Ions in Live System

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Lecture 1

Lecture Goals

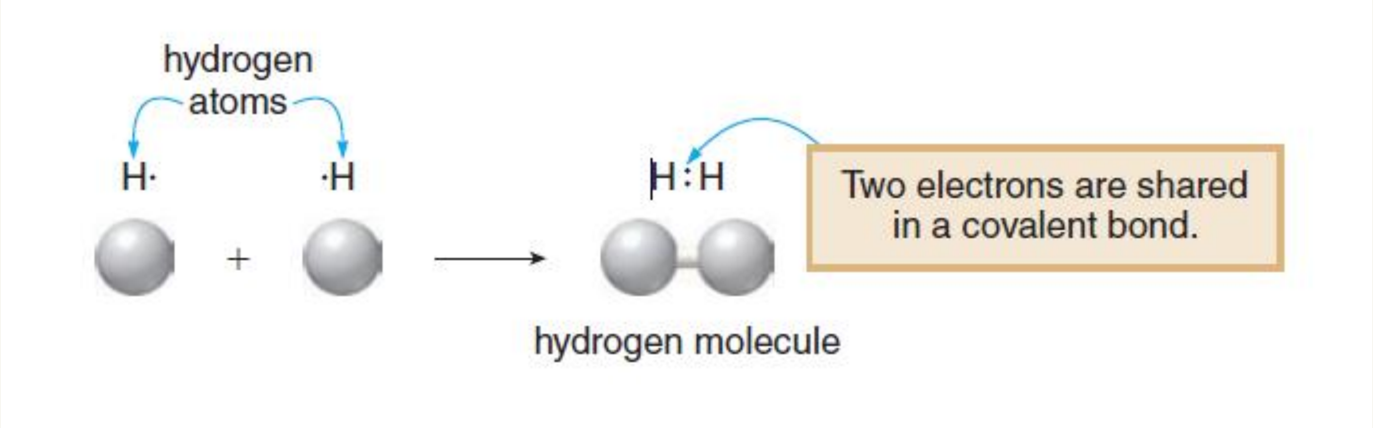
- Describe the basic features of ionic and covalent bonds.
- Ions
- Write the formula for an ionic compound.
- Describe the properties of ionic compounds.
- Useful ionic compounds.
- Ions in living system
- Ionization of Water.

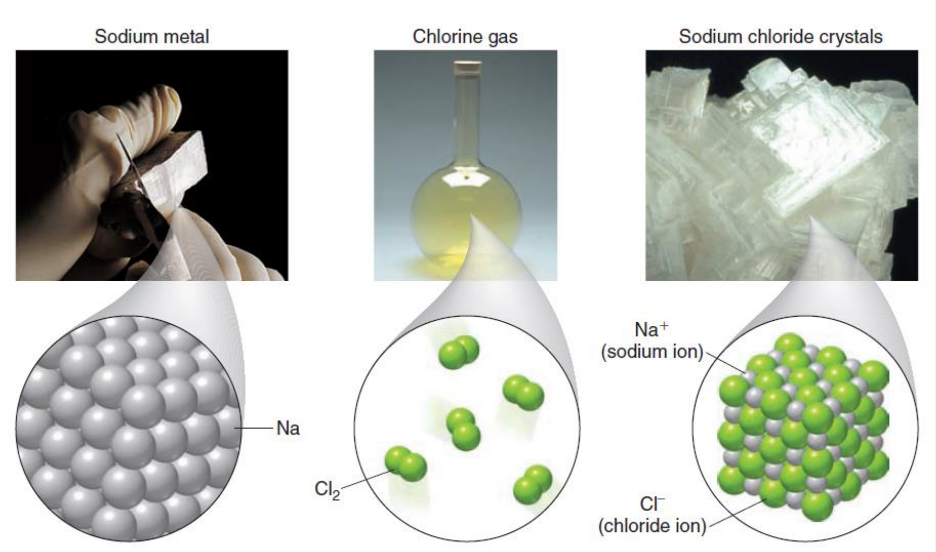
Types of Chemical Compounds

- There are two types of chemical compounds, ionic and covalent.
- **Ionic compounds** are composed of positively and negatively charged ions held together by strong electrostatic forces—the electrical attraction between oppositely charged ions. ***Examples*** of ionic compounds include the sodium chloride (NaCl) in table salt.
- **Covalent compounds** are composed of individual molecules, discrete groups of atoms that share electrons. Covalent compounds include water (H_2O) and methane (CH_4).

Bonding

- Bonding is the joining of two atoms in a stable arrangement.
- In bonding, elements gain, lose, or share electrons to reach the electronic configuration of the noble gas closest to them in the periodic table.
- There are two different kinds of bonding: ionic and covalent.
    - ➤**Ionic bonds** result from the transfer of electrons from one element to another.
    - ➤**Covalent bonds** result from the sharing of electrons between two atoms.





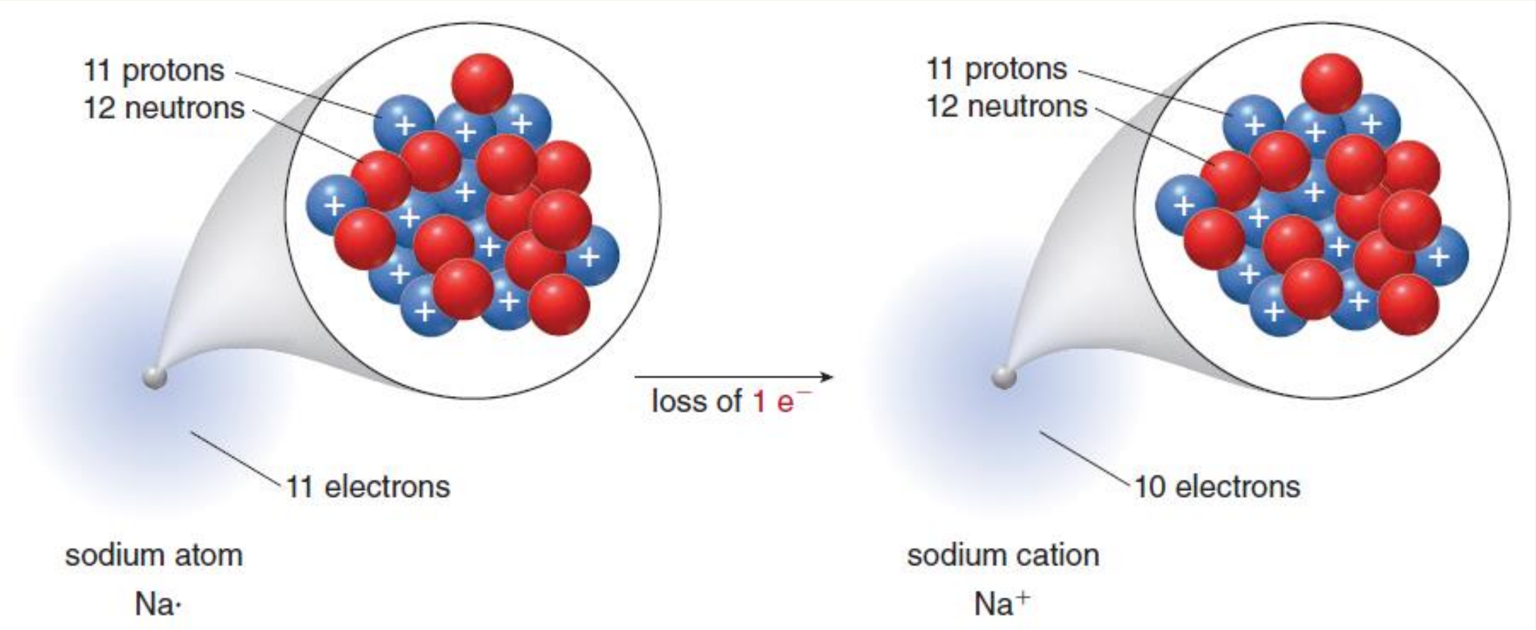
Sodium metal and chlorine gas are both elements. Sodium chloride is an ionic compound composed of sodium ions and chloride ions.

- Only the noble gases are particularly stable as individual atoms; that is, the **noble gases do not readily react to form bonds,** because the electronic configuration of the noble gases is especially stable.

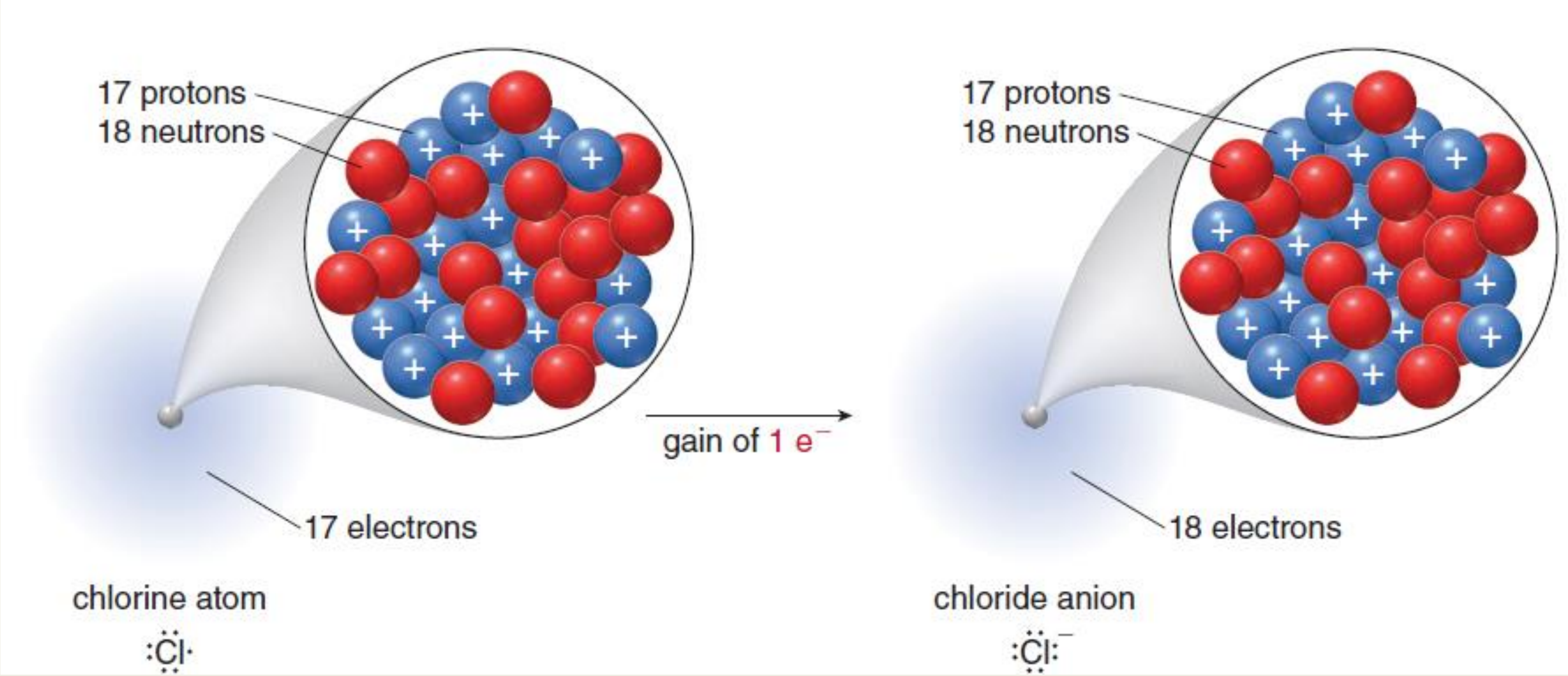
- **Ions**—charged species in which the number of protons and electrons in an atom is not equal.
- **A molecule** is a compound containing two or more atoms joined together with covalent bonds.

Ions

- There are two types of ions called **cations** and **anions**.
  - **Cations** are positively charged ions. A cation has fewer electrons than protons.
- Metals form cations. By losing one, two, or three electrons, an atom forms a cation with a completely filled outer shell of electrons.

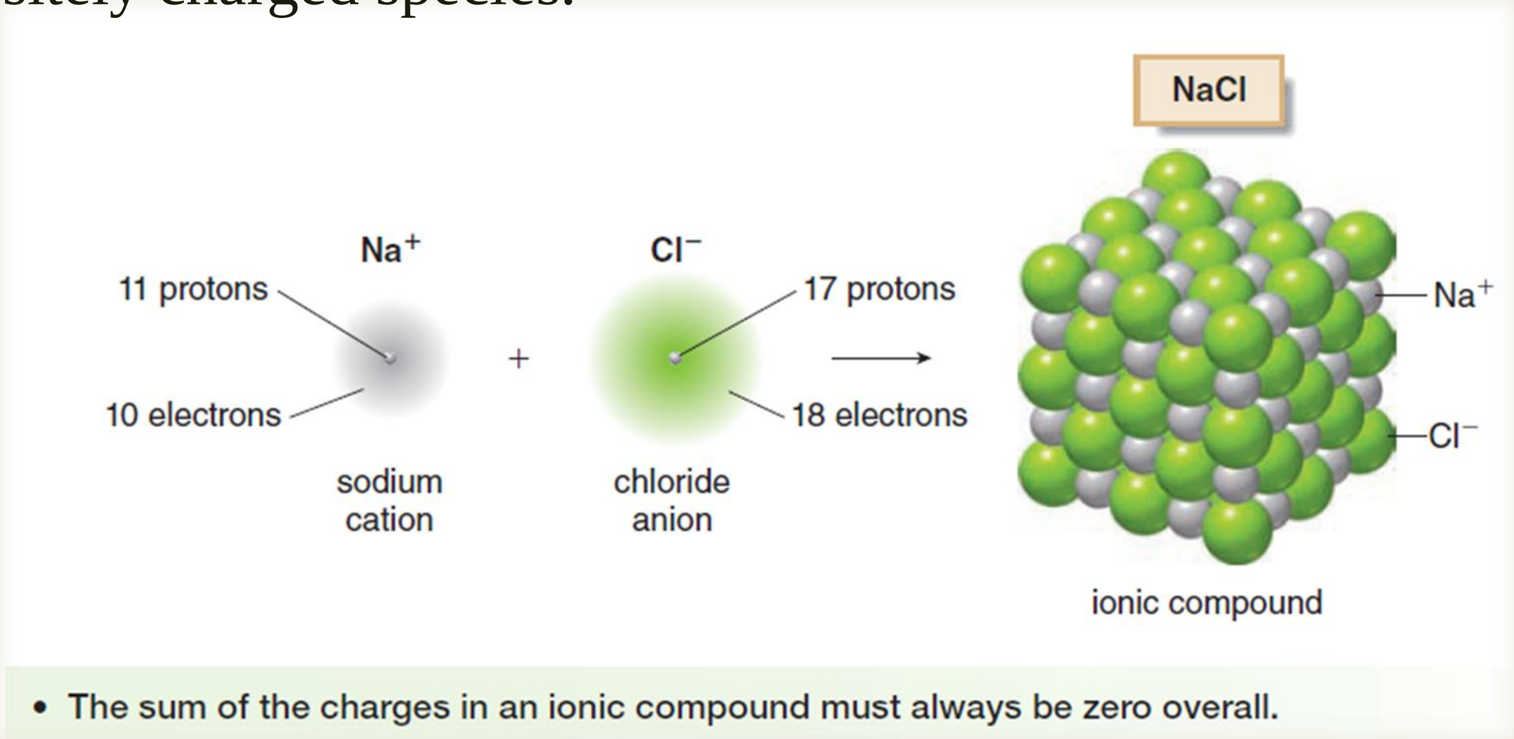


- **Anions** are negatively charged ions. An anion has more electrons than protons.
- Nonmetals form anions. By gaining one, two, or sometimes three electrons, an atom forms an anion with a completely filled outer shell of electrons.

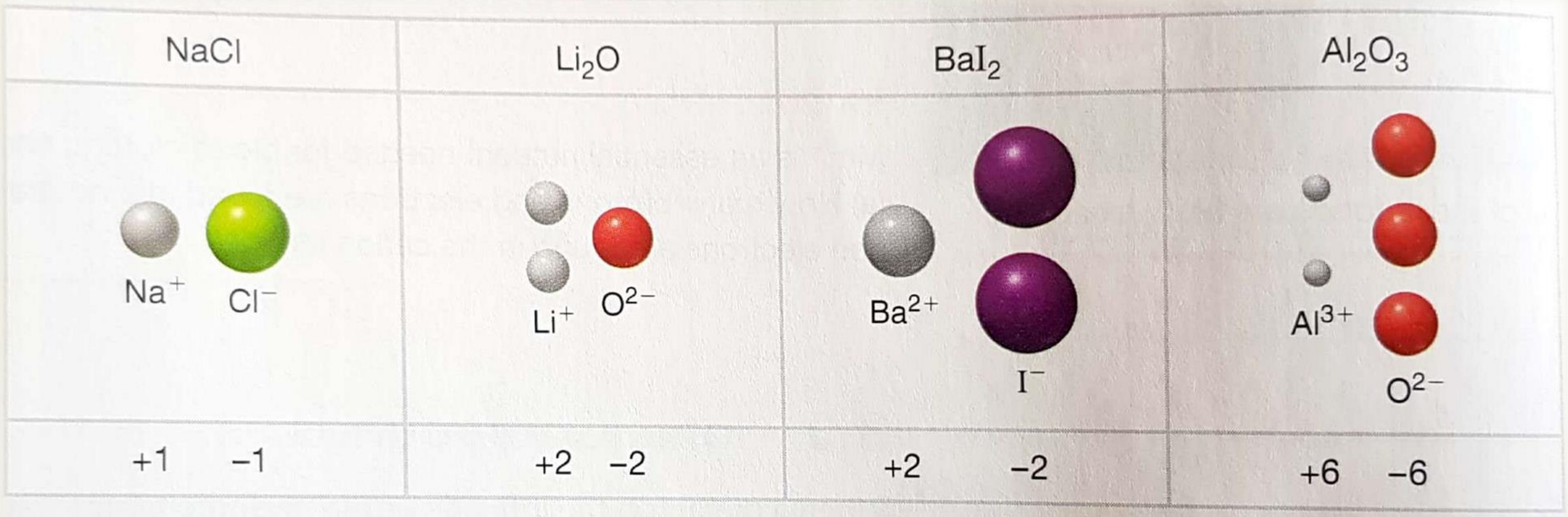


Ionic Compounds

- When a metal (on the left side of the periodic table) transfers one or more electrons to a nonmetal (on the right side), ionic bonds are formed.
- **Ionic compounds** are composed of cations and anions.
- The ions in an ionic compound are arranged to maximize the attractive force between the oppositely charged species.
- For example NaCl:



- When cations and anions having charges of different magnitude combine, the number of cations per anion is not equal.

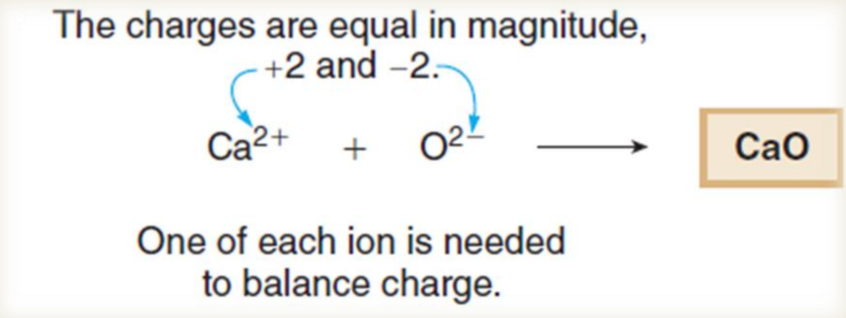


The ratio of oppositely charged ions that combine to form an ionic compound depends on the charge of the ions.

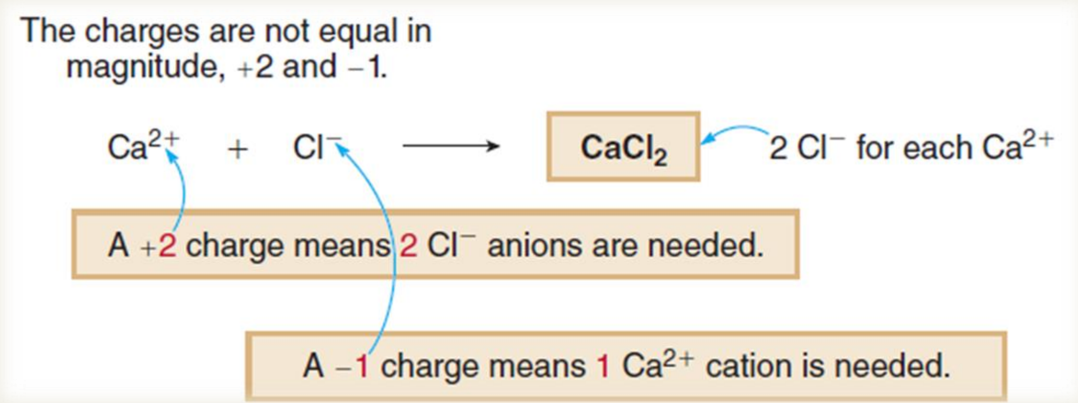
- $NaCl$: One Na^+ cation (+1 charge) combines with one Cl^- anion (–1 charge).
- Li_2O: Two Li^+ cations (+2 charge total) combine with one O^{2-} anion (–2 charge).
- BaI_2: One Ba^{2+} cation (+2 charge) combines with two I^- anions (–2 charge total).
- Al_2O_3: Two Al^{3+} cations (+6 charge total) combine with three O^{2-} anions (–6 charge total).

How To Write a Formula for an Ionic Compound

1. Identify which element is the cation and which is the anion.
2. Determine how many of each ion type are needed for an overall charge of zero.
   A. When the cation and anion have the same charge only one of each is needed.



   B. When the cation and anion have different charges, use the ion charges to determine the number of ions of each needed.



Physical Properties of Ionic Compounds

1. Ionic compounds are crystalline solids composed of ions packed to maximize the interaction of the positive charge of the cations and negative charge of the anions.
2. When a compound dissolve to form a liquid, energy is needed to overcome some of the attractive forces of the ordered solid, to form the less ordered liquid phase.
3. Ionic compounds have very high melting points.
4. Ionic compounds have extremely high boiling points.
5. An ionic compound dissolves in water, when dissolved the ions are separated.

Ions in living System

❑ Important Ions in the Body

- Many different ions are required for proper cellular and organ function. The major cations in the body are Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+}.
- K^{+} and Mg^{2+} are present in high concentrations inside cells,
- while Na^{+} and Ca^{2+} are present in a higher concentration outside of cells, in the extracellular fluids.
- Na^{+} is the major cation present in blood and extracellular bodily fluids and its concentration is carefully regulated to maintain blood volume and blood pressure within acceptable ranges that permit organ function.
- Ca^{2+} is found mainly in solid body parts such as teeth and bones, but it is also needed for proper nerve conduction and muscle contraction, as is Mg^{2+} .
- In addition to these four cations, Fe^{2+} and Cl^{-} are also important ions. Fe^{2+} is essential for oxygen transport by red blood cells. Cl^{-} is present in red blood cells, gastric juices, and other body fluids.
- Although Na+ is an essential mineral needed in the daily diet, the average American consumes three to five times the recommended daily allowance (RDA) of 2,400 mg. Excess sodium intake is linked to high blood pressure and heart disease.

All of these foods are high in sodium.

Ionic Compounds in Consumer Products

- Simple ionic compounds are added to food or consumer products to prevent disease or maintain good health. For example, **potassium iodide (KI)** is an essential nutrient added to table salt.
- **Iodine** is needed to synthesize thyroid hormones. A deficiency of iodine in the diet can lead to insufficient thyroid hormone production. In an attempt to compensate, the thyroid gland may become enlarged, producing a swollen thyroid referred to as a goiter.
- **Sodium fluoride (NaF)** is added to toothpaste to strengthen tooth enamel and help prevent tooth decay.

- Zinc oxide, an ionic compound formed from zinc and oxygen, is a common component of sunblocks. The zinc oxide crystals reflect sunlight away from the skin, and in this way, protect it from sun exposure. **What is the ionic formula for zinc oxide?**

Useful Ionic Compounds

- Ionic compounds are the active ingredients in several over-the-counter drugs. Examples include calcium carbonate ($CaCO_3$), the antacid in Tums; magnesium hydroxide [$Mg(OH)_2$], one of the active components in the antacids Maalox and milk of magnesia; and iron(II) sulfate ($FeSO_4$), an iron supplement used to treat anemia.
- **Bicarbonate (HCO_3^-)** is an important polyatomic anion that controls the acid–base balance in the blood. When the blood becomes too acidic, sodium bicarbonate (NaHCO3) is administered intravenously to decrease the acidity.
- **Magnesium sulfate ($MgSO_4$),** an over-the-counter laxative, is also given intravenously to prevent seizures caused by extremely high blood pressure associated with some pregnancies.

Health Notes

Some toothpastes contain the ionic compounds SnF_2 as a source of fluoride and Al_2O_3 as an abrasive.

Spam, a canned meat widely consumed in Alaska, Hawaii, and other parts of the United States, contains the preservative sodium nitrite, $NaNO_2$. Sodium nitrite inhibits the growth of *Clostridium botulinum,* a bacterium responsible for a lethal form of food poisoning.

Barium sulfate is used to visualize the digestive system during an X-ray procedure.

Ionization of water

- Water is an amphiprotic molecule, it can act as a very weak acid and a very weak base, donating protons to itself to a limited extent:

$$2H_2O\ (l) \rightleftharpoons H_3O^+(aq) + OH^-\ (aq)$$

- Applying the equilibrium law to the reaction above, we obtain

$$K_c = \frac{[\,H_3O^+][OH^-]}{[\,H_2O\,]^2}$$

- However, the concentration of water has a constant value of 55.5 mol dm^{-3} (the law of chemical equilibrium), and so its square can be multiplied by Kc to give a new constant Kw, called the ion-product constant of water:

$$K_w = K_c \times (55.5\ \text{mol dm}^{-3})^2 = [\,H_3O^+][OH^-]$$

- Measurements of the electrical conductivity of carefully purified water indicate that at 25°C $[H_3O^+] = [OH^-] = 1.00 \times 10^{-7}$ mol dm^{-3}, so that

$$K_w = 1.00\times10^{-7}\ \text{mol dm}^{-3}\times1.00\times10^{-7}\ \text{mol dm}^{-3} = 1.00\times10^{-14}\ \text{mol}^2\text{dm}^{-6}$$

- K_w depends on the strength of hydrogen bonding. Therefore, it is affected by the same factors that influence hydrogen bonding: Temperature, pressure, solute concentration and ionic strength.

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}}{1.00\ \text{mol dm}^{-3}}$$

$$= 1.00 \times 10^{-14}\ \text{mol dm}^{-3}$$

Calculate the hydronium-ion concentration in a solution of 0.516 *M* $Mg(OH)_2$.

Solution Since 1 mol $Mg(OH)_2$ produces 2 mol OH^- in solution, we have

$$[OH^-] = 2 \times 0.516 \frac{mol}{dm^3} = 1.032 \frac{mol}{dm^3}$$

Then

$$[\mathrm{H_3O^+}] = \frac{K_w}{[\mathrm{OH^-}]} = \frac{1.00 \times 10^{-14}\ \mathrm{mol^2\ dm^{-6}}}{0.612\ \mathrm{mol\ dm^{-3}}}$$

$$= 1.63 \times 10^{-14}\ \mathrm{mol\ dm^{-3}}$$

End