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Special class on

Physical Property of Mineral-1

Aug 4, 2020 • Saubhagya Ranjan Mahapatra

Physical Properties of Mineral

Presented by

Dr. Saubhagya Ranjan Mahapatra

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Employment

- Oil industry
- Geological Exploration
- Metallurgical Extraction
- Civil Engineering
- Fire-Resisting Materials Industry
- Ceramic Manufacture
- Cement Production
- Building Research
- Geological Survey Department
- CSIR
- private companies in mining, ceramics and fire- resisting materials production.
- self-employment, with the necessary experience, can be an independent consultant

Examination

- UGC CSIR NET
- GATE
- IIT JAM Geology
- Public Service Commission Geology

What is a mineral?

- Natural
  - Not as artificial or synthetic
- Inorganic
  - Not as wood or organic material
- Homogeneous
  - Same physical and chemical charecter
- Crystalline
  - Orderly atomic structure
- Definite chemical composition
  - Same chemical composition irrespective of its size , shape, origin, occurrence
- Solid
  - Not a gas, not a liquid

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Mode of formation of Mineral

- Minerals formed directly or indirectly out of magma during different stages of its solidification
- Rock forming mineral: feldspar, quartz, pyroxene, amphiboles, mica, olivine
- Precious Minerals: gemstones, garnet, topaz, magnetite, beryl, apatite, zinc etc
- Some mineral are formed from secondary process like weathering, prcipitation, deposition.
- Ex: calcite, dolomite, bauxite, limonite, salts, chlorite, phosphates
- Minerals is form out of metamorphism under influence of high temp. and pressure.
- Ex: Andalusite, silimanite, kyanite, staurolite, garnet, graphite etc.

Colour

- Materials absorbs some colour and the rest is reflected.
- The color of a macroscopic mineral specimen is the result of a complex interplay among the reflection, absorption, transmission, refraction, scattering and dispersion of light as it interacts with the mineral's chemical and structural components.
- Minerals tend to occur in a range of colours, and colour patterns which help to identify them.
- Most minerals are coloured by a limited number of metals present as impurities.
- The most common elements affecting colour are: chromium, iron, manganese, titanium and copper.
- It is chromium which produces the intense red of ruby and the brilliant green of emerald.
- Generally Mineral contain Al, Na, K, Ca, Mg, Ba are colourless or light.
- Mineral contain Fe, Cr, Mn, Co, Ni, Ti, Cu are dark in colour.

Idiochromatic minerals

- Idiochromatic minerals possess essentially the same color, independent of any impurities and/or defects that occur.
- Color is a diagnostic property of idiochromatic minerals and can be used as a criterion for their identification.
- Excellent examples of idiochromatic minerals include
  - azurite - blue,
  - sulfur - yellow
  - galena - gray

$Cu_3(CO_3)_2(OH)_2$.

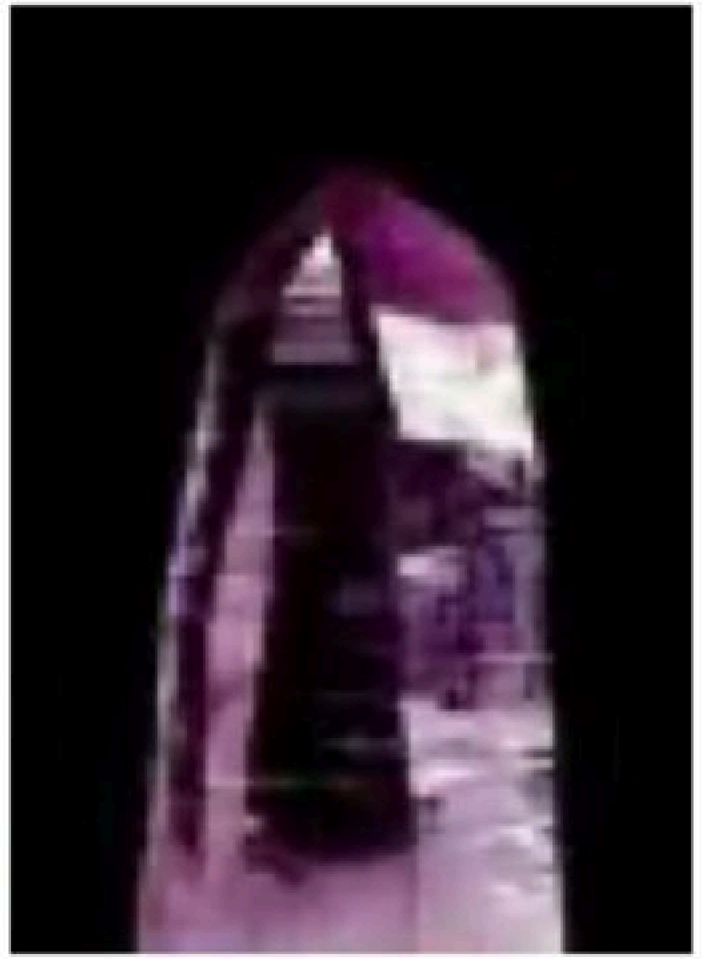
Sulfur

PbS

Allochromatic

- Which means “foreign colored”
- Their color is strongly influenced by impurities & defects so that different specimens possess different colors.
- A good example of an allochromatic mineral is quartz.
- It include colorless rock crystal, white milky quartz, pink-colored rose quartz, honey brown to dark brown smoky quartz, yellow citrine, blue to green aventurine and purple amethyst.


yellow is citrine


purple quartz is amethyst


colourless is rock crystal


brown is smoky quartz


black is morion


pink is rose quartz

Diagnostic colours of some minerals

Mineral	Diagnostic colour	Mineral	Diagnostic colour
Azurite	Deep blue	Malachite	Green
Biotite	Brown	Orthoclase	Flesh (buff) colured
Chalcopyrite	Golden yellow	Pyrite	Brass yellow
Galena	Lead gray	Sulphur	Yellow
Hematite	**Steel gray**	**Tourmaline**	**Black**

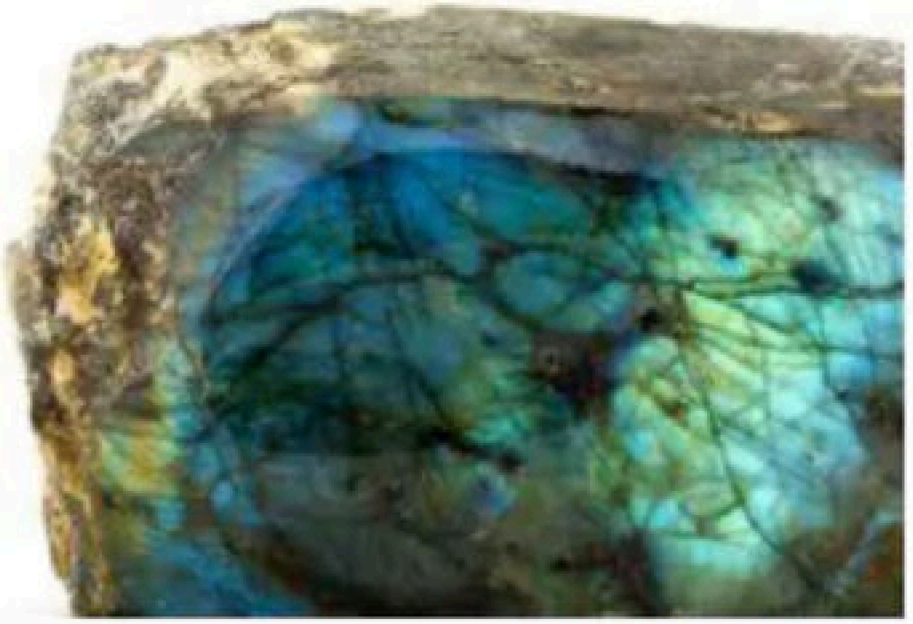
Play of colors

Many minerals exhibit colors that change as the angle at which the light strikes them changes, as when the mineral is rotated in incident light is known as Play of colour (Rinbow).
Ex: labradorite, peristerite, moonstone, opal and fire agate.

Asterism is caused by inclusions oriented according to the host mineral's crystal structure, which produces a six- sided, star -like pattern as light is scattered by the inclusions at specific incident angles. Ex: rubies, sapphires, and other gems (i.e. star garnet, star diopside, star spinel, etc.

Chatoyancy characteristic of certain fibrous minerals, in which a band of light moves perpendicular to the fibers, especially when the fibers are curved.

Iridescence in which the scattering of light from zones of contrasting composition within the mineral produces changes in color as the mineral is rotated.



labradorite

rubies

Luminescence

Luminescence is best observed in darkness, where such minerals appear to glow in the dark.

Many minerals luminesce when subjected to some type of short wavelength radiation, such as gamma rays, X-rays or ultraviolet waves.

Luminescence	Description
Fluorescence	Fluorescence occurs when materials are subjected to short wavelength radiation such as gamma rays, X-rays orultraviolet waves. The color produced during fluorescence depends on the wavelength of visible light emitted
Phosphorescence	Material emits visible light after it is no longer subjected to the incident radiation. This is used in glow - in - the - dark toys, which continue to emit light after removal of the light source
Thermoluminescence	Materials emit visible light when heated to 50 – 475 ° C
Triboluminescence	Materials emit visible light in response to stress induced by rubbing or crushing the specimen

Colour

Examples of colour variation in Fluorite

Colour

All these minerals are grey or white in colour

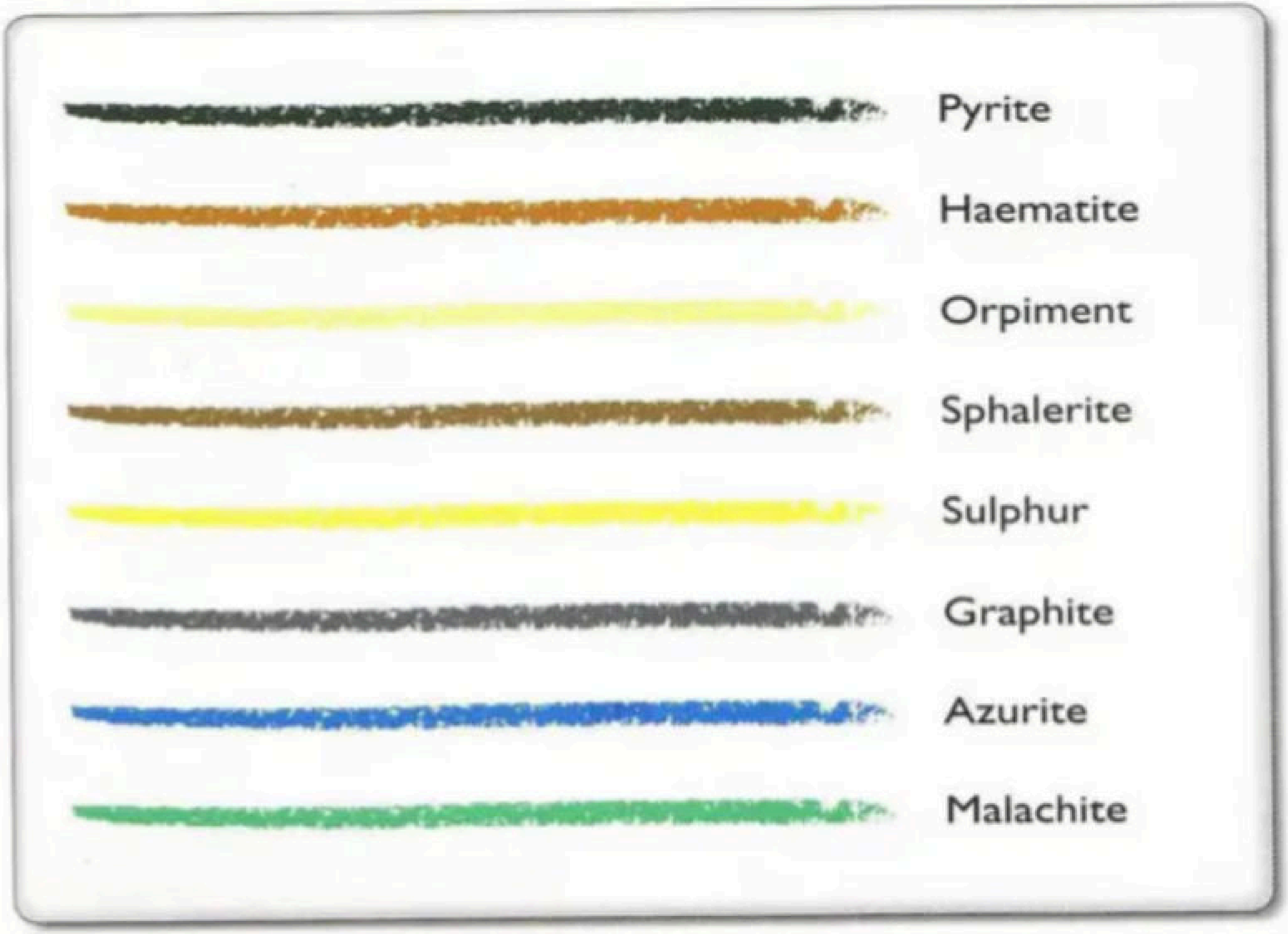
Streak


Haematite gives a cherry red streak

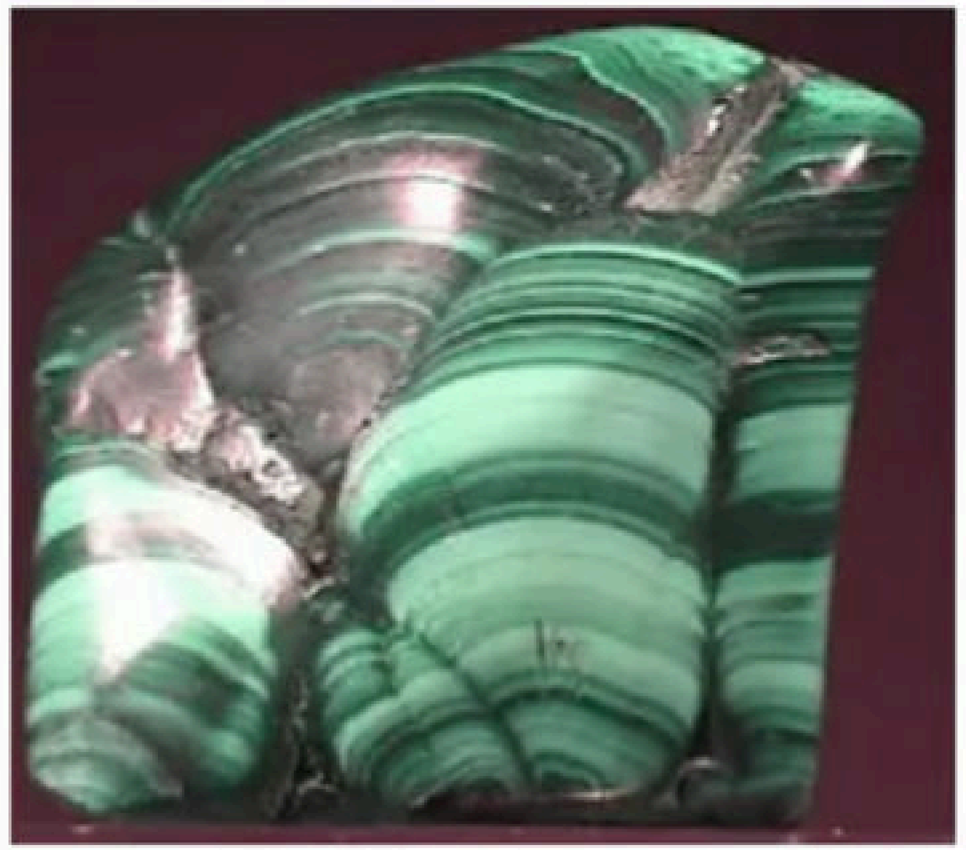
- The colour of a mineral's powder
- Obtained by rubbing a mineral specimen on an unglazed white porcelain tile (hardness – 6.5)
- Useful for identifying metallic ore minerals
- Silicates generally do not mark the tile and have no streak
- White minerals streaked on a white tile will have a white streak
- Any minerals harder than the tile (6) will scratch it

Characteristic streak of a few minerals

Mineral	Colour	Streak
Arsenopyrite	White	Black
Chalcopyrite	Golden yellow	Greenish black
Covelite	Indigo blue	Black
Hematite	Steel gray	Cherry red
Orthoclase	Flesh cohired	White
Pyrite	Brass yellow	Brownish black
Realgar	Red	Orange yellow
Rutile	Dark brown	Colourless

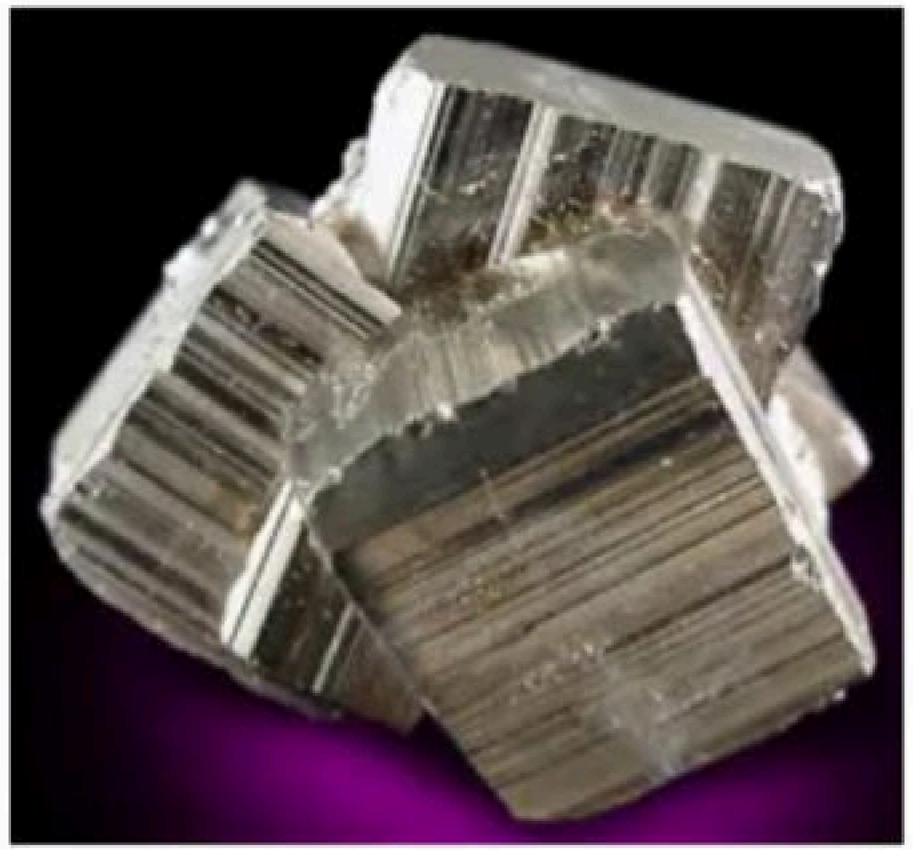


Streak



Malachite – pale green

Haematite – cherry red



Iron Pyrite – greenish black

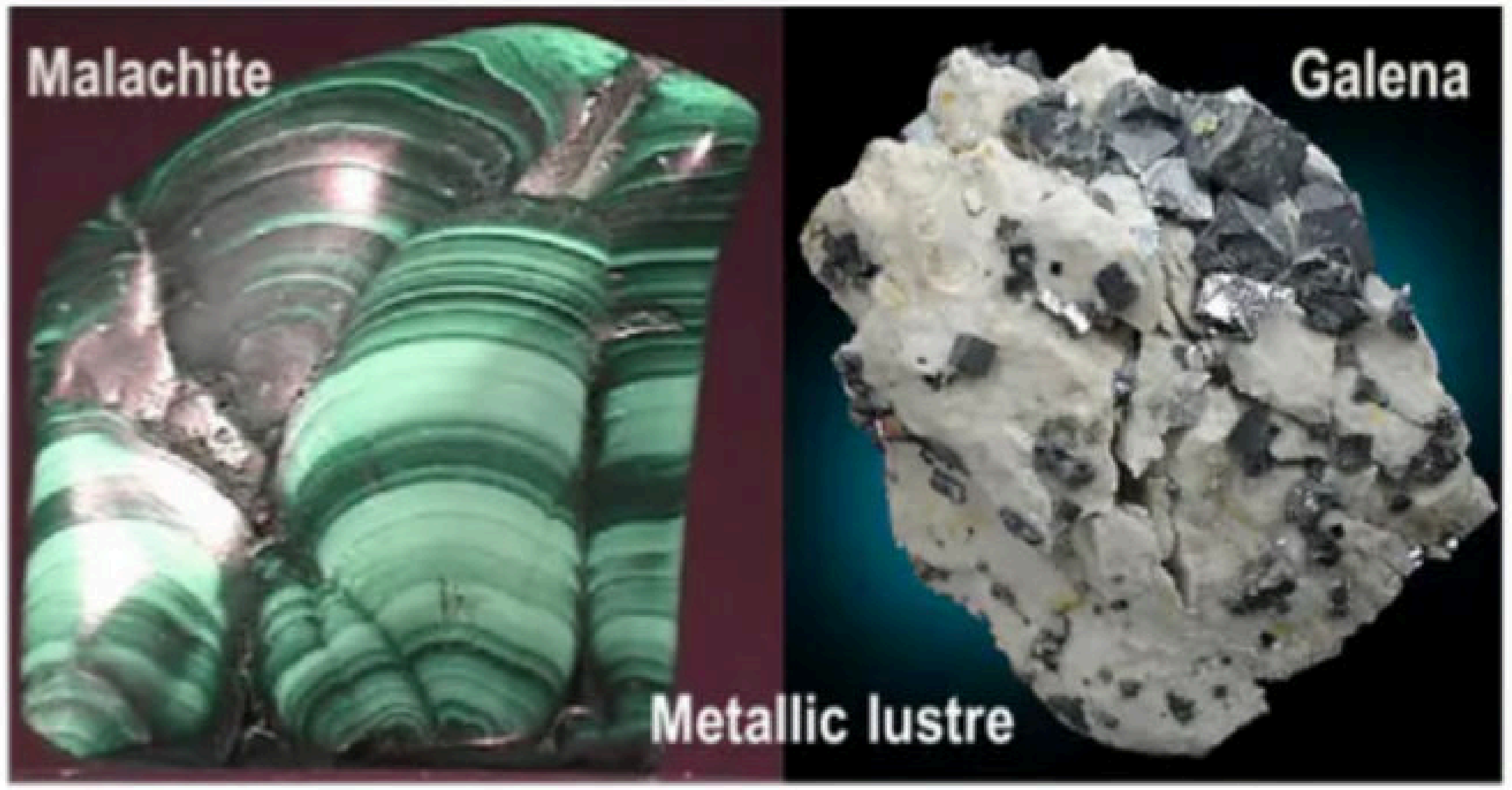
Galena – lead grey

Sphalerite – pale brown

Limonite – yellowish brown

Lustre

Lustre can be defined as the nature and amount of shine offered by a mineral due to reflection of light on its clean surface. There are three main varieties of lustre viz. metallic, sub-metallic and nonmetallic



Lustre	Description/ Example
Metallic	A mineral having a brilliant appearance of a metal is said to have metallic lustre. Galena, chalcopyrite, hematite are common minerals showing metallic lustre.
Sub-metallic	The imperfect metallic lustre is known as sub- metallic lustre. Chromite, psilomelane, wolframite etc.
Non metallic	Minerals with non-metallic lustre are generally light coloured and transmit light through thin edges. The following terms are used to describe the lustre of nonmetallic minerals.
Adamantine	It is the brilliant lustre shown by minerals of high refractive index. Examples are diamond, cerussite, sphalerite, anglesite etc.
Vitreous :	The lustre of broken glass, e.g. quartz, tourmaline
Sub-vitreous	Imperfect vitreous lustre is termed as sub-vitreous, e.g. lustre of feldspar, calcite etc.
Pearly	The lustre of pearl, e.g. talc, muscovite etc.
Resinous	The lustre of resin, e.g. sphalerite etc.
Greasy	The lustre of oily glass, e.g. nepheline, opal etc.
Silky	The lustre of silk, e.g. gypsum, asbestos etc.
Earthy	The lustre of clay, e.g. kaolinite
Splendent	The surface of the mineral is sufficiently brilliant to reflect objects distinctly like those from a mirror e.g. Galena.

Form or Habit

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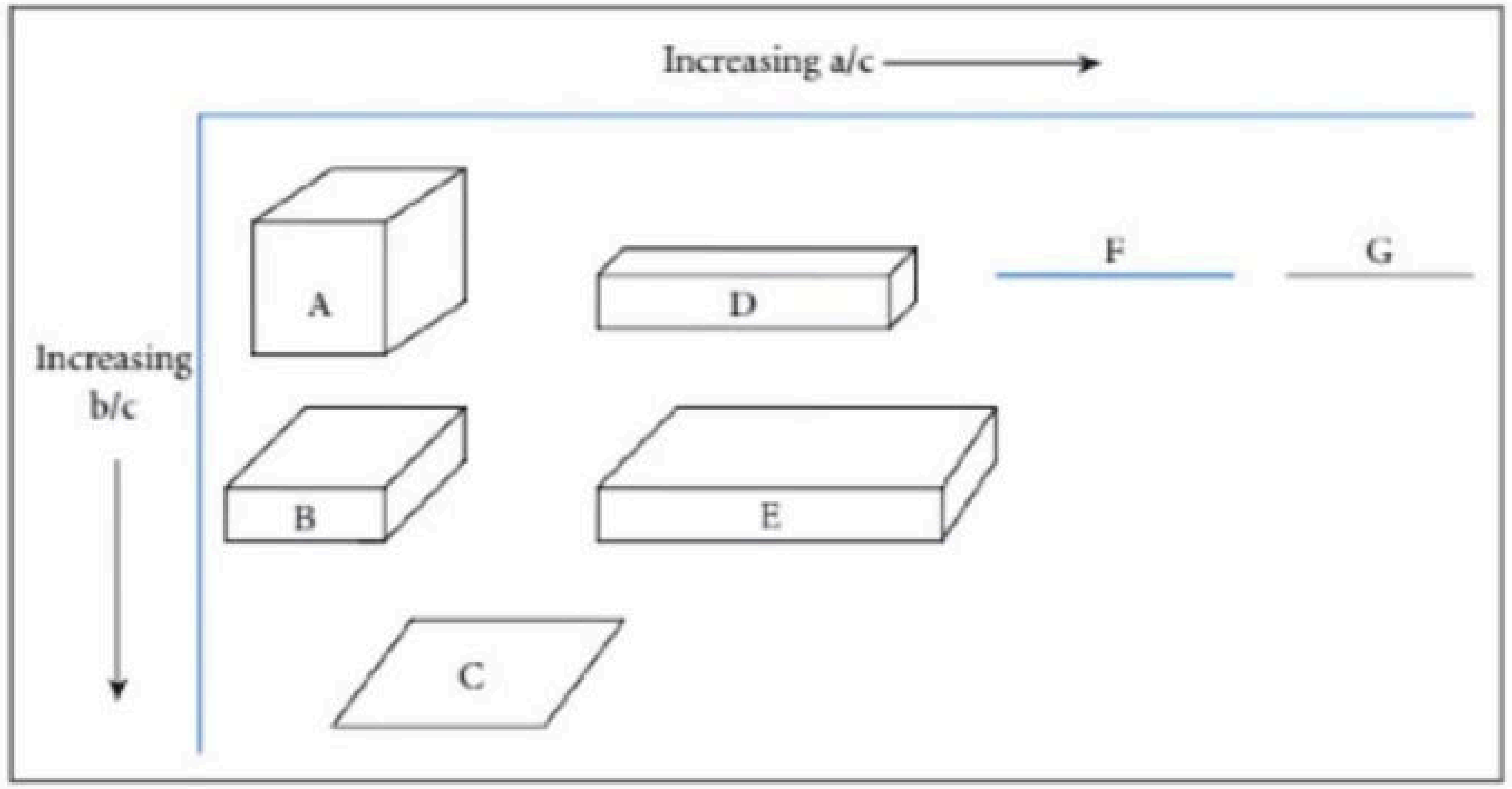
Crystal habit	Colloquial description	Crystal dimensions
Equant	Equal dimensions; shape may approach that of cube or sphere	a = b = c
Tabular	Tablet or diskette-like	a = b > c; c is thin
Platy	Sheet-like	a ≈ b >> c; c is very thin
Prismatic or columnar	Pillar-like or column-like; slender to stubby	a > b = c; a is long
Bladed	Blade- or knife-like	a > b > c; a is long, c is thin
Acicular	Needle-like; slightly thicker than filiform	a >>> b = c; b and c are very thin
Capillary or filiform	Hair-like	a >>> b = c; b and c are extremely thin

Crystal habits of individual crystals.



Individual crystal habits: A, equant; B, tabular; C, platy; D, prismatic or columnar; E, bladed; F, acicular; G, capillary or filiform.

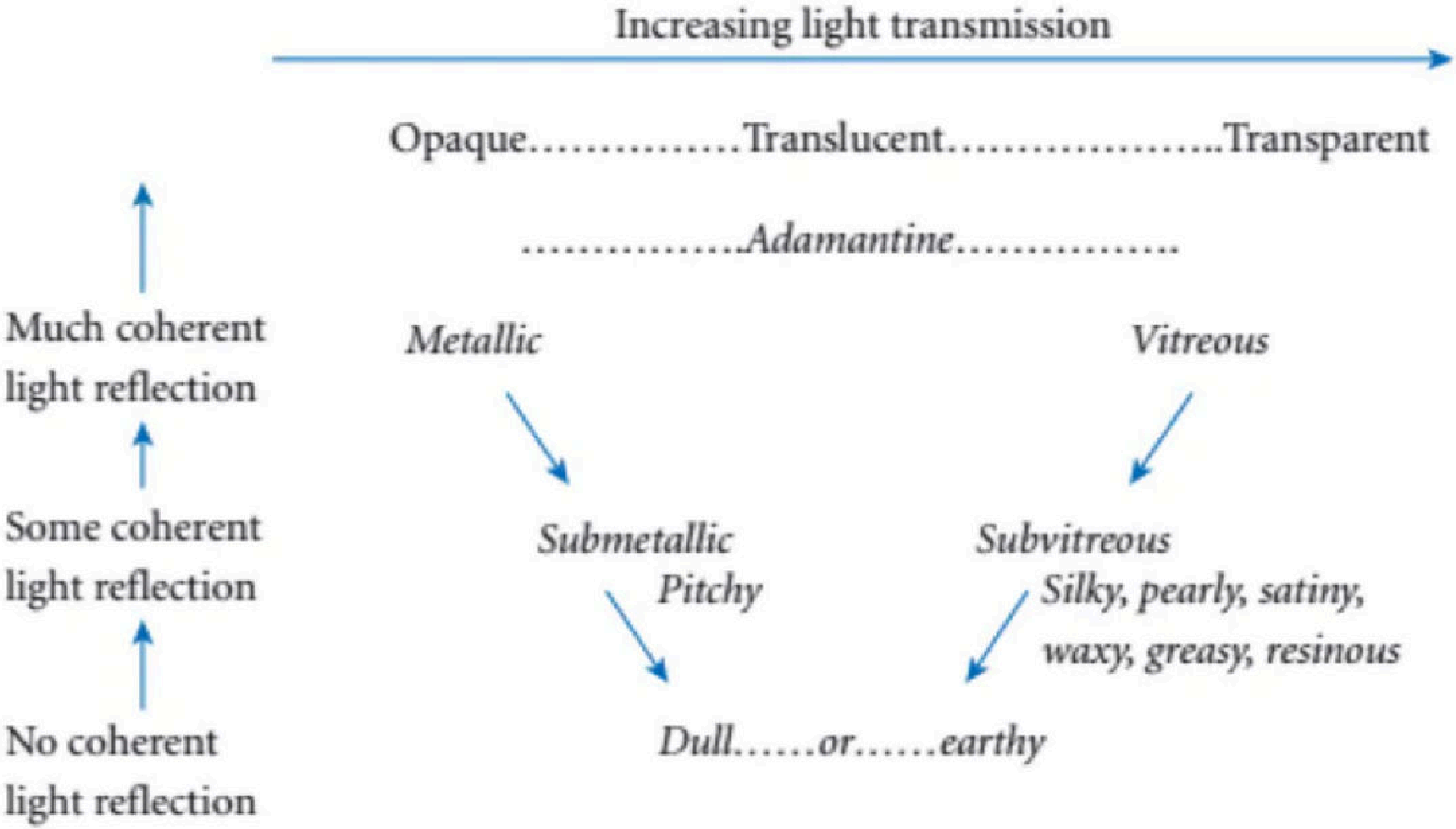
Single crystals can be described using a variety of terminology. The simplest terminology is based on the relative proportions of the crystals in three mutually perpendicular directions (a, b and c) where $a \geq b \geq c$.

Mineral with a definite internal atomic structure without the development of well-defined faces is said to be crystalline. Under favourable physico-chemical conditions, the outer form with well developed crystal faces develops.

A mineral is said to be cryptocrystalline when the degree of crystallization is noticeable under high power microscope.

The term amorphous is used to describe complete lack of crystallinity.

Depending on the development of outward form and structure, certain terms are used, which have their usual meaning.

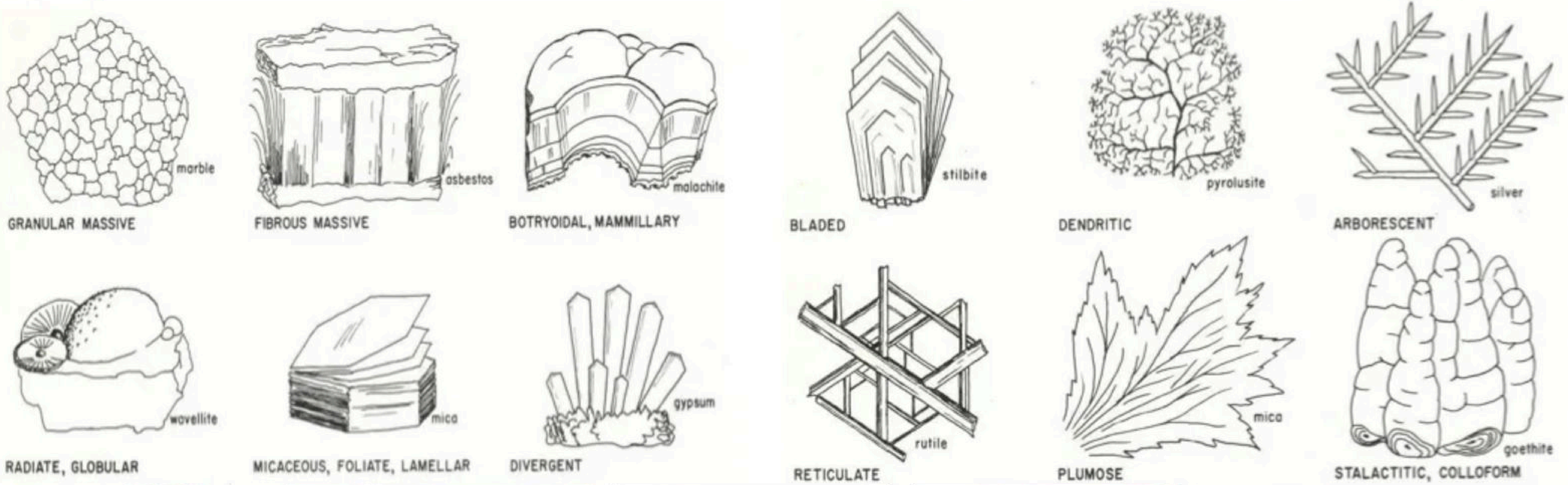


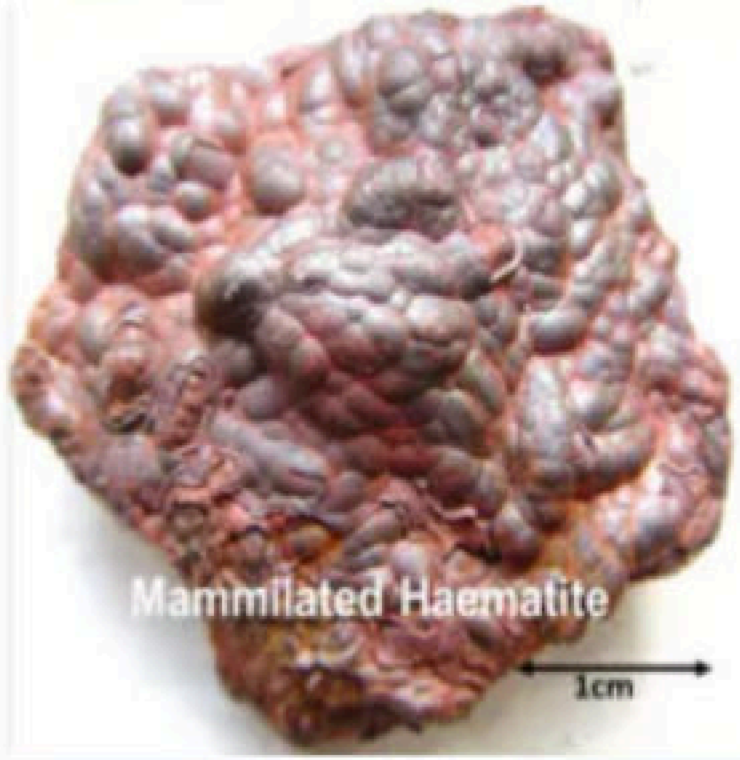
General relationships between light transmission (diaphaneity), light reflection/reradiation and luster. Light transmission increases from left to right and refl ectivity increases from bottom to top.

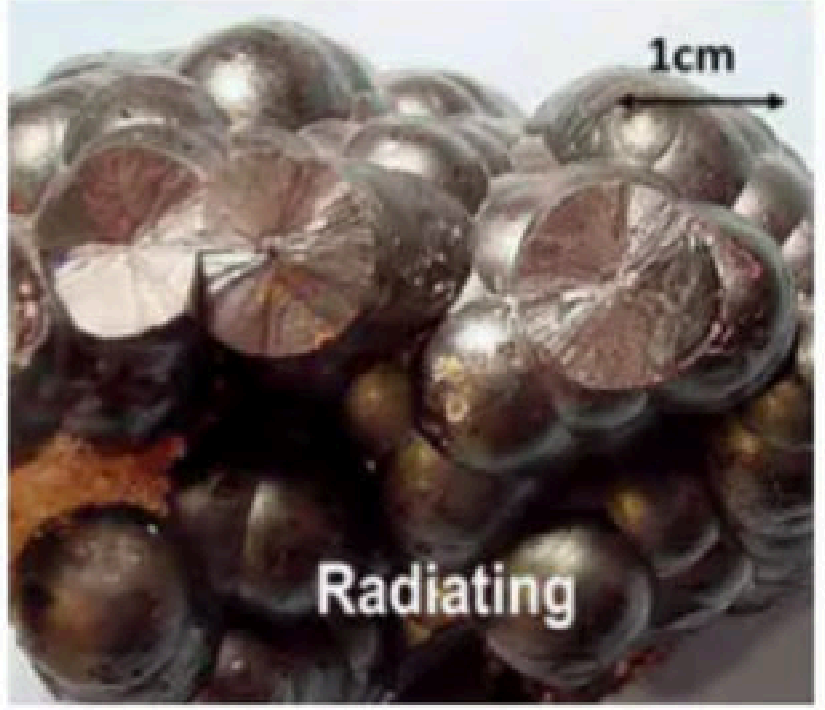
Variations in Habit/Form/Appearance of Minerals

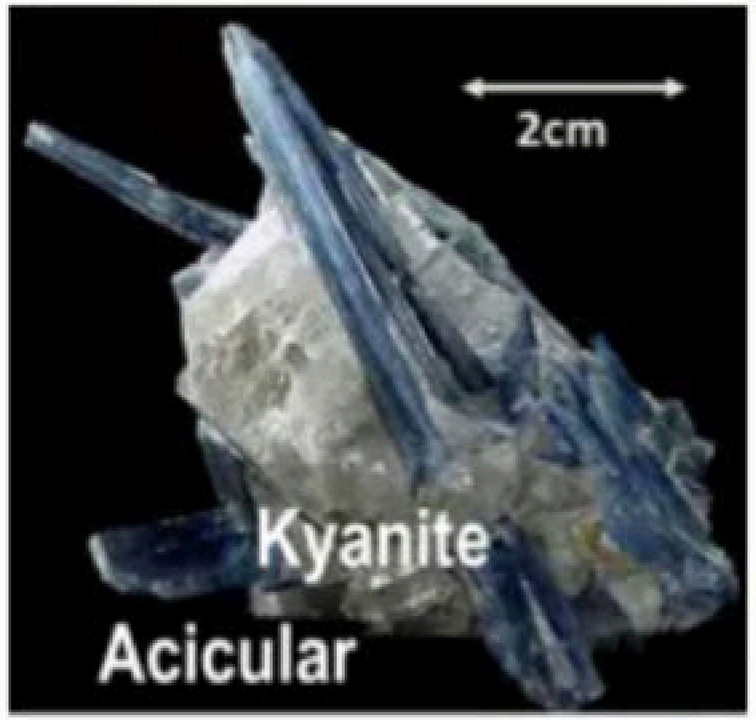
Terminology	Description	Example	Terminology	Description	Example
Acicular	Fine needle like crystals	Sillimanite	Granular	Coarse or fine grain like	Marble
Amygdaloidal	Almond shaped	Zeolites	Lamellar	Separable plates or leaves like	Gypsum
Bladed	Lath shaped	Kyanite	Lenticular	Flattened ball or pellet like	Azurite
Colloform	Combination of botryoidal, globular, mamillary and reniform	Psilomelane	Mammillary	Large mutually interfering spheroidal surfaces	Malachite
Capillary	Exhibiting a fine hair like form	Pyrite	Massive	Compact aggregate without form	Kaolin
Botryoidal	Resembling a bunch of grapes	Psilomelane	Tabular	Like broad flat surface	Wollastonite
Columnar	Form of slender column	Beryl	Oolitic	Aggregation of small spheres	Hematite
Radiating	Crystals of fibers arranged around a central point	Stibnite	Pisolitic	Aggregation of small rounded masses	Bauxite
Concentric	Onion shaped banding	Hematite	Tuberose	Irregular rounded surfaces	Aragonite
Concretionary	Spherical or ellipsoidal or tuberose forms on the surface	Goethite	Reniform	Kidney shaped	Hematite
Dendritic	Branching tree or moss like form	Copper	Reticulate	Form of cross meshes like a net	Rutile
Equidimensional	Equally developed in all directions	Garnet	Scaly	Small plate like	Tridymite
Fibrous	Consisting of fine thread like strands	Asbestos	Stalactitic	Cylindrical or conical form	Calcite
Foliaceous/flaky	Thin lamellae or leaves	Micas			

Variations in Habit/Form/Appearance of Minerals





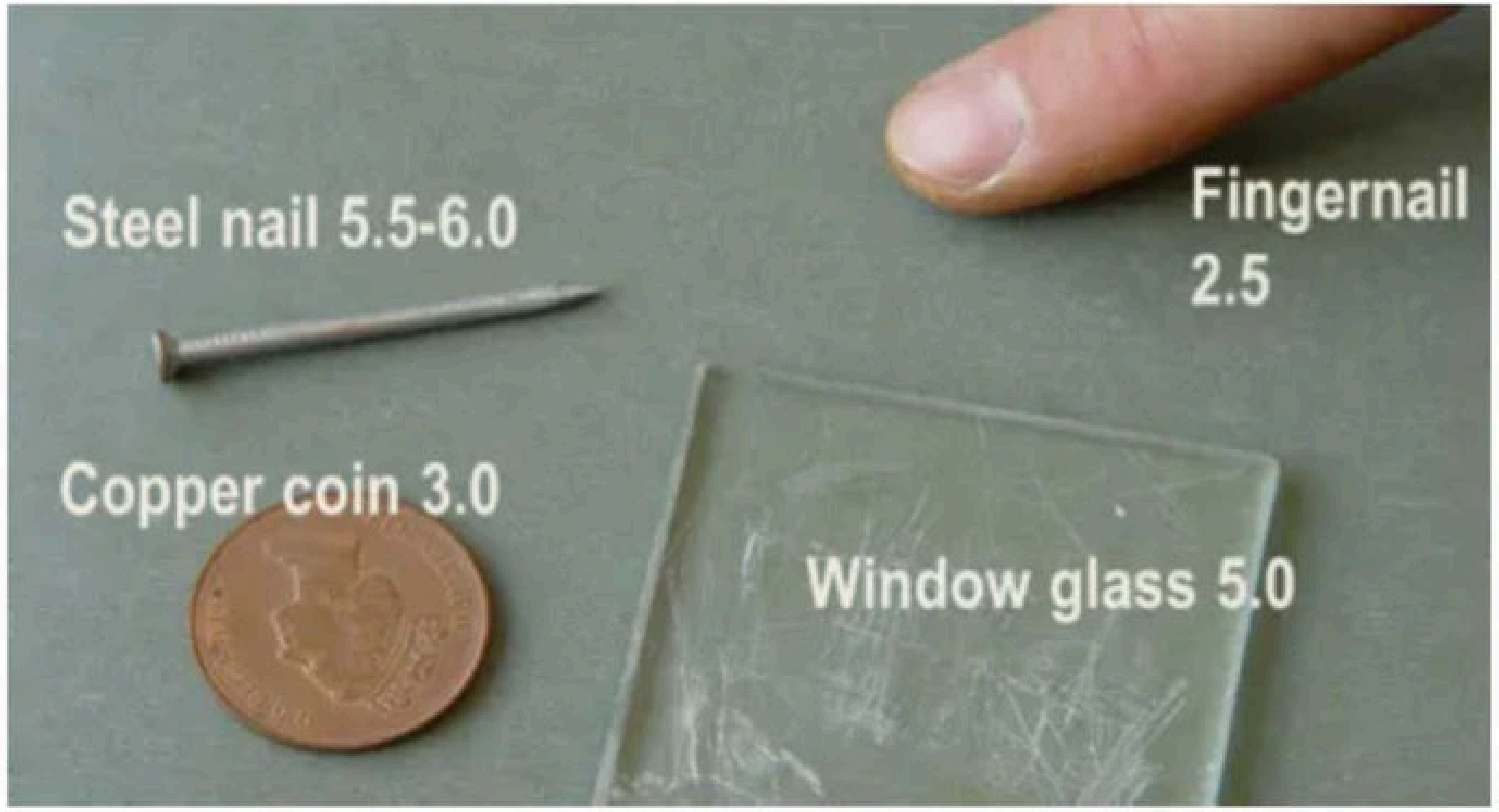




Hardness

- Hardness depends upon the forces holding the atoms of the mineral together.
- In 1812, a scientist, F. Moh devised a scale of hardness into which all minerals can be placed.
- He selected ten minerals and arranged them in order so that any one mineral could be used to scratch only minerals which are less.
- Diamond is the- hardest natural material, 140 times harder than corundum.

Everyday objects can be substituted for minerals on Moh's scale



Moh's Scale of Hardness

10. Diamond

C

9. Corundum

Al_2O_3

8. Topaz

$Al_2SiO_4(OH^-,F^-)_2$

7. Quartz

SiO_2

6. Orthoclase Feldspar

$KAlSi_3O_8$

5. Apatite

$Ca_5(PO_4)_3(OH^-,Cl^-,F^-)$

4. Fluorite

CaF_2

3. Calcite

$CaCO_3$

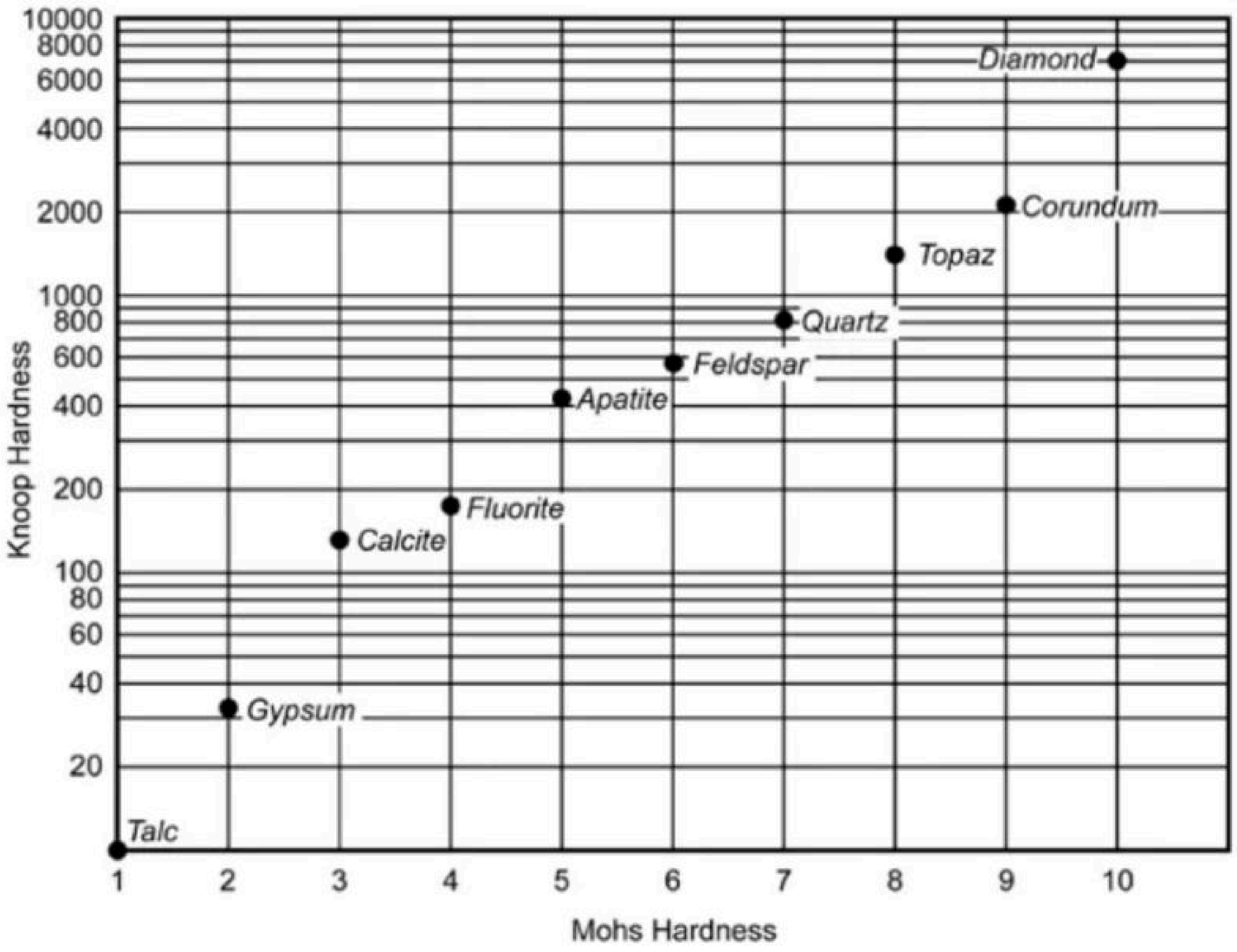
2. Gypsum

$CaSO_4{\cdot}2H_2O$

1. Talc

$Mg_3Si_4O_{10}(OH)_2$

Mineral Hardness

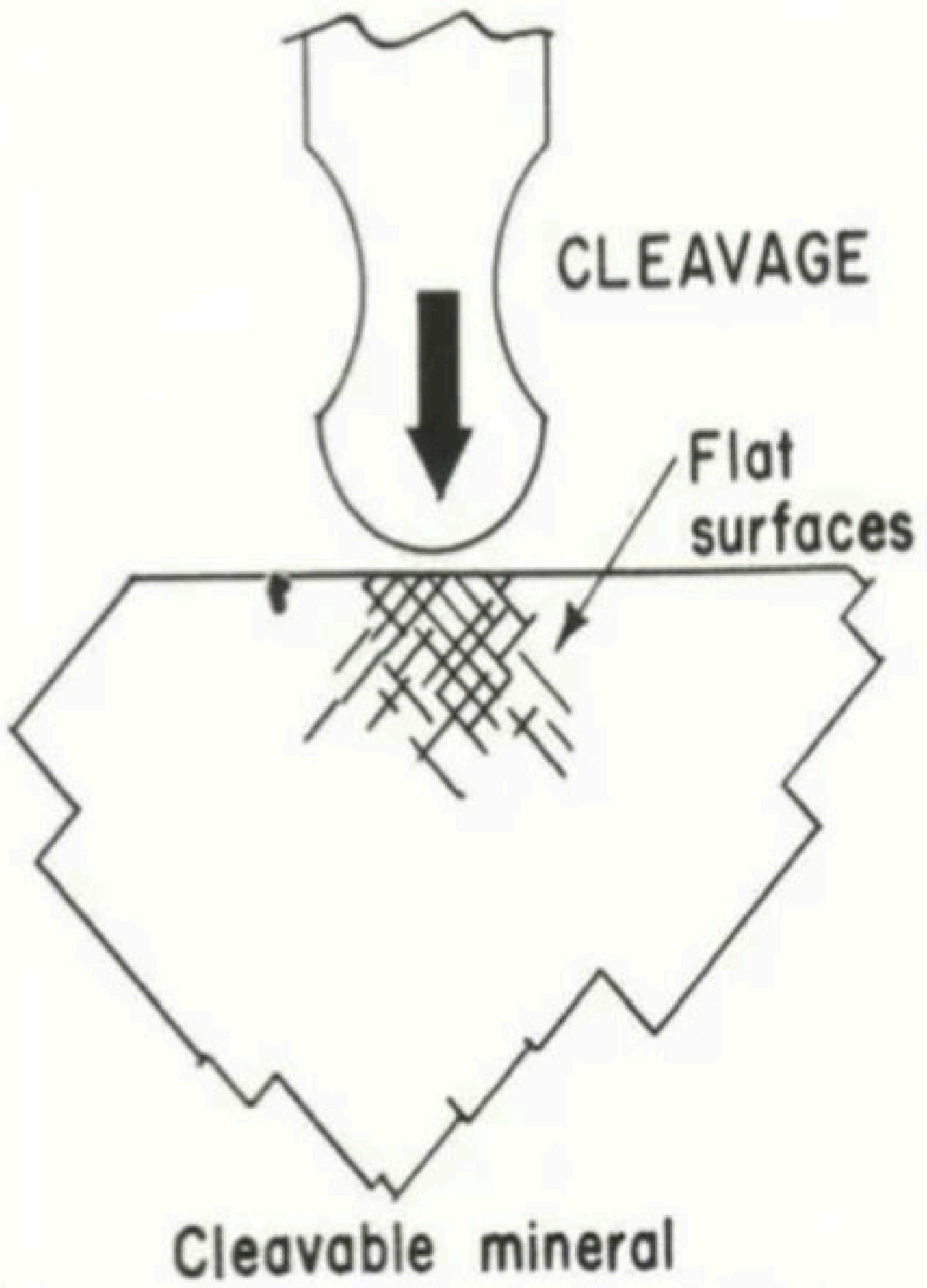


Knoop hardness, a measure of the hardness of a material, calculated by measuring the indentation produced by a diamond tip that is pressed onto the surface of a sample.

The test was devised in 1939 by F. Knoop and colleagues at the National Bureau of Standards in the United States.

Carompison between Mohs scale hardness and Knoop hardness. Knoop hardness is shown with a logarithmic scale.

Cleavage



CLEAVAGE. In the crystal structure of many minerals, some atomic bonds are weaker than others.

It is along these weak bonds that minerals tend to break when they are stressed.

Cleavage is the tendency of a mineral to break (cleave) along planes of weak bonding.

Not all minerals have cleavage, but those that do can be identified by the relatively smooth, flat surfaces that are produced when the mineral is broken.

The way a mineral breaks when struck by a hammer

Cleavage is controlled by lines of weakness in the atomic structure of the mineral

Minerals can have 1, 2, 3 or 4 planes of cleavage

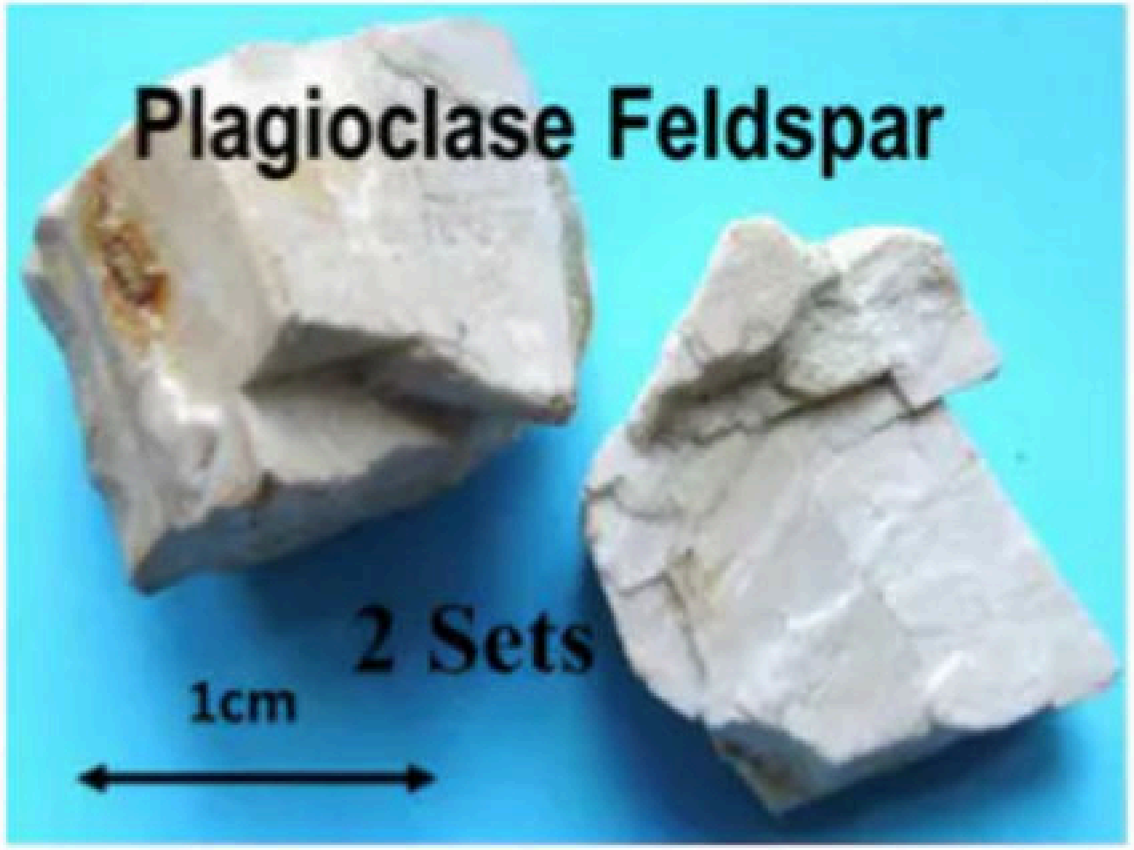
1 plane, parallel or basal cleavage

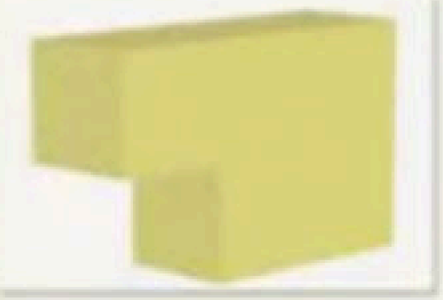
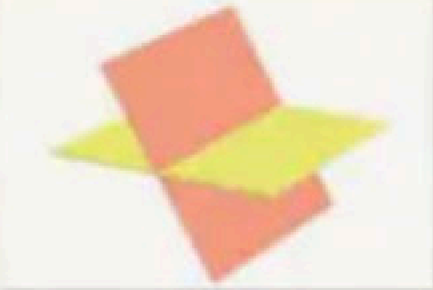
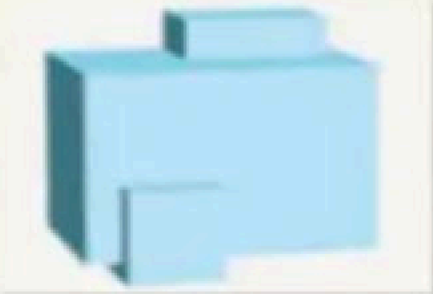
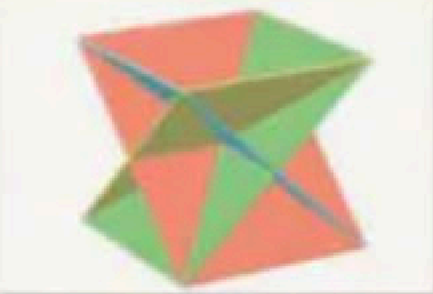
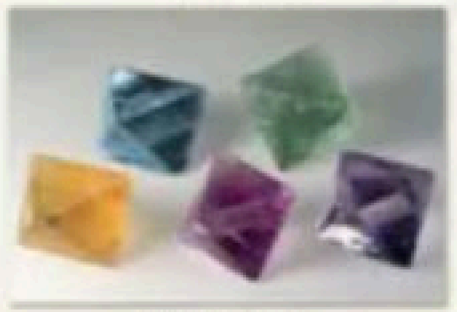
2 planes of cleavage that intersect at a characteristic angle

3 planes (cubic, rhombohedral)

4 planes, octahedral cleavage

Cleavage



Number of Cleavage Directions	Shape	Sketch	Directions of Cleavage	Sample
1	Flat sheets			 Muscovite
2 at 90°	Elongated form with rectangle cross section (prism)			 Feldspar
2 not at 90°	Elongated form with parallelogram cross section (prism)			 Hornblende
3 at 90°	Cube			 Halite
3 not at 90°	Rhombohedron			 Calcite
4	Octahedron			 Fluorite

Fracture

Fracture is the nature of the broken surface in any direction other than the cleavage plane. It is not related to the crystalline structure of the minerals.

Fracture	Description
Conchoidal	In this case the mineral breaks with a curved concave or convex surface as in case of quartz, opal, flint etc. The term subconchoidal is used to describe less developed conchoidal fracture.
Even	The fracture surface is flat as in case of chert.
Uneven	The fracture surface is rough due to minute elevations and depressions as in case of feldspars etc. It is the most common variety of fracture seen in case of majority of the minerals.
Hackly	The fracture surface is studded with sharp elevations as in case of sillimanite.

Fracture

Conchoidal Fracture: This type of fracture is the same as that shown by window glass. A series of concentric curved lines can be seen on the fractured surface. A diagnostic property of the mineral quartz

Quartz

Hackly fracture: (also known as jagged fracture) is jagged, sharp and not even. It occurs when metals are torn, and so is often encountered in native metals such as **copper and silver**.
A hackly fracture resembles broken metal, with rough, jagged, points. True metals exhibit this fracture.

Native copper

Fracture

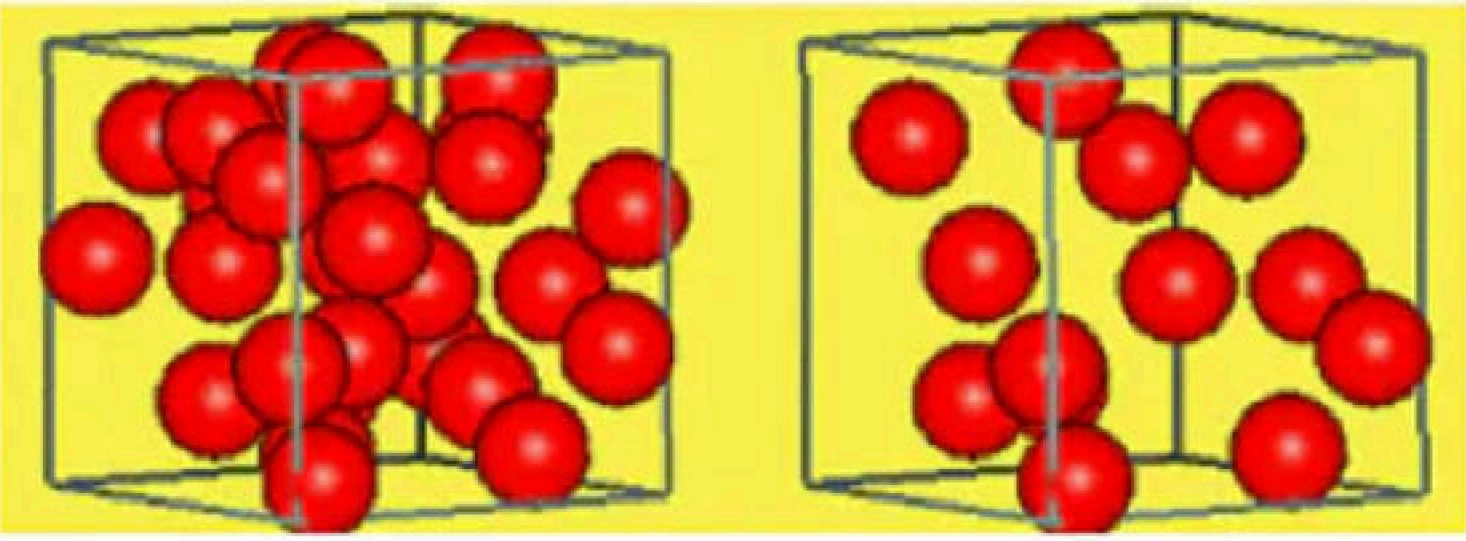
Splintery fracture: comprises sharp elongated points. It is particularly seen in fibrous minerals such as **chrysotile**, but may also occur in non-fibrous minerals such as **kyanite.**

Uneven fracture: is a rough surface or one with random irregularities. It occurs in a wide range of minerals including **arsenopyrite, pyrite and magnetite**.

Earthy fracture: is reminiscent of freshly broken soil. It is frequently seen in relatively soft, loosely bound minerals, such as **limonite, kaolinite and aluminite**.

Density, specific gravity and weight

Density is the mass per unit volume of a material.
It is expressed in units of mass divided by units of volume.
Units (kg/m^3) or, (g/cm^3).
The density of a mineral is proportional to the number of atoms per unit volume, which is called the **packing index**, and to their atomic mass number.
Minerals with very high density, such as native gold (Au), Minerals with very low density, such as ice (H^2O),



A box with more particles in it will be more dense than the same box with fewer particles

Specifi c gravity (SG) is a dimensionless quantity.
It is the ratio between the density of a material and the density of pure water at standard temperature and pressure (temperature = 3.9 °C, pressure = 1 atmosphere).
Since the density of pure water at standard temperature and pressure (STP) is $1.0 g/cm^3$, the

$$SG = \frac{\text{density of mineral}}{\text{density of water}} = \frac{7.5\ g/cm^3}{1.0\ g/cm^3} = 7.5$$

Density, specific gravity and weight

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- The **weight** of a mineral or of any other material is simply its total mass accelerated by gravity.
- For example, when an object is placed on a scale, its mass is accelerated downward by gravity to produce a downward force on
  the scale, which is the object's weight.
- The total mass of the object, in grams (g) or kilograms (kg), is the total mass of all of the atoms it contains.
- Mathematically, w = mg.
- Weight is a downward force and is expressed in force units called Newtons (N), which have the dimensions of kgm/s^2,
- Ex: Native gold, because of its closely packed, massive atoms has a density of $20g/cm^3$. Its specifi c gravity is 20 because the ratio of its density to the density of pure water at STP is:

$$\begin{aligned}\text{Total mass (m)} &= \text{density} \times \text{volume}\\ &= g/cm^3 \times cm^3\\ &= \text{grams or kilograms}\end{aligned}$$

$$w = mg = kg \cdot m/s^2 = \text{Newtons (N)}$$

$$\begin{aligned}\text{Specific gravity (SG)} &= \frac{\text{density of sample}}{\text{density of water}}\\ &= (20\ g/cm^3)/(1.0\ g/cm^3)\\ &= 20\end{aligned}$$

A cubic centimeter (cm3) of gold has a small total mass of 20g

$$\begin{aligned}\text{Mass (m)} &= \text{density} \times \text{volume}\\ &= 20\,g/cm^3 \times 1\ cm^3\\ &= 20\ g\end{aligned}$$

How much will this amount of gold weigh at Earth's surface? Since weight (w) = mg,

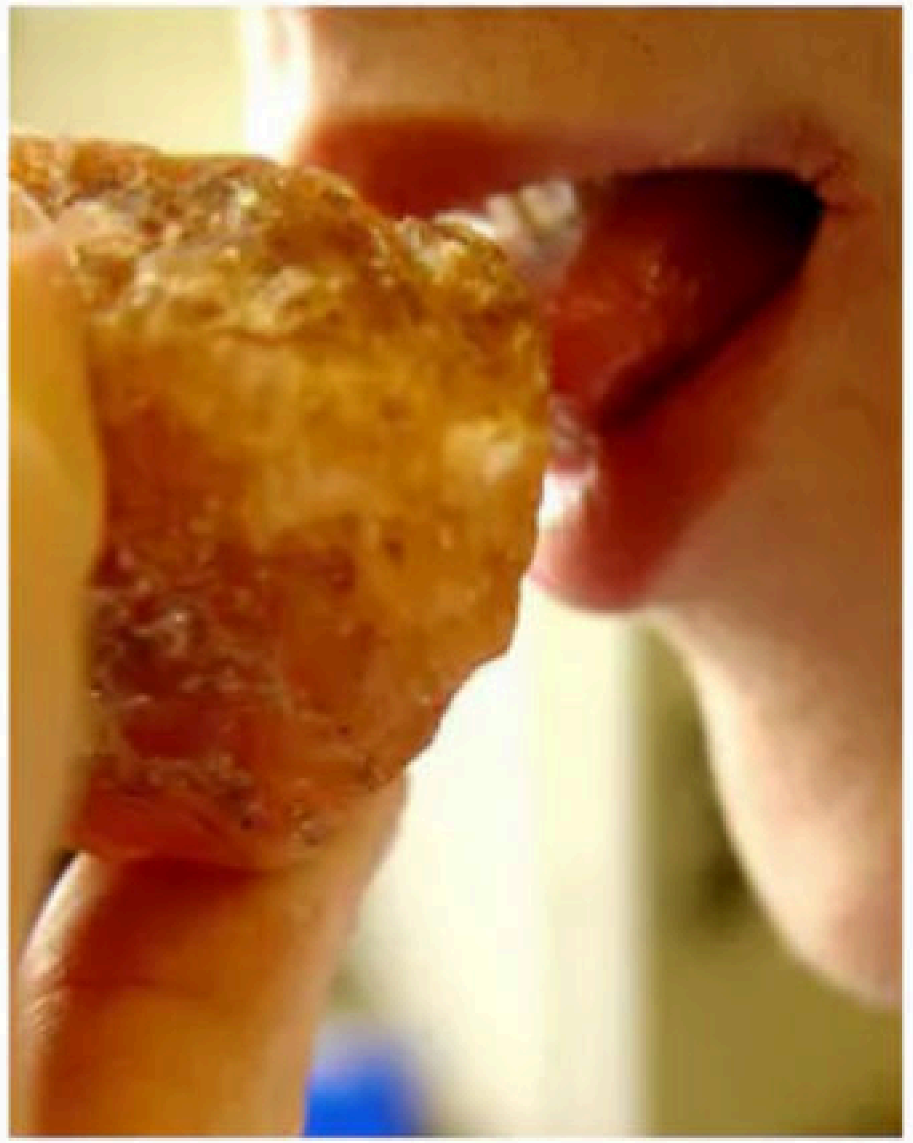
$$\begin{aligned}\text{Weight (w)} &= mg = 20\ g \times 9.8\ m/s^2\\ &= 196\ g \cdot m/s^2 = 0.196\ kg \cdot m/s^2\\ &= 0.196\ N\end{aligned}$$

Special properties

Special properties of the minerals are taste, odour, feel, tenacity, diaphaneity and properties based on magnetism, electricity, radioactivity and acid reaction.

Taste: The water-soluble minerals have some characteristic tastes.
The salty taste characteristic of halite, the bitter taste of sylvite and the sweet, alkaline taste characteristic of borax are good examples.

Taste	Substance
Saline	Halite, Common salt
Alkaline	Potash and soda
Cooling	Potassium chlorate, Nitre
Sweet	Alum
Astringent	Green vitriol
Bitter	Epsom salt, sylvite



Halite (rock salt) tastes salty and is a diagnostic property of the mineral

Taste (Don't do it. It might be witherite.)

Smell

- Some minerals have characteristic odour that comes out when the mineral is blown with mouth, rubbed or heated.

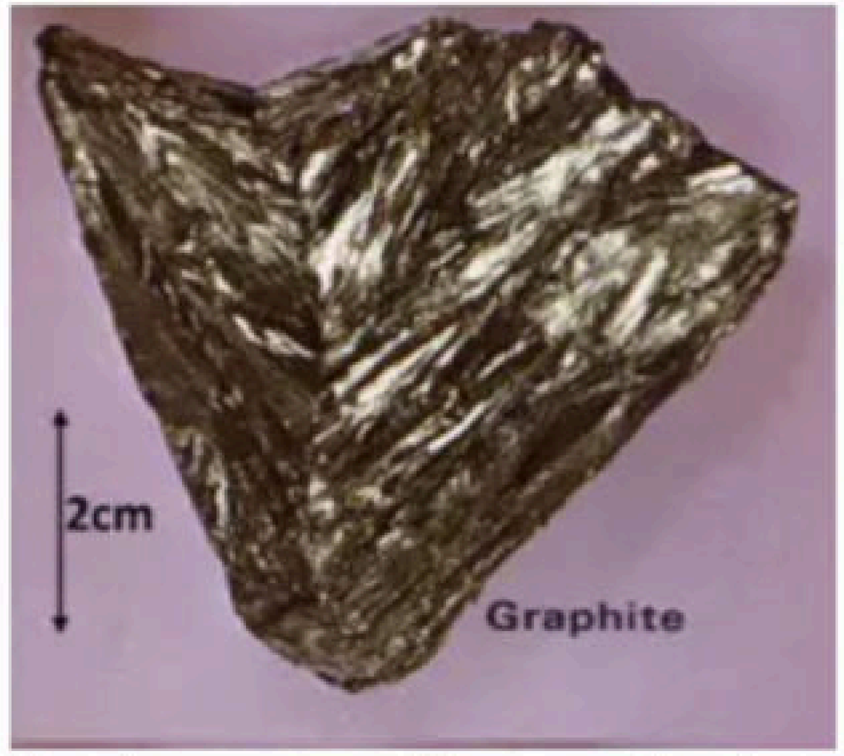
Mineral	Smell
Native sulfur (S) Marcasite (FeS2) Sphalerite (ZnS)	sulfur smell when crushed powdered
arsenopyrite (FeAsS) and realgar (AsS)	garlicky smell

Radioactivity: (U and Th minerals)

Feel

- Some minerals have characteristic feel

Feel	Mineral
Greasy	Graphite
Soapy	Talc, chlorite
Smooth	Galena
Rough	Bauxite



Graphite feels very cold upon the touch as it is a very good conductor of heat

Talc feels very greasy when rubbed between the fingers

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Tenacity

- Some minerals have definite properties dependent upon their tenacity.

Property	Mineral
Sectile	The mineral can be cut by a knife; e.g. graphite, gypsum, steatite
Malleable	The mineral flattens under hammer; e.g. native gold, silver and copper
Flexible	The mineral can be bent; e.g. talc, selenite
Elastic	The mineral restores its original position after bent; e.g. micaflakes
Brittle	The mineral when struck yields powder in stead of slice

Diaphaneity

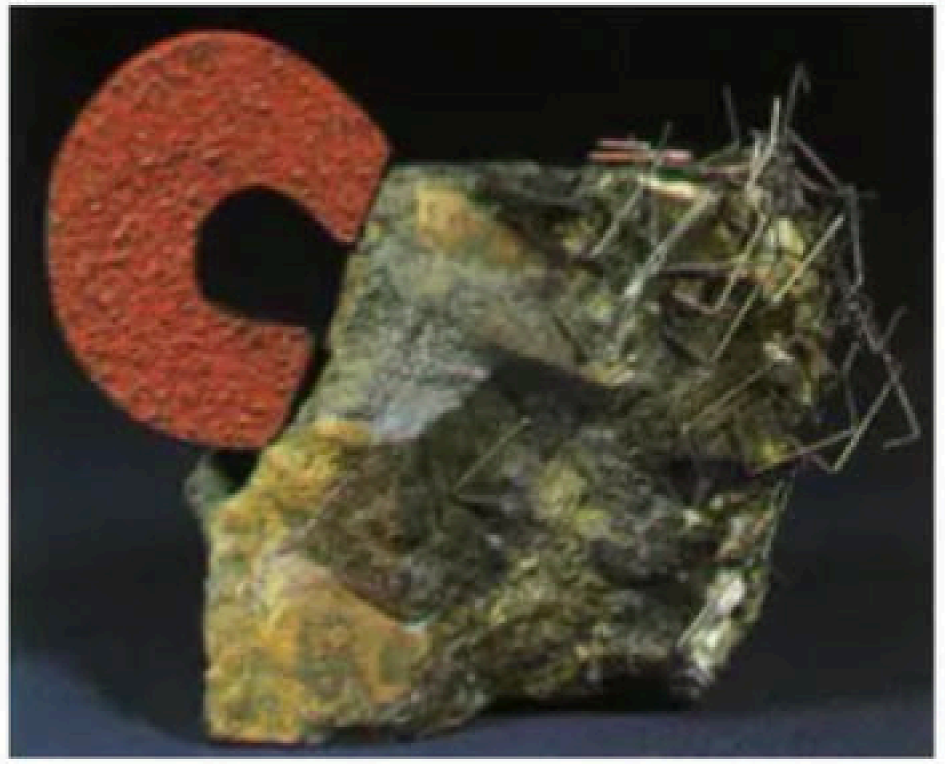
- Diaphaneity refers to the amount of light transmitted through the minerals.

Term	Description
Transparent	In this case the outline of an object is clearly seen through the mineral as in case of rock crystal.
Semitransparent	The objects are seen but the outlines are not distinct.
Translucent	Light is transmitted through the mineral but objects are not seen
Subtranslucent	Light is transmitted through the thin edges of the mineral and the objects are not seen
Opaque	No light is transmitted, even on the thin edges of small splinters.

Magnetism

On the basis of magnetic strength the minerals can be grouped under four groups

Degree of magnetism	Mineral
Highly magnetic	Magnetite, pyrrhotite
Moderately magnetic	Siderite, chromite, ilmenite, hematite
Weakly magnetic	Monazite, spinels, tourmaline
Non-magnetic	Quartz, feldspar, caicite and a numberof rock-forming minerals



Steel pins and magnet attracted to magnetite

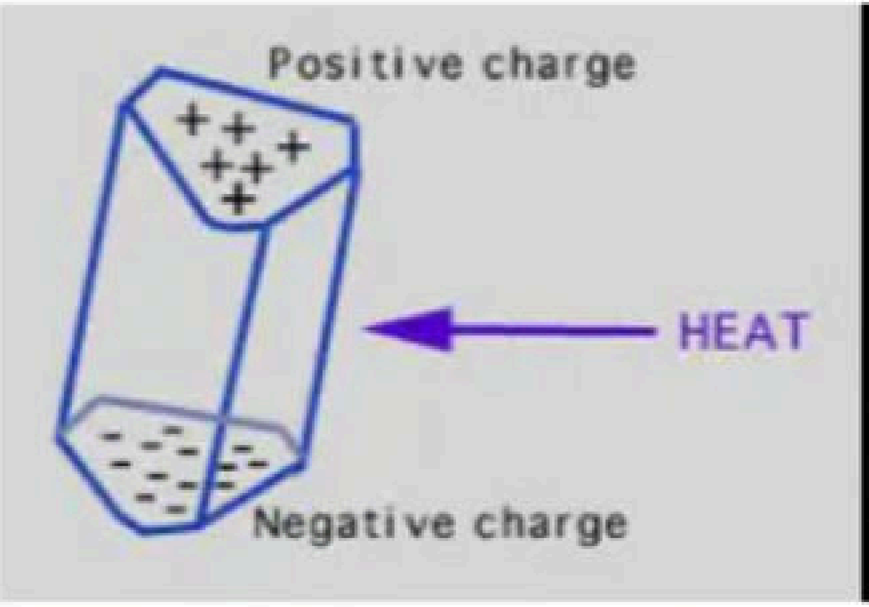
Octahedral crystals of Magnetite

Different varieties of magnetism exhibited by minerals.

Type of magnetism	Description
Dimagnetic minerals	Not attracted to even very powerful magnets; in fact they are slightly repelled by them
Paramagnetic minerals	Weakly attracted to strong magnets, become magnetized in an external magnetic field, but lose their magnetization when the external field is removed
Ferromagnetic – ferrimagnetic minerals	Strongly attracted to even weak magnets, and can retain magnetization for long periods of time

Electrical properties

Pyroelectricity is a phenomenon in which an increase in temperature induces an electric current that flows from one end of the crystal to the other.
Piezoelectricity is similar but is produced by a pressure or stress applied to one end of the mineral.



Acid Reaction

- Some carbonate minerals, such as calcite, aragonite, witherite and rhodochrosite, possess the property of effervescence.
- When a drop of dilute hydrochloric acid (HCl) is placed on the specimen, it effervesces by releasing carbon dioxide (CO_2) gas.
- Other carbonate minerals, such as dolomite, effervesce only when the specimen is powdered or the hydrochloric acid is heated to promote the chemical reaction that releases carbon dioxide gas.

Calcite reacting and giving off carbon dioxide