

Physical Properties of Minerals

Hardness

This is an indirect measure of the bond strength in the mineral. It is exhibited in the form of resistance to abrasion on a relatively smooth, fresh surface. Friedrich Mohs (1773-1839) developed a relative hardness scale for minerals we still use today.

Mohs hardness scale

			Hardness of some common items:	
10	Diamond	C		
9	Corundum	Al ₂ O ₃	7	File
8	Topaz	Al ₂ SiO ₄ (F,OH) ₂	6	Glass
7	Quartz	SiO ₂	5+	Knife
6	Orthoclase	KA1Si ₃ O ₈	3	Copper Penny
5	Apatite	Ca ₅ (PO ₄) ₃ F	2+	Finger nail
4	Fluorite	CaF ₂		
3	Calcite	CaCO ₃		
2	Gypsum	CaSO ₄ •2H ₂ O		
1	Talc	Mg ₃ Si ₄ O ₁₀ (OH) ₂		

Scale doubles for each succeeding mineral in terms of hardness. Because of different bond strengths in different mineral directions, the hardness varies depending upon the direction you try to scratch the mineral, but usually the difference is so slight that it cannot be detected without sophisticated techniques.

Be careful that you do not measure crushing instead of scratching (chalk marks will wipe off). First, try scratching one mineral against another, then reverse the process. If both substances have about the same hardness, they may slightly scratch each other (or no mark appears).

Cleavage

Cleavage is the ability of a mineral to split repeatedly along a given planar direction, producing smooth surfaces. These planar fractures are an expression of the orderly alignment of atoms along planes within the mineral structure. Between these planes the bonds are weaker than in other directions.

The cleavages can be described as excellent, good, or poor, depending upon the quality of the surface produced. More than one direction of cleavage may be characteristic of a mineral, and it becomes important to note the number of cleavages (directions), and the angles between the planar fractures.

Fracture

Where no planar fracture (cleavage) results, the type of fracture which does occur may still be diagnostic of the mineral, and reflect the way in which the bonds are established. Some descriptive terms which can be applied are:

conchoidal (after conch, a large marine mollusk, typical of glass)
fibrous or splintery (elongated thin segments)
hackly (jagged fractures producing sharp edges)
uneven or irregular (produce rough and uneven surfaces)
earthy (crumbles like dirt)

Crystal Form

Crystal: regular polyhedral form, bounded by planer surfaces, which is the outward expression of a periodic or regularly repeating internal arrangement of atoms.

We classify crystals into six different systems based on symmetry. To do this without the aid of an optical microscope or x-rays, the mineral must have grown with crystal faces present. The planar surfaces resulting from crystal growth may be distinguished with care from cleavage surfaces by the presence of impurities, growth striations, or tarnish (lack of fresh look) upon the growth surface. Since crystal faces are a reflection of an orderly internal atomic arrangement, there is a possibility that the planes they represent are also planes of weakness and cleavage. However, it may also be that the bonds across such planes are strong, in which case breaking the mineral would not produce parallel surfaces to the crystal face. In lab, do not break any mineral which you think might be a crystal without asking first, as good crystals are sometimes very difficult to come by.

Color

As a diagnostic property, the color of a mineral must be used with care, because small amounts of impurities within the mineral structure have a marked effect upon the color. The color in part therefore, gives us a clue to the composition of the mineral. It is determined in part by the elements in the mineral and the quantum state of the electron cloud about the atoms, hence the type of bonds which exist. Consequently, we often find that minerals which contain major amounts of metallic atoms have a metallic look to them. The type of incident light also plays a part in the color the mineral appears to be. In the lab it may look somewhat different from the color you would perceive if you looked at the specimen in direct sunlight.

The intensity of the color is a function of the amount of light reflected back to your eye. Since small grains have more surface area for a given volume, they tend to absorb more of the light falling on the surface, and give the appearance of being darker in color.

Keeping in mind that color reflects the ability of the specimen to absorb, reflect, and transmit various wavelengths or light, we may categorize color as follows:

Natural or inherent color - A product of the major element chemistry. However, many minerals are solid solutions between two end-member compositions. For example, olivine ($(\text{Mg,Fe})_2\text{SiO}_4$) is a solid solution between forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Forsterite (Mg-rich olivine) is typically a yellowish olive green, whereas fayalite (Fe-rich olivine) is a darker brownish green. That is, Fe substitution in olivine makes it darker in color. This is true of most (all?) minerals that exhibit $\text{Mg} \leftrightarrow \text{Fe}$ substitution.

Exotic color - caused by trace elements.

Emerald (beryl, $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) trace amounts of Cr

Ruby (corundum, Al_2O_3) trace amounts of Cr

Sapphire (corundum, Al_2O_3) trace amounts of Ti

Streak

Streak is the color of the powdered mineral when rubbed on a hard porcelain plate. The finely powdered mineral tends to absorb more light, and at the same time because of the smaller amount of impurity substances, the effect of exotic colors is diminished.

Most useful with metallic minerals, especially oxides and sulfides.

Luster (Reflection of light from the surface.)

adamantine:	brilliant, e.g. diamond
vitreous:	glassy
resinous:	appearance similar to resins or saps of certain trees or shrubs
greasy:	like oil on glass
pearly:	pearl
silky:	like silk, usually fibrous textures
earthy:	like dirt
metallic:	like metals, polished

Specific gravity

Ratio of the mass of a body to the mass of an equal volume of water at a specified temperature (generally 4°C , greatest density of water)

$$\begin{aligned}\text{Sp. Gr.} &= \frac{\text{wt. of body}}{\text{wt. of equal vol. water}} \\ &= \frac{\text{wt. In air}}{\text{wt. In air} - \text{wt. In water}}\end{aligned}$$

Feel

cold:	good conductors of heat, generally contain metals
greasy:	talc

rough
smooth
adhere to tongue (clay minerals)

Magnetic susceptibility

Diamagnetic minerals- minerals not attracted by a magnet.

Paramagnetic minerals - minerals attracted by a magnet.

Magnetite (Fe₃O₄) – strongly magnetic.

Ilmenite (FeTiO₃) – can be weakly magnetic.

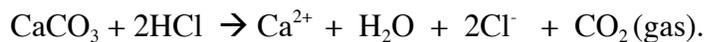
Taste

This technique can only be applied to those minerals which are soluble. Care must be taken in nature, for some minerals contain arsenic, lead, and other toxic elements.

Acid or sour:	sulfuric acid, indicates the presence of sulfur
Alkaline:	potash
Astringent:	(puckering) alum
Bitter:	epsom or bitter salts
Cooling:	saltpeter (NaNO ₃)
Metallic:	decomposed FeS ₂ , brassy taste
Saline:	salty, NaCl, etc.

Chemical

Certain minerals will effervesce (bubble) when dilute hydrochloric acid is applied to the surface. This is characteristic of those minerals containing the carbonate anion



The amount of effervescence depends upon how soluble the mineral is (calcite vs. dolomite) and the amount of surface area available for the reaction to take place (powdering of dolomite).

Twinning

In some minerals, the atomic lattice can become “kinked” in a symmetric fashion about a plane of symmetry. This can occur repeatedly through out the crystal (e.g. polysynthetic twinning in plagioclase) or only once (e.g. Carlsbad twinning in orthoclase). In hand sample, twins will appear as clean straight lines or striations.

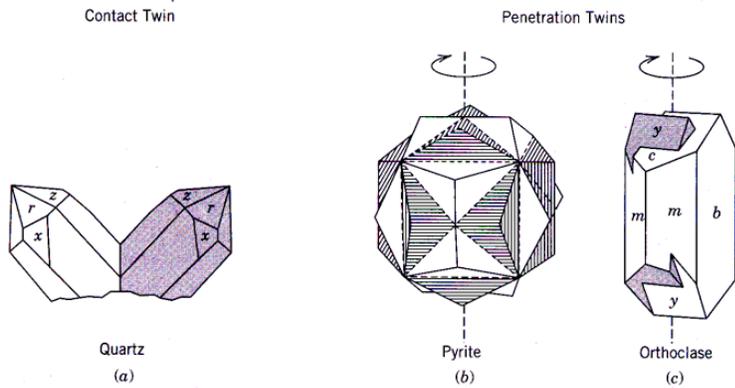


FIG. 2.6. (a) Two quartz crystals twinned across a mirror plane. This is referred to as a contact twin because there is a definite surface separating the two individuals. (b) and (c) are examples of penetration twins in which the individuals are joined along an irregular surface and the twin axis is parallel to the vertical axis. (b) Pyrite crystals in which the two individuals are related by 90° rotation about the vertical axis. (c) Orthoclase crystals that are related by 180° rotation about the vertical axis.

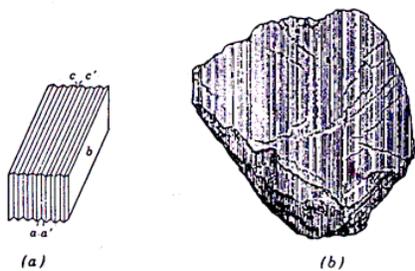


FIG. 2.7. Polysynthetic twinning and striations. (a) Albite polysynthetically twinned parallel to the vertical plane marked *b*; this plane is identified by the Miller index (010). (b) The appearance of albite twinning as striations or as parallel groovings across a cleavage surface or crystal face.

(Figures, above, from Klein, *Mineral Science*, 2002.)

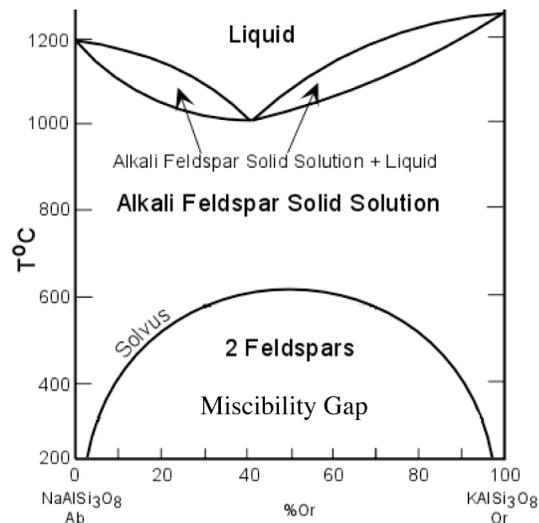
Exsolution lamellae

Some minerals exhibit diffuse, irregular striations on certain crystal faces or cleavage planes. These are typically formed from exsolution in the mineral during slow cooling, a process similar to the separation of oil and vinegar. Exsolution occurs in minerals that exhibit solid solution at high temperatures, but at lower temperatures, one of the end-member minerals separates from the other forming small, irregular blebs usually controlled by the crystallographic directions of the host.

Perthite: a mixture of albite (white) and orthoclase (pink).



(Photo: http://minerals.gps.caltech.edu/Brazil/icapui_to_mines/Mines)



(Figure modified from <http://www.tulane.edu/~sanelson/geol212/2compphasdiag.html>)

Acknowledgement of Credit:

This material is from the site of Cameron Davidson, Department of Geology, Carleton College, Northfield, Minnesota.