VALENCE AND CHEMICAL BONDING

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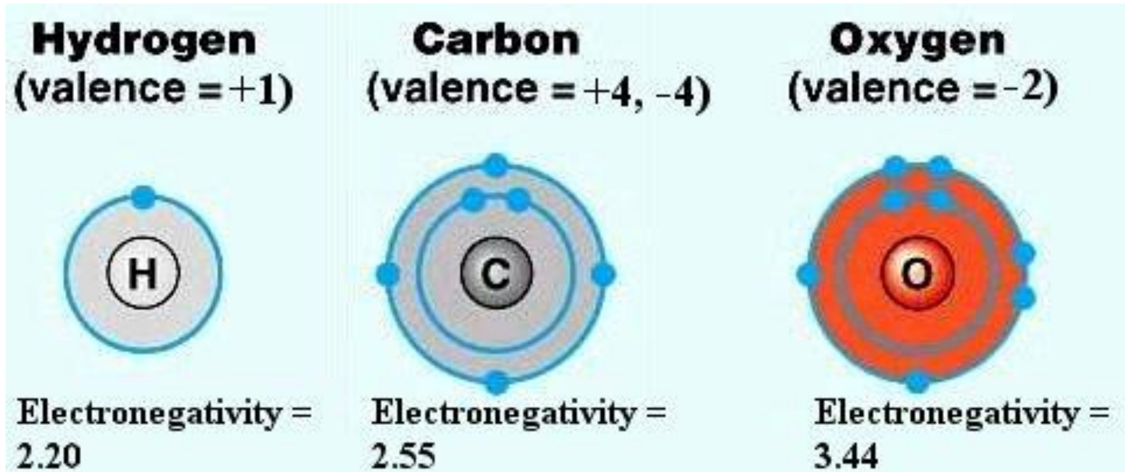
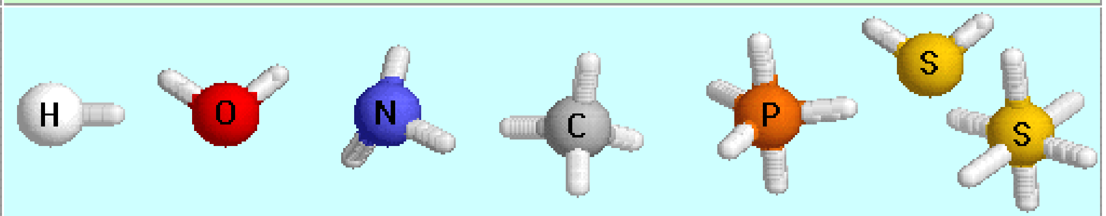
a. Valence (원자가)

- **The valence of an element can be defined as a measure of its <u>combining power</u> or the number of electrons an atom must gain, lose, or share to have a full or stable outer electron shell.**
- **The reason atoms combine is contained in this definition.**
- **There are certain electron configurations in nature that are unusually stable (unreactive).**
- **The elements that have these configurations are in Group VIII A of the periodic table.**

- **They are sometimes referred to as the inert or noble gasses because they are found in very few combinations in nature.**
- **Other elements, by gaining, losing, or sharing electrons, can try to make their outer electron shells resemble the shells of the noble gases and hence become very stable.**
- **We can see how this works by considering the two simplest elements, hydrogen, and helium.**
- **Hydrogen has one electron in the K shell since it has only one proton. Therefore, hydrogen is a very reactive element, occurring naturally in many compounds.**

- **Helium, a noble gas, has two electrons in the K shell since it has two protons. Helium is very unreactive. Note that helium, by having two electrons, has a completed outer shell, since the K shell can hold only two electrons.**
- **Hydrogen would like to be as stable as helium and could be if it could gain or share one more electron to give it a completed outer shell.**
- **Hydrogen seeks this electron in nature by combining with other elements.**



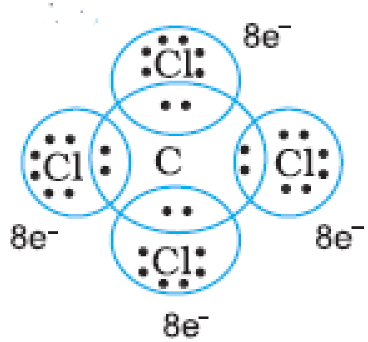
Atom	Hydrogen	Oxygen	Nitrogen	Carbon	Phosphorus	Sulfur
Valence	1	2	3	4	5	2, 6
Model						

b. Octet Rule.

- If you examine the noble (inert) gases (like helium), you will see that not all have a completed (full) electron shell.
- Except for helium, the noble gases have eight electrons in their outer shell, yet they are still very stable.
- Chemists have observed that other elements sometimes gain, lose, or share electrons in order to have eight electrons in their outer shell.
- This observation led to the development of the octet rule, which states that outer electron shells prefer to have eight electrons even though the shell may not be full. (Octet means a group of eight.)

- **examples of the electron configurations for various elements which indicate to us how many electrons they can gain, lose, or share to fit the octet rule or have a completed outer shell.**

ELEMENT	ATOMIC NUMBER	SHELLS K(2)	L(8)	M(18)	N(32)
H	1	1			
He	2	2			
Li	3	2	1		
Be	4	2	2		
Na	11	2	8	1	
K	19	2	8	8	1

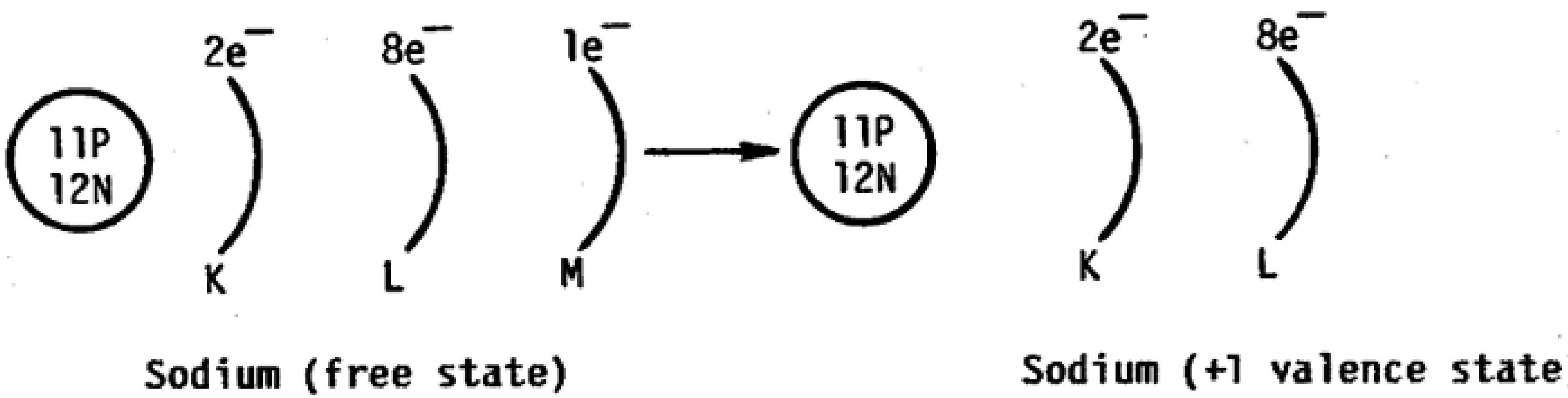


Each of the four Cl atoms along with the C atom attains octet of electrons

c. Positive Valence.

- An atom that must give up electrons to become stable will have more protons than electrons in its stable configuration and will not be electrically neutral.
- It will be positively charged since there are more positive charges than negative charges.
- This is indicated by a + sign.
- The number of electrons it gives up is the numerical value of its valence.

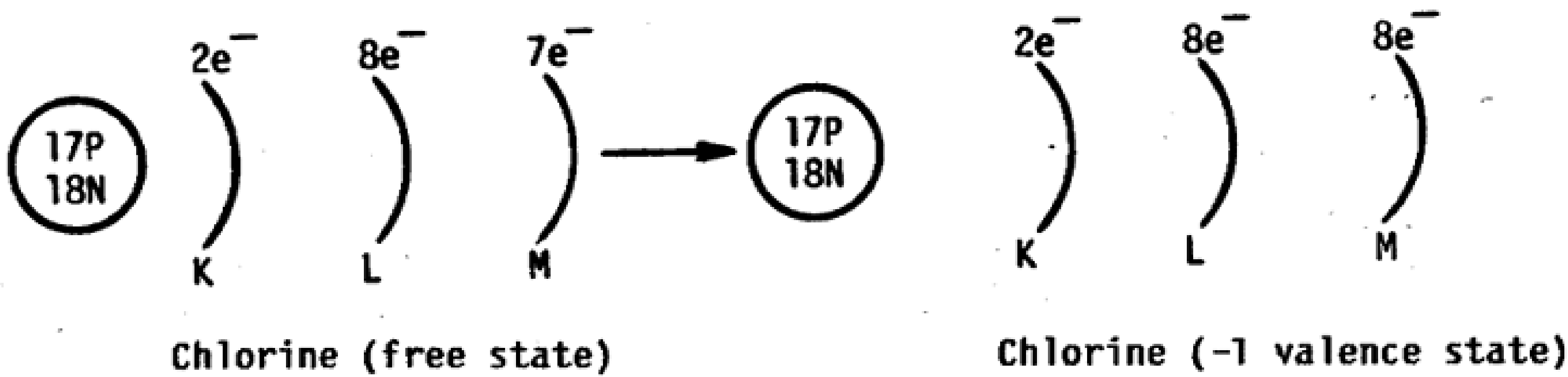
- Consider, for example, the element sodium, which has 11 protons and 11 electrons in its free state.
- It has one electron in the M shell, which it loses easily to become stable.
- After it loses the electron (that is, gives up a negative charge), it will have a positive one charge and its valence will be +1.



d. Negative Valence.

- **An atom that must gain electrons to become stable will have more electrons than protons in its stable configuration and will not be electrically neutral.**
- **It will be negatively charged since there are more negative than positive charges.**
- **This is indicated by a "-" sign.**
- **The number of electrons it gains is the numerical value of its valence.**
- **Consider, for example, the element chlorine, which has 17 protons and 17 electrons in its free state.**

- **It is one electron short of fitting the octet rule in the M shell as that shell contains 7 electrons.**
- **After it gains the electron, it will have a negative one charge and its valence will be -1.**



e. Important Symbols and Valences.

- Since it is very tedious to continually write complete names for elements, chemists developed the symbols for the elements which you observed on the periodic table.
- It will not be necessary for you to know all the symbols for your work but a number of them appear frequently enough that they should be memorized.
- Next Table lists important elements with their symbols and valences. These should be committed to memory. (Please note that most, but not all, valences conform either to the completed shell or octet rules.)

Table. Valences.

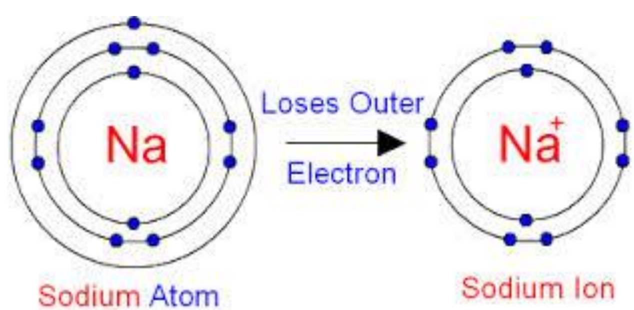
NAME	SYMBOL	VALENCE
Acetate	$C_2H_3O_2$	-1
Aluminum	Al	+3
Ammonium	NH_4	+1
Antimony	Sb	-3, <u>+3</u>, +5
Arsenic	As	-3, <u>+3</u>, +5
Barium	Ba	+2
Bicarbonate	HCO_3	-1
Bismuth	Bi	<u>+3</u>, +5
Bromine	Br	<u>-1</u>, +1, +3, +5, +7
Calcium	Ca	+2
Carbon	C	+2, <u>+4</u>, <u>-4</u>
Carbonate	CO_3	-2
Chlorine	Cl	<u>-1</u>, +1, +3, +5, +7
Copper	Cu	<u>+1</u>, <u>+2</u>
Fluorine	F	-1
Gold	Au	+1, +3
Hydrogen	H	+1
Hydroxide (Hydroxyl)	OH	-1
Iodine	I	<u>-1</u>, +1, +3, +5, +7
Iron	Fe	<u>+2</u>, <u>+3</u>

Table. Valences. (continued)

Lead	Pb	$\underline{+2}$, $\underline{+4}$
Lithium	Li	+1
Magnesium	Mg	+2
Manganese	Mn	$\underline{+2}$, +3, +4, +6, +7
Mercury	Hg	$\underline{+1}$, $\underline{+2}$
Nickel	Ni	$\underline{+2}$, +3
Nitrate	NO_3	-1
Nitrogen	N	+1, $\underline{-3}$, +3, +5
Oxygen	0	-2
Permanganate	MnO_4	-1
Phosphate	PO_4	-3
Phosphorus	P	-3, +3, +5
Potassium	K	+1
Silver	Ag	+1
Sodium	Na	+1
Strontium	Sr	+2
Sulfate	SO_4	-2
Sulfur	S	$\underline{-2}$, +2, +4, +6
Zinc	Zn	+2

f. Ions.

- Any atom that gains or loses electrons becomes charged (electrical charge) and is called an ion.
- An ion can be defined as any charged atom or group of atoms.
- If the ion is positively charged, it is called a cation.
- If it is negatively charged, it is called an anion.
- A group of atoms that has a charge and goes through a reaction unchanged is called a radical.
- Whenever we write the symbol for an element and wish to indicate it is an ion, we write the charge as a superscript to the symbol, for example, Cl^{-1} or Na^{+1}.



radical 과 ion의 차이점

- 라디칼(혹은 자유 라디칼)은 하나 이상의 "짝지어지지 않은(=unpaired)" 전자를 가진 원자(atm) 혹은 복합 화합물

예) 염소(Cl2)는 두 개의 염소 원자가 공유결합을 하여 분자의 안정된 상태인 Cl2로 존재. 결합하기 전 원자로서의 염소는 7족으로서 최외각 전자가 7개인 중성 상태인데, Octet 룰 을 만족 시키기 위해 염소 원자 두 개가 서로 하나의 전자를 공유하며 공유 결합을 이루어 안정된 염소 분자를 이루게 됩니다. 하지만 외부에서 에너지를 받게 되면 이 공유결합 상태의 염소 원자가 서로 결합하기 전의 상태인 **7**가의 원소 상태로 **"**순간적으로**"** 분리되 되는데 **(**우리는 이것을 라디칼인 **Cl·** 로 표기 합니다**)** 이 상태는 매우 불안정 하며 활성이 높아 극히 짧은 순간만 존재할 수 있습니다**.**
따라서 라디칼이란 **'**중성**(neutral)'** 상태로서 공유 결합에서 순간적으로 분리된 어떤 종**(species)**을 뜻함

radical 과 ion의 차이점

- 메탄(CH_4)의 경우 4가인 탄소 원자에 수소 원자 4개가 탄소 원자와 공유 결합하여 Octet Rule을 만족시킨 안정된 화합물인데, 메탄 라디칼의 하나인 $CH_3\cdot$ 은 CH_4에서 수소 원자 하나가 떨어져 나감으로써 탄소 측에 결합되지 않은 전자가 하나 존재하게 되는 상태

- 이온(ion)은 중성 상태인 원자의 최외각 전자 궤도에 전자가 '추가' 되거나 '감소'하여 원자 혹은 화합물의 '중성 상태가 파괴된' 것으로서 양극성(positive) 혹은 음극성(negative)를 띠게 됨. 즉 염소 이온의 하나인 Cl^- 은 중성인 염소 원자 최외각 전자 7개에 1개의 전자가 더 추가되어 원자의 중성 상태가 깨진 상태로서 이 경우 Cl^- 은 외각 전자가 8개를 이루므로 라디칼과는 달리 '안정된' 상태로 존재할 수 있다.

g. Chemical Bonding.

- When elements combine to form chemical compounds, the electrons in the outer shell may be transferred from one atom to another or there may be a mutual sharing of the electrons.
- In either case, a chemical bond is produced.
- This means the two atoms do not travel or react independently of one another but are held together by the exchange or sharing of the electrons.
- Both atoms involved in the reaction attain a completed outer orbit, and stability results.
- There are three types of chemical bonds--electrovalent, covalent, and coordinate covalent.

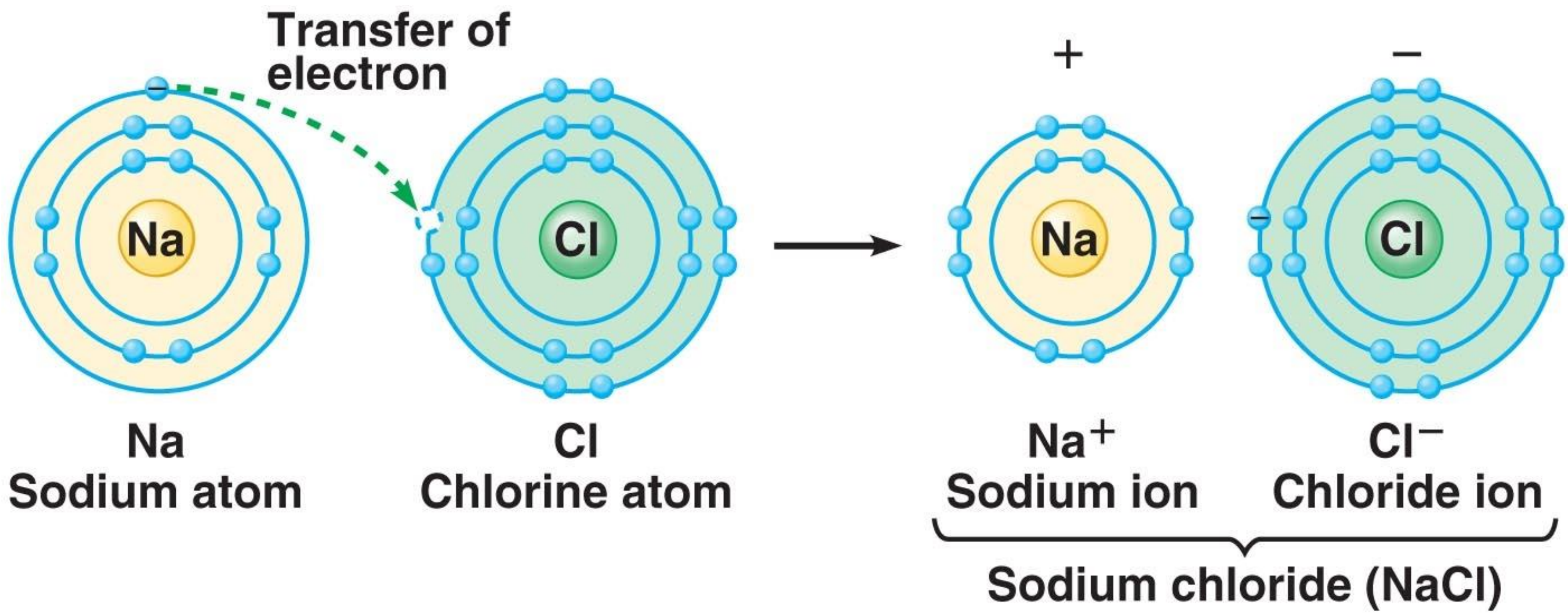
(1) Electrovalent (ionic) bonding.

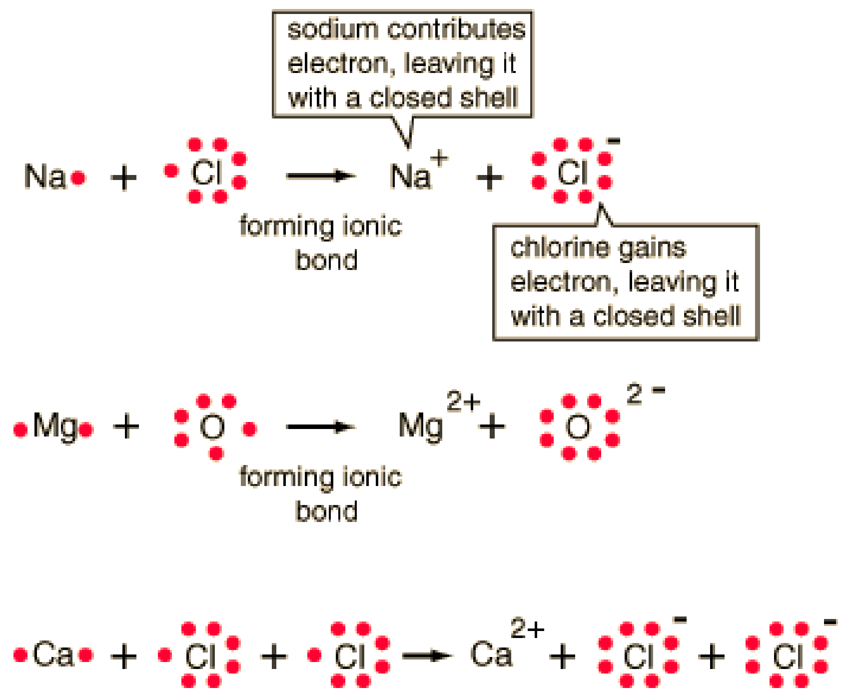
- **A transfer of one electron from one atom to another resulting in opposite charges on the two atoms that holds them together by electrostatic (opposite charges attract) attraction is called an electrovalent or ionic bond.**
- **A good example of this is the bond formed between a Na (sodium) and a Cl (chlorine) atom.**

$1\ e^-$ in M shell

$7\ e^-$ in M Shell

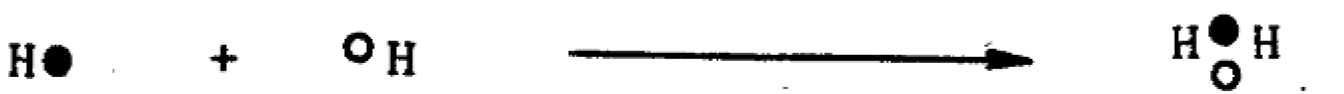
Sodium has a complete outer shell and a charge of +1. Chlorine has met the octet rule in the M shell and has a charge of –1.


Transfer of electron
Na
Cl
+
−
Na
Cl
Na
Sodium atom
Cl
Chlorine atom
Na+
Sodium ion
Cl−
Chloride ion
Sodium chloride (NaCl)


sodium contributes electron, leaving it with a closed shell
Na + Cl → Na+ + Cl-
forming ionic bond
chlorine gains electron, leaving it with a closed shell
Mg + O → Mg2+ + O2-
forming ionic bond
Ca + Cl + Cl → Ca2+ + Cl- + Cl-

(2) Covalent bond

- **If two atoms each donate an electron that is shared with the other atom, the bond is a <u>covalent bond</u>.**
- **An example of this is the bond between two H (hydrogen) atoms. Double and triple covalent bonds are also possible**



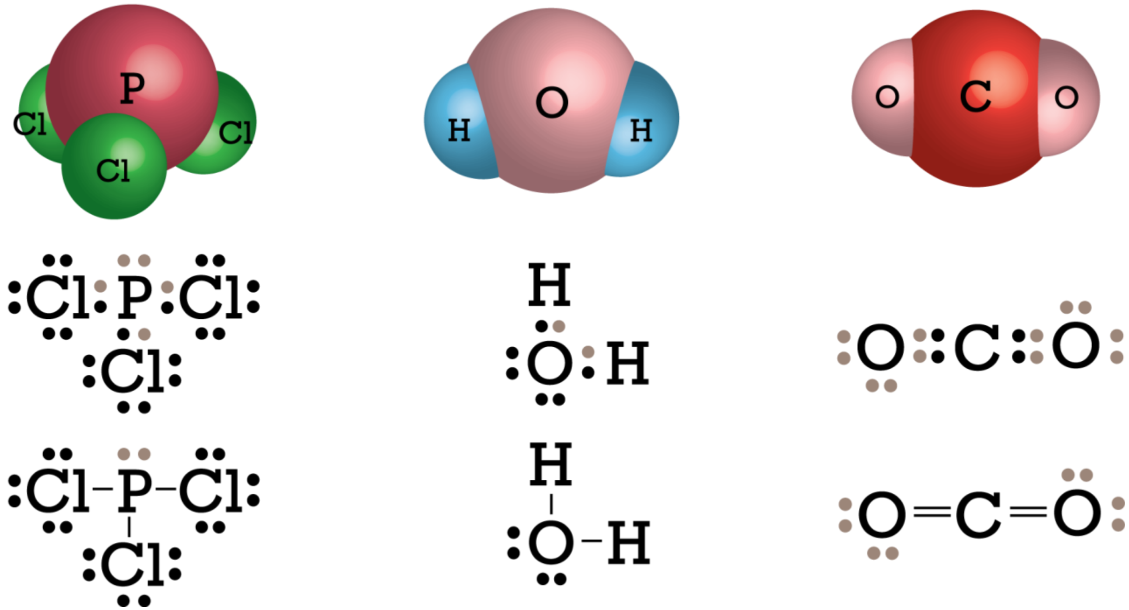
Both atoms have 1 e^- in the K shell.

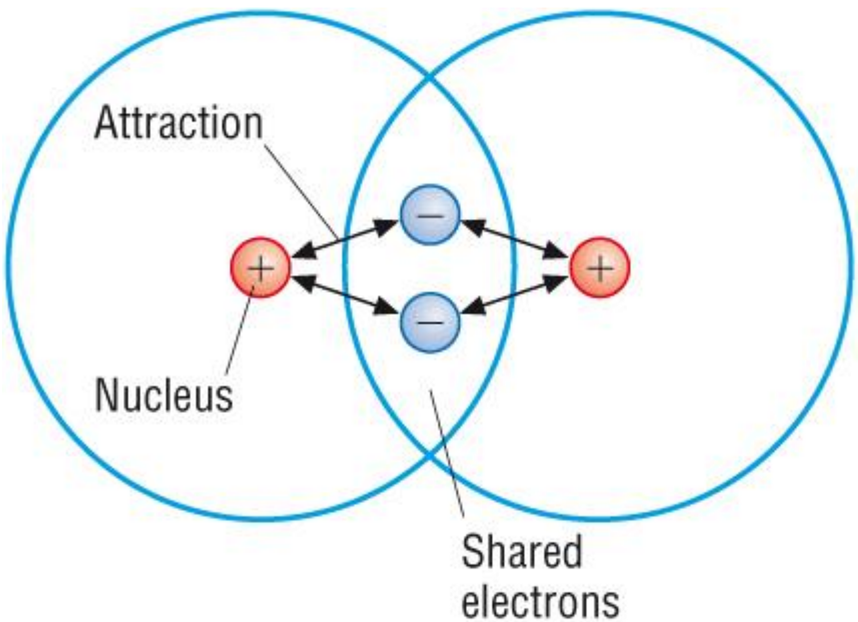
By sharing their electrons each hydrogen has 2 e^- in the K shell and both are stable because of the completed shell.

Phosphorus Trichloride PCl_3

Water H_2O

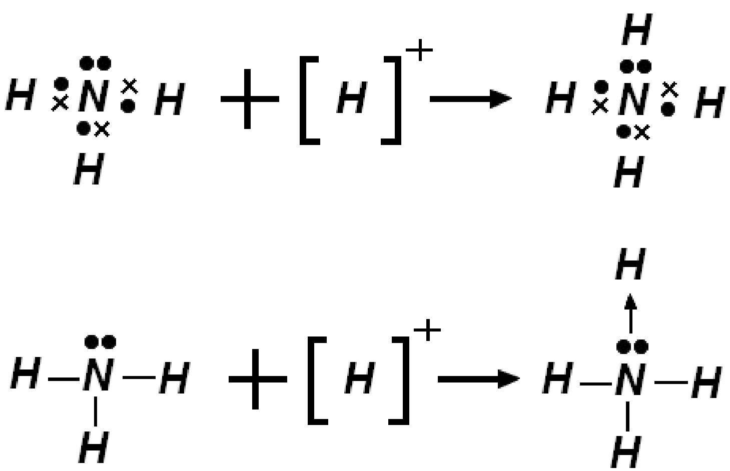
Carbon Dioxide CO_2

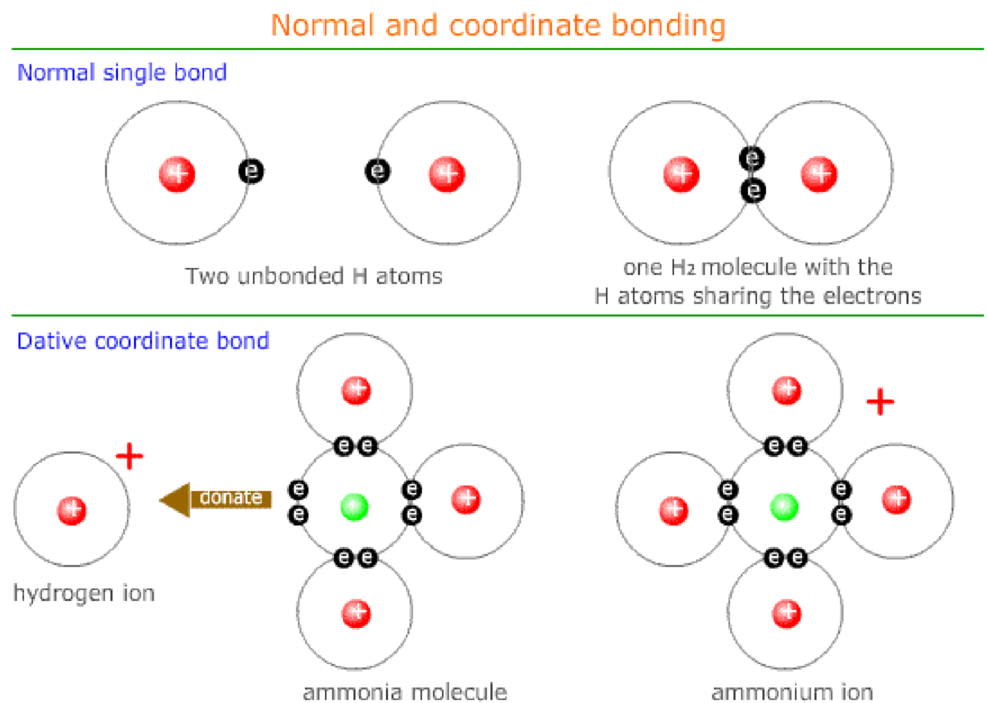




(3) Coorndinate covalent bond

- **If one atom donates two electrons for sharing with another atom (which donates no electrons), it is called a <u>coordinate covalent bond</u>.**
- **An example of this type of bond between N (nitrogen) in ammonia and a hydrogen ion (proton).**





FORMULA WRITING

a. Formulas.

- **Formulas are combinations of symbols that represent a compound.**
- **A formula indicates which elements are involved and the number of atoms of each element contained in the compound.**
- **In writing formulas, we use subscripts, coefficients, and parentheses in addition to the symbols of the elements.**

FORMULA WRITING

- **Subscripts** indicate the number of atoms of an element, as in H_2 where two is the subscript meaning two hydrogen atoms.
- If there is no subscript with a symbol, it is assumed there is only one atom of that element.
- **Coefficients**, numbers in front of the formula, indicate the number of molecules of compound , as in **4HCl** where four is the coefficient indicating four molecules of HCl.

- **Parentheses** are used to separate a radical from the rest of the formula when it would be confusing not to do so.
- In HNO_3, it is not necessary to include parentheses for the NO_3 - radical since there is little chance for confusion.
- However, we use parentheses for the same radical if it appears NO_3 in a compound such as $Hg(NO_3)_2$ where the 2 indicates that we have two NO 3- radicals.

b. Steps in Formula Writing

In writing formulas for compounds, there are four steps that should be followed.

(1) Determine the symbols for the elements in a compound.

(2) Determine the valence of each of the atoms or radicals.

(3) Write the positive element's symbol first, followed by that of the negative element.

(4) Make the compound electrically neutral by using subscripts.

c. Example.

Write the formula for calcium chloride.

(1) Calcium = Ca, Chloride = Cl.

(2) Ca valence is +2, Cl valence is -1.

(3) $Ca^{+2}Cl^{-1}$.

If we add the charges, we find that this compound is not neutral (+2 - 1 = +1).

Therefore, we must proceed to step (4).

(4) To have two negative charges to balance the two positive charges, we must have two Cl^{-1} ions (-1 x 2 = -2).

Thus, the formula would be $CaCl_2$.

d. Rule of Crossing Valences.

- **A convenient rule for determining what subscripts are necessary in writing formulas is the rule of crossing valences.**
- **This rule states that one can take the valence of the element at the left and make it the subscript of the element at the right, and in like manner take the valence of the element at the right and make it the subscript of the element at the left.**

For example:

Fe^{+3} SO_4^{-2} becomes $Fe_2(SO_4)_3$


Time for
Q&A