LECTURE 3.

3.0 PHYSICAL PROPERTIES OF MINERALS

3.1 INTRODUCTION

Welcome to lecture 3. In lecture 2 we looked at the elementary principles of crystallography and illustrated how the symmetry elements of the crystals are deduced. By definition we have shown that crystals are crystalline materials, and by extension are also minerals. In this lecture we shall introduce the elementary principles of Mineralogy. Minerals and consequently mineralogy- which is the science of minerals, is extremely important to economics, aesthetics, and science. Economically, utilization of minerals is necessary if we are to maintain anything like our current standard of living. Aesthetically, minerals shine as gems and enrich our lives, especially as we view them in the museum displays. Scientifically, minerals comprise the data bank from which we learn about our physical earth and its constituent materials. In addition, the basic principals in mineralogy are applied in other disciplines, such as agricultural sciences, the material sciences (ceramic engineering and metallurgy) and even medical science. In this lecture we shall study the major physical properties of minerals and show you how to identify mineral species using these properties.

OBJECTIVES

At the end of this lecture you should be able to:

a). Define a mineral

b). Demonstrate an understanding of the identifying characteristics of a mineral.

c). Recognize the characteristic physical properties such as cleavage, lustre, density and hardness, of common minerals.

d). Determine the physical properties of various mineral species.

3.2 MINERALS DEFINED

A mineral is a naturally occurring, inorganic, solid element or compound with a definite composition and a regular internal crystal structure. Naturally occurring, as distinguished from synthetic, means that minerals do not include the thousands of chemical substances invented by humans. That minerals must be solid means that the ice of a glacier is a mineral but liquid water is not. Chemically, minerals may consist either of one element – like diamond, which are pure carbon – or they may be compounds of two or more elements. Finally minerals are crystalline. Crystalline materials are solids in which the atoms are arranged in regular, repeating patterns.

3.3 IDENTIFYING CHARACTERISTICS OF MINERALS

The two fundamental characteristics of a mineral that together distinguish it from all other minerals are its **chemical composition** and its **crystal structure**. No two minerals are identical in both respects, though they may be the same on one respect. For example, **diamond** and **graphite** (the "lead" in a lead pencil) are chemically the same: Both are made up of pure carbon. Their physical properties, however, are vastly different because of the differences in their internal structures (see Figure 3.1). In diamond, each carbon atom is firmly bonded to every adjacent carbon atom in every direction. In graphite, the carbon atoms are bonded strongly in two dimensions into sheets, but the sheets are only weakly held together in the third dimension. Diamond is clear, transparent, colorless, and very hard, and a jeweler can cut it into beautiful precious gemstones. Graphite is black, opaque, and soft, and its sheets of carbon atoms tend to slide apart as the weak bonds between them are broken.

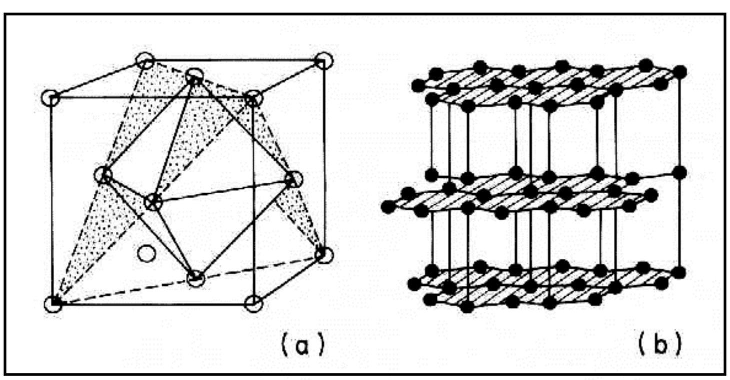


Figure 3.1. The atomic structure of diamond (a) and graphite (b).

A mineral's composition and crystal structure can usually be determined only by using sophisticated laboratory equipment. No one can look at a mineral and know its chemical composition without first recognizing what mineral it is. Thus, when scientific instruments are not at hand, mineral identification must be based on a variety of other physical properties that in some way reflect the minerals composition and structure. These other properties are often what make the mineral commercially valuable. Discussions of these other properties are discussed here below.

3.4 PHYSICAL PROPERTIES OF MINERALS

The physical properties of minerals are usually classified into colour, streak, transparency, cleavage, luster, form, fracture, density etc. A more detailed discussion of these properties will be given her below:

COLOUR

Colour is the most obvious feature of a mineral. However, there are some limitations of using colour as a physical property in the identification of minerals.

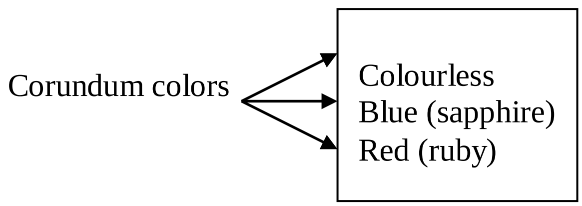
> What do you think are some of the limitations of colour as a means of identifying minerals?

Although colour is a common feature, it is not a diagnostic property. While some minerals always appear the same color, many vary from specimen to specimen. Variation in color is usually due to presence of small amounts of chemical impurities in the mineral that have nothing to do with the mineral's basic characteristic composition. The very common mineral **quartz**, for example, is colorless in its pure form. However, quartz also occurs in other colors, among them rose pink, golden yellow, smoky brown, purple (**amethyst**), and milky white. Clearly quartz cannot always be recognized by its color or lack of it.

Quartz colours ⟶

Colourless
Smoky brown
Purple
Golden yellow
Rose pink

Another example is the mineral **corundum**, a simple compound of aluminum and oxygen. In pure form, it is colorless and quite hard, which makes it a good abrasive. It is often used for the grit on sandpaper. Yet, a little color from trace impurities can transform this material into highly prized gems: Blue-tinted corundum is also known as the **sapphire**, and the red corundum is **ruby**.



An important thing to note about color is that, it is not unique to one mineral, and that there are thousands of minerals that may share one color. The colour difference may be due to chemical composition of the mineral. Surface alteration of the mineral also can change the colour e.g. metallic minerals can be oxidized or mineral oxides may hydrate.

STREAK

This is the colour of the powdered mineral. It is obtained by rubbing the mineral on a streak plate, which is a piece of unglazed porcelain. This rubbing powders the mineral and streak colour is seen. Streak is more useful than colour in that it is nearly constant for each colored mineral. Many minerals have a white streak, which is useless for identification. Examples of minerals with colored streaks are: **Haematite, Pyrite, and Chalcopyrite.**

LUSTRE

This is the surface appearance of the mineral in reflected light. Minerals could for instance have glassy, greasy, resinous, diamond-like, silky or pearly lustre. The two main types of lustre are:

- **Metallic** e.g. galena and pyrite
- **Non-metallic** e.g. glass, peal, resin, silk

The descriptive adjectives of the commonly used mineral luster are presented in Table 3.1

Table 3.1 Descriptions of Mineral Luster.

Mineral Luster	Description
Metallic	- Strong reflections produced by opaque substances
Vitreous	- Bright, as in glass
Resinous	- Characteristic of resins, such as amber
Greasy	- The appearance of being coated with an oily substance
Pearly	- The whitish iridescence of materials like pearl
Silky	- The sheen of fibrous materials like silk
Adamantine	- The brilliant luster of diamond and similar minerals.

TRANSPARENCY

The ability of a mineral to transmit light i.e. the ability for light to pass through the mineral. There are three classes:

- **Transparent** – this type of mineral transmits all light and can be looked through like glass e.g. some quartz and calcite.
- **Translucent** – Light is visible through the mineral but not brightly. It is not possible to see through the mineral e.g. opal, chalcedony and quartz.
- **Opaque** – These minerals have no light at all and examples of this would be metallic minerals.

NB: Transparency is not constant e.g. impurities can make a transparent mineral opaque and opaque minerals can sometimes be transparent.

FORM

This is the shape that the mineral occurs in. There are two types:

- **Euhedral** – This shows the perfect crystal shape. This is easy to identify but rarely occurs e.g. pyrite and garnet.
- **Anhedral** – This does not show good crystal form but occurs in aggregates.

Other examples of adjectives used in form descriptions are:

Bladed - Anhedral form (knife bladed form)

Acicular - Needle-like anhedral form

Fibrous - Very thin interwoven threads e.g. asbestos.

Radiating - Groups of fibers radiating out from a central point.

Micaceous - Excessive development of flat sheets like the pages of a book.

Saccharoidal - A mass of irregular equi-dimensional particles looking like sugar.

Rounded – Occurring in rounded masses.

Dendritic – Branching form often seen is surface film.

CLEAVAGE

Cleavage is the tendency of a mineral to break along planes of weak bonding. Minerals that posses cleavage (e.g. mica in Fig. 3.1) are identified by the smooth surfaces which are produced when the mineral is broken. The cleavage are related to the crystallographic construction of the crystal and they will develop along atom rich planes in the lattice like crystal faces.

Fig. 3.1 Mica cleavage. The large block (or "book") is bounded on the sides by crystal faces. Cleavage fragments lying in front of the large block are of different thicknesses, as indicated by their degrees of transparency.

FRACTURE

This defines how minerals break other than by cleavage and most minerals produce a rough irregular surface referred to as **Conchoidal Fracture** (i.e. a series of concentric rings around the point of percussion).

TENACITY

This defines how the mineral reacts under certain stress and it is not a particularly useful feature as most minerals are brittle and can break. A few minerals particularly the naturally occurring metals e.g. copper, gold and silver will bend under certain stress and are malleable.

HARDNESS

Hardness of a mineral is defined as the resistance of a mineral to resist scratching, and is a measure of the strength of its crystal lattice. Classically, hardness is measured on the **Mohs hardness scale** (see Table 3.2 below), in which ten common minerals are arranged in order of hardness. Unknown minerals are assigned a hardness on the basis of which minerals they can scratch and which minerals scratch them. For example, a mineral that scratches **gypsum** and is scratched by **calcite** is assigned a hardness of 2½ (the hardness of an average fingernail).

Table 3.2. The Mohs Hardness Scale

MINERAL	MOHS HARDNESS	EVERYDAY EQUIVALENT
TALC	1 (SOFTEST)	No everyday equivalent
GYPSUM	2	Fingernail – A little over 2
CALCITE	3	Copper coin – About 3
FLOURITE	4	Iron nail – About 4
APATITE	5	Penknife blade – A little over 5
FELDSPAR (orthoclase)	6	Steel file – About 6½
QUARTZ	7	Window glass – About 7.0
TOPAZ	8	-
CORUNDUM	9	No everyday equivalent
DIAMOND	10 (HARDEST)	No everyday equivalent (the hardest natural substance)

There are five important points to note about hardness:

(i). This is not a linear scale i.e. there is not an equal difference between each hardness diffusion e.g. the difference between 9 and 10 is very large.

(ii). Method of use: if a mineral X can be scratched by fluorite and if it scratches calcite, then its hardness lies between 3 and 4.

(iii). Always make sure that the hardness test mineral is scratching the unknown mineral and that the streak of dust seen on the unknown is not the result of the unknown scratching the test mineral.

(iv). Hardness of common instruments- Fingernail is 2½, a copper coin is 3½, a knife blade is 5½.

(v). Always make sure that a real scratch has occurred and don't test **Friable** or altered surfaces.

TOUCH

This is not a very useful feature but very soft minerals are very greasy. Examples include **Talc, Graphite, and Serpentine**.

DENSITY

This is a useful feature and can be measured in two ways:

- Appropriate measurement – The mineral is weighed on the hand and can be classified as heavy, normal or light. Noticeably heavy minerals include the metallic minerals and barites.
- Precise measurement – This involves finding the precise volume and mass of the sample.

TAKE NOTE

MINERALS MAKE MONEY!

Did you know that Kenya is endowed with abundant mineral deposits? For example – we have abundant deposits of Fluorite at KerioValley, Soda Ash (Sodium bicarbonate) at Lake Magadi, southern Kenya, Diatomite at Kariandusi near Naivasha, gold in south Nyanza and west Pokot,, and a variety of gemstones (e.g., garnets, corundum, beryl, feldspar, amethyst etc) in various parts of the country. All these minerals are very important to our country's economy.

ACTIVITY

Use your current lecture notes and any other textbook on mineralogy and attempt to establish the physical properties of the given minerals in the empty slots shown in Table 3.3. Incase you have any problems in completing Table 3.3, the lecture notes in the next topic (lecture 4) will assist you to complete this practical assignment.

Table 3.3. Mineral properties - A working exercise

MINERAL	COLOUR	LUSTRE	STREAK	S.G.	HARDNESS	DISTINCTIVE PROPERTIES
Calcite	White	Glassy	White	2.7	3	Fizzes with acid
Corundum	Grey, blue and others	Vitreous	None	3.9-4.1		Hardness
Feldspar (orthoclase)		Glassy		2.7		Good cleavage
Galena	Lead-grey			7.5		Bad egg smell in acid
Halite				2.2	2.5	Soft, salty taste
Fluorite		Glassy				Cubic crystals
Haematite	Grey-red		Dark red			Kidney-shaped lumps
Magnetite			Black	5.2		magnetic
Pyrite		Metallic		5		"Fools gold"
Quartz	Colouless, pink, yellow etc.	Glassy		2.7		Looks like greasy glass
Gold	Golden yellow					
Mica		Glassy	White	3		Flaky
Hornblende	Dark green		Pale grey	3.2		Rhombic cleavage
Talc	Green, white, Grey.	Silky		1 – 2.5		Greasy feel, very soft.

Summary

1. Minerals are naturally occurring inorganic solids, each of which is characterized by a particular composition and internal crystalline structure.

2. The physical properties of minerals, which include – colour, lustre, cleavage, streak, density and hardness - are determined by the kind of elements making

up the minerals, their bond types and crystal structures. These physical properties are used as a means of their identification.

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