Government Girls' General Degree College

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Department of Physics

PHYS-A-CC-5-12 : MAGNETIC PROPERTIES OF SOLIDS

1. Name an element that exhibits paramagnetism. Explain why the inert gases do not show paramagnetism.
2. Derive Curie's law of paramagnetism from Langevin's theory.
3. Derive an expression for diamagnetic susceptibility on the basis of classical theory.
4. Draw a typical M and H curve for a ferromagnetic substance and explain the various stage of magnetisation on the basis of domain theory.
5. Give an account of the Weiss theory of ferromagnetism. Explain hysteresis effect and the Curie point on its basis.
6. What is ferromagnetism? How does the molecular field theory account for the susceptibility of ferromagnet?
7. Derive the temperature dependence of the magnetic susceptibility of the paramagnetic substances.
8. A system of paramagnetic atoms (N per unit volume) which can occupy only two energy levels in a uniform external magnetic field H is at a temperature T. If occupancies of these levels are determined by a Boltzmann distribution,find the resulting magnetisation and susceptibility of the system when H is weak.
9. Describe the basic principle of Curie Weiss Law for ferromagnet.
10. Describe the phenomenon of hysteresis in ferromagnet.
11. What is spontaneous magnetisation in a ferromagnetic substance?
12. Compare the temperature dependence of magnetisation obtained from Curie Weiss law with the experimental results.

3. The Curie temperature of iron is 1043 K. If each iron atom has a magnetic moment of two Bohr magnetons, calculate the values of the Weiss constant and the Curie constant. Assume that the saturation magnetisation of iron is 1.75×10^6 ampere/meter.

Ans. We have for the Weiss constant

$$\gamma = \frac{3k_B\theta}{\mu_0 n \mu^2} = \frac{3k_B\theta}{\mu_0 M_s \mu}$$

Here the Curie temperatue, $\theta = 1043$ K, $\mu_0 = 4\pi \times 10^{-7}$ H/m, k_B, the Boltzmann constant $= 1.38 \times 10^{-23}$ J/K, $\mu = 2$ Bohr magnetons $= 2 \times 9.27 \times 10^{-24}$ A.m^2 < and $M_s = 1.75 \times 10^6$ A/m

$$\therefore \quad \gamma = \frac{3 \times 1.38 \times 10^{-23} \times 1043}{4\pi \times 10^{-7} \times 1.75 \times 10^6 \times 2 \times 9.27 \times 10^{-24}}$$

$$= 1059$$

The Curie constant C is given by

$$C = \frac{\mu_0 n \mu^2}{3k_B} = \frac{\mu_0 M_s \mu}{3k_B}$$

$$= \frac{4\pi \times 10^{-7} \times 1.75 \times 10^6 \times 2 \times 9.27 \times 10^{-24}}{3 \times 1.38 \times 10^{-23}}$$

$$= 9848 \text{ K}$$

► **Example 1.** *Estimate the order of diamagnetic susceptibility of Cu from the following data: radius of Cu-atom = 1 A, lattice parameter = 3.608 A. Assume that only one electron per atom makes the contribution.*

Solution: Given, $r = 1$ A $= 10^{-10}$ m, $a = 3.608 \times 10^{-10}$ m, $\chi_{dia} = ?$

Now copper is a face-centred cubic crystal. It has therefore 4 atoms per unit cell.

$$\therefore \text{ No. of electrons per unit volume, } N = \frac{n}{a^3} = \frac{4}{(3.608 \times 10^{-10})^3} = 8.5 \times 10^{28}/\text{m}^3.$$

$$\therefore \quad \chi_{dia} = -\frac{\mu_0 Z e^2 N \langle r^2 \rangle}{6m} = -\frac{4\pi \times 10^{-7} \times (16 \times 10^{-19})^2 \times 8.5 \times 10^{28} \times 10^{-20}}{6 \times 9.1 \times 10^{-31}}$$

$$= -5 \times 10^{-6}$$

1. The magnetic field strength in a piece of metal is 10^6 ampere per metre. Find the flux density and the magnetisation in the material. Assume that the magnetic susceptibility of the metal is -0.5×10^{-5}.

Ans. We have

$$M = \chi H = -0.5 \times 10^{-5} \times 10^6 = -0.5 \times 10$$
$$= -5 \text{ A/m}$$

Also,
$$B = \mu_0 (H + M)$$
$$= 4\pi \times 10^{-7} (10^6 - 5)$$
$$\approx 1.257 \text{ tesla}$$

▸ Example 4. *Assuming the magnetic moment μ_m to be 5 times the Bohr magneton μ_B, compute approximately how large should be the magnetic induction for the orientation energy to be comparable to thermal energy at room temperature* (27°C).

Solution: By the problem, $\mu_m = 5\mu_B$, $T = 27 + 273 = 300$ K.

If B be the magnetic induction, the orientation energy is $\mu_B B$. The thermal energy $= kT$ where k is Boltzmann constant.

By the condition, $\mu_m B \simeq kT \Rightarrow B = kT/\mu_m$.

$$\therefore\ B = \frac{kT}{\mu_m} = \frac{kT}{5\mu_B} = \frac{1.38 \times 10^{-23} \times 300}{5 \times 9.27 \times 10^{-24}}$$
$$= 89.32 \text{ Wb/m}^2 \simeq \mathbf{90\ Wb/m^2}$$

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