Minerals and their Basic Building Blocks

Rocks are made of minerals. Minerals are made of chemical compounds. And compounds are made of elements.

The smallest piece of a chemical compound that still has the properties of that compound is a molecule. A molecule is made of one or more atoms of various elements. An atom is the smallest piece of an element that still has the properties of that element. An atom is too small to see with the most powerful microscope.

ELEMENTS

Elements are the simplest, most basic kinds of material you can get. An atom of a particular element is the smallest particle of that element. For example, you can have a pail full of the element iron. You can take smaller and smaller pieces of iron until you get down to an atom of iron. You can't get pieces of iron that are smaller than an atom without splitting the iron atom so that it is no longer the element iron.

Elements are the basic ingredients of which everything is made. There are about 97 elements which occur naturally and 12 more elements which man has made. As a kind of shorthand or abbreviation in order to save space, each element has been given a symbol. The chemical symbol is usually the first letter or first few letters of its name with the first letter capitalized. For example, H = hydrogen, O = oxygen, Na = sodium (natrium is the Latin word for sodium carbonate), Cl = chlorine, S = sulfur, Fe = iron (ferrum is the Latin word for iron).

COMPOUNDS

Compounds are made when one or more elements combine chemically to form a new material that is different from the original ingredients or elements. For example, when the element sodium (Na) combines with the element chlorine (Cl), you get the compound sodium chloride (NaCl) or salt (mineral name = halite). If you have a pail full of salt, you can take smaller and smaller pieces of salt until you get down to the smallest piece of salt; this is a molecule of salt. If you split the molecule of salt (NaCl), you get an atom of the element sodium (Na) and an atom of the element chlorine (Cl). These two atoms do not have the same characteristics as salt (NaCl). We eat salt (NaCl), but sodium (Na) is a highly reactive, dangerous metal and chlorine (Cl) is a poisonous gas in its pure form.

MINERALS

Minerals are **naturally occurring** chemical compounds. They are **inorganic**; this means they are made of material that has never been a living plant or animal. They are also solid and not in their liquid or gaseous form. Each mineral has a definite chemical content, which can be described by a **chemical formula** or symbol. For example, halite (salt) is always NaCl, which means that one atom of sodium always goes with one atom of chlorine. Quartz is always SiO_2, which means two atoms of oxygen for each atom of silicon. Each mineral has a **regular structure** in which the atoms are always put together in the same pattern. For example, salt is always put together with an atom of sodium next to an atom of chlorine in all three directions (up-down, left-right, front-back) to make a cube shape.

Some minerals are made of only one element. Examples of minerals that are made of a single element are: gold (Au from the Latin aurum, meaning gold), graphite (C or carbon), diamond (C or carbon), and copper (Cu from the Latin *cuprum* for copper).

MINERALS

MINERAL IDENTIFICATION

PHYSICAL PROPERTIES

Luster

Luster is the surface appearance of the mineral. It refers to the character of the light reflected by the mineral. **Metallic luster** = looks like a metal. It is opaque to light, even in very thin sheets. Metallic looking minerals look like aluminum, lead, silver, gold, brass, copper iron, steel, etc. **Nonmetallic luster** = does not look like a metal. Light will pass through thin sheets. Examples are glassy, earth, silky, pearly, resinous, greasy, etc. Many nonmetallic minerals contain metals in their chemical makeup, but they do not look like metals, so are not classified as having metallic luster.

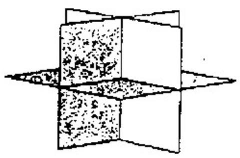
Cleavage

Cleavage is the pattern of breaking into regular planes. Cleavage is the splitting, or tendency to split, along planes determined by the crystal structure. Cleavage is the property of breaking in flat, parallel planes, such as layer, cubes, or pyramids. When rotating the mineral under a light, all the cleavage planes that are the same direction will reflect light at the same time, making one flash like a set of mirrors lined up parallel to each other, even though some of the faces are higher or lower than others. If you're not sure if it is a crystal face or a cleavage face, look on the edge of the shiny face to see if it has been broken. If it is a cleavage face, the breaks will be parallel to the other shiny surfaces. If it does not have cleavage, the breaks will be slightly curved, like broken glass, or will be irregular. Some minerals are composed of crystalline aggregates. If these have cleavage, the broken surface of the mineral will have many flat sparkles.

Types of cleavage:

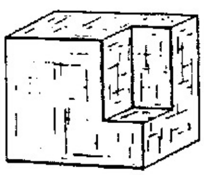
Basal or layers: One direction of cleavage. The mineral breaks into layers or breaks so the flat surfaces are parallel to only one direction, such as the top and bottoms parallel. An example of basal cleavage is mica.

Two directions: Two directions of cleavage. The mineral breaks into flat surfaces parallel to two directions, such as one that is parallel to the top and bottom and a second that is parallel to the front and back, while the other directions such as the sides are irregular surfaces. A mineral with two directions of cleavage is the feldspars, orthoclase and plagioclase.

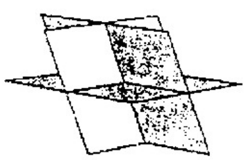


Three directions: Three directions of cleavage. The mineral breaks into flat surfaces in three planes, such as top and bottom, back and front, and left and right sides.

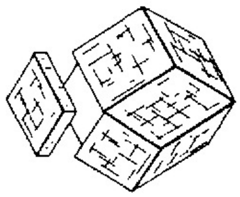
Cubic cleavage: Breaking in three directions that are at right angles to each other, producing small cubes with all sides perpendicular to each other. Examples are galena and halite (salt).



Rhombohedral cleavage: Breaking in three directions, two of which are at right angles and the third of which is slanted at an acute angle. Rhombohedrons look like a rectangular solid or cube that has been pushed over from one side. An example is calcite.

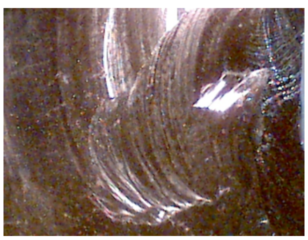


Four directions (Octahedral): Breaking in four directions at acute angles to each other. A perfect specimen of this type of cleavage would look like two pyramids with square bases placed with their bases together and with one pyramid upside down. An example of this is the common cleavage octahedrons of fluorite.

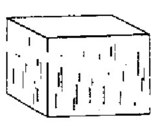


More than four directions: This type of cleavage can be distinguished by counting the different cleavage faces while not counting the surfaces which are parallel to a surface that has already been counted. An example is sphalerite.

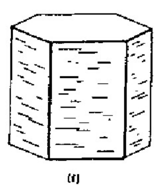
Fracture or no cleavage: The mineral breaks in an irregular, uneven manner. Types of fracture include fibrous, uneven, irregular, hackly, or conchoidal. Conchoidal fracture is breaking in curving planes like a conch shell or like glass or obsidian.



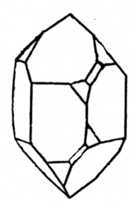
Other physical characteristics include crystal shape, which can be prismatic, acicular, tabular, cubic, scalenohedral, hexagonal, etc.



prismatic



hexagonal



Hardness

Hardness is a measure of how hard it is to scratch the mineral; it is the resistance that a smooth surface offers to scratching. The Mohs' scale of hardness is a sequence of minerals arranged in order of increasing hardness. They are 1 - talc, 2 - gypsum, 3 - calcite, 4 - fluorite, 5 - apatite, 6 - orthoclase, 7 - quartz, 8 - topaz, 9 - corundum, and 10 - diamond. These mineral hardnesses can be approximated with a few common, ordinary tools: 2 - fingernail, 3 - copper penny, 5 - knife blade, 5.5 - glass, and 6.5 - steel file.

The Mohs Hardness Scale

Hardness	Mineral	Test
1	Talc	
2	Gypsum	
		Fingernail
3	Calcite	
		Copper coin
4	Fluorite	
5	Apatite	
		Knife blade or glass plate
6	K-feldspar	
7	Quartz	
		Steel file
8	Topaz	
9	Corundum	
10	Diamond	

When using the hardness test be aware of several cautions. First, do the least amount of damage to the mineral as possible by scratching it in an unobtrusive spot and with a very small scratch. If other observations give you an idea of what the mineral is, use the hardness test after other tests as a way to distinguish between a few very similar minerals whose hardness you know, so you only have to make one or two tests. Test the hardness both ways - scratch the tool with the mineral and scratch the mineral with the tool. A scratch will be a groove which you can't rub off. Sometimes a softer mineral rubs off on the harder tool, looking like a scratch, but the powder can be rubbed off with your finger. The surface is often altered and softened by weathering, so you must test a freshly broken surface whenever possible. If a mineral is granular or splintery, it may not give an accurate hardness test because the grains or splinters rub off easily.

Streak

Streak is the color of the powdered mineral. Rub the mineral across a streak plate, which is an unglazed porcelain tile. This is chiefly used with metallic minerals, because non-metallic minerals often have a white, pastel, or colorless streak. This is not usually useful for minerals harder than 7, (which is the hardness of the porcelain tile) because harder minerals do not powder, but instead scratch the streak plate.

Color

For some minerals, color is constant and diagnostic. For other minerals, color varies depending upon composition. For other minerals, color varies with impurities.

Acid test

Fizzing (vigorous effervescence) occurs when dilute hydrochloric acid (10% HCl) or dilute muriatic acid is dropped on calcite. A few other minerals, such as dolomite, malachite, azurite, and siderite, will slowly fizz if the mineral is first powdered.

Specific Gravity

Specific gravity is the ratio of the mass of a mineral to the mass of an equal volume of water at a specified temperature, and can be measured by weighing the mineral in air and dividing by the weight of an equal volume of water (the weight of the amount of water displaced by the mineral).

$$\text{S. G.} = \frac{\text{mass of mineral}}{\text{mass of same volume of water}} = \frac{\text{weight of mineral in air}}{\text{weight of equal volume of water}}$$

Estimate the relative weight of the mineral compared to common stones to approximate the specific gravity. Average = like quartz, feldspar, calcite = 2.6-2.8; Heavy = like galena (lead sulfide) = 7.5; Light = lighter than quartz, like opal = 2.0 or graphite = 2.3 or gypsum = 2.3 or halite 2.16. Most metallic minerals are heavy and many nonmetallic minerals are average; very few minerals are lighter than average.

Mineral Identification Tables

Luster Cleavage	**Hardness**	**Color Streak St=**	**Diagnostic Features**	**Formula**	**Name**
Metallic good cleav.	1-1.5	Lead gray to blue gray St=Gray-black	Heavy (Sp.Gr. = 4.6-4.7)	MoS_2	Molyb-denite
Metallic good cleav.	1-2	Dark gray to black St=Black	Writes on paper Greasy look and feel	C	Graphite
Metallic good cleav.	2.5	Lead gray St=Gray to gray black	Cubic cleavage Very heavy (Sp.Gr.=7.5)	PbS	Galena
Metallic good cleav.	3.5-4	Yellow brown to brown black St=Yellow brown	Good cleavage -6 directions Resinous luster Streaks lighter than color	ZnS	Sphalerite
Metallic No cleavage	1-2	Sooty black - iron black St=Black	Soft - soils the fingers Splintery fracture Black dendritic growths (fernlike on surfaces)	MnO_2	Manganese Oxide
Metallic No cleavage	2.5-3	Silver white color St=silver white	Tarnishes brown - gray-black Hackly fracture Heavy (Sp.Gr-10) Malleable and ductile	Ag	Silver
Metallic No cleavage	2.5-3	Golden yellow color	Heavy (SG=15-19) Malleable, ductile, sectile Hackly fracture Irregular octahedral crystals and dendritic shapes	Au	Gold
Metallic No cleavage	3	Black to shiny gray St=Black	Dull black tarnish Sectile - leaves a shiny groove when scratched	Cu_2S	Chalcocite
Metallic No cleavage	3	Bronze on fresh surfaces St=gray black	Purple iridescent tarnish	Cu_5FeS_4	Bornite
Metallic No cleavage	2.5-3	Copper color on fresh surface St=metallic copper	Black to dark brown tarnish Malleable Copper color	Cu	Copper
Metallic No cleavage	3.5-4	Red of various shades St=brownish red	Luster metallic to adamantine Red glassy highlights	Cu_2O	Cuprite
Metallic No cleavage	3.5-4	Brassy yellow color St=greenish black	Brassy color, greenish streak Bronze or iridescent tarnish	$CuFeS_2$	Chalco-pyrite
Metallic No cleavage	5.5-6.5	Rusty red brown to silvery gray St=reddish brown	Red brown earthy, platy crystals if silvery gray Streak is important Earthy variety is softer	Fe_2O_3	Hematite
Metallic No cleavage	6	Black St=black	Black color Magnetic - sticks to magnet	Fe_3O_4	Magnetite
Metallic	6.5	Brown to black St=black	Prismatic crystals and massive, botryoidal or concretionary masses	SnO_2	Cassiterite
Metallic No cleavage	6-6.5	Pale brass yellow St=greenish black or brownish-black	Silvery pale brass yellow on fresh surface (Fool's gold) Harder than glass	FeS_2	Pyrite

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Nonmetallic good cleav.	1	Green, grey, white, variable St=white	Greasy to soapy feel Very soft	$Mg_2(Si_4O_{10})(OH)_2$	Talc
Nonmetallic good cleav.	2	Clear to white St=white	Good layered cleavage Selenite=clear layers Alabaster = white grainy, massive Satin Spar = fibrous	$CaSO_4.2H_2O$	Gypsum
Nonmetallic good cleav.	2.5-4	Colorless to greenish St=White	Thin sheets=clear mica Transparent to translucent	$KAl_2(Si_3O_{10})(OH)_2$	Muscovite
Nonmetallic good cleav.	2-2.5	Dark green, variable color St=greenish white	Flexible folia, not elastic Layers irregular, crumbly	$Mg_3(Si_4O_{10})(OH)_2Mg_3(OH)_6$	Chlorite
Nonmetallic good cleav.	2.5	Colorless to white color St=white	Salty taste Cubic cleavage colorless to white	NaCl	Halite
Nonmetallic good cleav.	2.5-3	Black to brown	Thin sheets Flexible sheets, black to smoky in color	$K(Mg,Fe)_3(AlSi_3O_{10})(O_4)_2$	Biotite
Nonmetallic good cleav.	3	Clear to white common, other colors possible	Good rhombohedral cleavage (3 directions, slanted cube) Fizzes in dilute acid (HCl)	$CaCO_3$	Calcite
Nonmetallic good cleav.	3-3.5	White, gray, various colors St=white	Rectangular cleavage	$CaSO_4$	Anhydrite
Nonmetallic good cleav.	3-3.5	White to pinkish, clear, blue, yellow, etc.	Very heavy for nonmetallic Sp.Gr.=4.5; good cleavage Crystals usually tabular or roses;	$BaSO_4$	Barite
Nonmetallic good cleav.	3.5-4	White to pink, etc.	Good rhombohedral cleavage Crystal faces often curved Fizzes in dilute HCl acid only if powdered first	$CaMg(CO_3)_2$	Dolomite
Nonmetallic good cleav.	4	Any color from purple, white yellow, green, etc.	Good octahedral cleavage (4) Cubic crystals common	CaF_2	Fluorite
Nonmetallic good cleav.	3.5-4	Yellow, yellow brown to black if more Fe is present St=reddish brown to yellow	Resinous luster Nonmetallic to metallic Good cleavage in 6 directions	ZnS	Sphalerite
Nonmetallic good cleav.	4.5-5	White, yellow, light brown St=white	Fluoresces bluish white in ultraviolet light Heavy Sp.Gr.=6 Pyramid shaped crystals	$CaWO_4$	Scheelite
Nonmetallic good cleav.	6	Dark green to black or brown	Prismatic crystals Good cleavage in 2 directions at 60^o and 120^o	$Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)_3Si_8O_{22}(O,OH)_2$	Hornblende (a type of amphibole)
Nonmetallic good cleav.	6	Dark green to black	Short prismatic 8-sided crystals Good cleavage in 2 directions at 90^o	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	Augite (a type of pyroxene)
Nonmetallic Good cleav.	6	White, some greenish	Columnar or figrus aggregates	$Ca_2Mg_5Si_8O_{22}(OH)_2$	Tremolite

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Nonmetallic good cleav.	6-6.5	White, pink, or blue green	Good cleavage in 2 directions at 90º	$KAlSi_3O_8$	Orthoclase (a type of feldspar)
Nonmetallic good cleav.; massive varieties no cleavage	6-6.5	White, gray, blue gray, gray black	Good cleavage in 2 directions at 90º Striations (fine parallel grooves) on some cleavage faces	$NaAlSi_3O_8$ to $CaAl_2Si_2O_8$	Plagioclase (a type of feldspar)
Nonmetallic good cleav.	6-7	Brown or black St=light colored	Heavy (Sp.Gr.=6.8-7.1) Poor cleavage in 1 direction Stream tin is globular	SnO_2	Cassiterite
Nonmetallic good cleav.; massive var. no cleavage	6-7	Yellow green to blackish green St=none (too hard)	Poor basal cleavage Yellowish green color Very hard If granular, no apparent cleavage	$Ca_2(Al,Fe)_3 Si_3O_{12}(OH)$	Epidote
Nonmetallic good cleav.	9	Brown, pink(=ruby), blue (=sapphire)	Hexagonal crystals Heavy nonmetallic Poor basal cleavage	Al_2O_3	Corundum
Nonmetallic no cleavage	1.5	Yellow brown to brown St=yellow brown	Earthy luster Yellow brown streak	$FeO(OH)\cdot nH_2O$	Limonite
Nonmetallic no cleavage	1.5-2.5	Bright yellow color St=yellow to white	Smells sulfurous Brittle - has no cleavage Crackles with heat of hand	S	Sulfur
Nonmetallic No cleavage	2 – 2.5	White, dull, earthy, plastic	Generally chalky, clay Sticks to tongue	$Al_4(Si_4O_{10})(OH)_8$	Kaolinite
NonMetallic No cleavage	2-6	Rusty red brown to silvery gray St=reddish brown	Red brown earthy Streak is important Earthy variety is softer	Fe_2O_3	Hematite
Nonmetallic no cleavage	3.5-4	Bright green, light to dark	Luster earthy to glassy Botryoidal or stalactitic form Powder fizzes in dilute HCl	$Cu_2CO_3 (OH)_2$	Malachite
Nonmetallic no cleavage	3.5-4	Bright blue	Luster earthy to glassy Complex radiating crystals Powder fizzes in dilute HCl	$Cu_3(CO_3)_2 (OH)_2$	Azurite
Nonmetallic no cleavage	2-4	Bluish green	Luster earthy to glassy Cryptocrystalline to massively compact Conchoidal fracture	$CuSiO_2 .nH_2O$	Chrysocolla
Nonmetallic no cleavage	2 - 5	Green to yellowish green St=white	Luster = greasy, silky or waxy Asbestos is fibrous form	$Mg_6(Si_4O_{10}) (OH)_8$	Serpentine
Nonmetallic no cleavage	6	Blue, bluish green, green	Luster = waxlike Cryptocrystalline	$CuAl_6(PO_4)_4(OH)_8.2H_2O$	Turquoise
Nonmetallic good cleav.; massive var. no cleavage	6-7	Yellow green to blackish green St=none (too hard)	Poor basal cleavage Yellowish green color Very hard If granular, no apparent cleavage	$Ca_2(Al,Fe)_3 Si_3O_{12}(OH)$	Epidote

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Nonmetallic No cleavage	6.5-7	Green, generally olive green to dark green or brown	Conchoidal fracture Vitreous, transparent to translucent, generally green glassy grains	$(Mg,Fe)_2SiO_4$	Olivine
Nonmetallic no cleavage	7	Colorless or white, also gray or any color Purple or violet (+ferric iron) Rose red or pink (+titanium) Smoky yellow to brown and black (+radiation) Light yellow quartz Milky white (+fluid inclusions Opalescent or chatoyant quartz (due to fibrous inclusions)	Glassy luster to greasy Conchoidal fracture Prismatic crystals	SiO_2	Quartz Amethyst Rose quartz Smoky quartz Citrine Milky quartz Cat's Eye quartz
Nonmetallic no cleavage	7	Colorless, white or any color Red = carnelian Brown = sard Apple green (+nickel oxide) Alternating layers of opal and chalcedony or granular quartz Green chalcedony with small red spots of jasper Layers of chalcedony Onyx with sard alternating with white or black layers	Fibrous quartz	SiO_2	Chalcedony Carnelian Sard Chryso-prase Agate Heliotrope Bloodstone Onyx Sardonyx
Nonmetallic no cleavage	7	Colorless, white or any color	Granular quartz Dull to dark, massive Light colored, massive Red (from hematite inclusions) Dull green	SiO_2	Granular quartz Flint Chert Jasper Prase
Nonmetallic no cleavage	6.5-7.5	Red, green, brown, yellow, white, green, black	Vitreous to resinous luster Somewhat heavy (Sp.Gr .= 3.5-4.3) Crystals often dodecahedrons (with diamond shaped faces) Conchoidal fracture	Mg,Fe,Mn,Ca,Al,Cr $(SiO_4)_3$	Garnet
Nonmetallic Basal cleavage	8	Colorless or white, others if tinted by impurities St=white	Prismatic crystals terminated by pyramids, flat base	$Al_2SiO_4(OH),F)_2$	Topaz

Uses of Common Minerals

The following text was abstracted from the Manual of Mineralogy (after James D. Dana) by Cornelius S. Hurlbut, Jr. and Cornelius Klein, 19th edition (1977).

Apatite: Crystallized apatite has been used extensively as a source of phosphate for fertilizer but today only the deposits on the Kola Peninsula are of importance and phosphorite deposits supply most of the phosphate for fertilizer. The calcium phosphate is treated with sulfuric acid and changed to super-phosphate to render it more soluble in the dilute acids that exist in the soil. Transparent varieties of apatite of fine color are occasionally used for gems. The mineral is too soft, however, to allow its extensive use as a gemstone.

Biotite: no significant use.

Calcite: The most important use for calcite is for the manufacture of cements and lime for mortars. Limeston is the chief raw material, which when heated to about 900°C forms quicklime, CaO, by the reaction: $CaCO_3 \rightarrow CaO + CO_2$. The CaO, when mixed with water, forms one or several CaO-hydrates (slaked lime), swells, gives off much heat, and hardens or, as commonly termed, "sets." Quicklime when mixed with sand forms common mortar.

The greatest consumption of limestone is in the manufacture of cements. The type known as Portland cement is most widely produced. It is composed of about 75% calcium carbonate (limestone) with the remainder essentially silica and alumina. Small amounts of magnesium carbonate and iron oxide are also present. In some limestones, known as cement rocks, the correct proportions of silica and alumina are present as impurities. In others these oxides are contributed by clay or shale mixed with the limestone before "burning." When water is mixed with cement, hydrous calcium silicates and calcium aluminates are formed.

Limestone is a raw material for the chemical industry, and finely crushed limestone is used as a soil conditioner, for whiting and whitewash. Great quantities are quarried each year as a flux for smelting various metallic ores, as an aggregate in concrete and as road metal. A fine-grained limestone is used in lithography.

Calcite in several forms is used in the building industry. Limestone and marble as dimension stone are used both for construction purposes and decorative exterior facings. Polished slabs of travertine and Mexican onyx are commonly used as ornamental stone for interiors. Indiana is the chief source of building limestone in the United States, with the most productive quarries in Lawrence and Monroe Counties. Many of the federal buildings in Washington, D.C., have been constructed from this limestone. The most important marble quarries are in Vermont, New York, Georgia, and Tennessee.

Iceland spar is valuable for various optical instruments; its best known use was in the form of the Nicol prism to produce polarized light, prior to the use of Polaroid plates.

Chlorite: no significant use.

Copper, native: A minor ore of copper; copper sulfides are today the principal ores of the metal. The greatest use of copper is for electrical purposes, mostly as wire. It is also extensively used in alloys, such as brass (copper and zinc), bronze (copper and tin with some zinc), and German silver (copper, zinc, and nickel). These and many other minor uses make copper second only to iron as a metal essential to modern civilization.

Dolomite: As a building and ornamental stone. For the manufacture of certain cements. For the manufacture of magnesia used in the preparation of refractory linings of the converters in the basic steel process. Dolomite is a potential ore of metallic Mg.

Fluorite: Fluorite is used mainly as a flux in the making of steel, in the manufacture of opalescent glass, in enameling cooking utensils, for the preparation of hydrofluoric acid. Formerly used extensively as an ornamental material and for carving vases and dishes. Small amounts of fluorite are used for lenses and prisms of various optical systems, but most of the optical material is now made synthetically. Also used in toothpaste.

Galena: Practically the only source of lead and an important ore of silver. The largest use of lead is in storage batteries, but nearly as much is consumed in making metal products such as pipe, sheets, and shot. Lead is converted into the oxides (litharge, PbO, and minimum, Pb3O4) used in making glass and in giving a glaze to earthenware, and into white lead (the basic carbonate), the principal ingredient of many paints. However, the use in paints is now diminished because of the poisonous nature of lead-based paints. Diminishing also is its use in gasoline antiknock additives because of environmental restrictions. Lead is a principal metal of several alloys as solder (lead and tin), type metal (lead and antimony), and low-melting alloys (lead, bismuth, and tin. Lead is used as shielding around radioactive materials.

Garnet: Chiefly used as a rather inexpensive gemstone. A green andradite, known as demantoid, comes from the Ural Mountains, USSR, and yields fine gems known as Uralian emeralds. At Gore Mountain, New York, large crystals of almandite in an amphibolite are mined. The unusual angular fractures and high hardness of these garnets make them desirable for a variety of abrasive purpose including garnet 'sand' paper.

Graphite: Used in the manufacture of refractory crucibles for the steel, brass, and bronze industries. Flake graphite for crucibles comes mostly from Sri Lanka and the Malagasy Republic. Mixed with oil, graphite is used as a lubricant, and mixed with fine clay, it forms the 'lead' of pencils. It is employed in the manufacture of protective paint for structural steel and is used in foundry facings, batteries, electrodes, generator brushes, and in electrotyping.

Gypsum: Gypsum is used chiefly for the production of plaster of Paris. In the manufacture of this material, the gypsum is ground and then heated until about 75 % of the water has been driven off, producing the substance $CaSO_4 \cdot ½ H_2O$. This material when mixed with water, slowly absorbs the water, crystallizes, and thus hardens or "sets." Plaster of Paris is used extensively for "staff," the material from which temporary exposition buildings are built, for gypsum lath, wallboard, and for molds and casts of all kinds. Gypsum is employed in making adamant plaster for interior use. Serves as a soil conditioner "land plaster," for fertilizer. Uncalcined gypsum is used as a retarder in Portland cement. Satin spar and alabaster are cut and polished for various ornamental purposes but are restricted in their uses because of their softness.

Halite: Halite finds its greatest use in the chemical industry, where it is the source of sodium and chlorine for the manufacture of hydrochloric acid and a large number of sodium compounds.

Salt is used extensively in the natural state in tanning hides, in fertilizers, in stock feeds, in salting icy highways, and as a weed killer. In addition to its familiar fuctions in the home, salt enters into the preparation of foods of many kinds, such as the preservation of butter, cheese, fish, and meat.

Hematite: Most important ore of iron for steel manufacture. Also used in pigments, red ocher, and as polishing powder.

Hornblende (Amphibole Group): no significant use.

Kaolinite (clay): Clay is one of the most important of the natural industrial substances. It is available in every country of the world and is commercially produced in nearly every state in the United States. Many and varied products are made from it, including common brick, paving brick, drain tile, and sewer pipe. The commercial users of clay recognize many different kinds having slightly different properties, each of which is best suited for a particular purpose. High-grade clay, which is known as china clay or kaolin, has many uses in addition to the manufacture of china and pottery. Its largest use is as a filler in paper, but it is also used in the rubber industry and in the manufacture of refractories.

The chief value of clay for ceramic products lies in the fact that when wet it can be easily molded into any desired shape, and when it is heated, part of the combined water is driven off, producing a hard, durable substance.

Limonite (goethite): An ore of iron.

Magnetite: An important ore of iron.

Malachite: An ore of copper. Has been used to some extent, particularly in Russia, as an ornamental material for vases, veneer for table topes, etc. Semi-precious gemstone for lapidary.

Microcline (K-feldspar group): Feldspar is used chiefly in the manufacture of porcelain. It is ground very fine and mixed with kaolin or clay, and quartz. When heated to high temperature, the feldspar fuses and acts as a cement to bind the material together. Fused feldspar also furnishes the major part of the glaze on porcelain ware. A small amount of feldspar is used in the manufacture of glass to contribute alumina to the batch. Amazonestone is polished and used as an ornamental material.

Muscovite (mica group): Because of its high di-electric and heat-resisting properties, sheet mica, single cleavage plates, is used as an insulating material in the manufacture of electrical apparatus. The isinglass used in furnace and stove doors is sheet mica. Many small parts used for electrical insulation are built up of thin sheets of mica cemented together. They may thus be pressed into shape before the cement hardens. India is the largest supplier of mica used in this way. Ground mic is used in many ways: in the manufacture of wallpapers to give them a shiny luster; as a lubricant when mixed with oils; a filler; and as a fireproofing material.

Olivine: As the clear green variety, peridot, it has some use as a gem. Olivine is mined as refractory sand for the casting industry.

Opal: Used as a gem. Opal is usually cut in round shapes, en cabochon. Stones of large size and exceptional quality are very highly prized. Diatomite is used extensively as an abrasive, filler, filtration powder, and in insulation products.

Orthoclase (K-feldspar group): see microcline.

Plagioclase (Na-Ca feldspar group): Plagioclase feldspars are less widely used than potash feldspars. Albite, or soda spar, as it is called commercially, is used in ceramics in a manner similar to microcline. Labradorite that shows a play of colors is polished and used as an ornamental stone. Those varieties that show opalescence are cut and sold under the name of moonstone.

Pyrite: Pyrite is often mined for the gold or copper associated with it. Because of the large amount of sulfur present in the mineral, it is used as an iron ore only in those countries where oxide ores are not available. It's chief use is a source of sulfur for sulfuric acid and copperas (ferrous sulfate). Copperas is used in dyeing, in the manufacture of inks, as a preservative of wood, and as a disinfectant.

Pyroxene: Transparent varieties of diopside have been cut and used as gemstones.

Quartz and microcrystalline varieties of quartz: Quartz has many and varied uses. It is widely used as gemstones or ornamental material, as amethyst, rose quartz, cairngorm, tiger eye, aventurine, carnelian, agate, and onyx. As sand, quartz is used in mortar, in concrete, as a flux, as an abrasive, and in the manufacture of glass and silica brick. In powdered form it is used in porcelain, paints, sandpaper, scouring soaps, and as a wood filler. In the form of quartzite and sandstone, it is used as a building stone and for paving purposes.

Quartz has many uses in scientific equipment. Because of its transparency in both the infrared and ultraviolet portions of the spectrum, quartz is made into lenses and prisms for optical instruments. The optical activity of quartz (the ability to rotate the plane of polarization of light) is utilized in the manufacture of an instrument to produce monochromatic light of differing wavelengths. Quartz wedges, cut from transparent crystals, are used as an accessory to the polarizing microscope. Because of its piezoelectric property, quartz has specialized uses. It is cut into small oriented plates and used as radio oscillators to permit both transmission and reception on a fixed frequency. The tiny quartz plate used in digital quartz watches serves the same function as quartz oscillators used to control radio frequencies. This property also renders it useful in the measurement of instantaneous high pressures such as result from firing a gun or atomic explosion.

Sphalerite: The most important ore of zinc. The chief uses for metallic zinc, or spelter, are in galvanizing iron; making brass, an alloy of copper and zinc; in electric batteries; and as sheet zinc. Zinc oxide, or zinc white, is used extensively for making paint. Zinc chloride is used as a preservative for wood. Zinc sulfate is used in dyeing and in medicine. Sphalerite also serves as the most important source of cadmium, indium, gallium, and germanium.

Sulfur: Sulfur is used in the chemical industry chiefly in the manufacture of sulfuric acid. It is also used in fertilizers, insecticides, explosives, coal-tar products, rubber, and in the preparation of wood pulp for paper manufacture.

Talc: As slabs of the rock soapstone, talc is used for laboratory table tops and electric switchboards. Most of the talc and soapstone produced is used in powdered form as an ingredient in paint, ceramics, rubber, insecticides, roofing, paper, and foundry facings. The most familiar use is in talcum powder.