Lecture 4; CH 101: Inorganic Chemistry

Dr. Akshai Kumar A. S

Department of Chemistry
&
Centre For Nanotechnology
Indian Institute of Technology Guwahati
Guwahati – 781039, Assam, India

Periodic Table of Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	1 H Hydrogen 1.00794 1	Atomic # Symbol Name Atomic Mass																2 He Helium 4.002602 2	K
2	3 Li Lithium 6.941 2,1	4 Be Beryllium 9.012182 2,2											5 B Boron 10.811 2,3	6 C Carbon 12.0107 2,4	7 N Nitrogen 14.0067 2,5	8 O Oxygen 15.9994 2,6	9 F Fluorine 18.9984032 2,7	10 Ne Neon 20.1797 2,8	K L
3	11 Na Sodium 22.98976928 2,8,1	12 Mg Magnesium 24.3050 2,8,2											13 Al Aluminium 26.9815386 2,8,3	14 Si Silicon 28.0855 2,8,4	15 P Phosphorus 30.973762 2,8,5	16 S Sulfur 32.065 2,8,6	17 Cl Chlorine 35.453 2,8,7	18 Ar Argon 39.948 2,8,8	K L M
4	19 K Potassium 39.0983 2,8,8,1	20 Ca Calcium 40.078 2,8,8,2	21 Sc Scandium 44.955912 2,8,9,2	22 Ti Titanium 47.867 2,8,10,2	23 V Vanadium 50.9415 2,8,11,2	24 Cr Chromium 51.9961 2,8,13,1	25 Mn Manganese 54.938045 2,8,13,2	26 Fe Iron 55.845 2,8,14,2	27 Co Cobalt 58.933195 2,8,15,2	28 Ni Nickel 58.6934 2,8,16,2	29 Cu Copper 63.546 2,8,18,1	30 Zn Zinc 65.38 2,8,18,2	31 Ga Gallium 69.723 2,8,18,3	32 Ge Germanium 72.64 2,8,18,4	33 As Arsenic 74.92160 2,8,18,5	34 Se Selenium 78.96 2,8,18,6	35 Br Bromine 79.904 2,8,18,7	36 Kr Krypton 83.798 2,8,18,8	K L M N
5	37 Rb Rubidium 85.4678 2,8,18,8,1	38 Sr Strontium 87.62 2,8,18,8,2	39 Y Yttrium 88.90585 2,8,18,9,2	40 Zr Zirconium 91.224 2,8,18,10,2	41 Nb Niobium 92.90638 2,8,18,12,1	42 Mo Molybdenum 95.96 2,8,18,13,1	43 Tc Technetium (97.9072) 2,8,18,14,1	44 Ru Ruthenium 101.07 2,8,18,15,1	45 Rh Rhodium 102.90550 2,8,18,16,1	46 Pd Palladium 106.42 2,8,18,18,0	47 Ag Silver 107.8682 2,8,18,18,1	48 Cd Cadmium 112.411 2,8,18,18,2	49 In Indium 114.818 2,8,18,18,3	50 Sn Tin 118.710 2,8,18,18,4	51 Sb Antimony 121.760 2,8,18,18,5	52 Te Tellurium 127.60 2,8,18,18,6	53 I Iodine 126.90447 2,8,18,18,7	54 Xe Xenon 131.293 2,8,18,18,8	K L M N O
6	55 Cs Caesium 132.9054519 2,8,18,18,8,1	56 Ba Barium 137.327 2,8,18,18,8,2	57–71	72 Hf Hafnium 178.49 2,8,18,32,10,2	73 Ta Tantalum 180.94788 2,8,18,32,11,2	74 W Tungsten 183.84 2,8,18,32,12,2	75 Re Rhenium 186.207 2,8,18,32,13,2	76 Os Osmium 190.23 2,8,18,32,14,2	77 Ir Iridium 192.217 2,8,18,32,15,2	78 Pt Platinum 195.084 2,8,18,32,17,1	79 Au Gold 196.966569 2,8,18,32,18,1	80 Hg Mercury 200.59 2,8,18,32,18,2	81 Tl Thallium 204.3833 2,8,18,32,18,3	82 Pb Lead 207.2 2,8,18,32,18,4	83 Bi Bismuth 208.98040 2,8,18,32,18,5	84 Po Polonium (208.9824) 2,8,18,32,18,6	85 At Astatine (209.9871) 2,8,18,32,18,7	86 Rn Radon (222.0176) 2,8,18,32,18,8	K L M N O P
7	87 Fr Francium (223) 2,8,18,32,18,8,1	88 Ra Radium (226) 2,8,18,32,18,8,2	89–103	104 Rf Rutherfordium (261) 2,8,18,32,32,10,2	105 Db Dubnium (262) 2,8,18,32,32,11,2	106 Sg Seaborgium (266) 2,8,18,32,32,12,2	107 Bh Bohrium (264) 2,8,18,32,32,13,2	108 Hs Hassium (277) 2,8,18,32,32,14,2	109 Mt Meitnerium (268) 2,8,18,32,32,15,2	110 Ds Darmstadtium (271) 2,8,18,32,32,17,1	111 Rg Roentgenium (272) 2,8,18,32,32,18,1	112 Uub Ununbium (285) 2,8,18,32,32,18,2	113 Uut Ununtrium (284) 2,8,18,32,32,18,3	114 Uuq Ununquadium (289) 2,8,18,32,32,18,4	115 Uup Ununpentium (288) 2,8,18,32,32,18,5	116 Uuh Ununhexium (292) 2,8,18,32,32,18,6	117 Uus Ununseptium	118 Uuo Ununoctium (294) 2,8,18,32,32,18,8	K L M N O P Q

- C Solid
- Hg Liquid
- H Gas
- Rf Unknown

Metals: Alkali metals · Alkaline earth metals · Lanthanoids · Actinoids · Transition metals · Poor metals

Nonmetals: Other nonmetals · Noble gases

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547 2,8,18,18,9,2	58 Ce Cerium 140.116 2,8,18,19,9,2	59 Pr Praseodymium 140.90765 2,8,18,21,8,2	60 Nd Neodymium 144.242 2,8,18,22,8,2	61 Pm Promethium (145) 2,8,18,23,8,2	62 Sm Samarium 150.36 2,8,18,24,8,2	63 Eu Europium 151.964 2,8,18,25,8,2	64 Gd Gadolinium 157.25 2,8,18,25,9,2	65 Tb Terbium 158.92535 2,8,18,27,8,2	66 Dy Dysprosium 162.500 2,8,18,28,8,2	67 Ho Holmium 164.93032 2,8,18,29,8,2	68 Er Erbium 167.259 2,8,18,30,8,2	69 Tm Thulium 168.93421 2,8,18,31,8,2	70 Yb Ytterbium 173.054 2,8,18,32,8,2	71 Lu Lutetium 174.9668 2,8,18,32,9,2
89 Ac Actinium (227) 2,8,18,32,18,9,2	90 Th Thorium 232.03806 2,8,18,32,18,10,2	91 Pa Protactinium 231.03588 2,8,18,32,20,9,2	92 U Uranium 238.02891 2,8,18,32,21,9,2	93 Np Neptunium (237) 2,8,18,32,22,9,2	94 Pu Plutonium (244) 2,8,18,32,24,8,2	95 Am Americium (243) 2,8,18,32,25,8,2	96 Cm Curium (247) 2,8,18,32,25,9,2	97 Bk Berkelium (247) 2,8,18,32,27,8,2	98 Cf Californium (251) 2,8,18,32,28,8,2	99 Es Einsteinium (252) 2,8,18,32,29,8,2	100 Fm Fermium (257) 2,8,18,32,30,8,2	101 Md Mendelevium (258) 2,8,18,32,31,8,2	102 No Nobelium (259) 2,8,18,32,32,8,2	103 Lr Lawrencium (262) 2,8,18,32,32,9,2

Molecular Structure & Bonding
- Lewis Structures

Covalent bond: formed when two neighboring atoms share an electron pair

Single bond - A shaired electron pair A:B A—B

Double bond - Two shaired electron pairs A::B A=B

Triple bond - Three shaired electron pairs A:::B A≡B

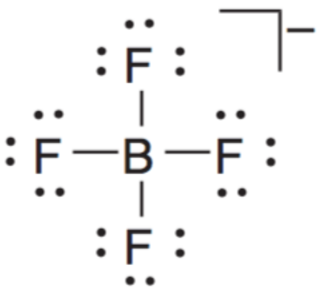
Lone pair - An unshaired valence electron pair A:

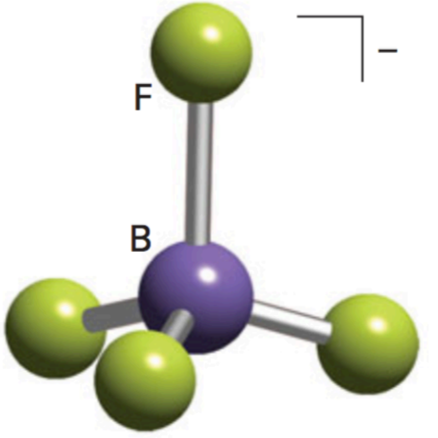
Diagram that shows the patterns of bonds and lone pairs in a molecule

Molecular Structure & Bonding
- Lewis Structures

Diagram that shows the patterns of bonds and lone pairs in a molecule

Does not portray the shape of species
Does not show the geometry of the molecule





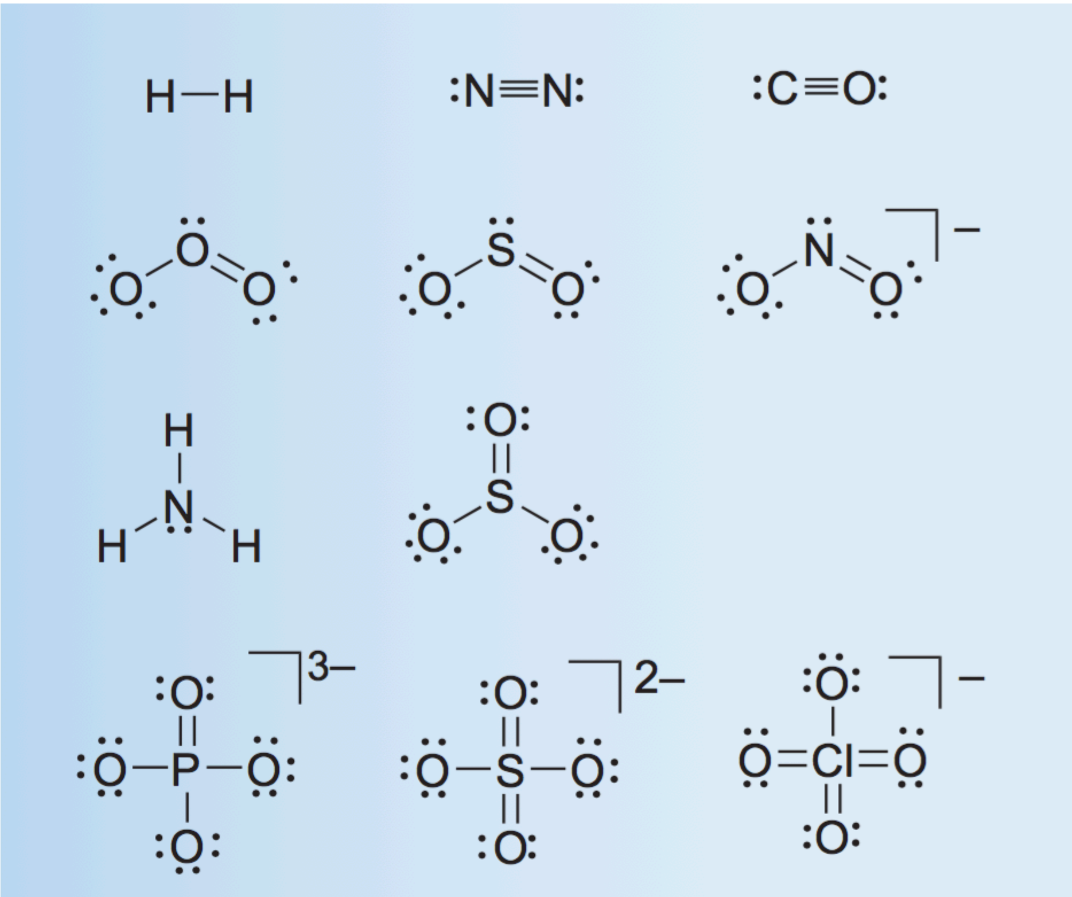
Molecular Structure & Bonding – Octet Rule

Atoms share electron pairs until they have acquired an octet of valence electrons

Provides a convenient method to construct Lewis structures

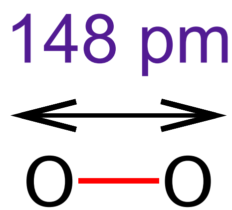
Decide: Number of electrons to be included
Arrange: Chemical symbols
Distribute: Electron pairs until each atom has an octet

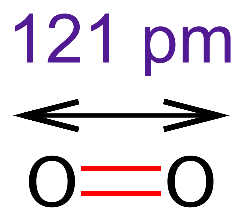
Molecular Structure & Bonding
- Lewis Structures

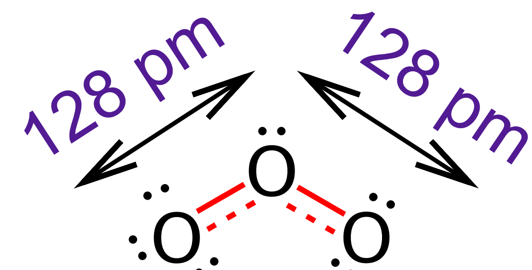


Structure & Bonding – Resonance

A single Lewis structure often provides an inadequate description of the molecule







Actual structure is the average of all possible Lewis structures corresponding to a given atomic arrangement

Structure & Bonding – Resonance

Actual wavefunction,

$$\psi = \psi(\mathrm{O{-}O{=}O}) + \psi(\mathrm{O{=}O{-}O})$$

Two structures have identical energies, hence equal contribution

Blended structure of two or more Lewis structures is called the resonance hybrid

Structures differ only in allocation of electrons

No resonance in structures where atoms lie in different positions (SOO & OSO)

Structure & Bonding – Resonance

Resonance averages the bond characteristics

Energy of resonance hybrid is lower than that of any single contributing structure

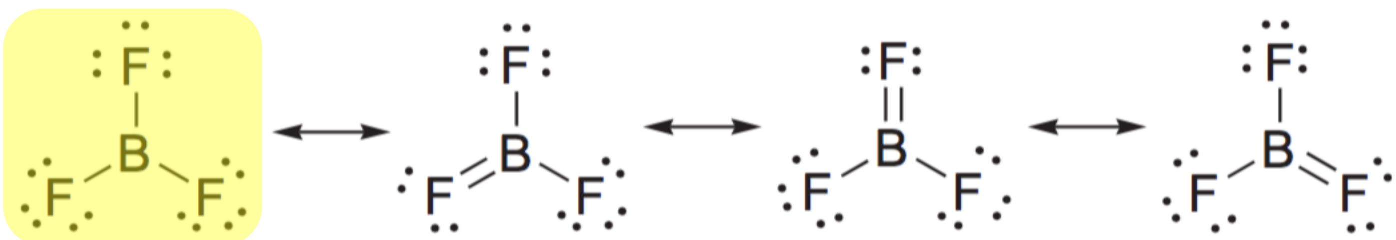
Lewis structures with similar energies provide greatest resonance stabilization

All the structures of the same energy contribute equally to the overall structure.

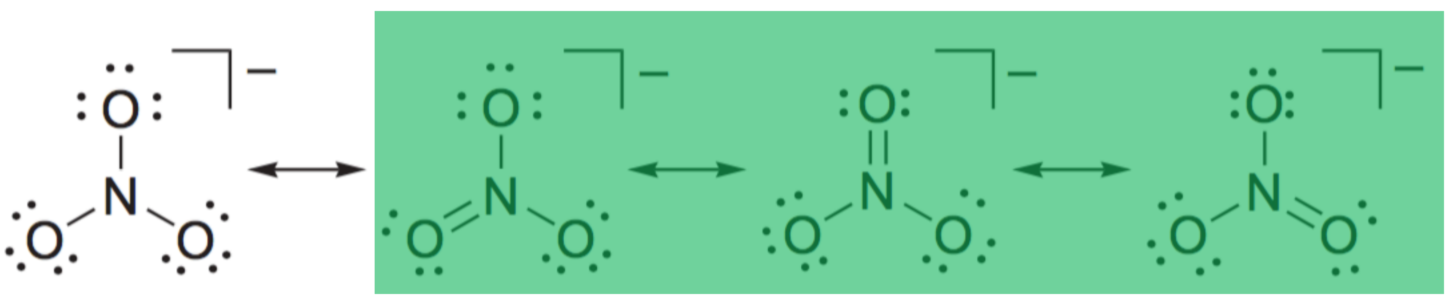
The greater the energy difference between two Lewis structures, the smaller the contribution of the higher energy structure.

Structure & Bonding – Resonance

Equal Contribution



Unequal



Unequal

Structure & Bonding – VSEPR Model

Regions of enhanced electron density take up positions as far apart as possible – Minimize repulsion

Number of electron regions	Arrangement
2	Linear
3	Trigonal planar
4	Tetrahedral
5	Trigonal bipyramidal
6	Octahedral

Structure & Bonding – VSEPR Model

Regions of enhanced electron density governs the shape of the molecule

Arrangement of atoms determines the name of the shape

Shape	Example
Linear	HCN, CO_2
Angular	H_2O, O_3
Trigonal planar	BF_3, SO_3
Trigonal pyramidal	NH_3
Tetrahedral	CH_4
Square planar	XeF_4
Square pyramidal	$Sb(Ph)_5$
Trigonal bipyramidal	PCl_5
Octahedral	SF_6

Structure & Bonding – VSEPR Model

Write down the Lewis structure of the molecule

Identify the central atom

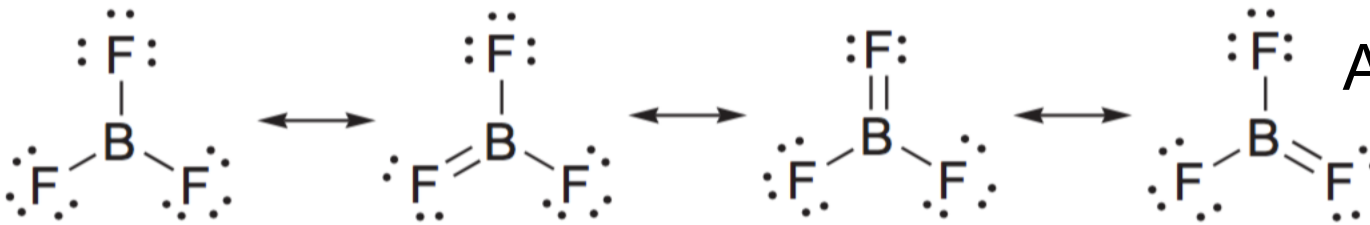
Count the number of lone pairs and atoms carried by the central atom

To achieve lowest energies lone pair regions take positions as far apart as possible

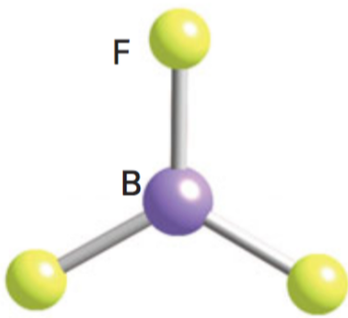
Identify the basic shape of the molecule

Name the shape of the molecule based on number/location of atoms

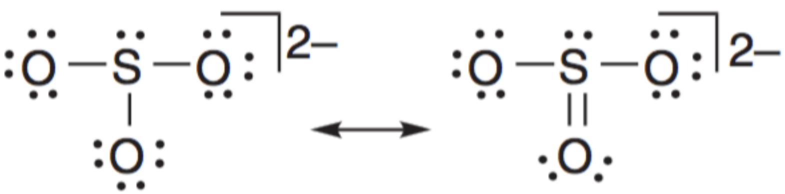
Structure & Bonding – VSEPR Model



Arrangement
Trigonal planar

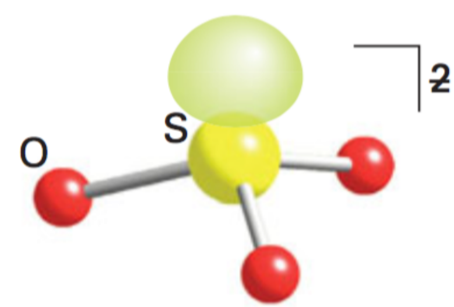


Name of the shape
Trigonal planar



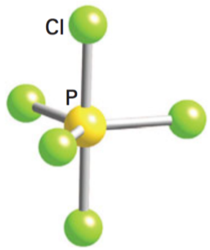
Arrangement: Tetrahedral

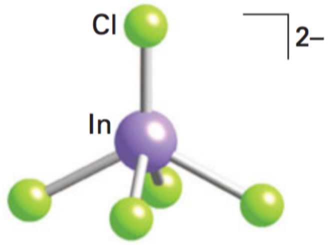
Name of the shape: Trigonal pyramidal



Structure & Bonding – VSEPR Model

A square-pyramidal arrangement is only slightly higher in energy than a trigonal-bipyramidal arrangement





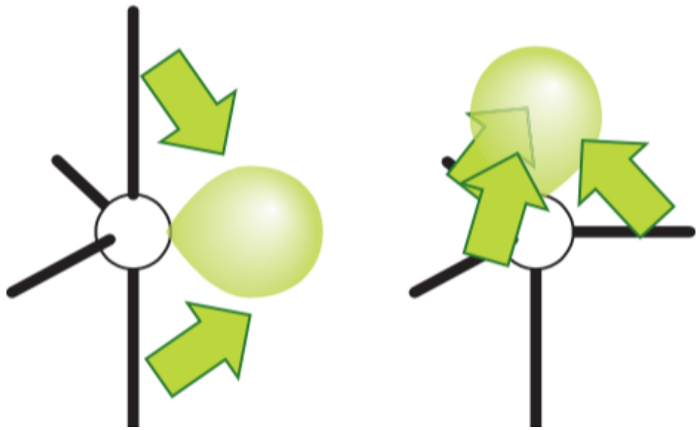
In p block, seven-coordination is dominated by pentagonal-bipyramidal structures (IF_7)

Lone pairs are stereochemically less influential when they belong to heavy p-block elements.

SeF_6^{2-} and $TeCl_6^{2-}$ ions, for instance, are octahedral (Lone pairs on Se and Te are **stereochemically inert** and are usually in the non-directional s orbitals.)

Structure & Bonding – VSEPR Model

lone pair/lone pair > lone pair/bonding region > bonding region/bonding region



CH_4 109.5

NH_3 107

H_2O 104.5