

CH. 2 WARM-UP

- What is the difference between an atom, element and compound?
- What are the 3 main components of an atom? What are their charges?
- What type of bond is found in:
 - H_2O ?
 - KCl ?
 - $\text{C}_6\text{H}_{12}\text{O}_6$?
 - N_2 ?
 - $\text{Ba}(\text{OH})_2$?

CH. 2A WARM-UP

- List 1 trace mineral found in living things and its purpose in the body.
- What is the difference between a polar and nonpolar substance? Name an example of each.
- What types of molecules can form hydrogen bonds? Explain.
- Draw a possible chemical structure diagram of $C_6H_{12}O_6$.



CHAPTER 2

THE CHEMICAL CONTEXT OF LIFE

WOOD ANTS & ACID



Ants shoot formic acid to defend themselves from attacks from predators (birds).

YOU MUST KNOW

- The three subatomic particles and their significance.
- The types of bonds and how they form.



CONCEPT 2.1

MATTER CONSISTS OF CHEMICAL
ELEMENTS IN PURE FORM AND IN
COMBINATIONS CALLED COMPOUNDS

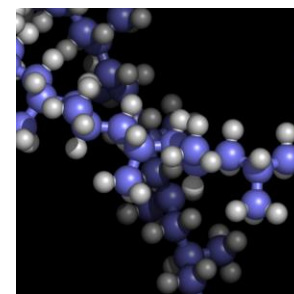
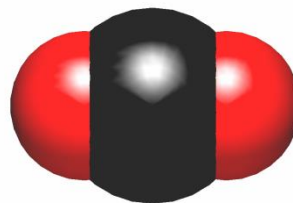
ELEMENTS & COMPOUNDS

ELEMENT

- Can't be broken down by chemical means to other substances
- Ex. hydrogen (H), nitrogen (N)

COMPOUND

- 2 or more different elements combined in a fixed ratio
- Ex. H_2O , CO_2



ELEMENTS OF LIFE

- 25 elements
 - 96% : O, C, H, N
 - ~ 4% : P, S, Ca, K & trace elements (ex: Fe, I)

Hint: Remember CHNOPS

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)

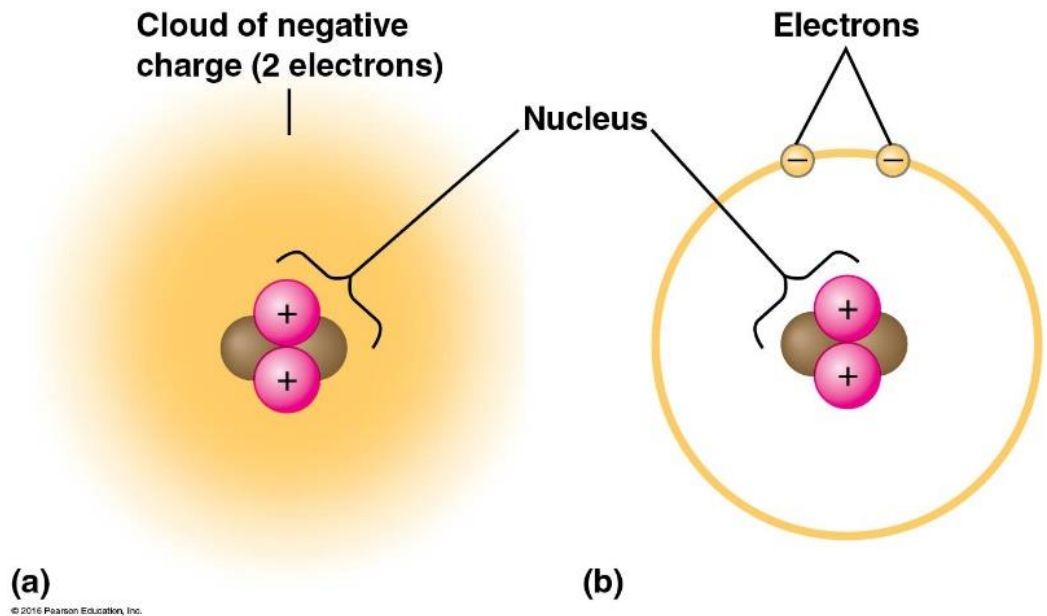


CONCEPT 2.2

AN ELEMENT'S PROPERTIES DEPEND ON
THE STRUCTURE OF ITS ATOMS

ATOMIC STRUCTURE

- **ATOM** = smallest unit of matter that retains properties of an element



SUBATOMIC PARTICLES

	Mass (dalton or AMU)	Location	Charge
neutron	~1	nucleus	0
proton	1	nucleus	+1
electron	negligible	shell	-1

Mass # (protons + neutrons)

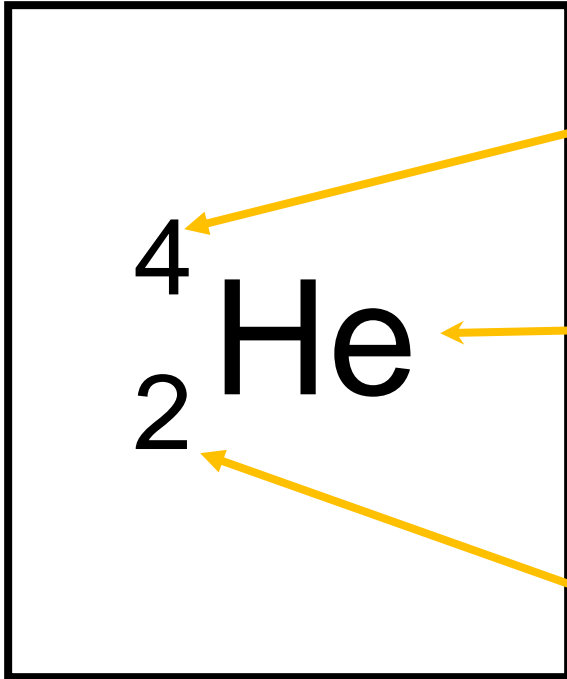
4

2

He

Symbol

Atomic # (protons or electrons)



ISOTOPES

- Atoms of the same element that differ in their number of neutrons
- Radioactive isotopes are used in medical diagnostics (tracer molecules, imaging like PET scans)
- Uncontrolled exposure causes harm

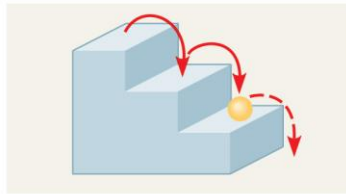
ISOTOPES OF CARBON

TABLE 2.4 ISOTOPES OF CARBON

	Carbon-12	Carbon-13	Carbon-14
Protons	6	6	6
Neutrons	6	7	8
Electrons	6	6	6

Electrons exist only at fixed levels of potential energy called **electron shells**

(a) A ball bouncing down a flight of stairs can come to rest only on each step, not between steps.

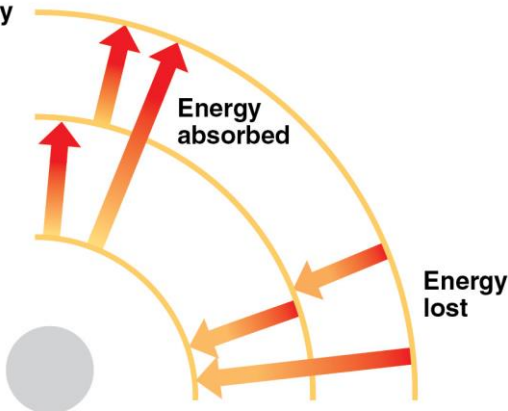


Third shell (highest energy level in this model)

Second shell (higher energy level)

First shell (lowest energy level)

Atomic nucleus



(b)

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The Periodic Table of the Elements, in Pictures

Periods
1
2
3
4
5
6
7
8

Alkali Metals
Group 1

H 1
Hydrogen
Sun and Stars

Li 3
Lithium
Batteries

Na 11
Sodium
Salt

K 19
Potassium
Fruits and Vegetables

Rb 37
Rubidium
Global Navigation

Cs 55
Cesium
Atomic Clocks

Fr 87
Francium
Laser Atom Traps

Alkali Earth Metals
Group 2

Be 4
Beryllium
Emeralds

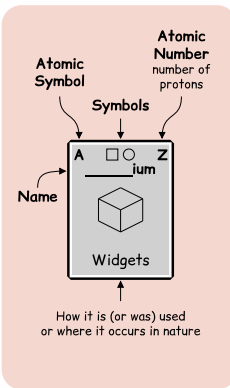
Mg 12
Magnesium
Chlorophyll

Ca 20
Calcium
Shells and Bones

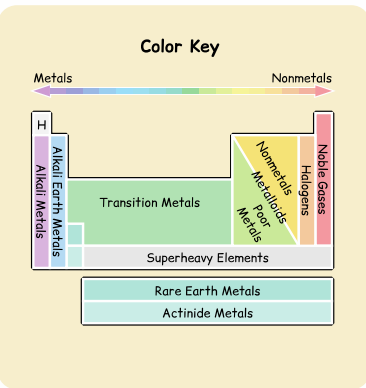
Sr 38
Strontium
Fireworks

Ba 56
Barium
X-Ray Diagnosis

Ra 88
Radium
Luminous Watches



- Solid** (square icon)
- Liquid** (teardrop icon)
- Gas** (cloud icon) at room temperature
- Human Body** (person icon) top ten elements by weight
- Earth's Crust** (globe icon) top eight elements by weight
- Magnetic** (magnet icon) ferromagnetic at room temperature
- Noble Metals** (crown icon) corrosion-resistant
- Radioactive** (radiation icon) all isotopes are radioactive
- Only Traces Found in Nature** (lightning bolt icon) less than a millionth percent of earth's crust
- Never Found in Nature** (X icon) only made by people



Noble Gases
Group 18

He 2
Helium
Balloons

Ne 10
Neon
Advertising Signs

Ar 18
Argon
Light Bulbs

Kr 36
Krypton
Flashlights

Xe 54
Xenon
High-Intensity Lamps

Rn 86
Radon
Surgical Implants

Boron Group 13 **Carbon Group 14** **Nitrogen Group 15** **Oxygen Group 16** **Halogens 17**

B 5 Boron Sports Equipment

C 6 Carbon Basis of Life's Molecules

N 7 Nitrogen Protein

O 8 Oxygen Air

F 9 Fluorine Toothpaste

Al 13 Aluminum Airplanes

Si 14 Silicon Stone, Sand, and Soil

P 15 Phosphorus Bones

S 16 Sulfur Eggs

Cl 17 Chlorine Swimming Pools

Br 35 Bromine Photography Film

Transition Metals 3 4 5 6 7 8 9 10 11 12

Sc 21 Scandium Bicycles	Ti 22 Titanium Aerospace	V 23 Vanadium Springs	Cr 24 Chromium Stainless Steel	Mn 25 Manganese Earthmovers	Fe 26 Iron Steel Structures	Co 27 Cobalt Magnets	Ni 28 Nickel Coins	Cu 29 Copper Electric Wires	Zn 30 Zinc Brass Instruments
Y 39 Yttrium Lasers	Zr 40 Zirconium Chemical Pipelines	Nb 41 Niobium Mag Lev Trains	Mo 42 Molybdenum Cutting Tools	Tc 43 Technetium Radioactive Diagnosis	Ru 44 Ruthenium Electric Switches	Rh 45 Rhodium Searchlight Reflectors	Pd 46 Palladium Pollution Control	Ag 47 Silver Jewelry	Cd 48 Cadmium Paint
La 57 Lanthanum Telescope Lenses	Ce 58 Cerium Lighter Flints	Pr 59 Praseodymium Torchworkers' Eyeglasses	Nd 60 Neodymium Electric Motor Magnets	Pm 61 Promethium Luminous Dials	Sm 62 Samarium Electric Motor Magnets	Eu 63 Europium Color Televisions	Gd 64 Gadolinium MRI Diagnosis	Tb 65 Terbium Fluorescent Lamps	Dy 66 Dysprosium Smart Material Actuators
Ac 89 Actinium Radioactive Medicine	Th 90 Thorium Gas Lamp Mantles	Pa 91 Protactinium Radioactive Waste	U 92 Uranium Nuclear Power	Np 93 Neptunium Radioactive Waste	Pu 94 Plutonium Nuclear Weapons	Am 95 Americium Smoke Detectors	Cm 96 Curium Mineral Analyzers	Bk 97 Berkelium Radioactive Waste	Cf 98 Californium Mineral Analyzers



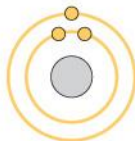
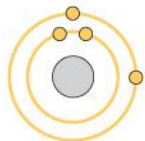
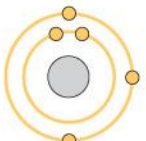
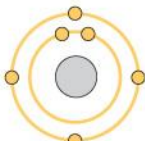
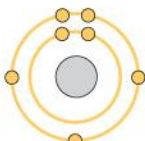
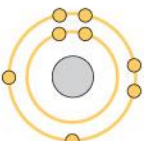
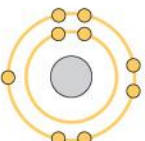
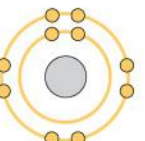
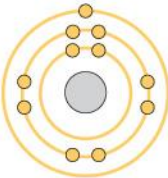
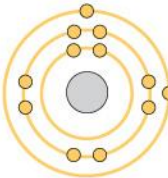
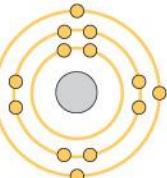
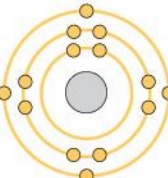
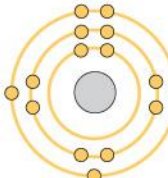
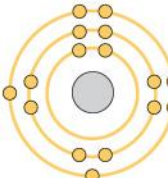
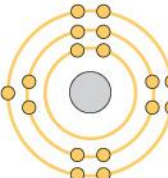
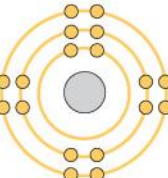
Ga 31 Gallium Light-Emitting Diodes (LEDs)	Ge 32 Germanium Semiconductor Electronics	As 33 Arsenic Poison	Se 34 Selenium Copiers	Br 35 Bromine Photography Film	Kr 36 Krypton Flashlights
In 49 Indium Liquid Crystal Displays (LCDs)	Sn 50 Tin Plated Food Cans	Sb 51 Antimony Car Batteries	Te 52 Tellurium Thermoelectric Coolers	I 53 Iodine Disinfectant	Xe 54 Xenon High-Intensity Lamps
Tl 81 Thallium Low-Temperature Thermometers	Pb 82 Lead Weights	Bi 83 Bismuth Fire Sprinklers	Po 84 Polonium Anti-Static Brushes	At 85 Astatine Radioactive Medicine	Rn 86 Radon Surgical Implants

Rare Earth Metals

La 57 Lanthanum Telescope Lenses	Ce 58 Cerium Lighter Flints	Pr 59 Praseodymium Torchworkers' Eyeglasses	Nd 60 Neodymium Electric Motor Magnets	Pm 61 Promethium Luminous Dials	Sm 62 Samarium Electric Motor Magnets	Eu 63 Europium Color Televisions	Gd 64 Gadolinium MRI Diagnosis	Tb 65 Terbium Fluorescent Lamps	Dy 66 Dysprosium Smart Material Actuators	Ho 67 Holmium Laser Surgery	Er 68 Erbium Optical Fiber Communications	Tm 69 Thulium Laser Surgery	Yb 70 Ytterbium Scientific Fiber Lasers	Lu 71 Lutetium Photodynamic Medicine
Ac 89 Actinium Radioactive Medicine	Th 90 Thorium Gas Lamp Mantles	Pa 91 Protactinium Radioactive Waste	U 92 Uranium Nuclear Power	Np 93 Neptunium Radioactive Waste	Pu 94 Plutonium Nuclear Weapons	Am 95 Americium Smoke Detectors	Cm 96 Curium Mineral Analyzers	Bk 97 Berkelium Radioactive Waste	Cf 98 Californium Mineral Analyzers	Es 99 Einsteinium	Fm 100 Fermium	Md 101 Mendelevium	No 102 Nobelium	Lr 103 Lawrencium

Actinide Metals

VALENCE ELECTRONS

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



CONCEPT 2.3

THE FORMATION AND FUNCTION OF
MOLECULES DEPEND ON THE
CHEMICAL BONDING BETWEEN
ATOMS

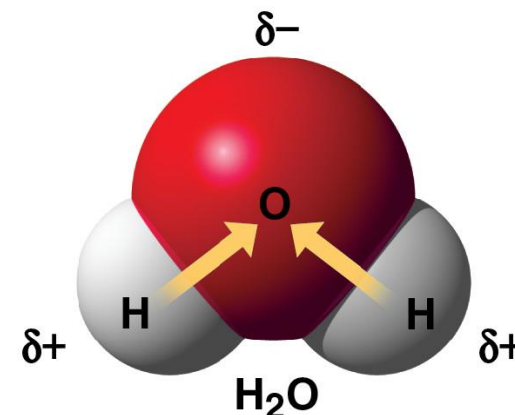
CHEMICAL BONDS

- Atoms will interact with other atoms in order to complete their valence shell
- These interactions are called **chemical bonds**
- The strongest types are **COVALENT** and **IONIC** bonds

CHEMICAL BONDS

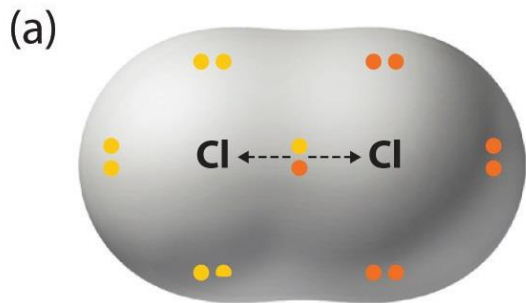
➤ *Covalent Bonds*

- When a pair of electrons is shared by two atoms
- Requires physical overlap of valence shells
- Two or more atoms held together by covalent bond = **molecule**



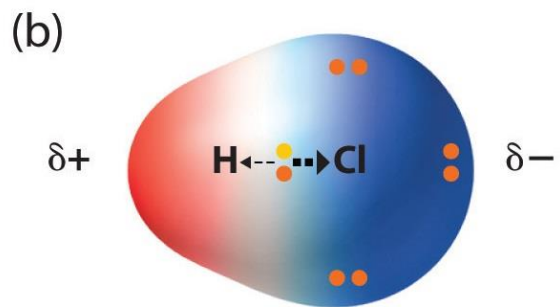
POLAR & NON-POLAR COVALENT BONDS

- **POLAR** - electrons are shared unequally due to differences in **electronegativity**
 - *The higher an atom's affinity for electrons, the more electronegative it is.*
 - Results in partial charges on the molecule
 - Eg. H₂O
- **NON-POLAR** – electrons are shared equally
 - Eg. O₂ or H₂



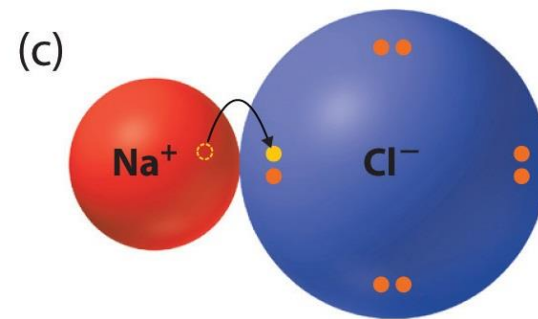
Nonpolar covalent bond

Bonding electrons shared equally between two atoms.
No charges on atoms.



Polar covalent bond

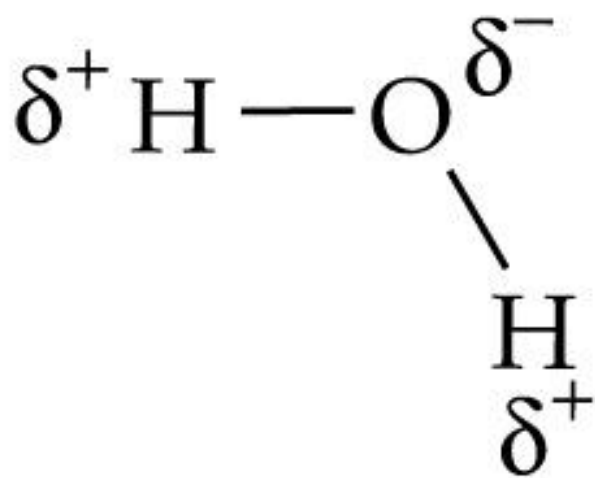
Bonding electrons shared unequally between two atoms.
Partial charges on atoms.



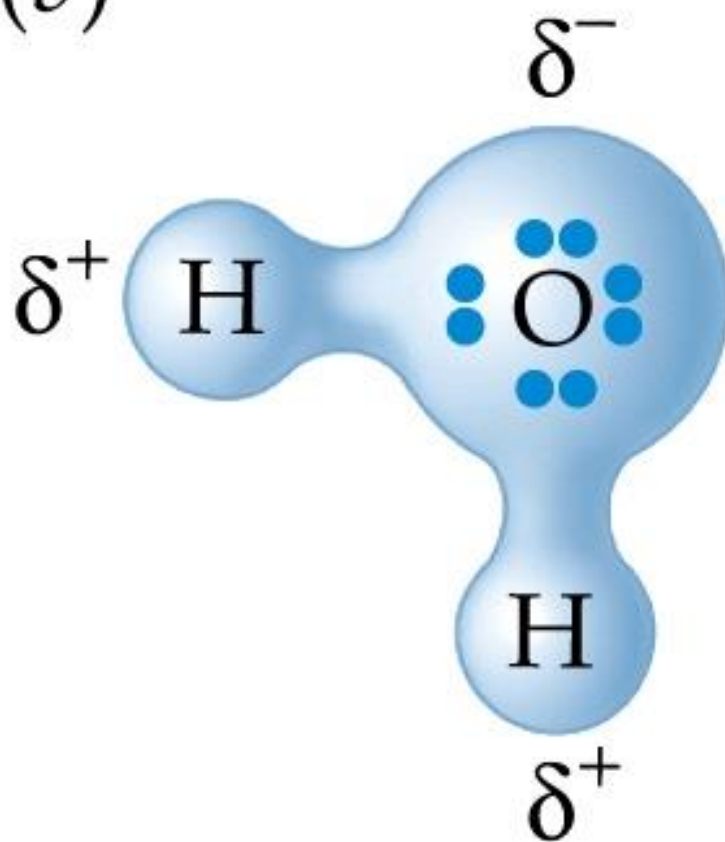
Ionic bond

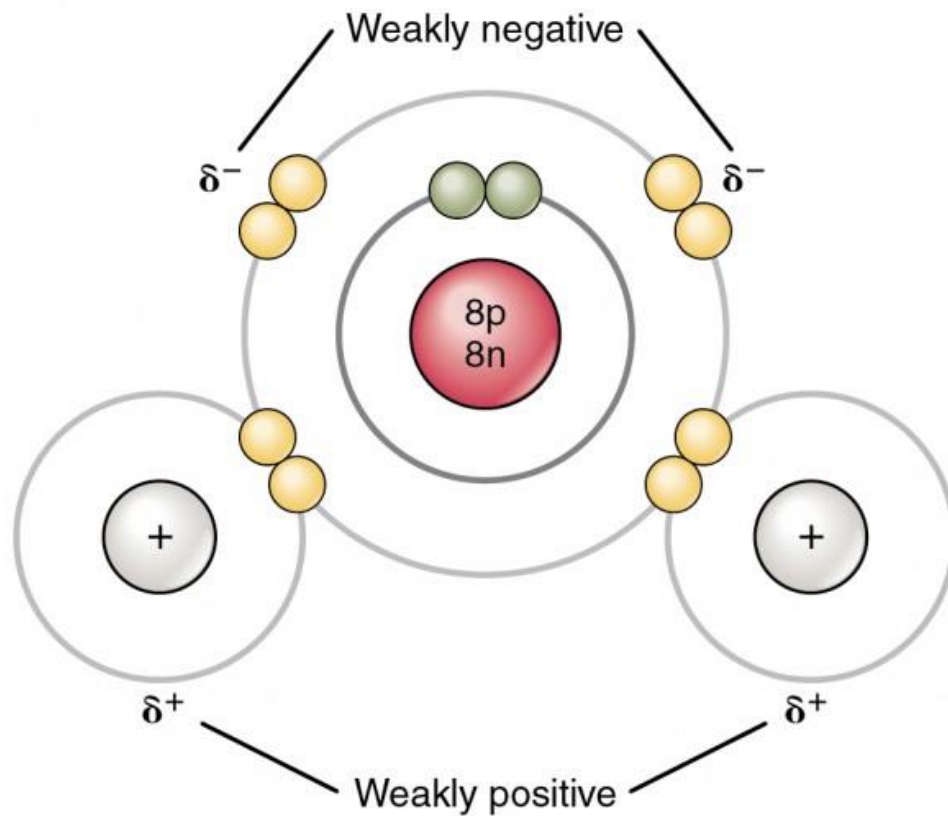
Complete transfer of one or more valence electrons.
Full charges on resulting ions.

(a)

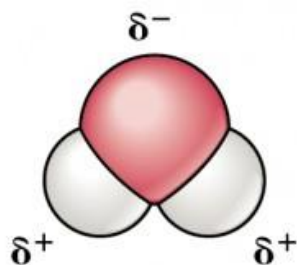


(b)

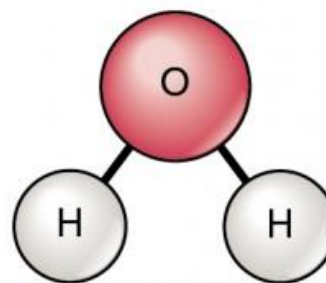




(a) Planetary model of a water molecule

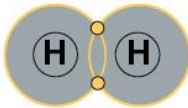


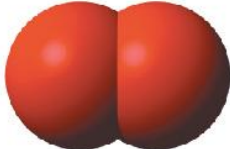
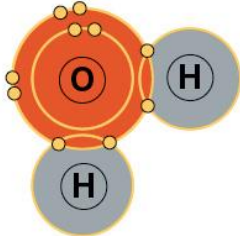

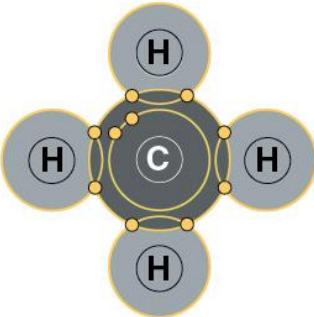



(b) Three-dimensional model of a water molecule



(c) Structural formula for water molecule

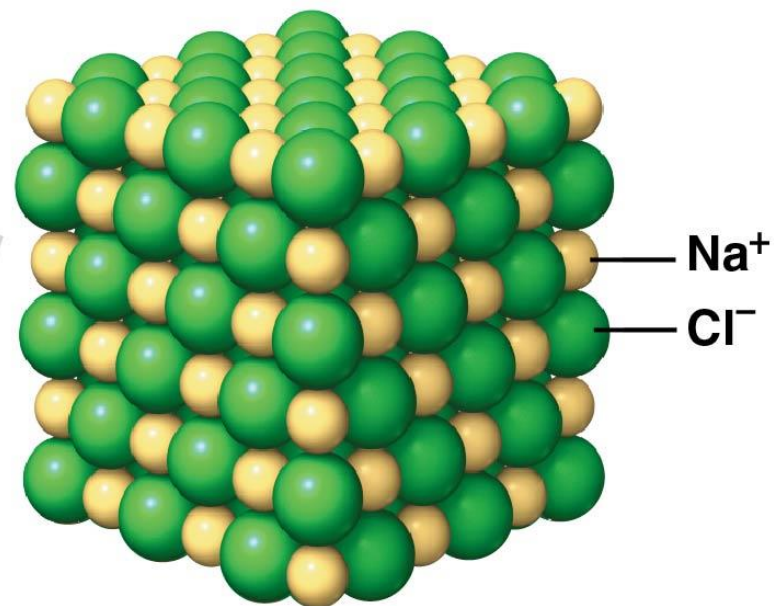
FIGURE 2.8 Covalent bonding in four molecules

Name and Molecular Formula	Electron Distribution Diagram	Structural Formula	Space-Filling Model
(a) Hydrogen (H ₂)		H—H	
(b) Oxygen (O ₂)		O=O	
(c) Water (H ₂ O)		$\begin{array}{c} \text{O} - \text{H} \\ \\ \text{H} \end{array}$	
(d) Methane (CH ₄)		$\begin{array}{c} \text{H} \\ \\ \text{H} - \text{C} - \text{H} \\ \\ \text{H} \end{array}$	

CHEMICAL BONDS CONTINUED

➤ *Ionic*

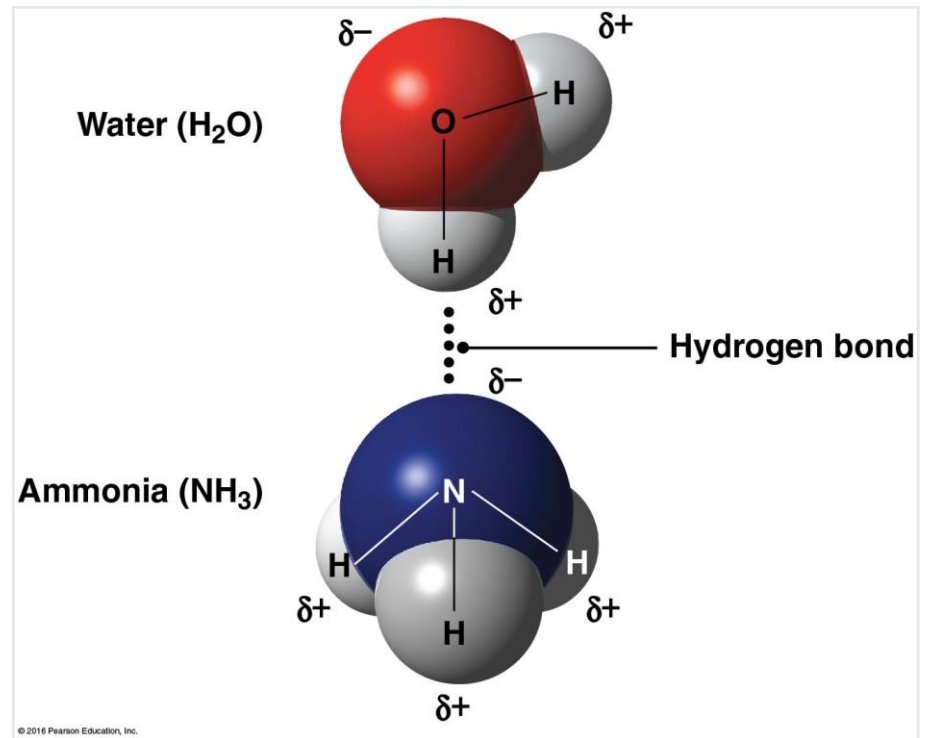
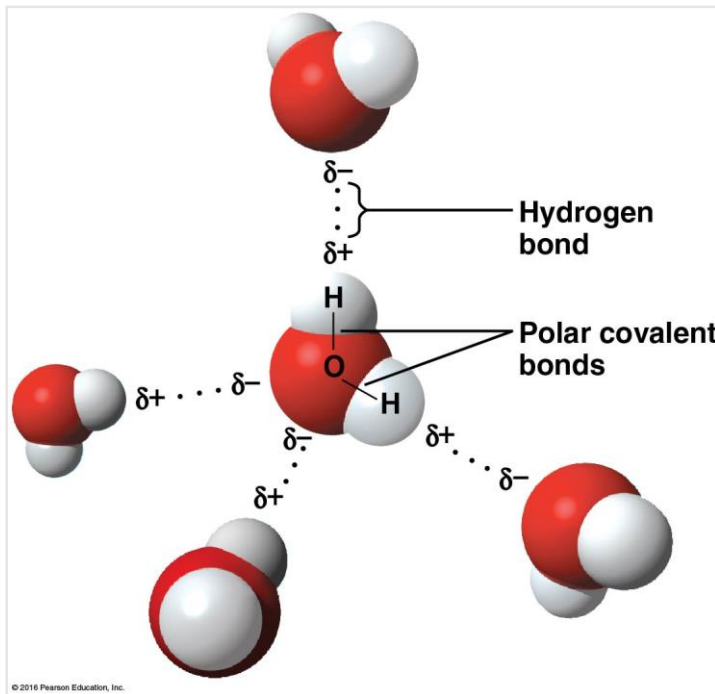
- Involves a transfer of valence electrons
- Results in positively and negatively charged ions
- Metals lose electrons (**cations +**)
- Non-metals gain electrons (**anions -**)
 - Ex. Na^+Cl^-
- Affected by environment (eg. water)



WEAK BONDS

➤ *Hydrogen Bonds*

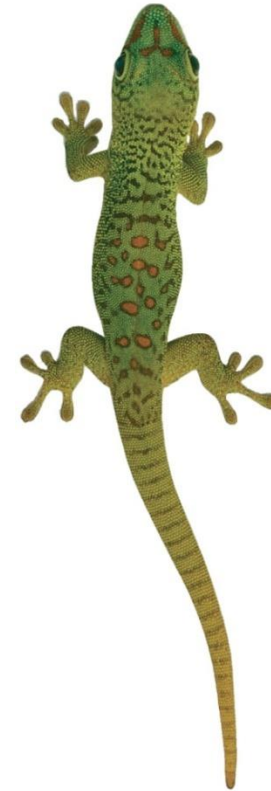
- H atom in *polar covalent* molecule bonds to electronegative atom of *other polar covalent* molecules
- The partial charges on these atoms creates a weak electrostatic interaction



WEAK BONDS...

➤ *Van der Waals Interactions*

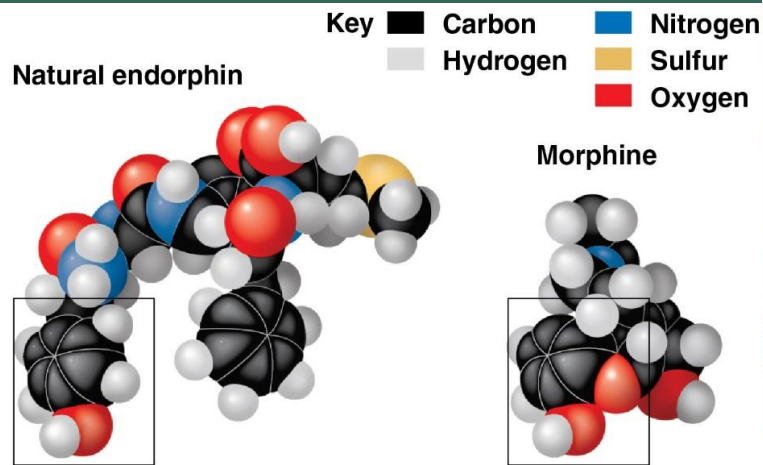
- Slight, fleeting attractions between atoms and molecules when close together
- Weakest bond
- Eg. gecko toe hairs + wall surface



BONDS

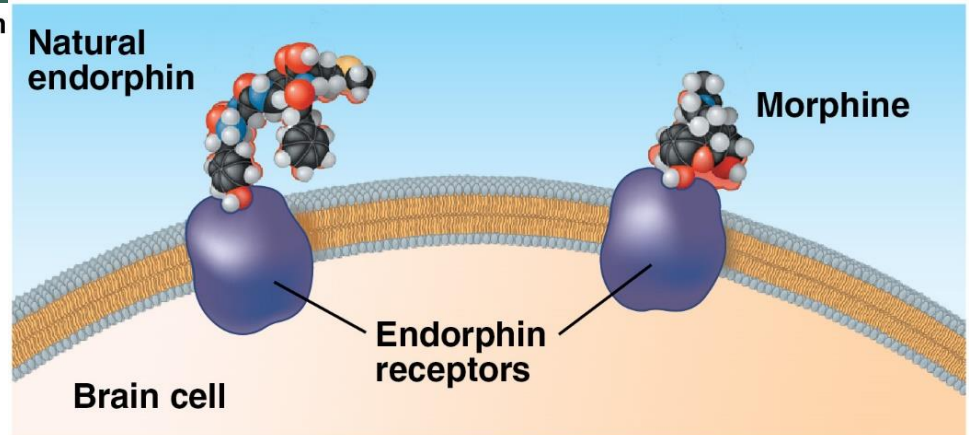
Covalent	Ionic	Hydrogen
All important to life		
Form cell's molecules	Quick reactions/ responses	H atoms bonds to other electronegative atoms
Strong bond	Weaker bond (esp. in H ₂ O – ions*)	Even weaker
Made and broken by chemical reactions		

A MOLECULE'S STRUCTURE (SHAPE) AFFECTS A MOLECULE'S FUNCTION



(a) Structures of endorphin and morphine

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(b) Binding to endorphin receptors

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➤ Similar shaped molecules can mimic one another

- morphine, heroin, opiates mimic natural endorphins
- They can all bind to the same receptor
- They help to block pain



CONCEPT 2.4

CHEMICAL REACTIONS MAKE AND
BREAK CHEMICAL BONDS.

CHEMICAL REACTIONS

- **Reactants → Products**
 - Eg. $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$
- Some reactions are reversible:
 - Eg. $3\text{H}_2 + \text{N}_2 \rightleftharpoons 2\text{NH}_3$
- **Chemical equilibrium**: point at which forward and reverse reactions offset one another exactly
 - Reactions still occurring, but **no net change** in concentrations of reactants/products



CONCEPT 2.5

HYDROGEN BONDING GIVES WATER
PROPERTIES THAT HELP MAKE LIFE
POSSIBLE ON EARTH