Mineralogy

Minerals – chemical compounds that form naturally as solids with shapes determined by the arrangement of atoms, e.g., quartz (SiO_2).

Crystals – the morphological manifestation of a mineral, e.g., quartz crystals commonly comprise hexagonal prisms topped by hexagonal pyramids and halite (NaCl) crystals commonly occur as cubes.

World's largest crystals:
A cave in the Naica Lead Zinc mine, Mexico

Miners in Cueva de los Crystals: the mineral gypsum

Crystals of a variety of gypsum ($CaSO_4.2H_2O$) precipitated from hot water at 60 degrees celsius in a limestone cave in the Naica mine

Minerals

Tourmaline on Feldspar

Emerald

Beryl
($Be_3Al_2(SiO_3)_6$

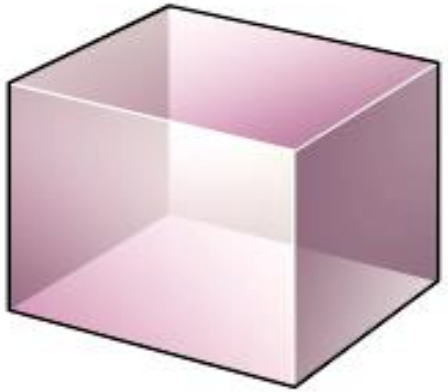
Pyrite (FeS_2) crystals

Feldspars – two of the most important rock-forming minerals

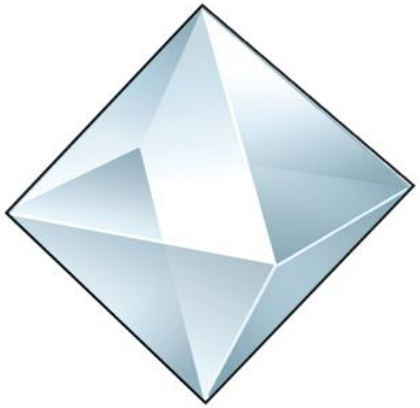
Colours and forms of quartz

Quartz crystals displaying prism and pyramid faces

Crystal Shapes

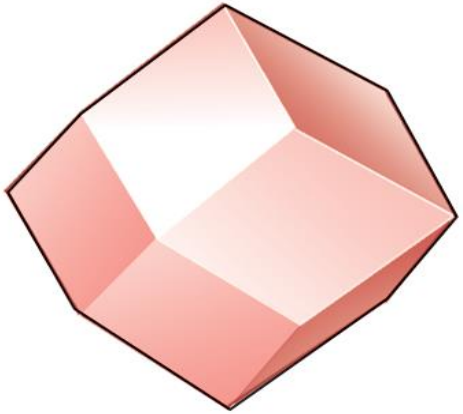


Halite
($NaCl$)



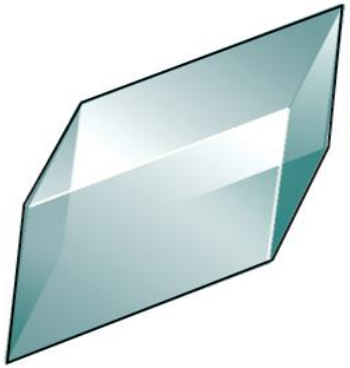
Diamond
(C)

Quartz
(SiO_2)



Garnet
($Fe_3Al_2Si_3O_{12}$)

Stibnite
(Sb_2S_3)



Calcite
($CaCO_3$)

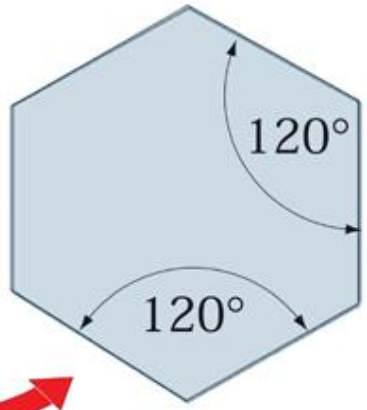
Quartz Crystal

Faces display consistent angular relationships

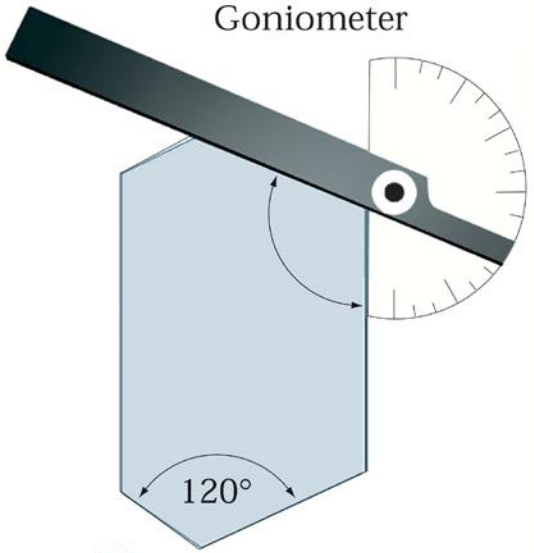
Angles measured with a goniometer

Pyramid

Basal cross section

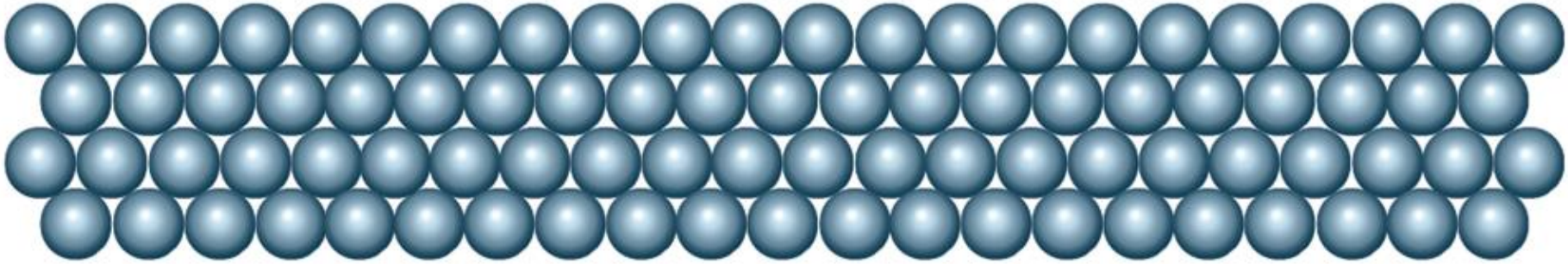


Prism

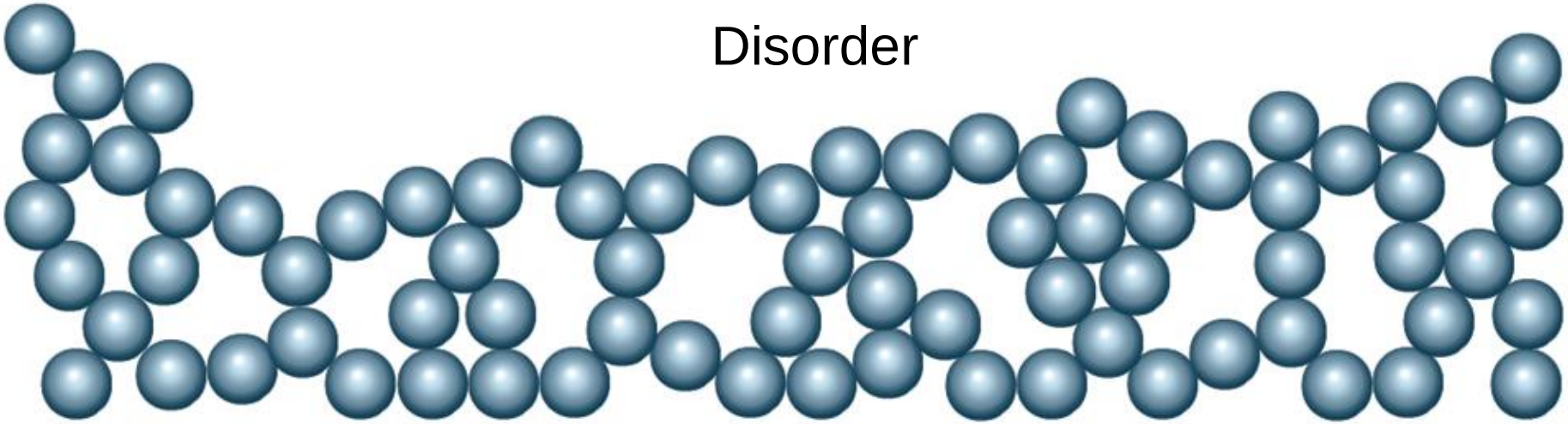


Crystals have ordered arrangements of atoms

Order

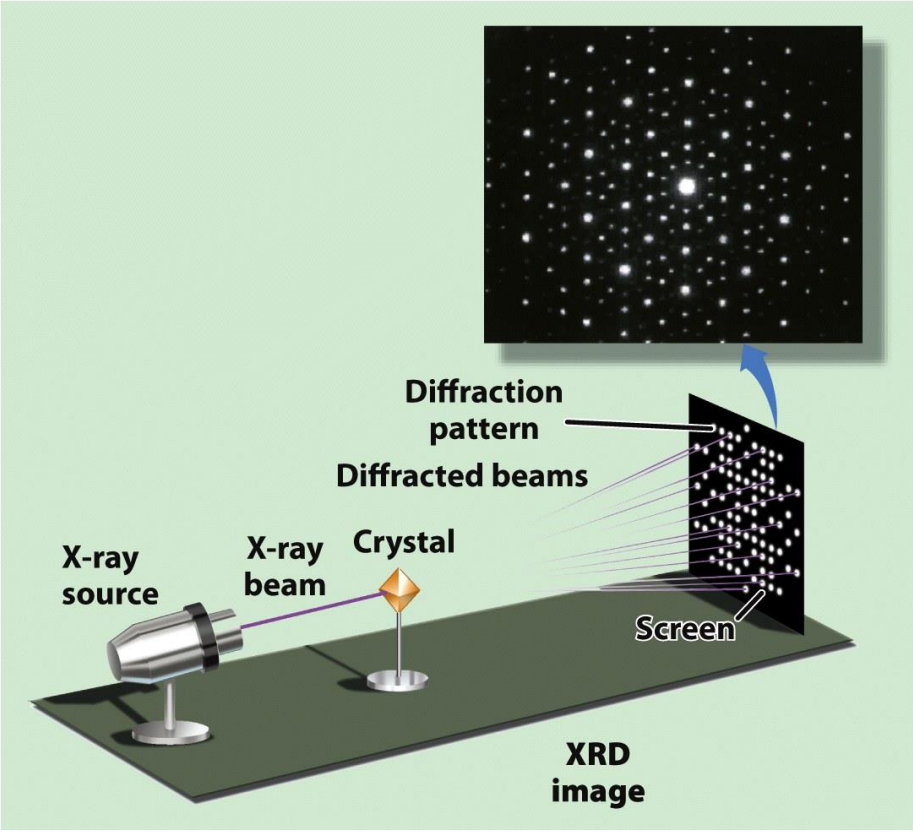


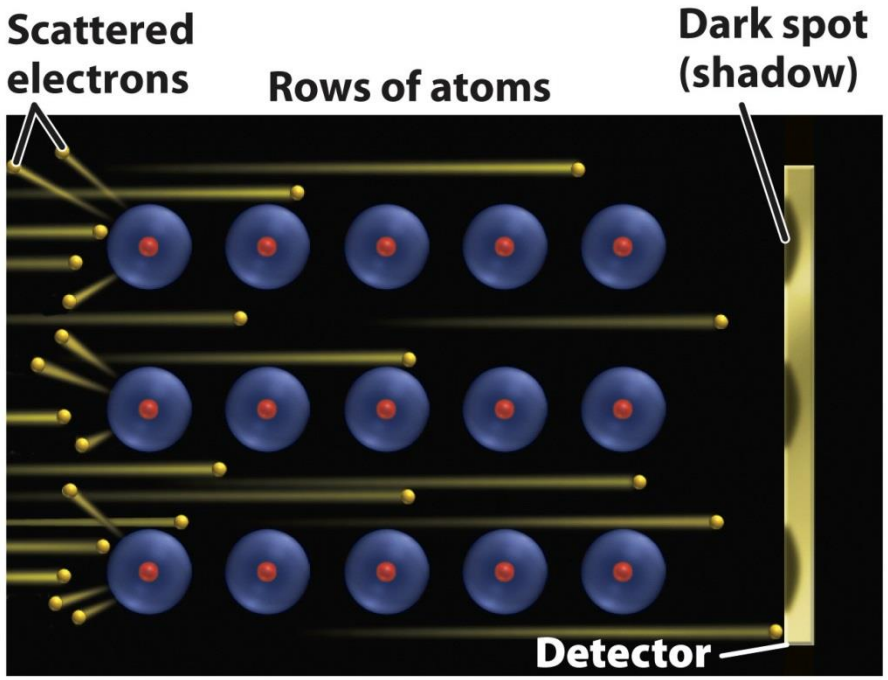
Disorder



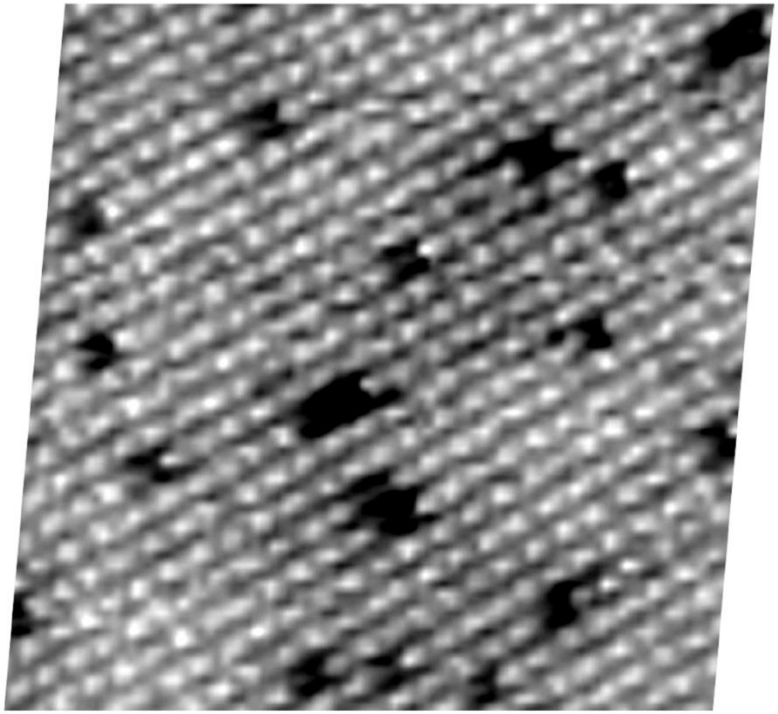
X-ray diffraction

X-ray beam splits into numerous smaller beams. Interference of waves of different beams produces a diffraction pattern on a screen or film. The pattern indicates the spacing and arrangement of atoms.

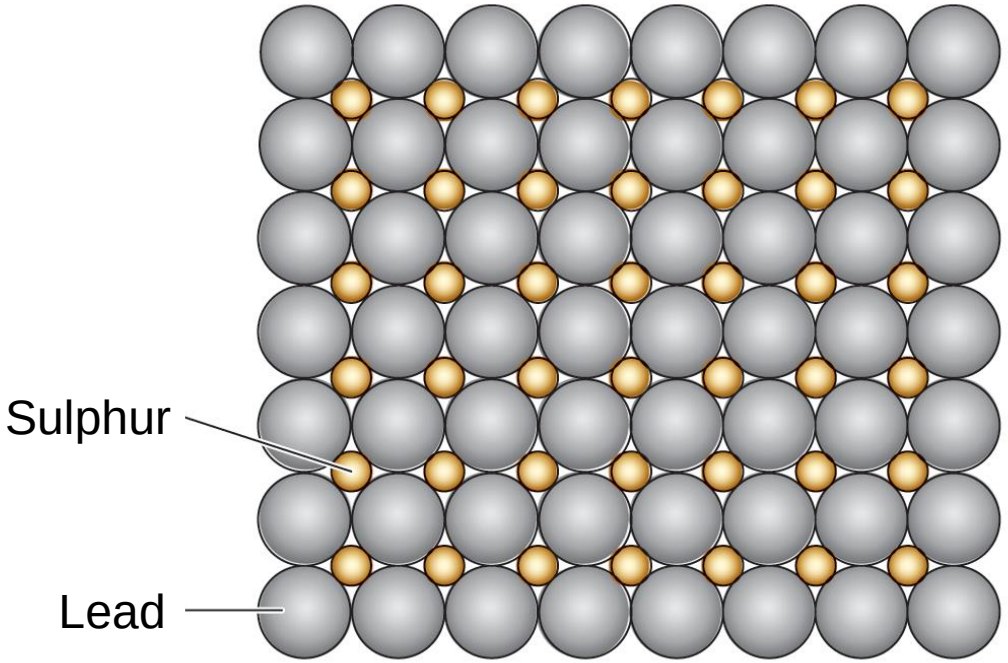




Surface of galena (PbS) imaged With an atomic force microscope

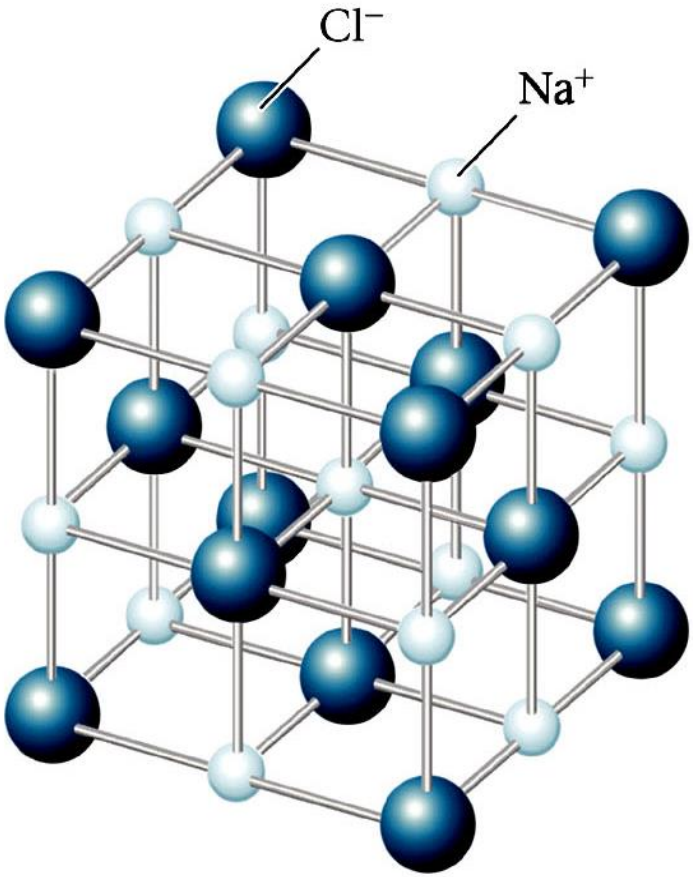


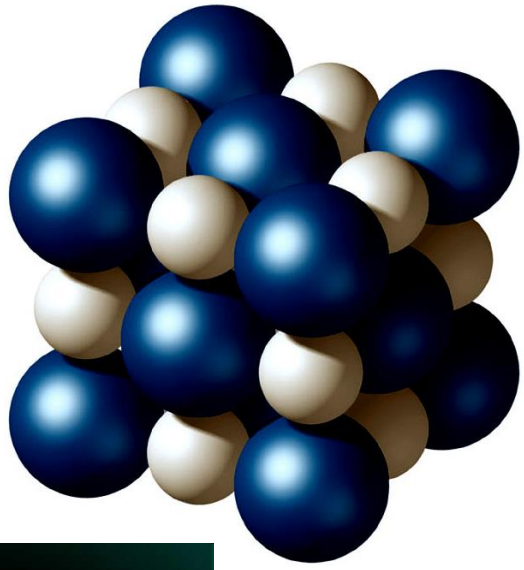
Atomic structure of galena (PbS)



The atomic structure of halite (NaCl)

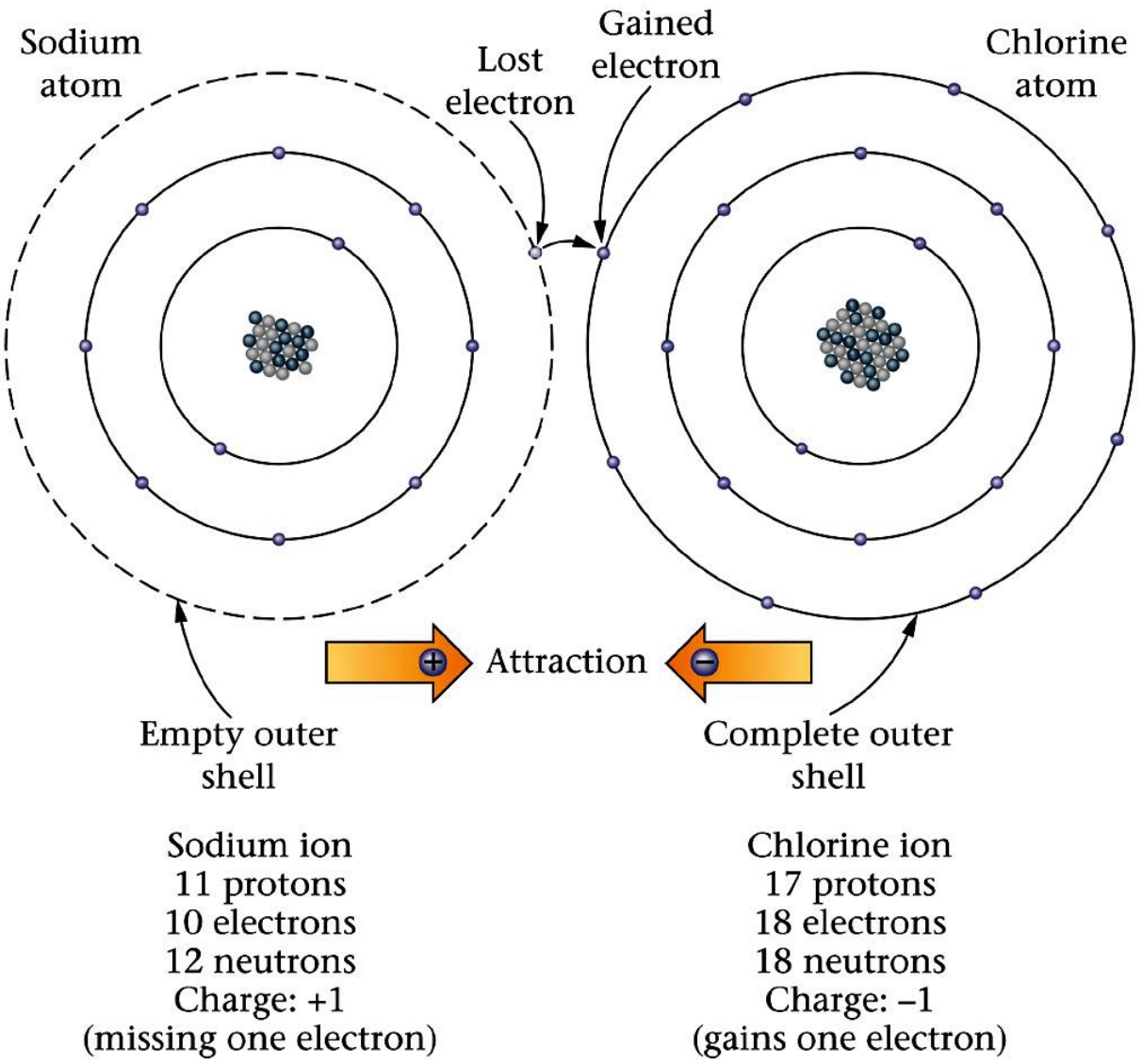
Ionic bonding





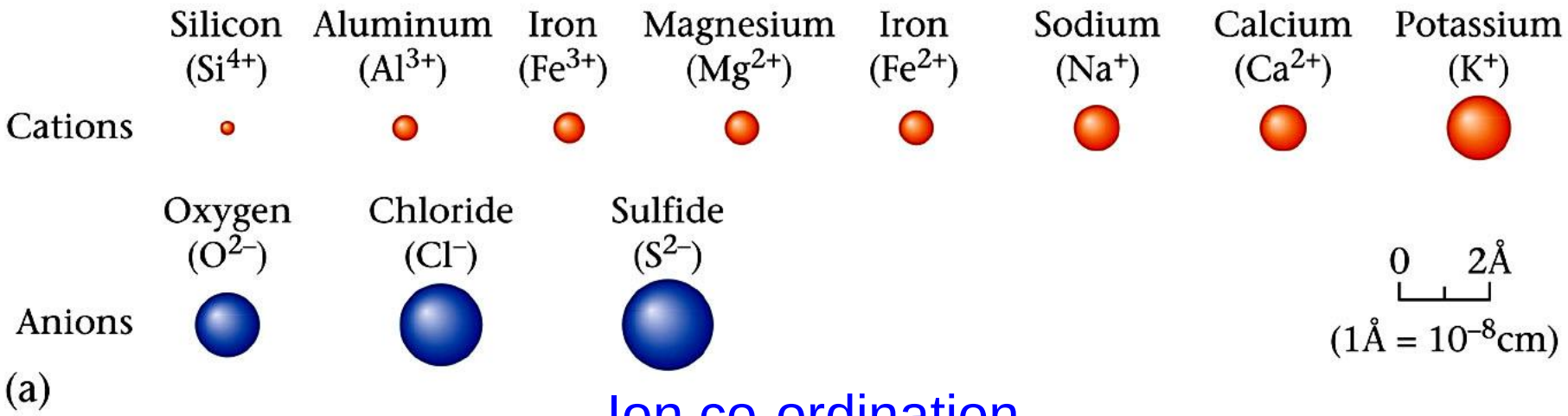
Ionic bonding – transfer of electrons

Cation +

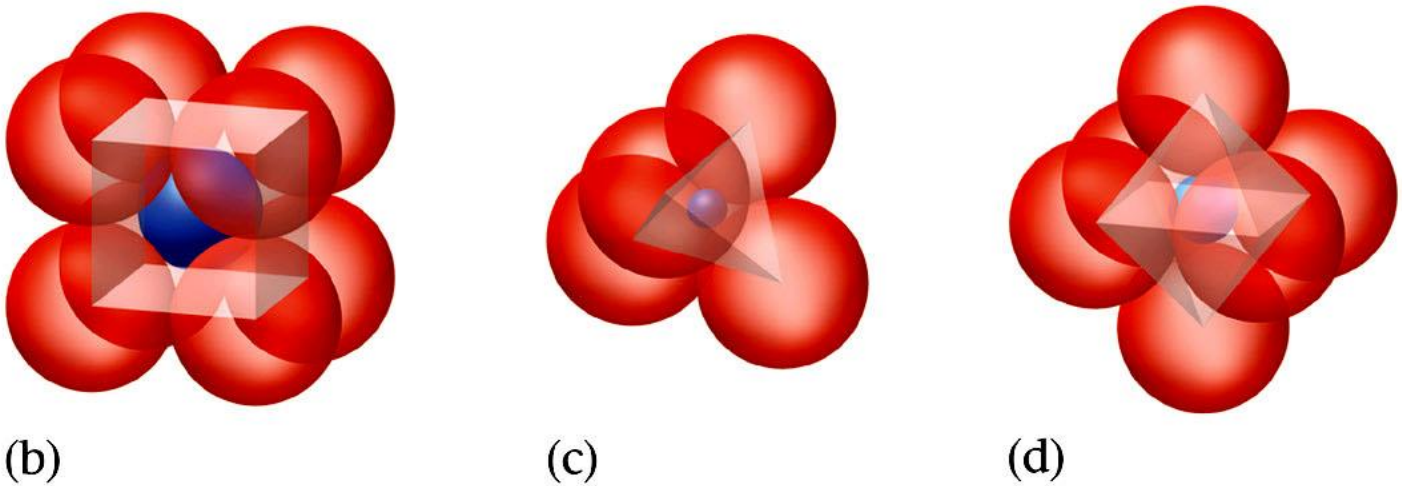


Anion -

Relative sizes of ions

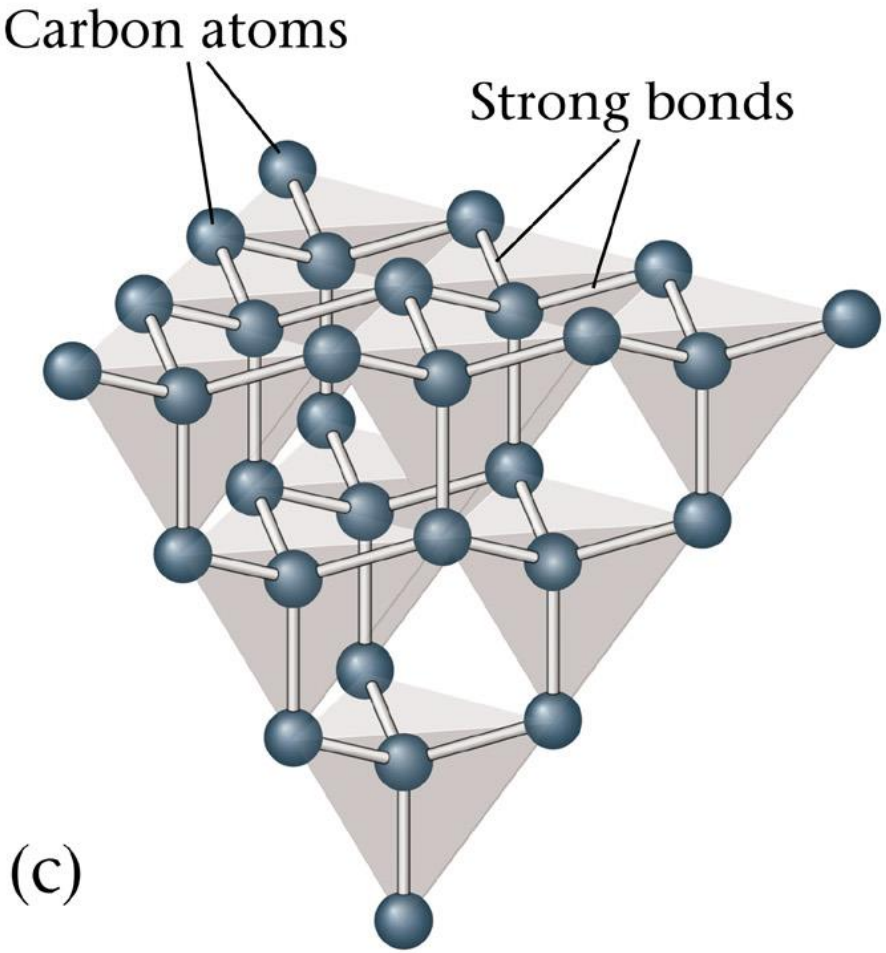


Ion co-ordination

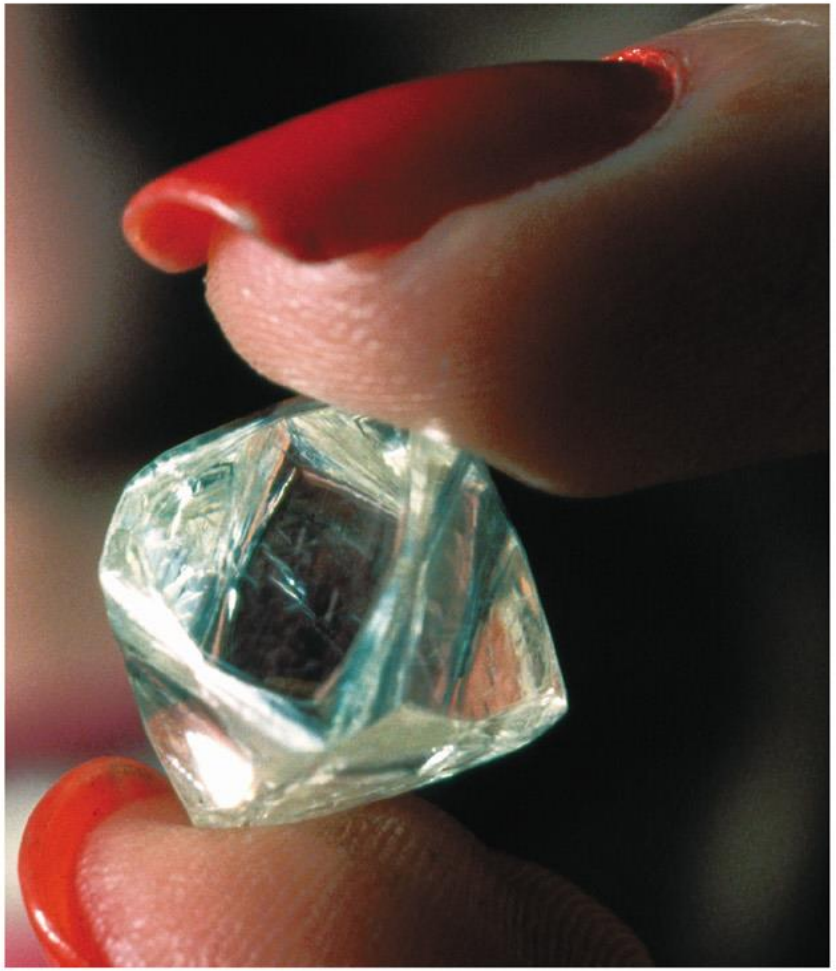


The atomic structure of diamond

Covalent bonding

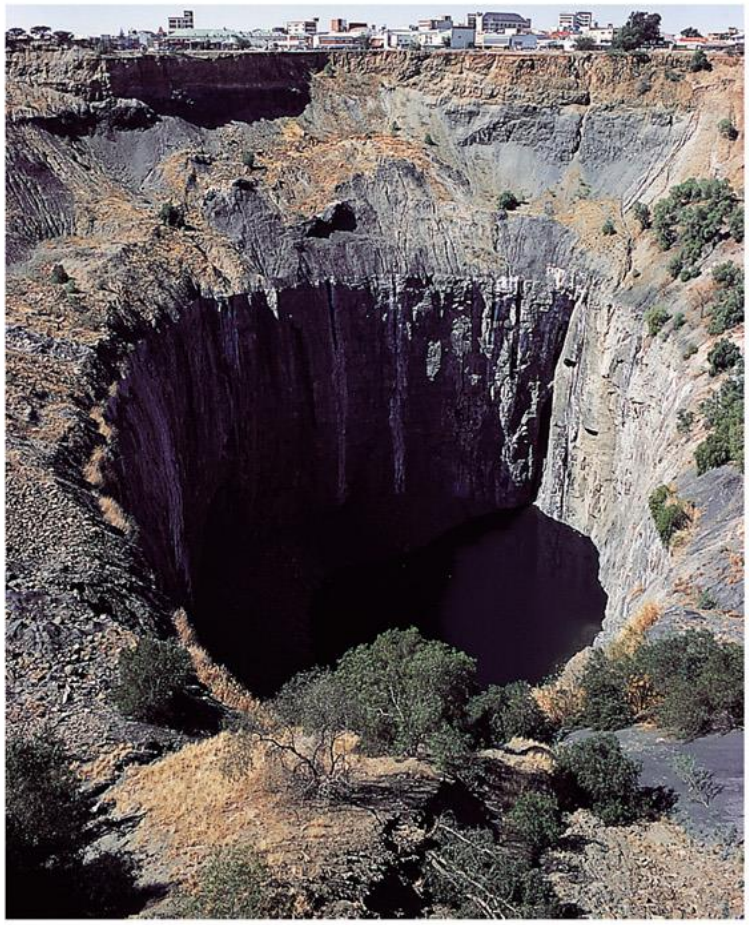


(c)



(d)

The source of Diamonds



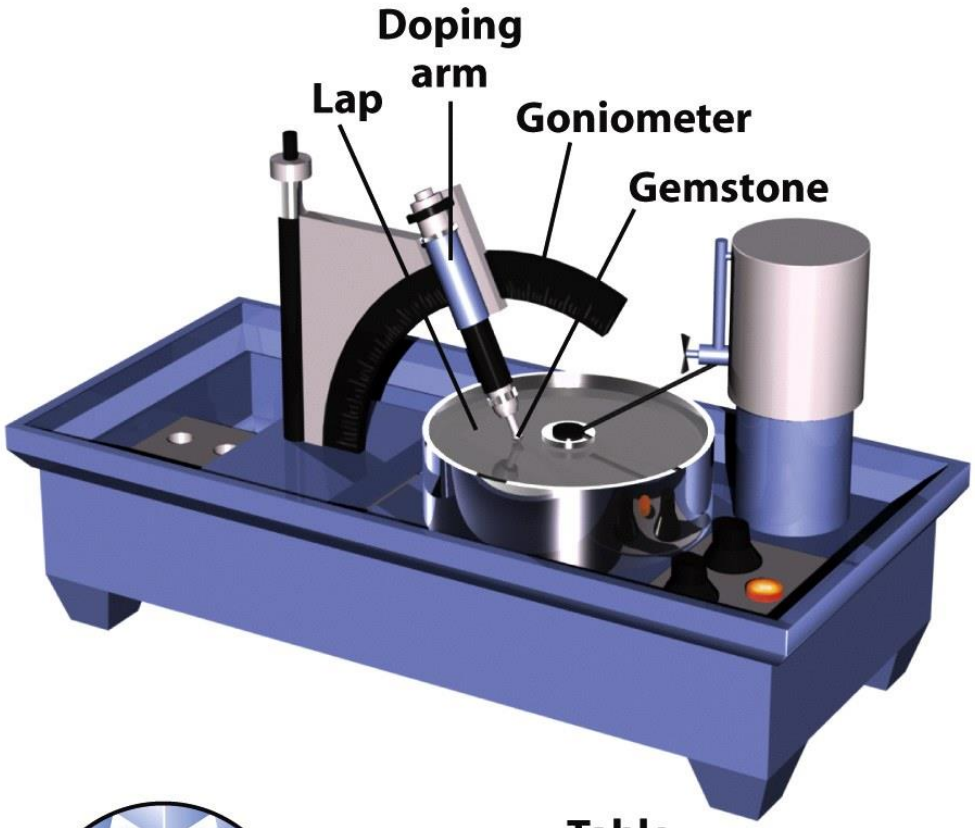
(a)

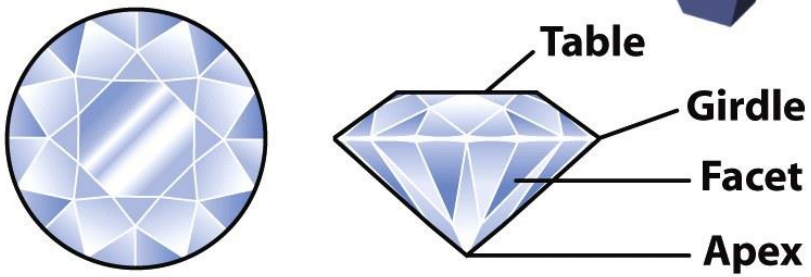
The ‘Big Hole’ at Kimberly, South Africa

Kimberlite containing diamond

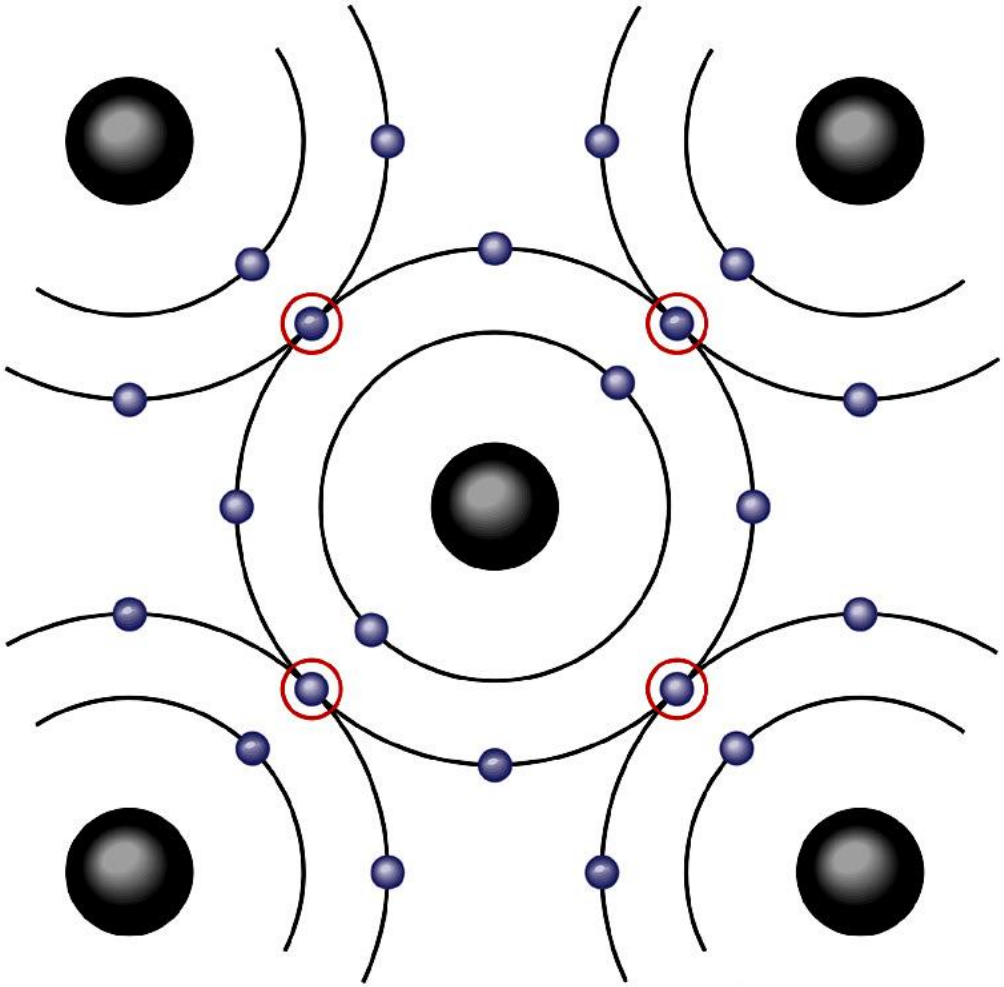
(b)

Cutting diamonds





Covalent bonding – sharing of electrons

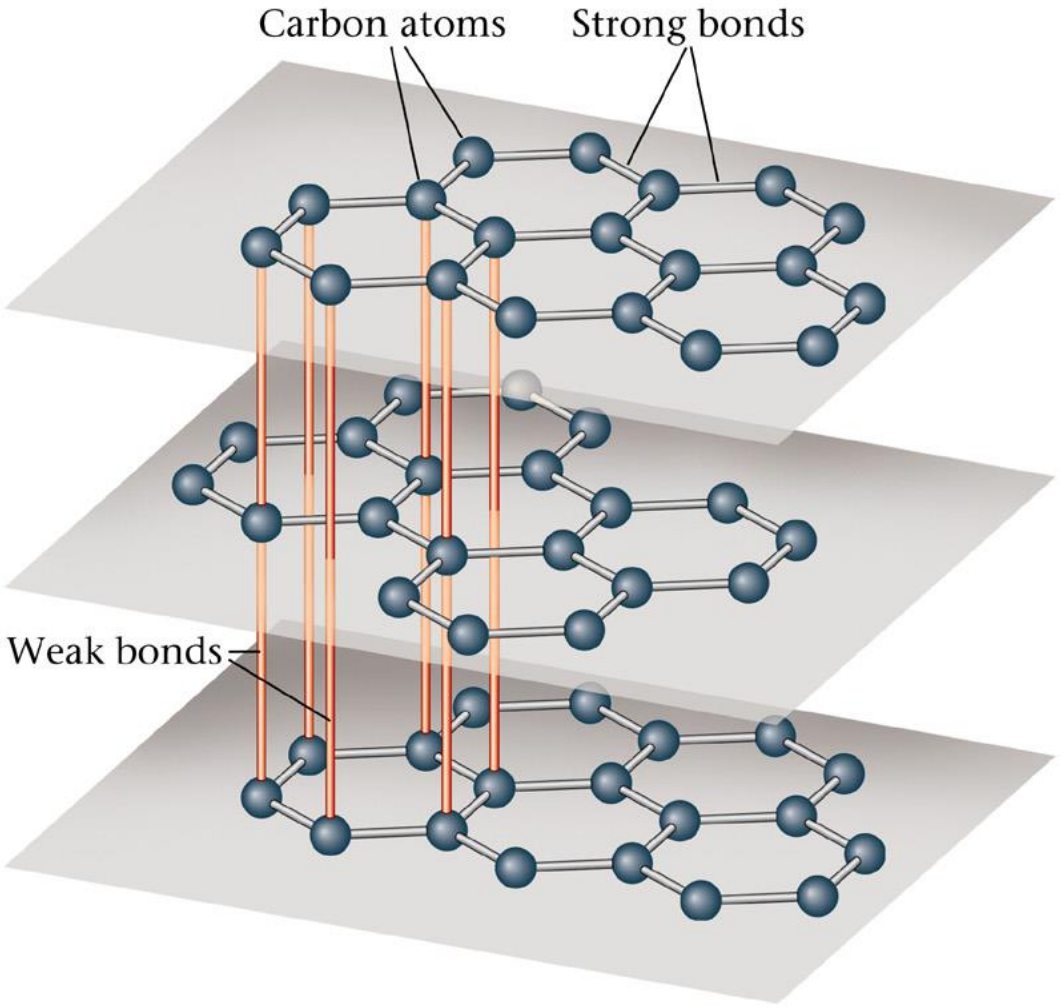


Unshared electron

Shared electron

Nucleus

Atomic structure of graphite



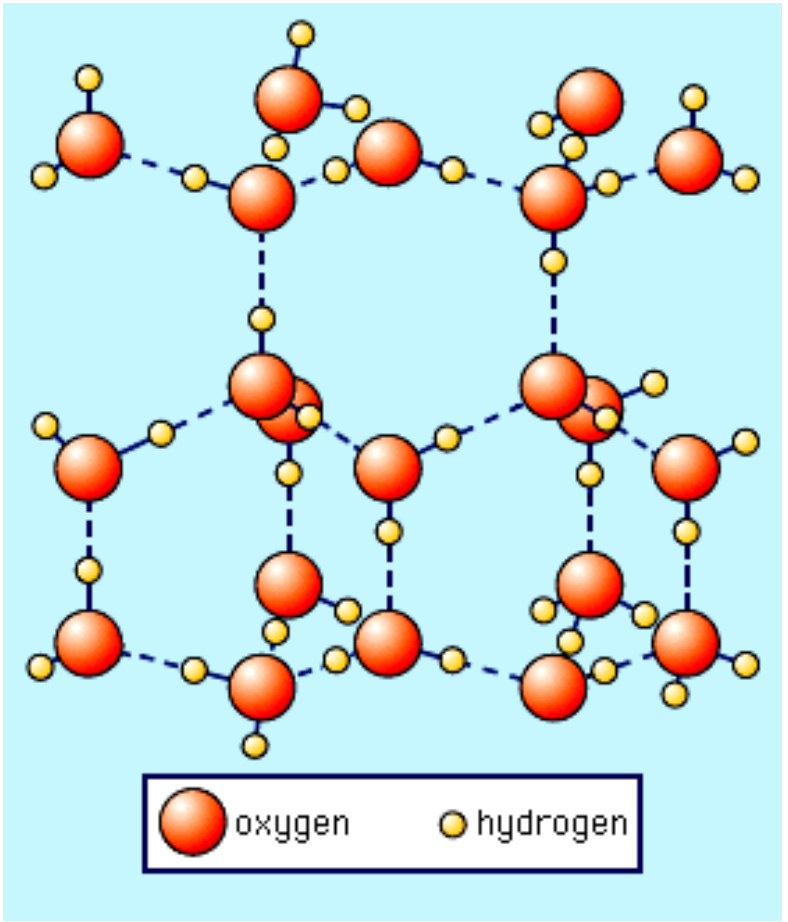
(e)

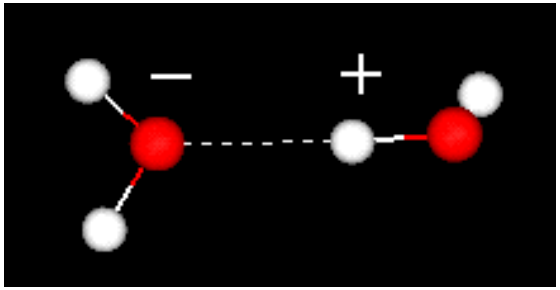
Covalent bonding within sheet

Van der Waal's bonding between sheets

(f)

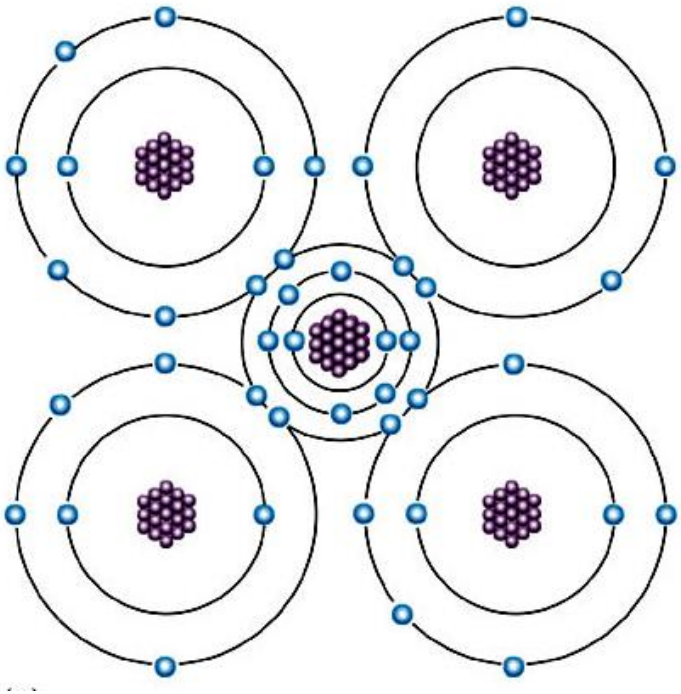
Ice Crystals

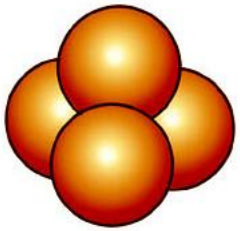


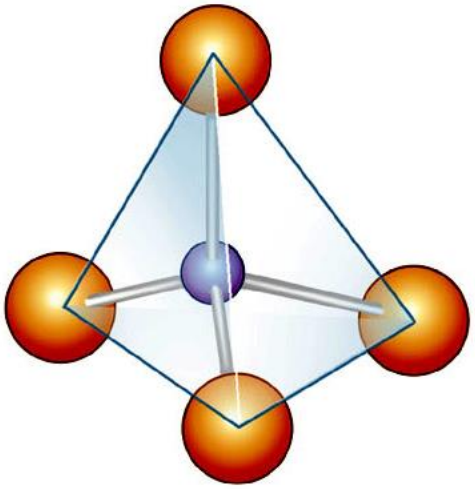


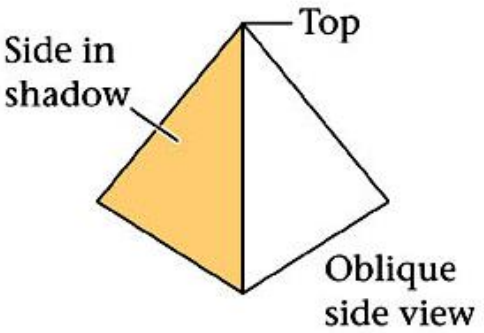
Hydrogen bonding

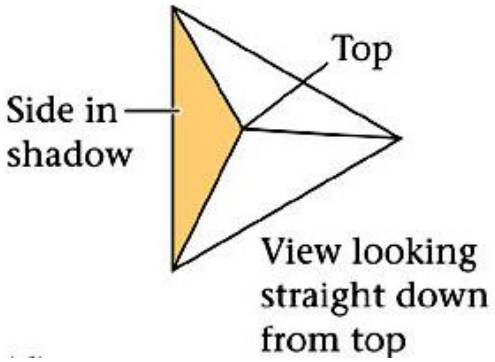
The silicon tetrahedron





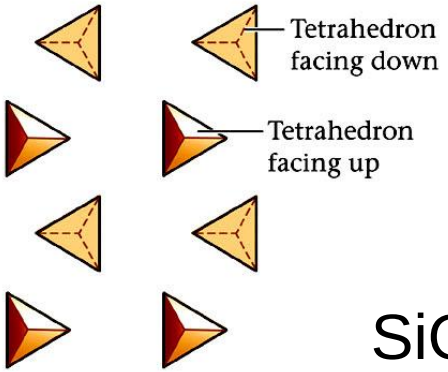






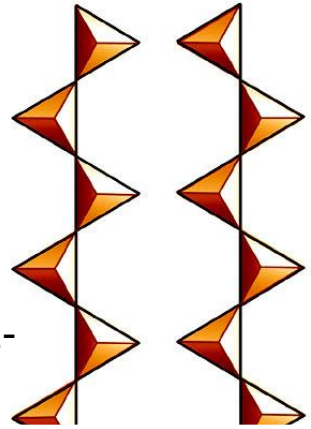
Silicate Structures

Nesosilicate



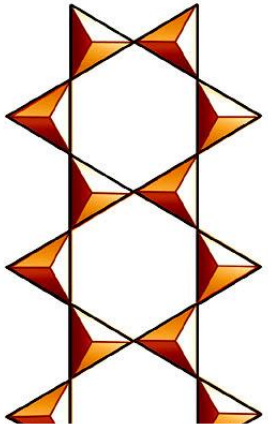
SiO_4^{4-}

Inosilicate (Single chain)



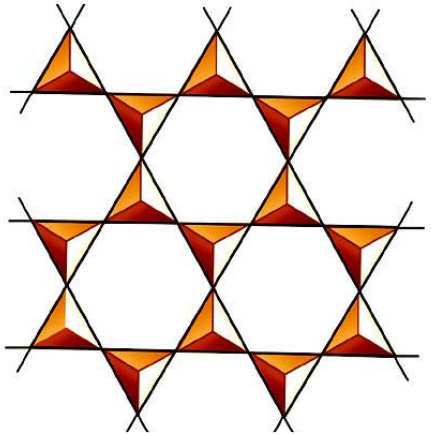
SiO_3^{2-}

Inosilicate (Double chain)



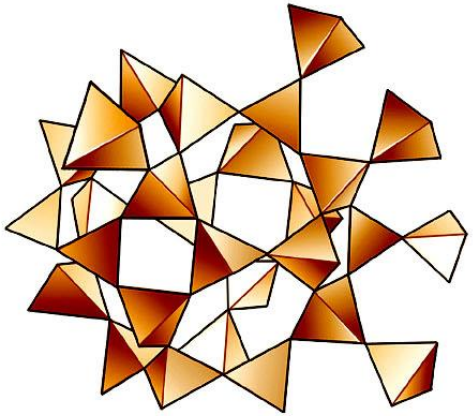
$Si_4O_{11}^{6-}$

Sheet silicate



$Si_4O_{10}^{4-}$

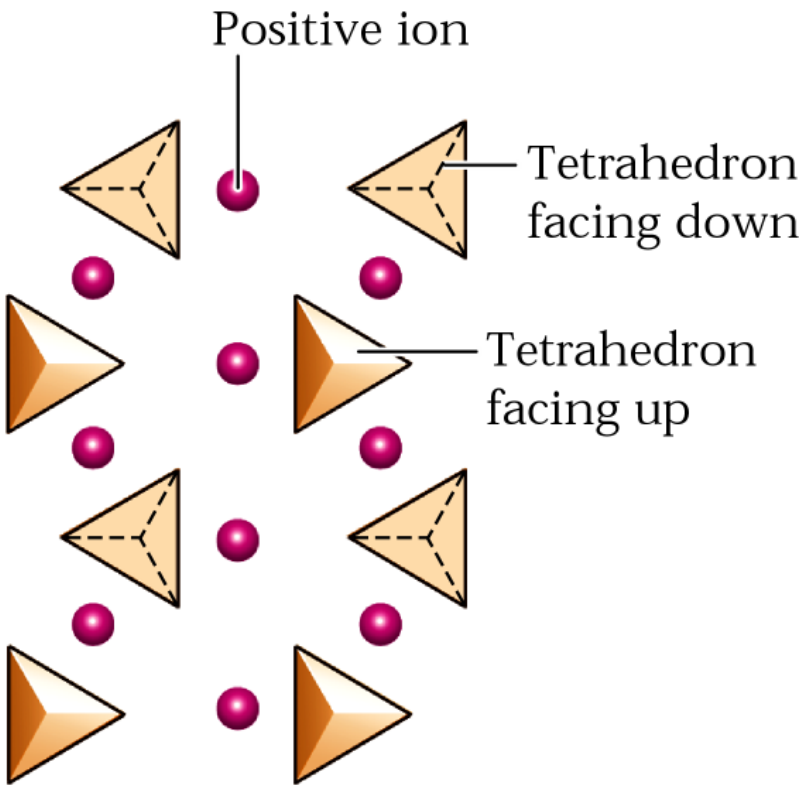
Framework silicate



SiO_2

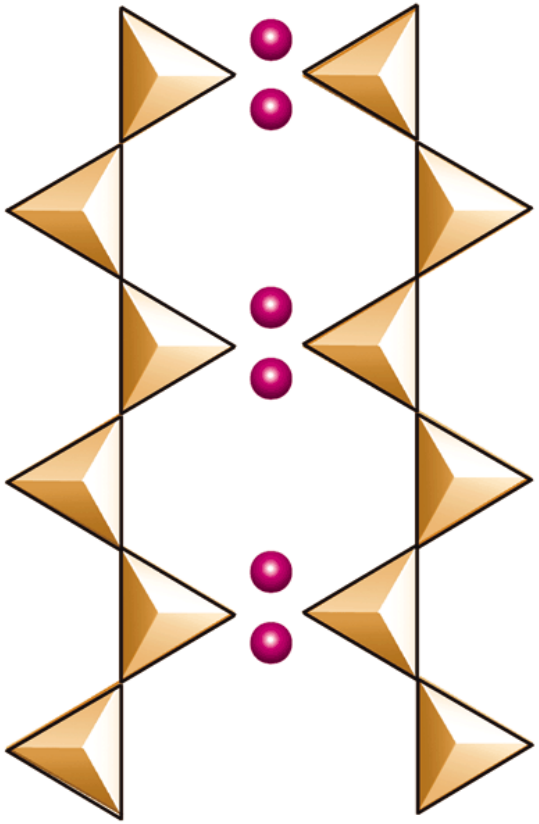
Nesosilicate

Olivine $(Fe,Mg)_2SiO_4$



Inosilicate (Single Chain)

Pyroxene



Diopside

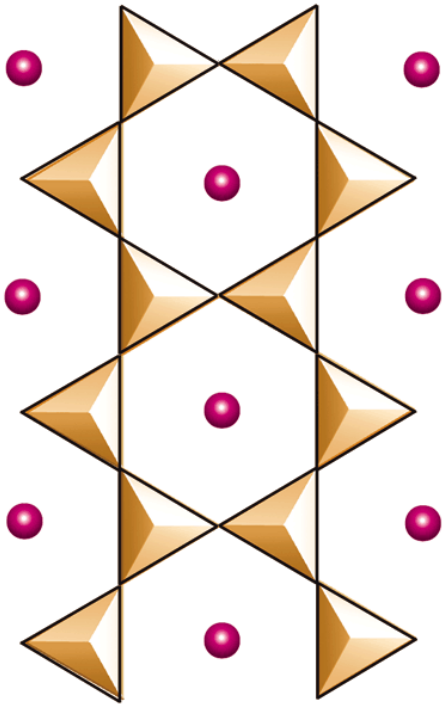
$CaMgSi_2O_6$

Hypersthene

$(Fe,Mg)SiO_3$

Inosilicate (Double Chain)

Amphibole



Tremolite
$Ca_2Mg_5Si_8O_{22}(OH)_2$

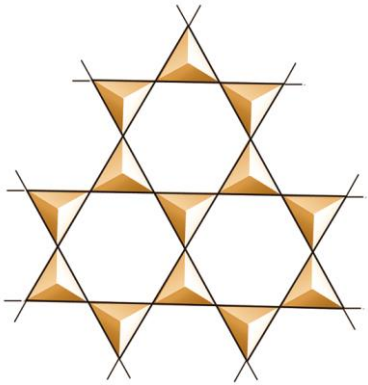
Riebeckite
$Na_2Fe_5Si_8O_{22(}OH)_2$

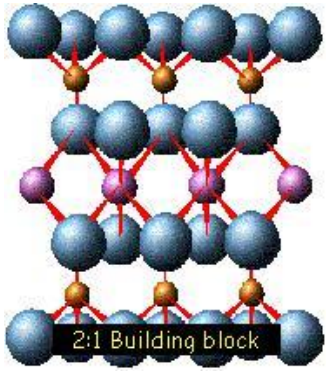
Tigers Eye

Sheet Silicate

Biotite

$KAl(Fe,Mg)_3Si_3O_{10}(OH)_2$





Muscovite

$KAl_3Si_3O_{10}(OH)_2$

Asbestos

Uses and risks

(Insulation, heat, fire resistance)

Framework Silicate

Quartz SiO_2

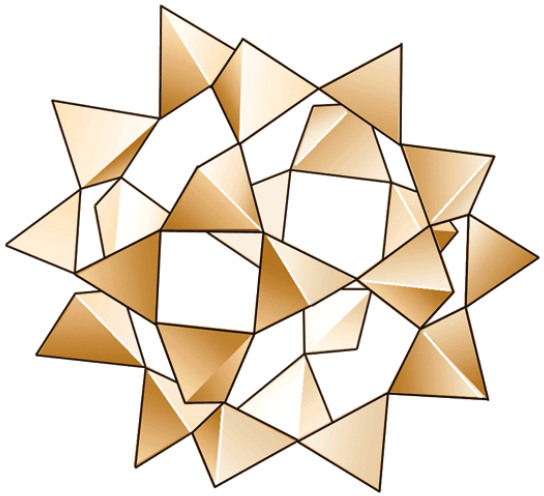
Plagioclase

Albite $NaAlSi_3O_8$

Anorthite $CaAl_2Si_2O_8$

K-feldspar $KAlSi_3O_8$

Amethyst SiO_2



Relationship of Quartz structure to Feldspar Structure

Imagine four SiO_2 molecules $4 \times SiO_2 = Si_4O_8$

Substitute Al^{3+} for Si^{4+} in one of these molecules

$$SiO_2 + AlO_2 + SiO_2 + SiO_2 = AlSi_3O_8^-$$

Add Na^+ or K^+ to supply missing charge = $NaAlSi_3O_8$ or $KAlSi_3O_8$

Albite K-Feldspar

$$SiO_2 + AlO_2 + AlO_2 + SiO_2 = Al_2Si_2O_8^{2-}$$

Add Ca^{2+} to supply missing charge = $CaAl_2Si_2O_8$

Anorthite