Quadrant II – Transcript and Related Materials (Notes)

Programme	**: Bachelor of Science (First Year)**
Subject	**: Geology**
Course Code	**: GEC 101**
Course Title	**: Fundamentals of Mineral Science**
Unit	**: III**
Module Name	**: Crystallography: Definition of a crystal; Crystalline state & Amorphous state**
Module No	**: 32**
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Notes:

Crystallography

- Science which deals with the study of the crystalline solids and the principals that govern their growth, external shape & internal structure is called **crystallography.**
- Word derived from the Greek word "**Krystalos**" meaning **clear ice**

Crystal

- A homogeneous solid possessing long range 3D Internal.
- Crystals have an internal ordered arrangement and when conditions are favourable and they may be bounded by smooth plane surfaces and **assume regular geometric form.**
- Something that is formed by the solidification of an element, compound or a mixture and has a regular repeating internal arrangement of its atoms, which is often reflected in external plane faces.
- The atomic structures of crystals are studied with **X-rays or TEM.**
- In crystallography, the external shape is denoted by the word ***Habit*****,** whereas ***form*** consists of an assemblage of faces demanded.

- Habit is controlled by the environment in which the crystal grows, it may vary with locality, at one place it may be equant, other places it may be fibrous.
- Therefore external flat faces is an expression of the internal regular atomic framework
- **Crystalline:** denotes the ordered arrangement of atoms in crystal structure.
- **Crystal**: in traditional sense "Regular geometric solid bounded by smooth plane surfaces".
- Thus a crystalline solid with well formed faces is ***euhedral***, if its faces are imperfect, ***subhedral*** and without faces, ***anhedral***.
- Crystalline substance may occur in fine grained aggregates that their crystalline nature can be determined only by aid of microscope, and are designated as ***microcrystalline***. If the aggregates are so fine that they cannot be resolved by microscope but detected by X-Ray diffraction technique, ***cryptocrystalline***. Those that lack any ordered internal atomic arrangement are called ***amorphous.***
- Naturally occurring amorphous substances are designated as **mineraloids**.
- Majority of the minerals are crystalline substances and display characteristic geometric forms.
- The study of external form or morphology of crystals is known as **morphological crystallography,** and, study of these forms helps in identification of minerals.

How are crystals formed?

- Crystals can be formed from solution (NaCl), melts and vapours (depending on T, P) by a process called as crystallization.
- The first stage is nucleation, i.e. seed needs to be formed first. The nucleus is the result of coming together of various ions (in the solution or melt) to form the initial regular structural pattern of a crystalline solid. After this the crystal grows meaning addition of ions (or atoms) to the outside of the crystal occurs in a regular and continuous pattern.

Atomic arrangement in crystalline matter (Internal order in crystals) - Crystalline State.

- The 3D internal order of a crystal can be considered as a repetition of a **motif (unit of a pattern)** such that the environment around the motif is identical. This motif in crystals may be molecules H_2O, ions such as Ca2+, Fe^{2+} and anionic groups $(SiO4)^{-4.}$
- The ordered patterns that characterize crystalline materials represent a lower energy state than random patterns.
- Order represent more stable & less energy than random arrangement
- A **pattern** is generated by repeating a motif in a regular sequence in a new location.

- Any motion (e.g. Translation, Rotation) that brings the original motif into coincidence with the same motif elsewhere in the pattern is referred to as an ***Operation*.**
- A homogeneous pattern therefore can be generated from a single motif be a set of geometrical operations. The types are: **Translation, rotation & combination of both.**

1) **Translation**: in 1D produces a linear pattern at an interval equal to the translation distance *t.*
2) **Rotation alone**, through an angle α, say 90deg, about an imaginary axis, generates a circle.
3) **Combination** such that the **axis of rotation** is parallel with **the translation** direction produces a **screw motion**.

Space Lattices:

- The constituent particles of a crystalline solid are arranged in a definite fashion in the 3D space. Such a regular arrangement of the constituent particles of a crystal in a 3D space is called ***crystal lattice* or *space lattice*.**
- From a complete space lattice, it is possible to select a smallest 3D portion which repeats itself in different directions to generate a complete space lattice, this is called the ***unit cell***

Unit cell

- The smallest 3D portion of a complete space lattice, which when repeated over and over again in different directions produces the complete space lattice.
- The size & shape of a unit cell is determined by the lengths of the edges of the unit cell (a, b, c) and by the angles (α, β, γ) between the edges b &c, c& a and a& b.
- The symmetry observed in crystals as exhibited by their crystal faces is due to the ordered internal arrangement of atoms in a crystal structure, this arrangement of atoms in crystals is called a ***lattice.***
- Crystal faces develop along planes defined by the points in the lattice. In other words, all crystal faces must intersect atoms or molecules that make up the points. **A face is more commonly developed in a crystal if it intersects a larger number of lattice points.** This is known as the ***Bravais Law.***

Crystalline State

- Composed of "points or motifs" arranged in a definite space patterns
- Each point considered to be the centre of gravity of an atom, ion, partial molecule or molecule.
- Environment of any one point is identical in orientation and arrangement with any other similar point
- Such patterns, of such points in space are called ***space lattices***

- Each space lattice is an assemblage of units
- When a unit cell is formed during crystallization, it becomes a centre of crystallization or the nucleus.
- Units are then added up to produce an expanding lattice.
- As long as it grows without interference, it will be bounded by plane, flat surfaces, arranged in a regular geometric pattern, which is in turn controlled by the arrangement of points within the lattice space.
- Resulting geometric form is external expression of the orderly internal arrangement of the structural units of which it is composed.
    - Such a form is called a crystal

"A crystal is a solid, bounded by naturally formed plane surfaces, arranged on a regular pattern, which is an expression of the orderly internal arrangement of the atoms."

- Atoms in crystalline substances, arranged on a regular repetitive pattern.
- Physical properties of crystals are different in different directions, i.e. for example electrical conductivity, optical properties, or elasticity vary with the direction of measurement, except in isotropic substance crystallizing in cubic system.
- They have a definite melting point. i.e. the temperature will remain constant until all of substance has been melted.

Amorphous state

- Have no regular internal structure therefore no external geometric form is possible.
- The atoms are situated at random, as in a liquid state. Solid amorphous substances are therefore regarded as "super cooled liquid".
- Lot of vacant space is left between atoms; hence they have a lower specific gravity then a crystal of some composition. E.g. Qtz (2.65 gm/cc & Opal 2.2g/cc)
- Lack a definite melting point; melt over a range of temperatures.
- All amorphous substance are isotropic i.e. their physical properties are similar in all direction.