INTERNATIONAL COLLEGE OF PHARMACEUTICAL INNOVATION
国际创新药学院

Class	Pharm, BioPharm
Course	Fundamentals of Medicinal & Pharmaceutical Chemistry
Code	FUNCHEM.7
Title	Ionic Bonding and the "electrolyte status" of body fluid
Lecturer	Prof. Xinchen Teng
Date	2024-10-23

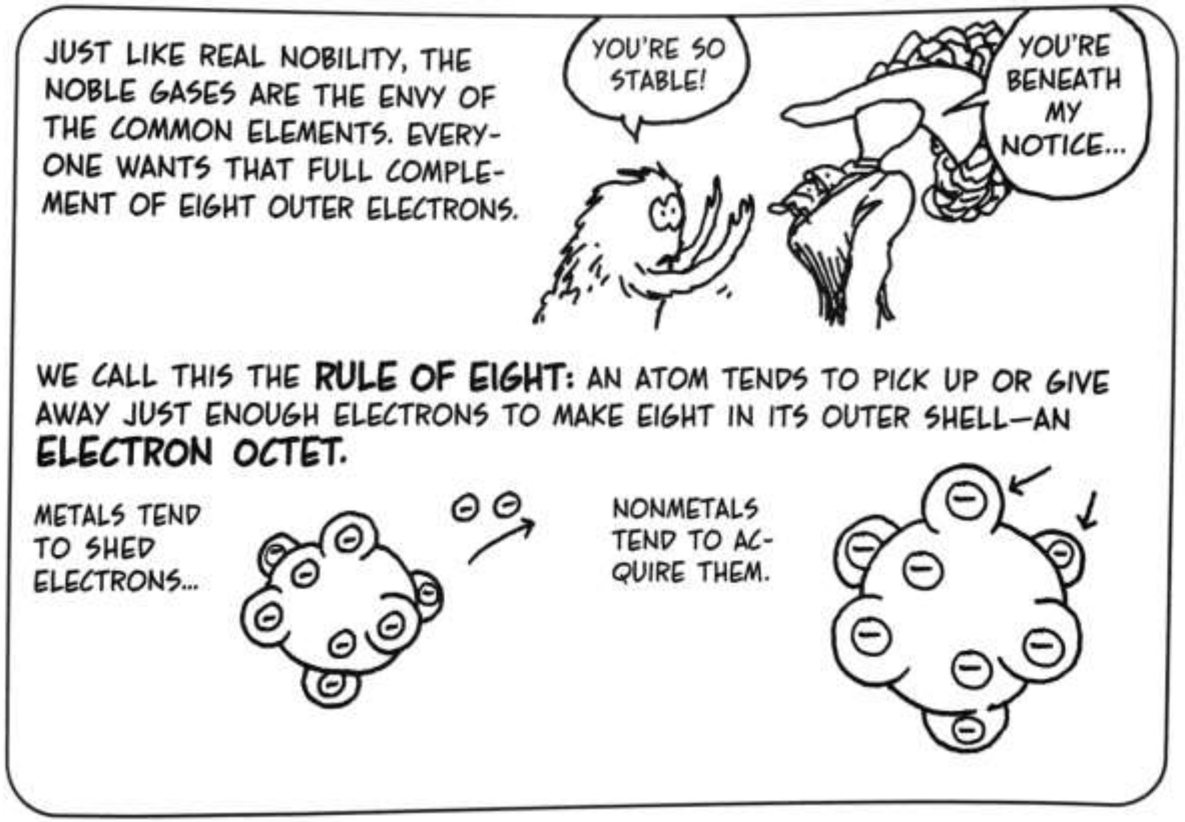
Recommended Reading

- General Chemistry - The Essential Concepts
  by Chang and Goldsby (7th edition)
  – Section 9.1, 9.2, 9.4, 9.5

FUNCHEM.7 Learning Outcomes

- Define ‘octet rule’ and recall ‘electronegativity’.
- Differentiate between ‘pure covalent’ and ‘polar covalent’ bonding.
- Explain ‘ionic bonding’ and ‘ionic character’.
- Predict whether a covalent, polar covalent or ionic bond will form based on a knowledge of electronegativity values.
- Explain the formation of ionic compounds using electronic configurations.
- Differentiate between ‘electrolytes’ and ‘non-electrolytes’ and recall principal electrolytes in body fluids.
- Solve calculations regarding electrolyte concentrations in mEq/L.
- Explain the importance of electrolytes in the body and consequences of electrolyte overload or deficiencies (e.g. hypo or hyperkalemia and hypo or hypernatremia).

Noble Gas Configuration



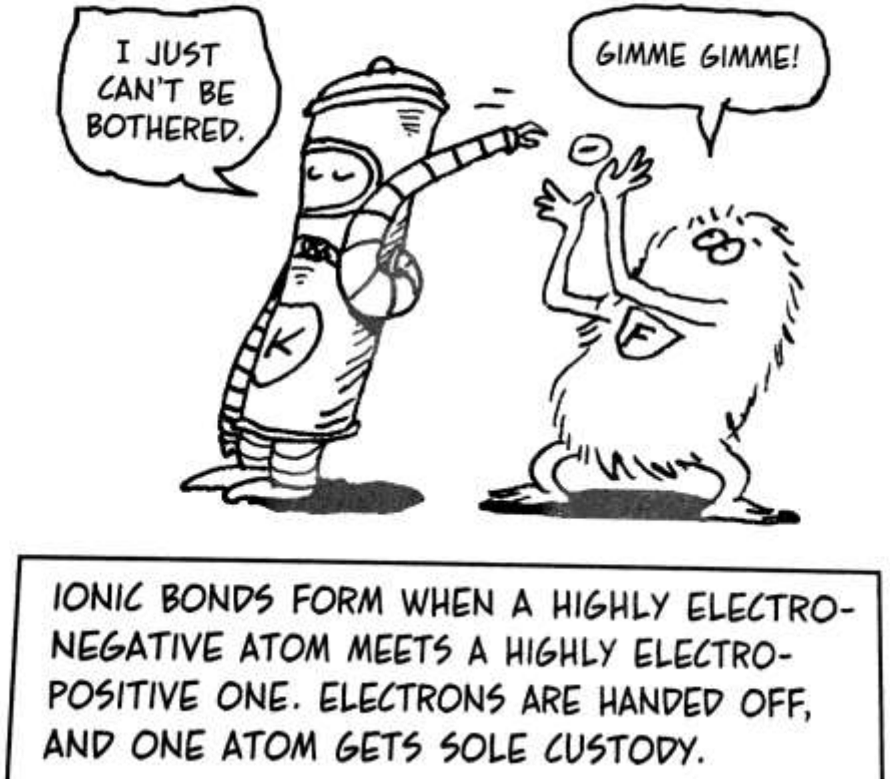
- Noble gases are chemically stable (chemically inert).
- They share a common e^- configuration of 8 valence electrons that is very stable.
- He is an exception with 2 e^-.

Octet Rule

- An atom other than hydrogen tends to form bonds until it is surrounded by eight valence electrons
  - Atoms are most stable if they have a filled or empty outer shell of electrons.
  - Except for H and He, a filled outer shell contains 8 valence e^-.
  - Atoms will:
    - gain or lose electrons (ionic)
    - share electrons (covalent)
    - to achieve a noble gas configuration.

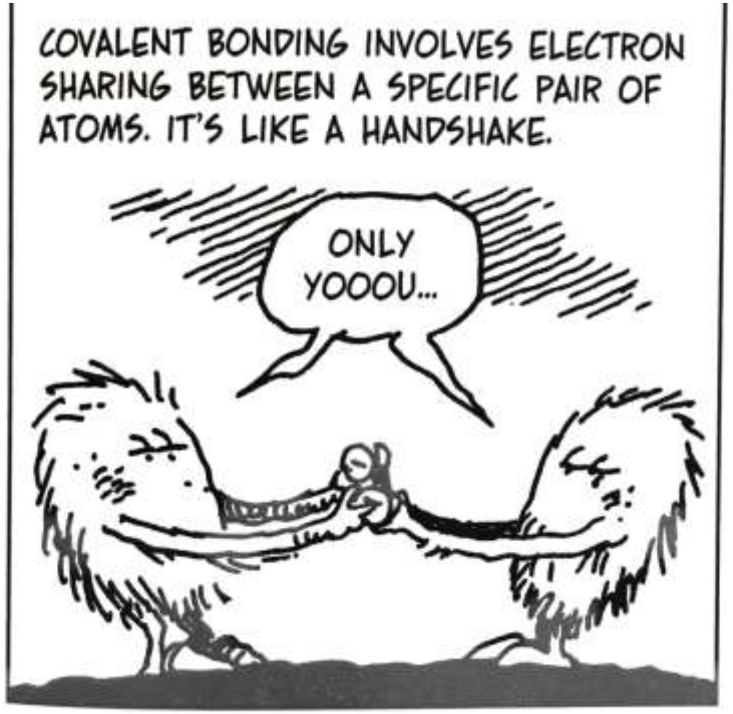
Chemical bonds

- Ionic bond
  - An ionic bond is the electrostatic force that holds the cations and anions in an ionic compound.
  - Atoms either completely lose one or more e^- to become positive cations or gain one or more e^- to become negative anions.



Watch the animation titled ‘Ionic vs Covalent Bonding’ on the VLE

Chemical bonds



- Covalent
  - A covalent bond is formed when atoms share one pair of electrons
  - Neither atom is willing to give up e^- or is strong enough to take e^- away.

Watch the animation titled 'Ionic vs Covalent Bonding' on the VLE

Ionic vs Covalent

- How do you know whether an ionic or covalent bond will form?
  - Knowing the **electronegativity** of individual atoms can help determine the type of interaction between atoms
  - Electronegativity values can be used to distinguish between covalent, polar covalent and ionic bonds

Electronegativity is the ability of an atom to attract toward itself the electrons in a chemical bond. – Recall from M2.4

Electronegativity

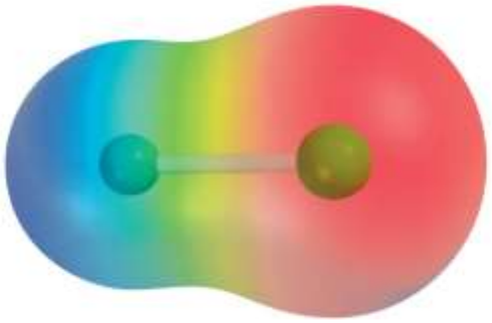
- The ability of an atom in a molecule to attract towards itself electrons in a chemical bond
- Electronegativity the same, electrons shared equally.
  - H_2, N_2, O_2
- One atom more electronegative than the other, e^- not equally shared.
  - H-F, H-Cl

H – H

Non-polar

$\delta+$ H – F $\delta-$

Polar



Electronegativity trends

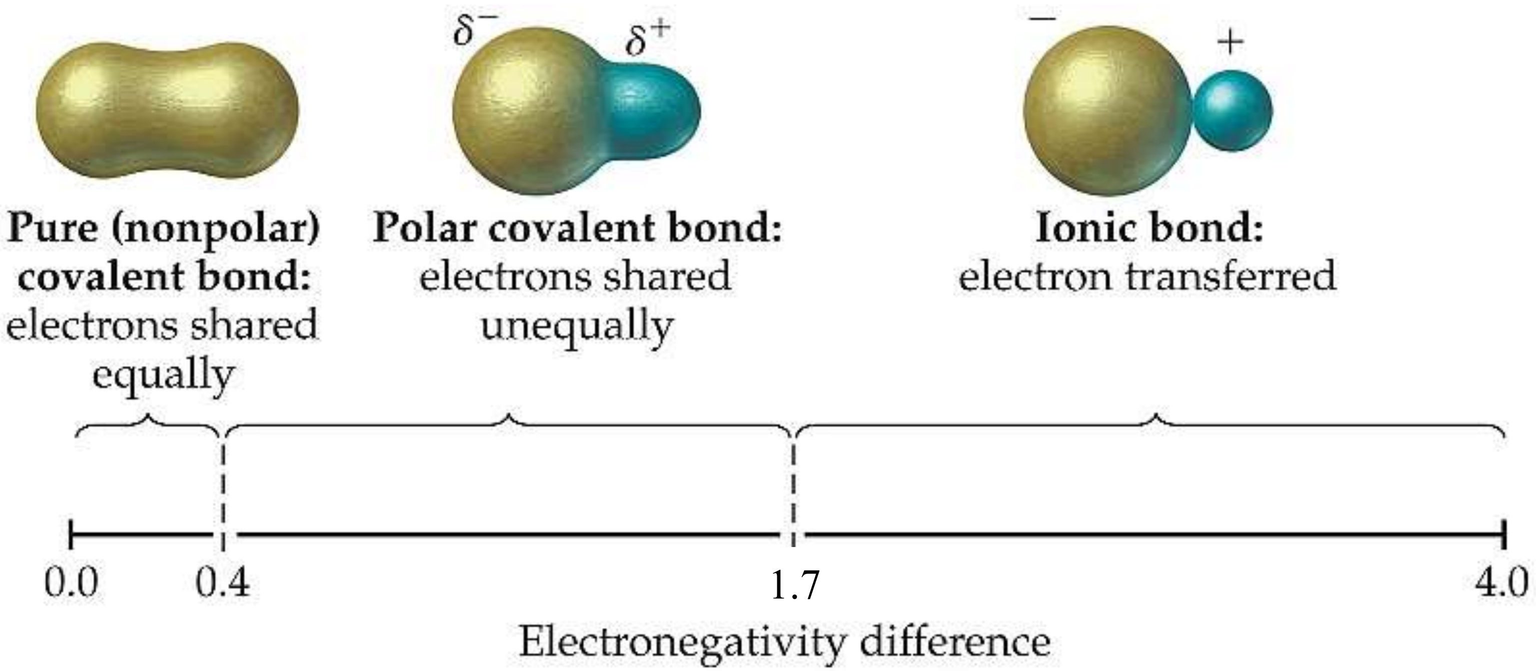
Increasing electronegativity

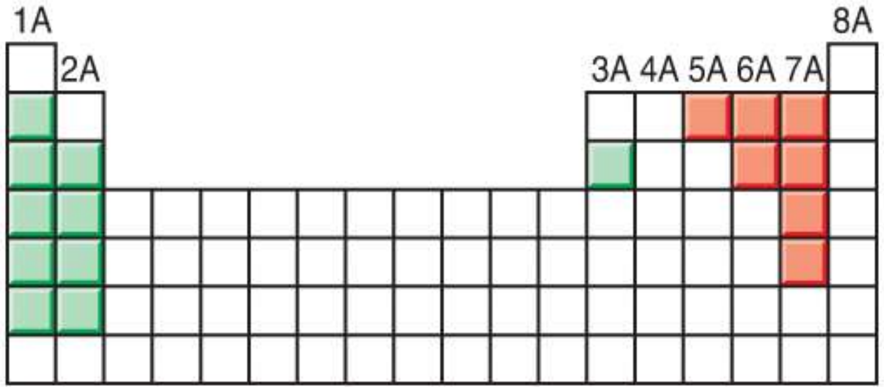
Increasing electronegativity

1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
H 2.1																	
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.9	Ni 1.9	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe 2.6
Cs 0.7	Ba 0.9	La-Lu 1.0-1.2	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2	
Fr 0.7	Ra 0.9																

Pauling scale of relative electronegativity values

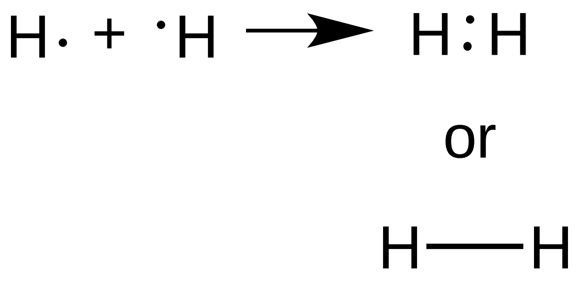
Types of chemical bonds

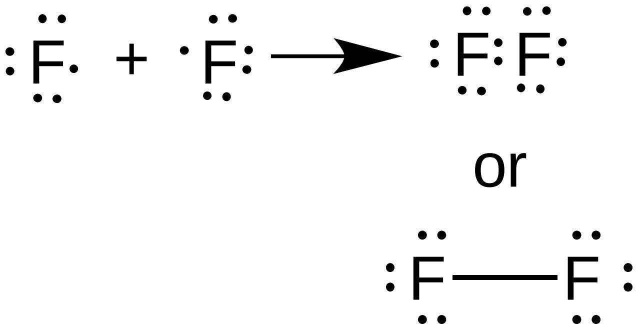




The most electronegative elements are the nonmetals (Groups 5A–7A) and the least electronegative elements are the alkali and alkaline earth metals (Groups 1A–2A) – Ionic bonds

Pure covalent – H_2 and F_2





E.N. [H] = 2.1 E.N. [H] = 2.1

ΔE.N. = 2.1 – 2.1 = 0

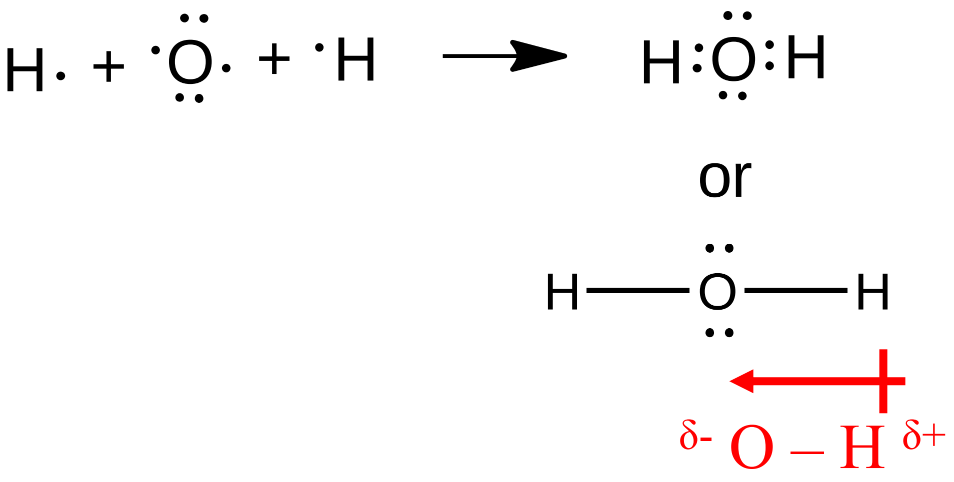
Pure covalent bond

E.N. [F] = 4.0 E.N. [F] = 4.0

ΔE.N. = 4.0 – 4.0 = 0

Pure covalent bond

Polar covalent – H2O



E.N. [O] = 3.5

E.N. [H] = 2.1

ΔE.N. = 3.5 – 2.1 = 1.4

Polar covalent bond

Ionic and ionic character

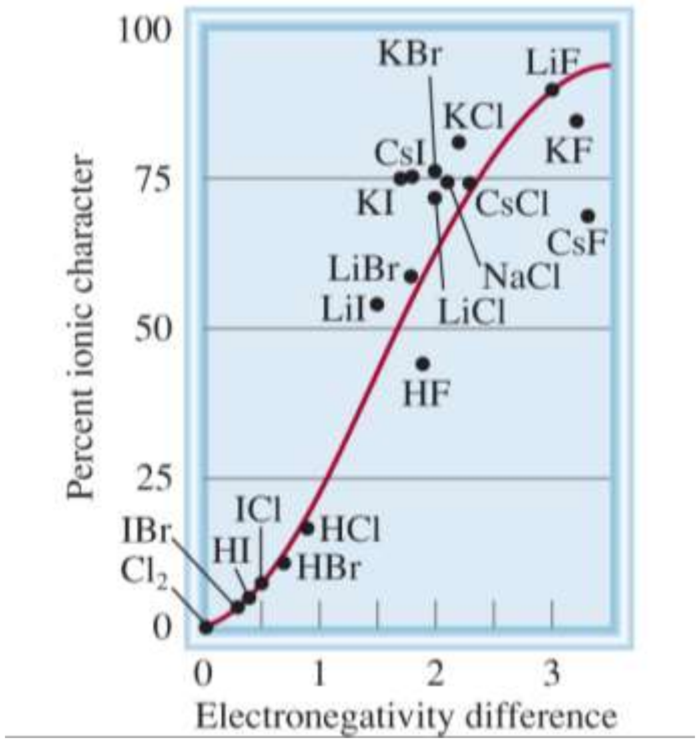
$$Li\cdot \; + \; \cdot\ddot{\underset{\cdot\cdot}{F}}: \longrightarrow Li^{+} \;\; :\ddot{\underset{\cdot\cdot}{F}}:^{-}$$

$1s^2 2s^1$ $1s^2 2s^2 2p^5$ $1s^2$ $1s^2 2s^2 2p^6$

E.N. [Li] = 1.0   E.N. [F] = 4.0

ΔE.N. = 4.0 – 1.0 = 3

Ionic bond



The greater the difference in electronegativity, the greater the ‘ionic character’

Some salt for practice

- NaCl   E.N. [Na] = 0.9   E.N. [Cl] = 3.0   ΔE.N. = 2.1

$_{11}Na : 1s^2 2s^2 2p^6 3s^1$

Removal of this e^- gives a very stable configuration

$[Na]^+ : 1s^2 2s^2 2p^6$

$_{17}Cl : 1s^2 2s^2 2p^6 3s^2 3p^5$

Requires an e^- to give a very stable configuration

$[Cl]^- : 1s^2 2s^2 2p^6 3s^2 3p^6$

A 3s electron from a sodium atom is transferred completely to a 3p orbital of a chlorine atom.

Calcium and oxygen

- Ca – O E.N. [Ca] = 1.00 E.N. [O] = 3.5 ΔE.N. = 2.5

$_{20}Ca$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

Removal of 2 e^- gives a very stable configuration (noble gas)

$[Ca]^{2+}$: $1s^2 2s^2 2p^6 3s^2 3p^6$

$_8O$: $1s^2 2s^2 2p^4$

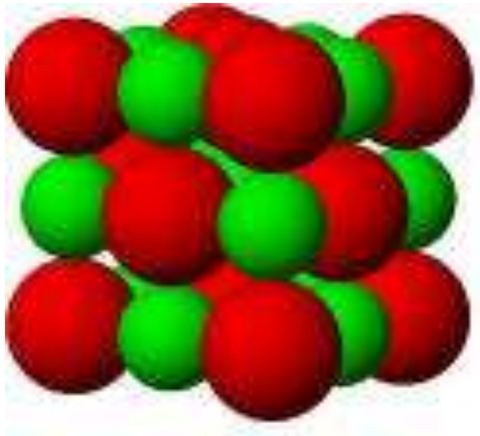
Requires 2 e^- to give a very stable configuration

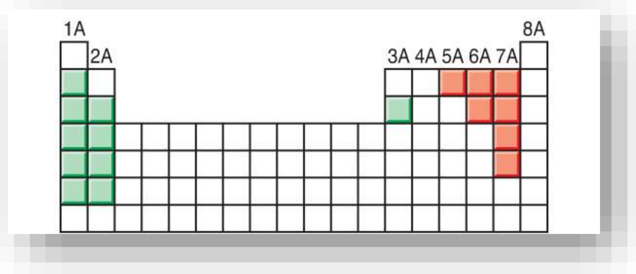
$[O]^{2-}$: $1s^2 2s^2 2p^6$

Two 4s electrons from a calcium atom are transferred completely to a 2p orbitals of the oxygen atom.

Properties of ionic compounds

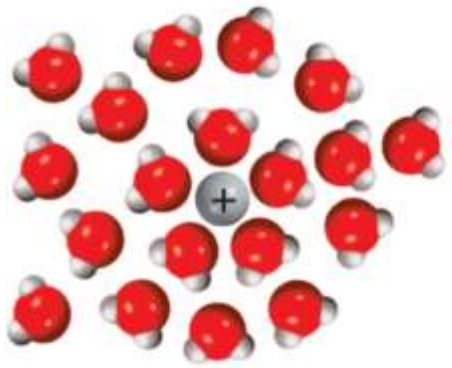
- Ionic interactions take place between metal and non-metal atoms.
- Can form lattice structures held together by electrostatic interactions.
- Have high melting points.
- Generally soluble in water.

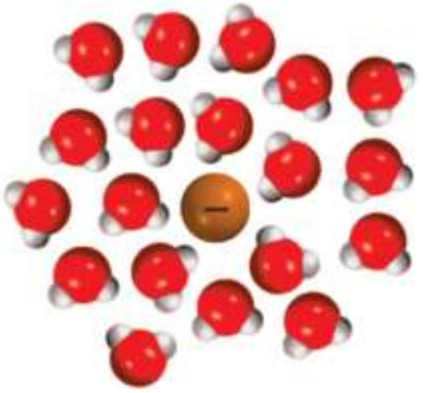




Electrolytes - ions in solution

- An electrolyte is a substance that, when dissolved in water, results in a solution that can conduct electricity (separate into charged particles).
  - Both weak electrolytes (separate partially) and strong electrolytes (separate fully) exist
- Nonelectrolytes do not conduct electricity when dissolved in water (do not form charged particles).
- Ions are hydrated in aqueous solution. This is the process by which ions are surrounded by water molecules in a specific manner (Displayed to the right).

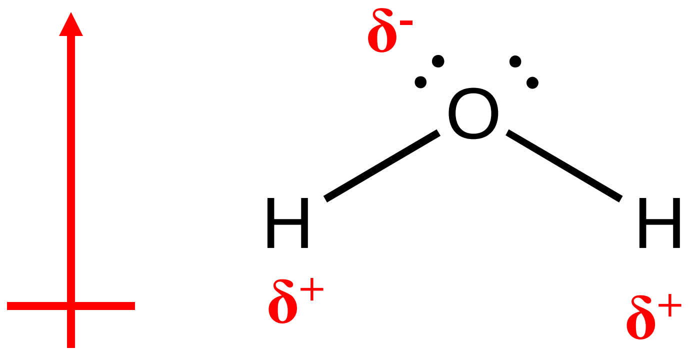




Electrolytes perform many important regulatory roles in our bodies by virtue of their charged properties.

Water – Dipole

- Hydrogen
  - E.N. = 2.1
- Oxygen
  - E.N. = 3.5
- Creation of a dipole moment. Area of partial negative charge & area of partial positive charge.



Electrolytes in the body

- Cell
  - K^+, Mg^{2+}, Na^+
  - HPO_4^{2-}, proteins, SO_4^{2-}, HCO_3^-, Cl^-
- Interstitial fluid
  - Na^+, K^+, Ca^{2+}, Mg^{2+}
  - Cl^-, HCO_3^-, organic acids, HPO_4^-, SO_4^{2-}
- Blood
  - Na^+, K^+, Ca^+, Mg^+
  - Cl^-, HCO_3^-, proteins, organic acids, HPO_4^-, SO_4^{2-}

Equivalents

- An equivalent of any substance is an amount of material that will give or react with an Avogadro's number of electrical charges

Weight Eq = Atomic or Molecular Weight/ n (the charge)

Examples

$Na \longrightarrow Na^+ + e^-$

23g — 6×10^{23} electrons

An equivalent of Na^+ is 23g

$Ca \longrightarrow Ca^{2+} + 2e^-$

40g — 2 moles of electrons

An equivalent of Ca^{2+} is 20g

Equivalents

In healthcare the most common representation of electrolyte concentration is **milliequivalents per litre** (mEq/L), which is equal to the ion concentration (mmol/L) multiplied by the number of electrical charges on the ion.

$$\text{Equivalents} = \frac{\text{mass} \times \text{charge}}{\text{molar mass}}$$

In Clinical Situations

Measurement of electrolyte status of the blood plasma or serum

Medscape® www.medscape.com

Test	Result	Normal Range
Glucose	74 mg/dL	60-105 mg/dL
Blood urea nitrogen (BUN)	8 mg/dL	7-22 mg/dL
Creatinine	0.4 mg/dL	0.3-0.7 mg/dL
Sodium	134 mEq/L	135-148 mEq/L
Potassium	3.7 mEq/L	3.5-5.0 mEq/L
Chloride	108 mEq/L	99-111 mEq/L
Carbon dioxide	30 mEq/L	20-24 mEq/L
Calcium	8.4 mg/dL	8.0-10.5 mg/dL
Uric acid	3.6 mg/dL	2.4-5.9 mg/dL
Total bilirubin	0.5 mg/dL	1 mg/dL
Total protein	4.4 g/dL	4.9-8.1 g/dL
Albumin	1.8 g/dL	3.5-5.0 g/dL
Aspartate aminotransferase (AST)	42 U/L	0-35 U/L
Alkaline phosphatase	242 U/L	100-320 U/L
Lactate dehydrogenase (LDH)	712 U/L	150-300 U/L

Source: J Pediatr Health Care @ 2003 Mosby-Year Book, Inc.

Importance of electrolytes

- Changes in the concentrations of sodium and potassium in blood can lead to serious medical emergencies
- Useful terms related to electrolyte disorders
  - -emia "in the blood"
  - -hypo a condition of low concentration
  - -hyper a condition of high concentration
  - -natr represents sodium (Latin – natrium)
  - -kal represents potassium (Latin – kalium)

Nervous system and electrolytes

- K^+ and Na^+ move in and out of channels in the membrane of nerve cell walls (some channels only permit K^+ to pass through)
  - Net result – electrical signal
- Deficiencies in these ions can lead to serious problems
  - Hypokalemia can lead to cardiac arrest. A diet low in K^+ can lead to hypokalemia

You can read this short review to gain an insight into the importance of K^+ ions in cardiac function and health. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3016067/pdf/ecc15e096.pdf

LoSalt – essential and deadly

- KCl
  - 40% more potassium in our bodies than sodium.
  - Potassium is found in all parts of the body.
  - Red blood cells have most, followed by muscles & brain tissue.
  - It is the main cationic electrolyte found inside cells.

33% NaCl
66% KCl

Deadly KCl

- If too much potassium outside the nerve cells, the potassium inside cannot escape and electrical impulse dies away.
- Potassium overdose paralyses the central nervous system, causes convulsions, diarrhoea, kidney failure and heart attack.
- In some countries condemned prisoners who agree to donate their organs for transplants may be executed by being given a ‘non-toxic’ lethal injection of potassium chloride.