Quadrant II- Notes

Programme: Bachelor of Science

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Paper Title: Properties and Processes of Molecular Chemistry

Unit: 02

Module Name: Measurement of Magnetic Susceptibility by Quincke's method

Module No.: 05

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Magnetic Susceptibility:

- It is a measure of how much a material will become **magnetized** when placed in an **applied magnetic field.**

Experimental methods for the determination of Magnetic Susceptibility:

- Various methods are used for the measurement of magnetic susceptibility can be grouped under two main heads:

(a) **Non-uniform field methods.**

(b) **Uniform field methods.**

One of the uniform field methods for determination of magnetic susceptibility is **Quincke's method.**

Determination of Magnetic Susceptibility (χ) by Quincke's method:

- In 1885, **Quincke's** adopted a method for susceptibility measurements strictly suitable for **liquids, aqueous solutions and some liquified gases.**
- **Example of liquid samples: $MnSO_4$, $FeCl_3$ solution**

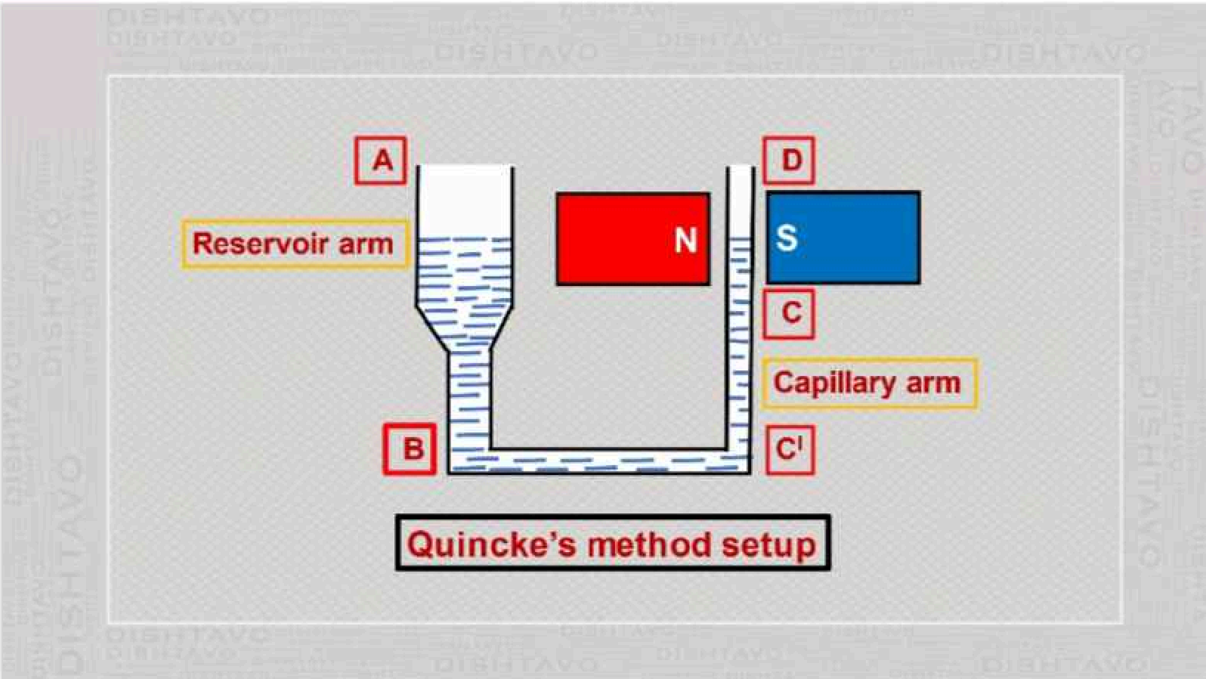
- It is a **uniform magnetic field method.**

Principle:

- The magnetic field exerted on the liquid sample, when placed in the magnetic field varies directly as its mass.
- The **force** acting on the liquid sample is measured in terms of **hydrostatic pressure.**
- When field is applied, the **meniscus will fall** if the liquid is **diamagnetic** or **will rise** if the liquid is **paramagnetic.**

Apparatus:

- This apparatus makes use of specially designed **U tube (ABC^{I}CD).**
- The wider arm acts as a **reservoir for the liquid** from where the liquid is filled in the apparatus.
- The limb C'D is a capillary tube placed in a **uniform magnetic field of strength 25,000 Oersted.**
- The field near the wider end of the tube (end C^{I}) is **50-100 Oersted which is quite negligible.**



Procedure:

1. The liquid is filled in the tube **through the reservoir arm.**
2. The **initial level of the liquid** is recorded.
3. The liquid meniscus **will rise if the liquid sample is paramagnetic.**
4. The liquid level **will fall if the liquid sample is diamagnetic.**
5. The difference between **initial and final height gives Δ h.**

Theory:

- There are **two mechanical forces** acting on the sample:

(i) The force acting on the body due to its **permanent magnetism.**

(ii) The force due to **induced magnetism.**

The magnetic force acting on the sample is given by,

$$F_1 = \frac{1}{2} (\kappa_1 - \kappa_2) . (H_1^2 - H_2^2) . A \longrightarrow (1)$$

κ_1 and κ_2 are volume susceptibilities of **liquid and the vapor above it** respectively.

H_1 and H_2 are **the maximum and minimum field intensities**

A is the **area of cross-section of the sample.**

In practice **H_2 is made negligible** by proper adjustments.

Thus equation (1) becomes,

$$F_1 = \frac{1}{2} (\kappa_1 - \kappa_2) . H_1^2 . A \longrightarrow (2)$$

Suppose **Δ h is the change in the height of the meniscus.**

The corresponding **hydrostatic pressure** is given by,

$$p = \rho . g . \Delta h$$

But **Force = pressure x area**

Thus, $F_2 = \rho . g . \Delta h . A \longrightarrow (3)$

Equating equation (2) and (3), we get,

$$\rho \, . \, g \, . \, \Delta h \, . \, A = \frac{1}{2} (\kappa_1 - \kappa_2) \, . \, H_1^2 \, . \, A$$

Cancelling and rearranging the terms, we get,

$$\kappa_1 - \kappa_2 = \frac{2 \, \rho \, . \, g \, . \, \Delta h}{H_1^2}$$

$$\frac{\kappa_1}{\rho} - \frac{\kappa_2}{\rho_0} \, . \, \frac{\rho_0}{\rho} = \frac{2 \, . \, g \, . \, \Delta h}{H_1^2} \longrightarrow (4)$$

where ρ is the **density of the liquid** and ρ_0 is the **density of the vapor**.

Substitute $\frac{\kappa}{\rho} = \chi$ = **mass susceptibility** in equation (4)

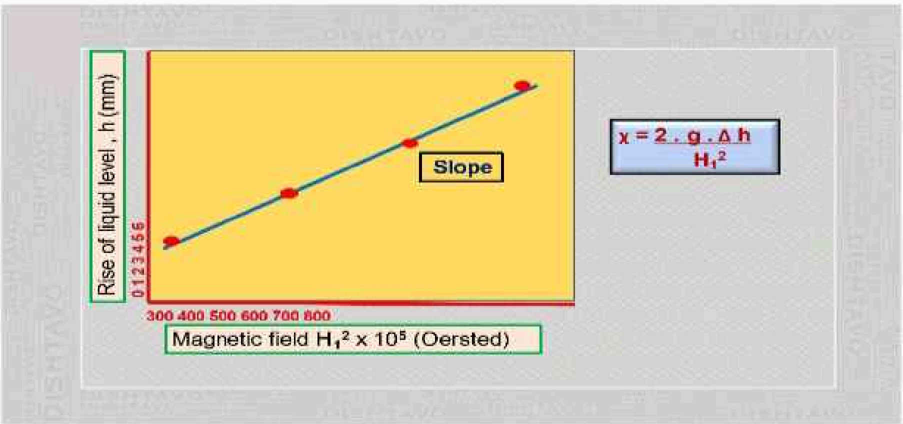
$$\chi - \chi_0 \, . \, \frac{\rho_0}{\rho} = \frac{2 \, . \, g \, . \, \Delta h}{H_1^2} \longrightarrow (5)$$

where χ and χ_0 are the **mass susceptibilities of liquid and vapor respectively.**

Neglecting the **mass susceptibility of the vapor,** equation (5) becomes,

$$\chi = \frac{2 \, . \, g \, . \, \Delta h}{H_1^2} \longrightarrow (6)$$

- So, by plotting **h vs.** H_1^2 we will get a straight line from whose **slope =** h/H_1^2 can be determined.
- Hence χ of the solution can be calculated.



Advantages:

1. No need to measure the **density of the liquid separately.**

2. The susceptibility of **liquid sample** can be measured with reference to **standard substance** under identical conditions.

$$\frac{\chi_s}{\chi_r} = \frac{(\Delta h)_s}{(\Delta h)_r}$$

$$\chi_s = \chi_r \frac{(\Delta h)_s}{(\Delta h)_r}$$

- X_s **is magnetic susceptibility of liquid sample.**
- X_r **is magnetic susceptibility of reference substance**