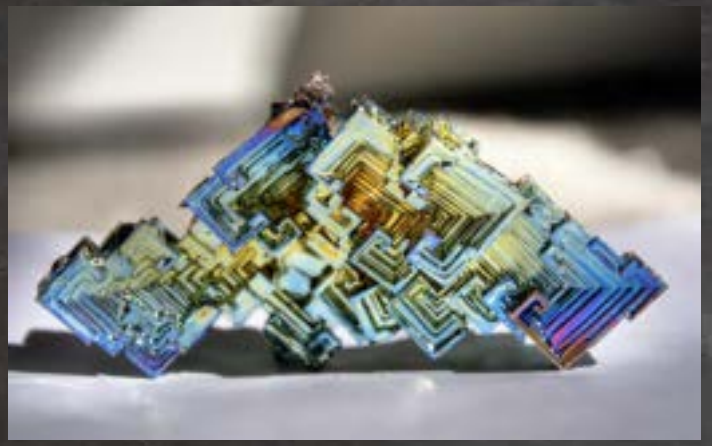
Ministry Of Higher Education and Scientific Research
Salahaddin University / College of Science
Department of Chemistry

Geochemistry and Mineralogy

Dr. Awaz K. Rasul

2022-2023

Lecture 3



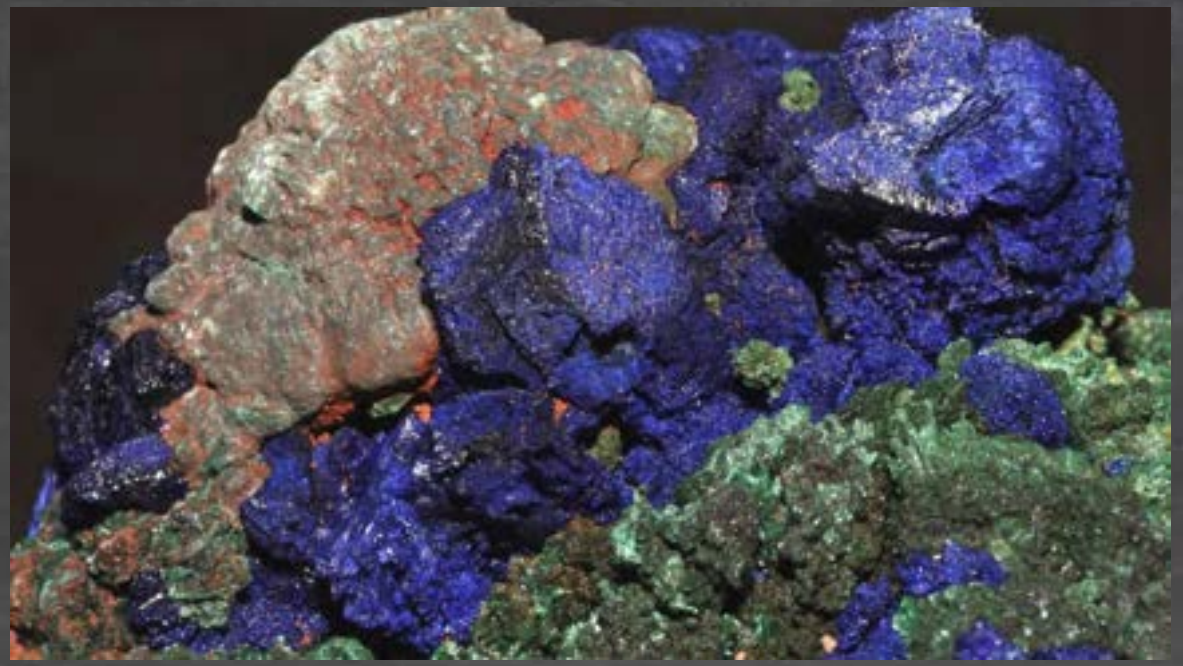
Mineralogy

outlines:

1. Terms.
2. Mineral naming.
3. Mineral forming.
4. Chemical bonds.
5. Physical properties of minerals.
6. Toxic Elements in Minerals.
7. Classification of minerals.

1.Terms:

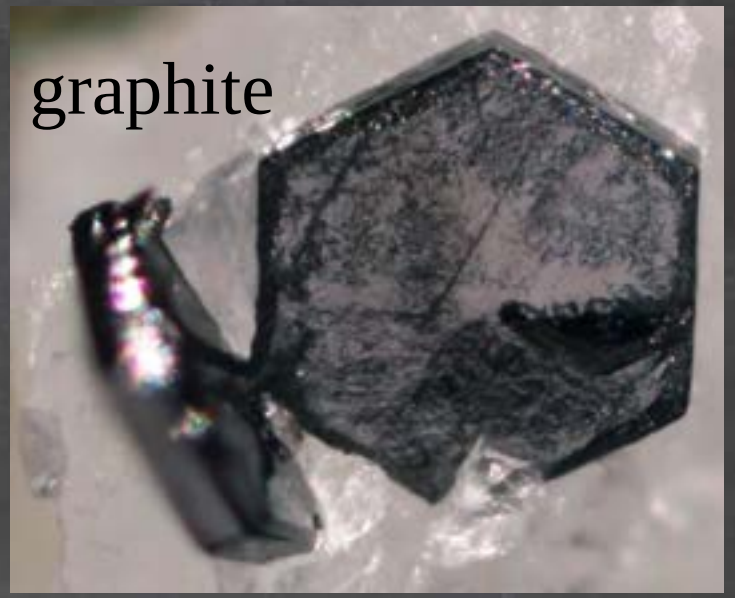
- ***Minerals*** are *naturally occurring*, macroscopically *homogeneous components* of the Earth, with a definite but not necessarily *fixed chemical composition*, with few exceptions. minerals are *inorganic*, *solid* and *crystalline*.



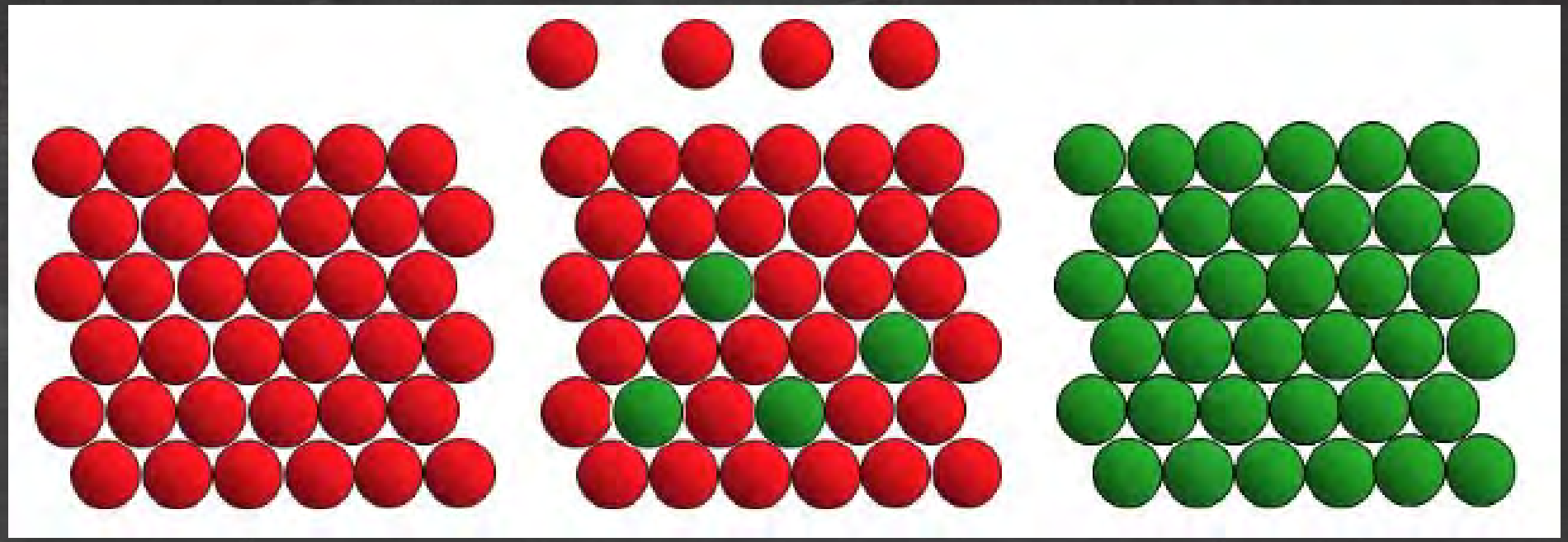
- A *mineraloid* is a naturally occurring mineral-like substance that does not demonstrate crystallinity (opal, $SiO_2 \cdot nH_2O$) and obsidian.

- ***Isomorphism:*** crystals that crystallize in the same crystal system with different chemical compositions, and their bond types are less important. halite, **NaCl,** with pure **ionic bonding** and of **galena PbS** with dominant **metallic bonding**, both of them are **cubic system**.

- ***Polymorphism:*** is a property of many chemical substances to crystallize in more than one crystal structure, depending on the respective thermodynamic conditions of state. Examples of polymorphic minerals are **orthorhombic and monoclinic sulfur, S, graphite** and **diamond, C, calcite and aragonite, $CaCO_3$, α-quartz, β-quartz.**



- Crystals, in which one or more point position(s) are statistically occupied by two or more chemical components are called *solid solutions.*



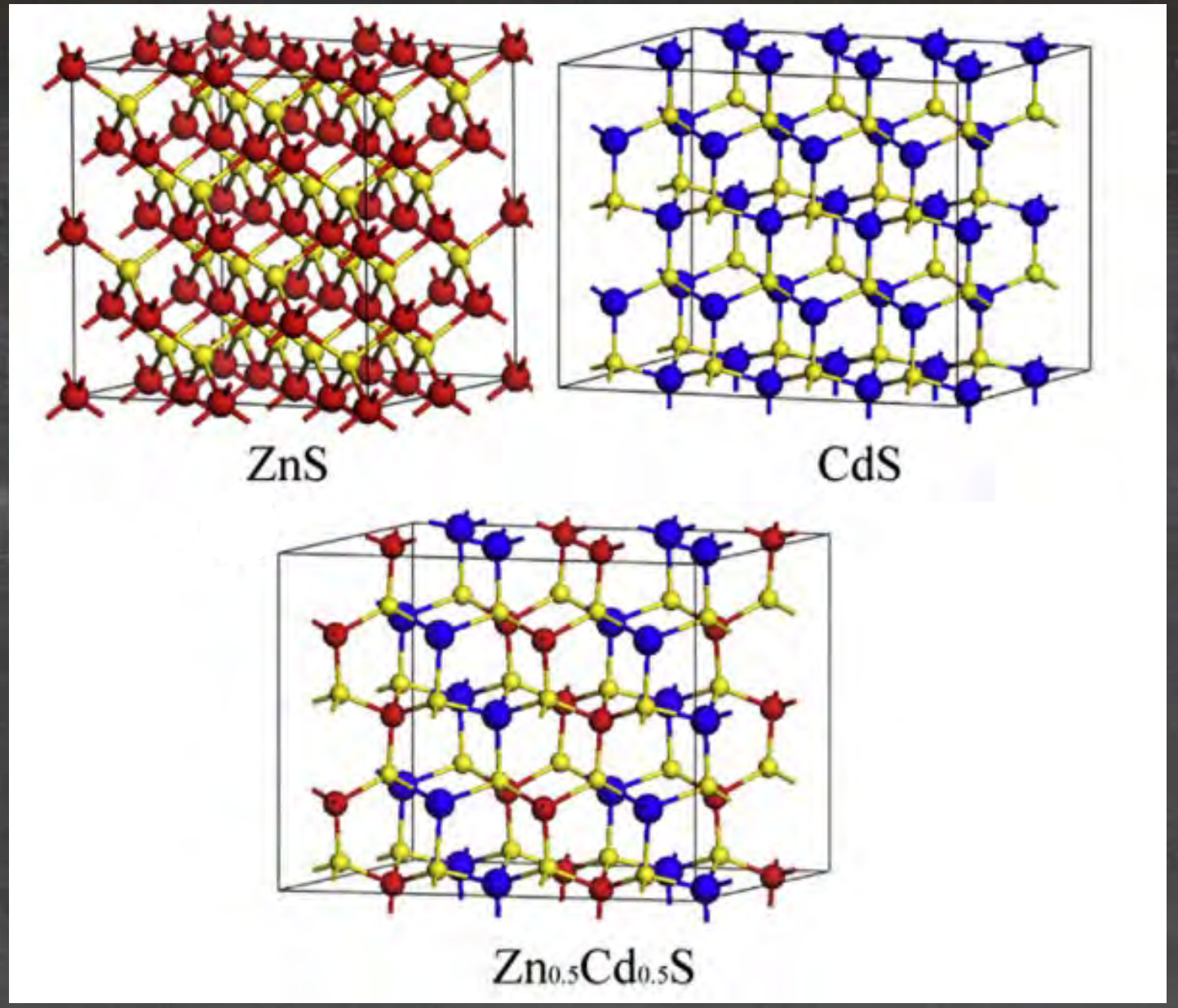
the rule of solid solution:

*1- **radii differ** less than approximately **15%**.*

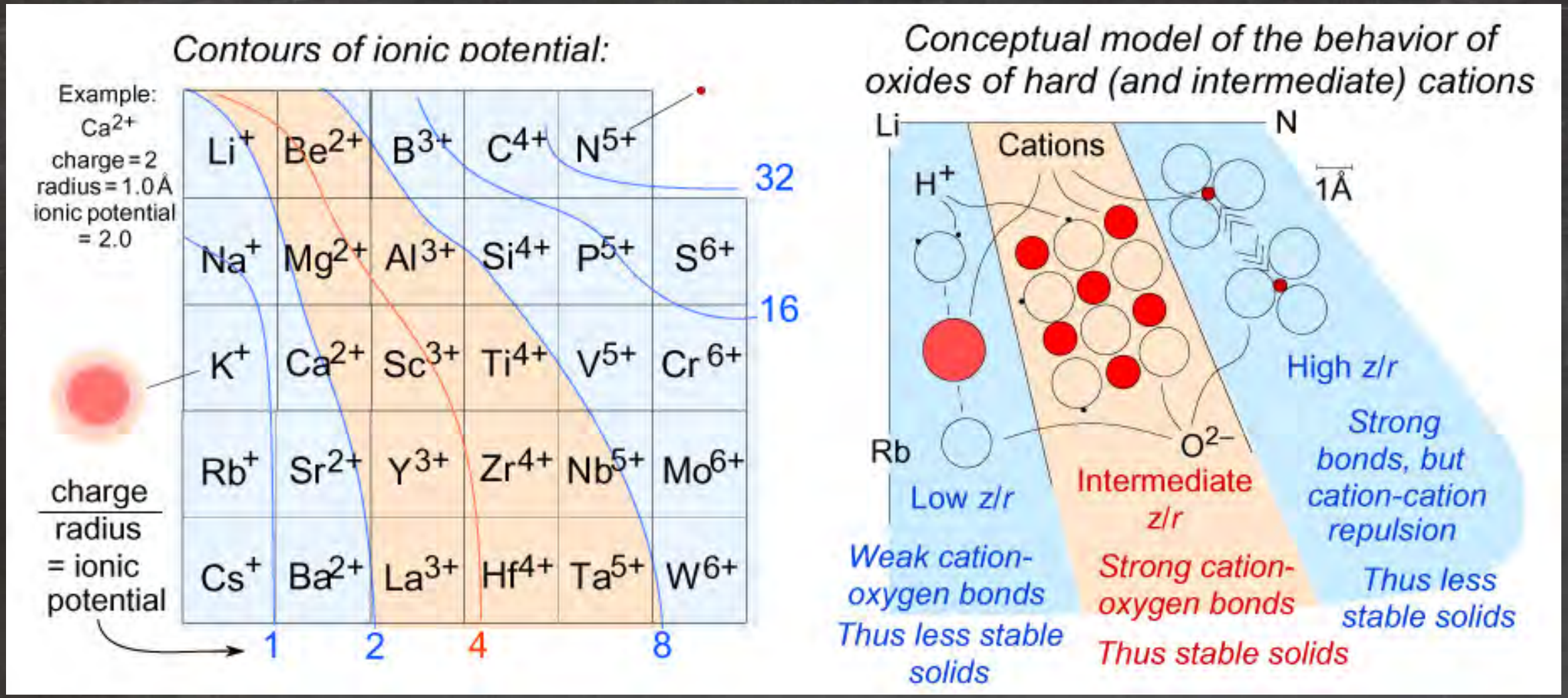
*2- Ions whose **charges** differ by **one**.*

*3- the **high ionic potential** forms a stronger bond with the anions surrounding the site.*

*4- **low differences in electronegativities**, For example, Na^+ and Cu^+ have the same radius and charge, but do not substitute for one another.*


ZnS
CdS
$Zn_{0.5}Cd_{0.5}S$

- *Ionic potential:* is the ratio of the electrical charge (z) to the radius (r) of an **ion**.



2. Minerals are named on the basis of:

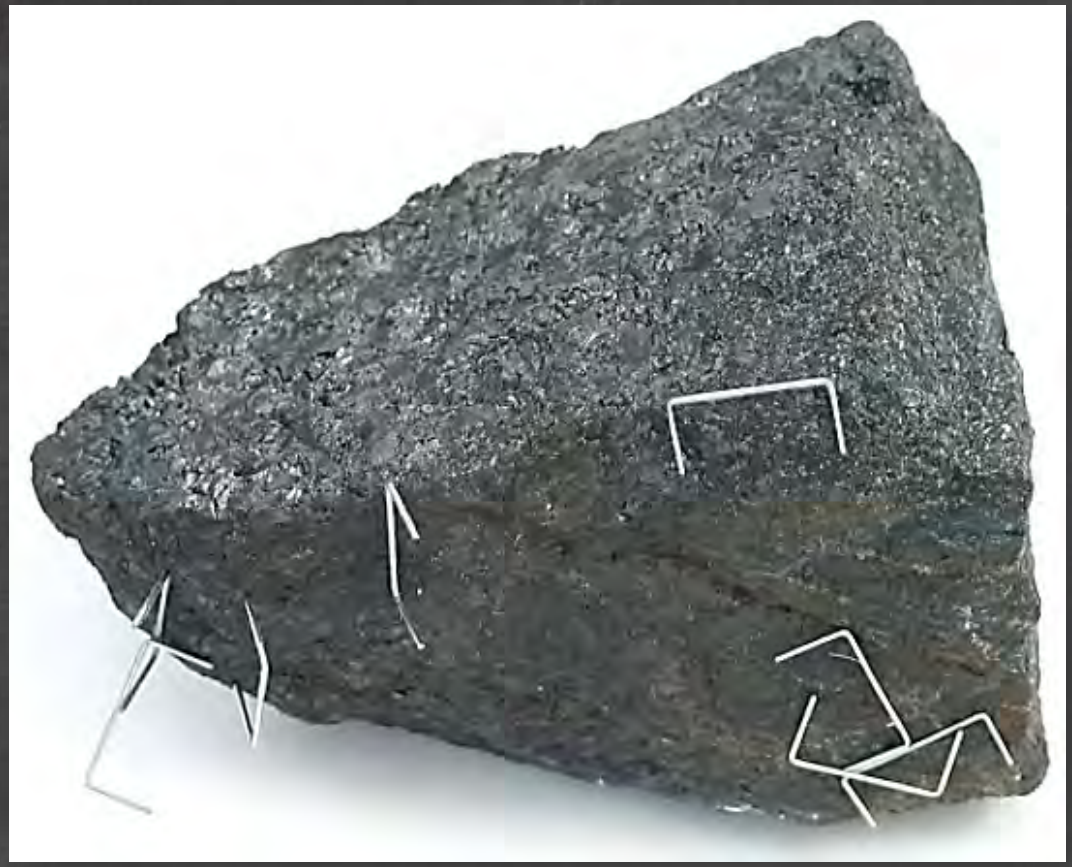
As of December 2020, **5,650** mineral species are approved by the IMA. Most names end in **"-ite";** the exceptions are usually names that were well-established before the organization of mineralogy as a discipline, like **galena and diamond.** Among these only about 250 are rock-forming, and only a few of them constitute a predominant portion of the Earth's crust.

Minerals in the Earth's crust in vol.%.

Mineral	vol.%
Plagioclase	39
Alkali feldspars	12
Quartz	12
Pyroxenes	11
Amphiboles	5
Micas	5
Olivine	3
Clay minerals (+ chlorite)	4.5
Calcite (+ aragonite)	1.5
Dolomite	0.5
Magnetite (+ titanomagnetite)	1.5
Others (garnet, kyanite, andalusite, sillimanite, apatite et al.)	4.9

Minerals are named on the basis of:

a)physical property: magnetic → magnetite, (Fe_3O_4)

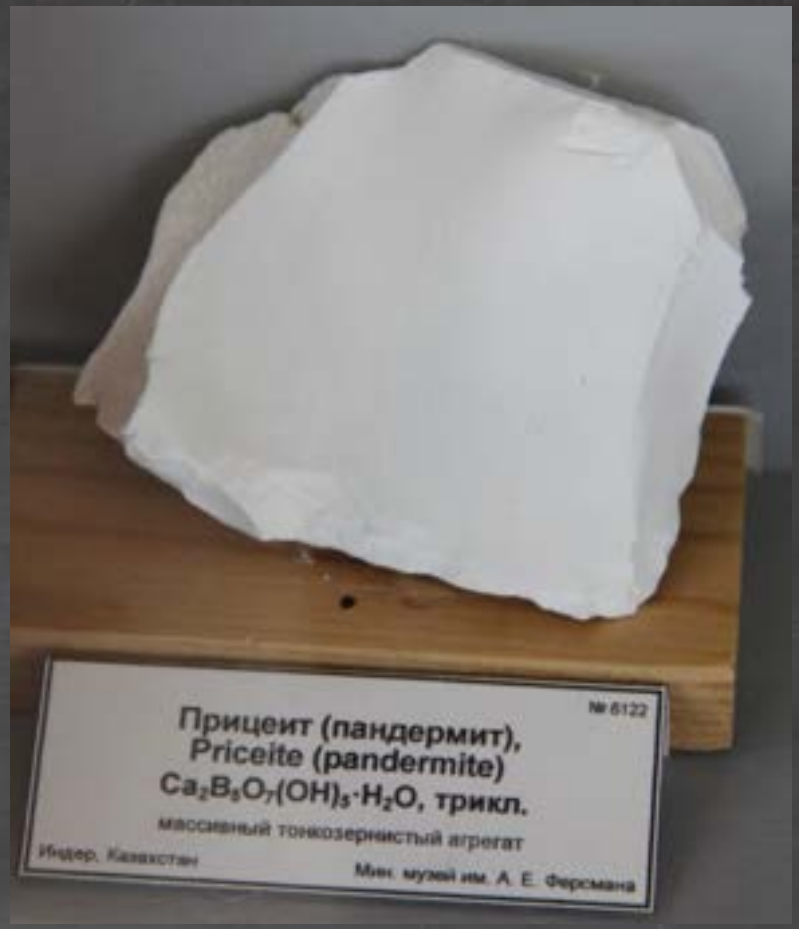


b) predominant element: Cr $\rightarrow$ chromite ($FeCr_2O_4$)

Ba $\rightarrow$ barite ($BaSO_4$)

c) locality: Franklin, New Jersey → franklinite ($ZnFe_2O_4$)

Panderma (Bandırma) → pandermite ($Ca_2B_5O_7(OH)_5 . H_2O$)



d) colour:

Albus (white) → albite ($NaAlSi_3O_8$)

Rhodon (rose) → rhodonite ($MnSiO_3$)

3. Mineral forming

Minerals form in all geologic environments and thus under a wide range of chemical and physical conditions, such as varying temperature and pressure.

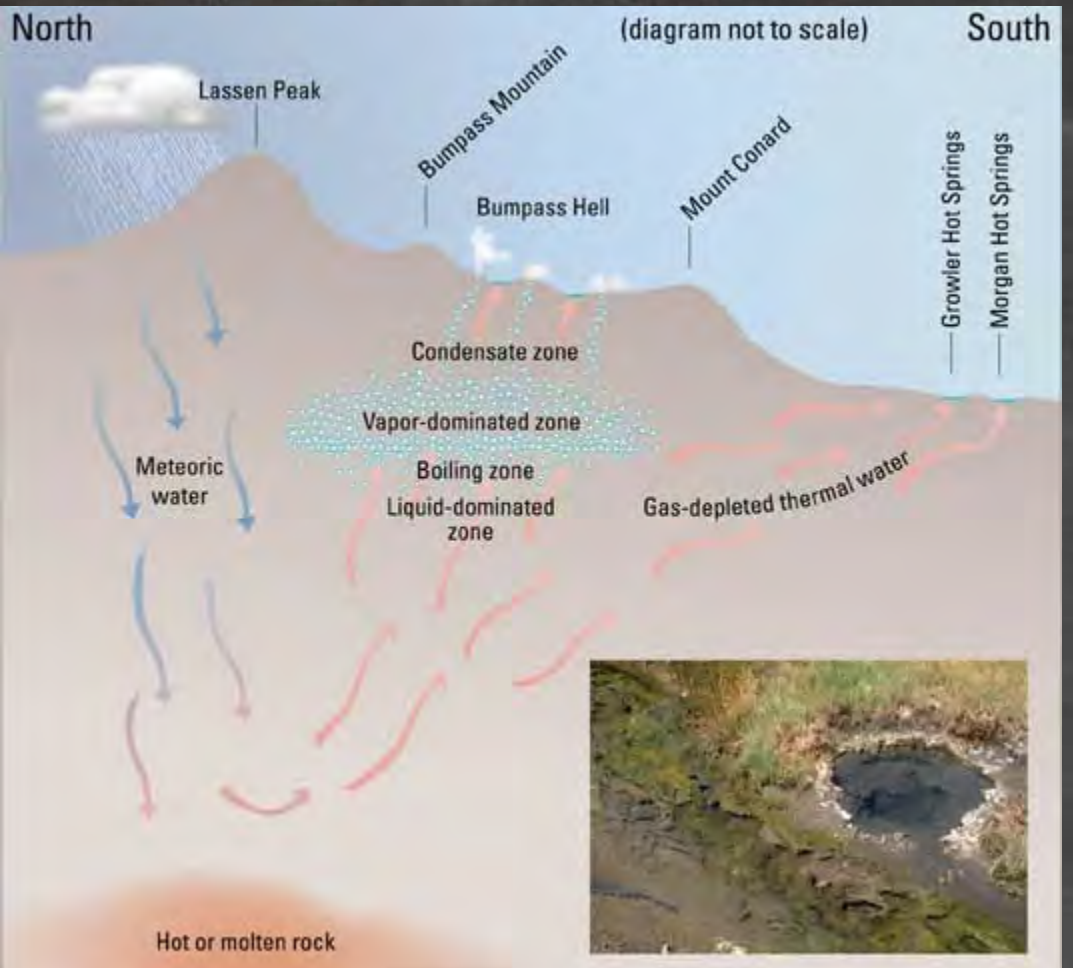
The four main categories of mineral formation are:

(1) **igneous**, or magmatic, in which minerals crystallize from a melt.

(2) **sedimentary,** in which minerals are the result of sedimentation, a process whose raw materials are particles from other rocks that have undergone weathering or erosion.

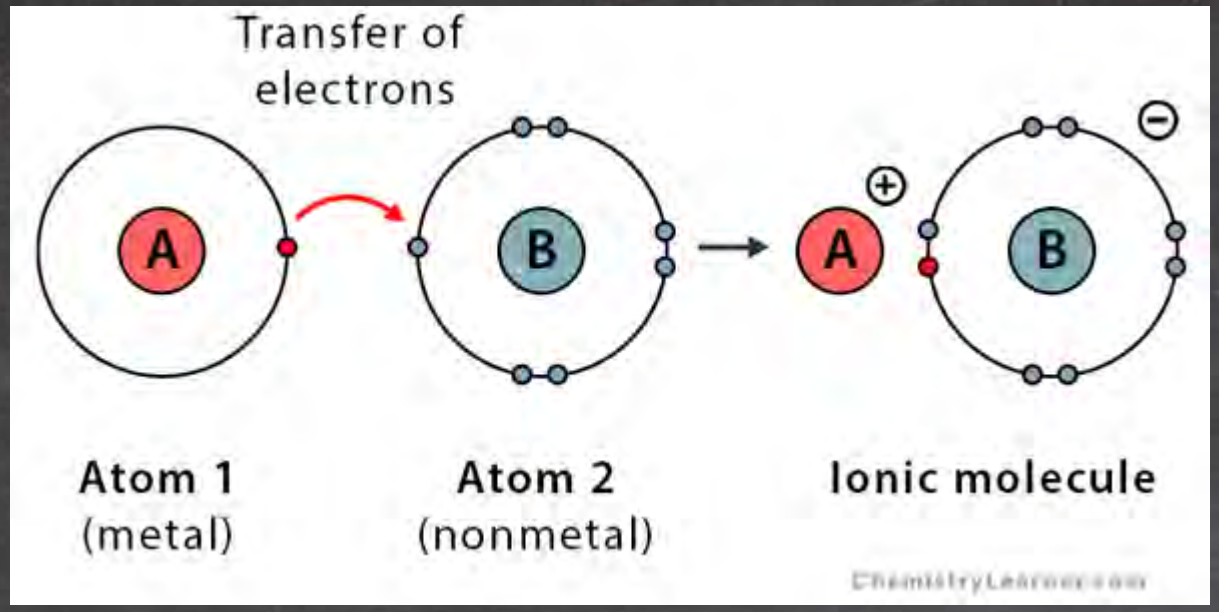
(3) **metamorphic,** in which new minerals form at the expense of earlier ones owing to the effects of changing—usually increasing—temperature or pressure or both on some existing rock type.

(4) **hydrothermal,** in which minerals are chemically precipitated from hot solutions within Earth.

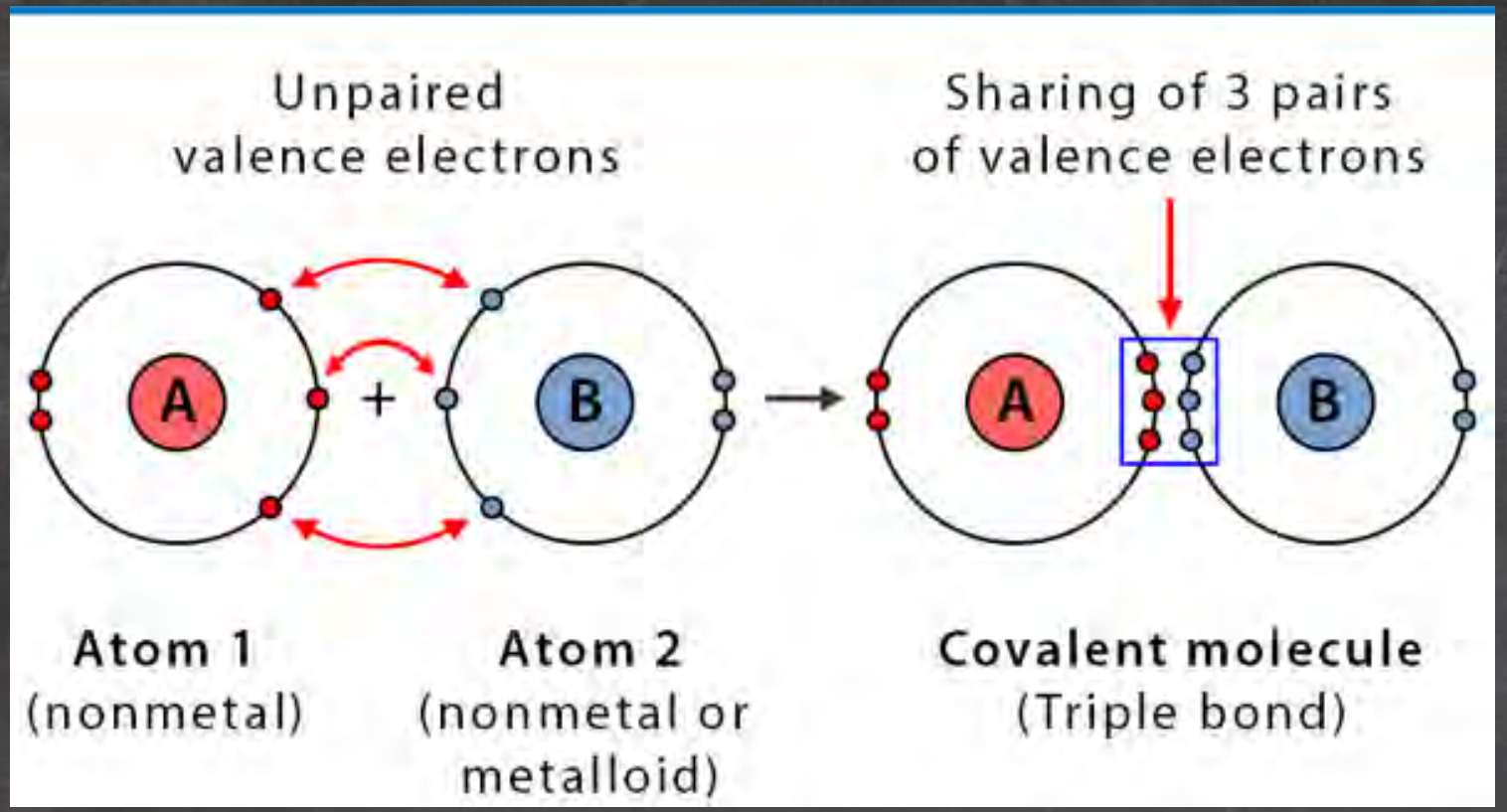


4. Types of Chemical Bonds

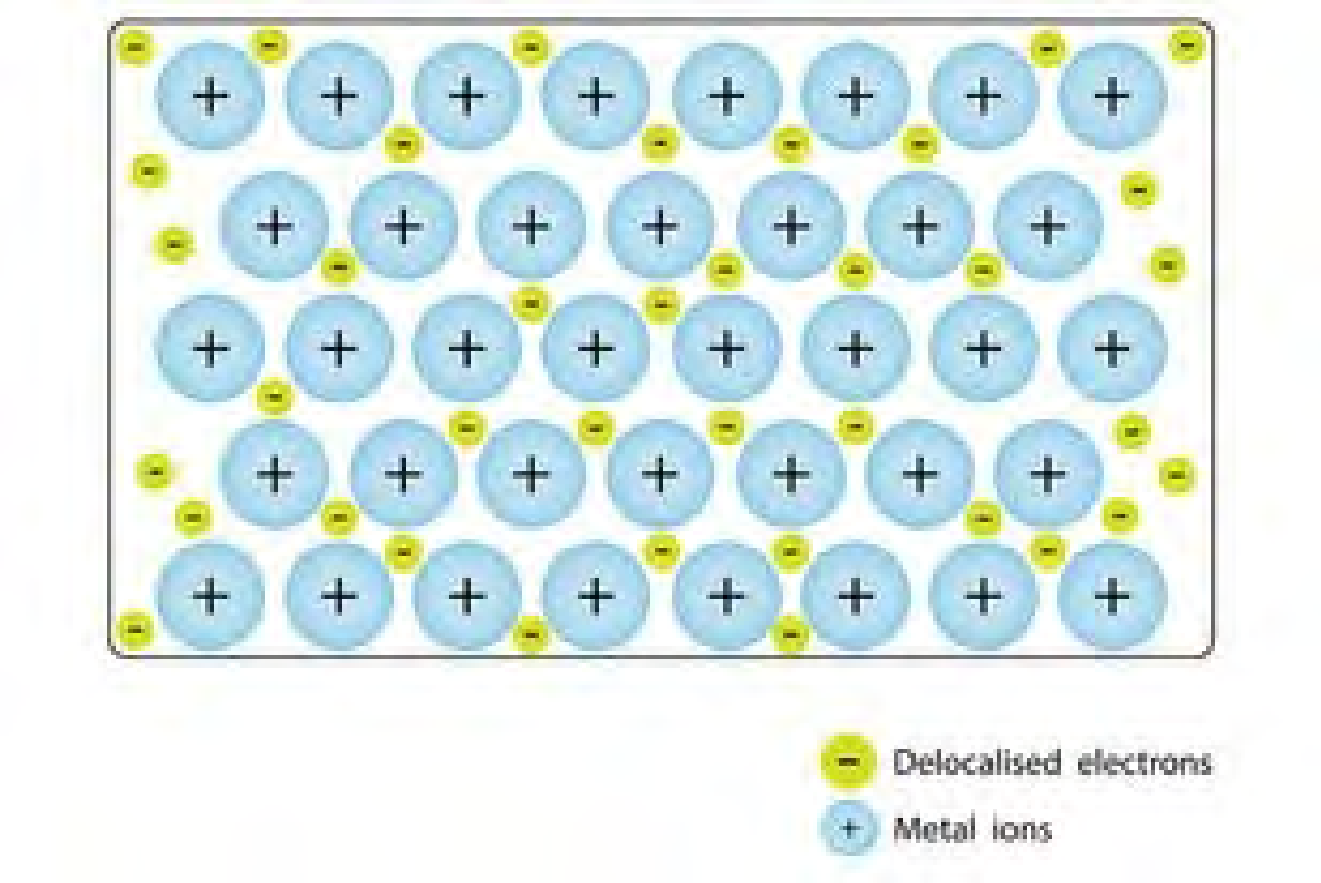
1- Ionic Bond (Heteropolar Bond)



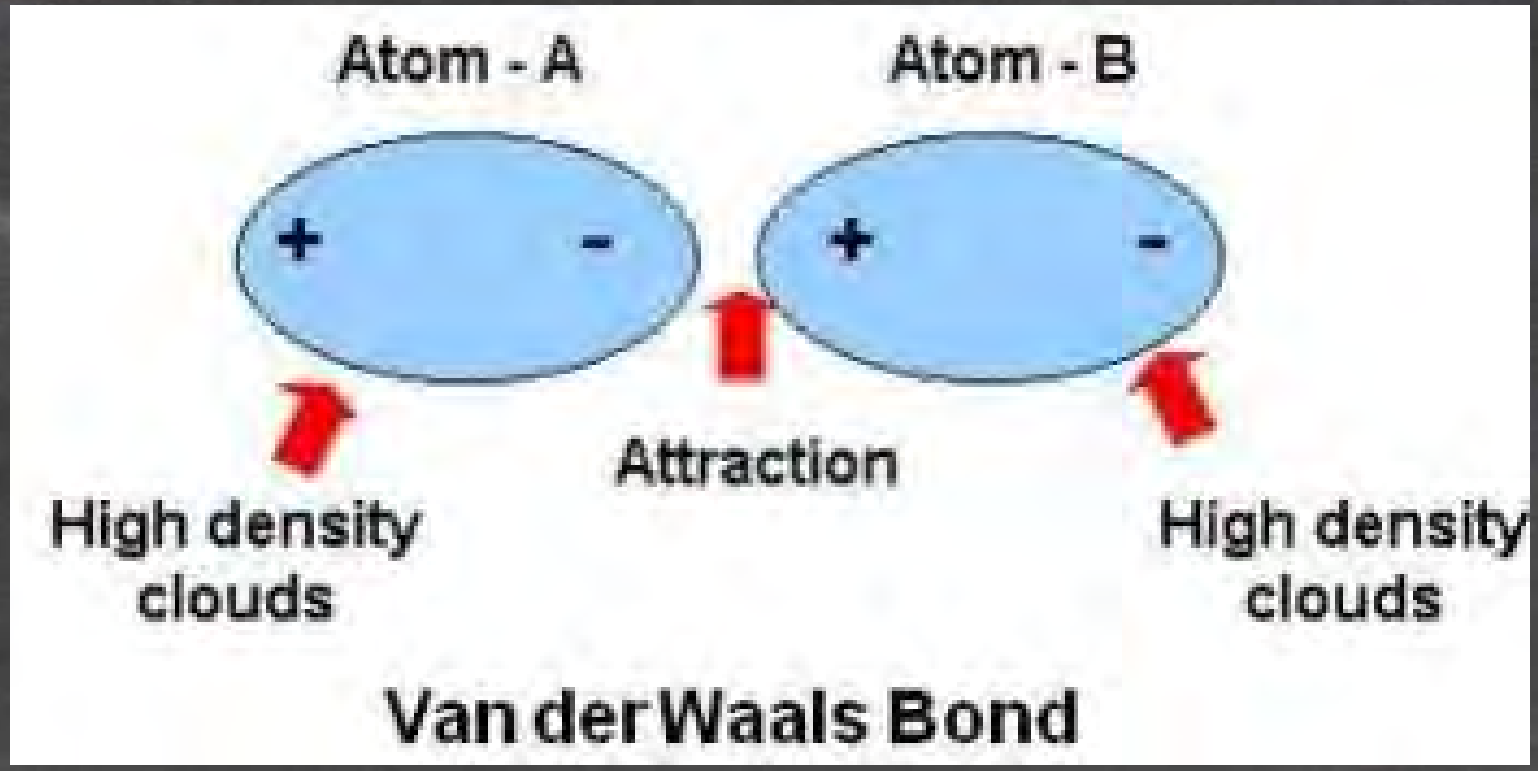
2- Atomic Bond (Covalent Bond)



3- Metallic Bond



4- Van der Waals Bond

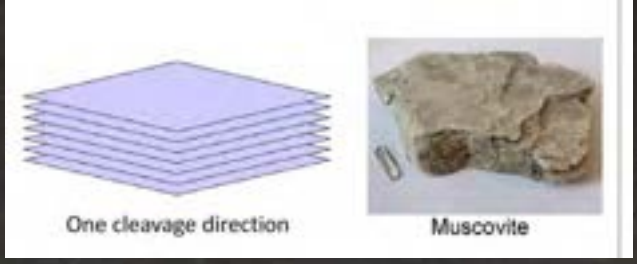


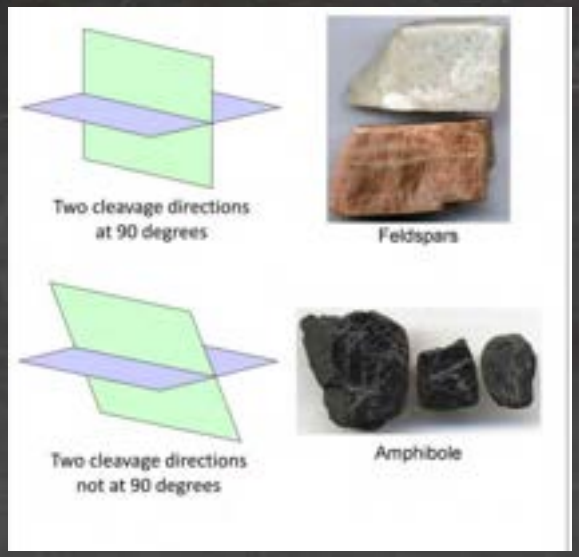
	Bond Type			
Property	Ionic (electrostatic)	Covalent (Electron-shared)	Metalic	Van der waals (Residual)
Bond strong	Strong	Very strong	Variable strength, generally moderate	weak
Mechanical	Hardness moderate to high	Hardneses great Brittle	Hardness low to moderate	crystal soft and somewhat plastic
examples	Halite, NaCl, Flourite, CaF2	Diamond, C; Sphalerite. ZnS	Copper, Cu; Silver, Ag,	sulfur (weak bond)

5. Physical properties of minerals.

- **CLEAVAGE:** Cleavage is tendency of a crystalline mineral to break in certain directions yielding more or less smooth planar surfaces. These planes of lowest bond energy have minimum value of cohesion . An amorphous body of course has no cleavage.

CLEAVAGE

- One set
  - 

- Two sets
  - perpendicular
  - imperpendicular
  - 

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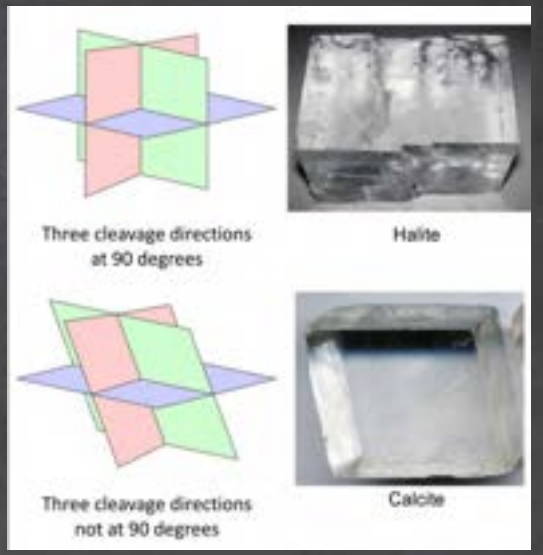
  - 

FRACTURE:

refers to rough or irregular surfaces along which the mineral breaks randomly.

Fracture

1. Conchoidal
2. Fibrous and splintery
3. Uneven or irregular
4. Even
5. Hackly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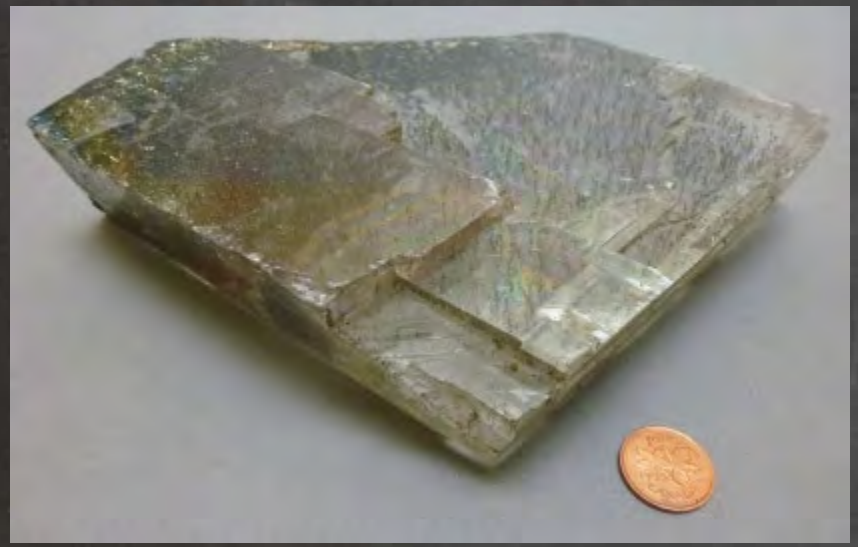


HARDNESS:

The resistance that a smooth surface of a mineral offers to scratching is its hardness (H).

Mohs Hardness Scale

Mineral Name	Mohs Number	Common Object
Diamond	10	
Corundum	9	Masonry Drill Bit (8.5-9)
Topaz	8	
Quartz	7	Steel Nail (6.5)
Orthoclase	6	
Apatite	5	Knife/Glass (5.5)
Fluorite	4	Copper Penny (3.5)
Calcite	3	
Gypsum	2	Fingernail (2.5)
Talc	1	



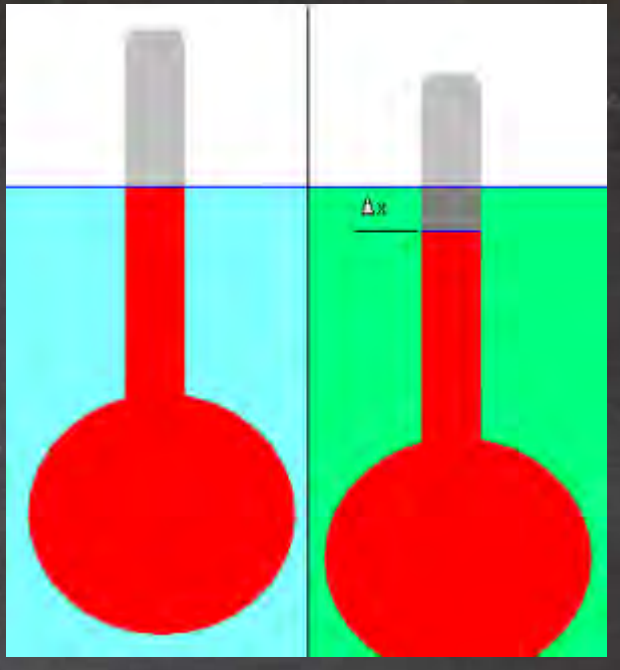






Specific Gravity

Sp.Gr. is measured with a simple balance by weighing the specimen in air (W_a) then in water (w_w)



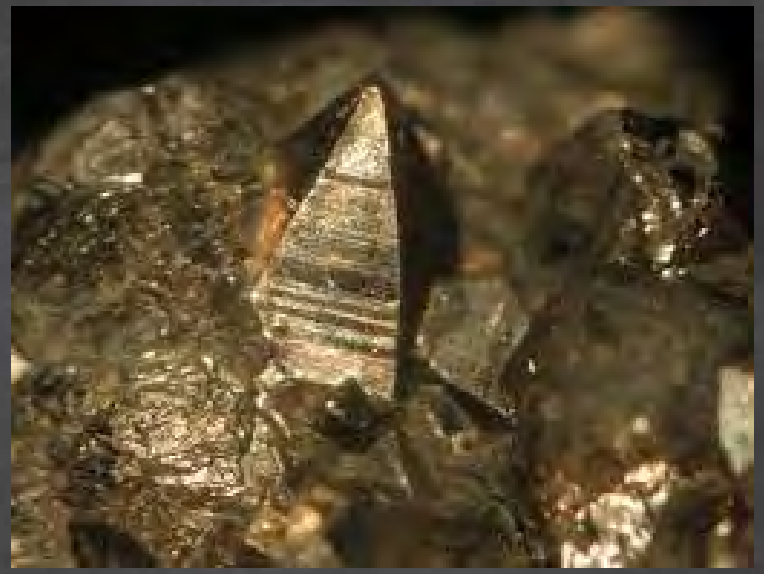
$$Sp.Gr. = w_a/(w_a - w_w)$$

Transparency

Transparent

Translucent

Opaque



Colour

different color of Garnet

Streak

Streak is the colour of the mineral powder. Colour of a mineral may vary but streak is usually constant. It is obtained by rubbing a mineral on a hard (H~7), white, unglazed porcelain. eg: magnetite; colour: black, streak: black; while hematite colour: black or red, but streak: red.

Luster

Luster is the general appearance of a mineral surface in reflected light. It is the degree of reflected light and directly related to optical properties (mainly RI) and surface conditions.

Luster

Metallic luster: strictly belongs to opaque minerals, where light is completely reflected from the surface. Most of the ore minerals having high content of metals shows metallic luster. eg., galena, magnetite, pyrite, chalcopyrite. Imperfect metallic luster → sub metallic.

Non-metallic luster: other luster types are collectively known as non-metallic luster. It may be brilliant or faint where reflection is poor which is due to scattering of light from the mineral.

Adamantine: diamond, zircon, corundum (Ruby).

Vitreous: silicates (quartz, feldspar), carbonate (calcite).

Resinous: sphalerite, sulfur.

Greasy: nepheline, massive quartz.

Pearly: talc, muscuvite.

Silky: gypsum, asbestose, malachite.

Earthy; limonite, kaolinite.

Dull Luster

Microcline feldspar

Vitrous Luster

Aurichalcite

Silky Luster

Actinolite

Metallic Luster

Pyrite

Earthy Luster

Azurite

Greasy Luster

Chrysocolla

Resinous Luster

Amber

Waxy Lustyer

Chalcedony

PearlyLuster

Barite

Adamantine Luster

Herkimer Diamond Quartz

Toxic Elements in Minerals

Many minerals contain major or minor amounts of heavy metals that are toxic for human and animal bodies.

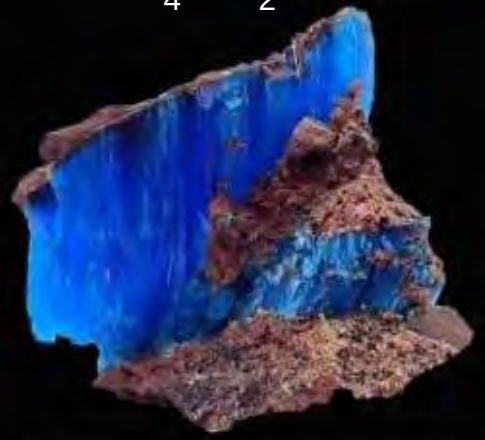
The most prominent examples are:

- *Arsenic*, present, e.g., in *arsenopyrite*, FeAsS, and *tennantite*, $Cu_{12}As_4S_{13}$.
- L*ead* in *galena*, PbS.
- M*ercury* in *cinnabarite*, HgS.
- *Cadmium*, frequently present as minor component in *sphalerite*, ZnS.

$Mg_3Si_2O_5(OH)_4$

Asbestos

$CuSO_4 \cdot 5H_2O$



Chalcanthite

HgS

Cinnabar

Sb_2S_3

Stibnite

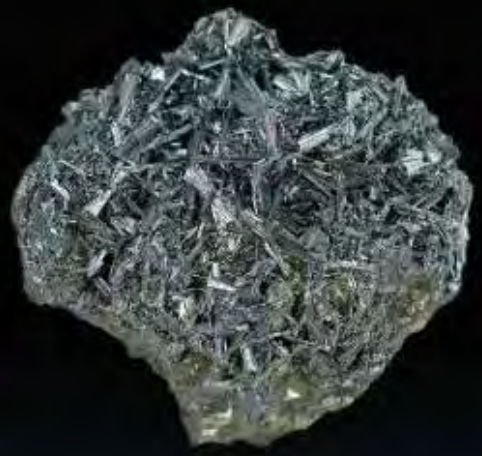
PbS

Galena

$Cu(UO_2)_2(PO_4)_2 \cdot 8 - 12\ H_2O$

Torbernite

$(Tl,Pb)_2As_5S_9$



Hutchinsonite

As_2S_3

Orpiment

Radioactive Minerals

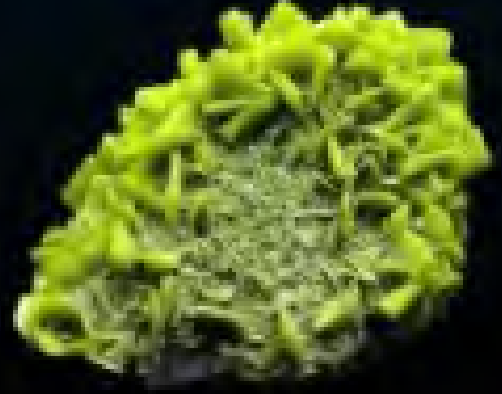
$Cu(UO_2)_2(PO_4)_2 \cdot 8 - 12\ H_2O$

Torbernite

$(Ce,La,Th)PO_4$

Monazite

$Ca(UO_2)_2(PO_4)_2 \cdot 10–12H_2O$



Autunite

$Ba(UO_2)_2(PO_4)_2 \cdot 10H_2O$

Uranocircite

$K_4(UO_2)_6(SO_4)_3(OH)_{10} \cdot 4(H_2O)$

Zippeite

$Cu(UO_2)_2(PO_4)_2 \cdot 8(H_2O)$

Metatorbernite

UO_2

Uraninite

$K_2(UO_2)_2$

Carnotite

7. Classification of minerals.

I. Native

In nature, about 20 chemical elements occur as minerals in their elementary form. These encompass native metals, metalloids (semi-metals) and non-metals. In most cases, metals form alloys, i.e., solid solutions such as (Au,Ag).

- *Metals*

Structures of metallic elements and intermetallic alloys approach a dense as possible packing and a high symmetry. This holds true especially for copper, silver, gold and most of the platinum-group metals that form face-centred cubic crystal lattices with cubic close packing parallel (*Gold*-Au; *Silver*-Ag; *Platinum*-Pt; *Iron*-Fe; *Copper*-Cu).

The physical properties of the metals, such as *high density*, *high thermal* and *electric conductivity*, *metallic lustre* as well as characteristic optical and mechanical properties are due to the *dense packing* and *metallic bonds* in the metal structures. For instance, metals are *opaque*.

- *Metalloids (Semi-metals)*

The metalloids arsenic, antimony and bismuth all belong to same structural type. It resembles a cubic primitive lattice. The physical properties of the three metalloids are similar. For instance, all of them are relatively *brittle* and their *thermal* and *electrical conductivity* is less distinct than in metals (Arsenic-As; Antimony-Sb; Bismuth-Bi).

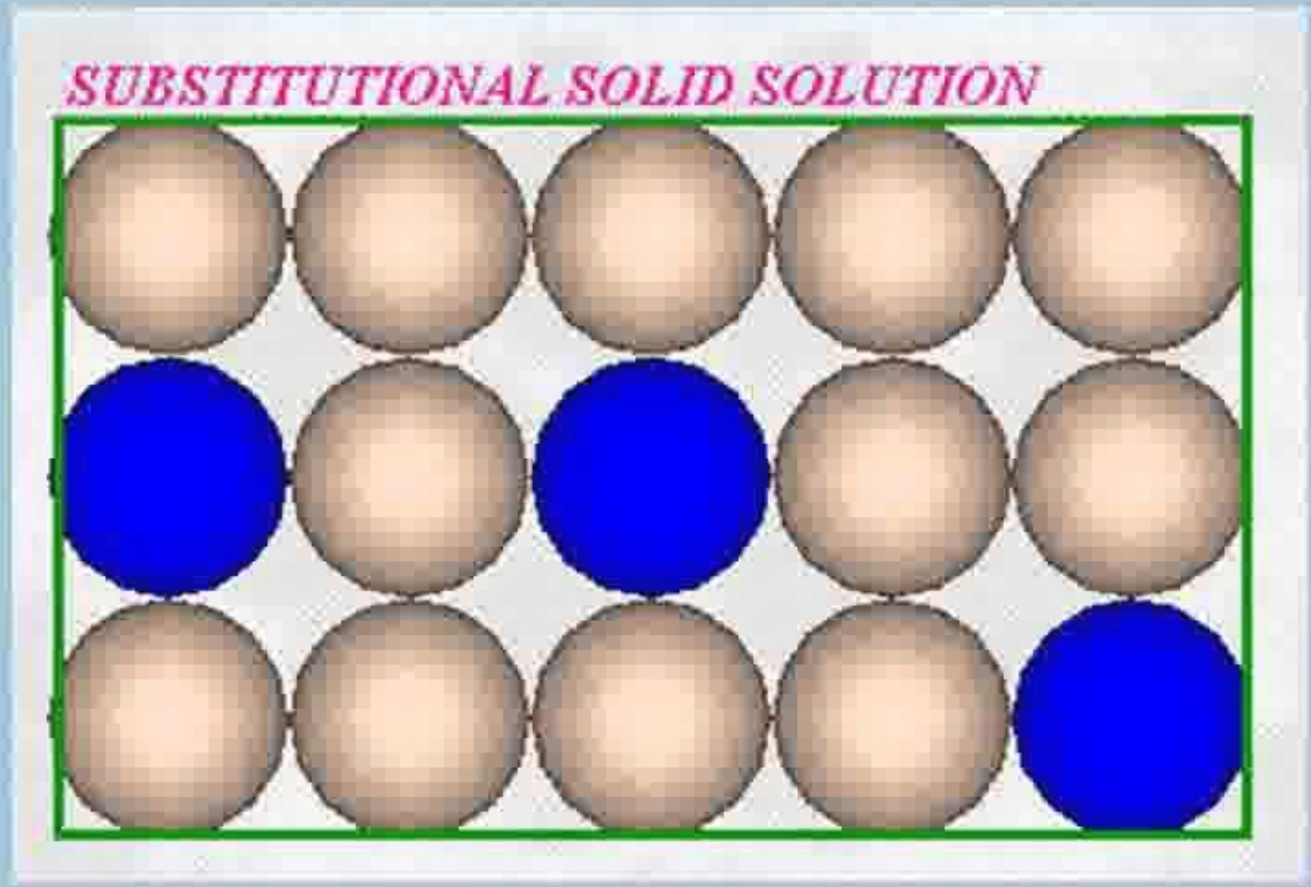

© Dakota Matrix

- *Non-metals*

Carbon – C (*Graphite/Diamond*); *Selenium* – Se: *Sulfur* – S

continue

Substitutional Solid solution



- As atoms of the parent metal (or solvent metal) are replaced or substituted by atoms of the alloying metal (solute metal)
- In this case, the atoms of the two metals in the alloy, are of almost same size.

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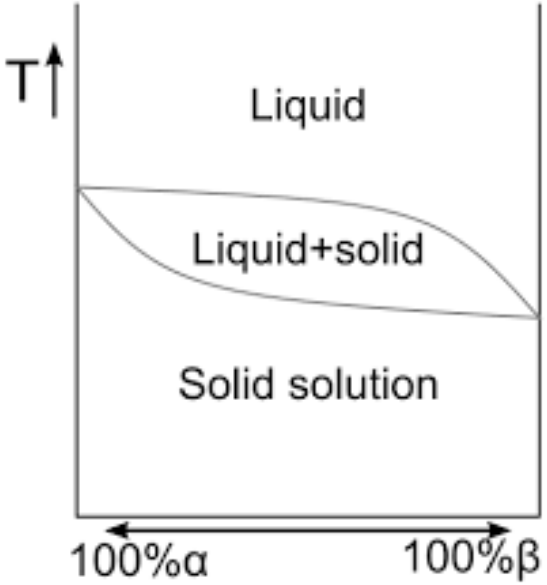
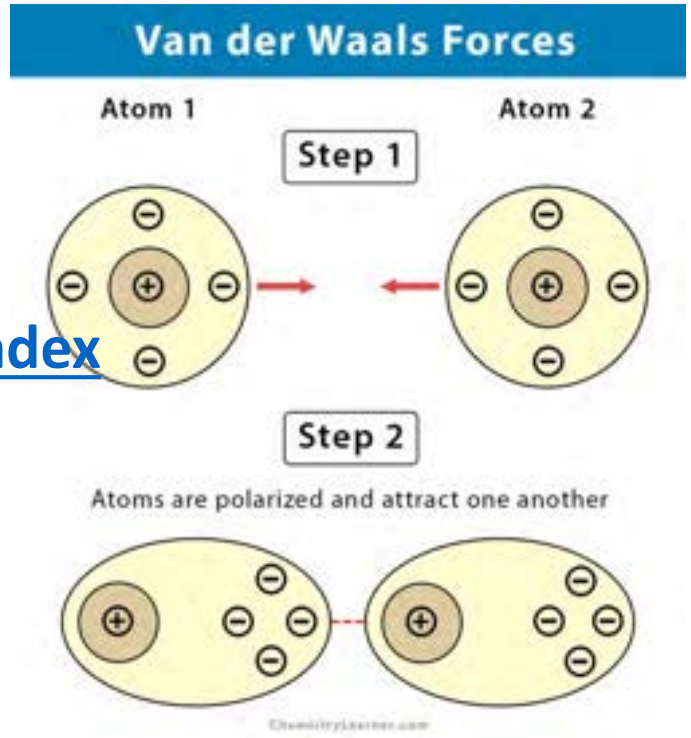
Ionic bond NaCl (transfere)

Atomic bond H2, N2, H2O Sharing)

Metalic bond Na+, Al+

Vader wals Hcl, HF





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