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Topic:- Magnetic Properties

Diamagnetic, Paramagnetic & Ferromagnetic

In order to understand the behaviour of these three classes of substances, it would be useful to consider the law of magnetic force.

m_1 and m_2 are the strength of two magnetic poles which are separated by a distance r in any medium. Then the force F acting between them is given by

$$F = \frac{1}{\mu} \cdot \frac{m_1 \cdot m_2}{r^2} \quad \text{—— (1)}$$

where μ is constant for the medium and is called magnetic permeability of the medium.

It gives a measure of tendency of magnetic lines of force to pass through the medium in comparison with air or vacuum. For air or vacuum, μ is taken as unity. For Paramagnetic substance μ is slightly greater than unity, For diamagnetic substance, μ is less than unity. Thus the magnetic lines will pass more readily through a paramagnetic substance and less readily through a diamagnetic substance than in air.

For ferromagnetic substance μ is of the order of 1000. Hence the lines of force pass very readily through a ferromagnetic substance.

Iron, Cobalt and their alloys are chief ferromagnetic substances.

Magnetic Permeability (μ) of a medium is related to specific magnetic susceptibility (χ) of the medium by the following equation

$$\chi = \frac{\mu - 1}{4\pi\rho} \quad \text{——— (2)}$$

where ρ is the density of the substance. In the case of diamagnetic substances μ is smaller than unity hence χ is negative. For paramagnetic substances, since μ is greater than unity, χ is positive.

Molecular magnetic susceptibility, χ_M of a compound is given by the expression $\chi_M = \chi \cdot M$

Where M is the molecular weight of the compound

Measurement of magnetic susceptibilities

Guoy method :-

The substance is taken in a vertical cylinder which is suspended vertically by means of a wire from one arm of a balance in such a way that its lower part lies in the middle of the two poles of an electromagnet. The cylinder is counterbalanced by putting weights on the other pan of the balance. When the current is switched on, the cylinder will be drawn downward, towards the electromagnetic field, if the substance placed in it is paramagnetic.

If the substance is diamagnetic the cylinder will be drawn upward away from the field.

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In the first case, weights will have to be added to the other pan while in the second case weights will have to be removed to restore the cylinder to its original position.

Let Δm be the change in mass in either case. This is related to specific magnetic susceptibility χ of a compound by the following equation

$$\Delta m \cdot g = \frac{1}{2}(\rho \cdot \chi - \rho_a \cdot \chi_a) \cdot AH^2 \quad \text{— (3)}$$

where g is the acceleration due to gravity, ρ is the density of the medium, ρ_a is the density of air, χ_a is the specific magnetic susceptibility of air, A the cross-sectional area of the specimen and H the strength of the magnetic field in gauses.
The value of $\rho_a \cdot \chi_a$ is known to be $.03 \times 10^{-6}$.

The method can be simplified by measuring the value of Δm of a substance of known magnetic susceptibility at the same value of H. Water is generally taken as the standard substance for this purpose. Then

$$\frac{\Delta m}{\Delta m_s} = \frac{\rho \cdot \chi - \rho_a \cdot \chi_a}{\rho_s \cdot \chi_s - \rho_a \cdot \chi_a} \quad \text{— (4)}$$

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where Δm_s is the change of weight on the pan when water is taken in the cylinder and ρ_s and χ_s are the density and specific magnetic susceptibility of water respectively.

Knowing χ from eq-(4)

the molecular magnetic susceptibility χ_M is obtained by multiplying it with molecular weight of the substance.

Substance	$\chi_M \cdot 10^6$
Al (s)	16.5
$CuCl_2$ (s)	1180
$NiCl_2$ (s)	6145
CoI_2 (s)	10760
$FeSO_4$ (s)	10200
$FeCl_2$ (s)	14750

(Value of Molecular Magnetic susceptibility

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