CERAMIC AND COLLOIDAL PROCESSING - EXERCISES

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Exercises 7

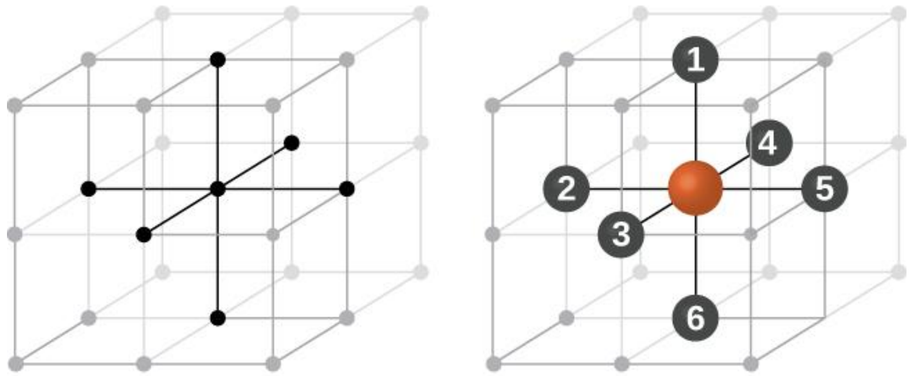
1. Calculate the surface tension of a liquid at temperature, *T* knowing its molar mass *MM*, its density ρ as well as the values of W_{AA} and z_b. Example: perform the calculation for CCl_4 (*MM* = 153.82 g/mole) at 25°C,

With, ρ = 1.6×103 [kg/m^3], W_{AA} = –1.78×10–20 [J/bond] and z_b = 6.

Note: Assume for simplicity that the CCl_4 molecules form a simple cubic structure in the liquid phase. (length of unit cell = side of cube = c= $((MM/\rho)/(N_A))^{1/3}$

Solution.

By transferring a liquid molecule from the bulk to the surface, its coordination changes from z_b = 6 to z_s = 5. i.e. central orange atom below as bulk Z_b = 6 and atom 1 for surface, z_s = 5.



Knowing the density and assuming for simplicity a simple cubic arrangement of molecules in the liquid, we calculate the side of the cube

$c = [(153.82\ 10^{-3}/1.6\ 10^{3})/(6.0\ 10^{23})]^{1/3} = 5.42\ 10^{-10}$ [m] = 0.542 [nm]

So the area A of a face of the cube is:

$A = c^2 = 2.94\ 10^{-19}$[m^2] = 0.294 [nm^2]

From Eq. (2.1.3) we calculate :
$E_s/A = 0.5\times(-1.78\ 10^{-20})\times(5-6)/(2.94\ 10^{-19}) = 3.02\ 10^{-2}$ [J/m^2] = 30.2 [mN/m]

2 Given the respective surface tensions of water and benzene (in air) are :

γ_{water} = 72.8 [mN / m], $\gamma_{benzene}$ = 28.9 [mN / m],

and the interfacial tension for the water / benzene interface is

$\gamma_{water / benzene}$ = 35.0 [mN / m],

calculate the initial water – benzene spreading coefficient.

After equilibration, a little benzene dissolves in the water which brings its surface tension to γ_{water} = 62.4 [mN / m]. What happens to the water-benzene spreading coefficient?

Solution.
Using Equation 2.1.15b –

$$S_{SL} = -\Delta G_{SL} = (\gamma_{SV} - \gamma_{SL}) - \gamma_{LV}$$

S(init.) = 72.8 – (28.9 + 35.0) = 8.9 [mN/m] > 0 : benzene spread on water ;
S(eq.) = 62.4 – (28.9 + 35.0) = –1.5 [mN/m] < 0 : benzene no longer spreads on water.

3. Capillary Rise
Determine the height h [cm] that a liquid rises in a capillary tube, knowing γ_{LV}, the surface tension of the liquid, ρ_L, the density of the liquid, r, the internal radius of the tube, and θ, the wetting angle of the tube wall by the liquid.

Example: the liquid is water (γeau = 72.8 [mN / m], MM = 18.02 [g / mole], ρ = 1'000 [kg / m^3]), the wetting angle θ = 20 °, and the radius of the capillary r = 0.10 [mm].

Solution.

Equation (2.2.4) gives, after transformation:

$h = 2\gamma_{LV} \cos\theta / \Delta\rho g r$;

$\Delta\rho = \rho_L - \rho_V \cong \rho_L \Rightarrow h = 2\gamma_{LV} \cos\theta / \rho_L g r$

thus :

$h = 2\gamma_{LV} \cos\theta / \rho_L g r = 2 \times 72.8 \times 10^{-3} \cos(20°) / 1'000 \times 9.81 \times 1.0 \times 10^{-5} = 0.148 \times 0.940$
= 0.139 [m] =13.9 [cm]

4. What is the Hamaker constant and its role in the attractive forces between 2 particles?

Solution.
With Van der Waals attractive forces, the intensity of the interaction energy is

$$V_A(h) = - A \cdot H$$

Where h is the separation distance between particles, H is a geometric factor and A is the Hamaker constant. This constant depends on the dielectric properties of the particles and of the medium separating them and determines the magnitude of the attractive VdW force.