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Appendix: The derivation of the energetic terms ΔG_i ($i = \overline{1,3}$) describing the micellar process (eq. 3)

Contributions to ΔG include¹⁶ the energy required to form a cavity in the solvent, which will be occupied by the micelle (ΔG_1), the energy needed to bring the hydrophobic moieties of the interacting molecules together to fill this cavity (ΔG_2) and the energy cost for placing the hydrophilic patches (the hydroxy groups) on micelle surface (ΔG_3).

ΔG_1 represents the energy required to form a cavity in the solvent that will be occupied by the micelle (see the blue marked region in Fig. 2a). This is $\Delta G_1 = \gamma A$, where A represents the surface area of the cavity and γ stands for the water-vapor surface tension. The CA units (or CA-PEG₄, for PEGylated CA systems) arrange themselves so that their hydrophobic moieties are lying toward each other, forming a hydrophobic cavity (see the magenta marked region in Fig. 2a) that can contains n_w water molecules. In the spherical symmetry approximation, the radius (R) and surface area (A) of the micelle can be approximated by $R \cong (3/4\pi(nV_{CA} + n_w v_w))^{1/3}$ and $A \cong (6\pi^{1/2}(nV_{CA} + n_w v_w))^{2/3}$, respectively. Here V_{CA} is the molecular volume of the CA molecule, $V_{CA} \cong ASA\delta$, and $v_w \sim a_w^3$ stands for the volume of a water molecule. Therefore, we can write $\Delta G_1 = \gamma A \cong 4.84\gamma(nV_{CA} + n_w v_w)^{2/3}$.

ΔG_2 is the energy needed to bring the interacting molecules together to fill the cavity, which is given by $\Delta G_2 \cong -n\Delta\mu_{CA} - \Delta\gamma A$, where $\Delta\gamma = \gamma - \gamma_{ow}$ with γ_{ow} standing for the interface tension between water and hydrophobe ($\gamma > \gamma_{ow}$). The surface area A is approximated by $A \cong (6\pi^{1/2}(nV_{CA} + n_w v_w))^{2/3}$, as seen in above, and

$\Delta\mu_{CA}$ is given by eqn. 2. ΔG_2 can be written as

$$\Delta G_2 \cong -n\Delta\mu_{CA} - 4.84(\gamma - \gamma_{ow})(nV_{CA} + n_w v_w)^{2/3}.$$

Finally, ΔG_3 reflects the energy cost for placing the polar ends on micelle surface.

Usually, this is estimated from the electrostatic analogy of stoichiometric constraints¹⁷ by $\beta\Delta G_3 \cong 1.96nL^2/\delta^2$, where δ represents the mean separation distance between polar tails and CH_3 groups and L is the radial distance occupied by surfactant molecules in the micelle (see Fig. 2a). The latter can readily be approximated by

$$L \cong R - (3/4\pi n_w v_w)^{1/3},$$

where the radius of the micelle is

$$R \cong (3/4\pi(nV_{CA} + n_w v_w))^{1/3}.$$

So that, the energy cost for placing the polar groups on the spherical hydrophobic surface can be written as

$$\Delta G_3 \cong 0.76\beta^{-1}n\delta^{-2}\left[(nV_{CA} + n_w v_w)^{1/3} - (n_w v_w)^{1/3}\right]^2$$