

Q.1. What is polarization? Describe all the polarization mechanisms in detail.

(5)

Sol: **Mechanisms of Polarization**

**Basically, there are four mechanisms of polarization:**

1. **Electronic or Atomic Polarization**

This involves the separation of the centre of the electron cloud around an atom with respect to the centre of its nucleus under the application of electric field (see (a) in figure below).

2. **Ionic Polarization**

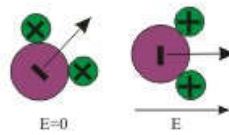
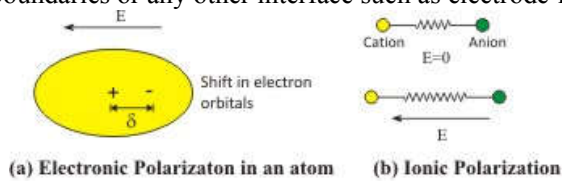
This happens in solids with ionic bonding which automatically have dipoles but which get cancelled due to symmetry of the crystals. Here, external field leads to small displacement of ions from their equilibrium positions and hence inducing a net dipole moment (see (b)).

3. **Dipolar or Orientation Polarization**

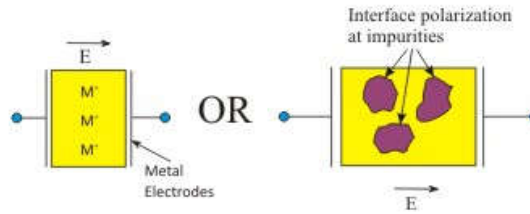
This is primarily due to orientation of molecular dipoles in the direction of applied field which would otherwise be randomly distributed due to thermal randomization (see (c) and d)) and finally

4. **Interface or Space Charge Polarization**

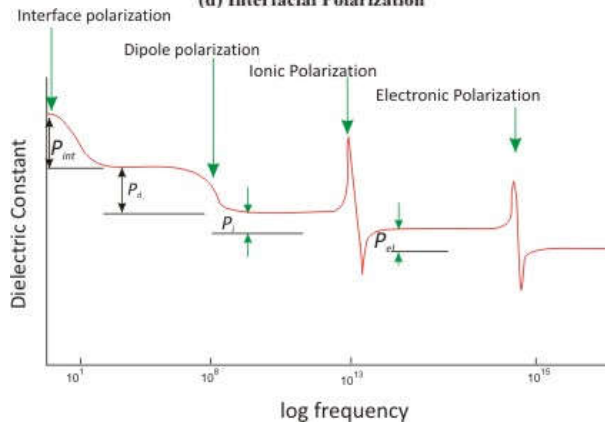
This involves limited movement of charges resulting in alignment of charge dipoles under applied field. This usually happens at the grain boundaries or any other interface such as electrode-material interface.



(c) **Dipolar or Orientation Polarization**



(d) **Interfacial Polarization**



**Q.2.** What are piezoelectric materials. Explain with some examples.

(5)

**Sol: Piezoelectricity** is the electric charge that accumulates in certain solid materials (such as crystals, certain ceramics, and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. The word *piezoelectricity* means electricity resulting from pressure and latent heat.

The piezoelectric effect is understood as the linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect (the internal generation of electrical charge resulting from an applied mechanical force) also exhibit the reverse piezoelectric effect (the internal generation of a mechanical strain resulting from an applied electrical field). For example, lead zirconate titanate crystals will generate measurable piezoelectricity when their static structure is deformed by about 0.1% of the original dimension. Conversely, those same crystals will change about 0.1% of their static dimension when an external electric field is applied to the material. The inverse piezoelectric effect is used in the production of ultrasonic sound waves.

**Quartz** is a mineral composed of silicon and oxygen atoms in a continuous framework of SiO<sub>4</sub> silicon–oxygen tetrahedra, with each oxygen being shared between two tetrahedra, giving an overall chemical formula of SiO<sub>2</sub>. Quartz is the second most abundant mineral in Earth's continental crust, behind feldspar.

Quartz crystals are chiral, and exist in two forms, the normal  $\alpha$ -quartz and the high-temperature  $\beta$ -quartz. The transformation from  $\alpha$ -quartz to  $\beta$ -quartz takes place abruptly at 573 °C (846 K). Since the transformation is accompanied by a significant change in volume, it can easily induce fracturing of ceramics or rocks passing through this temperature limit.

There are many different varieties of quartz, several of which are semi-precious gemstones. Since antiquity, varieties of quartz have been the most commonly used minerals in the making of jewelry and hardstone carvings, especially in Eurasia.

**Potassium sodium tartrate tetrahydrate**, also known as **Rochelle salt**, is a double salt of tartaric acid first prepared (in about 1675) by an apothecary, Pierre Seignette, of La Rochelle, France. Potassium sodium tartrate and monopotassium phosphate were the first materials discovered to exhibit piezoelectricity. This property led to its extensive use in "crystal" gramophone (phono) pick-ups, microphones and earpieces during the post-World War II consumer electronics boom of the mid-20th Century. Such transducers had an exceptionally high output with typical pick-up cartridge outputs as much as 2 volts or more. Rochelle salt is deliquescent so any transducers based on the material deteriorated if stored in damp conditions.

It has been used medicinally as a laxative. It has also been used in the process of silvering mirrors. It is an ingredient of Fehling's solution (reagent for reducing sugars). It is used in electroplating, in electronics and piezoelectricity, and as a combustion accelerator in cigarette paper (similar to an oxidizer in pyrotechnics).

In organic synthesis, it is used in aqueous workups to break up emulsions, particularly for reactions in which an aluminium-based hydride reagent was used. Sodium Potassium tartrate is also important in the food industry.

It is a common precipitant in protein crystallography and is also an ingredient in the Biuret reagent which is used to measure protein concentration. This ingredient maintains cupric ions in solution at an alkaline pH.

**Q.3.** Define: (a)Magnetic field strength; (b) Magnetic flux density; (c) Remanence; (d) Coercive force

(5)

**Sol: (a) Magnetic field strength:** Magnetic field strength is one of two ways that the intensity of a magnetic field can be expressed. Technically, a distinction is made between magnetic field strength  $H$ , measured in amperes per meter (A/m), and magnetic flux density  $B$ , measured in Newton-meters per ampere (Nm/A), also called teslas (T). The magnetic field can be visualized as magnetic field lines. The field strength corresponds to the density of the field lines.

**(b) Magnetic flux density:** Magnetic flux density is defined as the amount of magnetic flux in an area taken perpendicular to the magnetic flux's direction. An example of magnetic flux density is a measurement taken in teslas.

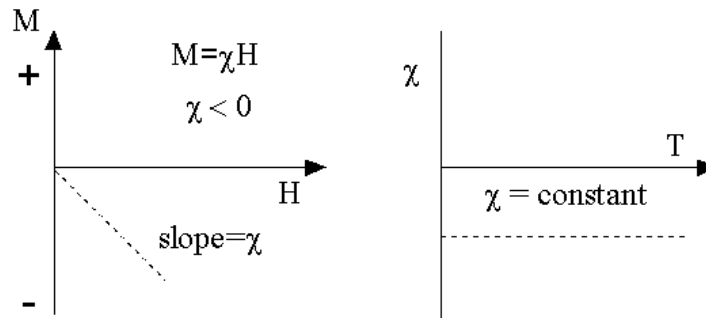
(c) **Coercive Force:** It is the magnetic intensity needed to reduce to zero the magnetic flux density of a fully magnetized magnetic specimen or to demagnetize a magnet.

**Q.4.** Explain different types of magnetic materials in detail with some examples.

(5)

**Sol: Diamagnetism**

Diamagnetism is a fundamental property of all matter, although it is usually very weak. It is due to the non-cooperative behavior of orbiting electrons when exposed to an applied magnetic field. Diamagnetic substances are composed of atoms which have no net magnetic moments (ie., all the orbital shells are filled and there are no unpaired electrons). However, when exposed to a field, a negative magnetization is produced and thus the susceptibility is negative. If we plot M vs H, we see:



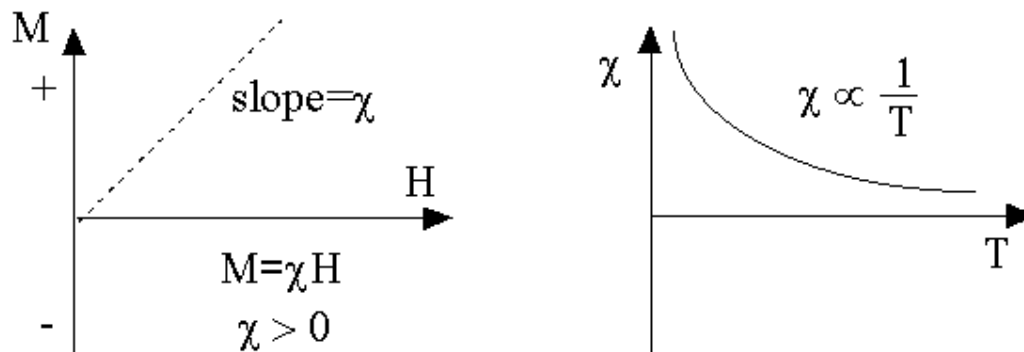
*Diamagnetism*

Note that when the field is zero the magnetization is zero. The other characteristic behavior of diamagnetic materials is that the susceptibility is temperature independent. Some well known diamagnetic substances, in units of  $10^{-8} \text{ m}^3/\text{kg}$ , include:

- quartz (SiO<sub>2</sub>) -0.62
- Calcite (CaCO<sub>3</sub>) -0.48
- water -0.90

**Paramagnetism**

This class of materials, some of the atoms or ions in the material have a net magnetic moment due to unpaired electrons in partially filled orbitals. One of the most important atoms with unpaired electrons is iron. However, the individual magnetic moments do not interact magnetically, and like diamagnetism, the magnetization is zero when the field is removed. In the presence of a field, there is now a partial alignment of the atomic magnetic moments in the direction of the field, resulting in a net positive magnetization and positive susceptibility.



*Paramagnetism*

In addition, the efficiency of the field in aligning the moments is opposed by the randomizing effects of temperature. This results in a temperature dependent susceptibility, known as the Curie Law.

At normal temperatures and in moderate fields, the paramagnetic susceptibility is small (but larger than the diamagnetic contribution). Unless the temperature is very low ( $\ll 100 \text{ K}$ ) or the field is very high paramagnetic susceptibility is independent of the applied field. Under these conditions, paramagnetic susceptibility is proportional to

the total iron content. Many iron bearing minerals are paramagnetic at room temperature. Some examples, in units of  $10^{-8} \text{ m}^3/\text{kg}$ , include:

- Montmorillonite (clay) 13
- Nontronite (Fe-rich clay) 65
- Biotite (silicate) 79
- Siderite(carbonate) 100
- Pyrite (sulfide) 30

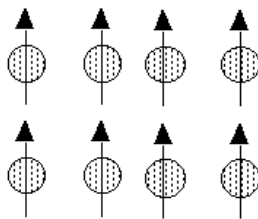
The paramagnetism of the matrix minerals in natural samples can be significant if the concentration of magnetite is very small. In this case, a paramagnetic correction may be needed.

## Ferromagnetism

When you think of magnetic materials, you probably think of iron, nickel or magnetite. Unlike paramagnetic materials, the atomic moments in these materials exhibit very strong interactions. These interactions are produced by electronic exchange forces and result in a parallel or antiparallel alignment of atomic moments. Exchange forces are very large, equivalent to a field on the order of 1000 Tesla, or approximately a 100 million times the strength of the earth's field.

The exchange force is a quantum mechanical phenomenon due to the relative orientation of the spins of two electron. Ferromagnetic materials exhibit parallel alignment of moments resulting in large net magnetization even in the absence of a magnetic field.

parallel alignment



*Ferromagnetism*

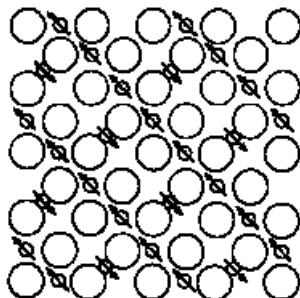
## Ferrimagnetism

In ionic compounds, such as oxides, more complex forms of magnetic ordering can occur as a result of the crystal structure. One type of magnetic ordering is called ferrimagnetism. A simple representation of the magnetic spins in a ferrimagnetic oxide is shown here.

The magnetic structure is composed of two magnetic sublattices (called A and B) separated by oxygens. The exchange interactions are mediated by the oxygen anions. When this happens, the interactions are called indirect or superexchange interactions. The strongest superexchange interactions result in an antiparallel alignment of spins between the A and B sublattice.

In ferrimagnets, the magnetic moments of the A and B sublattices are not equal and result in a net magnetic moment. Ferrimagnetism is therefore similar to ferromagnetism. It exhibits all the hallmarks of ferromagnetic behavior—spontaneous magnetization, Curie temperatures, hysteresis, and remanence. However, ferro- and ferrimagnets have very different magnetic ordering.

Magnetite is a well known ferrimagnetic material. Indeed, magnetite was considered a ferromagnet until Néel in the 1940's, provided the theoretical framework for understanding ferrimagnetism.



*Ferrimagnetism*

