University of Anbar
Collage of Science
Department of Geology
Minerals / 1st stage.

Mineral Properties

Assistant lecturer
Nazar Zaidan Khalaf

What is a Mineral?

A mineral:

- is a naturally occurring inorganic crystalline solid
- has an ordered internal arrangement of atoms
- has specific physical properties that are either fixed or that vary within some defined range.
- has a definite chemical composition that may vary within specific limits

Quartz Amethyst

Chemical Composition and Internal Structure of Minerals

- Elements are the building blocks of minerals.
- Some minerals exist as single elements; however, most minerals consist of a combination of several elements joined by a chemical bond to form a stable mineral compound.
- Elements chemically bond to one another when their atoms gain, lose, or share electrons with other elements.
- Ionic bonds occur when valence electrons are transferred from one atom to another, constituting a respective gain or lose between one or the other atom.
- Covalent bonds occur when atoms from different elements share their valence electrons with one another to form a chemically stable bond.
- In addition to ionic and covalent bonds, other bonds can also occur through various combinations of transferred and shared electrons.
- Of the 112 elements, only 92 are naturally occurring.
- Nearly 4,000 minerals are identified on the planet Earth, and new minerals continue to be discovered all the time.

How Do Minerals Grow?

- New minerals are forming everyday on the Earth's surface, in the Earth's crust, and deep within the Earth's interior.
- Minerals form from molten rock and volcanic magma within the Earth's interior and crust. In these environments, changes in temperature and pressure and chemical composition influence the type of minerals which form, the size of their individual crystals, and their growth rate.
- Minerals grow from saturated solutions in rock cavities. Differences in temperature, chemical composition, and the saturation content of the solution influence the type of minerals which form, the size of their individual crystals, and their growth rate.
- The arrangement of atoms during crystal formation determines what the mineral will be and what crystal shape it will have.
- The crystal form is one of several characteristics that Geologists use to identify different minerals.

Mineral Properties

Minerals have distinctive physical properties that geologists use to identify and describe them.

There are 7 major physical properties of minerals:

- 1. Crystal Form
- 2. Hardness
- 3. Luster
- 4. Color
- 5. Streak
- 6. Cleavage
- 7. Specific Gravity

A variety of different minerals.

Standard 3-3.1
Standard 3-3.2

Crystal Form

- Crystal form is the external expression of the internally ordered arrangement of atoms.
- During mineral formation, individual crystals develop well-formed crystal faces that are specific to that mineral.
- The crystal faces for a particular mineral are characterized by a symmetrical relationship to one another that is manifest in the physical shape of the mineral's crystalline form.
- Crystal forms are commonly classified using six different crystal systems, under which all minerals are grouped.

The six major crystal forms:

1. Isometric (Cubic)
2. Tetragonal
3. Orthorhombic
4. Hexagonal
5. Monoclinic
6. Triclinic

Axes and Angles

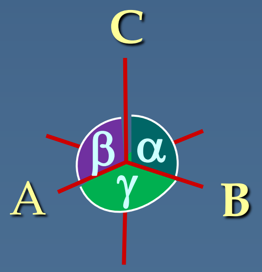
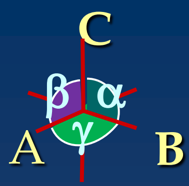


Table of Contents

Standard 3-3.1
Standard 3-3.2

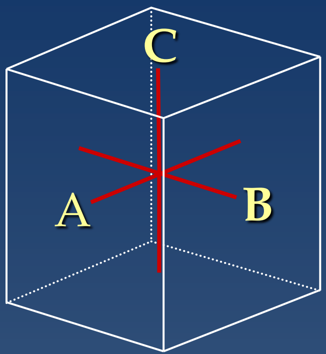


Crystal Form, cont.

❖ Isometric:

Isometric crystals are block shaped with relatively similar and symmetrical faces. The crystal form has three axes all at 90° angles and all the same length.
Mineral Example: Pyrite

Axes Length Relationships: A = B = C
Angles: α = β = γ = 90°

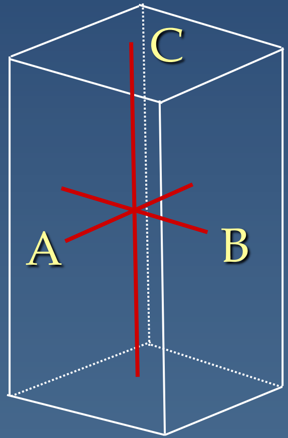


Isometric: Pyrite

❖ Tetragonal:

Tetragonal crystals are shaped like four-sided pyramids or prisms. The crystal form has three axes that are all perpendicular to one another. Two axis have the same length, and one is different. The axes that are the same length lie on a horizontal plane, with the third axis at a right angle to the other two.
Mineral Example: Zircon

Axes Length Relationships: A = B ≠ C
Angles: α = β = γ = 90°

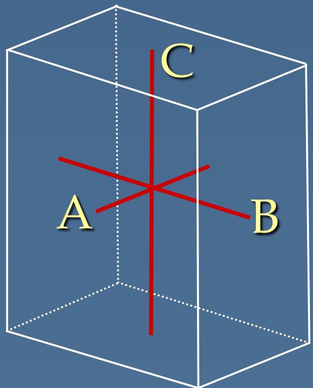


Tetragonal: Zircon

❖ Orthorhombic:

Orthorhombic crystals are shaped like a rectangular prism with a rectangular base. The crystal has three axes of different lengths and intersect at 90° angles.
Mineral Example: Topaz

Axes Length Relationships: A ≠ B ≠ C
Angles: α = β = γ = 90°

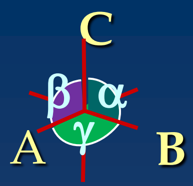


Orthorhombic: Topaz

Photo Courtesy USGS

Table of Contents

Standard 3-3.1
Standard 3-3.2



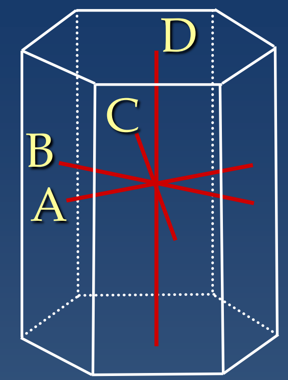
Crystal Form, cont.

❖Hexagonal:

Hexagonal crystals have three symmetrical axes that occur in the same plane and are all the same length. The fourth axis may be either longer or shorter, and it intersects the other three axis at 90° angles. The sides intersect at 120 ° angles.
Mineral Example: Amethyst

Axes length Relationships: A = B = C ≠ D

Angles: α = β = 90° and γ = 120°



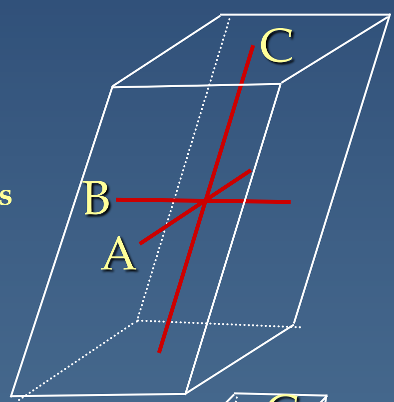
Hexagonal: Amethyst

❖Monoclinic:

Monoclinic crystals are short and stubby with tilted faces. Each crystal has three axes that are unequal. Two of the axes lie in the same plane at right angles to each other, the third axis is inclined. Mineral Example: Gypsum

Axes Length Relationships: A ≠ B ≠ C

Angles: α ≠ γ = β = 90°



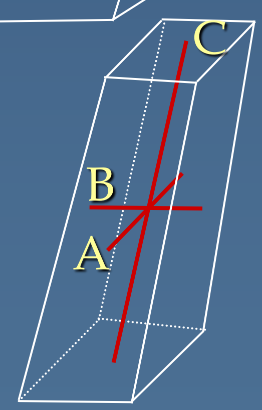
Monoclinic: Gypsum

❖Triclinic:

Triclinic crystals have three axis which are all different lengths and all three axis intersect at angles other than 90°.
Mineral Example: Kyanite

Axes Length Relationships: A ≠ B ≠ C

Angles: α ≠ β ≠ γ



Triclinic: Kyanite

Table of Contents

Standard 3-3.1
Standard 3-3.2
Standard 3-3.14
Standard 3-3.17

Hardness

- Hardness is the ability of a mineral to resist abrasion or scratching on its surface.
- One way geologists measure hardness is using a relative scale referred to as Moh's scale of mineral hardness which ranks 10 common minerals along a scale from 1-10 (1 refers to the softest minerals while 10 refers to the hardest mineral).
- Geologists measure a mineral's hardness by scratching the surface of a mineral using minerals of known hardness, or by scratching the surface using a variety of other hardness indicators such as fingernails, pennies, or glass.

Talc

Talc is a soft mineral that you can scratch with your fingernail, and has a hardness of "1" measured by Moh's relative scale of mineral hardness.

Moh's Scale of Mineral Hardness

Hardness of Common Minerals:

Softest
- 1-Talc
- 2-Gypsum
- 3-Calcite
- 4-Fluorite
- 5-Apatite
- 6-Orthoclase
- 7-Quartz
- 8-Topaz
- 9-Corundum
- 10-Diamond

Hardest

Common Scratching Tools:

....your fingernail has a hardness of 2.5

....a penny has a hardness of about 3.5

....glass and a steel nail have nearly equal hardness of 5.5

....a streak plate has a hardness of 6.5

Standard 3-3.1
Standard 3-3.2
Standard 4-1.3
Standard 4-1.4
Standard 4-1.6

Measuring a Mineral's Hardness

Standard 5-1.1
Standard 5-1.2
Standard 5-1.3
Standard 5-1.6
Standard 5-1.8

Students can conduct the following experiment to measure a mineral's hardness:

- Hold the specimen firmly and attempt to scratch it with the point of an object of known hardness. In this example, we use a nail (H=5.5).
- Select a fresh, clean surface on the specimen to be tested.
- Press the point of the nail firmly against the surface of the unidentified specimen.
- If the "tool" (in this case the nail) is harder, you should feel it scratching into the surface of the specimen.
- Look for an etched line. It is a good idea to rub the observed line with your finger to ensure that it is actually etched into the surface of the specimen.
- Because the specimen was scratched by the nail, we know its hardness is less than that of the nail-less than (H<5.5).
- If there is any question about the result of the test, repeat it, being sure to use a sharp point and a fresh surface.

Standard 3-3.1
Standard 3-3.2
Standard 4-1.3
Standard 4-1.4
Standard 4-1.6

Approximating Hardness

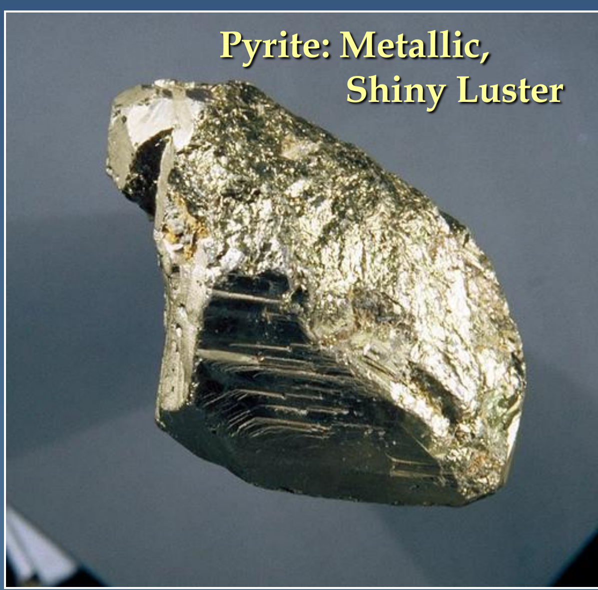
Standard 5-1.1
Standard 5-1.2
Standard 5-1.3
Standard 5-1.6
Standard 5-1.8

- Take the unknown mineral and attempt to scratch with your fingernail (H=2.5), copper penny (H=3.5), a glass plate (H=5.5), and a streak plate (H=6.5).
- If the mineral scratches any of the materials, then it is harder than that material.
- If it scratches your fingernail and not the penny, than the hardness is between 2.5 and 3.5, probably 3.0.
- By this process, we can determine the approximate hardness of the unknown mineral.
- We do not need to know the exact hardness of the mineral because we will use other physical properties to refine the identification.

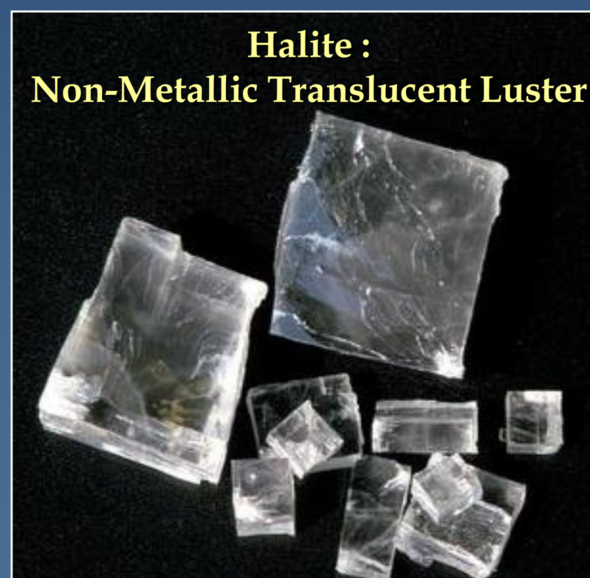
Standard 3-3.1
Standard 3-3.2

Luster

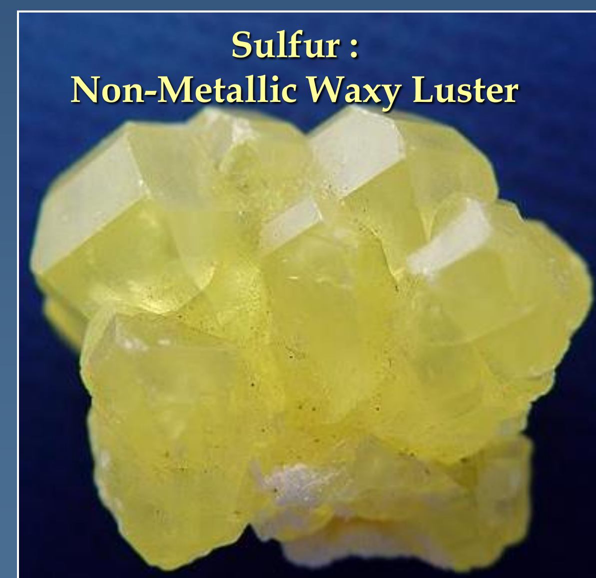
- Luster refers to how light is reflected from the surface of a mineral.
- There are two main types of luster: metallic and non-metallic:
  - Minerals with a metallic luster are described as shiny, silvery, or having a metal-like reflectance.
  - Non-metallic minerals may be described as resinous, translucent, pearly, waxy, greasy, silky, vitreous/glassy, dull, or earthy
- Luster may be subjective, and thus is not always a reliable identifier



Pyrite: Metallic, Shiny Luster



Halite : Non-Metallic Translucent Luster



Sulfur : Non-Metallic Waxy Luster

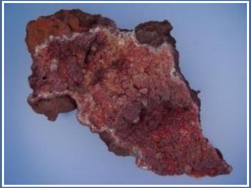
Standard 3-3.1
Standard 3-3.2

Color

- Mineral color is determined by how the crystals absorb and reflect light. Although color is easy to recognize, it is often misleading.
- Minerals, such as quartz, fluorite, halite, and calcite occur in a wide variety of colors, and other minerals, such as olivine, malachite, and amphibole have fairly distinctive colors.
- Variations in a mineral's color may be the result of impurities in the atomic structure of the crystal or the presence of a particular chemical when the crystal formed.
- Because some minerals can occur in several colors, color is generally not a good characteristic for describing and identifying minerals.

Different Colors of Calcite

Image courtesy of the USGS



copyright@Stonetrust, Inc

Different Colors of Fluorite

copyright@Stonetrust, Inc

Image courtesy of the USGS

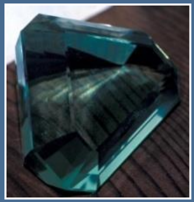


Image courtesy of the Albert Copley Oklahoma University Archives

Different Colors of Quartz

copyright@Stonetrust, Inc

Table of Contents

Standard 3-3.1
Standard 3-3.2

Streak

- Streak refers to the color of a mineral's powdered form left behind after it is scraped or rubbed across a porcelain streak plate.
- A mineral may appear one color and then produce a streak with a different color.
- A mineral's streak color is a more reliable identification characteristic than the minerals perceived surface color.

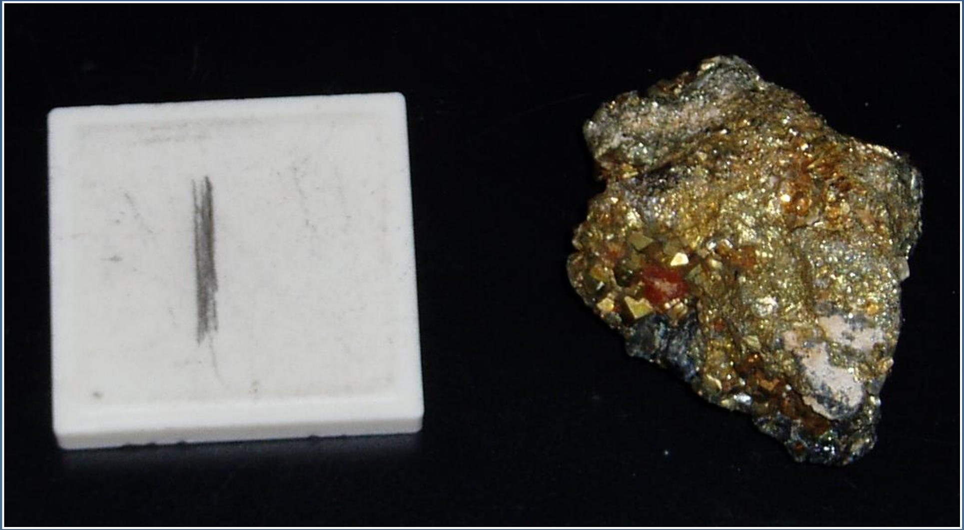


Photo: SCGS

Even though the mineral pyrite is gold in color, it leaves a grey "pencil lead" streak on the porcelain streak plate.

Table of Contents

Cleavage

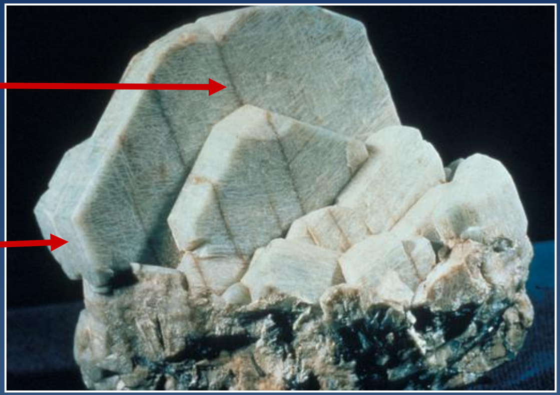
- Cleavage refers to the tendency of a mineral to break along planes of weakness in the chemical bonds, or along planes where bond strength is the least.
- Some minerals break along one dominant plane of cleavage producing parallel sheets, where as others may break along two or more planes of cleavage, producing blocks or prism shapes.
- Not all minerals have distinct planes of weakness that produce cleavage, but those minerals that do, will consistently produce predictable cleavage planes.

Standard 3-3.1
Standard 3-3.2

Cleavage

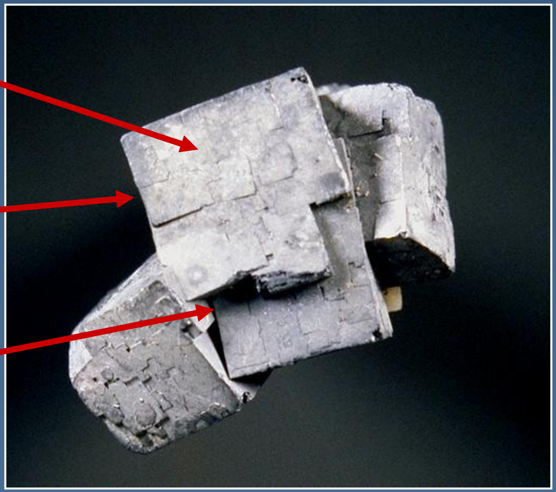
- One direction of cleavage (one plane)
  - Mineral Example: Micas (muscovite)
- Two directions of cleavage (two planes)
  - Mineral Example: Feldspar
- Three directions of cleavage (three planes)
  - Cubic : Mineral Example: Galena
  - Rhombohedral: Mineral Example: Calcite
- Four directions of cleavage (four planes)
  - Mineral Example: Flourite

Feldspar: Two Cleavage Planes



Courtesy United States Geological Survey

Galena: Three Cleavage Planes



Calcite: Three Cleavage Planes

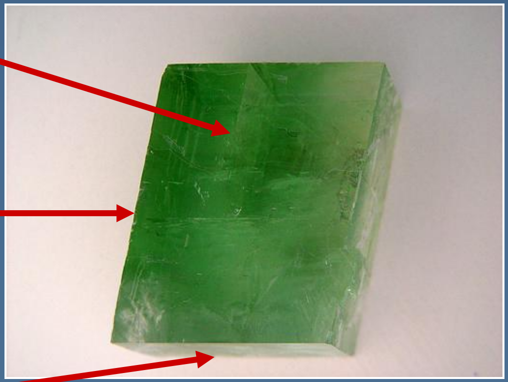


Table of Contents

Fracture

- Fracture refers to the non-planar breakage of minerals.
- Minerals that break along fractures (as oppose to cleavage planes) do not exhibit predictable weakness along specified bonds.
- Fractures may be described as splintery, uneven, or conchoidal.

Conchoidal Fractures on a Quartz Mineral

Specific Gravity

- Specific gravity refers to the weight or heaviness of a mineral, and it is expressed as the ratio of the mineral's weight to an equal volume of water.
- Water has a specific gravity of 1. Therefore, a mineral with a specific gravity of 1.5, is one and a half times heavier than water.
- Minerals with a specific gravity ≤ 2 are considered light, 2-4 are average, and >4.5 are heavy
- Specific gravity can be measured using complex lab tools such as the hydrostatic balance or more simple procedures involving beakers and water displacement measurements.

REFERENCES

- S. K. HALDAR &JOSIP TISLJAR 2013, INTRODUCTION TO MINERALOGY AND PETROLOGY - Elsevier 225 Wyman Street, Waltham, MA 02451, USA Publishers . 341 p.
- Blackburn, W.H. and Dennen, W.H., 1988, Principles of Mineralogy: Iowa, WCB Publishers . 413 p.
- ابراهيم مضوي بابكر. ٢٠٠٤. علم المعادن، جامعة النيلين، كتاب منشور. ٢٣٢ ص