Indian Institute of Technology, Kanpur

Department of Earth Sciences

ES0213A: Fundamentals of Earth Sciences

Lecture 11. Atomic Structures of Matters

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IITK Experimental Rock Deformation Laboratory

Aims of this lecture

- Historical developments on the concept of Matter
- The basic structure of Matters
- Definition and Idea of Minerals

Reference:
Chapter 3, Grotzinger_Jordan's Book
Chapter 5, Marshak's Book

FROM NOW ON, YOU WILL BE FLOODED WITH NAMES AND TERMINOLOGIES ….

Instructor's advice: Take is easy.. spend little time and keep patience

Historical Developments

- The idea of the matters and their forms originated from the Greek Philosophgers (Plato, Aristotle).
- Greeks though of 4 basic elements: Fire, Air, Water and Earth
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  (a similar idea was there also in Vedas, much later, though: ***kshiti*** *[soil],* ***ap*** *[water],* ***tej*** *[light],* ***marut*** *[air]* and ***byom*** *[space]* and the processes as ***sattwa*** *[illumination],* ***rajas*** *[active]* and ***tamas*** *[static]*)
- Democritus is credited with coming up with the concept of ***atom*** …. "if you keep breaking something down, you would get to a size that could no longer be broken. This would be the indivisible piece. In Greek, atomos = indivisible"
- Interestingly, the Aristotelian view of the composition of matter was popular for over two thousand years, and the idea of Demicritus of atom was suppressed.

Historical Developments

- English schoolteacher John Dalton proposed his hypothesis that the behaviour of matter could be explained using an atomic theory, published in 1907.
  - Matter is composed of exceedingly small particles called atoms. An atom is the smallest unit of an element that can participate in a chemical change.
  - An element consists of only one type of atom, with a characteristic mass of the element and is the same for all atoms of that element. A macroscopic sample of an element contains an incredibly large number of atoms, all of which have identical chemical properties.
  - Atoms of one element differ in properties from atoms of all other elements.
  - A compound consists of atoms of two or more elements combined in a small, whole-number ratio. In a given compound, the numbers of atoms of each of its elements are always present in the same ratio
  - Atoms are neither created nor destroyed during a chemical change, but are instead rearranged to yield substances that are different from those present before the change.

Historical Developments

- If matter were composed of atoms, what were atoms composed of? Were they the smallest particles, or was there something smaller?
- J J Thompson experimented with a gas-filled cathode ray tube and concluded there mist be negatively charged particle inside the atoms and the particles are much smaller and lighter.. Discovery of ELECTRONS.
- The next major development by Ernest Rutherford, who experimented with a beam of high-speed, positively charged α particles to a thin gold foil and found most particles passed through the foil, but a few of then showed deviation and total deflection – discovery of positively charged NUCLEUS, also the most the volume occupied by an atom is empty, and protons.
- In 1932, James Chadwick found evidence of neutrons, uncharged, subatomic particles with a mass approximately the same as that of protons.

Some terminologies and their meanings

- **ELEMENTS:** A pure substance that cannot be separated into other materials is an **element**. There are 92 natural elements and can be represented in a periodic table. The elements have names and symbols.
- **ATOMS & COMPONENTS:** The smallest segment of an element retaining the characteristics of the element is an **atom**. At the centre of each atom the is a dense *nucleus* containing virtually all the mass of the atom in two kinds of particles: **protons** (positively charged) and **neutrons** (electrically inert). An atom consists of a nucleus surrounded by a cloud of orbiting **electrons** (negatively charged).
- **ATOMIC NUMBER:** The number of protons in the nucleus of an atom is its **atomic number.**
- **ATOMIC MASS:** The **atomic mass** of an element is the sum of the masses of its protons and its neutrons.
- **ISOTOPES:** Atoms of an element that have differing numbers of neutrons (but a constant atomic number) are called **isotopes.** [Carbon has six protons, but may contain six, seven, or eight neutrons, giving atomic masses of 12, 13, and 14.]
- **MOLECULES:** The smallest particle of an element or a compound, which is capable to exist independently and shows all the properties of the respective substance. A molecule, normally, is a group of two or more atoms (same or different elements) which are chemically bonded together.

Some terminologies and their meanings

- **CHEMICAL BOND:** A molecule or compound is formed either by electron sharing or by electron transfer, the ions or atoms that make up the compound are held together by some attractions – Chemical Bonds.
  - IONIC BONDS: The electrostatic attraction between ions of opposite charge, such as ***Na^+*** and ***Cl^-*** in sodium chloride
  - COVALENT BONDS: Atoms held together in ccompounds by sharing electrons by covalent bonds and are stronger than ionic bonds.
  - METALIC BONDS: Mostly with metallic elements which lose electrons and the free electron sharing results kind of covalent bonds.
- **Some other terms:**
  Ion; Anion; Cation; State of Matter; Changing of State; Chemical Formula; Chemical Reactions; Electron Transfer; Electron Sharing; Avogadro Number; Law of Conservation of Mass; Radioactivity; Van der Waals forces etc. (.. and if you are interested see also ***Antimatter*** and ***Dark Matter***).

Definition of a Mineral

- A **mineral** is a naturally occurring, homogeneous solid crystalline substance, usually inorganic, with a specific chemical composition.
  - Naturally occurring: Synthetic minerals are not considered minerals !!
  - *Solid crystalline substance:* neither liquids nor gases. When we say that a mineral is crystalline, we mean that the tiny particles of matter, or atoms, that compose it are arranged in an orderly, repeating, three-dimensional array (*glass, amorphous materials are not minerals*)
  - *Inorganic:* Coal is not a mineral..
  - *Chemical Composition:* A mineral's chemical composition either is fixed or varies within defined limits and possible to write the chemical formula of a mineral.

QUARTZ

SiO_2

OLIVINE

$(Mg, Fe)_2SiO_4$

Forsterite: Mg_2SiO_4
Fayalite: Fe_2SiO_4

How does a mineral form?

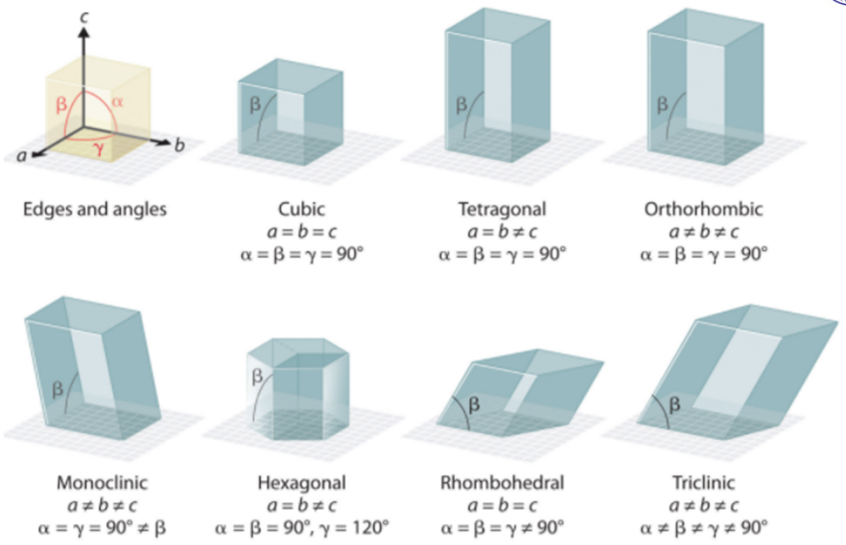
- One can view the minerals either in microscale (submicroscopic atoms organized in an ordered three-dimensional array) or in macroscale (crystals that we can see with the naked eye… crystals can me microscopic, too).

- Minerals from by crystallization – (A) from melt/magma; (B) precipitation from fluid and (C) Solid-state transformation. During crystallization, the initially microscopic crystals grow larger, maintaining their crystal faces (flat boundaries of crystals) as long as they are free to grow. Pressure and Temperature are the crucial factors to govern the crystallization process.

Crystal Systems

- In Crystal Systems, the crystals are classified based on the length of the faces and their mutual interaction angles.

- The edge lengths of a crystal are represented by the letters ***a***, ***b***, and ***c***. The angles at which the faces intersect are represented by the Greek letters ***α***, ***β***, and ***γ***

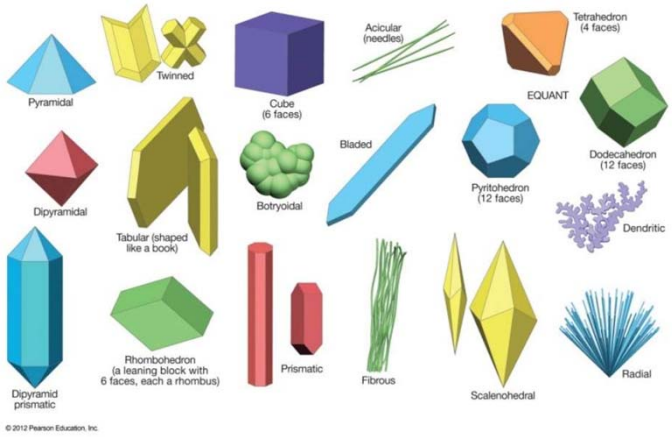


Read more on…

- CRYSTAL FORMS: General Form; Special Form; Open Form; Closed Form
- There are 48 possible forms of crystals that can be developed as the result of the 32 combinations of symmetry.

- A few names of the common forms are:

  Pedions; Pinacoids; Domes; Sphenoids; Prisms; Pyramids; Dipyramids; Trapezohedrons; Scalenohedrons; Rhombohedrons; Hexahedrons; Octahedrons; Dodecahedrons; Tetrahexahedron….



Next Lecture

Classification & Identification of Minerals