PHYSICAL AND CHEMICAL PROPERTIES OF MINERALS IN HAND SPECIMEN

There are a number of physical properties which are suitable for field use on hand specimens. One chemical test also falls in this category. No test will work on every specimen. By combining the results of a number of tests which do produce good results, a "fingerprint" of the mineral may be obtained. By using the data gathered from these tests it is often possible to identify a mineral. In other cases it will be possible to greatly narrow the range of possible minerals. While there are over 3000 known minerals, only about 200 are likely to be seen except in highly specialized locations. Even among the two hundred minerals only a small fraction are common, rock-forming minerals. This semester we will examine non-silicate minerals, which make up about half of all known minerals but only account for a small number of rock-forming minerals. The non-silicate minerals will be tested on the laboratory midterm. After the midterm, we will examine silicate minerals, which form the bulk of rock-forming minerals. These will be tested on the final examination.

PHYSICAL PROPERTIES

Hardness

One measure of hardness is the resistance a smooth surface offers to scratching. A simple scale of hardness was developed by Frederick Mohs. He numbered a series of common (except for diamond) minerals from one to ten, with one being the softest and ten the hardest. Any mineral with a higher number will scratch a lower numbered mineral, but the lower numbered minerals will not scratch the higher. The Moh's Scale is shown in Figure 1. Other methods of testing hardness are available, but these involve the use of sophisticated laboratory tests and are not suitable for field use.

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

Figure 1 **MOH'S SCALE OF HARDNESS**

Using one of the hardness kits, convince yourself that the higher numbered specimens will scratch the softer samples. Use a sharp edge and try to scratch a smooth surface of the mineral under consideration. Be sure to wipe away any dust that forms. Then look to see if a true scratch was formed. A hand lens is often useful in looking for scratches. If a mineral is weathered the apparent hardness may be well below what it should be. Try to use an unweathered surface. Soft minerals ($H < 3$) may be greatly affected by small amounts of impurity, sometimes giving hardness values considerably higher than listed in the tables.

Color and Streak Color

The color of many minerals can vary considerably in hand specimen. Color in minerals is affected by a number of factors, including impurities, which greatly change the color although present in very small quantities. Color should be noted and reported. In most cases, however, a much more reliable property is the streak color. The streak color is obtained by rubbing the sample across a streak plate and noting the color. The streak plate is a piece of unglazed porcelain with a hardness of about seven. Minerals softer than seven will be powdered and will leave a thin streak of powdered mineral on the plate. This powdered streak is much more consistent in color than the hand specimen color. It should be noted that the streak color may be white. Great care must be used to differentiate a white streak from a mineral leaving no streak (usually because the mineral has a hardness greater than or equal to seven). Many geologists consider white streaks to be “colorless”. Although this is not good practice, it is common. Minerals harder than seven will scratch the streak plate and may leave a "streak" of powdered white porcelain.

Using the streak color and luster kits, determine the streak color of minerals with metallic luster. Metallically bonded substances are opaque and the minerals usually produce a dark streak.

Luster

Luster is the appearance a mineral has when light strikes it and is reflected. It can be quantitatively related to the index of refraction. More often it is qualitatively described using a variety of terms, as shown in Figure 2.

Category	Example
Metallic	Galena, Copper
Submetallic	Chromite, Ilmenite (both may be metallic in some cases)
Non-metallic	Quartz, Calcite

Figure 2 **LUSTER CATEGORIES**

Most minerals belong to the non-metallic category. This category is further subdivided, with many of the subdivision terms being self-explanatory. Figure 3 lists some common terms.

A sheen is a type of luster, generally produced by internal reflecting surfaces. Pearly and silky lusters are actually sheens. Other examples are **Schiller luster** in Pyroxene and **Play of Colors** in feldspars (moonstone), both of which are due to a phenomenon known as exsolution. Exsolution produces regions of different minerals. Light may reflect off the mineral surfaces. **Opalescence** is another type of sheen, caused by minute water inclusions in silica. These minute water inclusions may give a cloudy appearance, or may act to split light into the colors of the rainbow, thus giving the opals their characteristic "fire".

TERM	EXAMPLE	DESCRIPTION
Vitreous	Quartz, Tourmaline	The luster of glass, and the most common non-metallic luster.
Resinous	Sphalerite, Sulfur	Reminiscent of a freshly broken rosin or shellac surface.
Pearly	Phlogopite, Talc	Generally results from internal reflections from within a crystal. In these minerals the reflections are off of partly developed cleavage faces.
Greasy (or Oily)	Halite, Nepheline	The surface appears to be coated with a fine layer of oil. This may be the result of a hydration layer on a mineral surface, or a microscopically rough surface.
Silky	Gypsum (Satin Spar), Tremolite	Luster produced by internal reflections from threadlike fibers within the mineral. Minerals with directional cleavage which results in a fiber-like habit often have this luster.
Adamantine	Cinnabar, Diamond	A hard, brilliant luster like that of a diamond. This occurs in minerals with a high index of refraction, which may result from the presence of a heavy metal ion (Hg in cinnabar).
Waxy	Chalcedony, Turquoise	Typical of crystals with minute granular surfaces. Minerals which are crypto-crystalline may be waxy.
Dull, Earthy	Clay minerals, Manganite	Often typical of weathered surfaces. Light is scattered and reflectance is typically low.

Figure 3 **NON-METALLIC LUSTER TERMS**

Weathering often changes the luster of a mineral, often making the luster dull. Metallic minerals may sometimes be reduced to submetallic, and often to dull, luster by weathering.

Lusters are subjective impressions but with practice most people can agree on a fairly standard terminology. Some words, such as "glimmering", are not good choices since they may refer to either non-metallic or metallic lusters. Examine the minerals in the kit for some examples of luster.

Diaphaneity

Diaphaneity refers to the light transmitting (as opposed to reflecting) ability of a mineral. Three common descriptive terms are used (see Figure 4). In practice this property is not ordinarily mentioned unless a mineral is not opaque. This convention saves space and time in describing minerals, but must be understood by the reader.

Category	Description
Transparent	Images may be clearly seen through the mineral.
Translucent	Light may be seen through the mineral but images will be blurred beyond recognition.
Opaque	No light may be seen through the mineral. In hand specimen most minerals belong to this category. Some opaque minerals may be transparent or translucent on a thin edge.

Figure 4 **Diaphaneity Categories**

Cleavage, Parting, and Fracture

These properties are related. One of more of these is present in all minerals, but any given mineral surface shows only one of these properties. Cleavage occurs when a mineral consistently breaks along the same planar surface. In describing cleavage its quality (see Figure 5) and crystallographic direction (if known) should be given. If more than one direction of cleavage is present in a mineral it is extremely important to measure or estimate the angle between the cleavage planes and use this in the description. For example the mineral augite might be described as having two directions of cleavage at right angles. In some cases the cleavage angle may be the most important property for identifying minerals in hand specimen. Cleavage is an inherent crystal property which should always be present. Cleavage is due to low bond strength and/or low bond density across a plane. Parting is similar to cleavage in that a break occurs along a particular planar surface. Unlike cleavage, parting is not an inherent property and may not be present in every specimen. Parting is often due to a defect (such as twinning or exsolution). Such defects are often invisible in hand specimen and the only clue to their presence is the presence of parting. Fracture is an irregular break which occurs when neither cleavage or parting is present on a surface. Fracture may be smooth, mimicking cleavage, but more often is uneven. Various types of fracture (see Figure 5) are recognized and some of these are diagnostic.

Quality of Cleavage		Description/Example
American	British	
Perfect	Eminent	Always present. Smooth, easy breakage along the cleavage plane. The breakage is so easy that it is hard not to cause breakage. Biotite and muscovite show perfect cleavage.
Good	Perfect	Easily broken along cleavage plane. The octahedral {111} cleavage in fluorite is an example.
Fair	Distinct	Breaks, but not as evenly or as easy as the previous category. Hypersthene (an orthopyroxene) shows fair prismatic cleavage on {110}.
Poor	Imperfect	Breaks only part way. The basal cleavage in apatite {0001} is an example.

Figure 5 **Cleavage Quality**

Cleavage always occurs on a crystal face or a possible crystal face. Cleavage may be described relative to the name or indices of a form which it parallels. Examples: Cubic cleavage is on {001}, octahedral on {111}, and rhombohedral on $\{10\bar{1}1\}$. If enough material is available (mainly in the field) you may repeatedly break a specimen to see if it consistently breaks in the same place. This would prove the existence of cleavage. A crystal face which was not a cleavage plane would fracture. Samples showing parting generally produce inconsistent results. In addition the spacing on parting planes is often irregular, whereas cleavage planes are more evenly spaced.

Fracture types are listed in Figure 6. Fracture is diagnostic in some cases. If enough material is available try to obtain fresh breaks. Weathering can dull hackly or jagged fracture, etc.

Fracture type	Description/Example
Conchoidal	Smooth, curved fracture resembling the interior surface of a shell. Often seen in broken glass. May be present in volcanic glass (obsidian), and sometimes in crystalline minerals such as quartz.
Fibrous, splintery	Generally present in minerals with prismatic cleavage and a tendency to form long, thin crystals. Certain amphibole minerals such as Tremolite and crocidolite are usually fibrous.
Hackly	Jagged fractures with very sharp edges, seen only in minerals with metallic bonding. True hackly fracture can easily cut fingers. Jagged fracture is a term that can be used for sharp, uneven surfaces in non-metallically bonded minerals.
Uneven, irregular	Fractures which produce rough, uneven surfaces.
Even	Smooth fracture which may mimic the lower quality cleavage planes. Will not be as repeatable as cleavage. Often used for rocks breaking smoothly along bedding planes, but this is a type of rock cleavage, not mineral cleavage.

Figure 6 **Fracture Types**

Magnetism

A few minerals, usually containing iron, will respond to a magnet. One mineral, magnetite, may itself be naturally magnetic. This variety of magnetite is known as lodestone. To test a specimen simply place a magnet next to the specimen. If the magnet is attracted to the magnet the specimen is magnetic. The only common minerals that are attracted to a small hand magnet are magnetite (Fe_3O_4) and pyrrhotite ($Fe_{1-x}S$). Rocks containing more than about 5% magnetite usually exhibit a noticeable pull on the magnet. While working in the field a geologist will often have a Brunton compass. The compass can be used to test for the presence of magnetic minerals. The compass should be placed on a level spot well away from any substances which contain iron (vehicles, rock outcrops, etc.) and the mineral to be tested waved near the compass. If the compass needle moves the sample contains magnetic material.

Specific Gravity

It is possible to estimate specific gravity within about 0.5 units by comparing the unknown mineral with similar sized samples of known specific gravity. It is essential that the unknown mineral be homogeneous, and that it not be vesicular. Rocks composed of several minerals have specific gravities which are an average of the minerals present. Generally this value is of limited use for identification purposes. Vesicular samples will appear to have a lower specific gravity than that of the mineral. There are more accurate ways of determining specific gravity, but these are limited to laboratory use.

Luminescence

Some minerals will exhibit luminescence when subjected to ultraviolet radiation. Usually this luminescence is not strong enough to be seen in room light. Therefore it is necessary to work in a darkened room or in a specially constructed dark box. There are two ranges of ultraviolet light. Long-wave ultraviolet light (LW UV) has a wavelength between 315-400 nm, and short-wave ultraviolet is between 200-315 nm. Most UV lamps are mercury vapor lamps. They have long-wave emission at 366 nm, and short-wave at 253.7 nm. **WARNING: SHORT-WAVE ULTRAVIOLET RADIATION CAN SERIOUSLY DAMAGE THE RETINA.** Eye damage or blindness can result from short exposures to short-wave UV. Do not look at a short-wave lamp directly, and do not hold the lamp in such a position that anyone else may accidently look at it.

Reaction to Acid

Many carbonate minerals will fizz or bubble when a drop of dilute (1 or 2 molar) HCl is placed on them. To make the test, place one drop on the specimen and observe the specimen for the formation of any gas bubbles. It is sometimes possible to hear the release of gas even if bubbles form too slowly to be seen. Note the degree of reaction, using words such as very fast, fast, moderate, slow, etc. Be sure to wash off the specimen after testing. Some carbonate minerals react to cold acid, others react only to hot acid, and still others react slowly at any temperature. Hot acid is potentially dangerous. Acid should be heated on a hot plate inside a working chemical hood and all tests using hot acid should be done inside the hood. Should any acid get in the eye, immediately flush the eye with water. The chemical reaction involved in this test is as follows, using calcite ($CaCO_3$) as an example.

$$CaCO_3 + 2\ HCl \Rightarrow CaCl_2 + CO_2\Uparrow + H_2O$$

The acid test can also be used as a measure of the minerals ability to absorb a fluid. Minerals which rapidly absorb the fluid, even though no reaction is seen, should be noted.

Radiation

Use the radiation meter to examine all specimens for signs of radioactivity. First, check the meter in open air to estimate what background radiation in the room is. Then, place the meter close to each sample, and note any samples which show signs of radiation levels clearly above background.

Instructions for Lab 1

For each of the specimens, perform each test and record the results on the answer sheet you are given. It is important to differentiate between a test that was not performed and a test that was performed with a negative result. The notation ND is often used to indicate no data, meaning that the test was not performed or, less commonly, that in the opinion of the researcher the results obtained were totally unreliable. Results which are questionable should be noted, e.g. H = 5 (?). Very doubtful results may be noted with a double question mark. The other properties column on the answer sheet is for tests for which no room is specifically provided, such as diaphaneity or magnetism. It is not necessary to note negative results for these tests, although you may if you wish. The notes column is for other observations such as the presence of a distinct mineral habit, obvious impurity, the presence of twinning, weathering, etc. Always note any feature which may aid in the identification of a mineral, or any feature which might make the usual identification tests unreliable. While tables such as the answer sheet are convenient for the answers to tests on minerals in a lab setting, a more abbreviated style is usually used by geologists when recording data in field books. While doing field work, even of a non-mineralogical nature, observations on the presence of obvious minerals should be noted. The presence of economic minerals or minerals which may weather to produce pollution (such as sulfides) should definitely be noted.

Not all of the tests will be easy, and some will produce ambiguous or faulty results. Part of the practice of science is to learn to recognize good and bad test results, and to put full weight on those results felt to be good, while discounting to various degrees results which appear flawed.

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