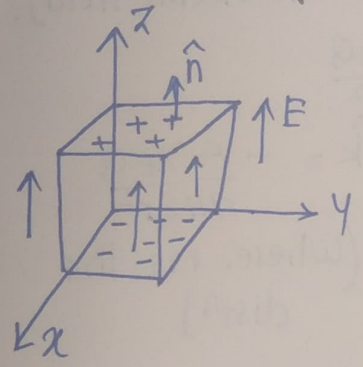
Q. Consider a cube of volume $1cm^3$ which is filled with liquid He (density $= 0.14 g/cm^3$). An electric field is applied in the z-direct^n & because of field the electron in each atom shift by 0.1nm opposite to the field direction.

Find a) dipole moment induced in each atom

b) the polarization vector

&c) bound charge induced on the surface.



We know that,

He contain $2e^-$ & atomic mass $= 4g$.

the shift because of field results in displacement of e^- in -ve z-direction.

as, $+2e^-$ (+ve charge) & $-2e^-$ displaced by 0.1nm.

i.e. $+2e^-$ ($Nu^{\oplus}$)

$\updownarrow$ } 0.1nm $= 0.1 \times 10^{-9} m$.

$-2e^-$ (electron)

a) Dipole moment of each atom is

$$p = qd = (2e) \times (0.1nm) = 2 \times 1.6 \times 10^{-19} C \times 0.1 \times 10^{-9} m$$

$$= 3.2 \times 10^{-29} Cm.$$

b) As given, density is $0.14 g/cm^3$. & vol. of cube is $1 cm^3$.

So we can say that,

over $1 cm^3$ vol. there is 0.14g mass of He.

Now, 4g is atomic mass of He which contain 6.022×10^{23} atoms

$\therefore$ 0.14g have $\Rightarrow \frac{6.022 \times 10^{23} \times 0.14}{4}$ atoms.

$\therefore$ Total dipole moment of cube $(p_{Total}) = \frac{6.022 \times 10^{23} \times 0.14}{4} \times 3.2 \times 10^{-19}$

$$= 6720 Cm$$

b) Polarization ($\vec{P}$) = $\frac{\text{Total dipole moment}}{\text{Volume}}$ also $P = \varepsilon_0 \chi_e E$
↳ electric susceptibility.

$= \frac{6720\,Cm}{10^{-6}\,m^3} = 6720 \times 10^6\,C\,m^{-2}$

$= 6.72 \times 10^9\,C\,m^{-2}$

– (as $\hat{n}$ points same as direct^n to electric field).

c) Now, bound charge, $\sigma_b = \vec{P} \cdot \hat{n}$

σ_b = P. (upper surface) $= +P\hat{k} = \frac{\varepsilon_0 \chi_e Q}{4\pi\varepsilon r^2}$

σ_b = P. (lower surface) $= -P(-\hat{k}) = -P\hat{k} = -\frac{\varepsilon_0 \chi_e Q}{4\pi\varepsilon r^2}$

elsewhere the bound charge is zero. (where, r is the dist^n)

$\therefore \sigma_b = \pm 6.72 \times 10^9\,\hat{k}$

Bound charge ⇒ charges in solid that cannot move around & conduct current.

Motivation & Significance →

- Dielectric materials are poor conductors of electricity because, they don't have any loosely bound / free e⁻ that may drift through material. e⁻ required to support the flow of electric current.
- Dielectric material support dielectric polarization, which enables them to act as dielectrics rather than conductors.

But, dielectric are different from isulator in sense, dielectric can develop an internal electric field & *nullifies* external electric fie but insulators can't develop an electric field.

- Use of dielectric as they have ability to store charge, most commonly used for energy storage in capacitor

Note → if in problem, ε (permittivity) is given then one can calculate it from that,

$$\varepsilon \equiv \varepsilon_0 (1 + \chi_e)$$

from this we get χ_e value then from this we can calculate P (polarization) from that bound charge.