Al-Rasheed University College
Department of Dentistry
1st Stage

MEDICAL CHEMISTRY

lecture 1
Ions in live System

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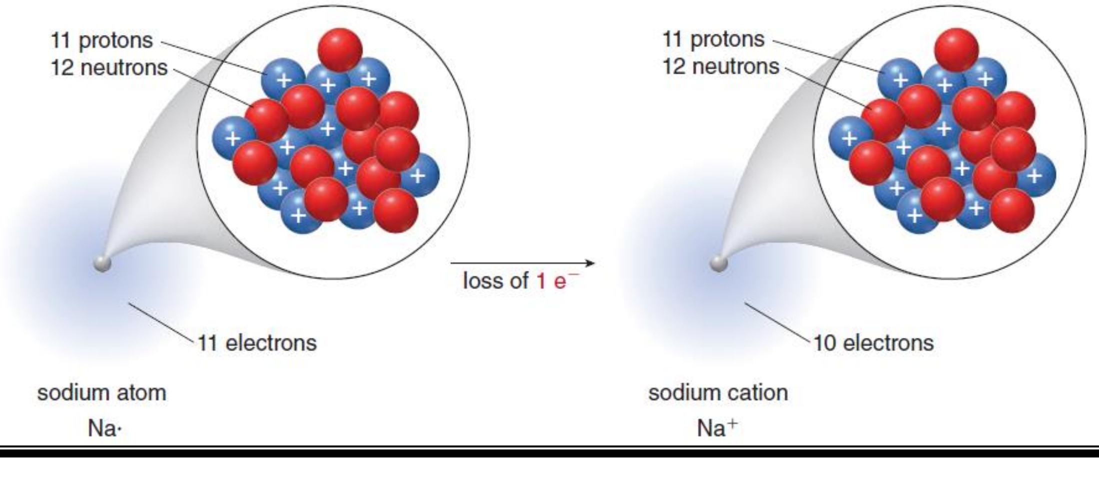


Introduction

Ions in the Body, play an important role in the body. Calcium, potassium, sodium, chloride, and copper ions are some key ions that participate in the body's electrical events. Potassium is the major positive ion inside the cell. Sodium is the major positive ion found in the fluid outside the cell. Ionic chlorine is the most abundant negative ion.

Types of Chemical Compounds

❖ There are two types of chemical compounds, ionic and covalent.

1. ***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.
2. ***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:

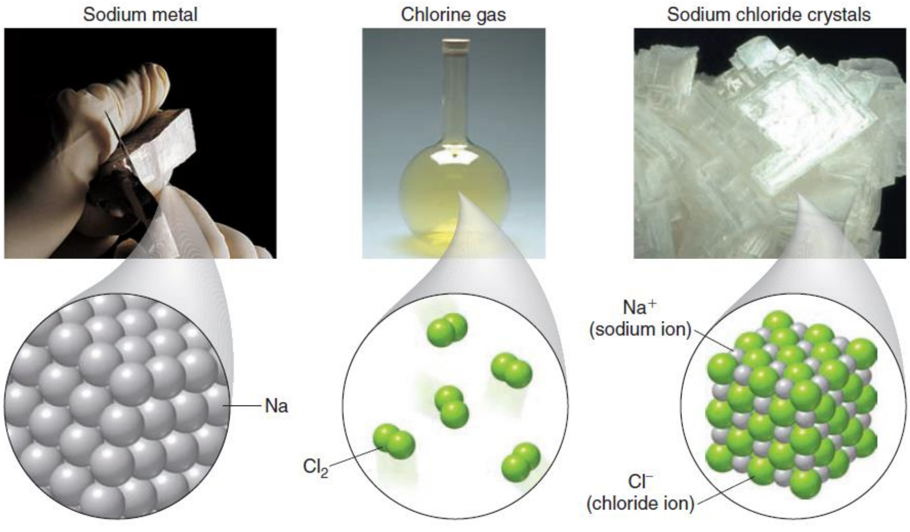
It is rare in nature to encounter individual atoms. Instead, anywhere from two to hundreds or thousands of atoms tend to join together to form compounds. The oxygen we breathe, for instance, consists of two oxygen atoms joined together, whereas the hemoglobin that transports it to our tissues consists of thousands of carbon, hydrogen, oxygen, nitrogen, and sulfur atoms joined together. **We say two atoms are bonded together**.

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.

Only the noble gases in group 8A of the periodic table 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 to begin with.

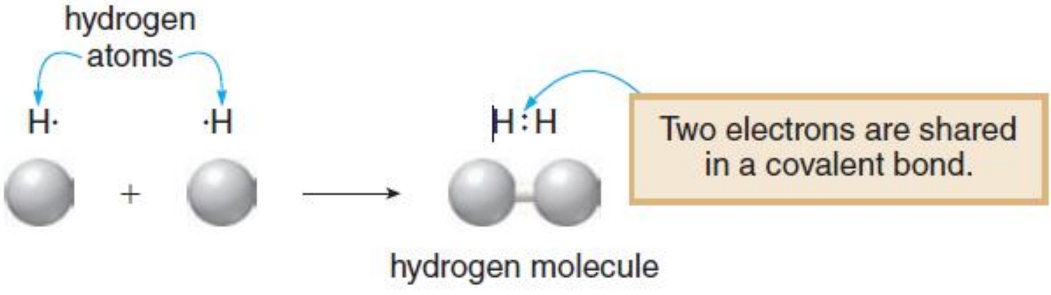
There are two different kinds of bonding: **ionic** and **covalent**.

i. **Ionic bonds** result from the transfer of electrons from one element to another.
The position of an element in the periodic table determines the type of bonds it makes. Ionic bonds form between a metal on the left side of the periodic table and a nonmetal on the right side. As shown in bellow Figure, when the metal sodium (Na) bonds to the nonmetal chlorine (Cl_2), the ionic compound sodium chloride (NaCl) forms. Ionic compounds are composed of ions—charged species in which the number of protons and electrons in an atom is not equal.



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

ii. **Covalent bonds** result from the sharing of electrons between two atoms.
Covalent bonds are formed when two nonmetals combine, or when a metalloid bond to a nonmetal. A molecule is a compound containing two or more atoms joined together with covalent bonds. For example, when two hydrogen atoms bond they form the molecule H_2, and two electrons are shared.



Ions

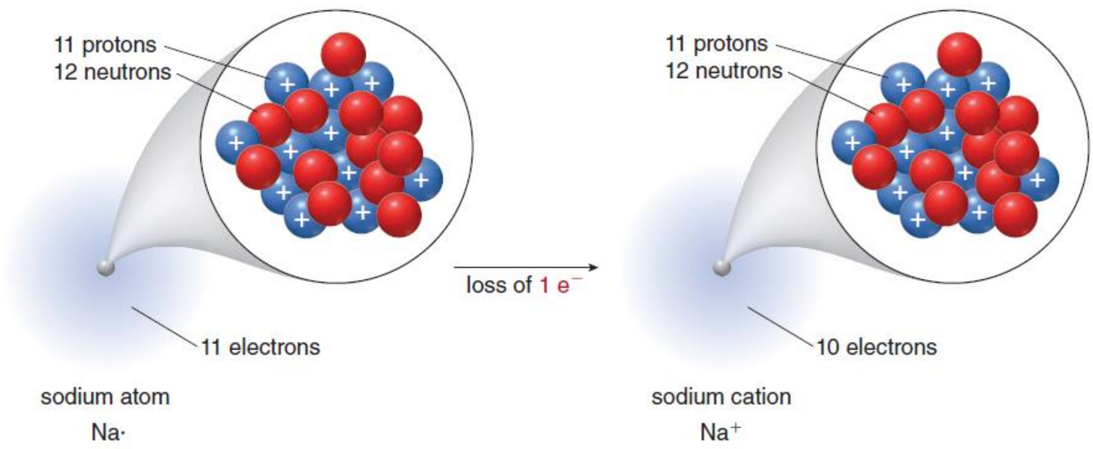
The charge on an ion depends on the position of an element in the periodic table. In forming an ion, an atom of a main group element loses or gains electrons to obtain the electronic configuration of the noble gas closest to it in the periodic table. This gives the ion an especially stable electronic arrangement in which the electrons completely fill the shell farthest from the nucleus.

There are two types of ions called cations and anions.

1. **Cations** are positively charged ions. A cation has fewer electrons than protons.

For example, sodium (group 1A) has an atomic number of 11, giving it 11 protons and 11 electrons in the neutral atom. This gives sodium one more electron than neon, the noble gas closest to it in the periodic table. In losing one electron, sodium forms a cation with a +1 charge, which still has 11 protons, but now has only 10 electrons in its electron cloud.

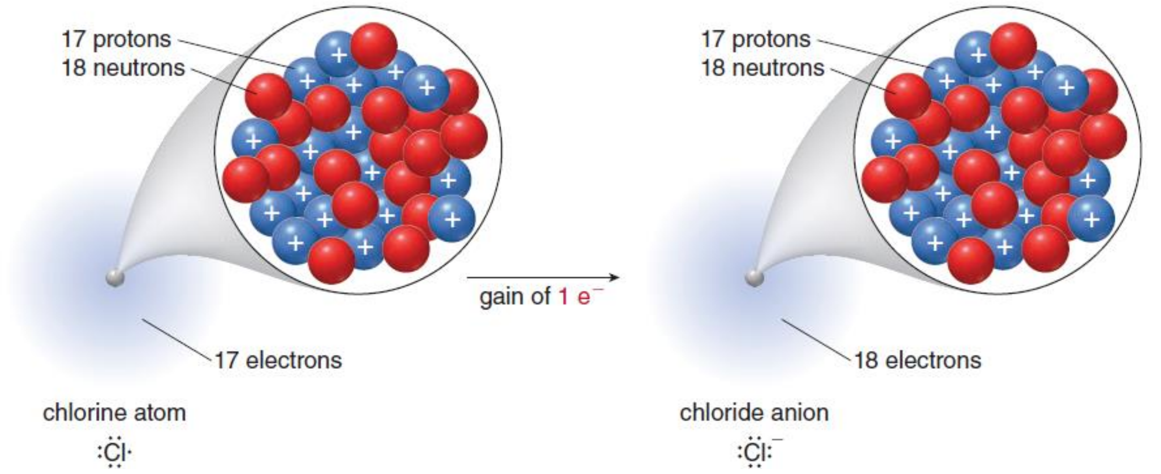
Metals form cations. By losing one, two, or three electrons, an atom forms a cation with a completely filled outer shell of electrons.



2. **Anions** are negatively charged ions. An anion has more electrons than protons.

A neutral chlorine atom (group 7A), on the other hand, has 17 protons and 17 electrons. This gives it one fewer electron than argon, the noble gas closest to it in the periodic table. By gaining one electron, chlorine forms an anion with a –1 charge because it still has 17 protons, but now has 18 electrons in its electron cloud.

Nonmetals form anions. By gaining one, two, or sometimes three electrons, an atom forms an anion with a completely filled outer shell of electrons.

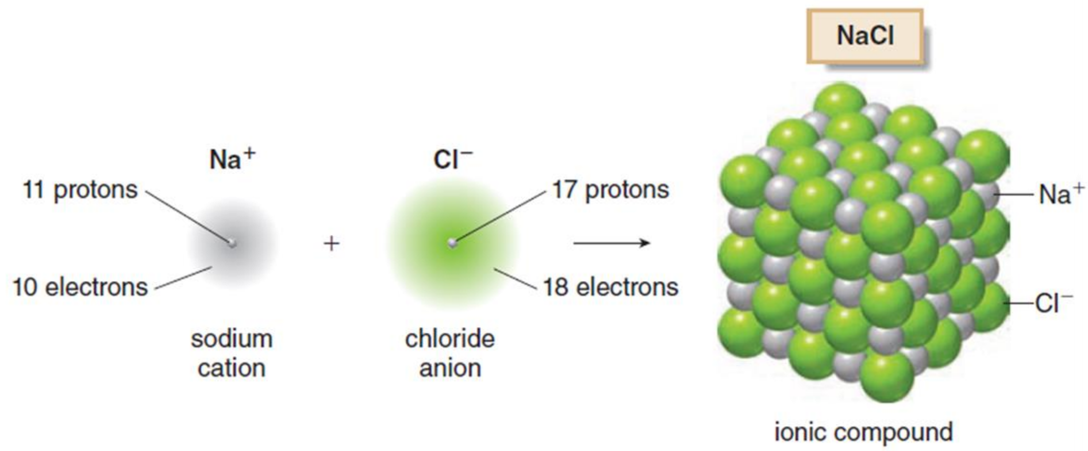


Ionic Compounds

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 examples NaCl.

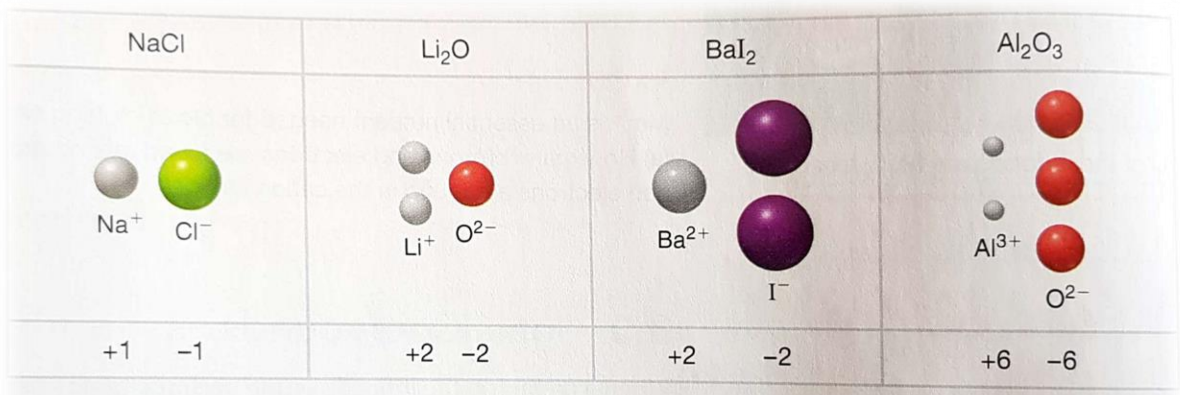


• The sum of the charges in an ionic compound must always be zero overall.

The formula for an ionic compound shows the ratio of ions that combine to give zero charge. Since the sodium cation has a +1 charge and the chloride anion has a –1 charge, there must be one Na^+ cation for each Cl^- anion; thus, the formula is NaCl.

When cations and anions having charges of different magnitude combine, the number of cations per anion is not equal. Consider an ionic compound formed from calcium (Ca) and fluorine (F).

Since calcium is located in group 2A, it loses two valence electrons to form Ca^{2+}. Since fluorine is located in group 7A, it gains one electron to form F^- like other halogens. When Ca^{2+} combines with the fluorine anion F^-, there must be two F^- anions for each Ca^{2+} cation to have an overall charge of zero.

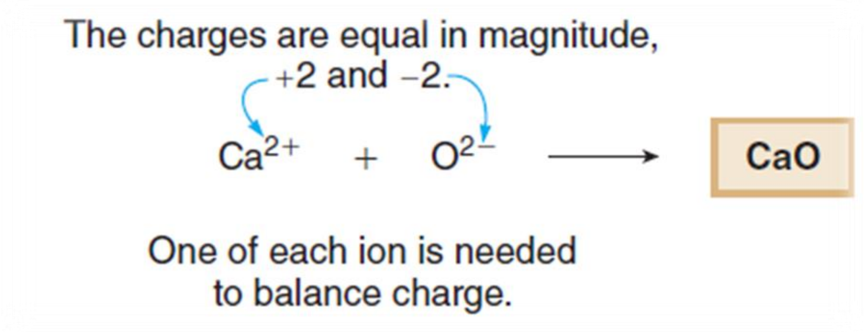


The ratio of oppositely charged ions that combine to form an ionic compound depends on the charge of the ions.

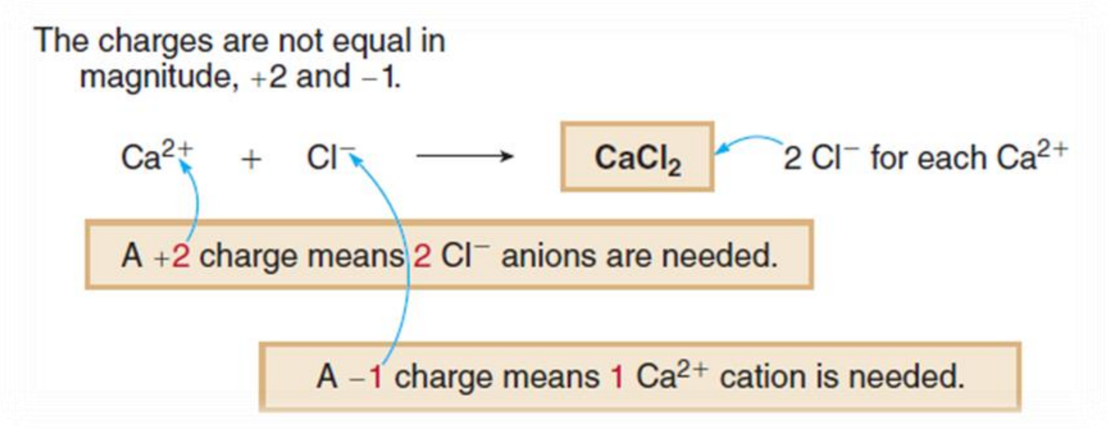
- NaCl: One Na^+ cation (+1 charge) combines with one Cl^- anion (–1 charge).
- Li_2O: Two Li^+ cations (+2 charge total) combine with one O^{2-} anion (–2 charge).
- BaI_2: One Ba^{2+} cation (+2 charge) combines with two I^- anions (–2 charge total).
- Al_2O_3: Two Al^{3+} cations (+6 charge total)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

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+}.

a) K^+ and Mg^{2+} are present in high concentrations inside cells,

b) while Na^+ and Ca^{2+} are present in a higher concentration outside of cells, in the extracellular fluids.

c) 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.

d) 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+}.

e) 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.

f) 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.

Table 3.1 Na^+ Content in Common Foods

Foods High in Na^+		Foods Low in Na^+	
Food	Na^+ (mg)	Food	Na^+ (mg)
Potato chips (30)	276	Banana (1)	1
Hot dog (1)	504	Orange juice (1 cup)	2
Ham, smoked (3 oz)	908	Oatmeal, cooked (1 cup)	2
Chicken soup, canned (1 cup)	1,106	Cereal, shredded wheat (3.5 oz)	3
Tomato sauce, canned (1 cup)	1,402	Raisins, dried (3.5 oz)	27
Parmesan cheese (1 cup)	1,861	Salmon (3 oz)	55

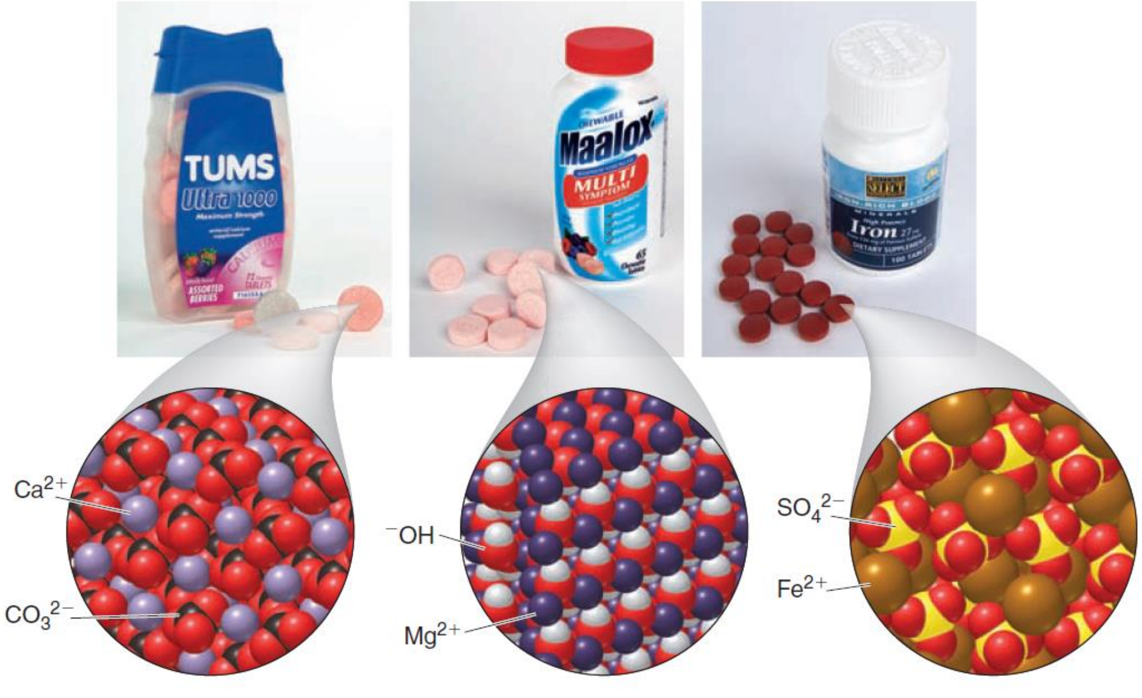
Ionic Compounds in Consumer Products

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.
- Potassium chloride (KCl), sold under trade names such as K–Dur, Klor–Con, and Micro–K, is an ionic compound used for patients whose potassium levels are low. Potassium chloride can be given as tablets, an oral suspension, or intravenously. Adequate potassium levels are needed for proper fluid balance and organ function. Although potassium is readily obtained from many different food sources (e.g., potatoes, beans, melon, bananas, and spinach), levels can become low when too much potassium is lost in sweat and urine or through the use of certain medications.

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 ($NaHCO_3$) 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.



$CaCO_3$ $Mg(OH)_2$ $FeSO_4$

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

- $K_w = 1.00\times10^{-7}$ mol dm$^{-3}\times1.00\times10^{-7}$ mol dm^{-3} = 1.00×10^{-14} mol^{2}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

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

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