

# Minerals

Rocks are made of minerals.

Minerals are made of chemical compounds.

Compounds are made of elements.

## Basic Building Blocks

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.

## Definition of 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<sub>2</sub>, 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).

## 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, cast iron.

**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. This generally looks like stairsteps.

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:

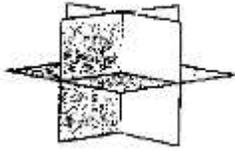
**Basal or layers: One direction of cleavage.** The mineral breaks into layers or breaks so the flat surfaces are parallel to only one direction, such as the top and bottom parallel. An example of basal cleavage is mica.



layered or 1 direction of cleavage



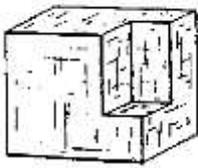
**Two directions:** Two directions of cleavage. The mineral breaks into flat surfaces parallel to two directions, such as one that is parallel to the top and bottom and a second that is parallel to the front and back, while the other directions such as the sides are irregular surfaces. A mineral with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



3 directions of cleavage (cubic)

**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).



cubic cleavage



**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.



rhombohedral cleavage



**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.

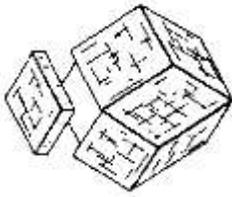


octahedral cleavage



**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.



more than 4 directions of cleavage

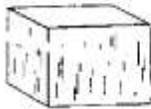
**Fracture or no cleavage:** The mineral breaks in an irregular, uneven manner. Types of fracture include fibrous, uneven, irregular, hackly, or conchoidal. Conchoidal fracture is breaking in curving planes like a conch shell or like glass or obsidian.



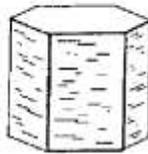
conchoidal fracture



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



prismatic



hexagonal



crystals

### 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.

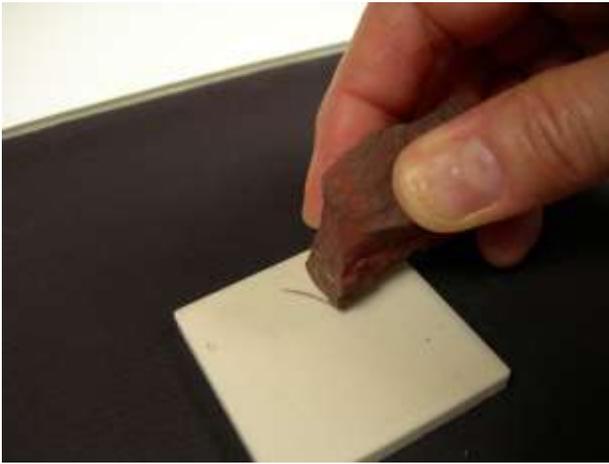
## The Mohs Hardness

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 <sub>2</sub>	Molybdenite
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 <sub>2</sub>	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 <sub>2</sub> S	Chalcocite
Metallic No cleavage	3	Bronze on fresh surfaces St=gray black	Purple iridescent tarnish	Cu <sub>5</sub> FeS <sub>4</sub>	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 <sub>2</sub> O	Cuprite
Metallic No cleavage	3.5-4	Brassy yellow color St=greenish black	Brassy color, greenish streak Bronze or iridescent tarnish	CuFeS <sub>2</sub>	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 <sub>2</sub> O <sub>3</sub>	Hematite
Metallic No cleavage	6	Black St=black	Black color Magnetic - sticks to magnet	Fe <sub>3</sub> O <sub>4</sub>	Magnetite
Metallic	6.5	Brown to black St=black	Prismatic crystals and massive, botryoidal or concretionary masses	SnO <sub>2</sub>	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 <sub>2</sub>	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	$Mg_3(Si_4O_{10})(OH)_2$	Talc
Nonmetallic good cleav.	2	Clear to white St=white	Good layered cleavage Selenite=clear layers Alabaster = white grainy, massive Satin Spar = fibrous	$CaSO_4 \cdot 2H_2O$	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° and 120°	$Ca_2Na(Mg,Fe)_4(Al,Fe,Ti)_3Si_8O_{22}(O,OH)_2$	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°	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	Augite (a type of pyroxene)

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
Nonmetallic Good cleav.	6	White, some greenish	Columnar or fibrous aggregates	$\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$	Tremolite
Nonmetallic good cleav.	6-6.5	White, pink, or blue green	Good cleavage in 2 directions at $90^\circ$	$\text{KAlSi}_3\text{O}_8$	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 $90^\circ$ Striations (fine parallel grooves) on some cleavage faces	$\text{NaAlSi}_3\text{O}_8$ to $\text{CaAl}_2\text{Si}_2\text{O}_8$	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	$\text{SnO}_2$	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	$\text{Ca}_2(\text{Al,Fe})_3\text{Si}_5\text{O}_{12}(\text{OH})$	Epidote
Nonmetallic good cleav.	9	Brown, pink(=ruby), blue (=sapphire)	Hexagonal crystals Heavy nonmetallic Poor basal cleavage	$\text{Al}_2\text{O}_3$	Corundum
Nonmetallic no cleavage	1.5	Yellow brown to brown St=yellow brown	Earthy luster Yellow brown streak	$\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$	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	$\text{Al}_4(\text{Si}_4\text{O}_{10})(\text{OH})_8$	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	$\text{Fe}_2\text{O}_3$	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	$\text{Cu}_2\text{CO}_3(\text{OH})_2$	Malachite
Nonmetallic no cleavage	3.5-4	Bright blue	Luster earthy to glassy Complex radiating crystals Powder fizzes in dilute HCl	$\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$	Azurite
Nonmetallic no cleavage	2-4	Bluish green	Luster earthy to glassy Cryptocrystalline to massively compact Conchoidal fracture	$\text{CuSiO}_2 \cdot n\text{H}_2\text{O}$	Chrysocolla
Nonmetallic no cleavage	2 - 5	Green to yellowish green St=white	Luster = greasy, silky or waxy Asbestos is fibrous form	$\text{Mg}_6(\text{Si}_4\text{O}_{10})(\text{OH})_8$	Serpentine
Nonmetallic no cleavage	6	Blue, bluish green, green	Luster = waxlike Cryptocrystalline	$\text{CuAl}_6(\text{PO}_4)_4(\text{OH})_8 \cdot 2\text{H}_2\text{O}$	Turquoise
Nonmetallic	6-7	Yellow green to	Poor basal cleavage	$\text{Ca}_2(\text{Al,Fe})_3$	Epidote

Luster Cleavage	Hardness	Color Streak St=	Diagnostic Features	Formula	Name
good cleav.; massive var. no cleavage		blackish green St=none (too hard)	Yellowish green color Very hard If granular, no apparent cleavage	Si <sub>3</sub> O <sub>12</sub> (OH)	
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) <sub>2</sub> SiO <sub>4</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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 <sub>2</sub>	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 <sub>4</sub> ) <sub>3</sub>	Garnet
Nonmetallic Basal cleavage	8	Colorless or white, others if tinted by impurities  St=white	Prismatic crystals terminated by pyramids, flat base	Al <sub>2</sub> SiO <sub>4</sub> (OH),F <sub>2</sub>	Topaz