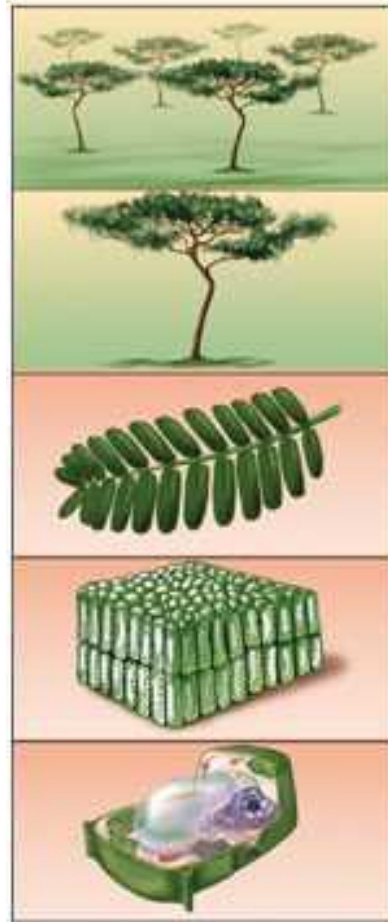


# The Chemistry of Life

By Rungtiwa Radchakid



# A Chemical Connection to Biology



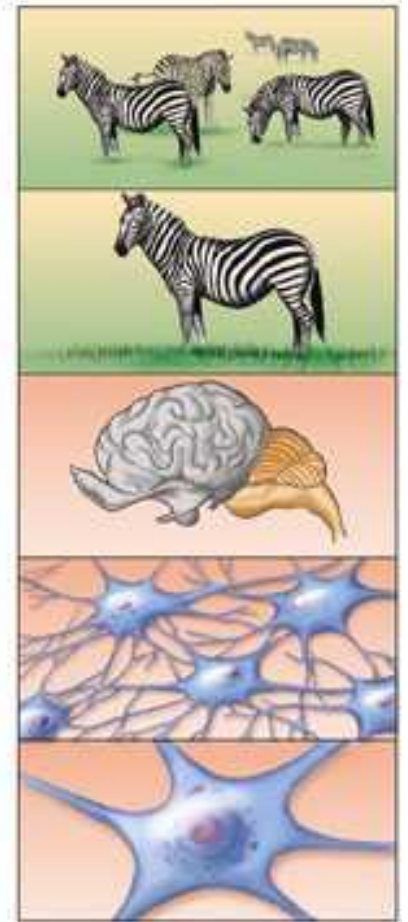
**Population**  
Several organisms of the same kind in a particular area

**Organism**  
An individual; complex individuals contain organ systems

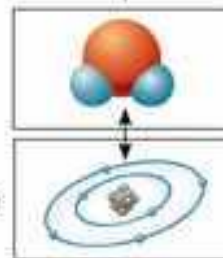
**Organ**  
Composed of a number of tissues and organized for a particular task

**Tissue**  
A group of cells with a common structure and function

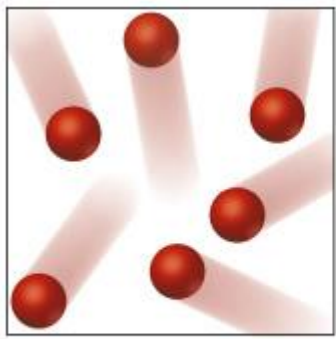
**Cell**  
Smallest unit of a living thing



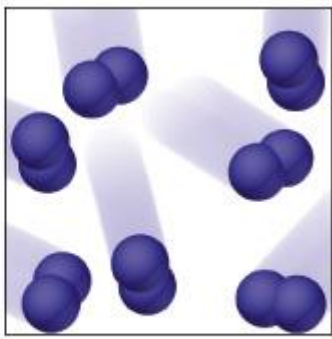
**Atom**  
Smallest unit of a molecule



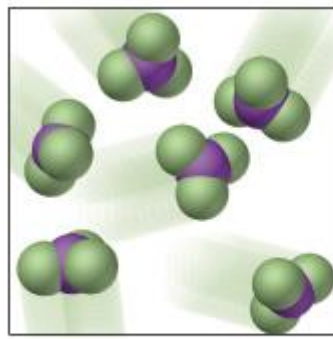
**Molecule**  
Smallest unit of a compound that still has the properties of the compound



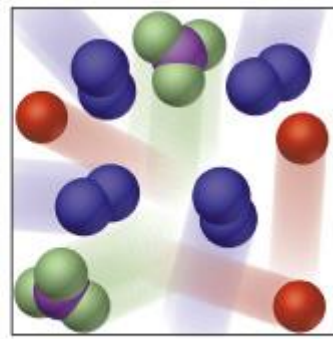
(a) Atoms of an element



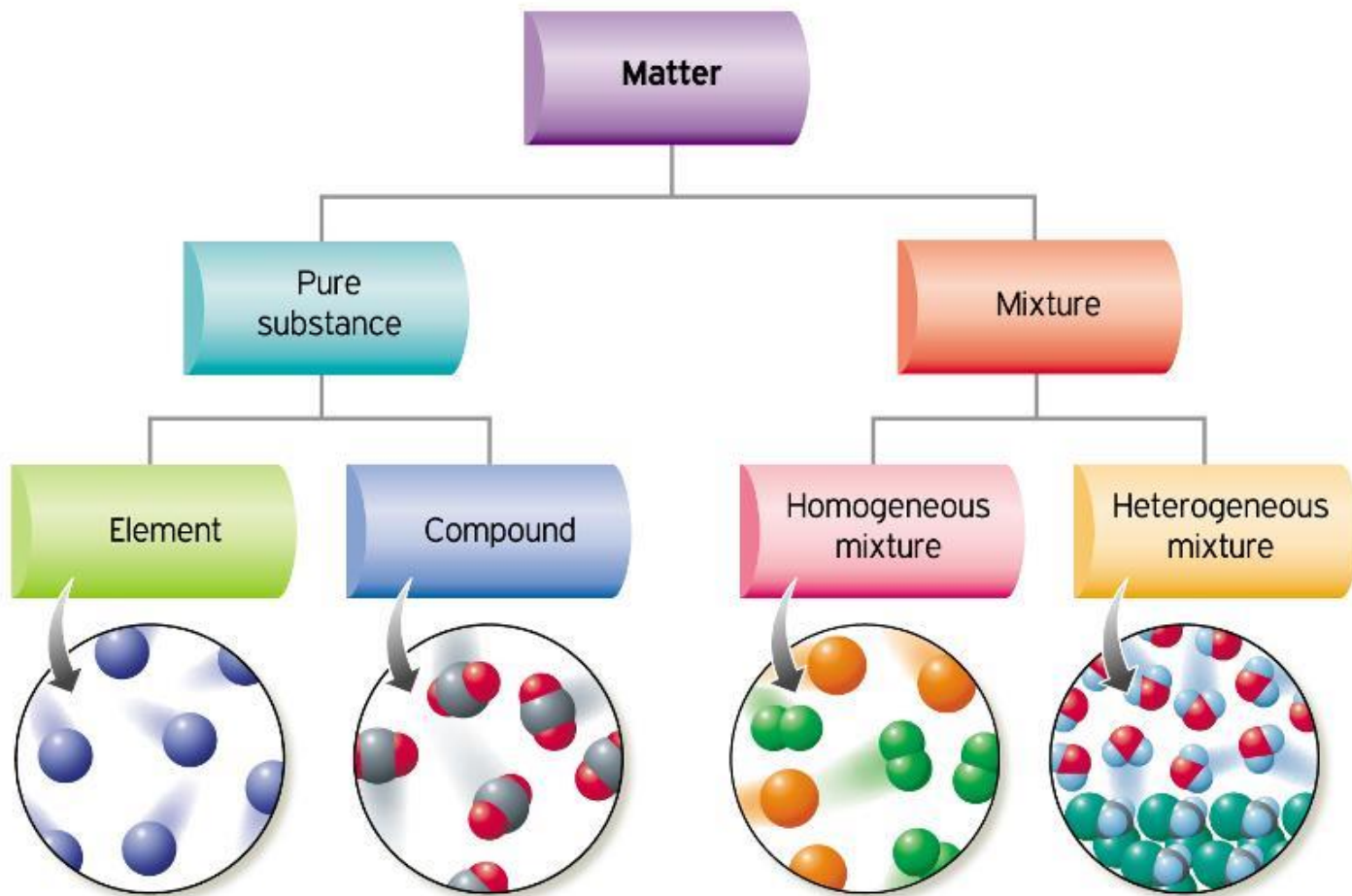
(b) Molecules of an element



(c) Molecules of a compound



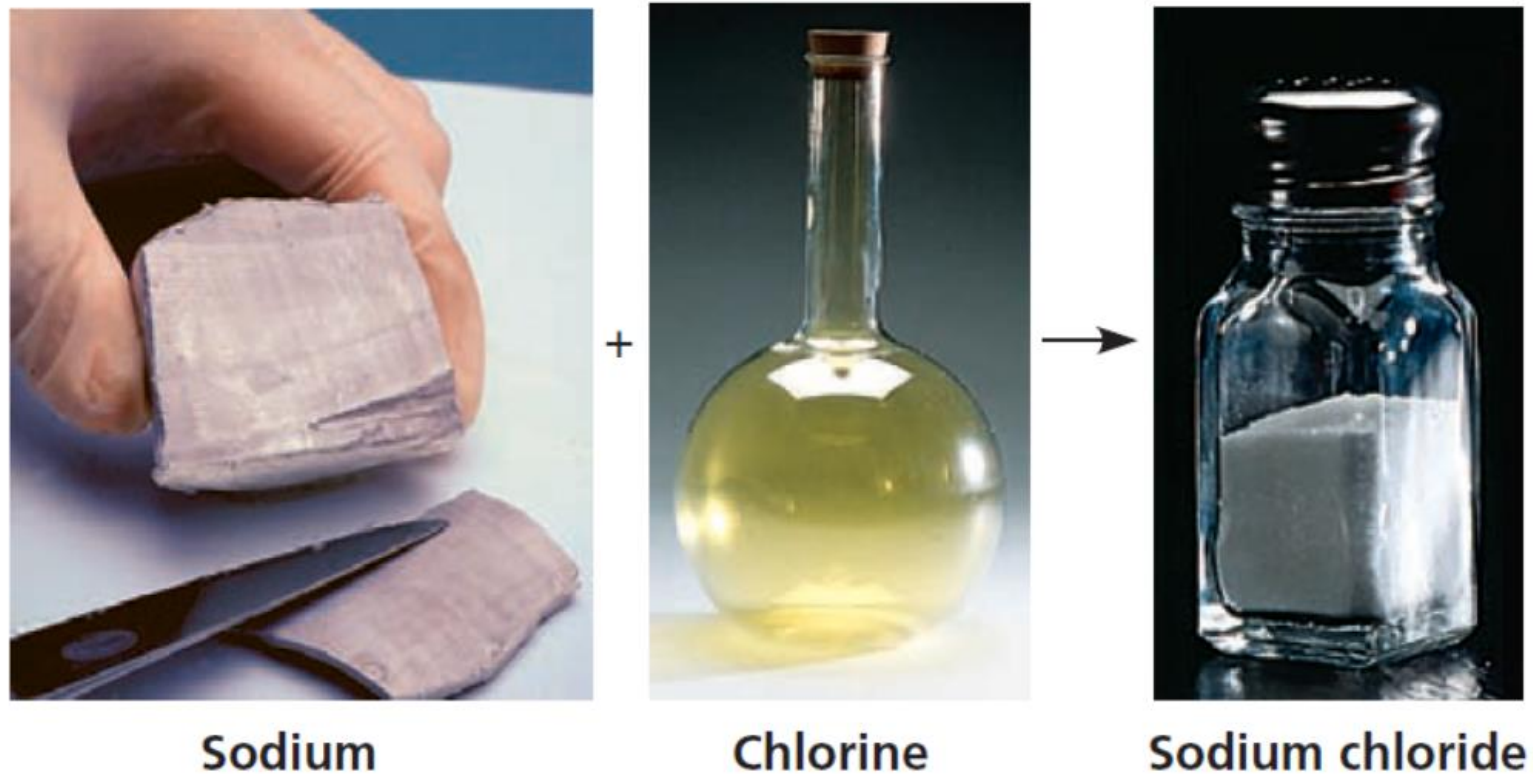
(d) Mixture of elements and a compound



of chemical elements in pure form and in combinations called



A **compound** is a substance consisting of two or more different elements combined in a fixed ratio.



▲ **Figure 2.2** The emergent properties of a compound. The metal sodium combines with the poisonous gas chlorine, forming the edible compound sodium chloride, or table salt.

Today, chemists recognize 92 elements occurring in nature.

○ **Bulk element**

○ **Trace element**

○ **Ultra trace element**

**Table 2.1** Elements in the Human Body

Element	Symbol	Percentage of Body Mass (including water)	
Oxygen	O	65.0%	} 96.3%
Carbon	C	18.5%	
Hydrogen	H	9.5%	
Nitrogen	N	3.3%	
Calcium	Ca	1.5%	} 3.7%
Phosphorus	P	1.0%	
Potassium	K	0.4%	
Sulfur	S	0.3%	
Sodium	Na	0.2%	
Chlorine	Cl	0.2%	
Magnesium	Mg	0.1%	

Trace elements (less than 0.01% of mass): 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)

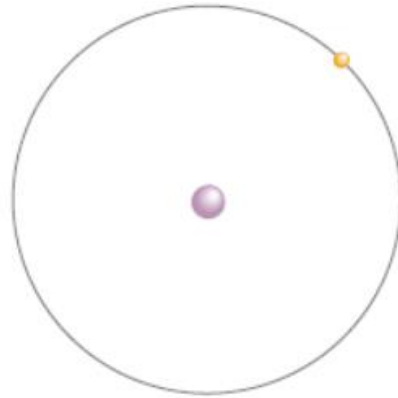


▲ **Figure 2.3** Serpentine plant community.

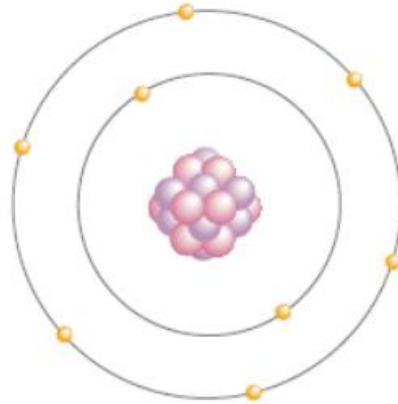
These plants are growing on serpentine soil, which contains elements that are usually toxic to plants. The insets show a close-up of serpentine rock and one of the plants, a Tiburon Mariposa lily.

# An element's properties depend on the structure of its atoms.


**Hydrogen**  
1 Proton  
1 Electron



**Oxygen**  
8 Protons  
8 Neutrons  
8 Electrons



Proton   
(Positive charge)

Neutron   
(No charge)

Electron   
(Negative charge)

## Structure of an Atom

Cloud of negative charge (2 electrons)

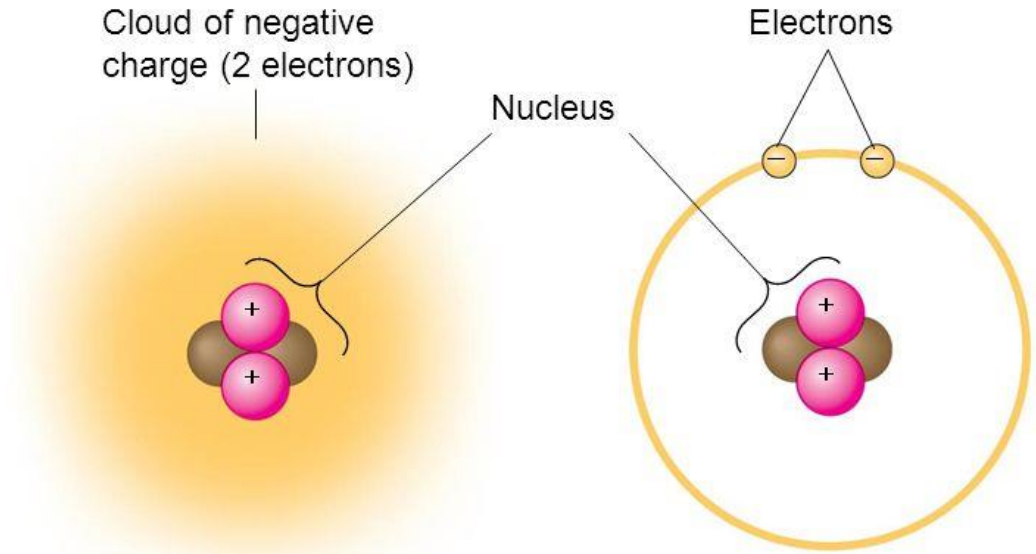
Nucleus

Electrons

(a)

(b)

Helium (He)



# Atomic Number and Atomic Mass

**Mass number** = number of protons + neutrons  
= 23 for sodium

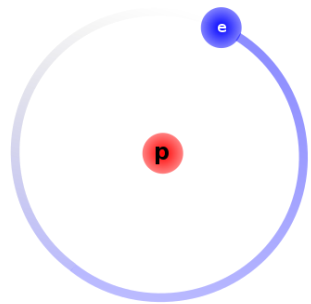
${}_{11}^{23}\text{Na}$

**Atomic number** = number of protons  
= number of electrons in a neutral atom  
= 11 for sodium

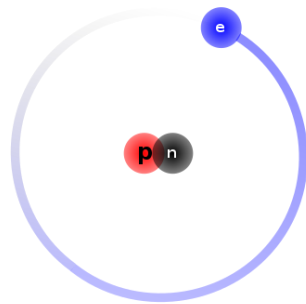
Number of neutrons = mass number – atomic number  
=  $23 - 11 = 12$  for sodium

(# Protons) Atomic Number (Z)	(# Protons + Neutrons) Atomic Mass (A)
29	63.55
52	127.60
<b>Cu</b> Copper	<b>Te</b> Tellurium

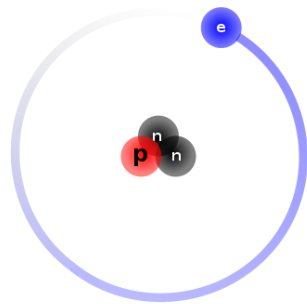
# Isotopes



Protium



Deuterium

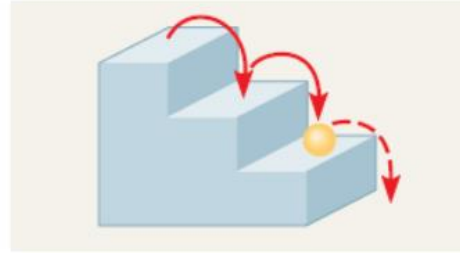


Tritium



# The Energy Levels of Electrons

(a) A ball bouncing down a flight of stairs provides an analogy for energy levels of electrons, because the ball can come to rest only on each step, not between steps.

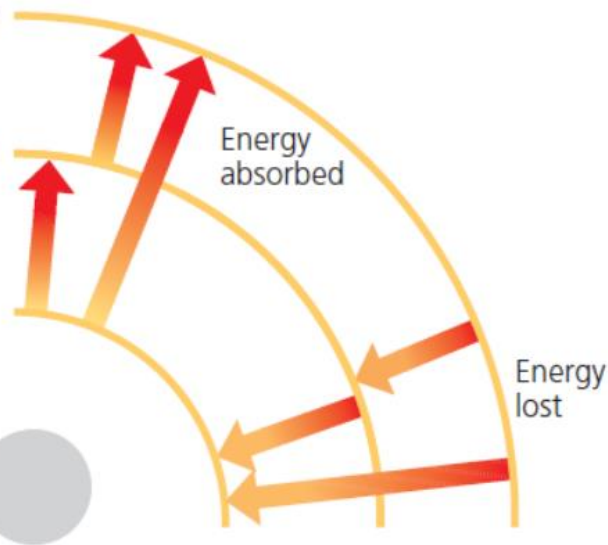


Third shell (highest energy level in this model)

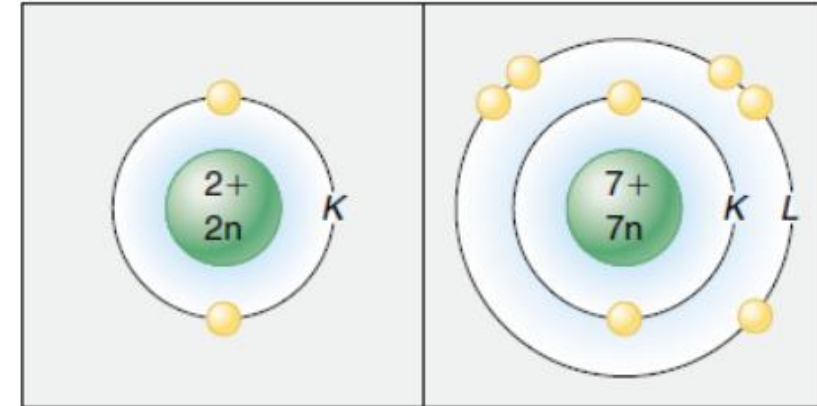
Second shell (next highest energy level)

First shell (lowest energy level)

Atomic nucleus

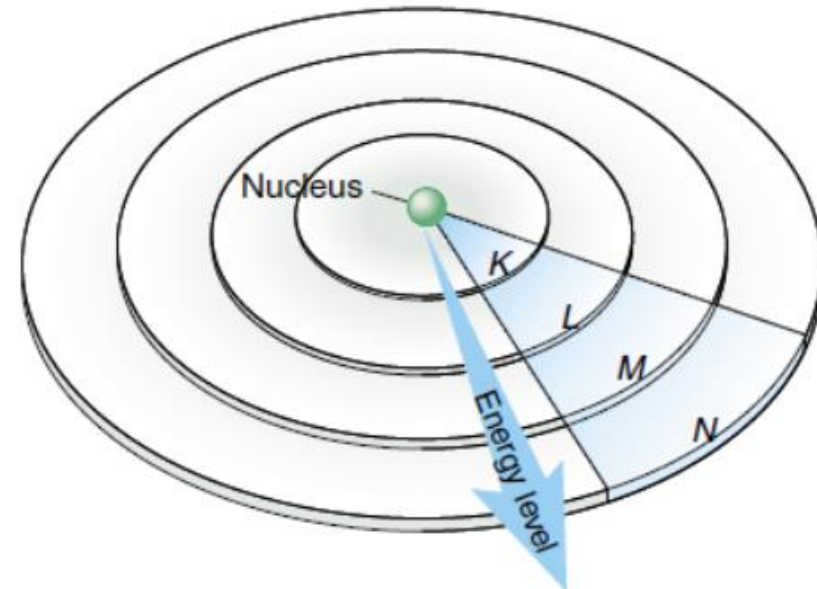


(b) An electron can move from one shell to another only if the energy it gains or loses is exactly equal to the difference in energy between the energy levels of the two shells. Arrows in this model indicate some of the stepwise changes in potential energy that are possible.





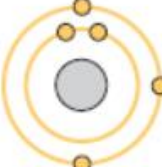
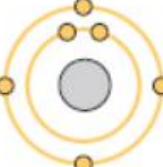
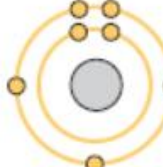
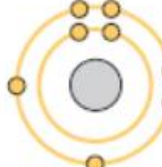
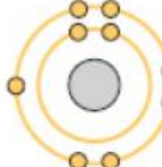
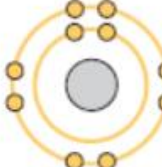
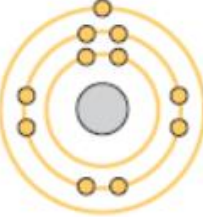
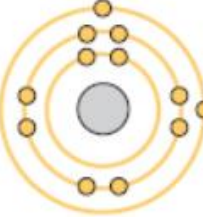
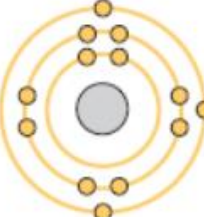
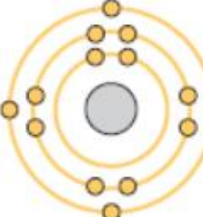
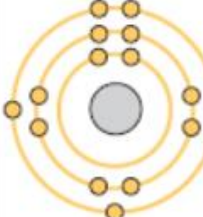
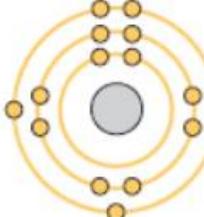
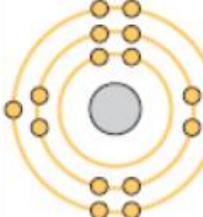
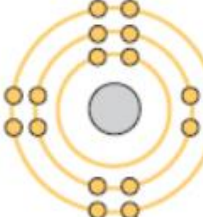


Helium

Nitrogen



▲ **Figure 2.6** Energy levels of an atom's electrons. Electrons exist only at fixed levels of potential energy called electron shells.

First shell	<p>Hydrogen <math>{}_1\text{H}</math></p> 	<div style="display: flex; align-items: center; justify-content: center;"> <div style="border: 1px solid black; padding: 5px; margin-right: 10px;"> <p>2</p> <p><b>He</b></p> <p>4.003</p> </div> <div style="margin-right: 10px;"> <p>Atomic number</p> <p>Element symbol</p> <p>Atomic mass</p> </div> <div style="margin-right: 10px;"> <p>Helium <math>{}_2\text{He}</math></p> </div> <div> <p>Electron distribution diagram</p> </div> </div>						<p>Helium <math>{}_2\text{He}</math></p> 
Second shell	<p>Lithium <math>{}_3\text{Li}</math></p> 	<p>Beryllium <math>{}_4\text{Be}</math></p> 	<p>Boron <math>{}_5\text{B}</math></p> 	<p>Carbon <math>{}_6\text{C}</math></p> 	<p>Nitrogen <math>{}_7\text{N}</math></p> 	<p>Oxygen <math>{}_8\text{O}</math></p> 	<p>Fluorine <math>{}_9\text{F}</math></p> 	<p>Neon <math>{}_{10}\text{Ne}</math></p> 
Third shell	<p>Sodium <math>{}_{11}\text{Na}</math></p> 	<p>Magnesium <math>{}_{12}\text{Mg}</math></p> 	<p>Aluminum <math>{}_{13}\text{Al}</math></p> 	<p>Silicon <math>{}_{14}\text{Si}</math></p> 	<p>Phosphorus <math>{}_{15}\text{P}</math></p> 	<p>Sulfur <math>{}_{16}\text{S}</math></p> 	<p>Chlorine <math>{}_{17}\text{Cl}</math></p> 	<p>Argon <math>{}_{18}\text{Ar}</math></p> 

**Electron distribution diagrams for the first 18 elements in the periodic table.**

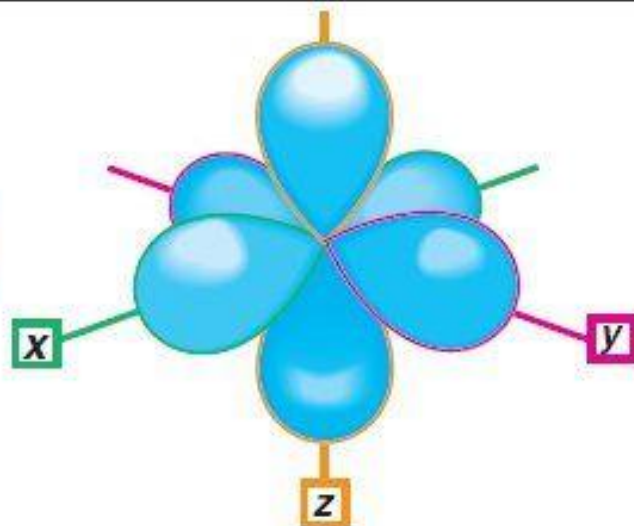
Electron orbitals



1s orbital



2s orbital



Three 2p orbitals

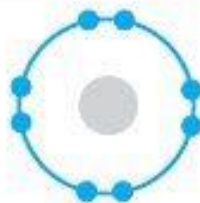


1s, 2s, and 2p orbitals

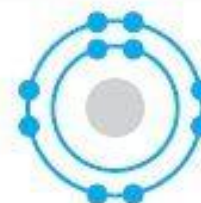
Electron-shell diagrams



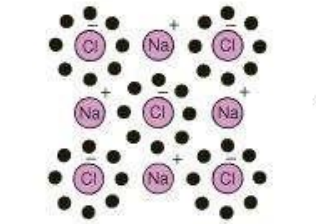
(a) First shell  
(maximum  
2 electrons)



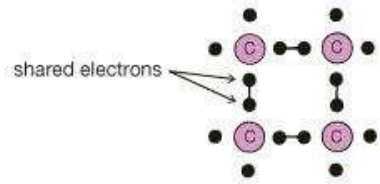
(b) Second shell  
(maximum  
8 electrons)



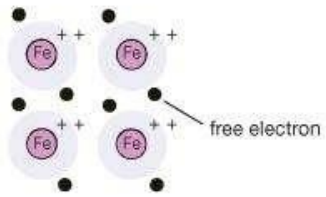
(c) Neon, with two  
filled shells  
(10 electrons)



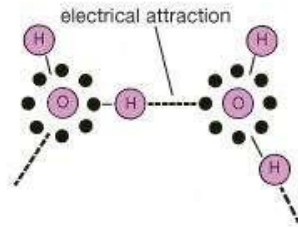
ionic bonding  
electron transferred from Na to Cl



covalent bonding  
atoms share electrons



metallic bonding  
ions surrounded by free electrons

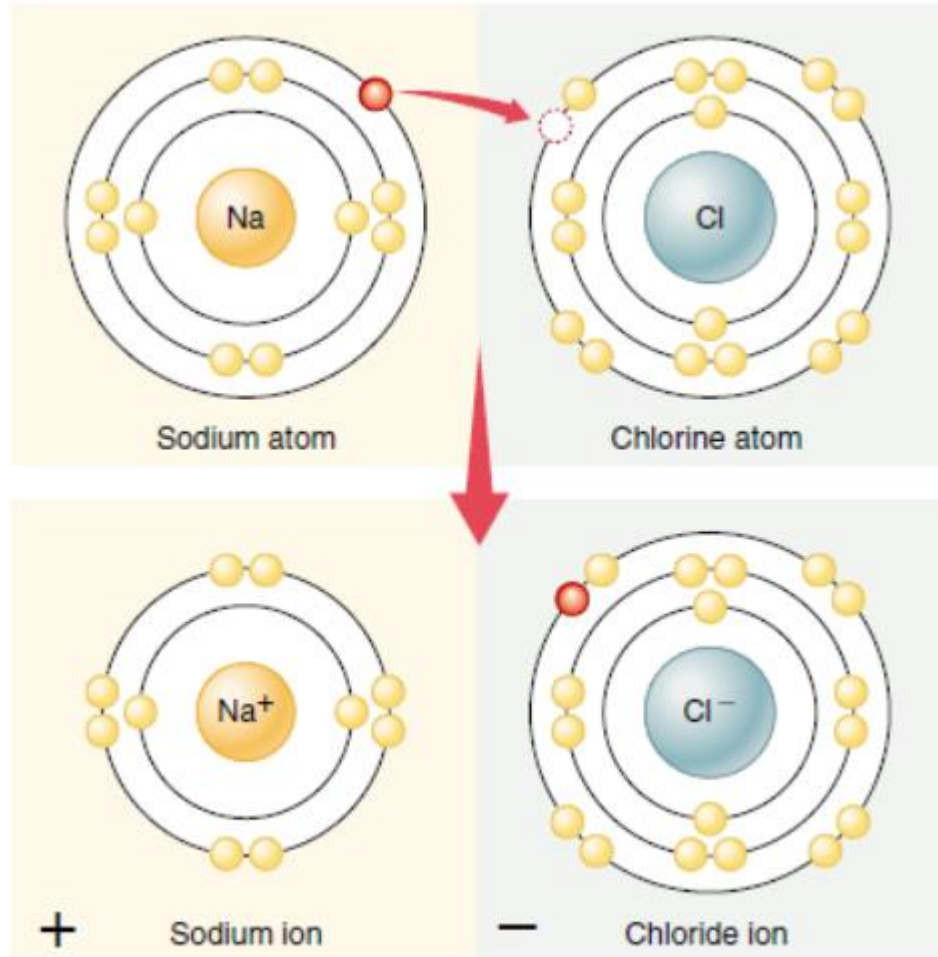


molecular bonding  
weak electrical attraction binds molecules

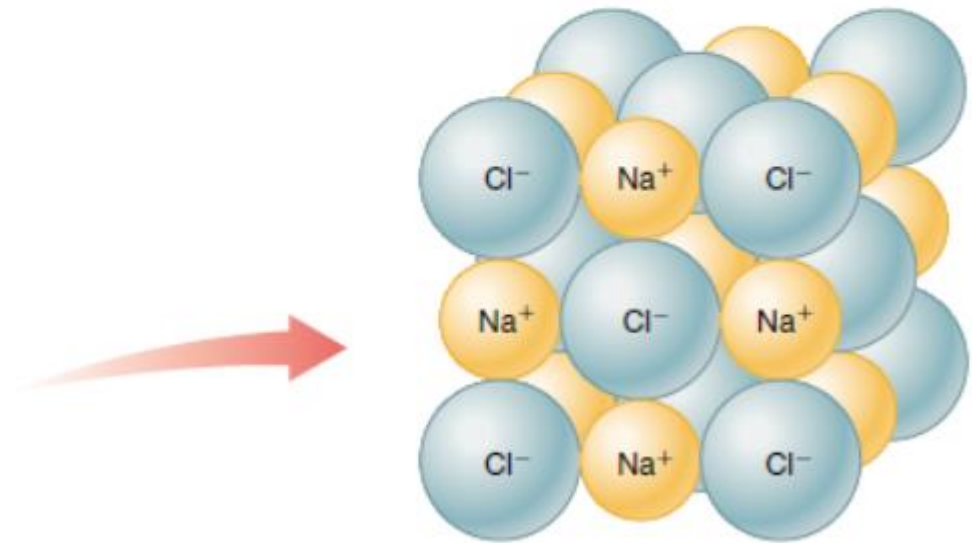
© 2010 Encyclopædia Britannica, Inc.

The formation and function of molecules depend on chemical bonding between atoms.

# Ionic Bond



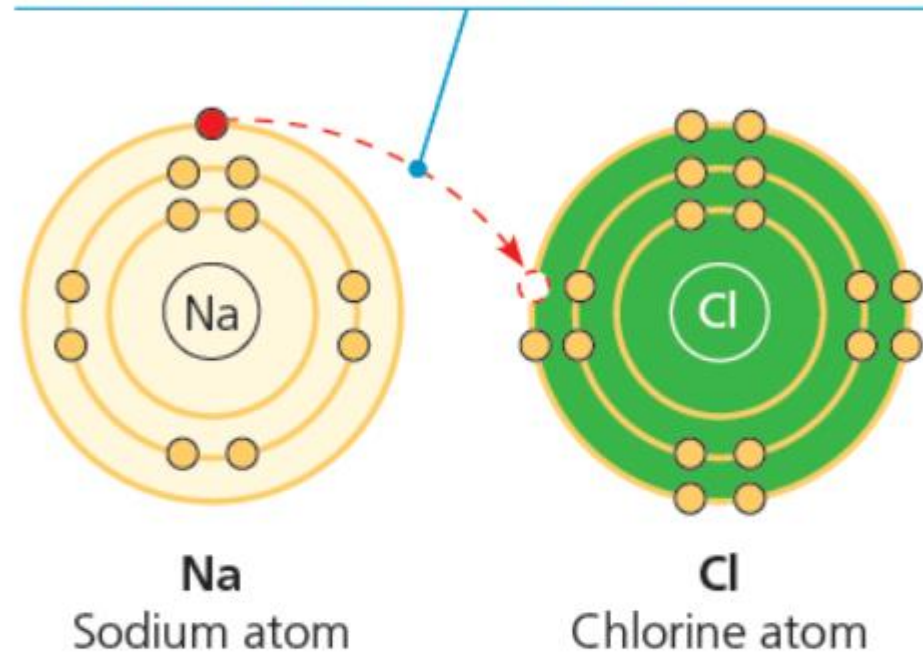
(a)



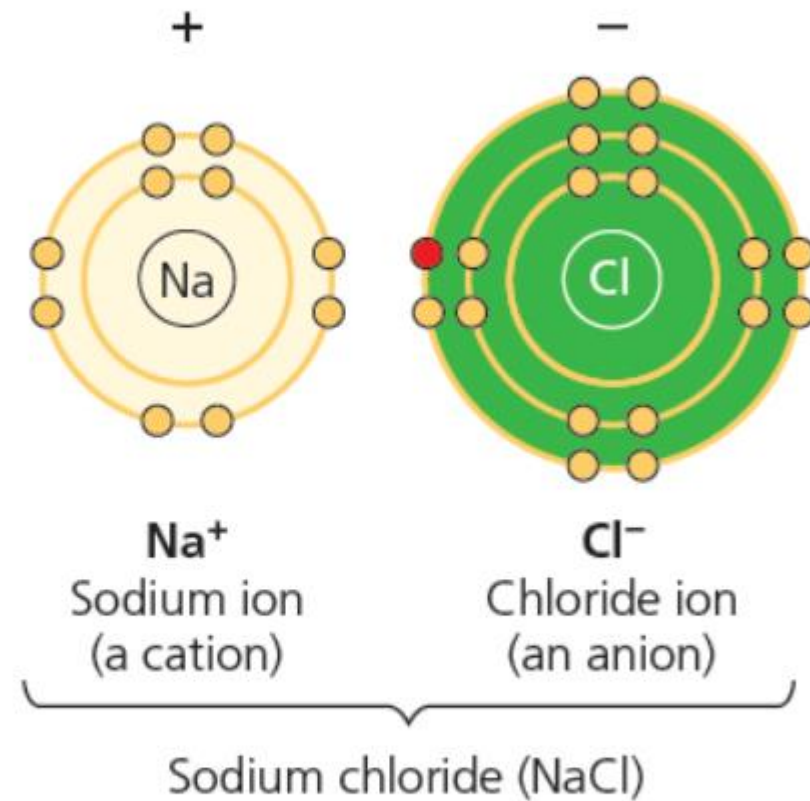
(b)

NaCl crystal

1 The lone valence electron of a sodium atom is transferred to join the 7 valence electrons of a chlorine atom.



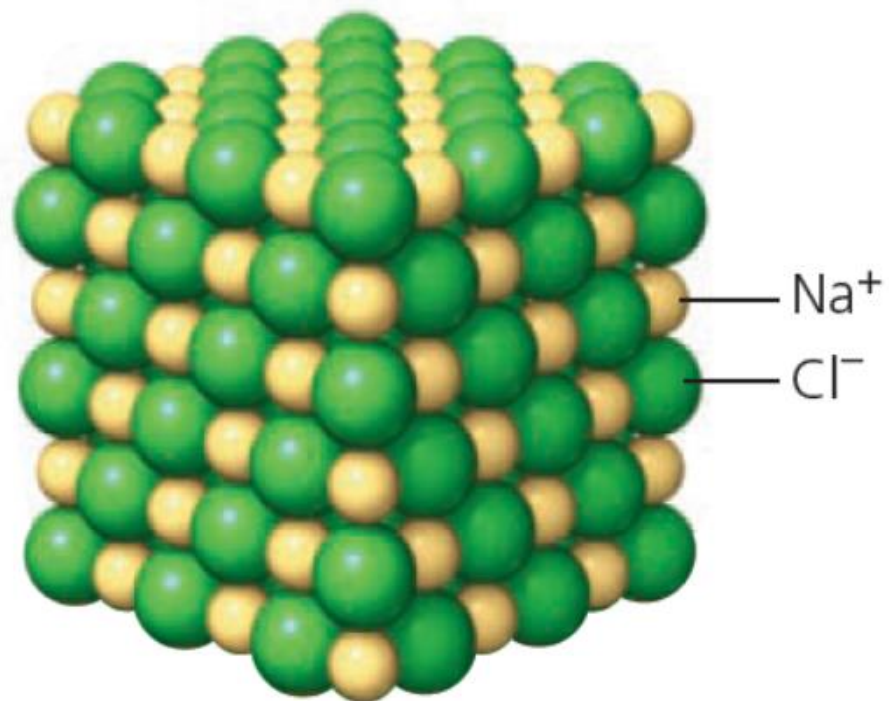
2 Each resulting ion has a completed valence shell. An ionic bond can form between the oppositely charged ions.



▲ **Figure 2.12 Electron transfer and ionic bonding.** The attraction between oppositely charged atoms, or ions, is an ionic bond. An ionic bond can form between any two oppositely charged ions, even if they have not been formed by transfer of an electron from one to the other.



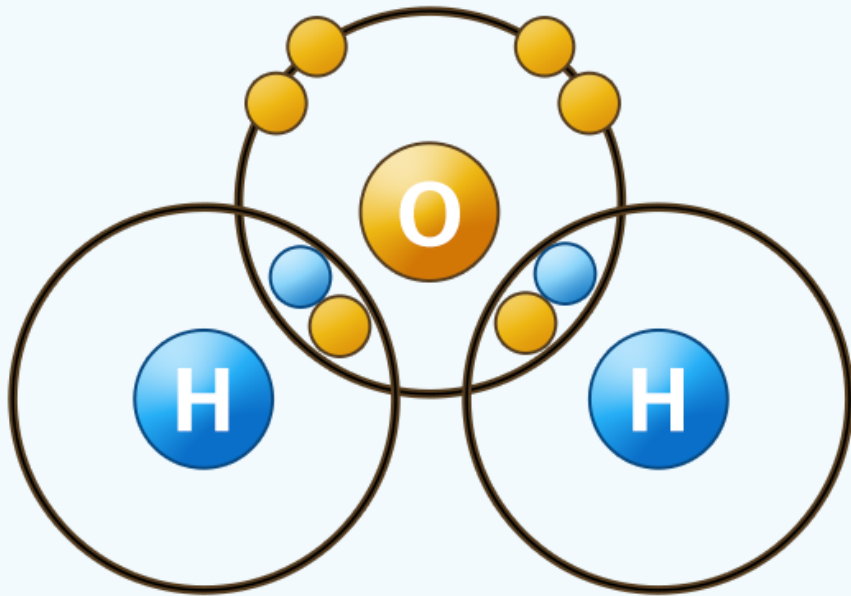
▲ **Figure 2.13** A sodium chloride (NaCl) crystal. The sodium ions ( $\text{Na}^+$ ) and chloride ions ( $\text{Cl}^-$ ) are held together by ionic bonds. The formula NaCl tells us that the ratio of  $\text{Na}^+$  to  $\text{Cl}^-$  is 1:1.



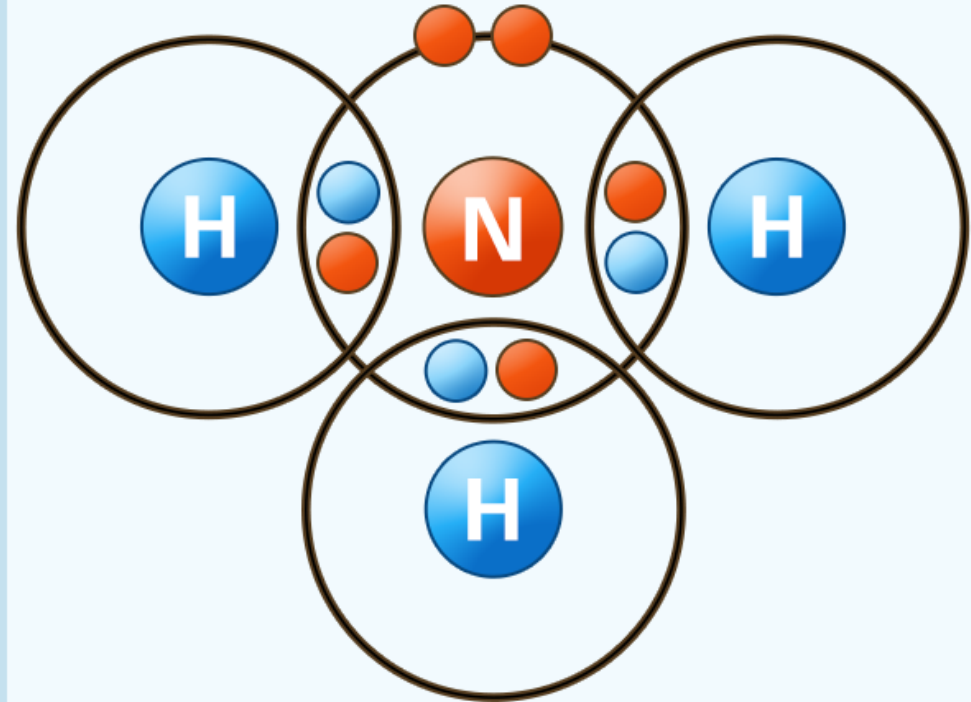
# Covalent Bond

## Examples of Covalent Bond

ScienceStruck.com



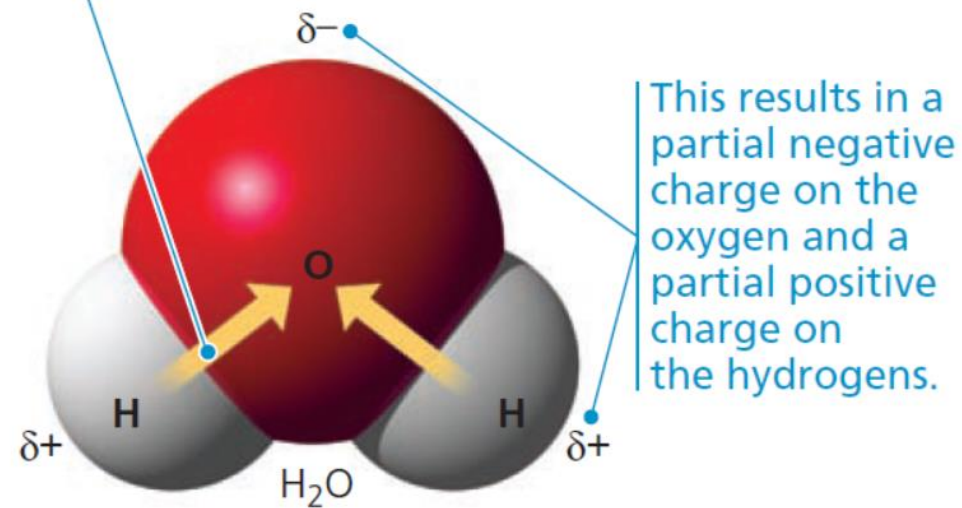
**Water (H<sub>2</sub>O)**



**Ammonia (NH<sub>3</sub>)**

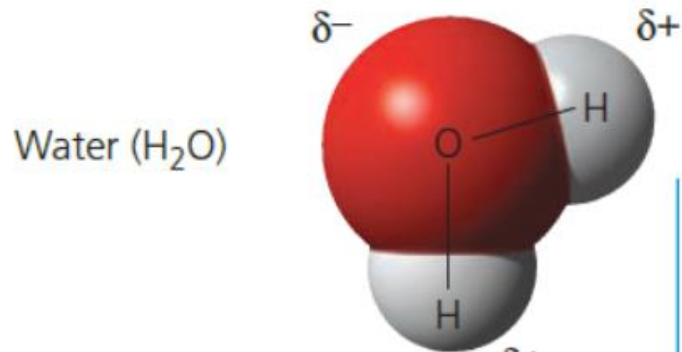
Name and Molecular Formula	Electron Distribution Diagram	Lewis Dot Structure and Structural Formula	Space-Filling Model
<b>(a) Hydrogen (H<sub>2</sub>).</b> Two hydrogen atoms share one pair of electrons, forming a single bond.		H:H H—H	
<b>(b) Oxygen (O<sub>2</sub>).</b> Two oxygen atoms share two pairs of electrons, forming a double bond.		:O::O: O=O	
<b>(c) Water (H<sub>2</sub>O).</b> Two hydrogen atoms and one oxygen atom are joined by single bonds, forming a molecule of water.		:O:H H O—H H	
<b>(d) Methane (CH<sub>4</sub>).</b> Four hydrogen atoms can satisfy the valence of one carbon atom, forming methane.		H H:C:H H H H—C—H H	

Because oxygen (O) is more electronegative than hydrogen (H), shared electrons are pulled more toward oxygen.

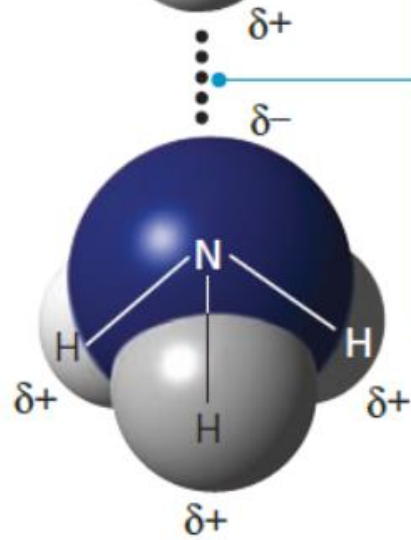


▲ **Figure 2.11** Polar covalent bonds in a water molecule.

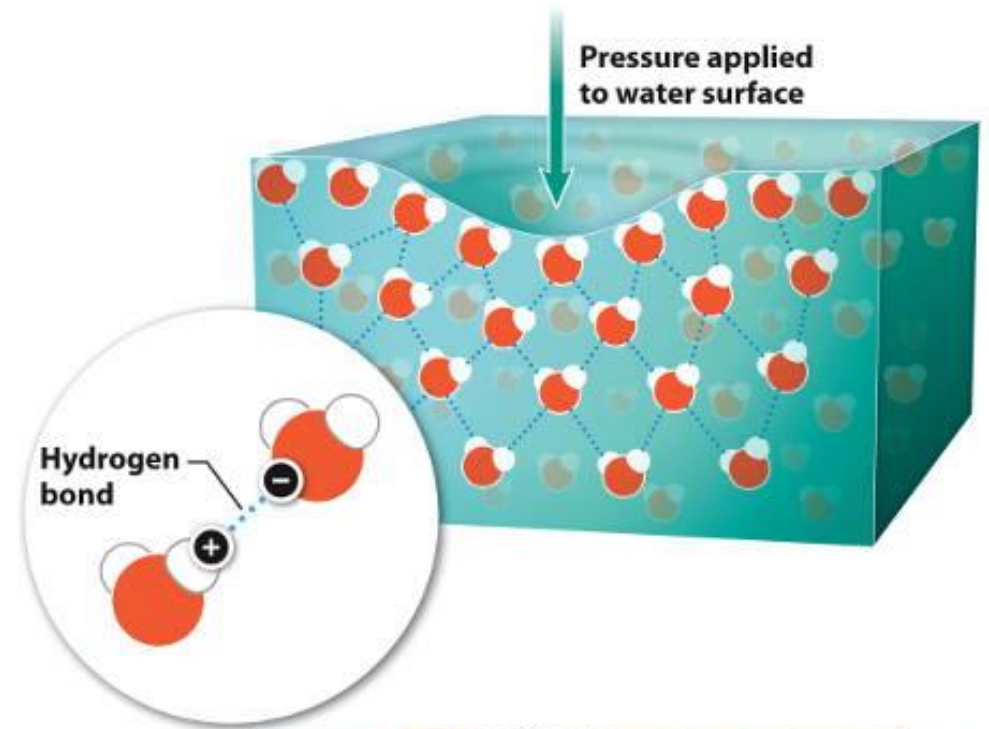
# Hydrogen Bonds



Ammonia ( $\text{NH}_3$ )



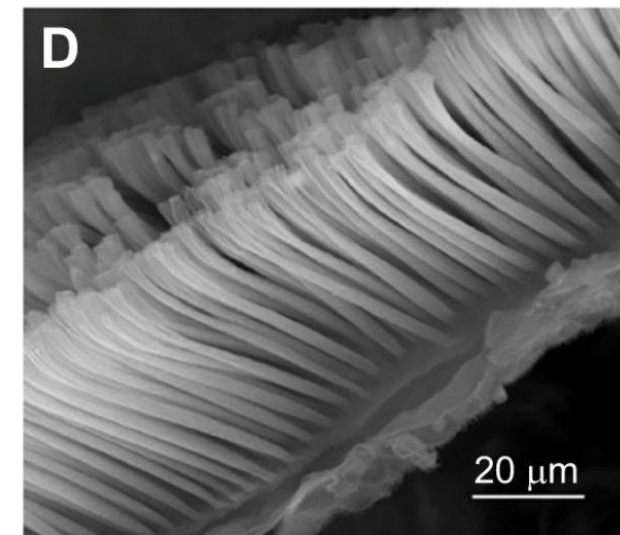
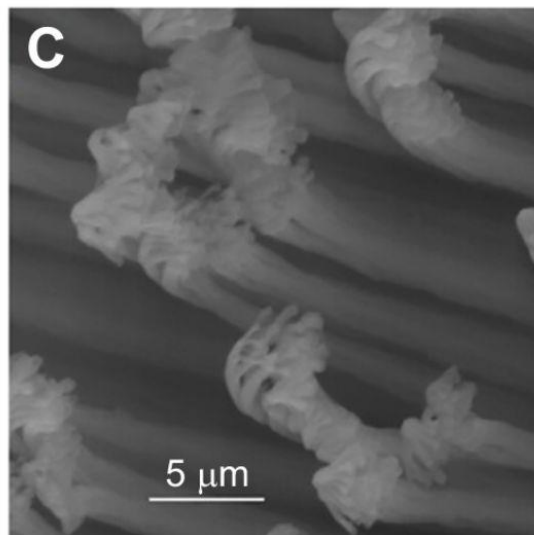
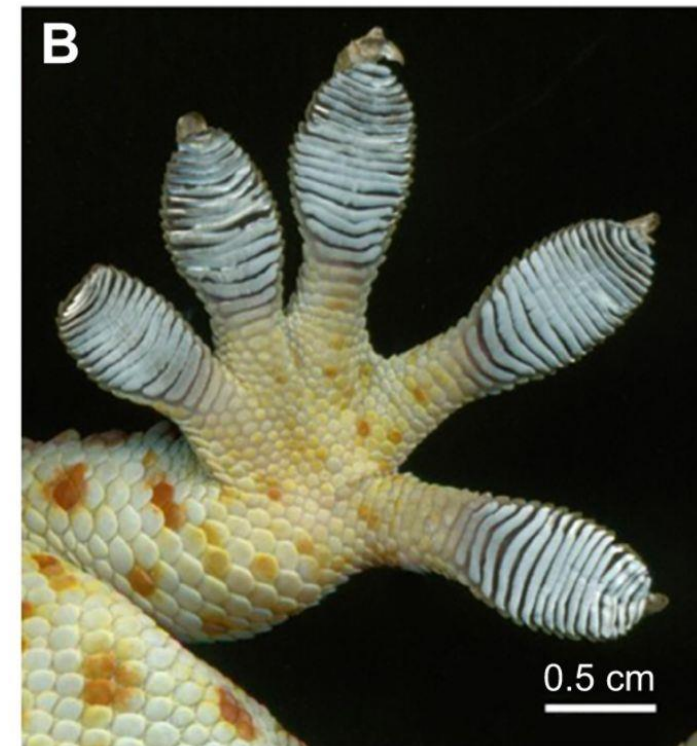
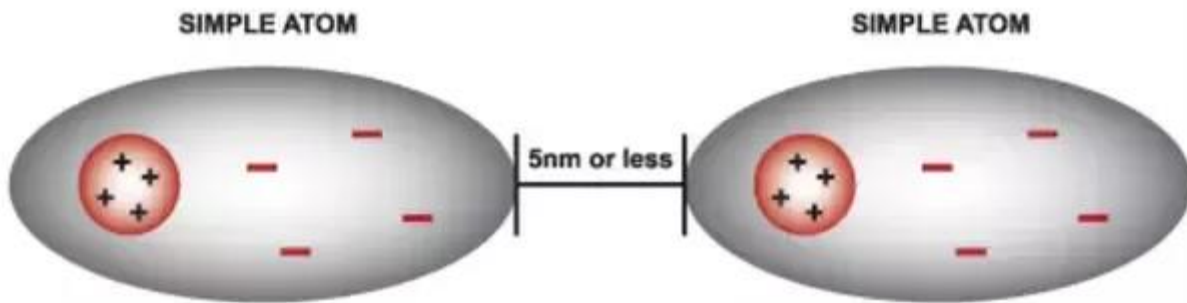
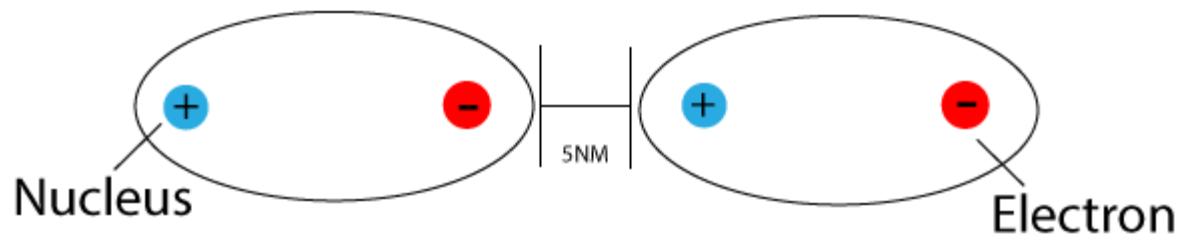
This hydrogen bond results from the attraction between the partial positive charge on the hydrogen atom of water and the partial negative charge on the nitrogen atom of ammonia.



▲ **Figure 2.14**  
A hydrogen bond.

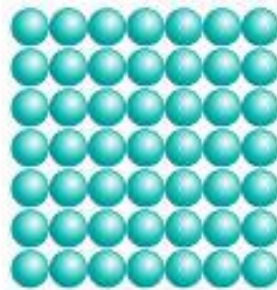
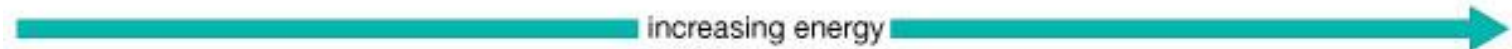
# Van der Waals Interactions

van der Waals Forces



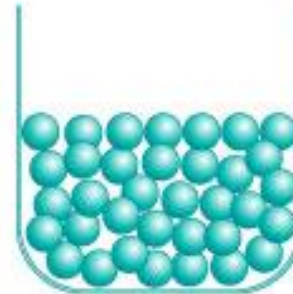
# State of matter

## Physical states



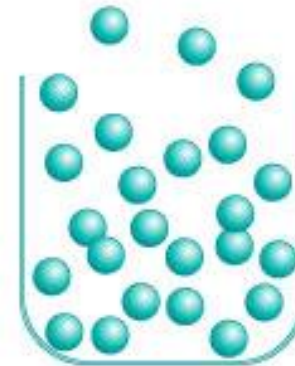
### Solid

The molecules that make up a solid are arranged in regular, repeating patterns. They are held firmly in place but can vibrate within a limited area.



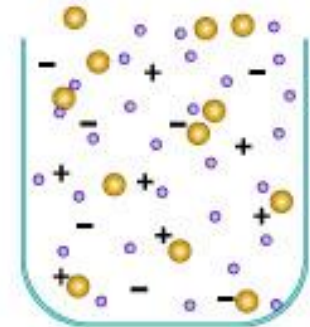
### Liquid

The molecules that make up a liquid flow easily around one another. They are kept from flying apart by attractive forces between them. Liquids assume the shape of their containers.



### Gas

The molecules that make up a gas fly in all directions at great speeds. They are so far apart that the attractive forces between them are insignificant.



### Plasma

At the very high temperatures of stars, atoms lose their electrons. The mixture of electrons and nuclei that results is the plasma state of matter.

➤ bose einstein condensate

➤ Solid

➤ Liquid

➤ Gas

➤ Plasma

➤ Filament

➤ Fermionic condensate

