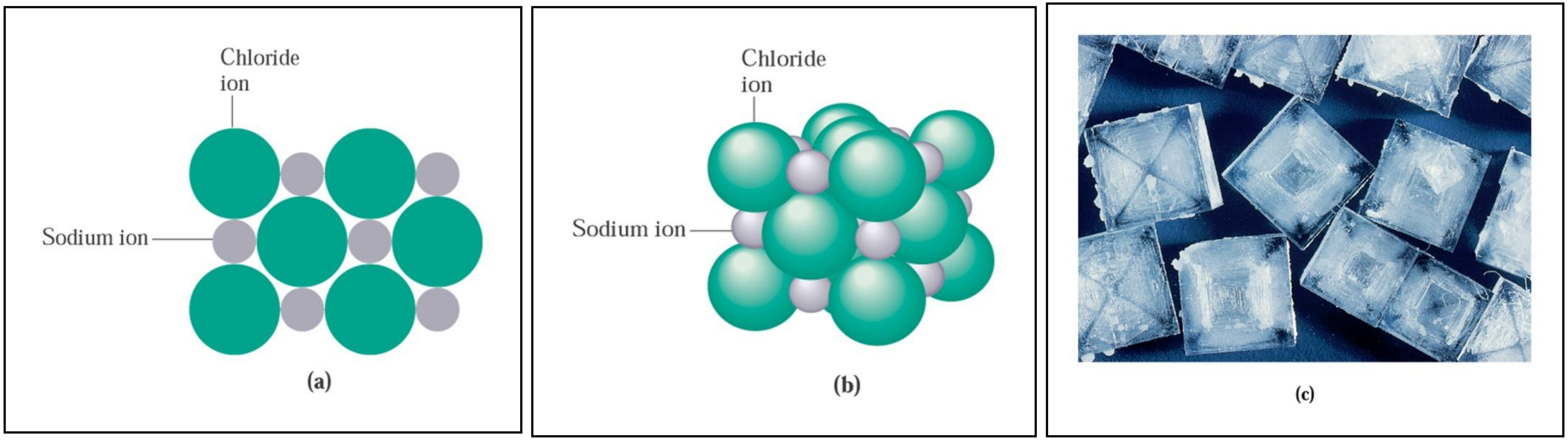


Fig. 4.4 a-c ***(a,b) Two-dimensional cross section and a three-dimensional view of sodium chloride. (c) sodium chloride crystals***

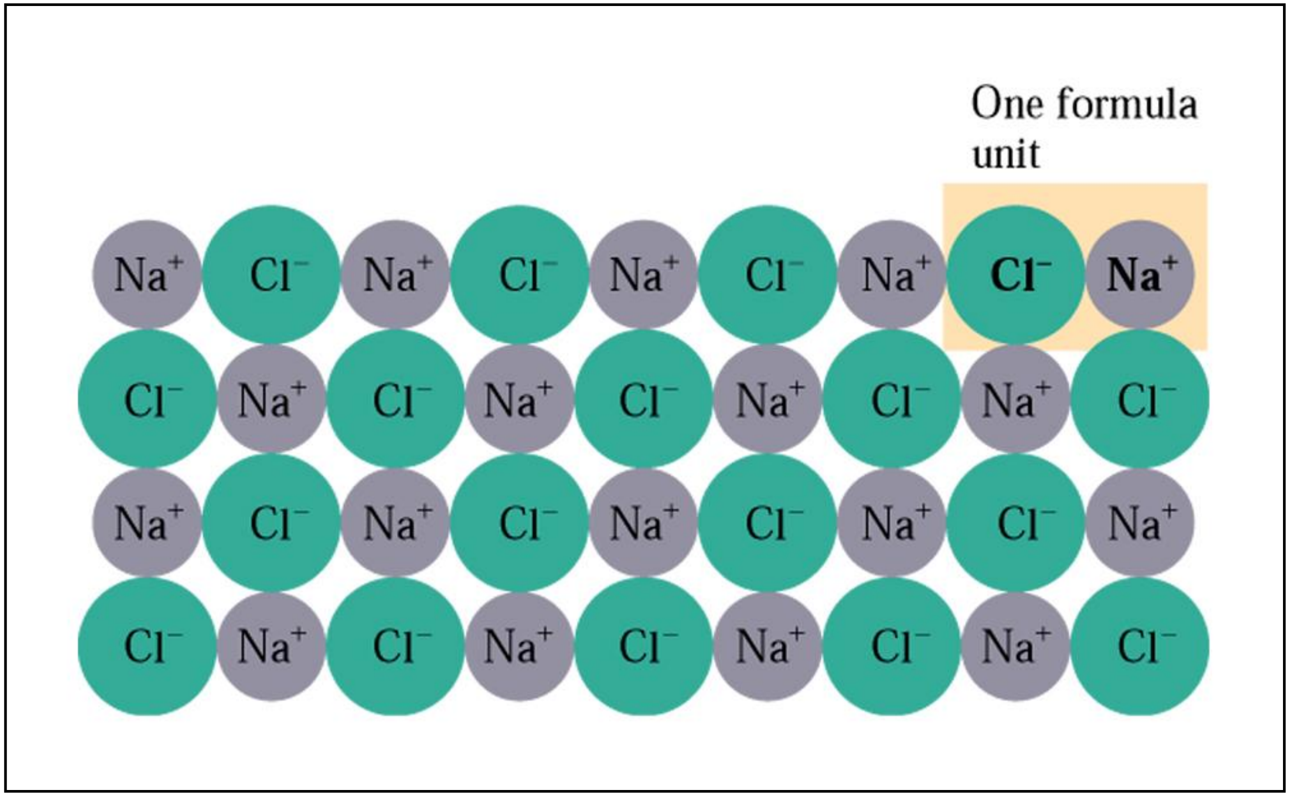
Charge on Ions

	Ne atom	Mg^{2+} ion
Protons (in the nucleus)	10	12
Electrons (around the nucleus)	10	10
Atomic number	10	12
Charge	0	+2

Table 4.1

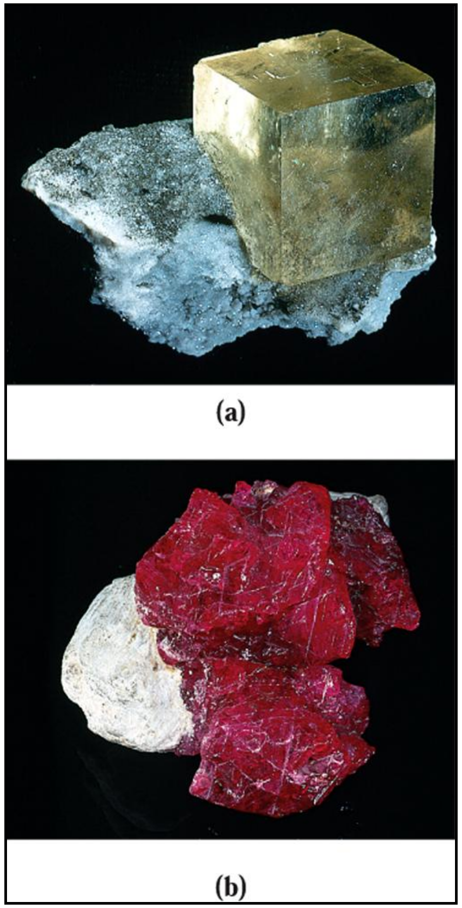
Repeating Arrangement of Ions in NaCl

→ **Fig. 4.5**
Cross section of the structure of the ionic solid NaCl.



E. R. Degginger/Color-Pic

Most Ionic Compounds are Crystals



E. R. Degginger/Color-Pic

← **Fig. 4.6**

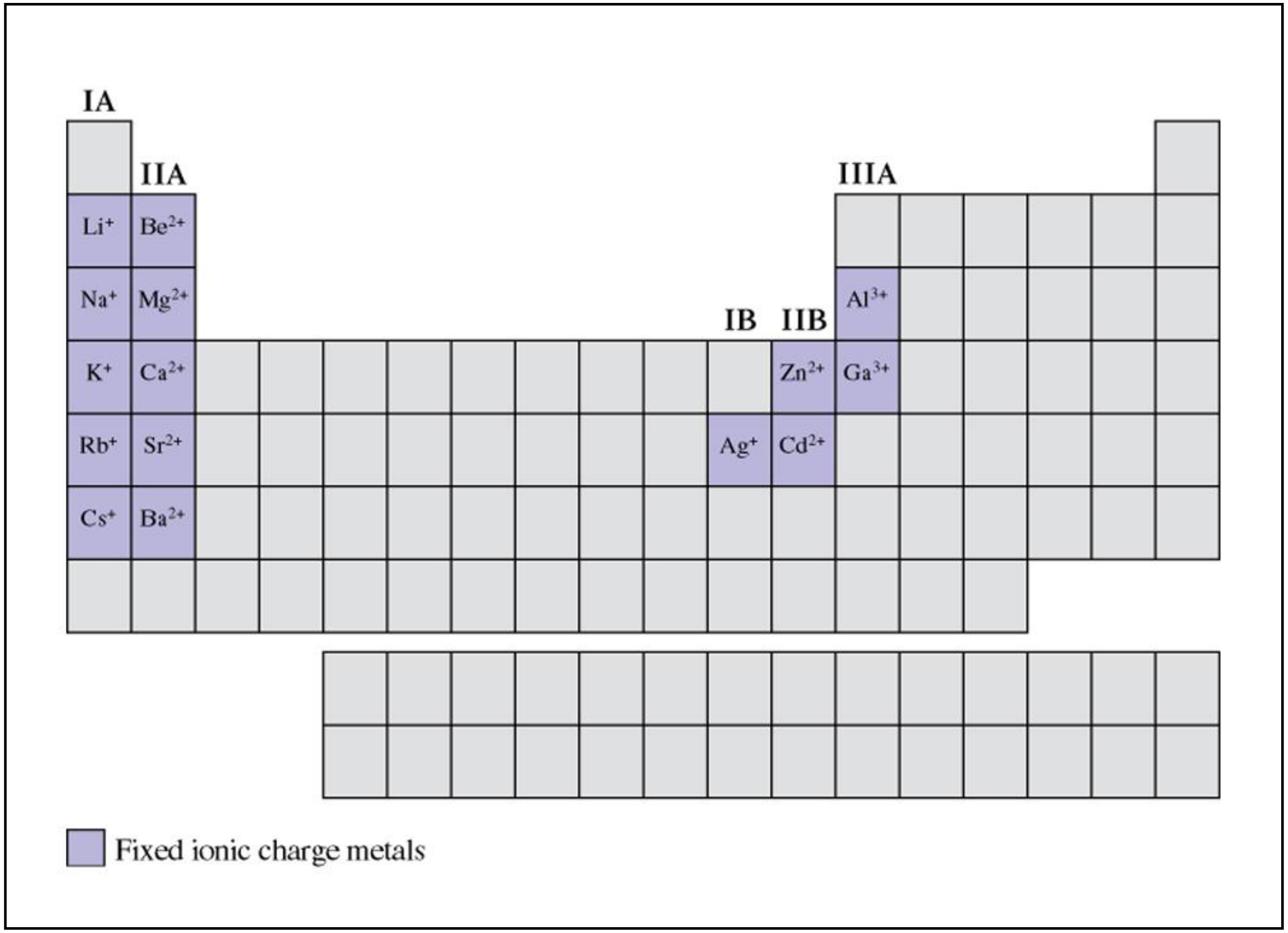
Ionic compounds usually have crystalline forms, such as in (a) fluorite and (b) ruby.

Colors of Ionic Compounds

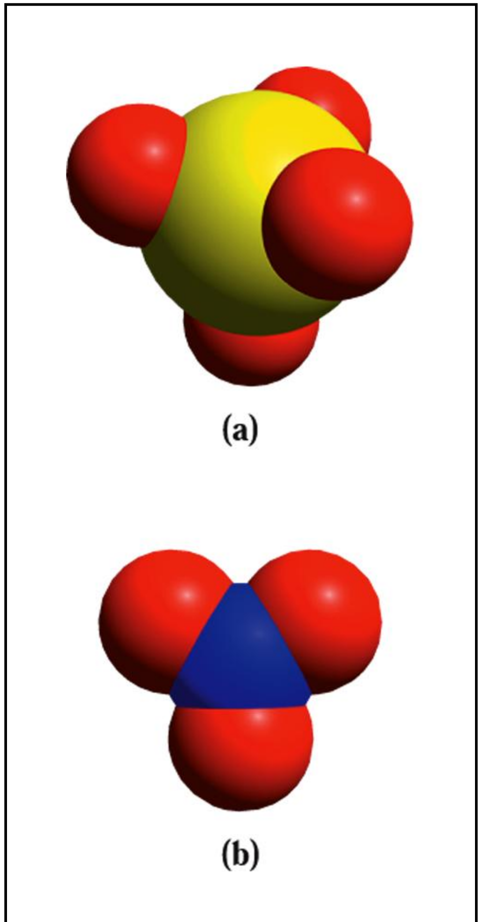
Fig. 4.7 ***Copper (II) oxide is black, whereas copper (I) oxide is reddish brown. Iron (II) chloride is green, whereas iron (III) chloride is bright yellow.***

Charge of Metals and Periodic Table

→ ***Fig. 4.8 Periodic table in which the metallic elements that exhibit a fixed ionic charge are highlighted.***



Polyatomic Ions



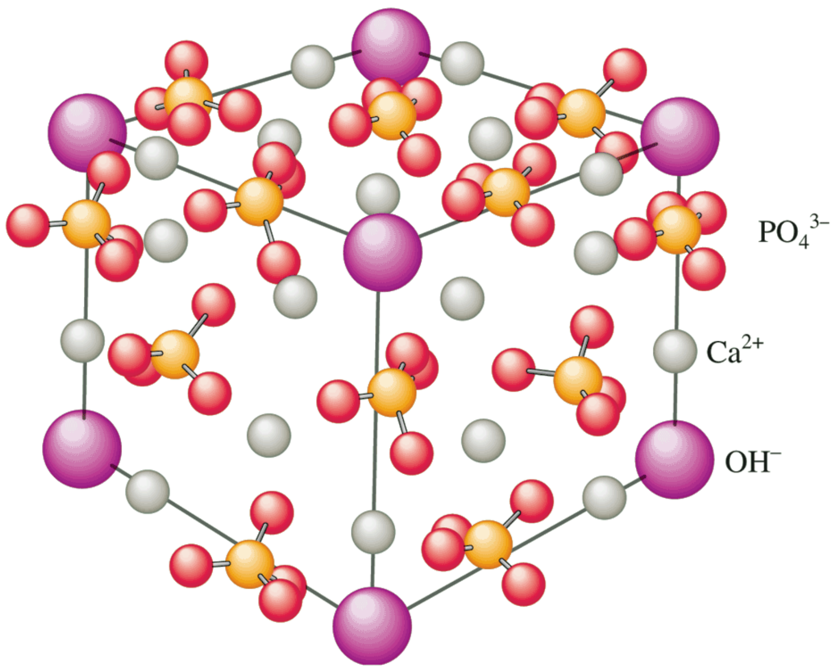
← **Fig. 4.9**
Models of polyatomic ions: (a) a sulfate ion and (b) a nitrate ion.

Name, Formula and Charge of Polyatomic Ions

Key Element Present	Formula	Name of Ion
nitrogen	NO_3^-	nitrate
	NO_2^-	nitrite
	NH_4^+	ammonium
	N_3^-	azide
sulfur	SO_4^{2-}	sulfate
	HSO_4^-	bisulfate or hydrogen sulfate
	SO_3^{2-}	sulfite
	HSO_3^-	bisulfite or hydrogen sulfite
	$S_2O_3^{2-}$	thiosulfate
phosphorus	PO_4^{3-}	phosphate
	HPO_4^{2-}	hydrogen phosphate
	$H_2PO_4^-$	dihydrogen phosphate
	PO_3^{3-}	phosphite
carbon	CO_3^{2-}	carbonate
	HCO_3^-	bicarbonate or hydrogen carbonate
	$C_2O_4^{2-}$	oxalate
	$C_2H_3O_2^-$	acetate
	CN^-	cyanide
chlorine	ClO_4^-	perchlorate
	ClO_3^-	chlorate
	ClO_2^-	chlorite
	ClO^-	hypochlorite
hydrogen	H_3O^+	hydronium
	OH^-	hydroxide
metals	MnO_4^-	permanganate
	CrO_4^{2-}	chromate
	$Cr_2O_7^{2-}$	dichromate

← **Table 4.3**

Ions in Tooth Enamel

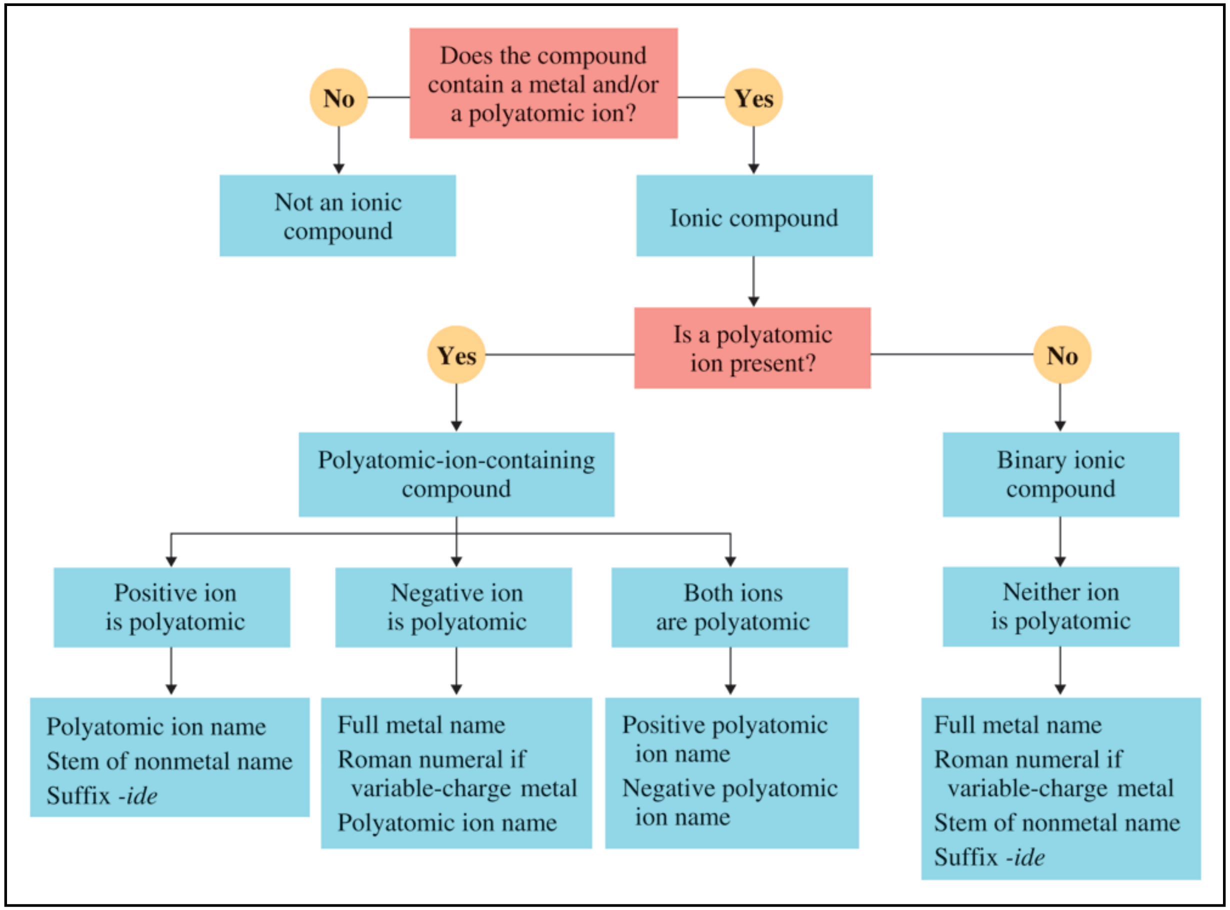


$$Ca_{10}(PO_4)_6(OH)_2 + 2\,F^- \longrightarrow Ca_{10}(PO_4)_6F_2 + 2\,OH^-$$

Hydroxyapatite　　　　Fluoroapatite

← **CC 4.2**
Tooth enamel

Naming Ionic Compunds



← **CAG 4.2 Nomenclature of ionic compounds.**