Summary: Chapter 2-Chemistry Review

I. Bonding

A. How many bonds between C, O, N, and H

B. Geometry

1. Tetrahedral
2. Planar - e.g. C forms double bond with C or O

C. Electronegativity

1. (N & O) > (C & H)
2. Bonds between C or H and O or N are polar; bonds between C & H are not

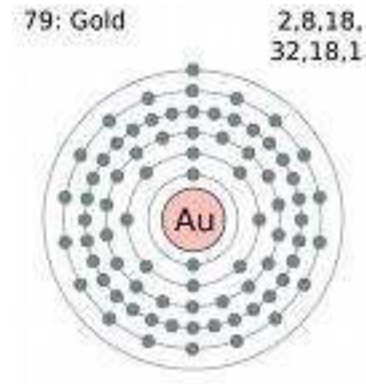
D. H_2O

1. is more electronegative ➔ Polar Bonds
2. Hydrogen Bonds attract molecules
3. dissociation of $H_2O = H^+ + OH^-$

E. Ionic bonds -- e.g. Na^+ and Cl

F. van der Waals Interactions$^-$

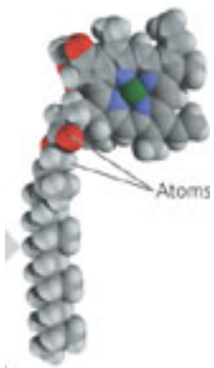
Elements & Compounds

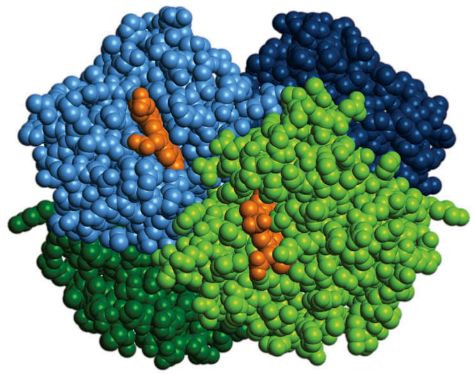


- An **Element** is a substance that cannot be broken down to other substances by chemical means.
- A **Compound** is a substance consisting of two or more elements in **fixed ratios**.
- A compound has characteristics different from those of its elements.

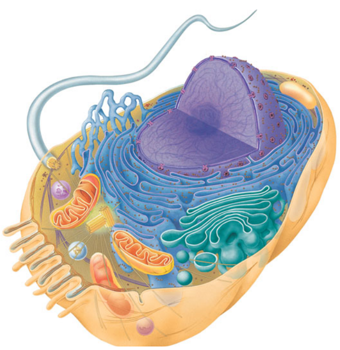
Elements & Compounds

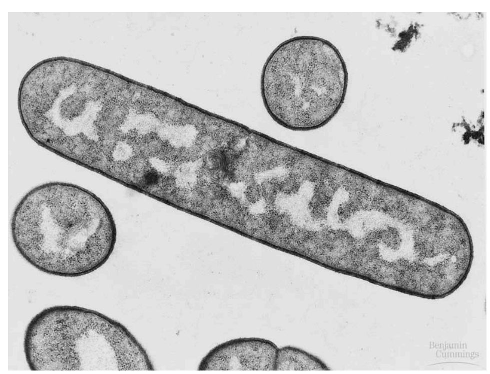
Atoms (Elements)





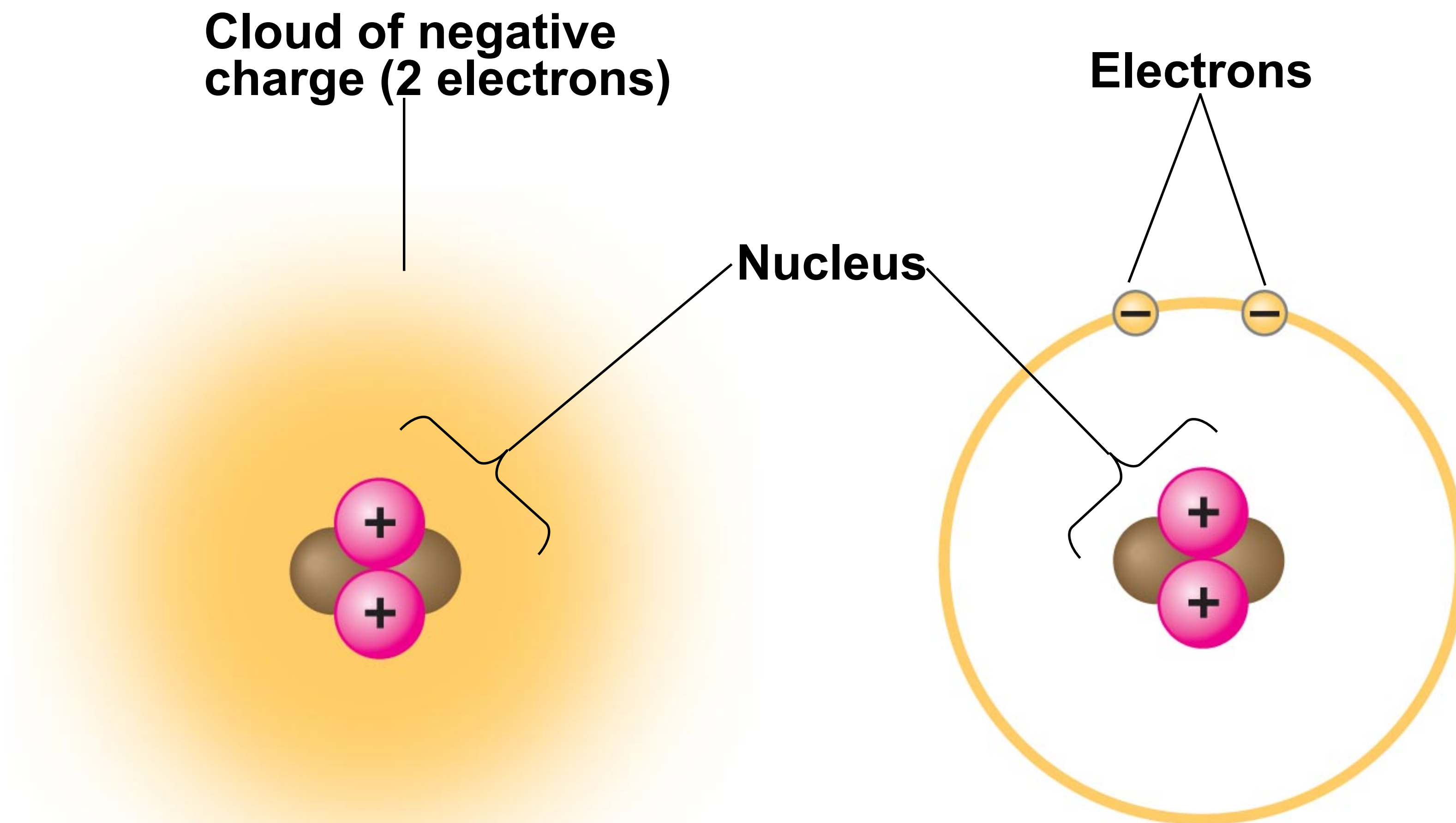
Molecules (Compounds)





Cells

Fig. 2.5: Simplified model of a Helium (He) Atom



Atomic number = number of protons → 2

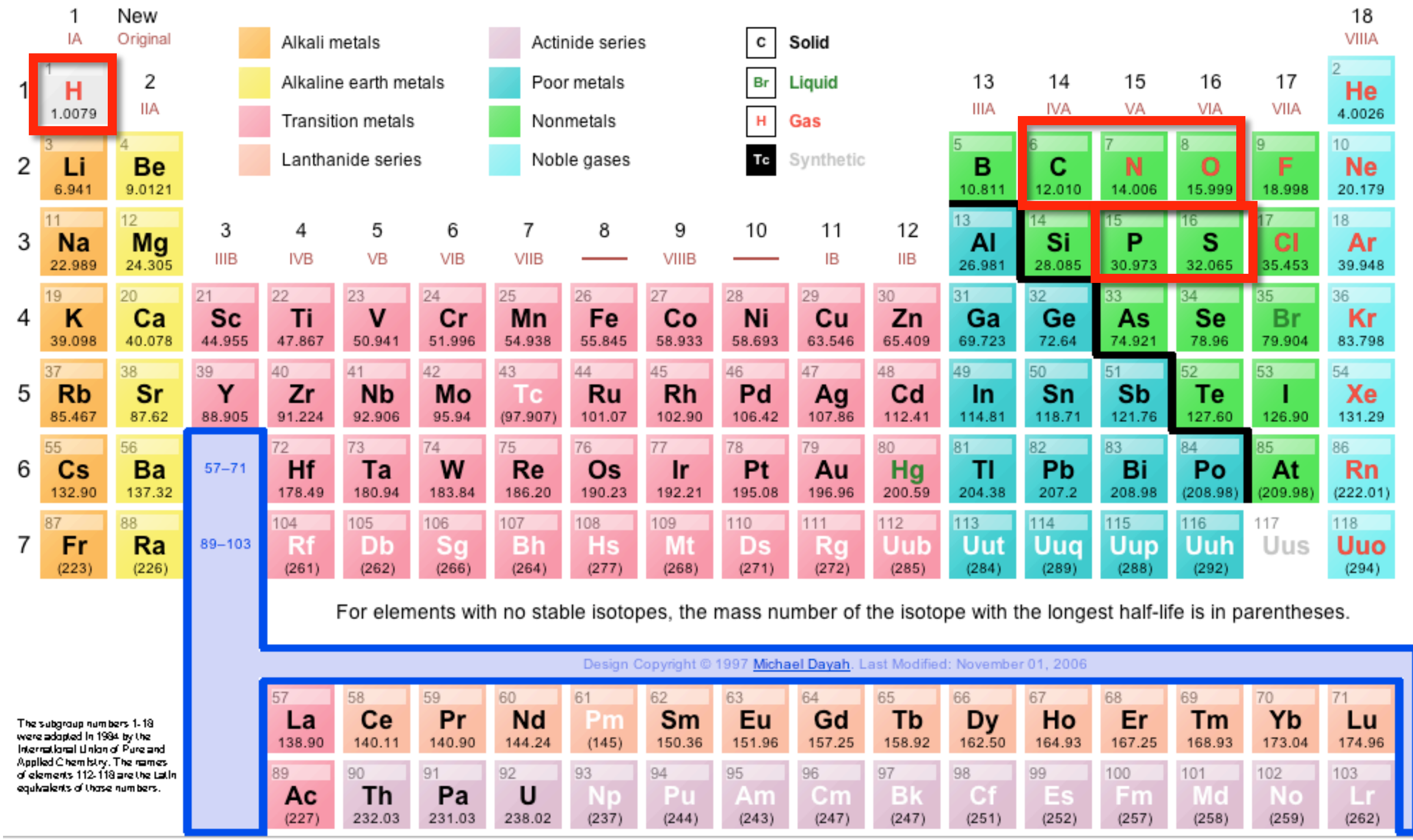
Mass Number (~atomic mass)
= number of **Neutrons** + **Protons**
= 4 for **Helium**

Atomic Mass → 4.002602

2
He
Helium
4.002602

The Periodic Table of the Elements

These Elements make up ~97% of living organisms



Properties of Elements Depends Upon Atomic Structure

Atoms of different elements differ in their number of subatomic particles:

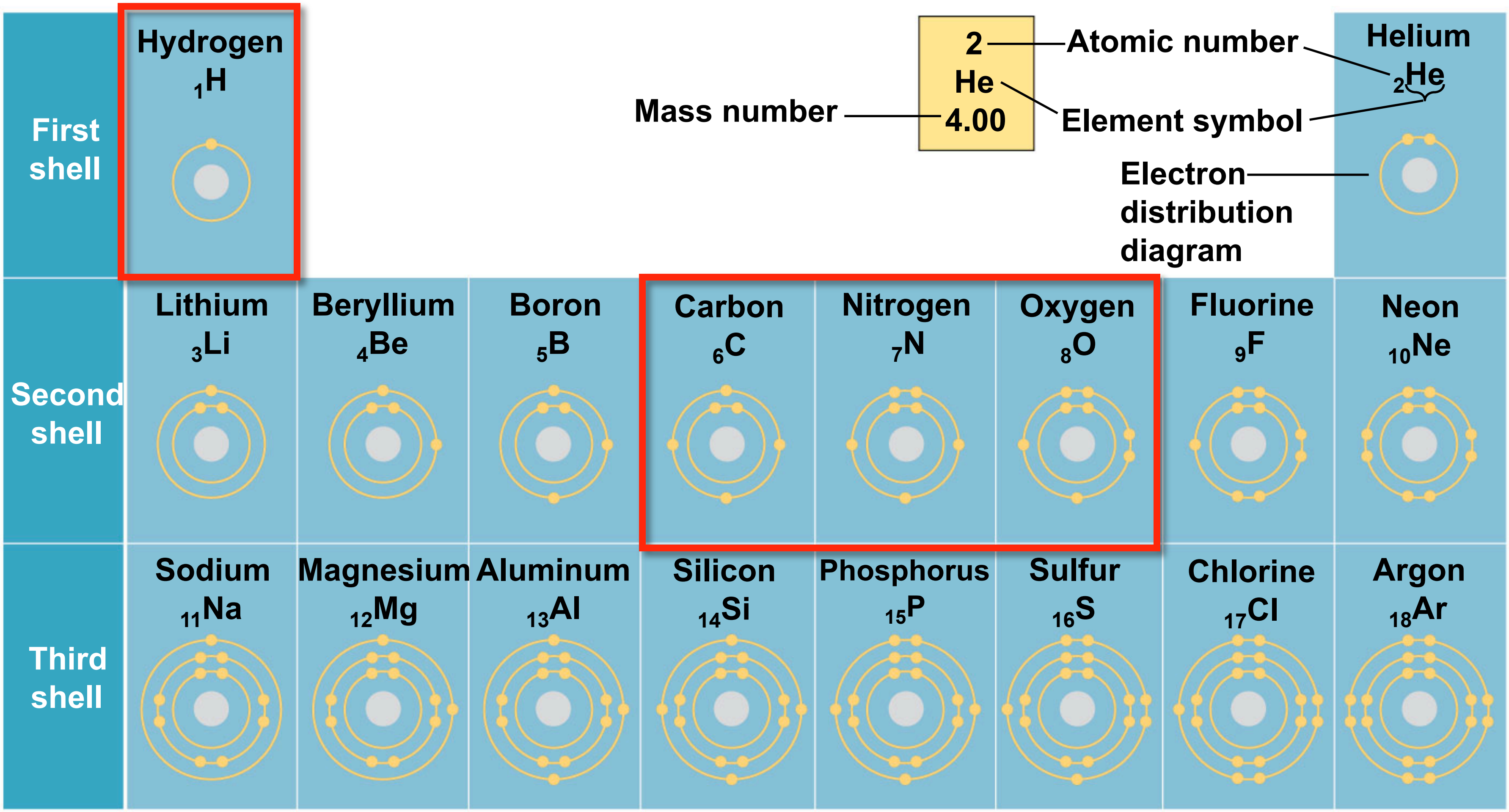
$^{1}_{1}H$ $^{6}_{12}C$ $^{7}_{14}N$ $^{8}_{16}O$ $^{11}_{23}Na$ $^{15}_{31}P$

Isotopes of an element have same number of **protons** but different number of **neutrons**:

$^{6}_{12}C$ $^{6}_{13}C$ $^{6}_{14}C$ Unstable (radioactive)

Stable isotopes

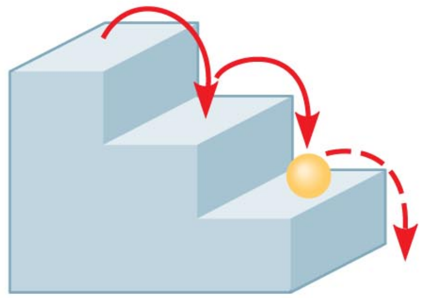
Fig. 2.9: Electrons are distributed in shells of orbitals. Each orbital contains a maximum of two electrons.



Chemical behavior of an atom depends mostly on number of electrons in **outermost shell** called **Valence Electrons**

Fig. 2.8: Energy Levels of Electrons / Electron Shells

(a) A ball bouncing down a flight of stairs provides an analogy for energy levels of electrons

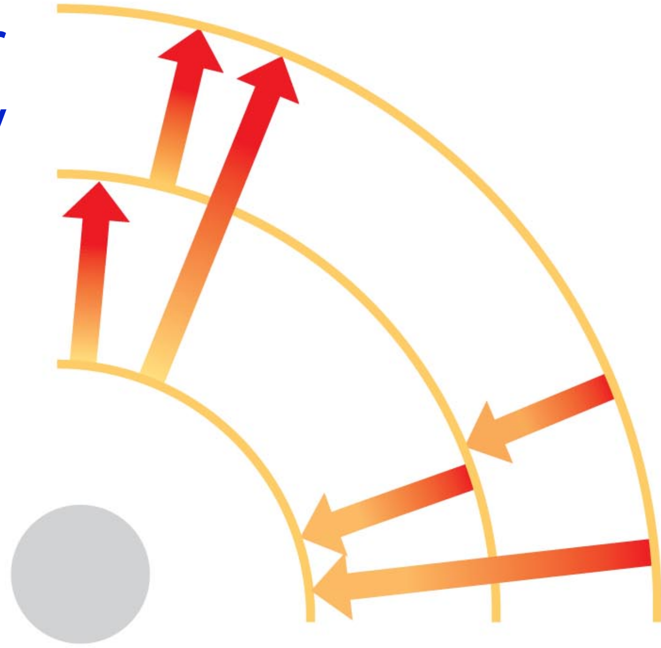


Electrons in an atom vary in the amount of **potential energy** they possess (fixed, discrete amounts)

Different discrete energy levels correlate with average distance of electron from nucleus (**electron shells**)

Higher energy

Lower energy



We Are Carbon-Based Lifeforms

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (see p. 33)	Percentage of Human Body Weight
Elements making up about 96% of human body weight			
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Elements making up about 4% of human body weight			
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1
Elements making up less than 0.01% of human body weight (trace elements)			
Boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), zinc (Zn)			

~96 % of the Human Body is:

Oxygen (**O**)

Carbon (**C**)

Hydrogen (**H**)

Nitrogen (**N**)

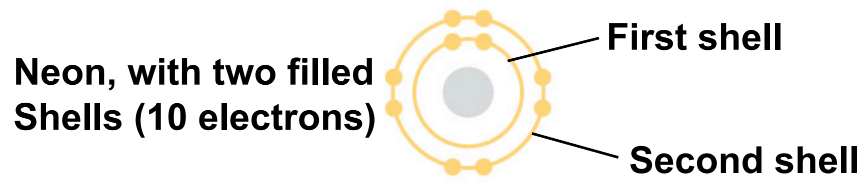
~4 %: Ca, **P**, K, S, Na, Cl, Mg

Trace elements (< 0.01%):
B, Cr, Co, Cu, F, I, Fe, Mn,
Mo, Se, Si, Sn, V, Zn

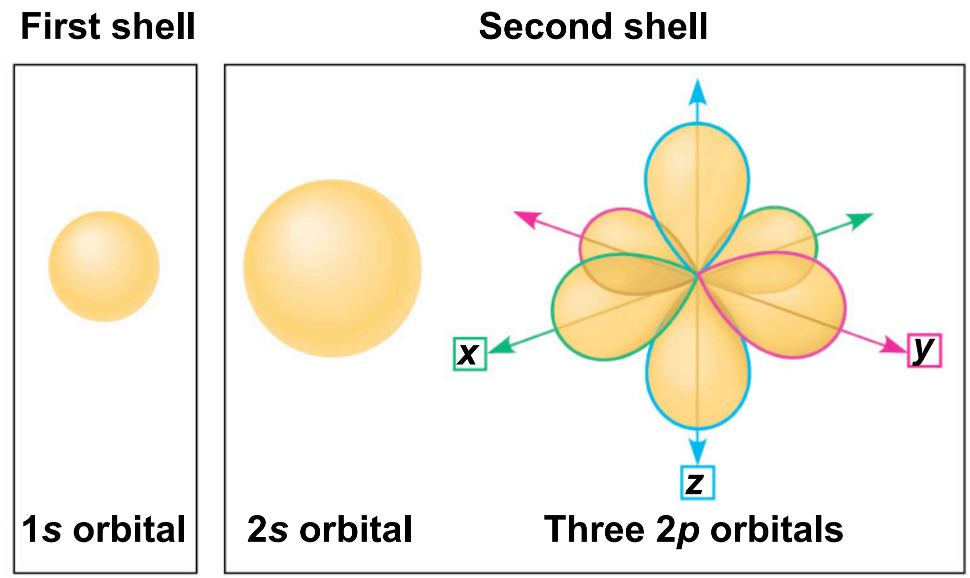
Composition of other organisms on Earth is similar

Fig. 2.10: Electrons are arranged in orbitals that have characteristic shapes and energies

- The first shell has only an s orbital that is spherical in shape.
- The second shell has another spherical s orbital and 3 p orbitals that are each shaped somewhat like dumbells aligned along 3 orthogonal axes.
- Each orbital can hold a maximum of 2 electrons.



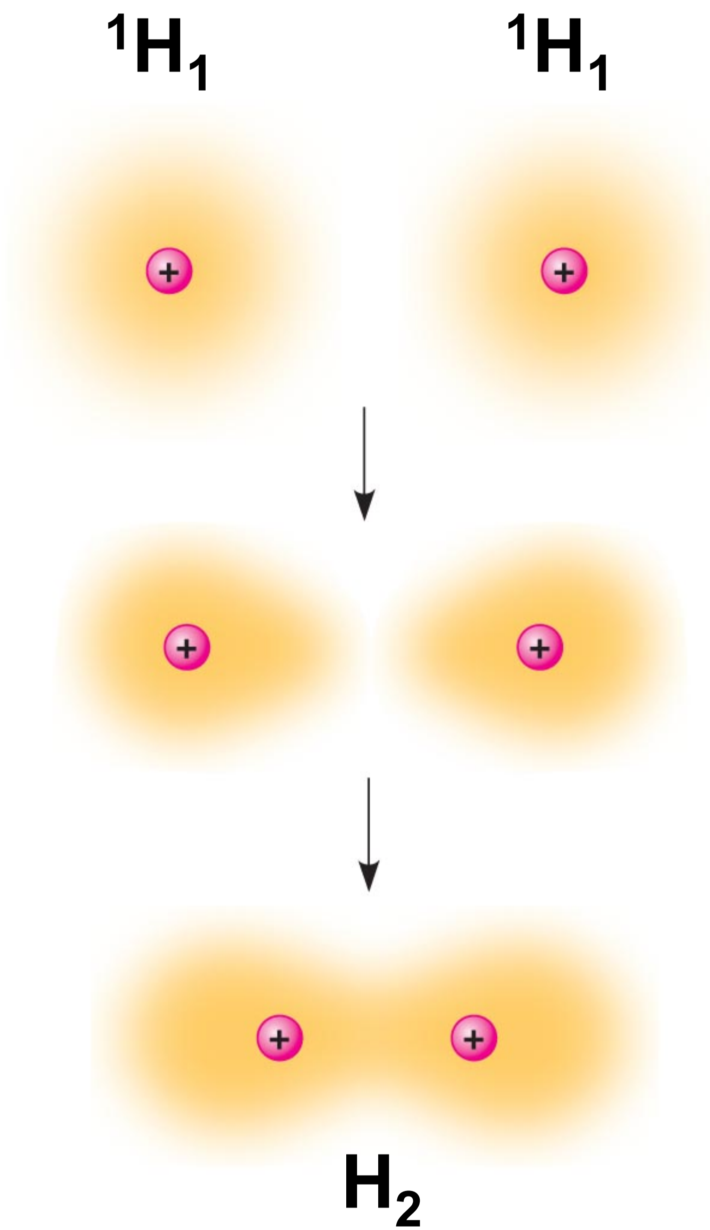
(a) Electron distribution diagram



(b) Separate electron orbitals

(c) Superimposed electron orbitals

Fig. 2.11: Chemical Bonds Link Atoms Together



Covalent bonds

- Form when two atomic nuclei share one or more pairs of electrons filling their **orbitals**.
- The **orbitals** have orientations in space that give molecules three-dimensional shapes.
- In **H_2** – Each **H** atom is able to fill its 1s orbital by sharing its single electron with the other **H** atom.

Bonding properties of the most common elements in biological molecules

H: Atomic No. 1 → **1 electron**: $1s^1$
1st shell needs 1 electron → Forms **1 covalent bond**

C: Atomic No. 6 → **6 electrons**: $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^0$
2nd shell needs 4 electrons → Forms **4 covalent bonds**

N: Atomic No. 7 → **7 electrons**: $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$
2nd shell needs 3 electrons → Forms **3 covalent bonds**

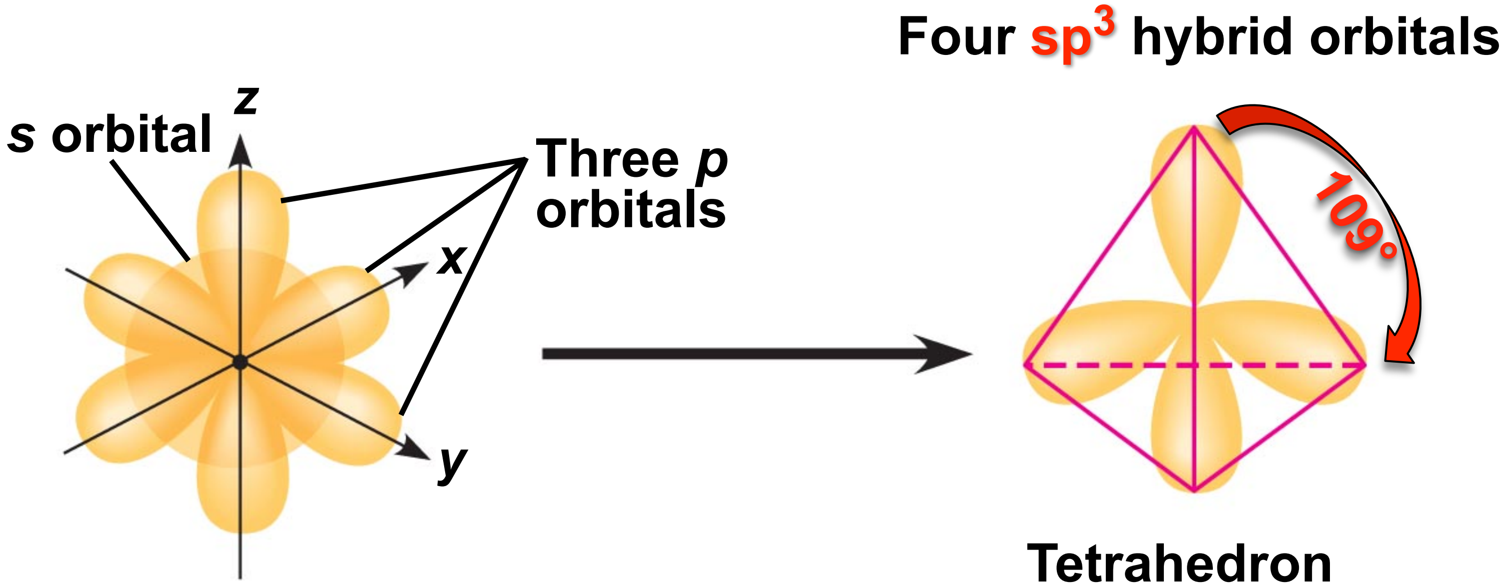
O: Atomic No. 8 → **8 electrons**: $1s^2\ 2s^2\ 2p_x^2\ 2p_y^1\ 2p_z^1$
2nd shell needs 2 electrons → Forms **2 covalent bonds**

Fig. 2.17a: Hybrid Atomic Orbitals

The orbitals used by **C** to form **4 bonds** to **4 different atoms** are **sp^3 hybrid atomic orbitals**, a combination of the **2s, $2p_x$, $2p_y$, and $2p_z$ orbitals**.

sp^3 orbitals point to the corners of a **Tetrahedron**.

This is called "**Tetrahedral Geometry**" characterized by bond angles of **109°**.

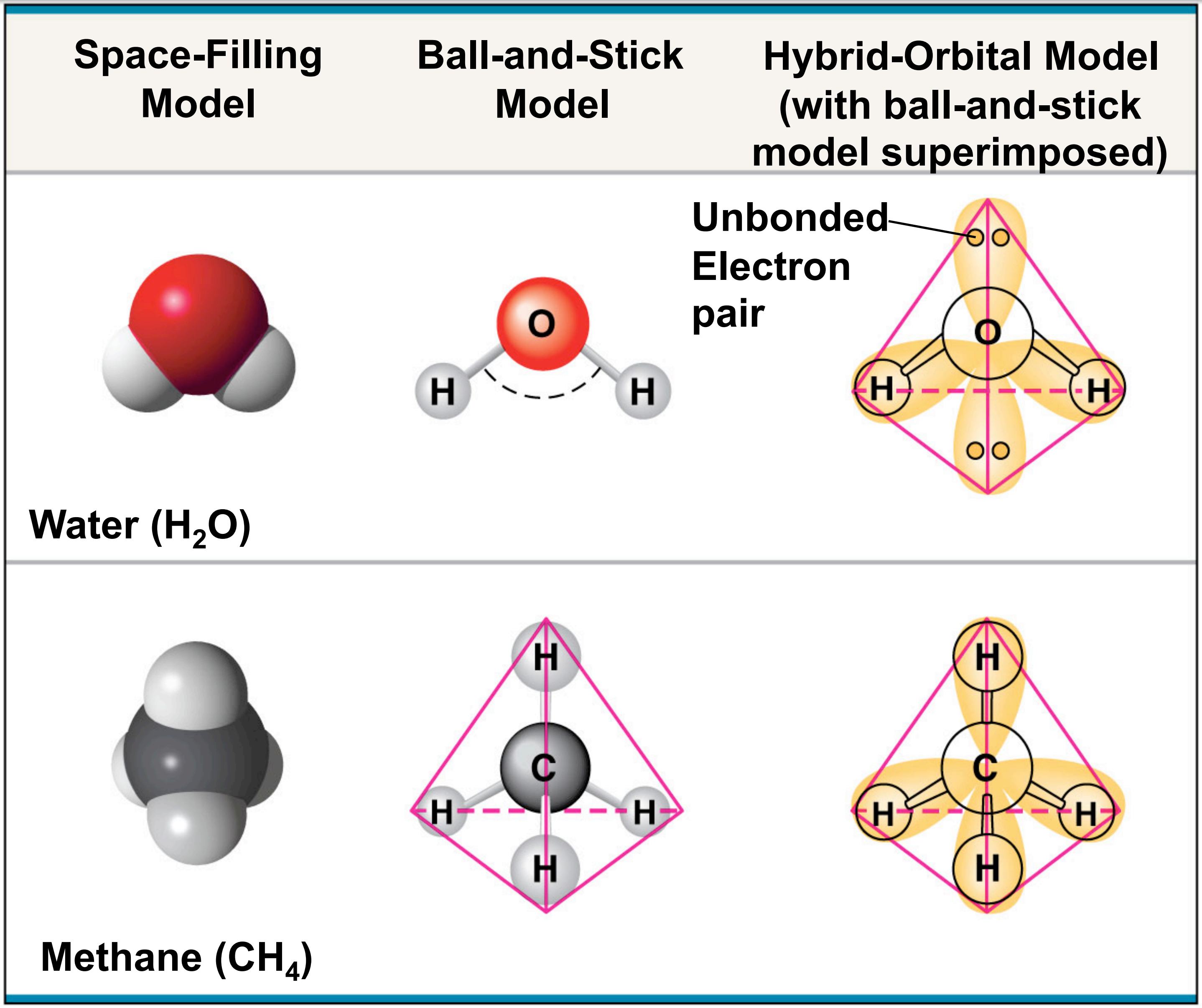


(a) Hybridization of orbitals

Fig. 2.17b: Molecular Shape Models

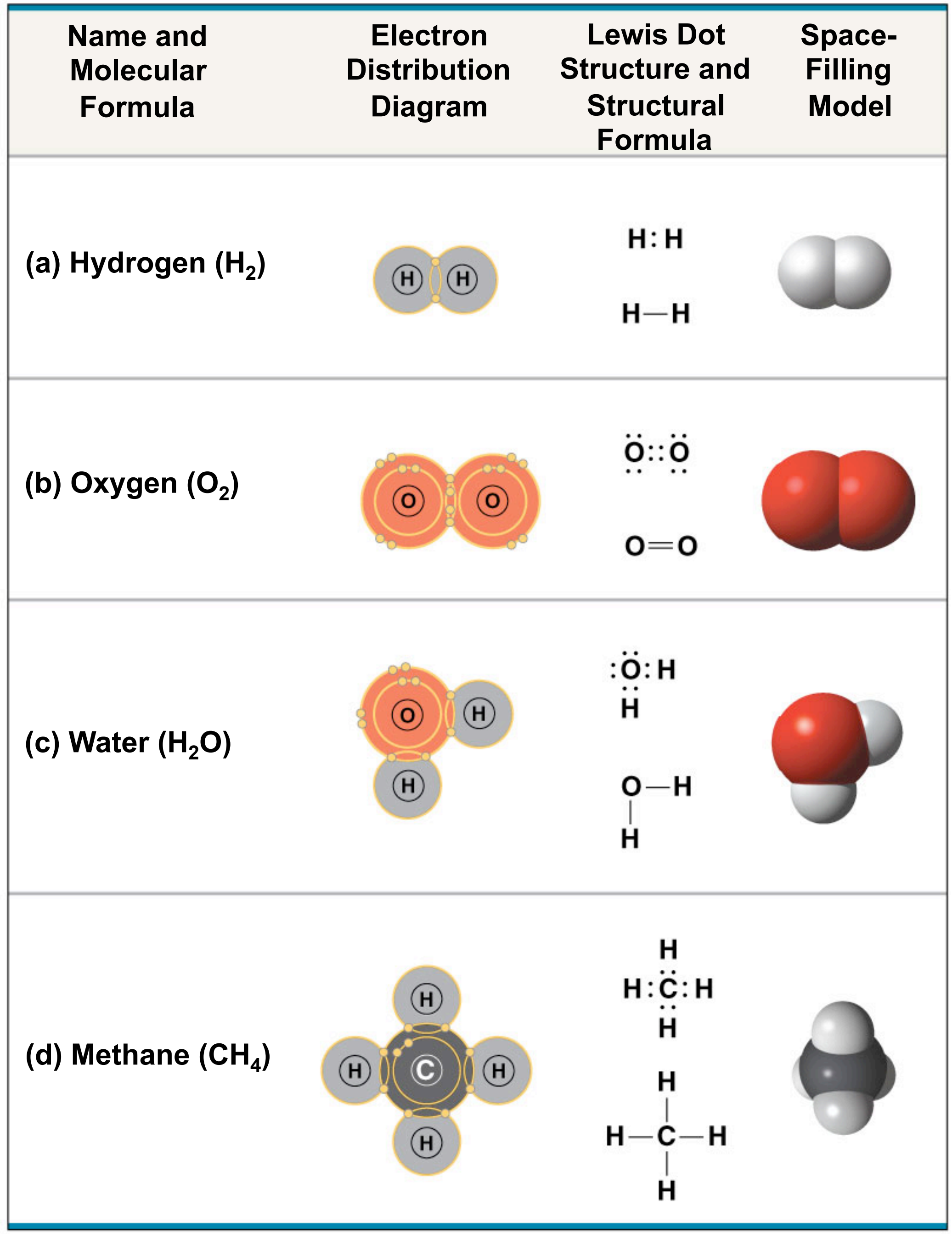
A covalent bond that has electron density from shared electrons between the atoms is called a **σ bond**

The atoms in water and methane are connected by **σ bonds**.

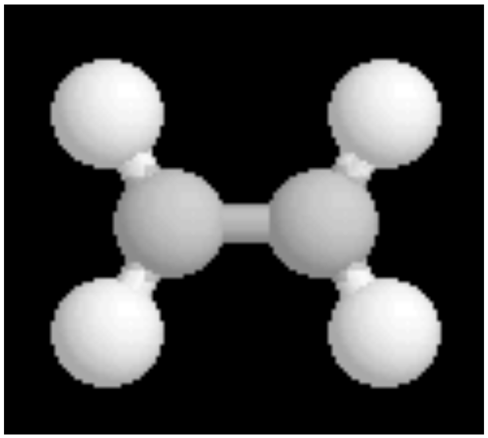


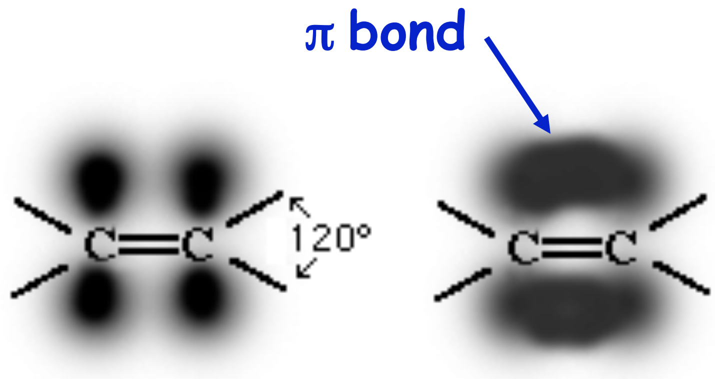
(b) Molecular-shape models

Fig. 2.12: Covalent Bonding in Four Molecules



When carbon forms bonds to three different atoms, it uses sp^2 hybrid orbitals by combining the 2s orbital and two of the 2p orbitals.





- The two C atoms in **Ethene** form a second or **double bond** between themselves using their third unhybridized **2p** orbitals.
- The second bond is called a **π bond** and prevents the C atoms from rotating around the bonds connecting them.
- Note: the **π bond** does not place electron density between the atoms.

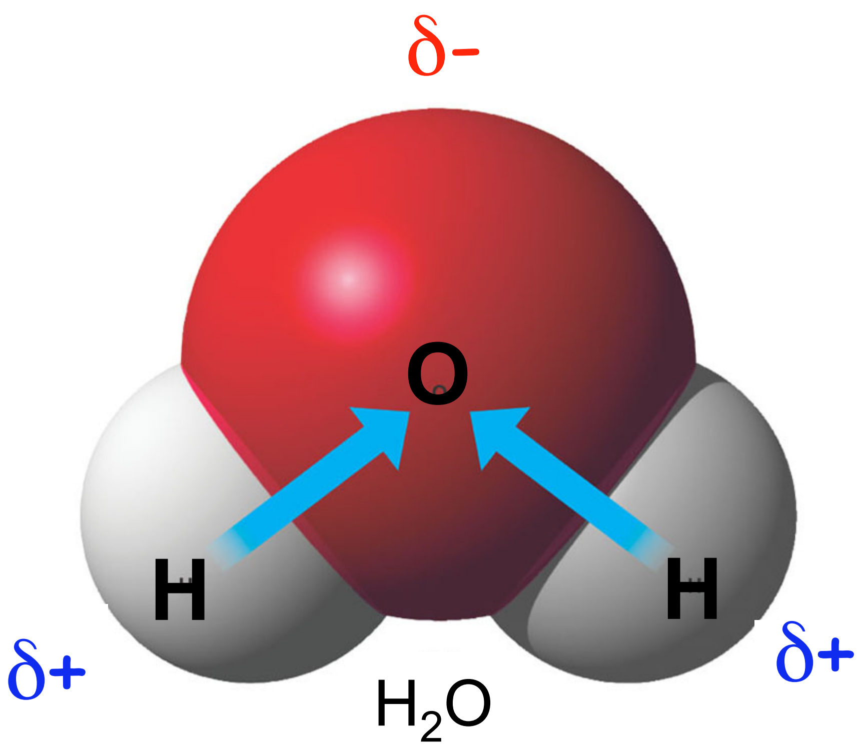
Chemical Bonds: Linking Atoms Together

Electronegativity is a measure of how strongly an atom attracts electrons

Element	*Symbol*	*Electronegativity*	
Oxygen	O	3.5	← **High**
Chlorine	Cl	3.1	
Nitrogen	N	3.0	← **High**
Carbon	C	2.5	←
Phosphorous	P	2.1	
Hydrogen	H	2.1	←
Sodium	Na	0.9	
Potassium	K	0.9	

- **Nonpolar** covalent bonds form when the **Electronegativities** of two atoms are approximately equal.
- **Polar** covalent bonds form between atoms with strong electronegativity (such as **oxygen**) bonded to atoms with weaker electronegativity (such as **hydrogen**).
- In a **polar covalent bond** one atom has a partial positive charge or δ^+ and the other atom has a partial negative charge or δ^-.

Fig. 2.13: Polar Covalent Bonds Are Formed Between Atoms With Unequal Electronegativity



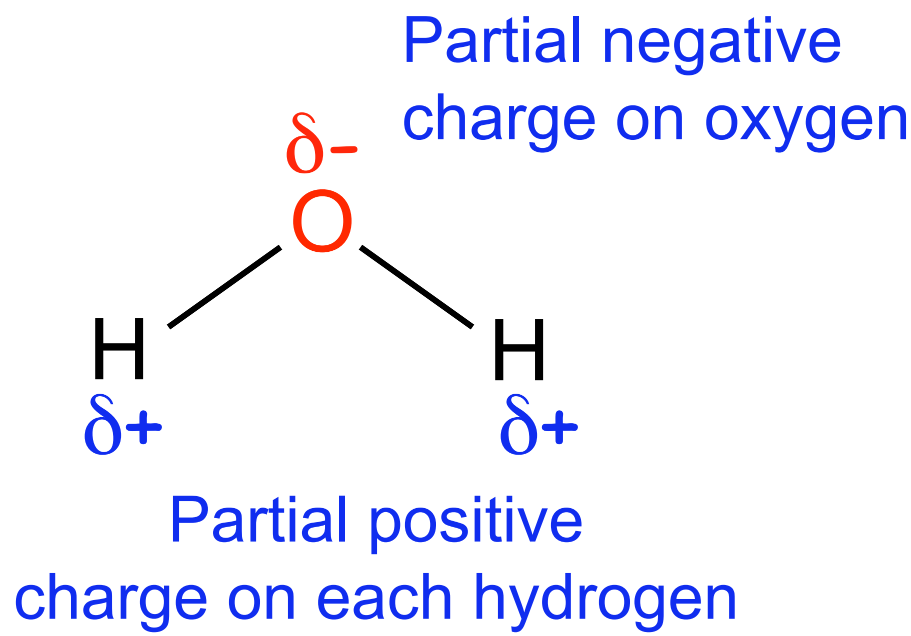


Fig. 2.17b: sp^3 Hybrid Orbitals in Water, H_2O

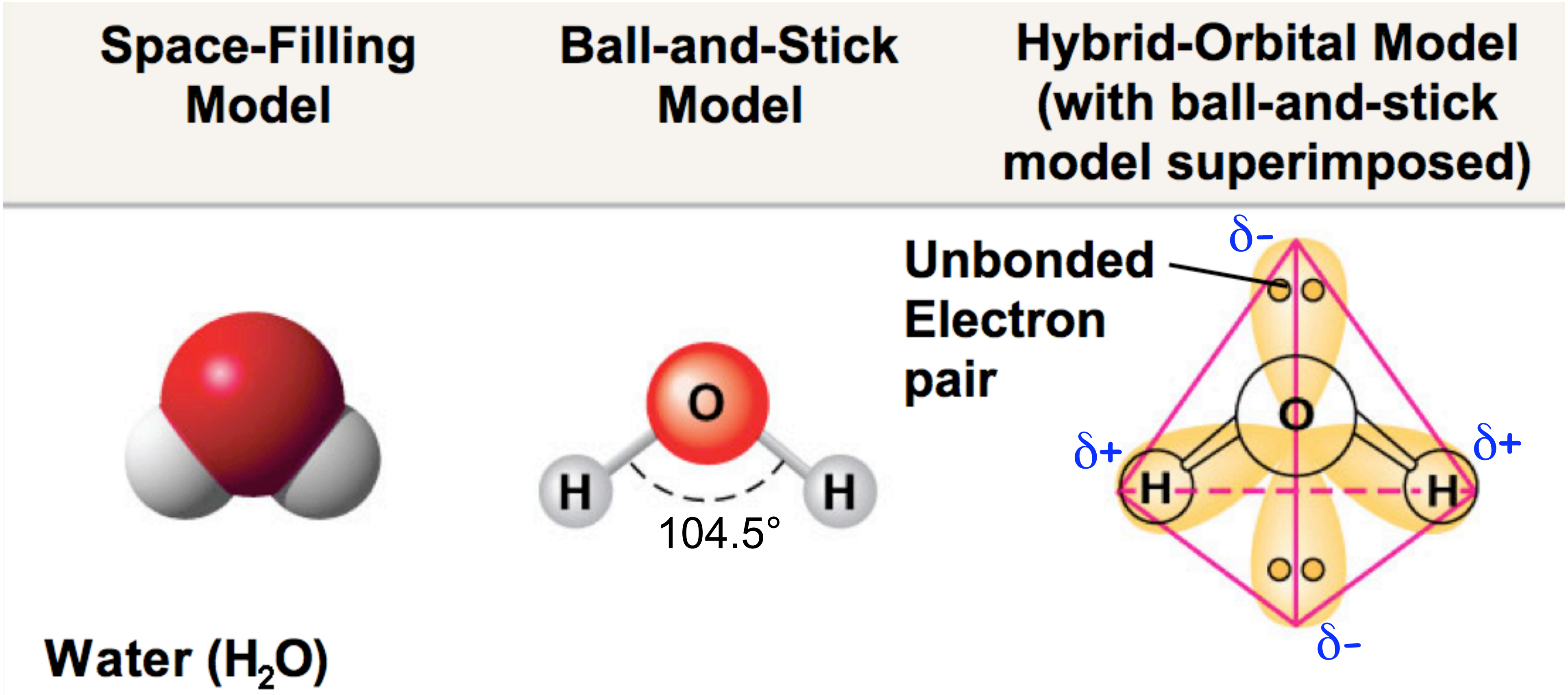


Fig. 3-2: **Hydrogen Bonds** form between water molecules.

- Hydrogen Bonds are attractions between the partial negative charge on the Oxygen atoms and the partial positive charges on the Hydrogen Atoms.
- This gives water special properties that we will discuss next time.

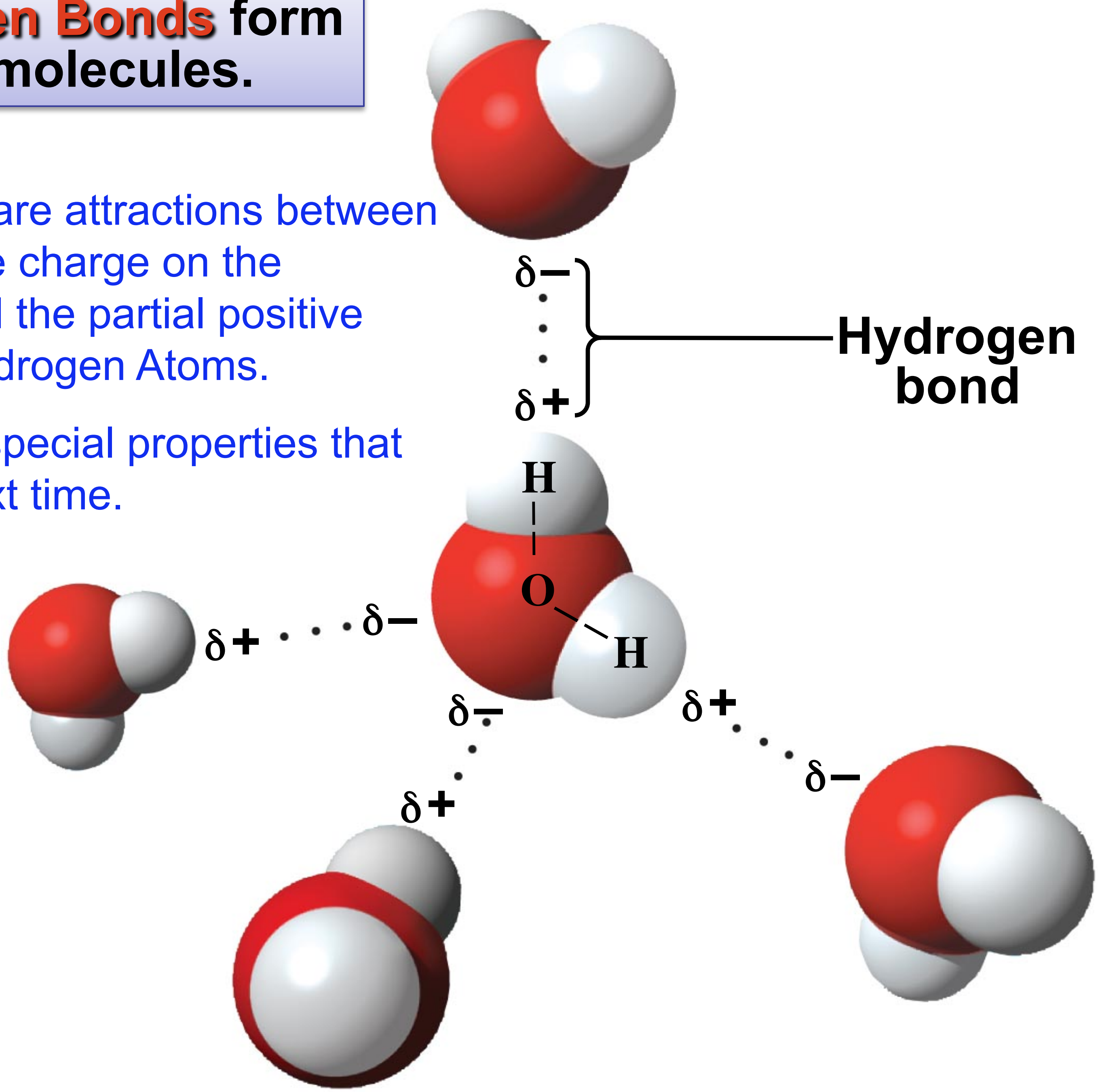


Fig. 2.16: Hydrogen Bonds can form between water and other polar molecules.

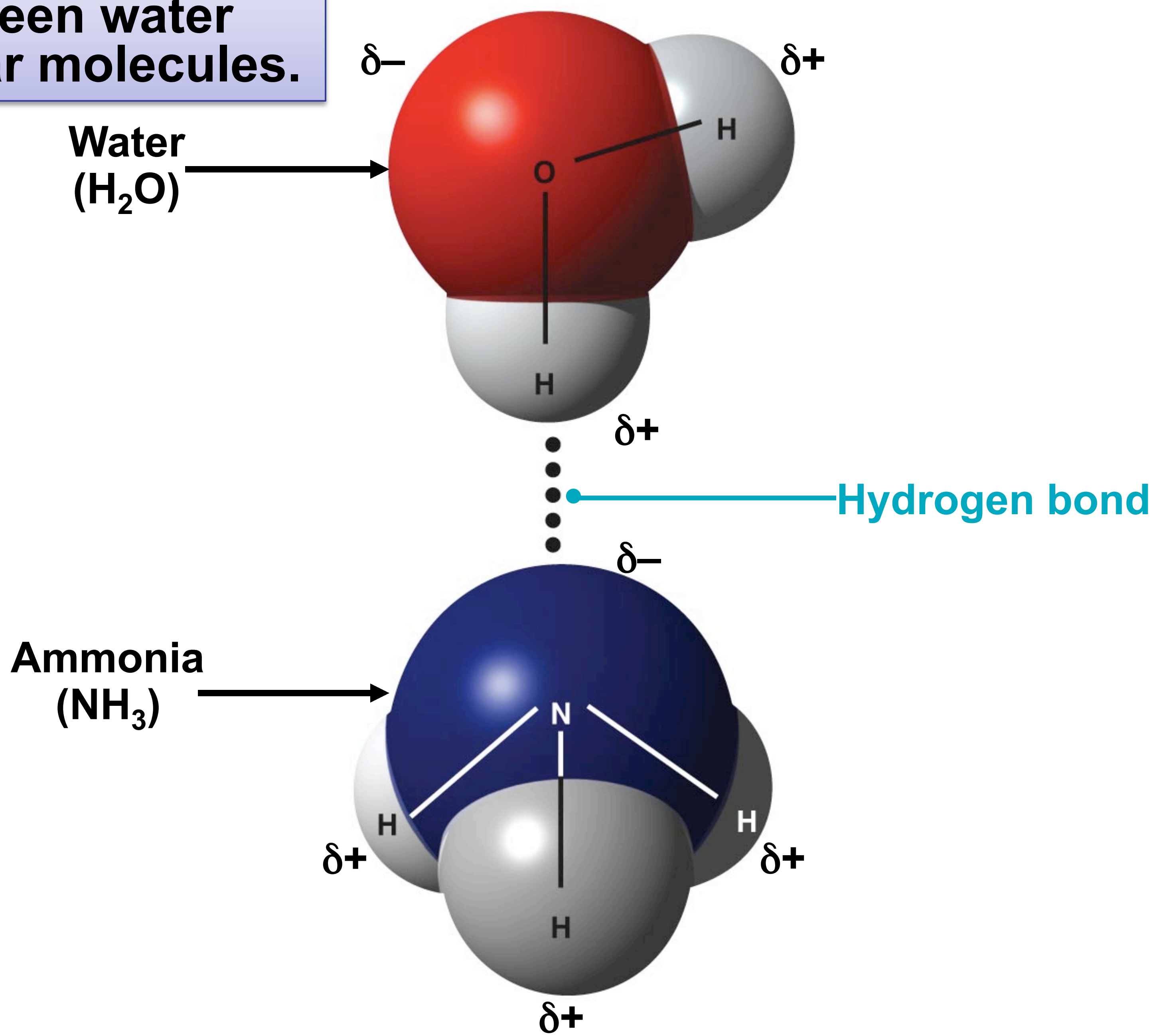
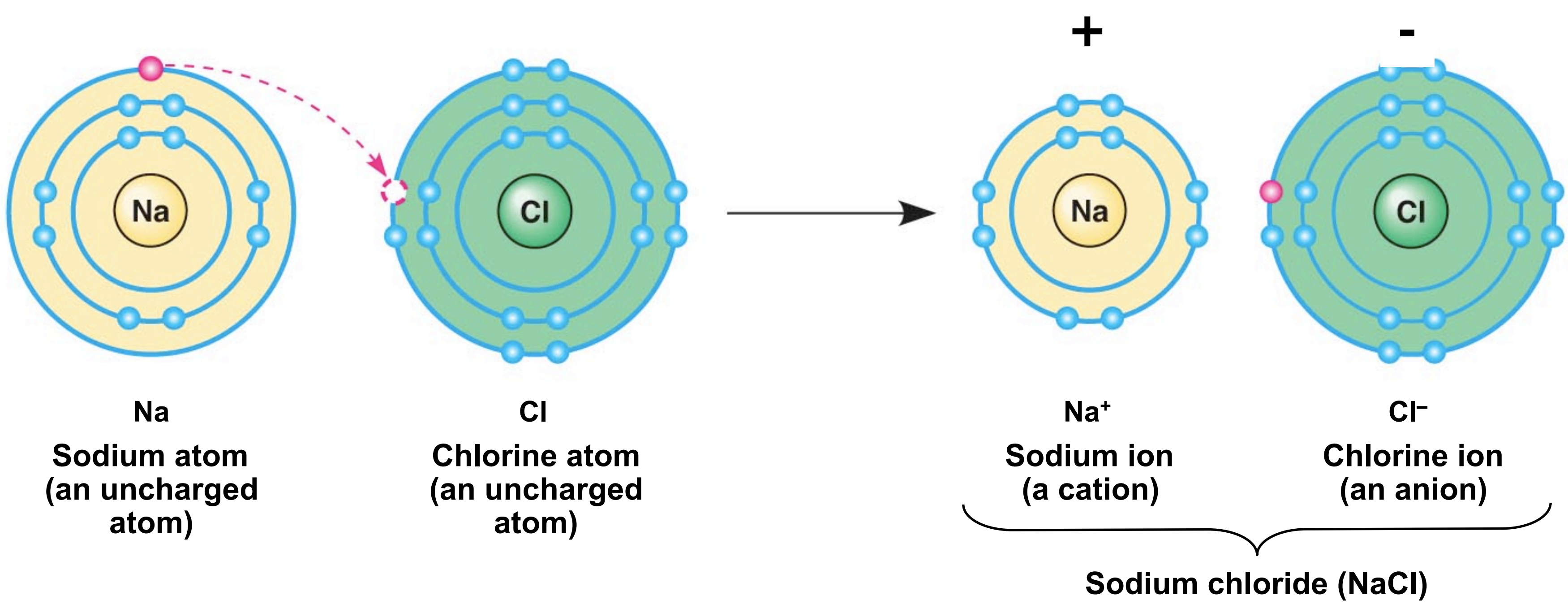


Fig. 2.14: Ionic Bonds

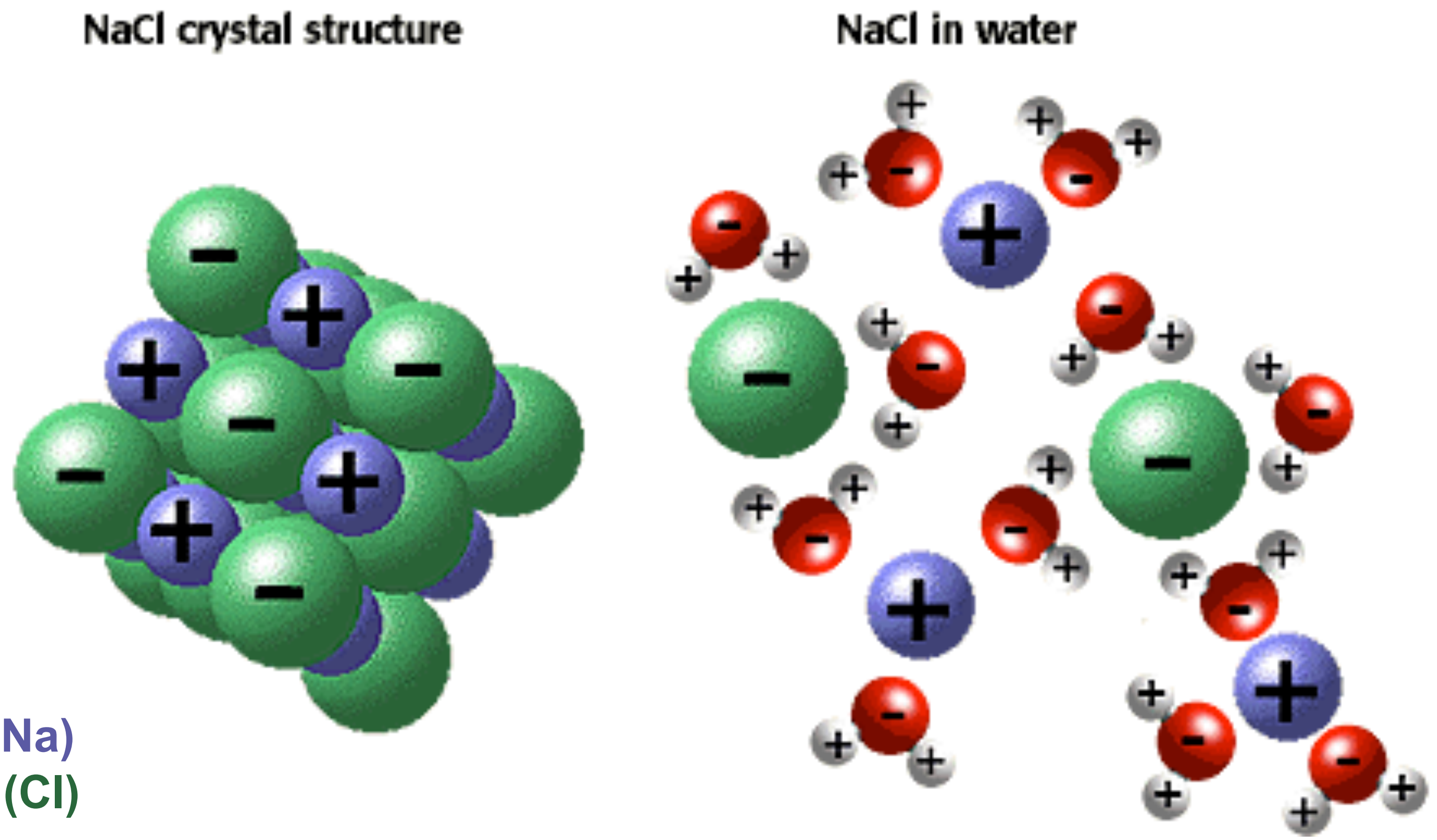


Electronegativity: **Na = 0.9** & **Cl = 3.1**

Electrically charged **ions** form when an atom gains or loses one or more electrons to an atom of **very** different **electronegativity**.

Ionic Bonds are electrical attractions between oppositely charged ions.

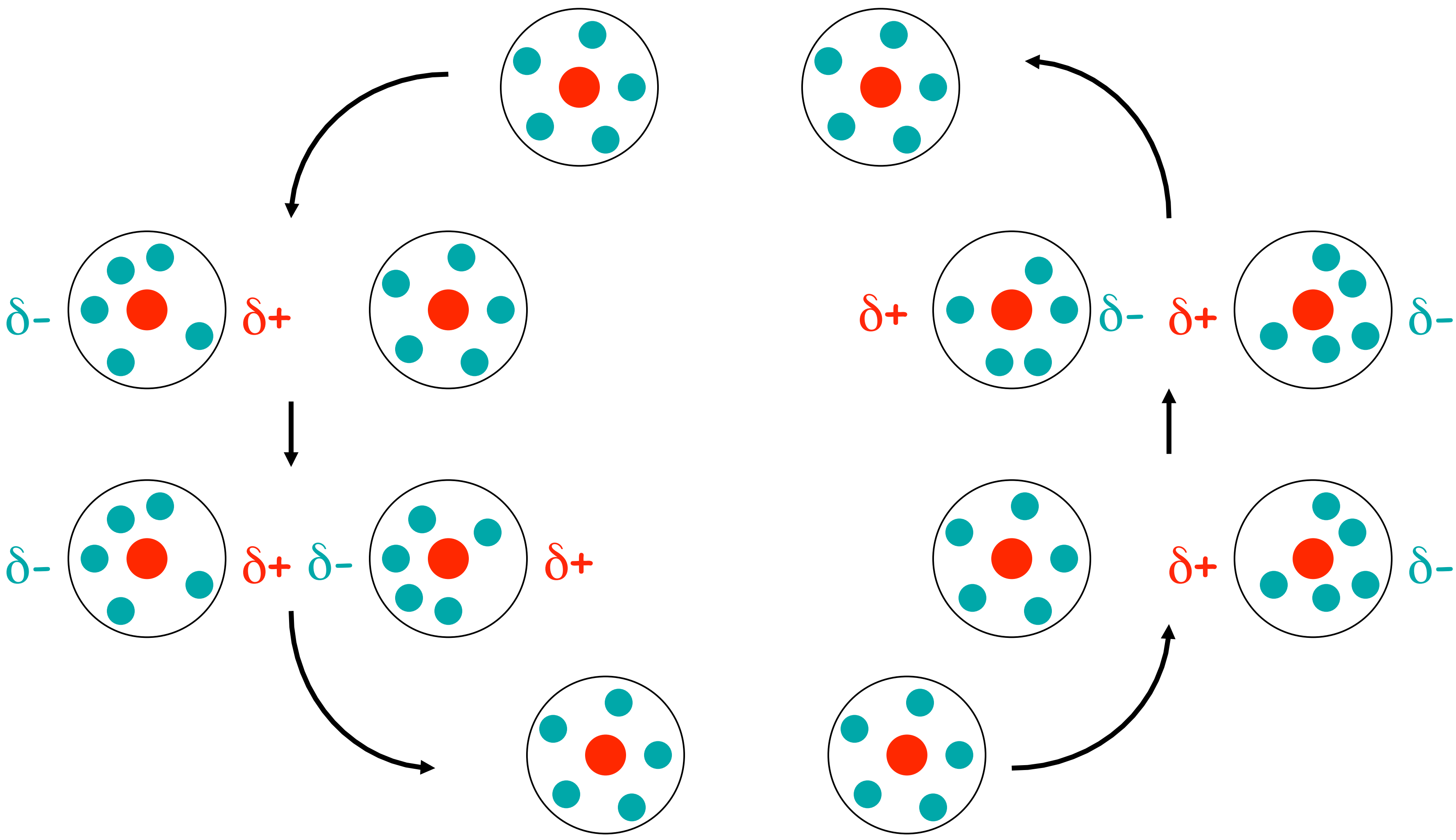
Solvation: Water molecules surround ions and neutralize their charge.



Sodium (Na)
Chlorine (Cl)

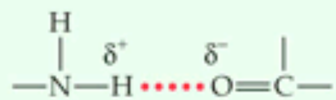
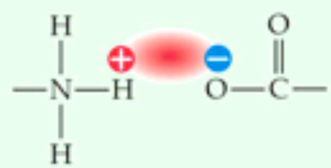
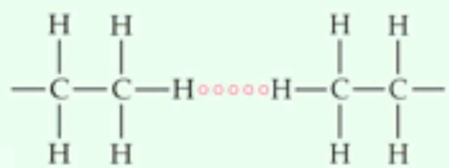
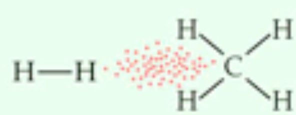
Weak Chemical Bonds: van der Waals Interactions

Weak attraction of atoms due to constant motion of electrons:



Chemical Bonds and Interactions

2.1 *Chemical Bonds and Interactions*

NAME	BASIS OF INTERACTION	STRUCTURE	BOND ENERGY[a] (KCAL/MOL)
Covalent bond	Sharing of electron pairs		50–110
Hydrogen bond	Sharing of H atom		3–7
Ionic bond	Attraction of opposite charges		3–7
Hydrophobic interaction	Interaction of nonpolar substances in the presence of polar substances		1–2
van der Waals interaction	Weak attraction of atoms due to the constant motion of electrons nonpolar substances		1

[a] *Bond energy* is the amount of energy needed to separate two bonded or interacting atoms under physiological conditions.

← High Energy ← Low Energy ← Very Low Energy