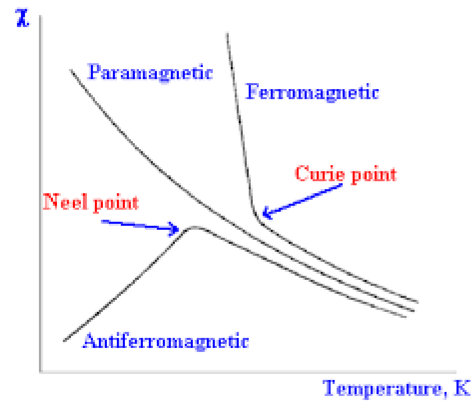
ENTRI

HSST PHYSICS

MODULE 7 PART 5

ANTIFERRO MAGNETS

- Antiferromagnetism is the presence of magnetic domains that are aligned in opposite directions in magnetic materials. These opposite magnetic domains have equal magnetic moments which are canceled out (since they are in opposite directions)
- The key difference between ferromagnetism and antiferromagnetism is that ferromagnetism can be found in materials having their magnetic domains aligned into the same direction whereas antiferromagnetism can be found in materials having their magnetic domains aligned in opposite directions.
- The materials that exhibit the antiferromagnetism are known as antiferromagnetic material. When these materials are kept in the presence of the strong magnetic field, they get magnetized weakly in the direction of the magnetic field. This is known as antiferromagnetism.
- The antiferromagnetic materials are commonly found among the transition metal compounds. Hematite, chromium, alloys of iron manganese and oxides of nickel are the examples of antiferromagnetic material.
- In an antiferromagnet, unlike a ferromagnet, there is a tendency for the intrinsic magnetic moments of neighboring valence electrons to point in opposite directions. When all atoms are arranged in a substance so that each neighbor is anti-parallel, the substance is antiferromagnetic.
- Antiferromagnets have a zero net magnetic moment, meaning that no field is produced by them. Manganese oxide (MnO) is one material that displays this behavior.
- Generally, antiferromagnetic order may exist at sufficiently low temperatures, but vanishes at and above the Néel temperature. Above the Néel temperature, the material is typically paramagnetic, that is, the thermal energy becomes large enough to destroy the microscopic magnetic ordering within the material. The Néel temperature of MnO is about 116K.



Neel temperature

Antiferromagnetic material's magnetic moments are temperature dependent and their critical temperature is the Neel temperature, T_N , at which a magnetic phase change occurs. Typically T_N is found to be below room temperature but there are some exceptions. Above this temperature the material behaves paramagnetically with all magnetic moments aligned with the applied magnetic field direction therefore enhancing the overall magnetic field. Below the Neel temperature the magnetic moments spontaneously align antiparallel and the net magnetization of the material is zero because the individual magnetic moments within the sublattices cancel out. The susceptibility increases inversely with temperature above T_N and decreases inversely below this temperature.

Curie-Weiss Law

- The temperature dependence of paramagnetic materials can be determined by the Curie Law given by $\chi = C/T$

Where χ , the susceptibility is inversely proportional to the absolute temperature, T, and C is the Curie constant. The more general Curie-Weiss Law gives

$$\chi = \frac{C}{T - \theta}$$

Where Θ is another Curie constant in units of temperature and can be positive or negative depending on the material. Therefore the material's susceptibility is a function of temperature where an increase in temperature will decrease the material's responsiveness to the applied magnetic field.

The increase in susceptibility for anti-ferromagnetic materials above T_N leads to a negative Θ, so that the Curie-Weiss Law for anti-ferromagnetic materials becomes

$$\chi = \frac{C}{T+\theta}$$

- What is the main difference between antiferromagnetism and ferromagnetism?

The main difference between antiferromagnetism and ferromagnetism is the alignment of the magnetic moments. Ferromagnetic materials have magnetic moments that align parallel to the applied magnetic field whereas antiferromagnetic materials have antiparallel magnetic moments. This results in a positive magnetism for ferromagnetic materials and zero total magnetism for antiferromagnetic materials. Antiferromagnets also have a critical temperature below room temperature and a negative Cure-Weiss constant, Θ.

- Difference Between Curie Temperature and Neel Temperature:

The key difference between Curie temperature and Neel temperature is that Curie temperature is the temperature at which certain materials lose their permanent magnetic properties whereas Neel temperature is the temperature above which certain antiferromagnetic materials become paramagnetic.

- What is Curie Temperature?

Curie temperature is the temperature at or above which certain materials lose their permanent magnetic properties. This is a sharp change in the magnetic properties of materials. Induced magnetism can often replace this lost magnetism. Permanent magnetism arises due to the alignment of magnetic moments of the material while induced magnetism arises when we force disordered magnetic moments to align in the presence of a magnetic field.

At or above the Curie temperature, the ordered magnetic moments change into a disordered state, which causes the materials to change from ferromagnetic to paramagnetic. Therefore, higher temperatures can make magnets weaker. Moreover, spontaneous magnetism arises only below the Curie temperature. In addition, this term was named after Pierre Curie, who discovered that magnetism is lost at a critical temperature.

- What is Neel Temperature?

Neel temperature is the temperature above which certain antiferromagnetic materials become paramagnetic. To be specific, antiferromagnetic means the magnetic moments of the material are aligned in a regular pattern. It is similar to ferromagnetism and ferrimagnetism. Furthermore, at Neel temperature, the energy of heat is enough to destroy the regular pattern of the magnetic moments.

- What are the Similarities between Curie Temperature and Neel Temperature?
- Curie temperature and Neel temperature describe the magnetic properties of certain substances.
- Moreover, both are high-temperature values.