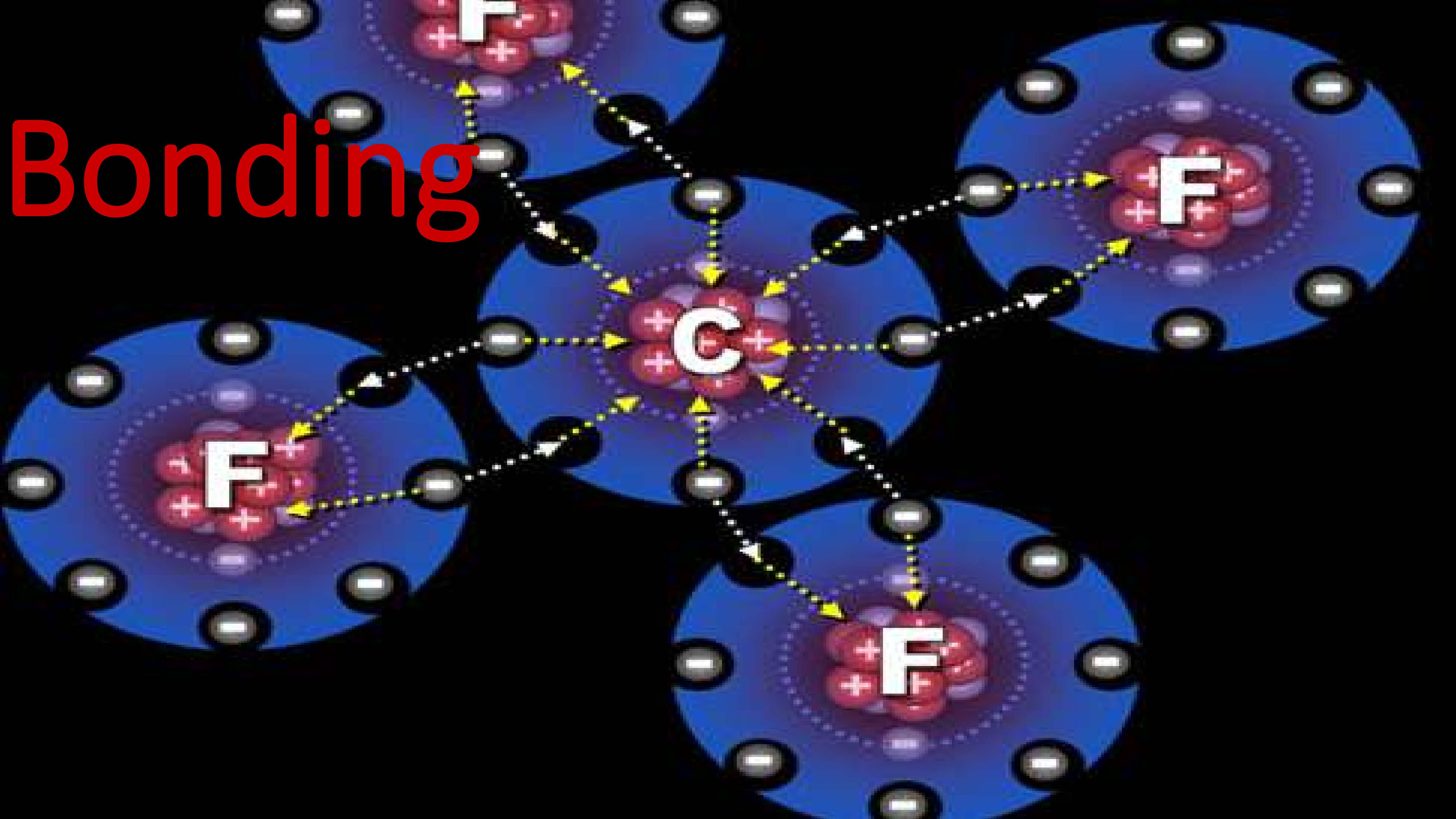
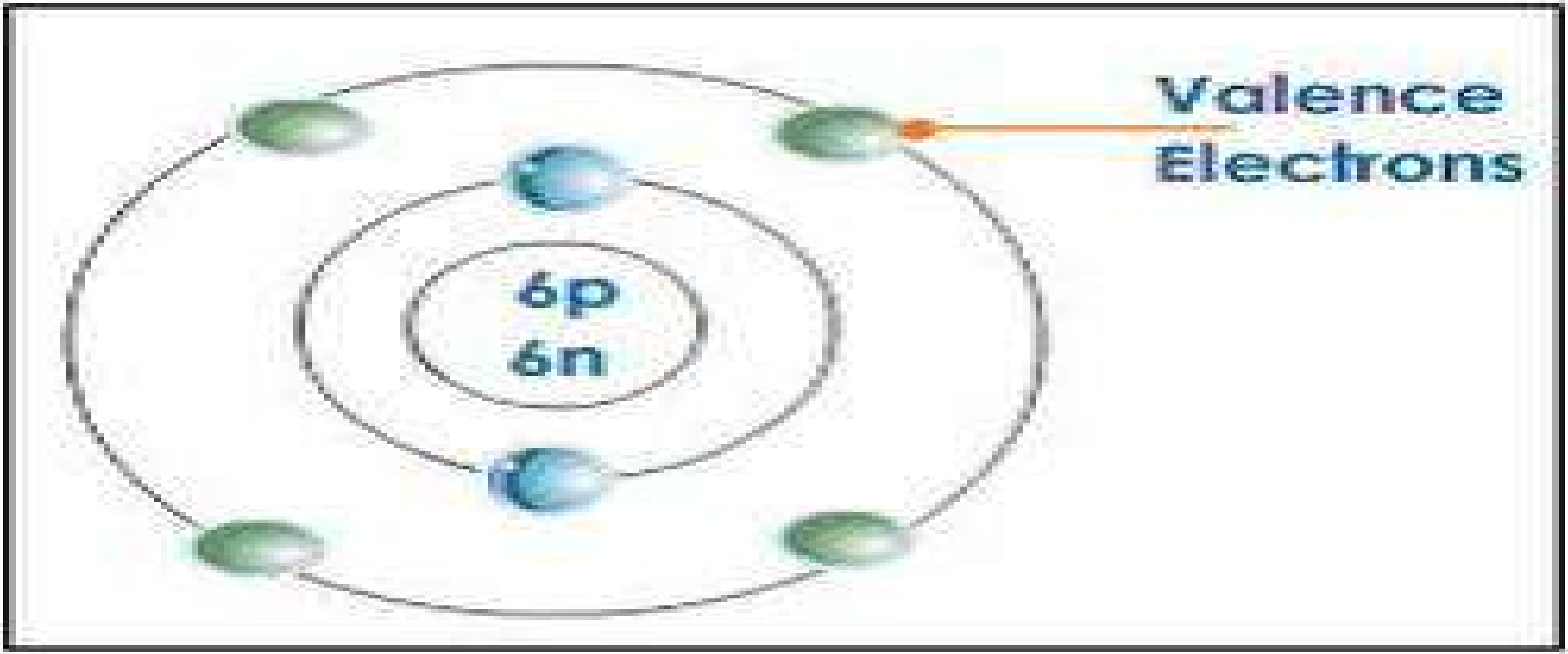
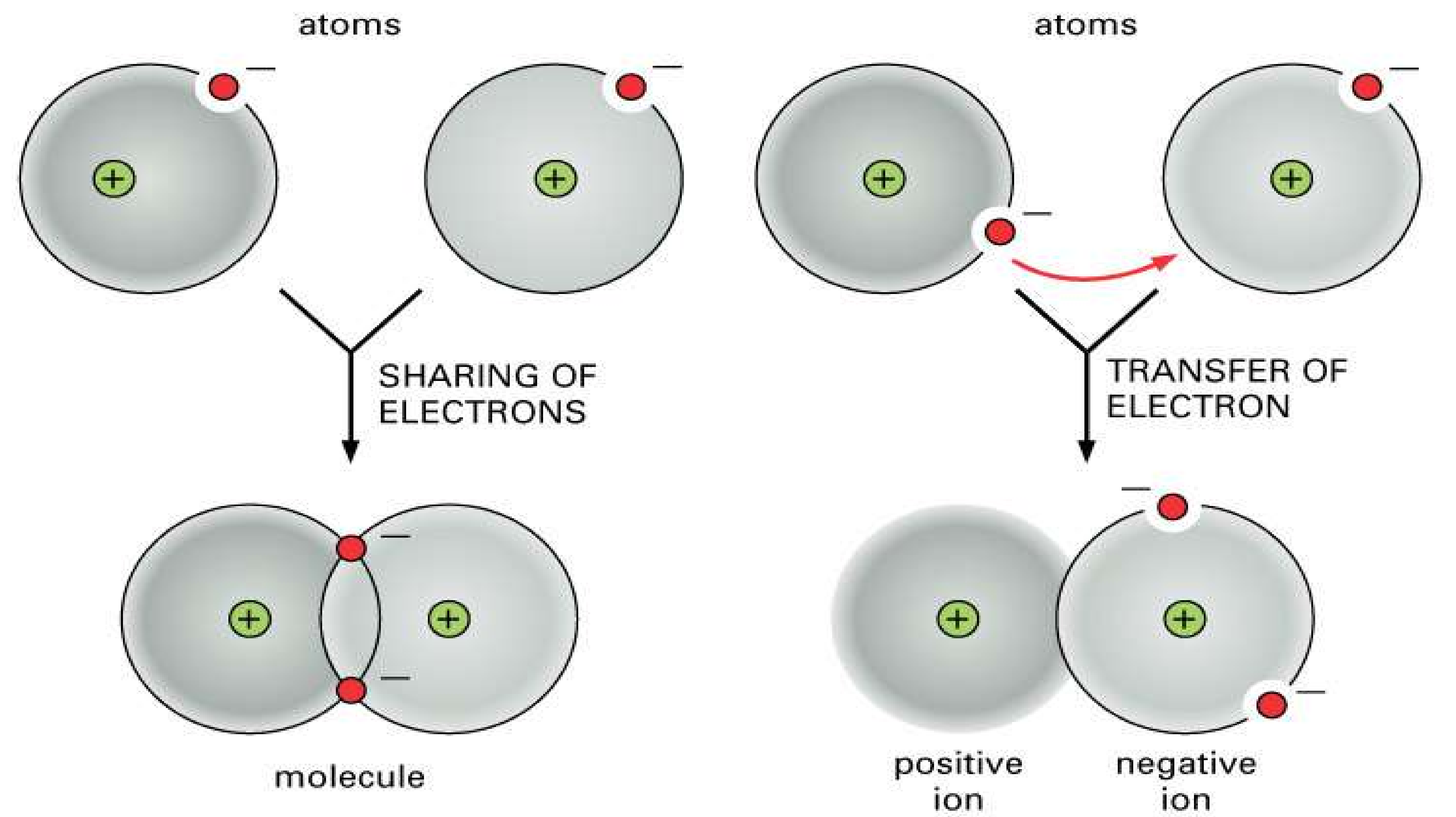
Bonding



A. Why Bond?

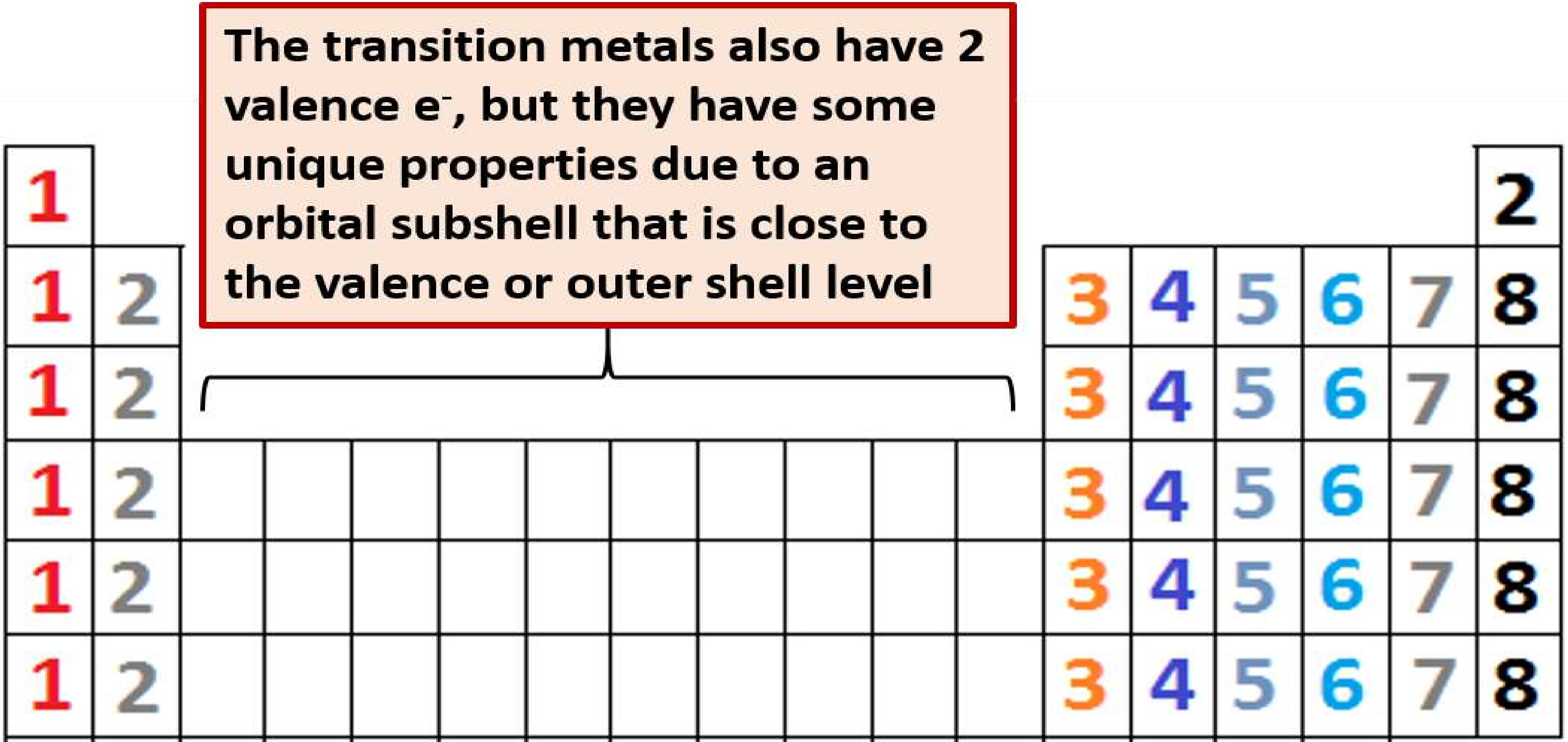
1. Any physical or chemical system tends towards the most stable state of being.
2. In chemicals this means that the outer, valence electron level is full. This can be accomplished when elements that give, take or share their valence electrons.

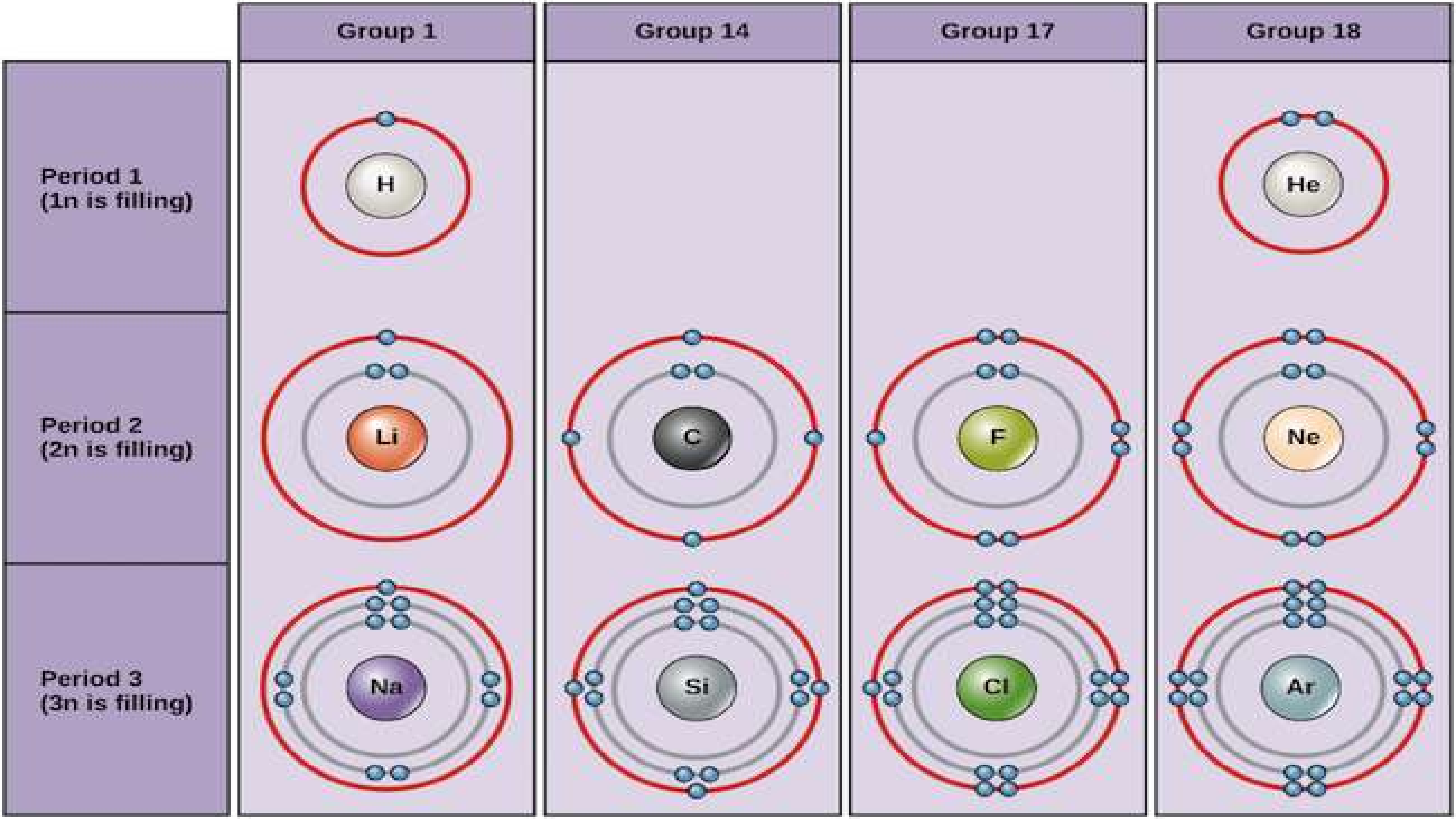




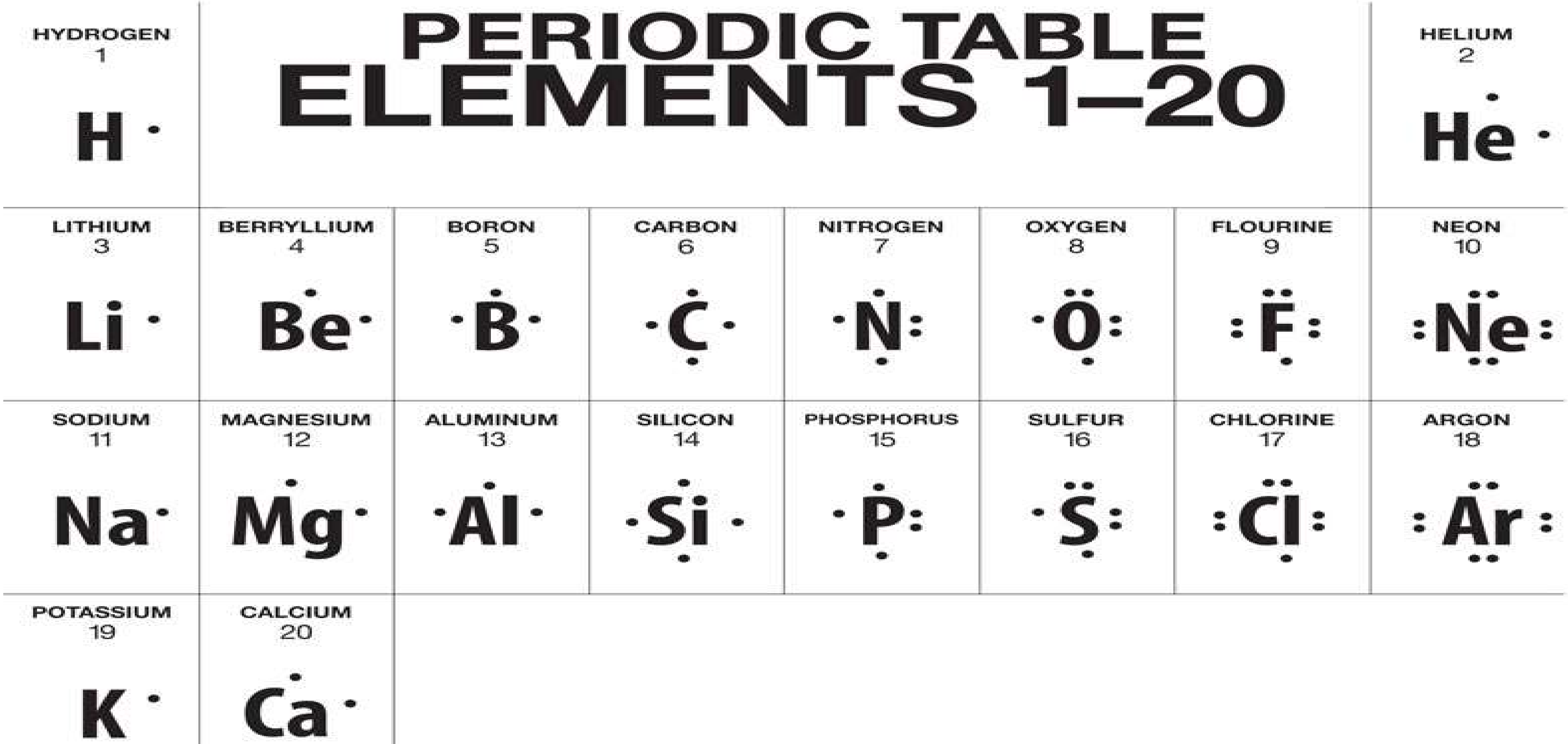
atoms
SHARING OF ELECTRONS
molecule
atoms
TRANSFER OF ELECTRON
positive ion
negative ion

3. The number of valence electrons determines the chemical properties of that element. Members of the same family, vertical column on the periodic table, share chemical properties b/c they all have the same # of valence electrons.




Group 1
Group 14
Group 17
Group 18
Period 1
(1n is filling)
Period 2
(2n is filling)
Period 3
(3n is filling)
H
He
Li
C
F
Ne
Na
Si
Cl
Ar

4. Electron dot structures, AKA Lewis dot structures, can be used to show the number of valence electrons and thus to determine the way an element will bond.



5. Bond Dissociation Energy – the amount of energy need to break a single bond.

High Bond Dissociation Energy
→ low chemical reactivity

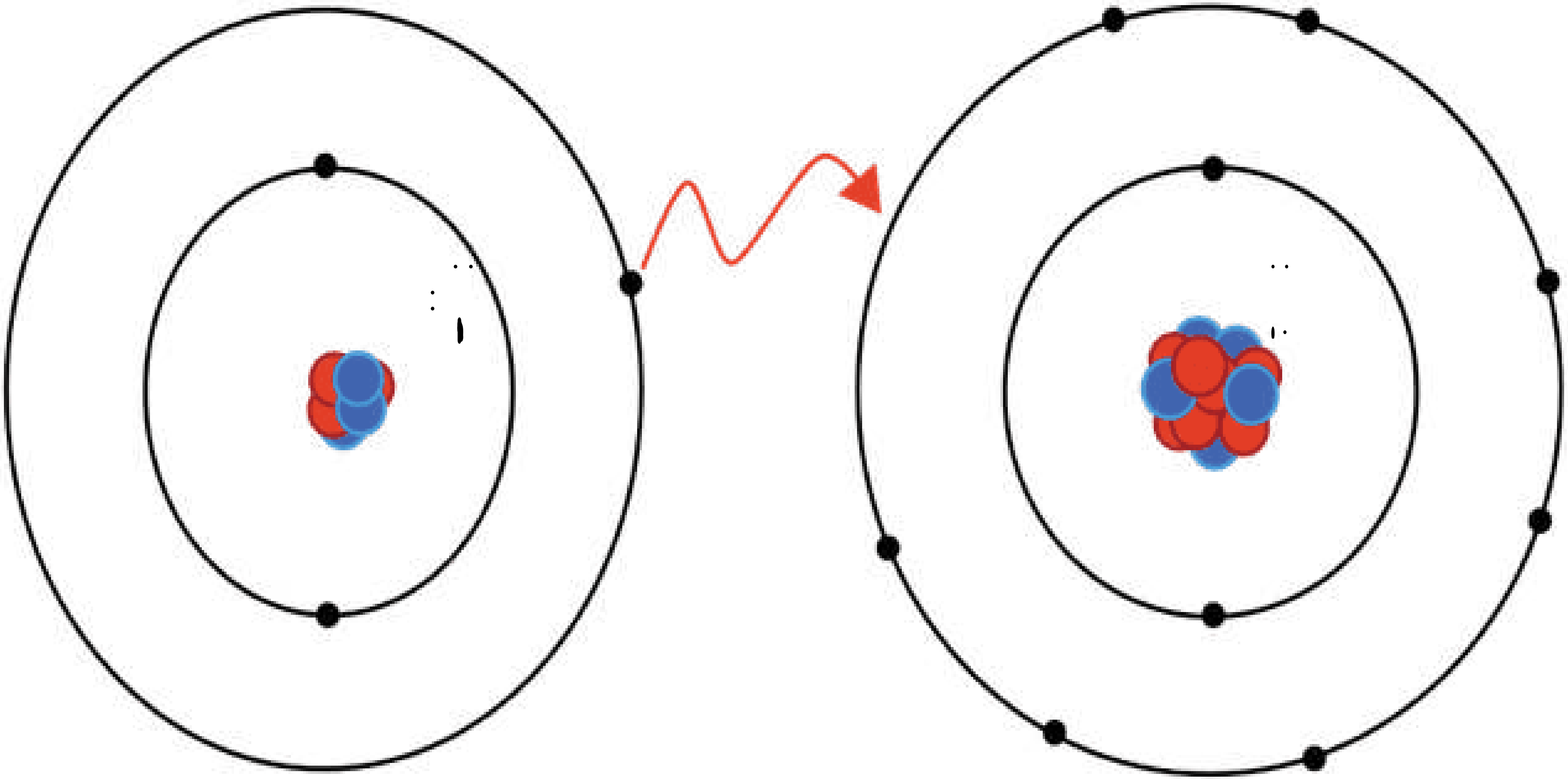
Low Bond Dissociation Energy
→ high chemical reactivity

Bond Lengths and Bond Energies

	Bond Length (nm)	Bond Energy (kJ/mol)
H–H	0.074	435
H–Cl	0.127	431
Cl–Cl	0.198	243
H–C	0.109	414
C–Cl	0.177	328
C–C	0.154	331
C=C	0.134	590
C≡C	0.120	812
C–O	0.143	326
C=O	0.120	803
C≡O	0.113	1075
N–N	0.145	159
N=N	0.125	473
N≡N	0.110	941

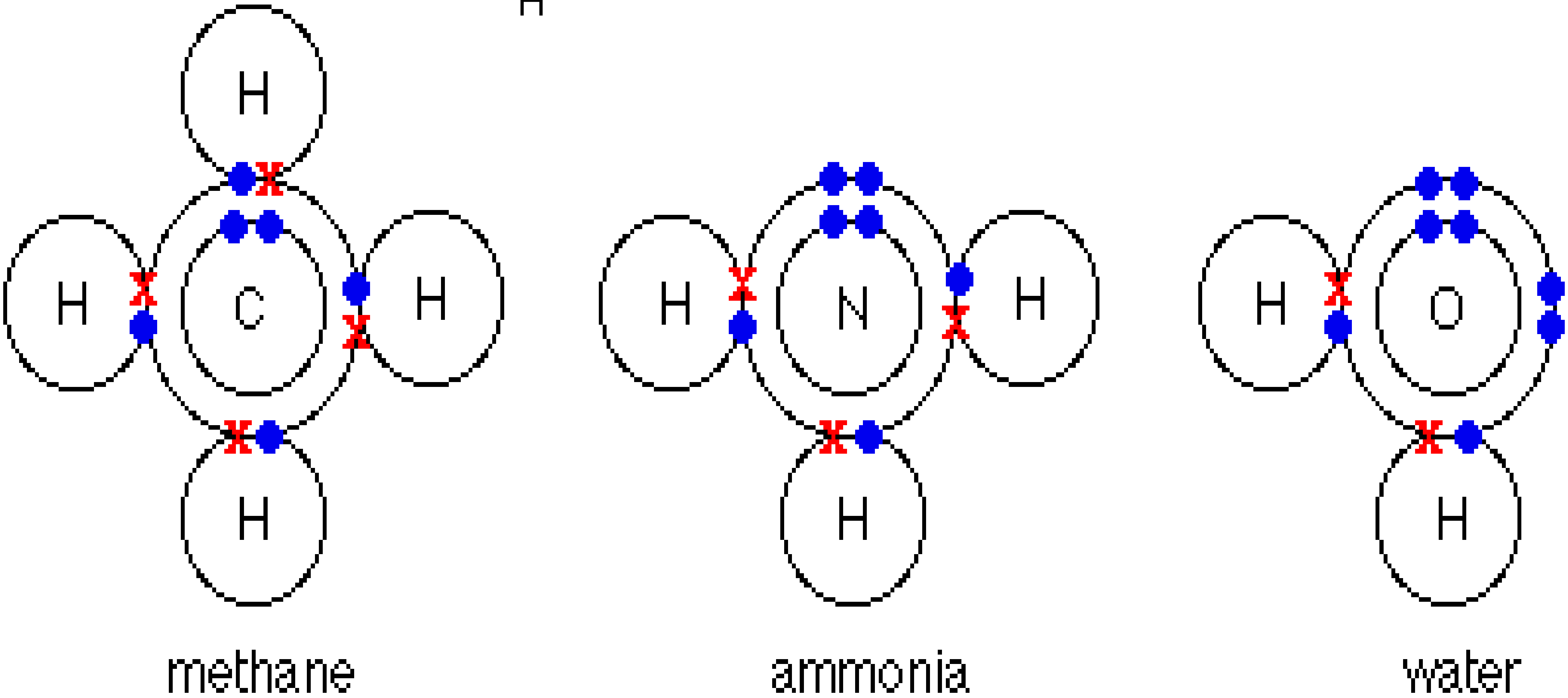
B. Types of Bonds

1. **Ionic-** formed by the giving or taking of valence electrons creating the electrostatic attractive forces binding oppositely charged ions.
   EX- Na^{+1} + Cl^{-1} → NaCl

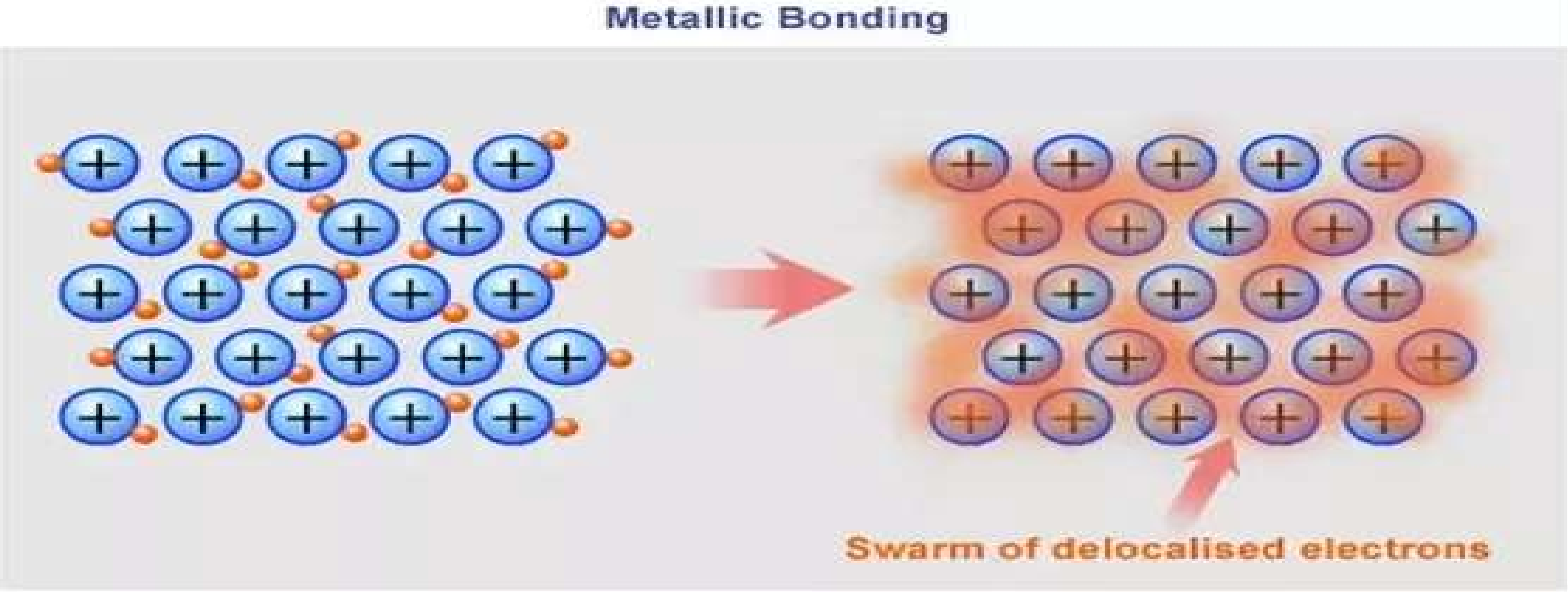


2. **Covalent-** formed by the sharing of valence electrons. Slashes are used to represent bonds.

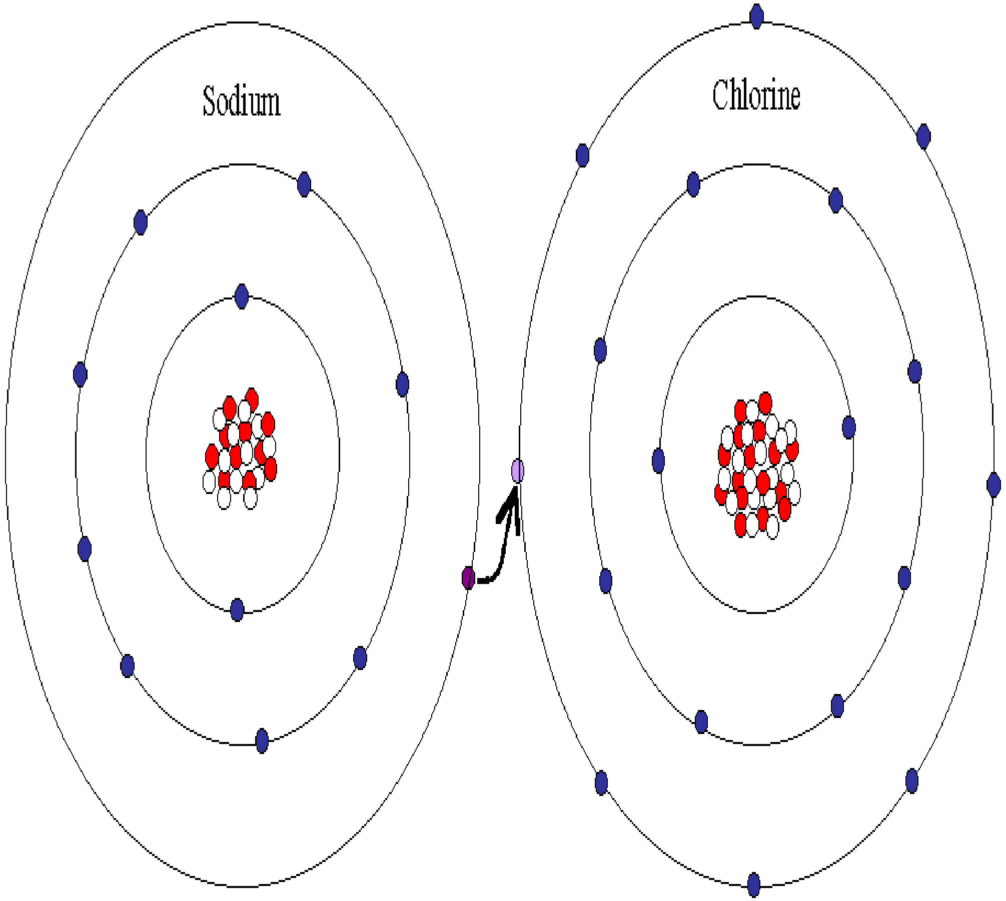
EX – H_2O O-H H or CO_2 C=O=C

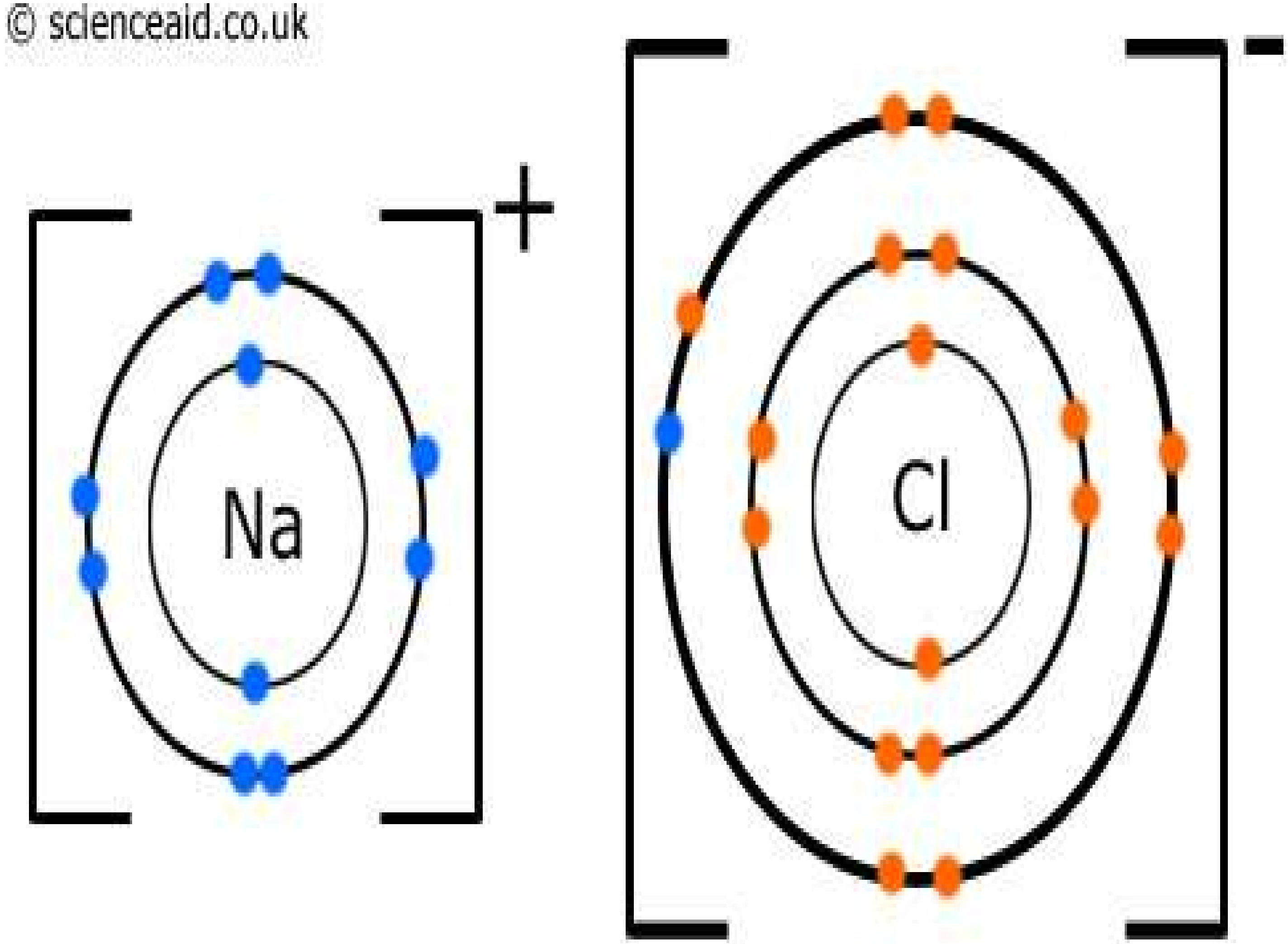


3. **Metallic-** a densely packed section of cations surrounded by free floating valence electrons that are shared between atoms



The outer electrons are so weakly bound to metal atoms that they are free to roam across the entire metal. Having 'lost' their outer electrons, individual metal atoms are more like positive ions in a swarm of communal electrons.



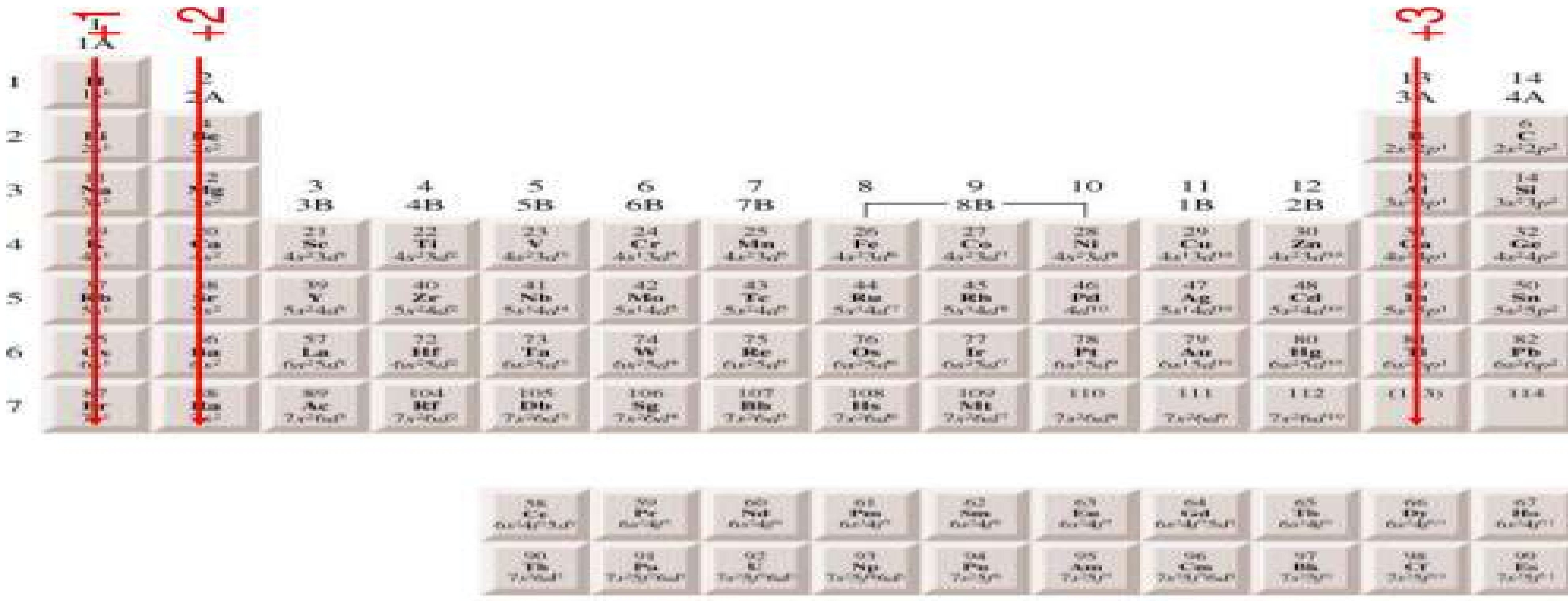


C. Ionic Bonds

1. Properties

a. Formed from a metal and nonmetal which form ions (charged particles) - cations and anions.

Cations and Anions Of Representative E



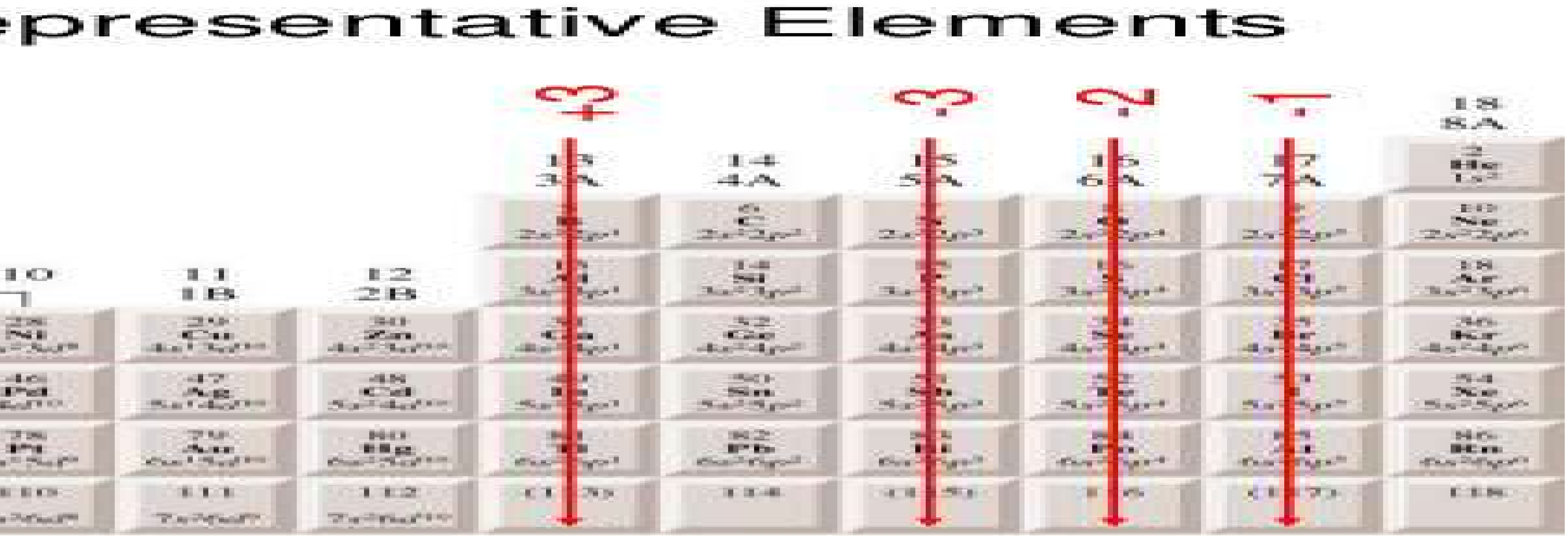
(c) When neutral elements lose negative electrons, they become positive. Groups 1A, 2A, 3A tend to lose electrons to have oxidation numbers of +1, +2, +3 respectively. Oxidation numbers are the charges of the ion.

(2) Anions

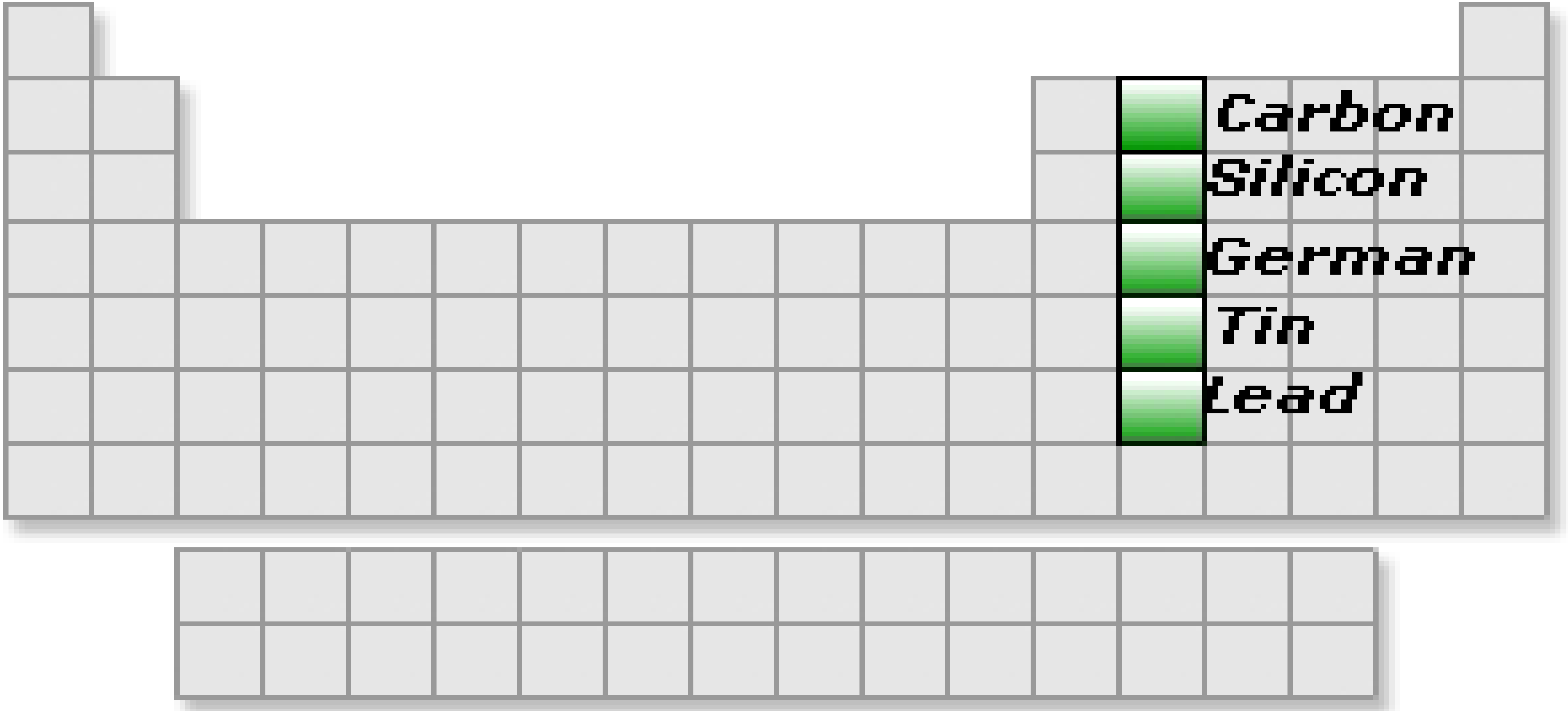
(a) An anion is an atom with a negative charge.

(b) Anions are formed when neutral atoms, following Lewis' octet rule, gain 1 or more valence electrons.

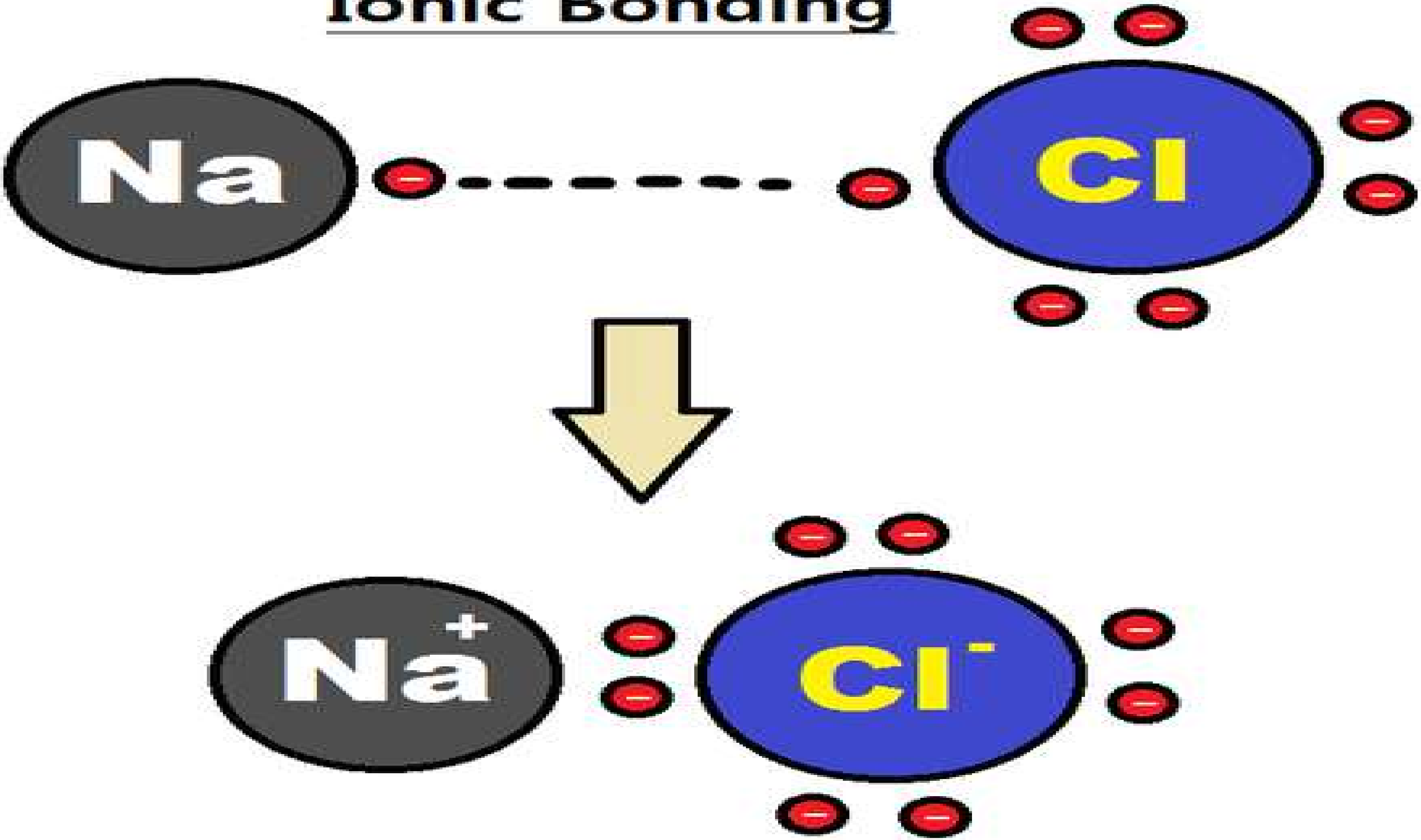
(c) When neutral elements gain negative electrons, they become negative. Groups 5A, 6A, 7A tend to gain electrons to have oxidation numbers of –3, -2, -1 respectively.



(d) Group 4A – Carbon family. This group, having 4 valence electrons, will either gain or lose 4 electrons to attain an oxidation number -4 or +4.

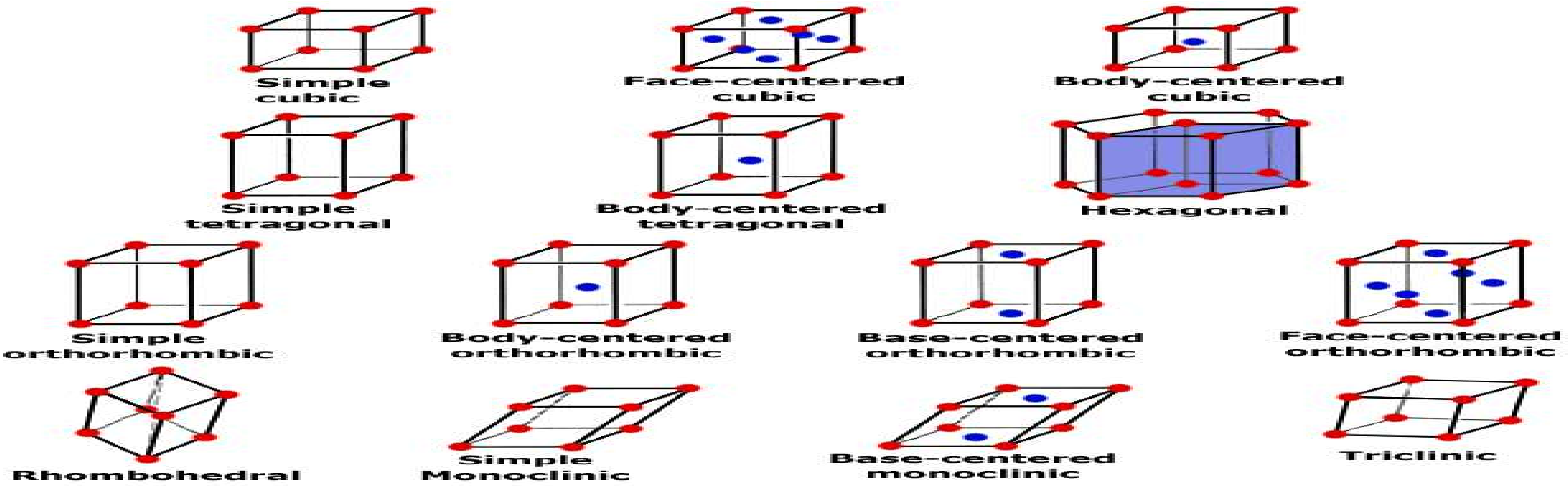


Ionic Bonding



More ionic bond properties

b. Most are crystal lattices – repeating 3-D patterns. Why? Salt crystals, such as NaCl, are repeating patterns of positive and negative ions held together by electrostatic attraction.
c. Very stable.
d. High melting points.
e. Good electrical conductors in solution.
f. Generally soluble.



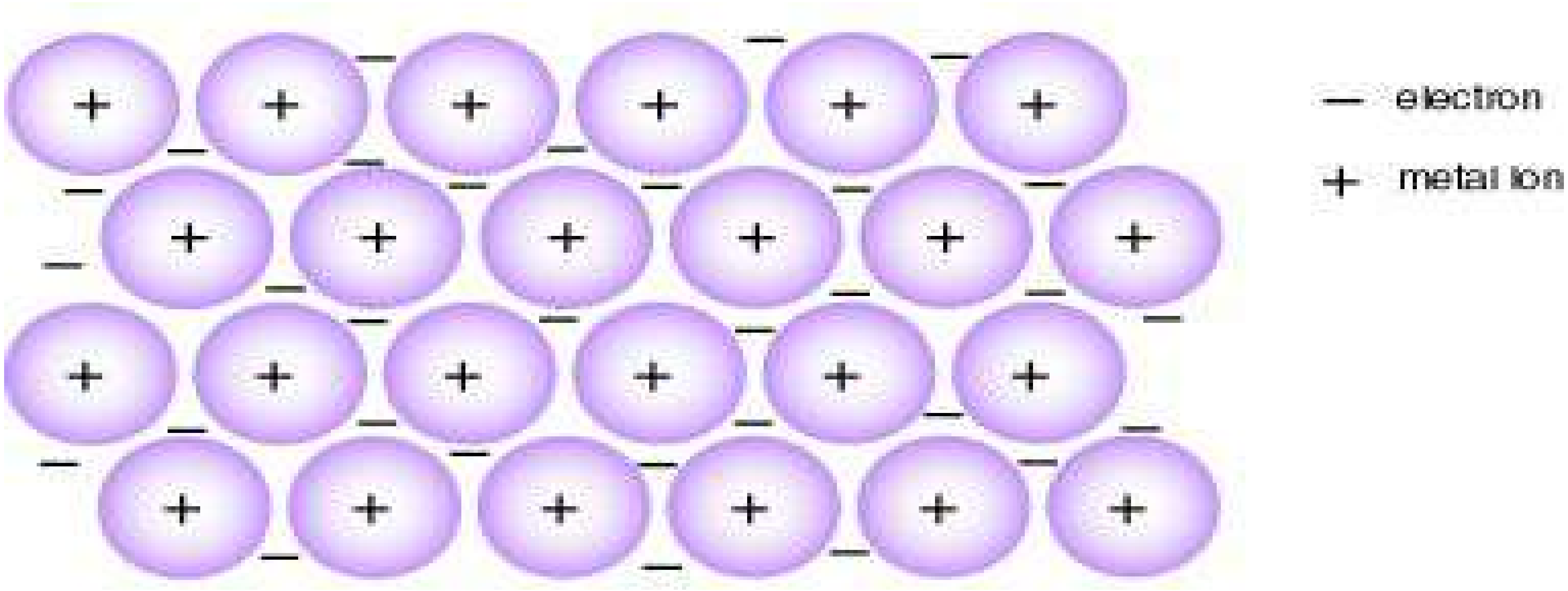
D. Metallic Bonds

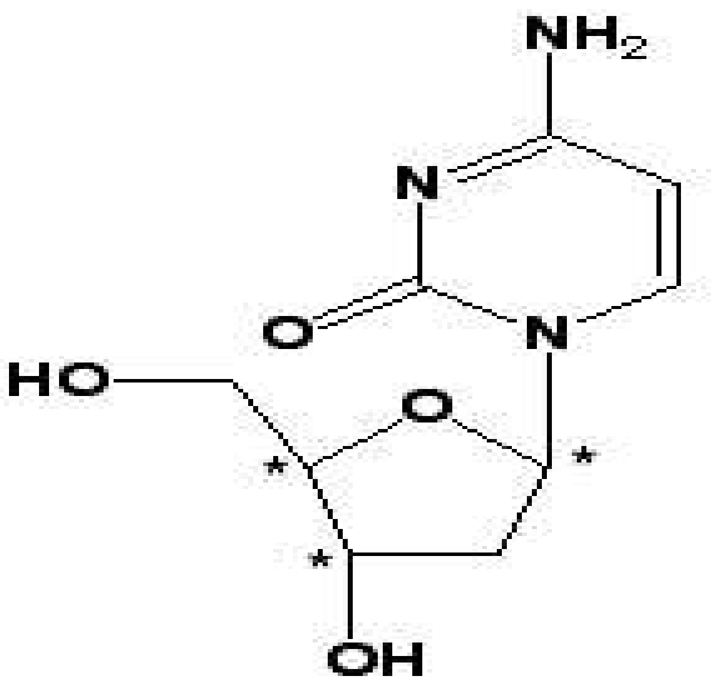
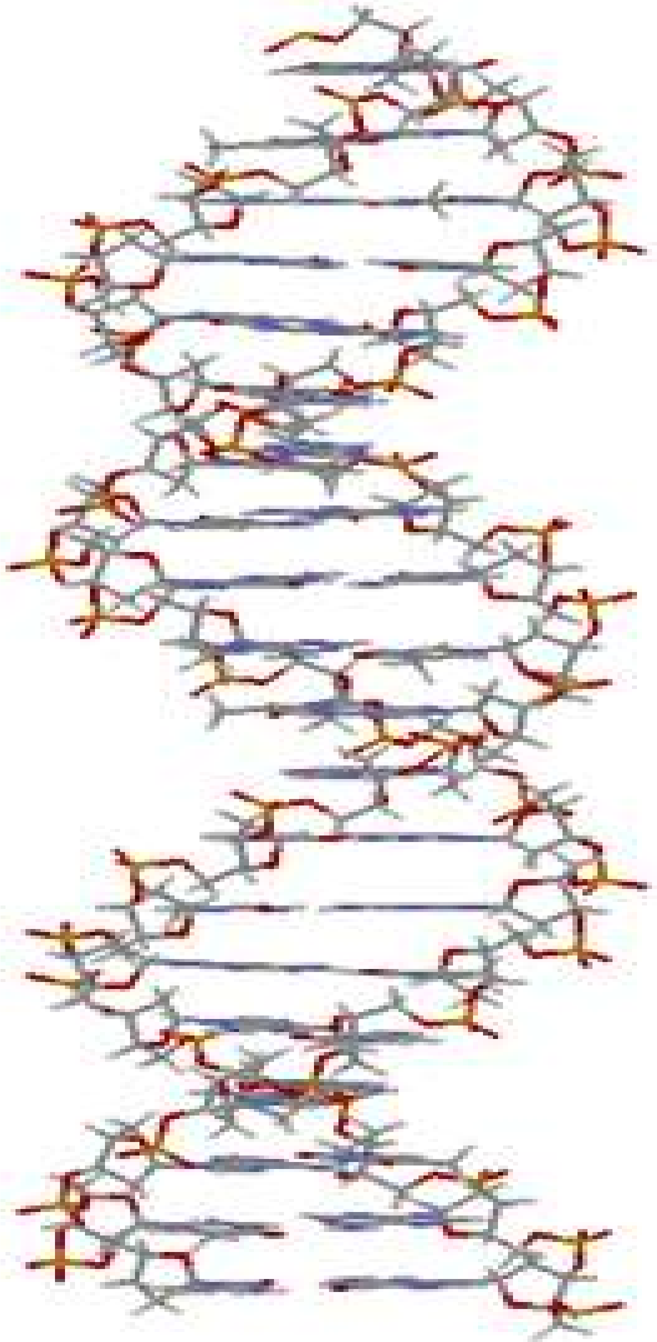
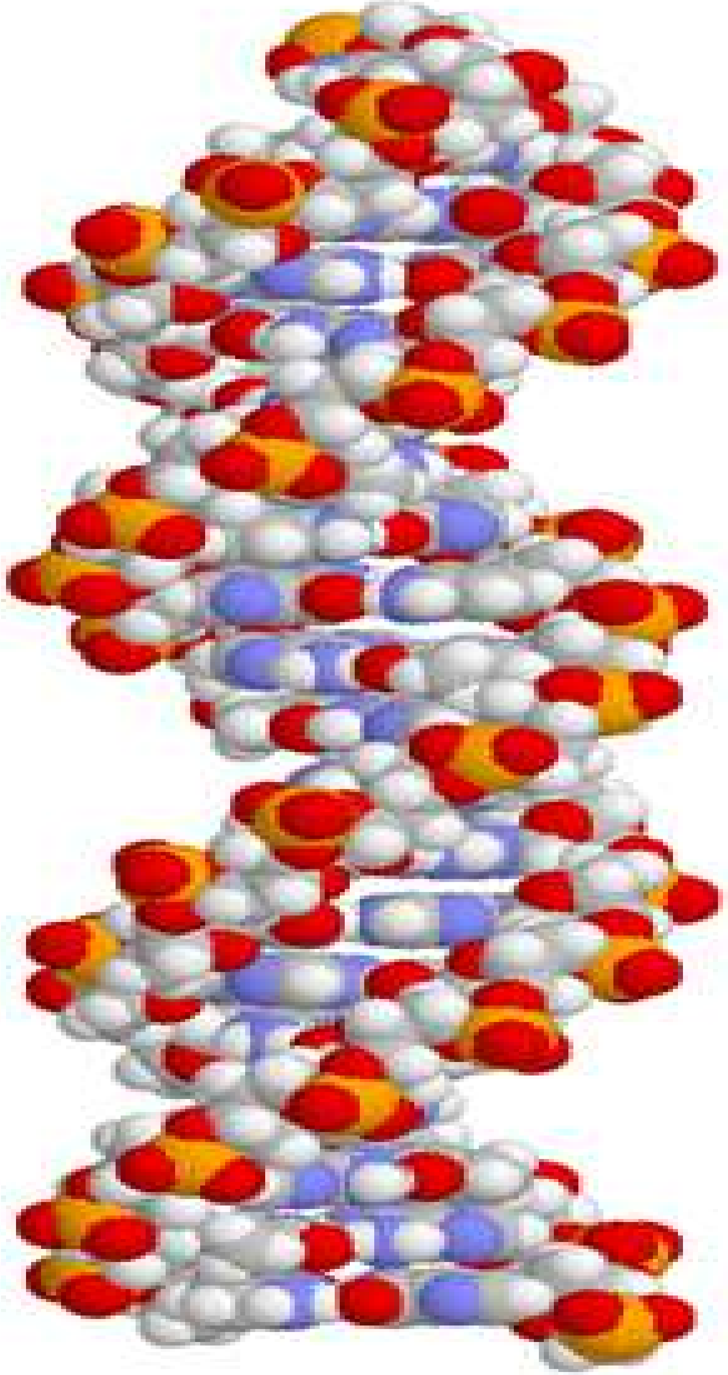
1. Properties

a. Excellent conductors of heat and electricity.

b. Ductile- easily drawn into wires.

c. Malleable- bendable/ shapeable.




NH2
N
O
N
HO
O
*
*
*
OH



4. Properties

a. Formed between nonmetals.

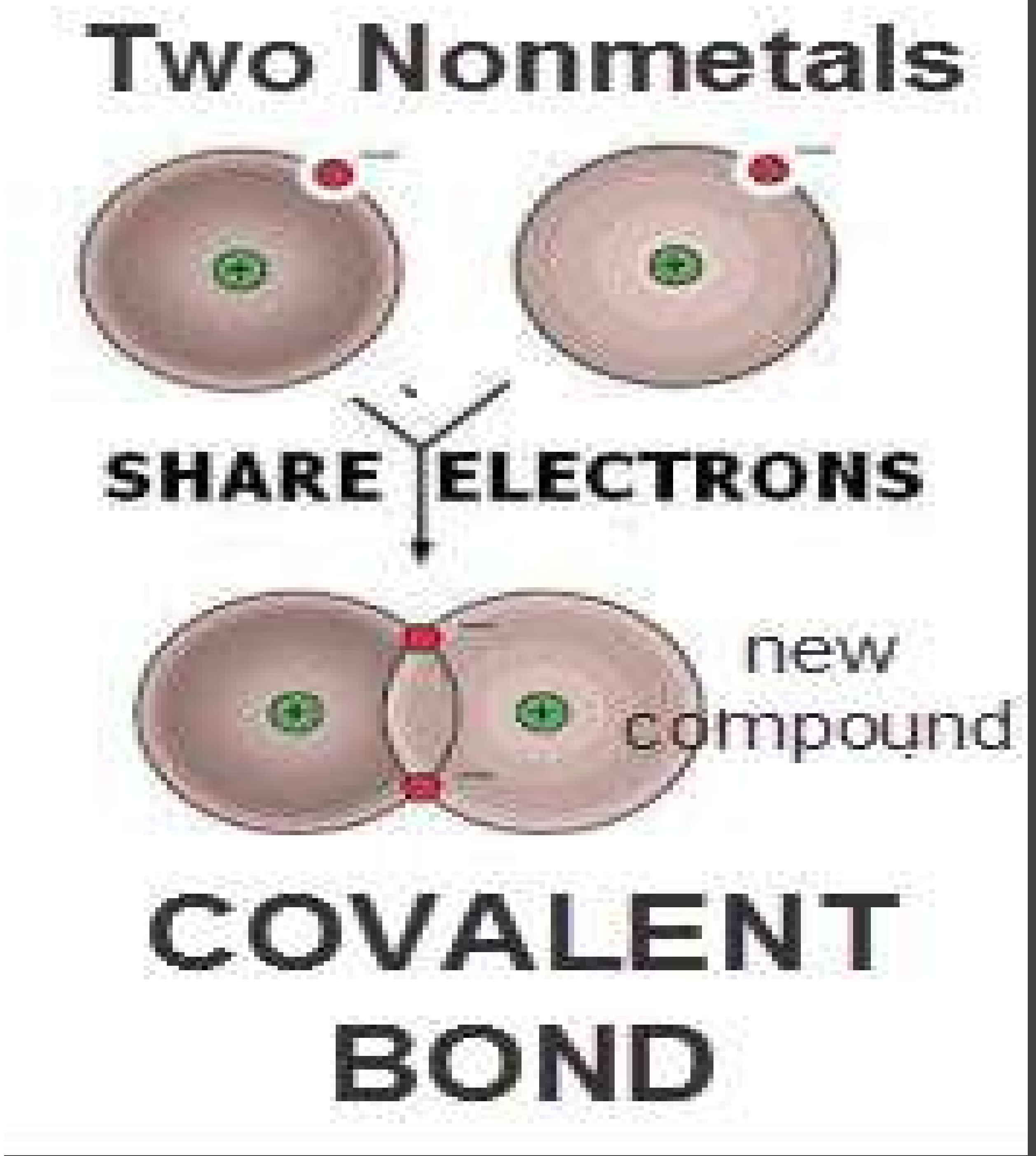
b. Can be in any state of matter.

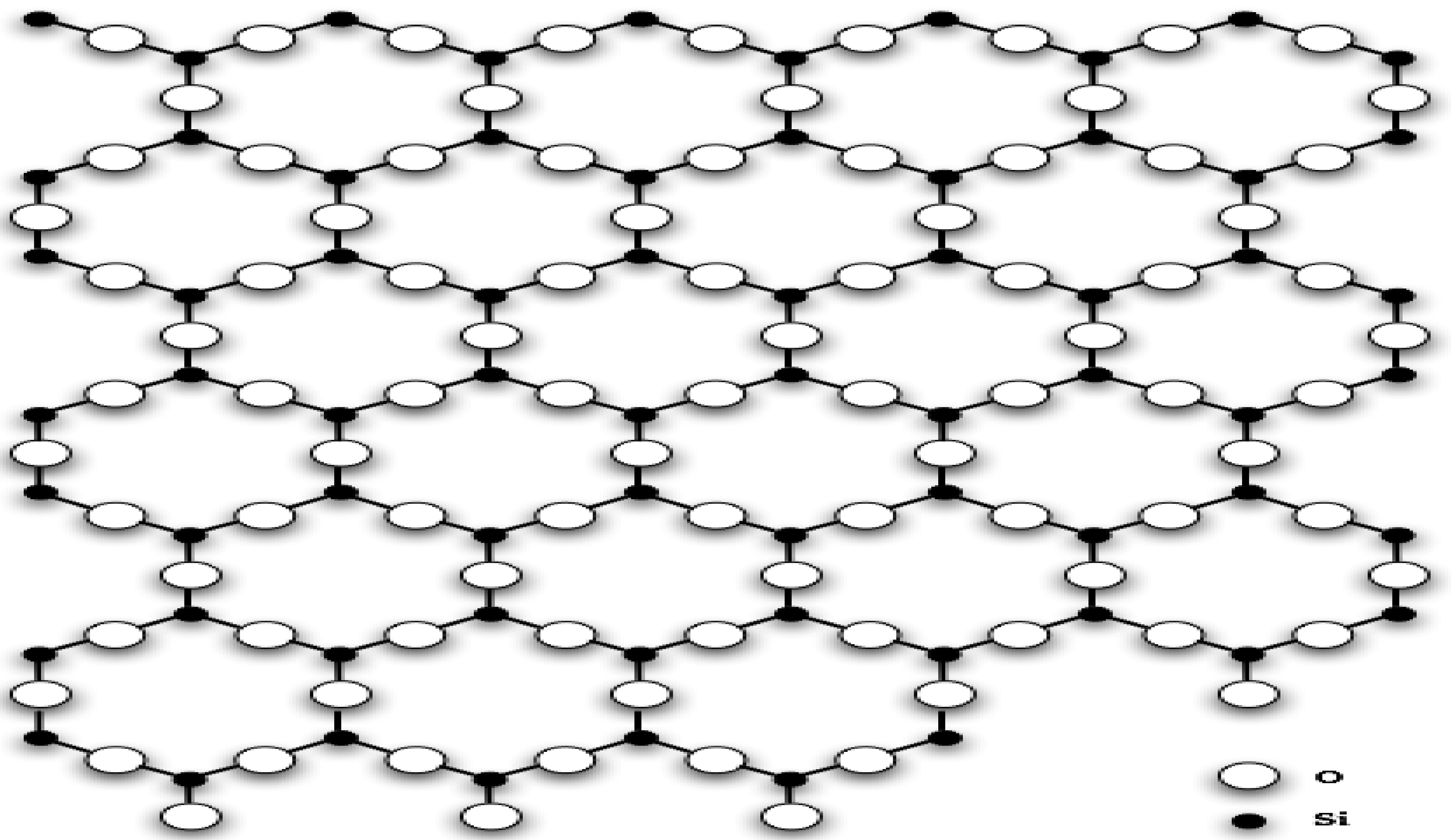
c. Low melting/ boiling points.

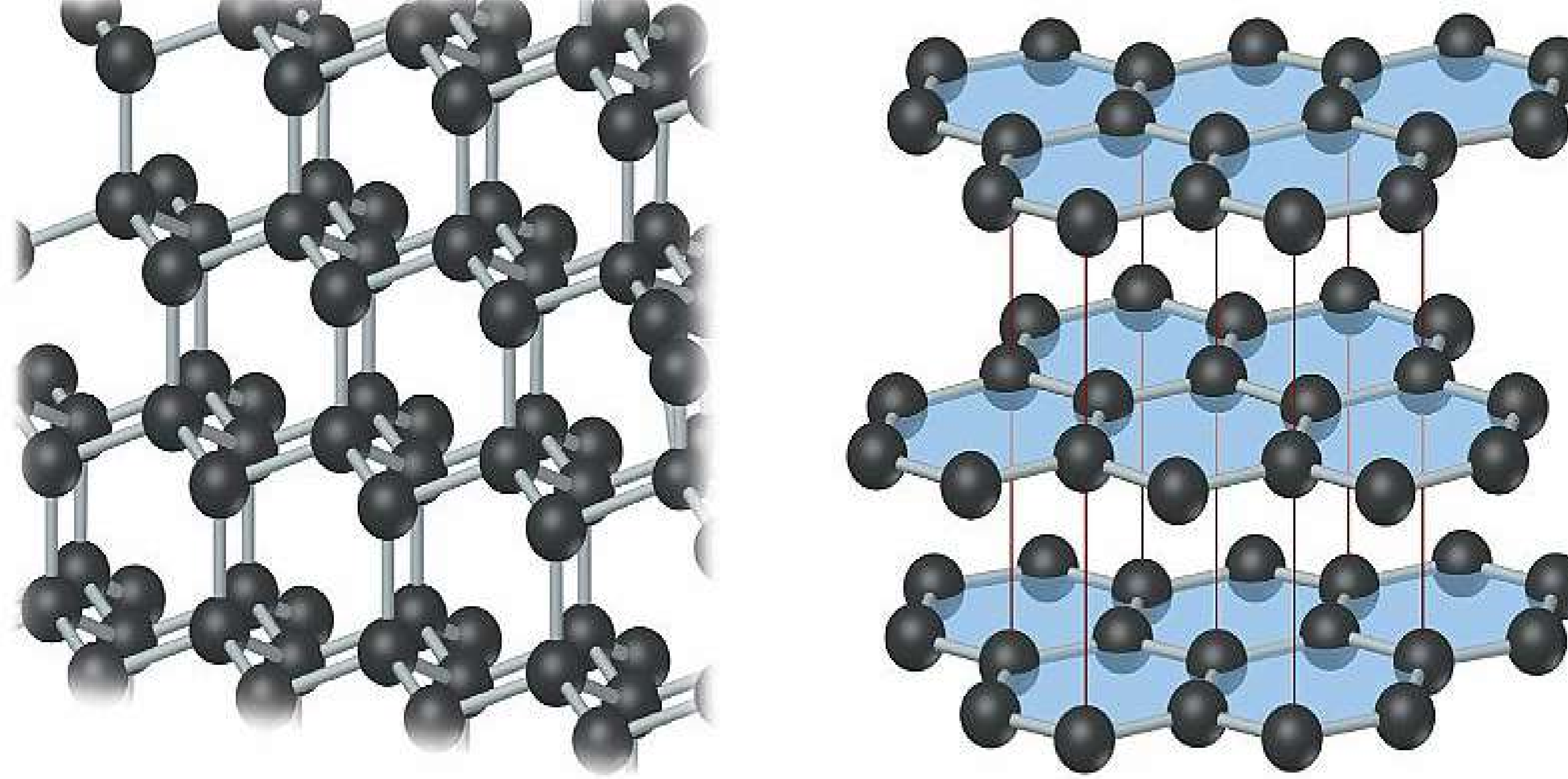
d. No electrical conductivity.

e. Variable solubility

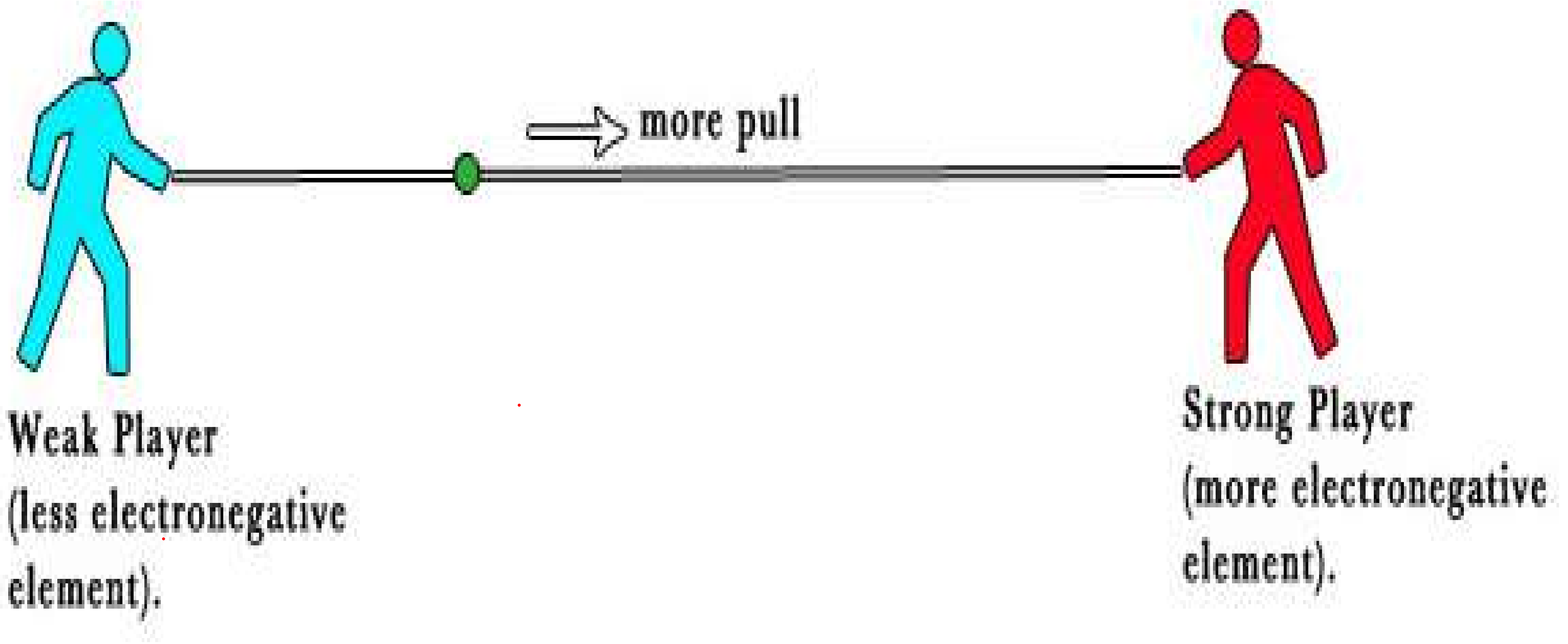
f. Can form a network solid- a very stable molecule in which all atoms are covalently bonded to one another EX- diamond. HOW?




O
Si



(a) Diamond (b) Graphite



5. Types of covalent bonds
   a. The type of covalent bond depends on the number, kind of atoms bonded and the EN difference between the atoms.
      (1) Electronegativity (EN) – the measure of the attraction an atom has for a shared pair of electrons.

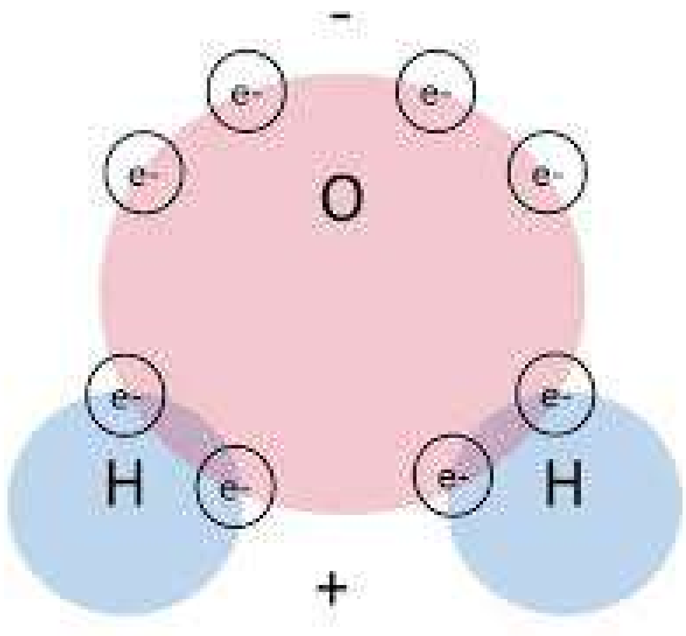
b. When the atoms that are sharing their valence electrons are the different elements, the EN difference is not zero and the electrons are not shared equally between the atoms. This causes one atom (the one with the higher EN) to pull on the shared electrons more strongly than the other. This side of the molecule will tend to keep the electrons more often and be more negatively charged. The opposite is true for the other side. Molecules like this are called polar. If the EN difference equals …

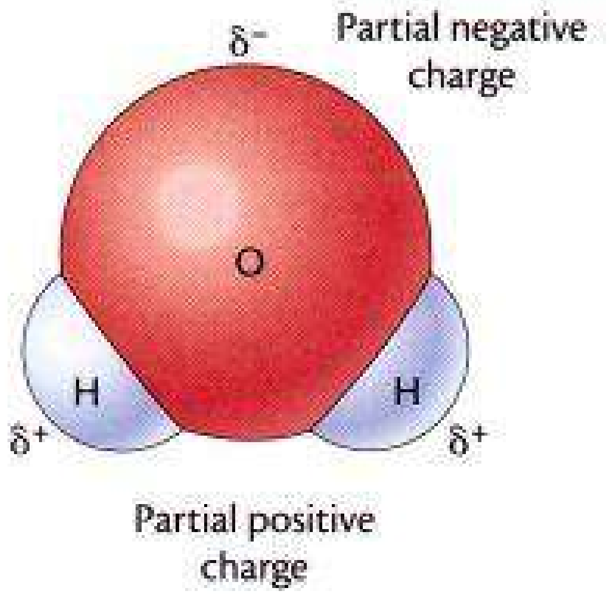
0 - 0.4 → nonpolar covalent

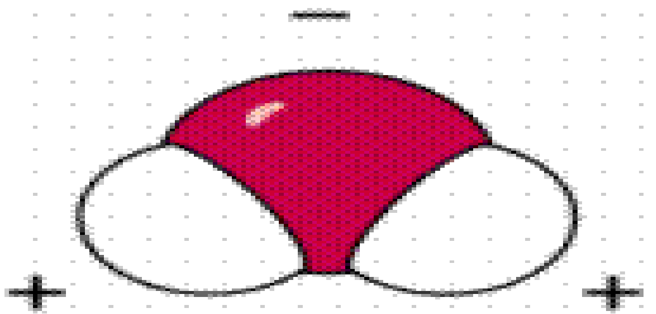
0.41– 1.0 → moderately polar covalent

1.1 – 2.0 → very polar covalent

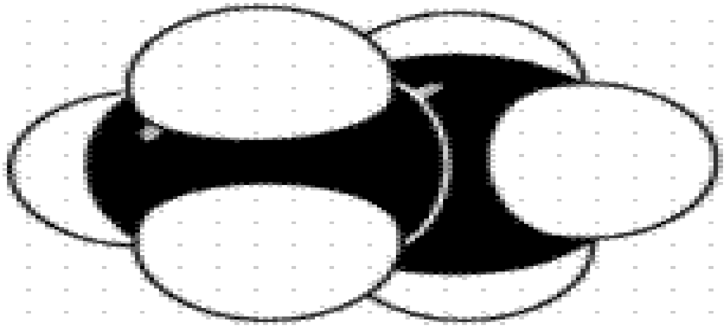
above 2.0 → Ionic bond





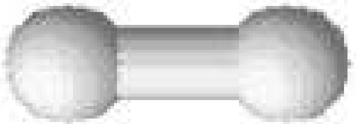
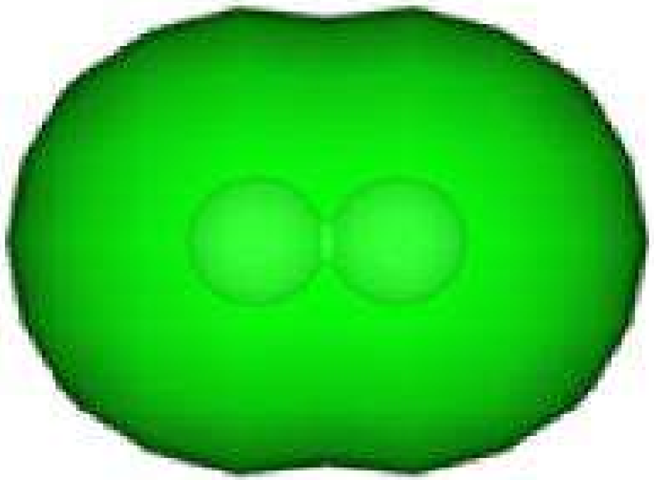
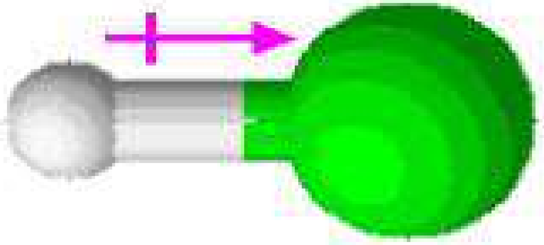
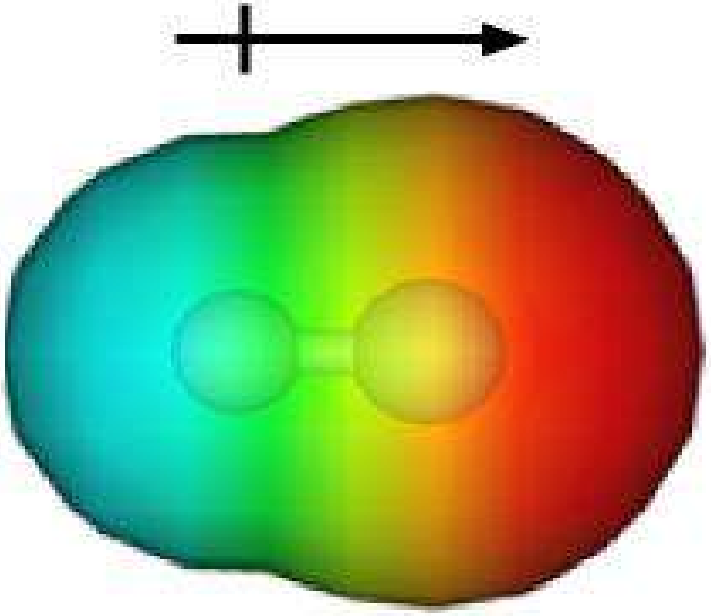


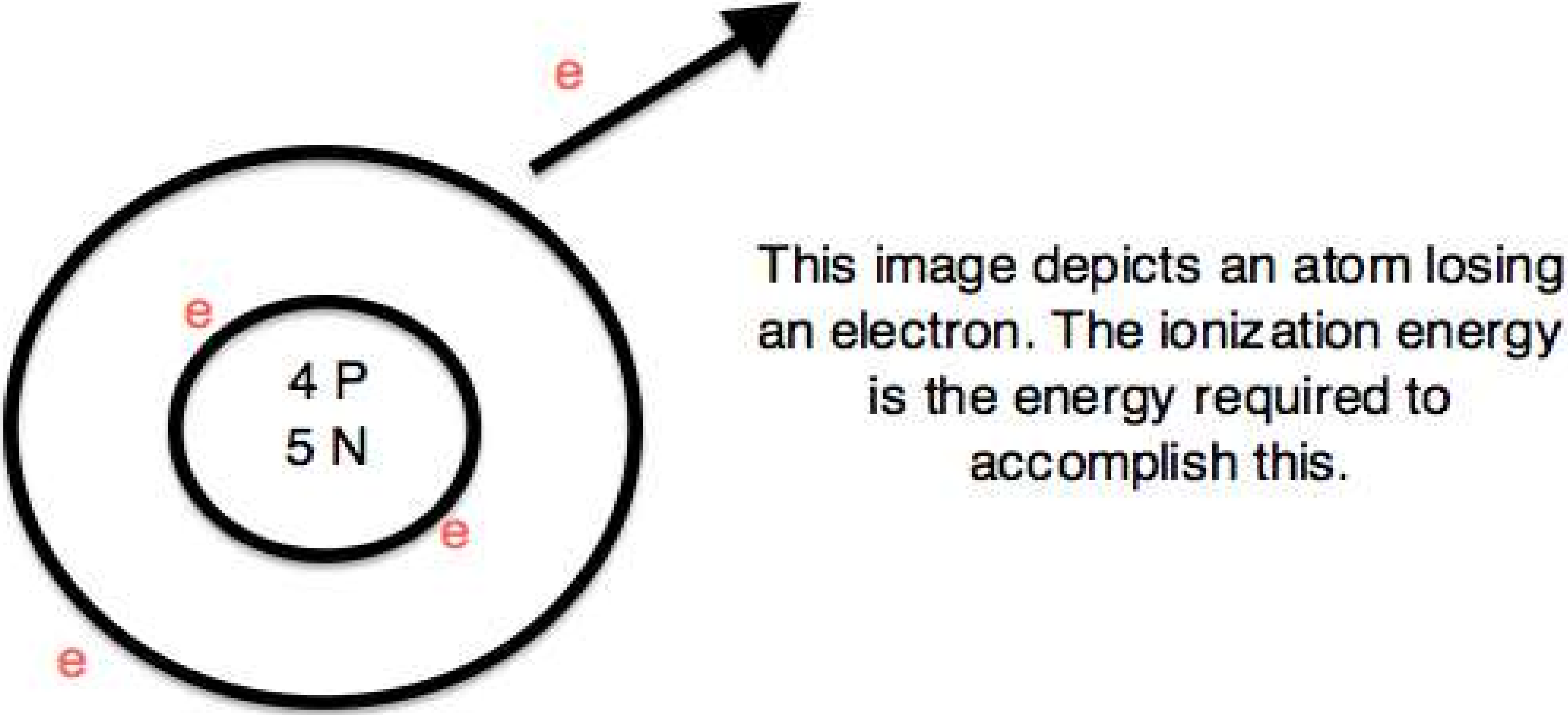
Water, a polar molecule


Ethane, a nonpolar molecule

c. Nonpolar Covalent Bond – when the atoms that are sharing their valence electrons are of the same element or the EN difference is small, the electrons are shared fairly equally between the atoms. There are no poles. ↑ or ↓ EN?

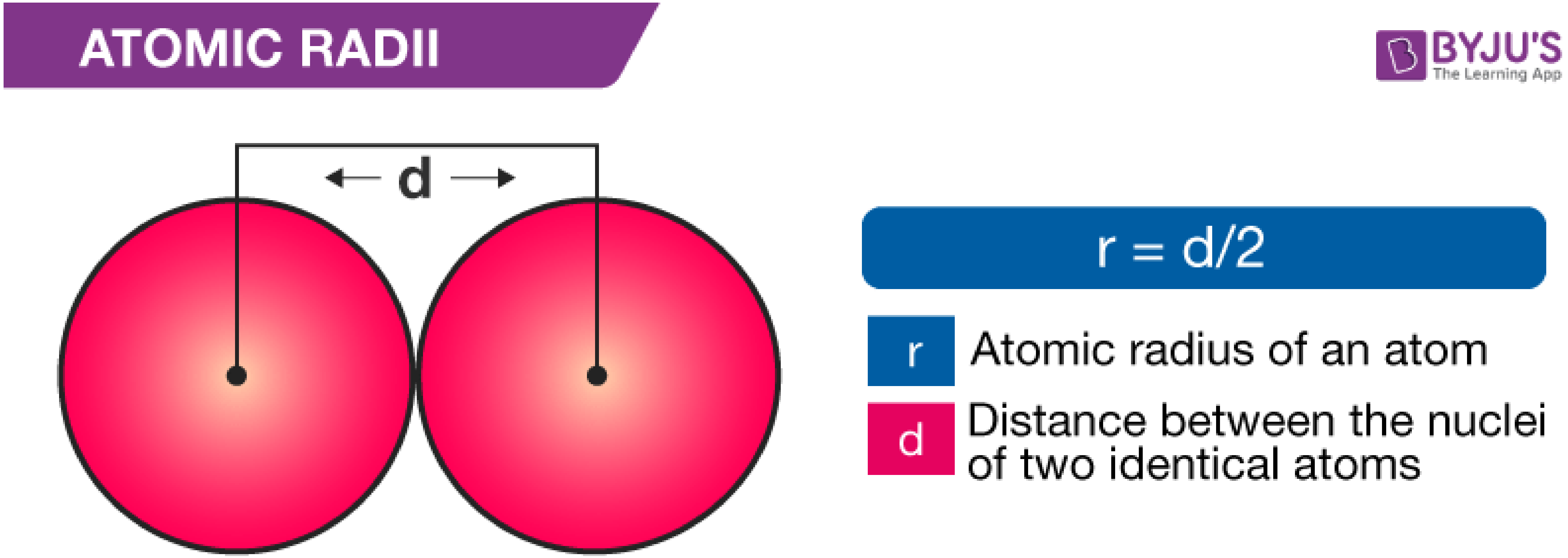
d. A molecule with 2 poles is called a dipole.

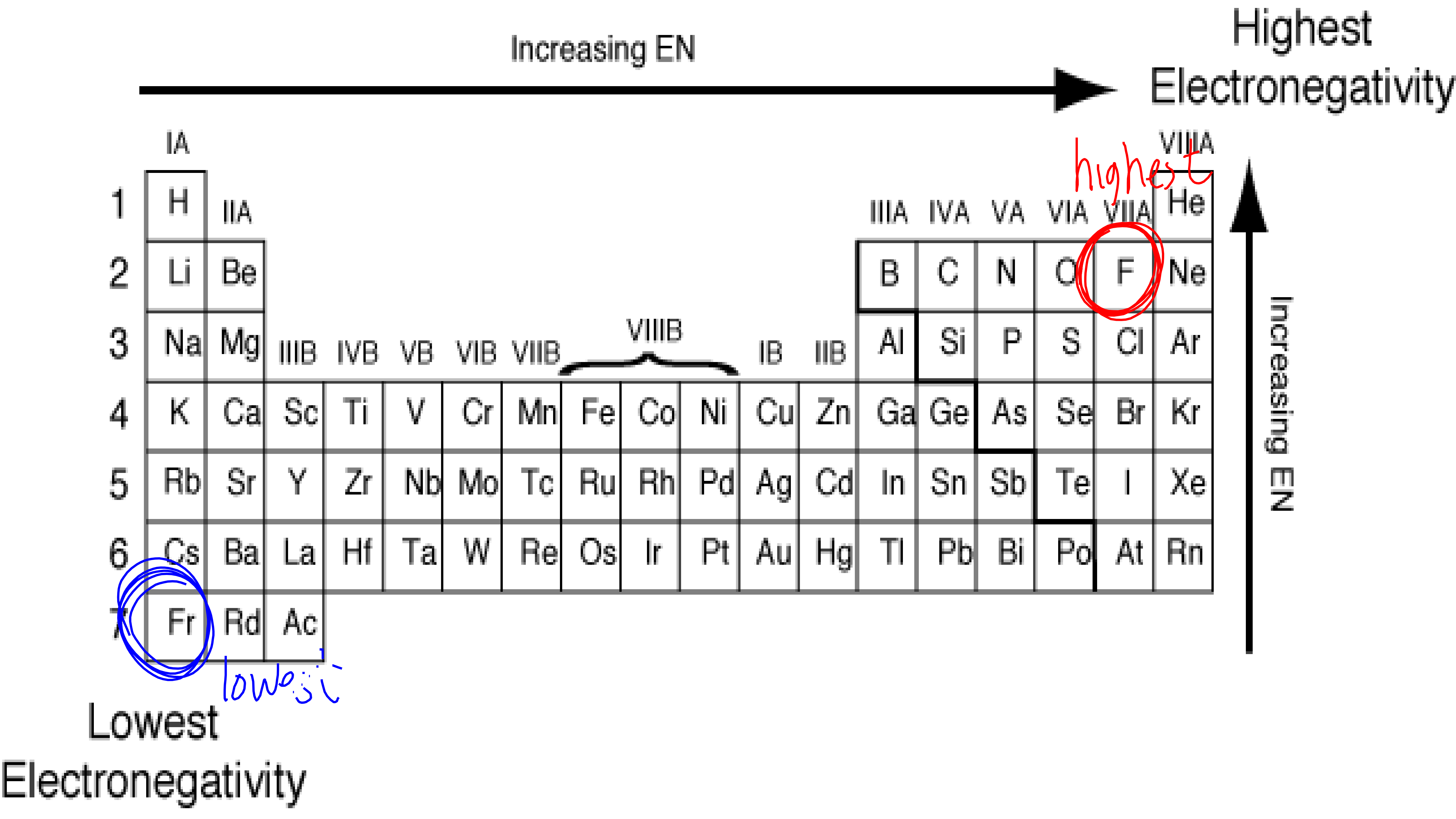
Compound	Bond polarity	Molecule polarity red = most electrons, blue = fewest electrons
Non-polar molecules		
hydrogen, H_2 H — H		 Dipole moment = 0
Polar molecules		
hydrogen fluoride, HF H — $\ddot{\underset{..}{F}}$:		δ+  δ-



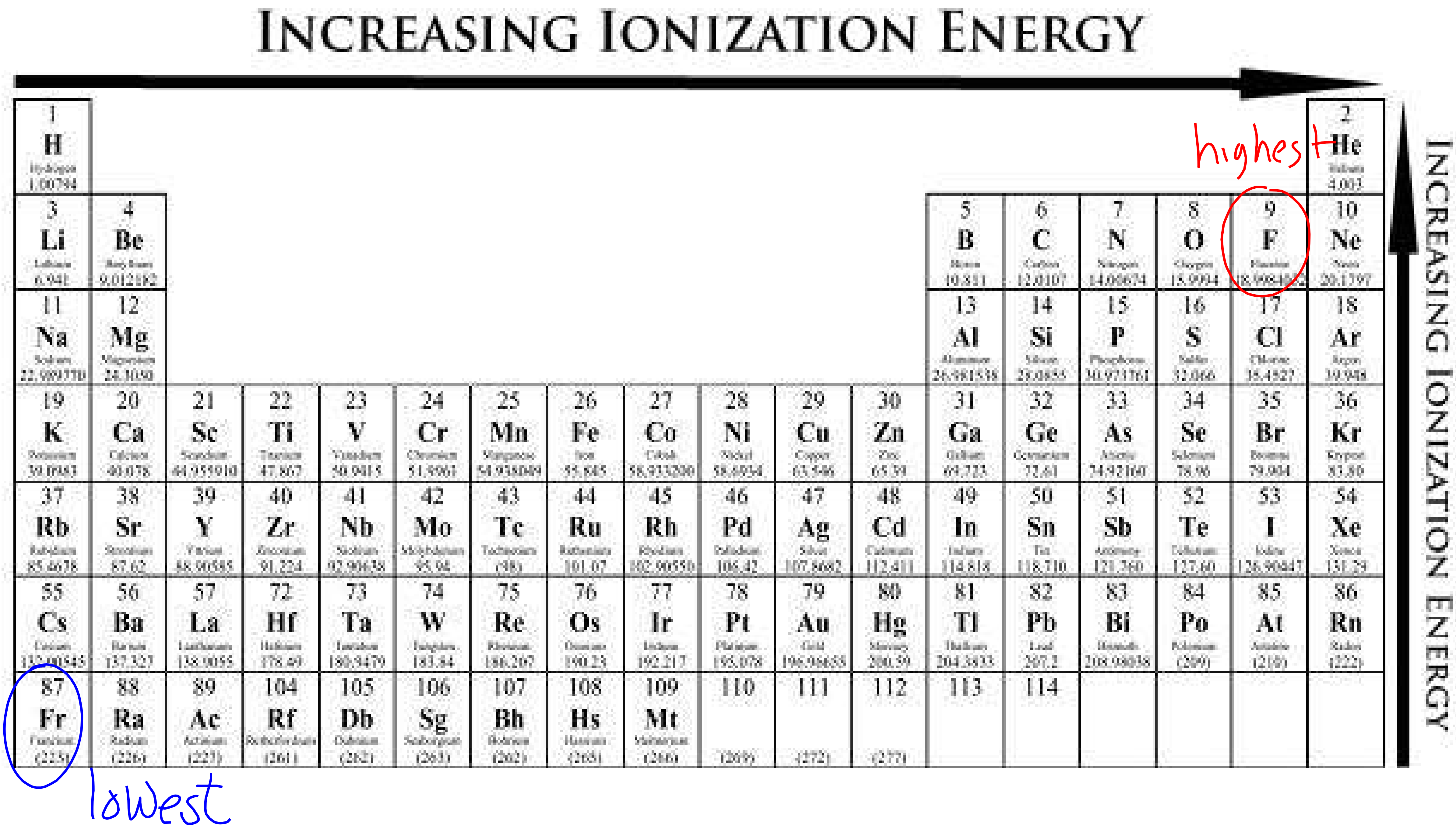
(2) The ionization energy is the amount of energy it takes to take away one electron from a neutral atom. This is sort of opposite what EN is.

(3) Relative sizes of ions and atoms -





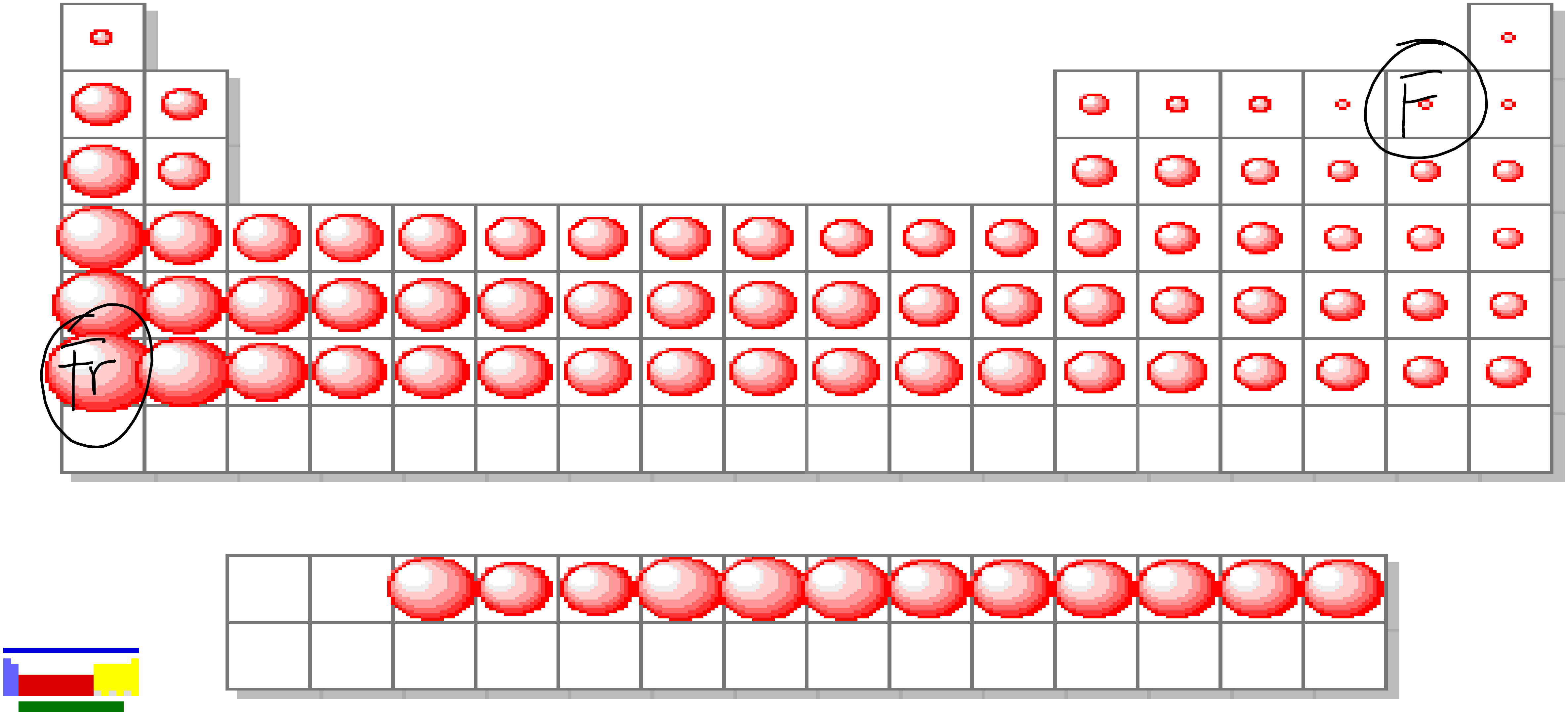
Increasing EN
Highest Electronegativity
highest
IA
IIA
IIIA IVA VA VIA VIIA
VIIIA
IIIB IVB VB VIB VIIB
VIIIB
IB IIB
1 H He
2 Li Be B C N O F Ne
3 Na Mg Al Si P S Cl Ar
4 K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
5 Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
6 Cs Ba La Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
7 Fr Rd Ac
Increasing EN
lowest
Lowest Electronegativity



INCREASING IONIZATION ENERGY
INCREASING IONIZATION ENERGY
highest
lowest
1 H
2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
55 Cs 56 Ba 57 La 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
87 Fr 88 Ra 89 Ac 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 111 112 113 114

WebElements

Atomic radius [pm] coded by ball size



http://www.cassiopeiaproject.com/vid_courses3.php?Tape_Name=Chemistry

Bonds 7:18

F. Intermolecular forces

1. ***Kinetic Theory***

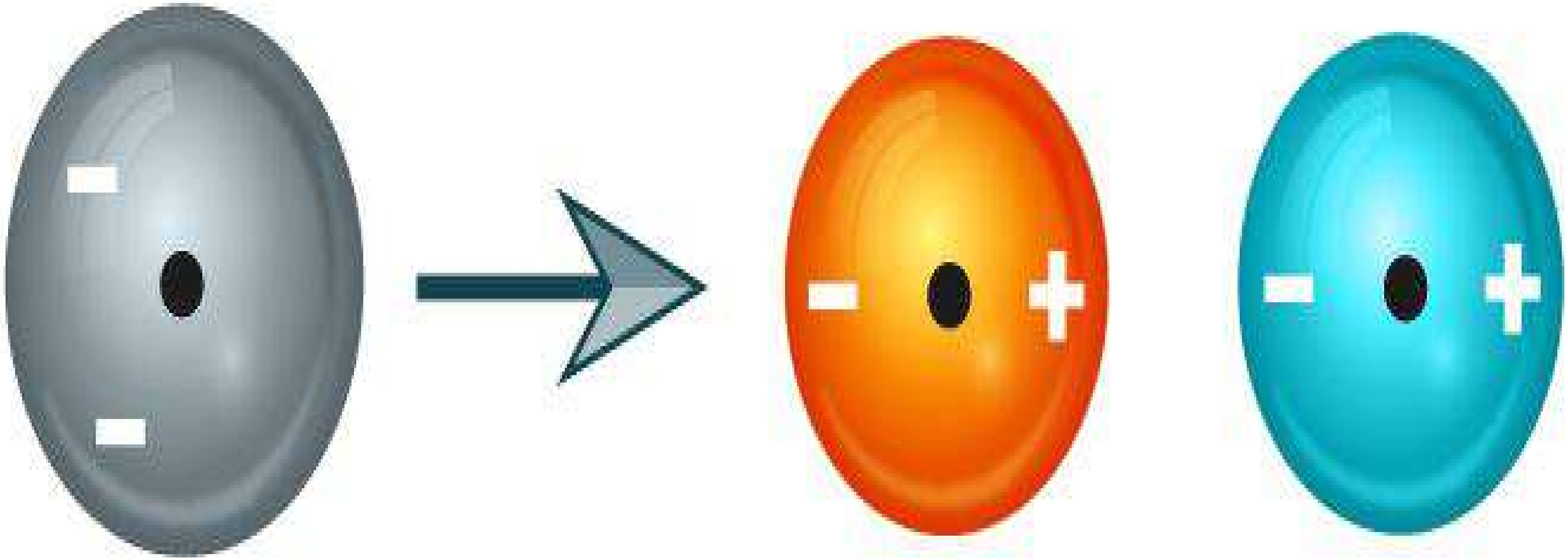
Says that the tiny particles in all forms of matter are all in constant, straight line, random motion. It says that collisions between these particles are perfectly elastic (no loss in energy). Collisions against the container walls produce pressure. The moving particles exert no attractive or repulsive forces upon one another. The energy of the particles' movements depends on the temperature, pressure and volume of the situation. The above model works with gases, but to make sense with solids and liquids, the ***intermolecular forces*** (attractions between separate molecules) must be taken into account.

F. Intermolecular Attractions (IMA)

1. Definition- forces that pull separate molecules together.
2. Types - Van der Waals and hydrogen bonding
   a. Van der Waals

   (1) ***Dispersion forces***- these arise when the temporarily positive pole of one nonpolar molecule is attracted to the temporarily negative pole of another nonpolar molecule. This temporary polarity is caused by the motion of the electrons. In general, the dispersion forces increase with increasing mass because when the mass increases there are more electrons to cause attractions. All molecules have this type of IF because all molecules have electrons. A molecule would only have dispersian if it was nonpolar covalent,having an EN difference of less than 0.4.

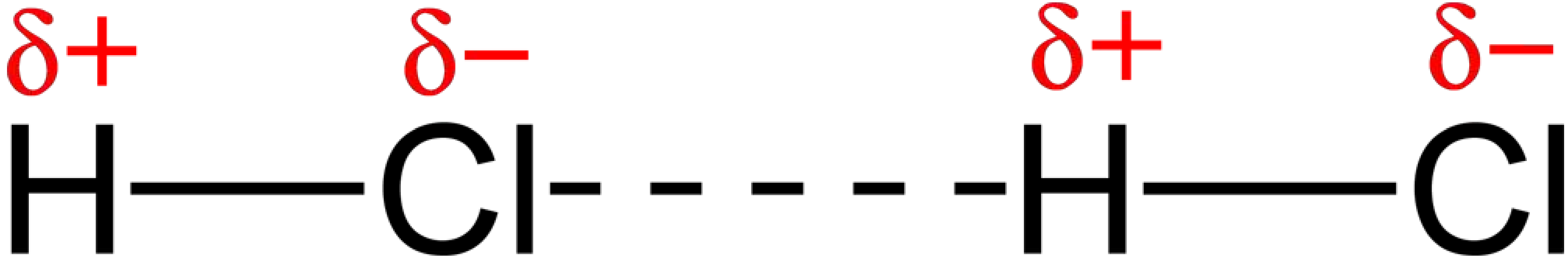
LONDON DISPERSION FORCES



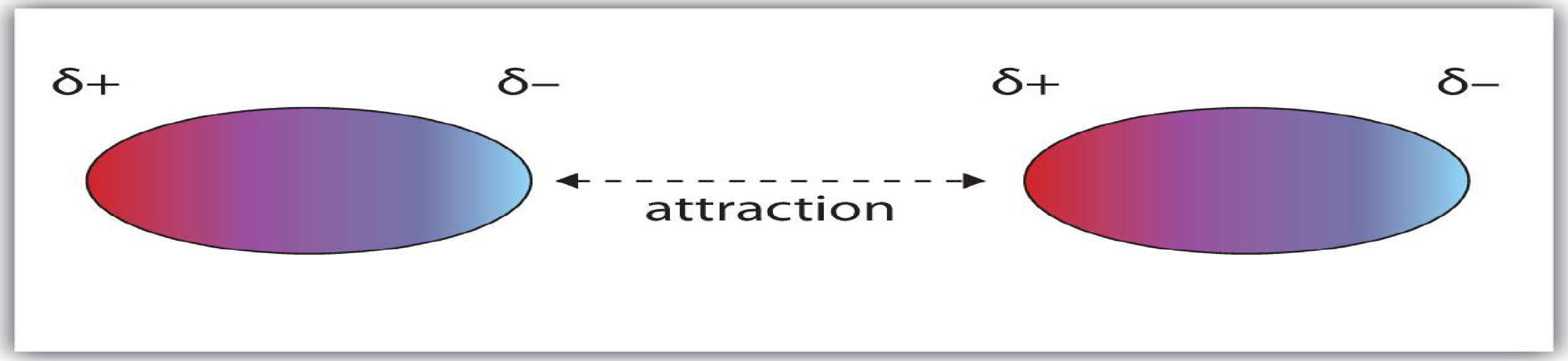
Uneven distribution of electrons in He

Instantaneous dipole

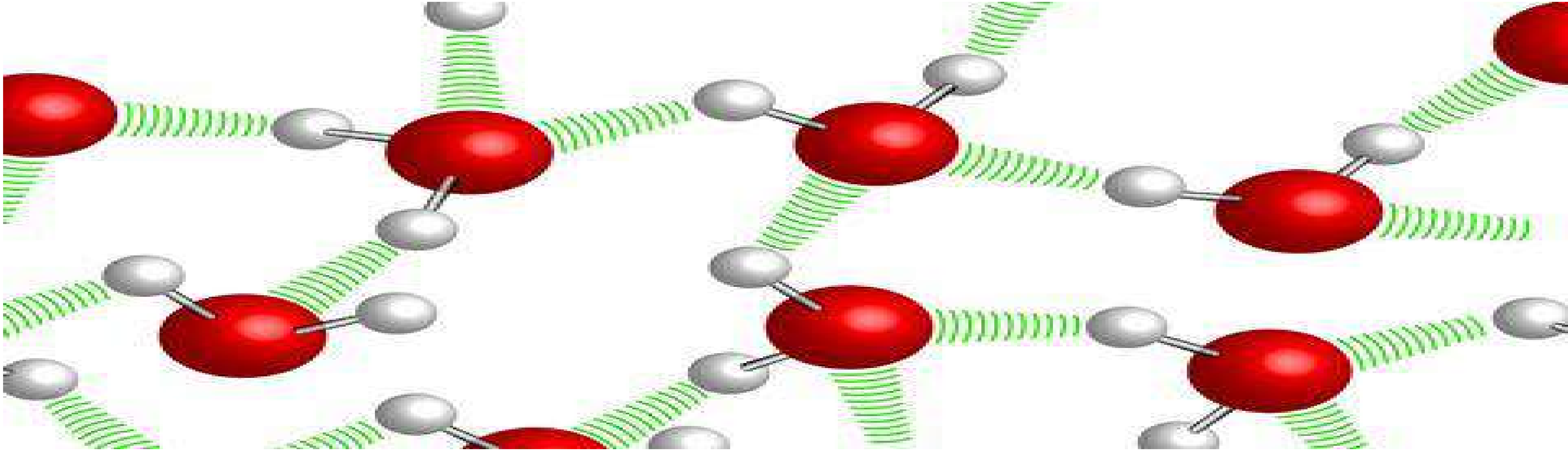
Induced dipole On neighboring He



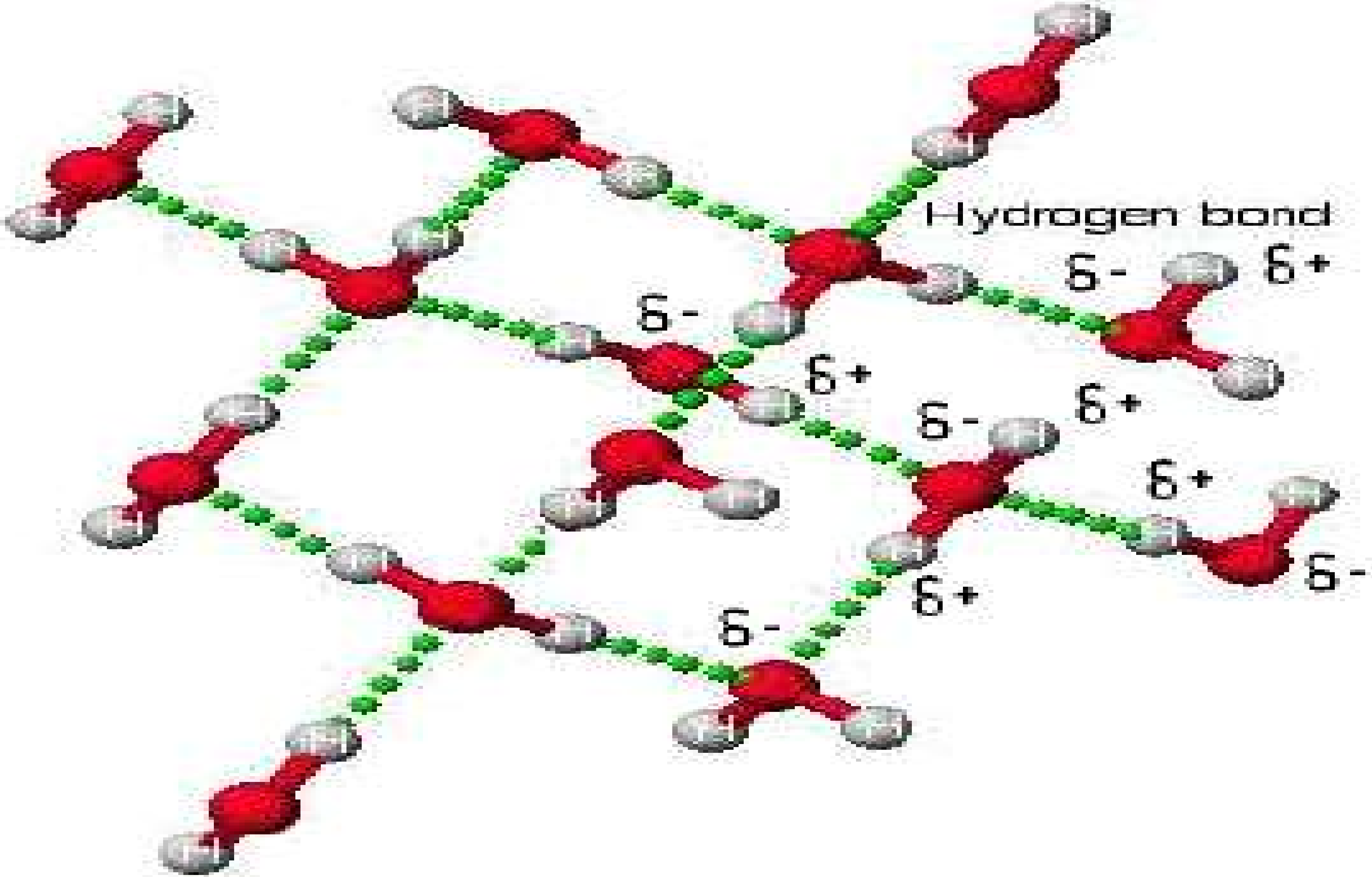
(2) ***Dipole-dipole*** these arise from the electrostatic attraction between the opposite poles of polar molecules. This is a stronger force than the dispersion forces since it comes from a permanent polarity. Molecules with this type of IF have an EN difference of over 0.4 because they need to be polar covalent. They also have dispersian forces because they have electrons.



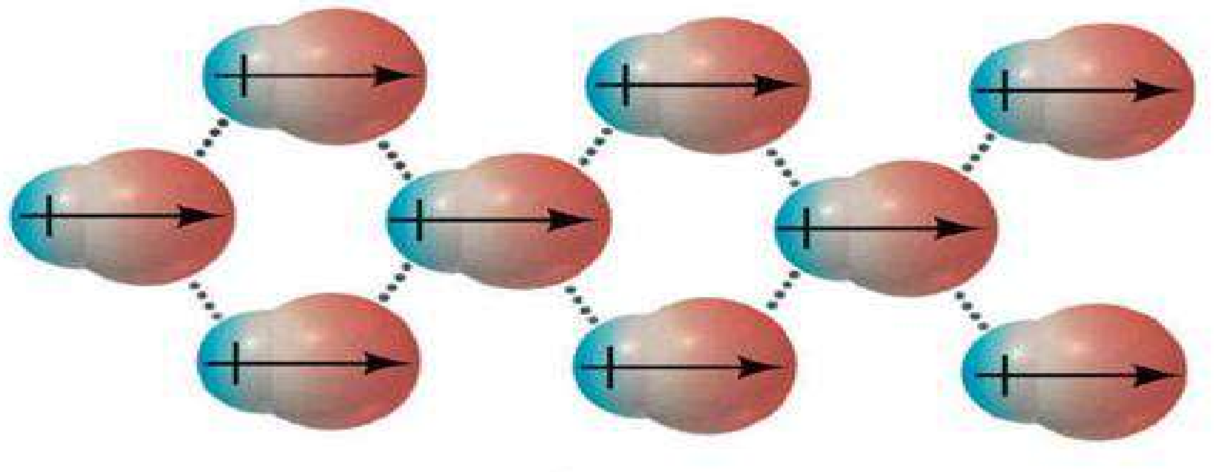
b. *Hydrogen bonding* - this is an extra strong form of a dipole-dipole force. This comes from the bonds between hydrogen and a strongly EN 2nd atom, specifically oxygen, nitrogen and fluorine. It is very strong because hydrogen, when unbonded, has 1 proton and 1 electron. When it bonds to the very EN oxygen, nitrogen or fluorine, those 3 elements are strong enough to pull hydrogen's only electron far from its proton. This causes a marked exposure of the positive proton as a pure positive and thus very attractive positive source. Not all elements bonded to H have the hydrogen bond IF, only oxygen, nitrogen and fluorine.



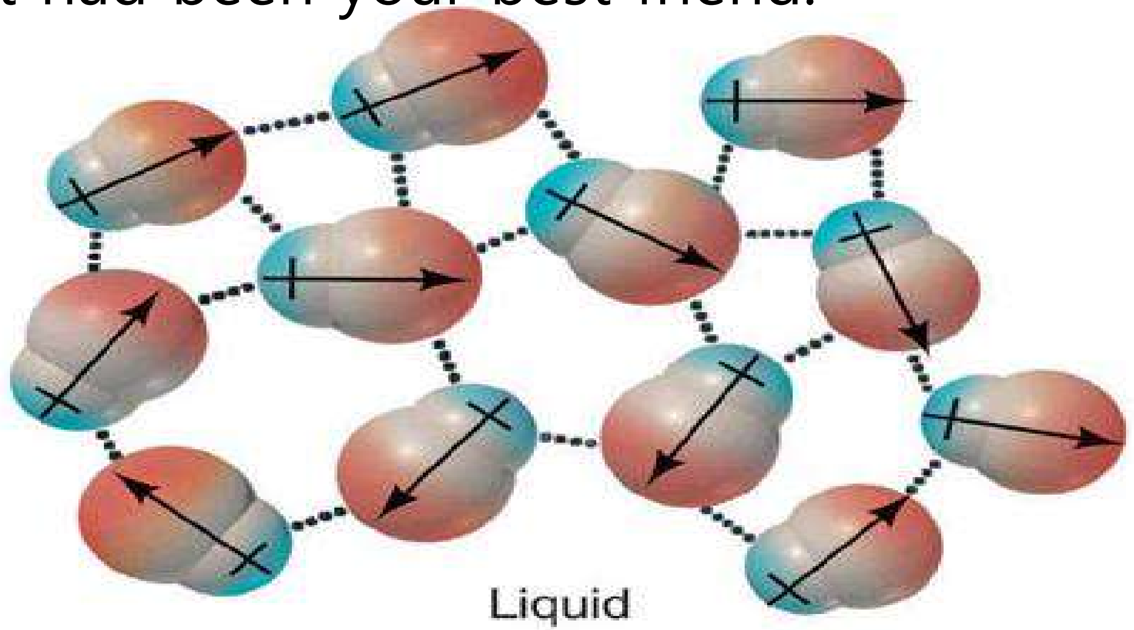
Hydrogen Bonding in Water



3. 3. IF determines the melting point of a solid, the freezing/boiling points of liquids, the surface tension/volatility of liquids and the condensation point of a gas. Imagine IFs as a form of friendship between people. Some friendships are strong and some are weak. If the friendship is strong, like with best friends since kindergarten, the 2 friends don't want to split up and try very hard to stay together. Weak friendship/low IF means that the molecules don't care if they stay together or separate. Like when the bells rings to leave class and the person you sit next to walks away. You don't really know them. You don't particularly care if they leave. You'd have walked together to your next class if it had been your best friend. Matter molecules can act like that.



Solid



Liquid

States of Matter

1. A state of matter is a physical property of matter. There are 4 states of matter - solid, liquid, gas and plasma.

Liquids

Properties-

Definite mass	Indefinite shape	Definite volume
Some heat expansion	Almost incompressible	Med strength IF

(1) Unique properties - surface tension, vapor pressure, volatility (liquids that readily evaporate are called volatile)

(2)The type of intermolecular force (IF) that a liquid has determines its surface tension, vapor pressure and freezing/boiling point.

(B) Solids

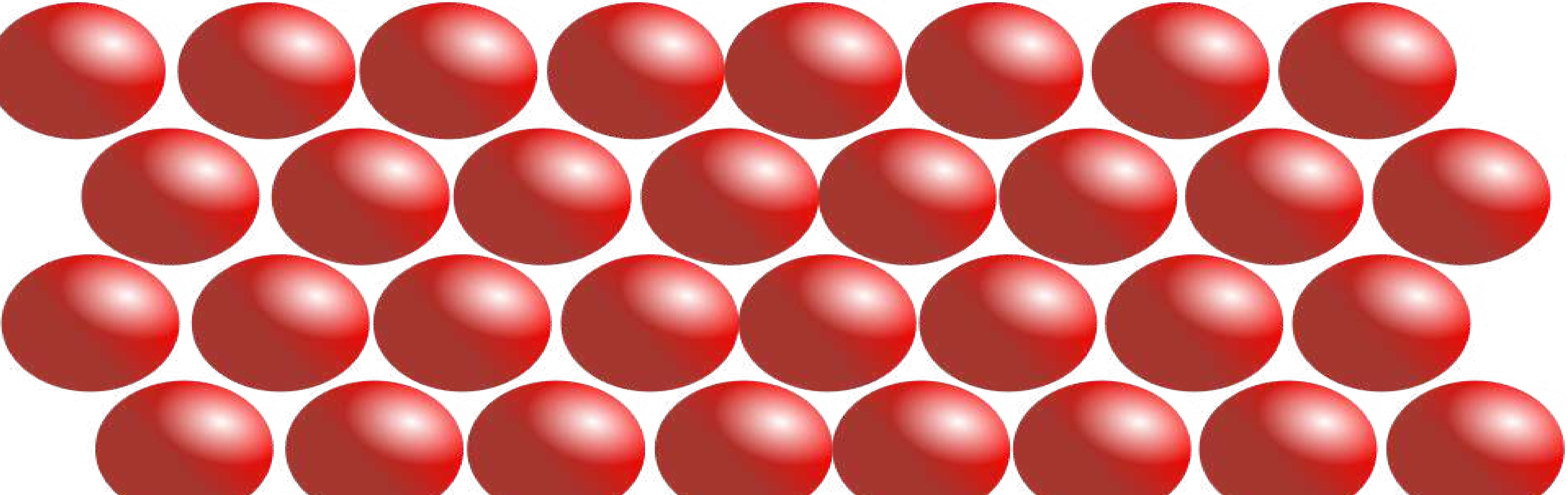
Properties

Definite mass	Definite shape	Definite volume
Small heat expansion	Virtually incompressible	High strength IF

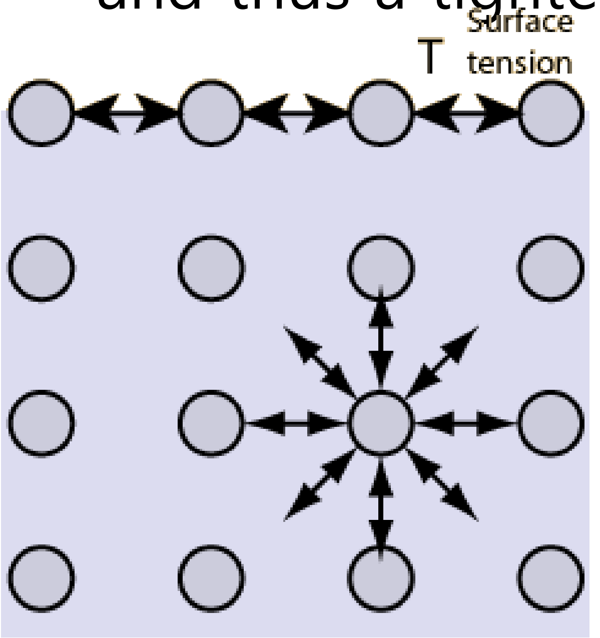
(C) Gases

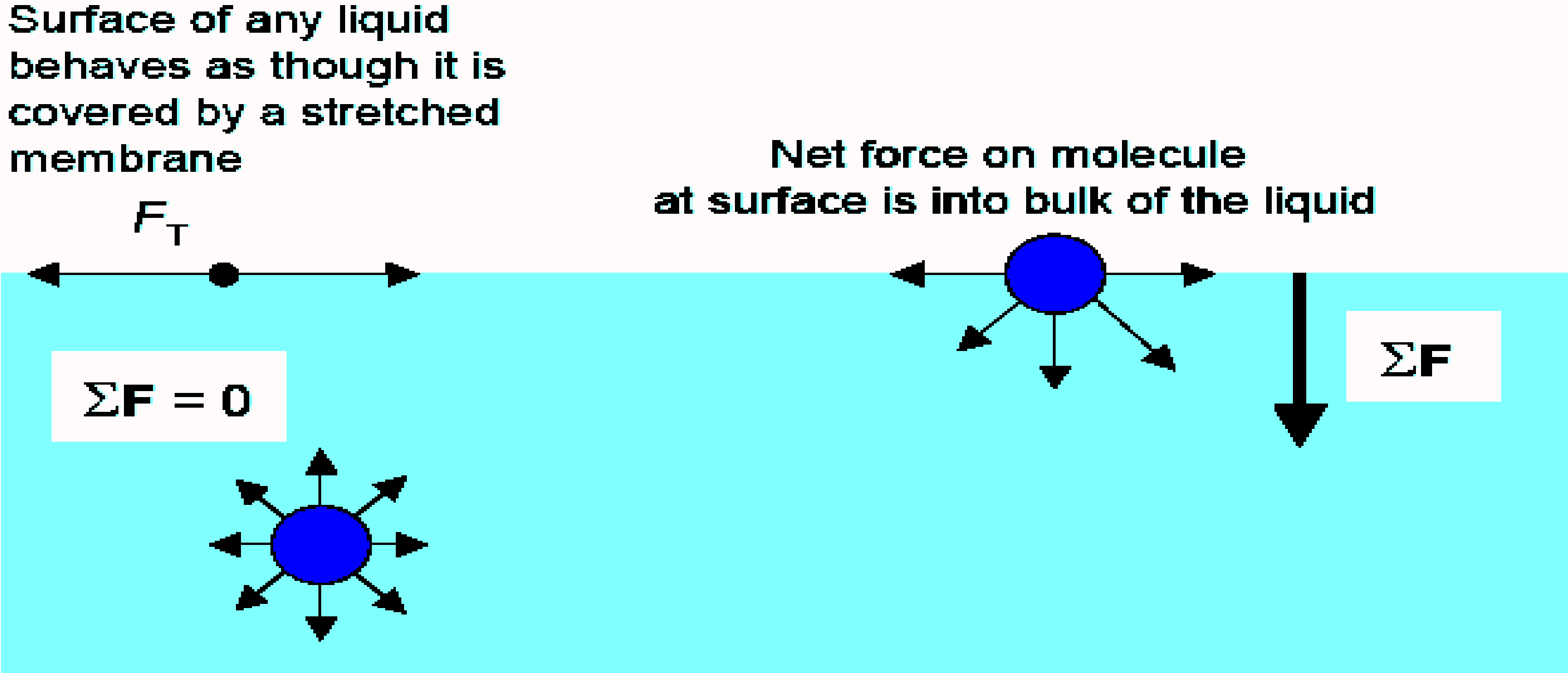
Properties

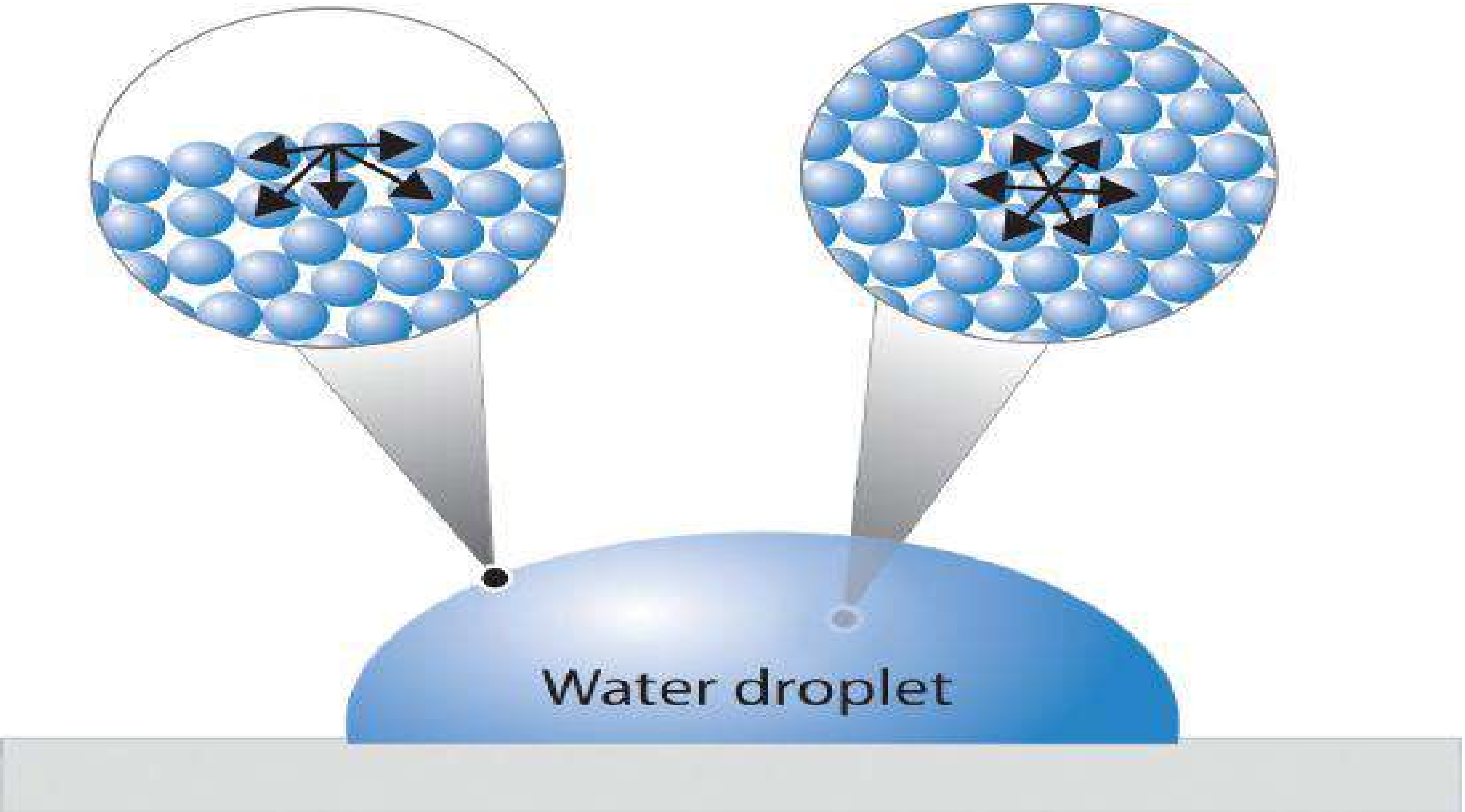
Definite mass.	Indefinite shape	Indefinite volume
Large heat expansion	Compressible	No IF



(a) Surface tension (ST) is the extra holding ability created at the surface of any liquid, analogous to a skin. Liquid molecules all have medium IF's. Liquid molecules in the center of a liquid are attracted and stretched out in all directions by their neighbors. Liquid molecules at the surface are not attracted upwards. At the surface there in no liquid above to be attracted to. So, liquid molecules at the surface are not pulled upwards and attain a more compacted shape. This surface shape holds weight better than the shape of the liquid molecules below. The amount of surface tension depends on the strength of the IF in the liquid. High IF means more "friendliness" between the molecules and then more holding on and thus a tighter ST.





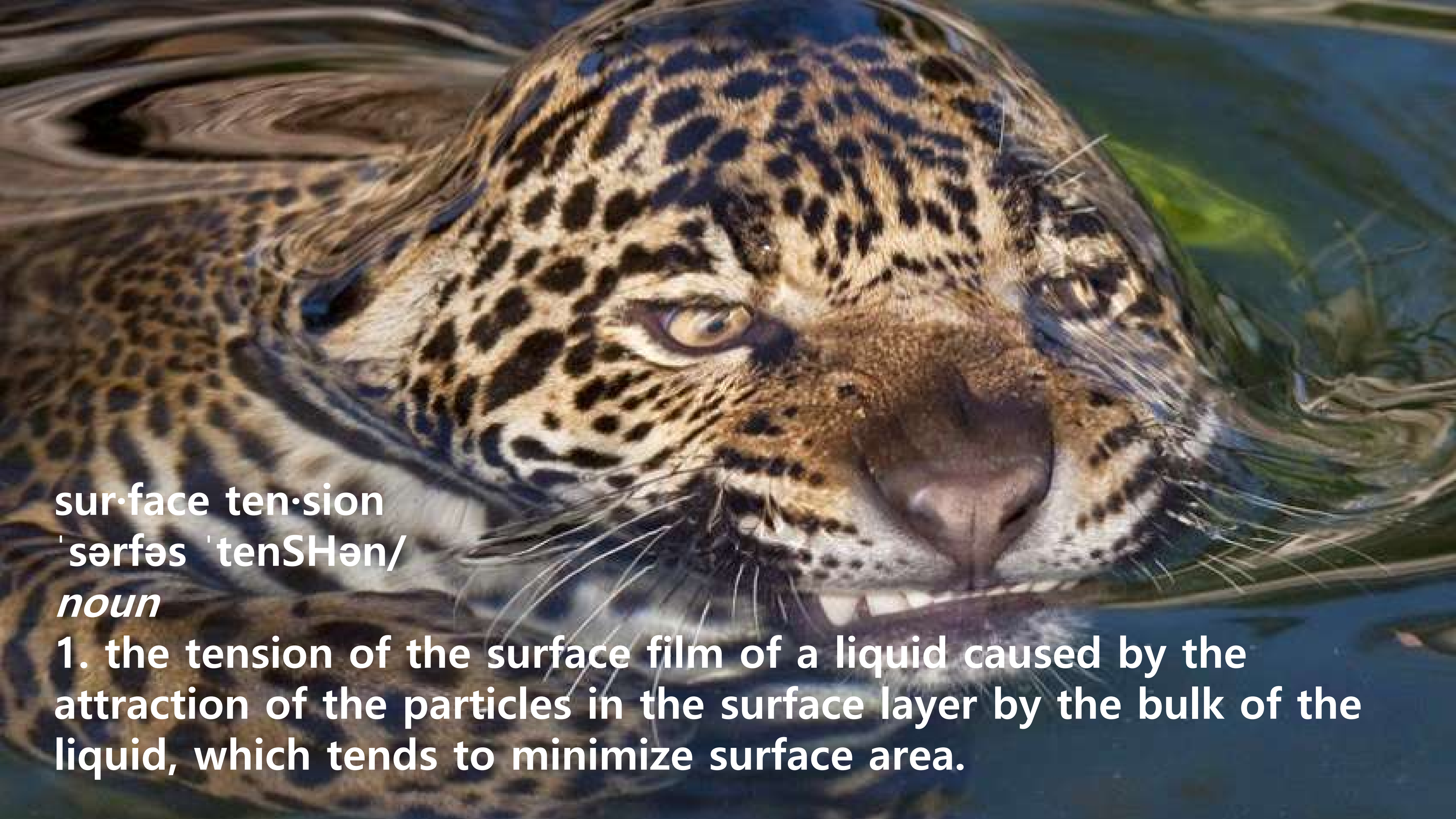

Water droplet

sur·face ten·sion

ˈsərfəs ˈtenSHən/

noun

1. the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.



sur·face ten·sion

ˈsərfəs ˈtenSHən/

noun

1. the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.

sur·face ten·sion

ˈsərfəs ˈtenSHən/

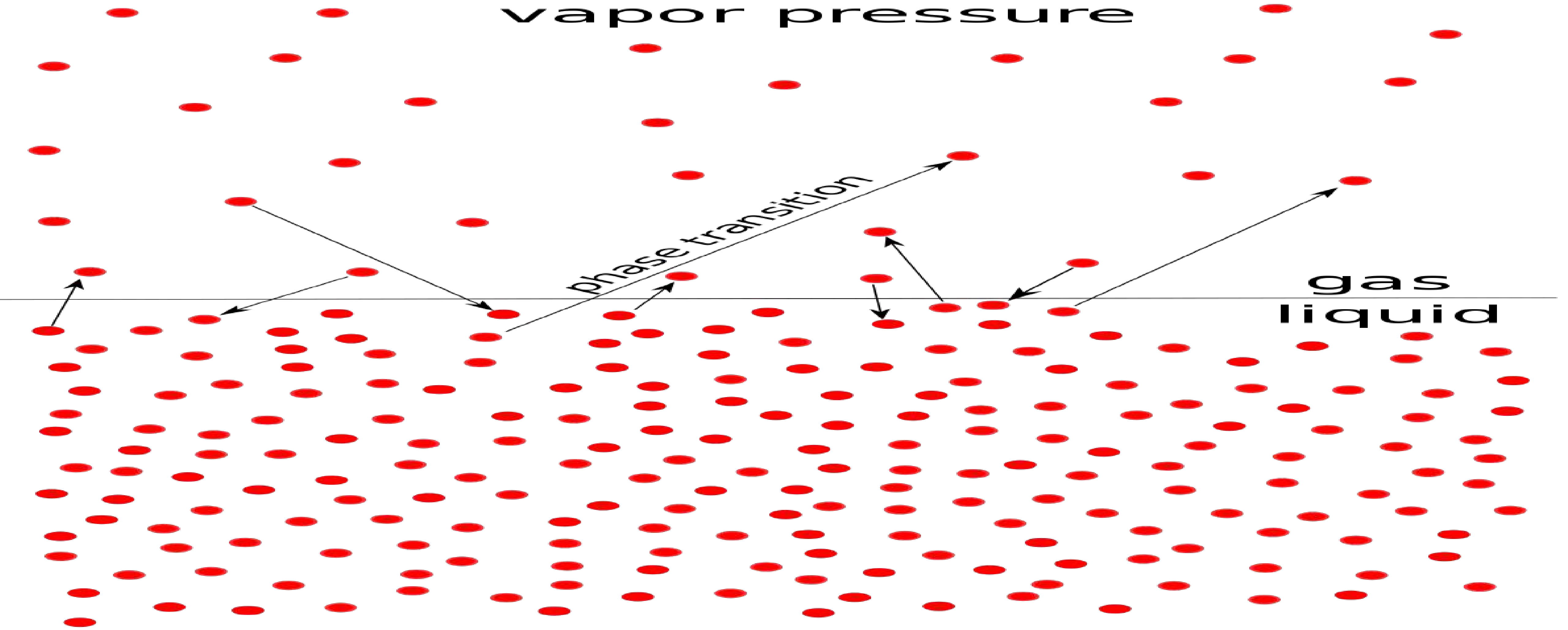
noun

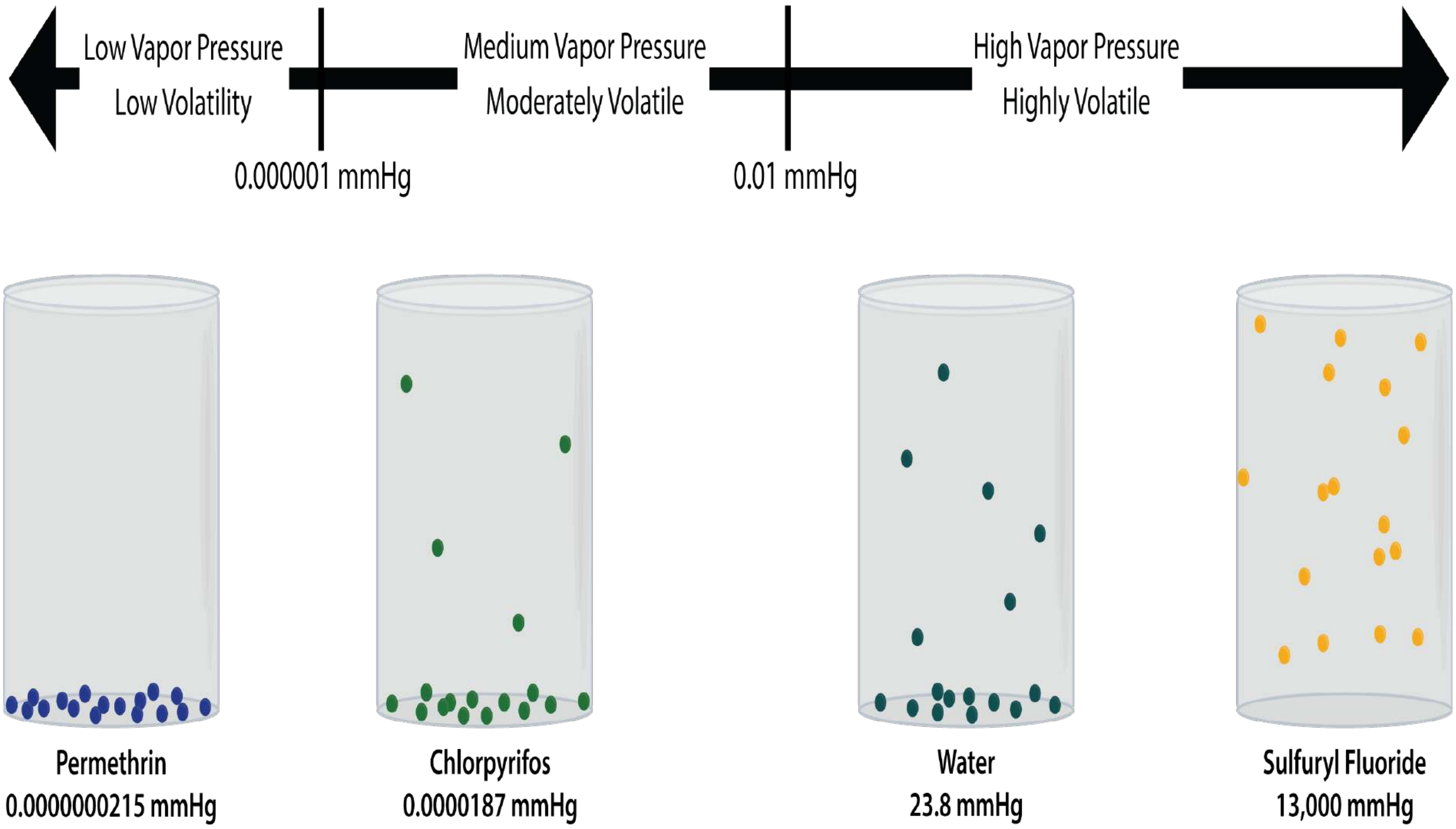
1. the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.

https://www.youtube.com/watch?v=FJ5_2OykNrk&t=11s

Milk and dye and soap

(b) ***Vapor pressure*** is the force exerted by a gas/vapor. More gas created means more pressure. Recall that molecules with high IF are like best friends. High IF liquids (best friends) don't want to spread apart so it takes more energy to split apart (change to gas) high IF molecules than low IF molecules. Therefore, high IF molecules make less gas/vapor and thus have less vapor pressure



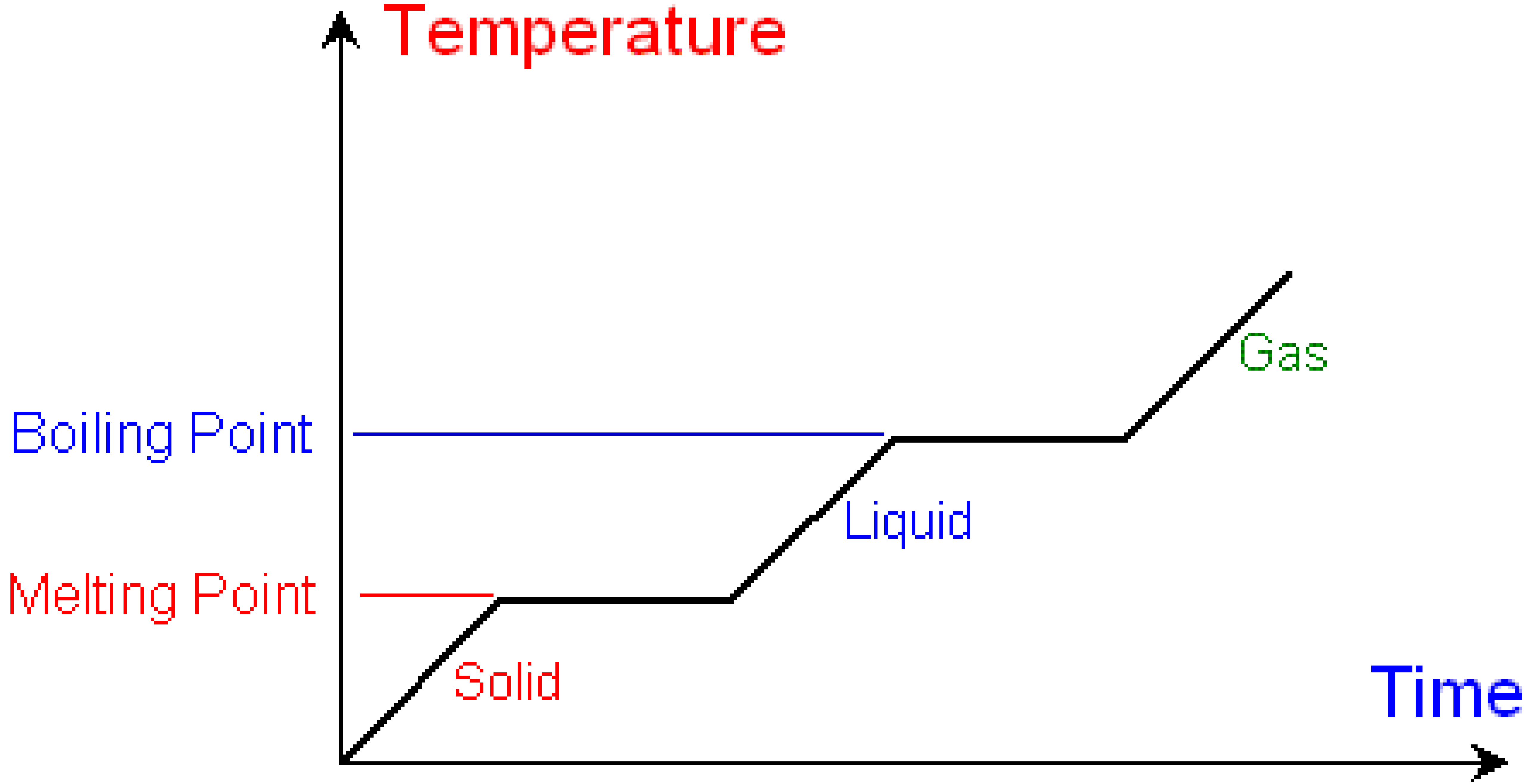

Low Vapor Pressure
Low Volatility
Medium Vapor Pressure
Moderately Volatile
High Vapor Pressure
Highly Volatile
0.000001 mmHg
0.01 mmHg
Permethrin
0.0000000215 mmHg
Chlorpyrifos
0.0000187 mmHg
Water
23.8 mmHg
Sulfuryl Fluoride
13,000 mmHg

(c) ***Volatile*** liquids separate or evaporate very easily. What type of IF do you believe they have?

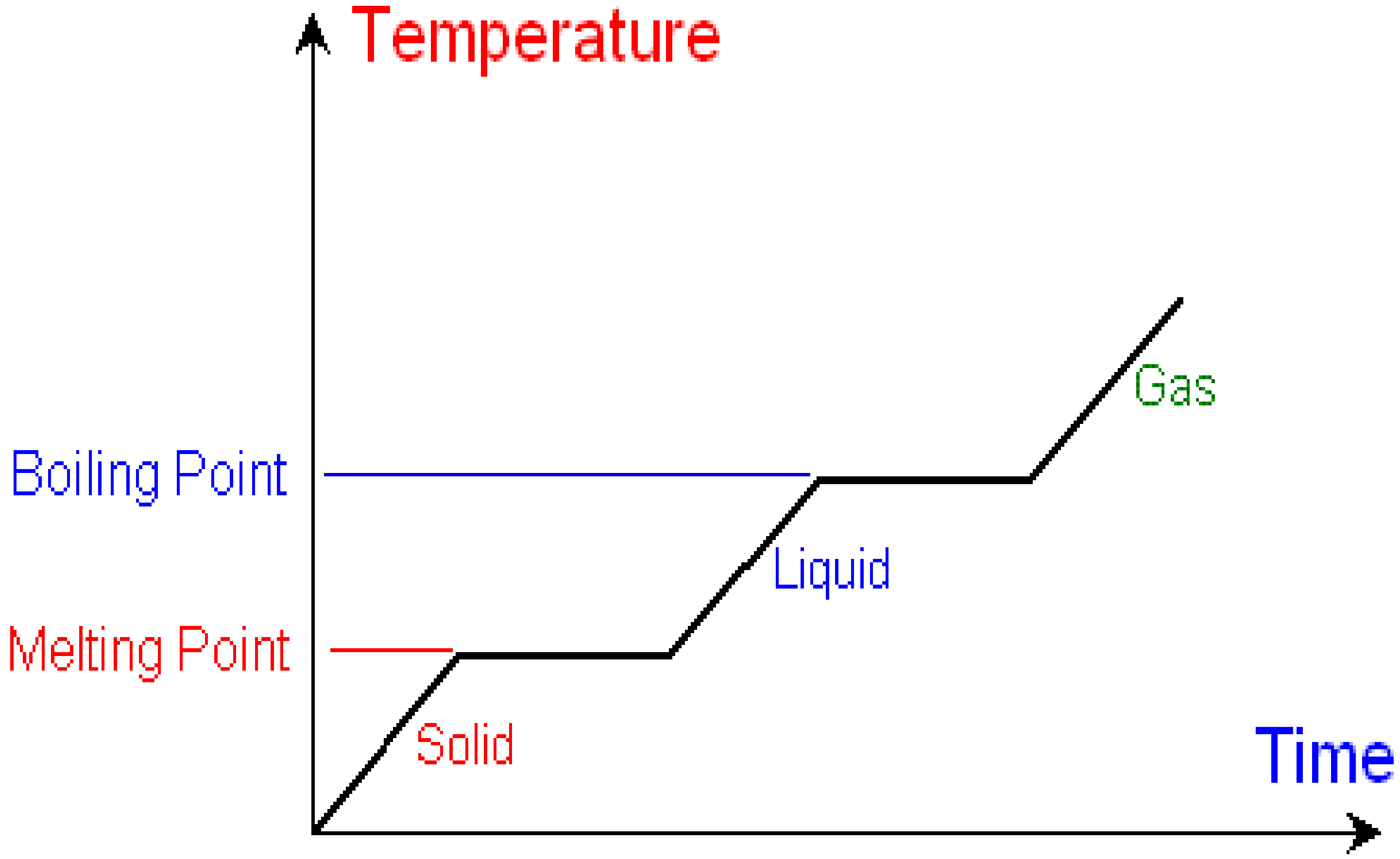
Conversions between the 3 States of Matter

SOLID **LIQUID** **GAS**

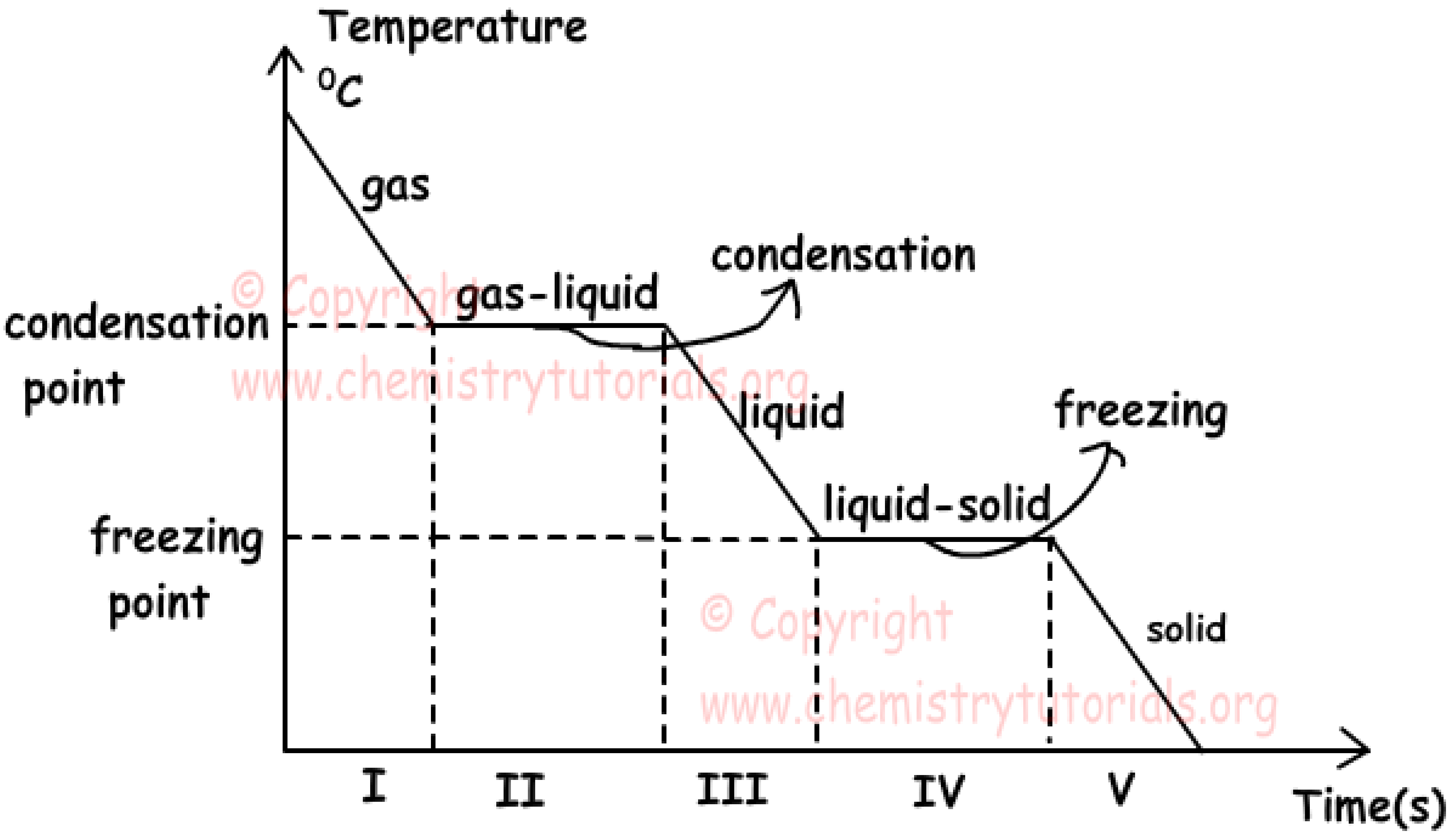
1. *Melting* – the process of a solid changing to a liquid.
2. *Melting Point* (MP) - The temperature at which a solid changes to a liquid. The temp. at which the solid is moving fast enough to separate into a liquid. It is 0ºC for solid water. Melting means that the solid molecules are spreading far apart to become a liquid, like your best friend moving across the world to Australia. High IF solids (best friends) don't want to spread apart so it takes a higher melting point (more energy) to split apart (change to liquid) a high IF molecules than low IF molecules.


Temperature
Boiling Point
Melting Point
Solid
Liquid
Gas
Time

3. *Boiling* - the process of a liquid changing to a gas.
4. *Boiling Point* (BP) - The temp. at which the liquid is moving fast enough to separate into a gas. It is 100°C for liquid water. Boiling means that the liquid molecules are spreading far apart to become a gas. High IF liquids don't want to spread apart so it takes a higher boiling point to split apart (change to gas) a high IF molecules than low IF molecules.

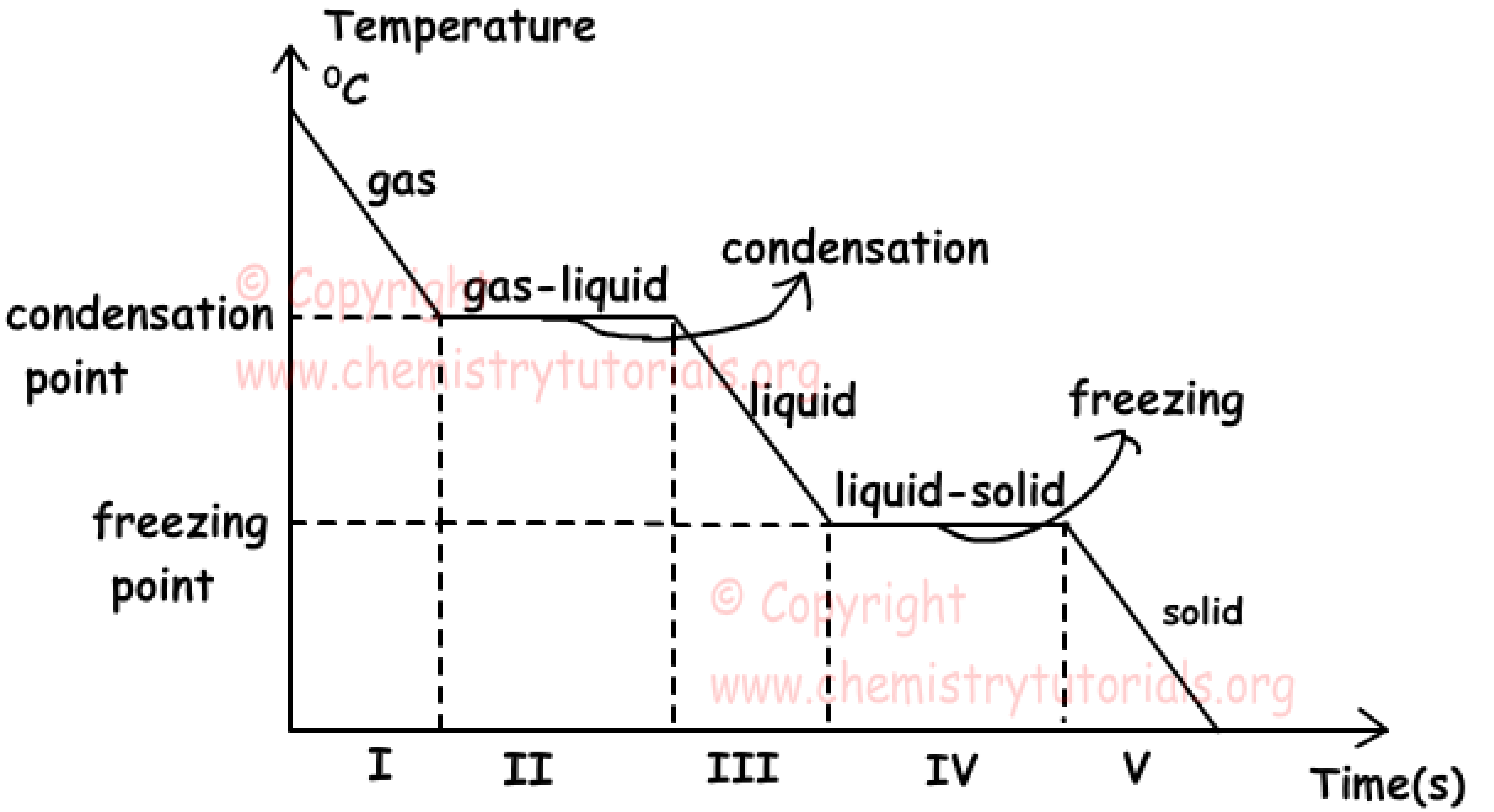


5. *Freezing* - the process of a liquid changing to a solid.
6. *Freezing Point* (FP) - the temperature at which a liquid changes to a solid. It is 0°C for liquid water. High IF would manifest in a high freezing point for a liquid. As the liquid cools, the kinetic energy lowers and at some point, the kinetic energy is low enough that IF is felt by the slower liquid molecules and they begin to freeze (come together). High IF liquids would have a high freezing point. Because with a high IF, the molecules **want** to be together and are able to get together at higher speeds (high temperature/kinetic energy) – a high freezing point.


Temperature
°C
gas
gas-liquid
condensation
condensation point
liquid
freezing
liquid-solid
freezing point
solid
I
II
III
IV
V
Time(s)
© Copyright www.chemistrytutorials.org
© Copyright www.chemistrytutorials.org

7. *Condensation* - the process of a gas changing to a liquid.

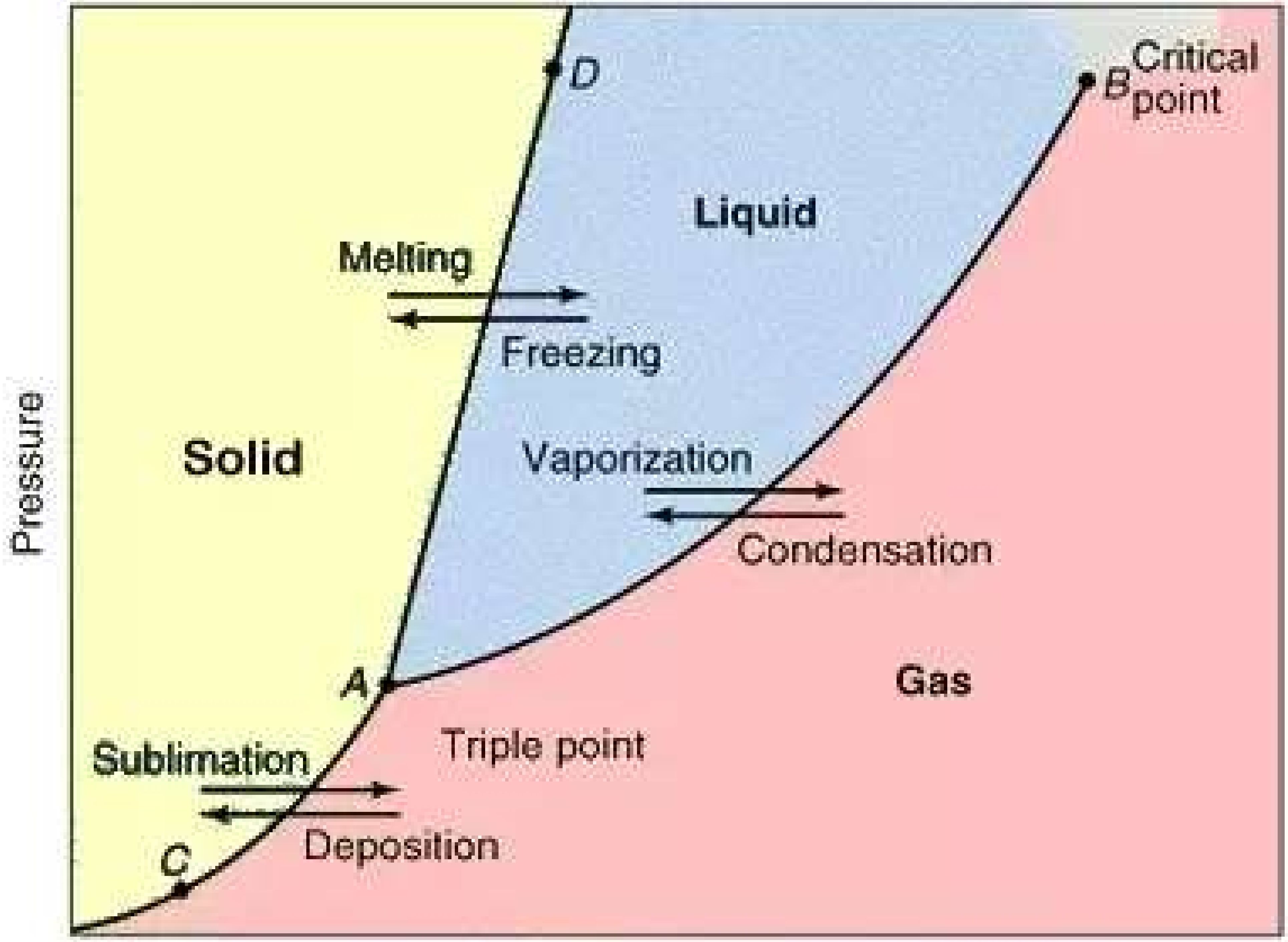
8. *Condensation point* (CP) – The temperature at which the gas has slowed enough to begin moving closer together to become a liquid. It is 100ºC for steam water. High IF would manifest in a high condensation point for a gas. Normally the kinetic energy of a gas results inthere being no IF between gas molecules. But as the gas cools, the kinetic energy lowers and at some point, the kinetic energy is low enough that IF is felt by the slow gas molecules and they begin to condense (come together). High IF liquids would have a high CP for its gas phase. Because with a high IF, the molecules **want** to be together and are able to get together at high speeds (high temperature/kinetic energy) – a high CP.



Temperature
°C
gas
condensation
gas-liquid
condensation
point
liquid
freezing
liquid-solid
freezing
point
solid
I
II
III
IV
V
Time(s)
© Copyright
www.chemistrytutorials.org
© Copyright
www.chemistrytutorials.org

9. *Sublimation*- The conversion of a solid directly to the gaseous state.

10. *Triple Point*- The only temperature and pressure that the 3 states of any substance can exist in equilibrium; shown on a phase diagram


Pressure
Solid
Liquid
Gas
Melting
Freezing
Vaporization
Condensation
Sublimation
Deposition
Triple point
Critical point
A
B
C
D

Plasma - The Fourth State of Matter

1. *Plasma* - A mixture of free electrons and positive ions resulting from the exposure of a gas to extremely high temperatures and / or pressure. Only found in stars.