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Comparison of Types of Nanoscale Heterogeneity on Colloid Retention and Release at Interfaces

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Nanoscale roughness (NR) is a physical heterogeneity on all surfaces, whereas chemical heterogeneity (CH) may sometimes arise from spatial variability in charge (CH1), Hamaker constant (CH2), and contact angles (CH3). Expressions were developed to determine the mean interaction energy between a colloid and a solid-water interface, or another colloid, when both surfaces contain binary NR and CH1 or CH2 or CH3. All of these interaction energy relations considered double layer, van der Waals, Lewis acid-base, and Born interactions. The influence of nanoscale roughness and CH parameters, solution ionic strength (IS), and colloid size on predicted interaction energy profiles was then investigated. CH tended to reduce the energy barrier and create deeper primary minima on net electrostatically unfavorable surfaces. However, the role of CH was always greatest on smooth surfaces with larger amounts of CH, especially for smaller colloids and higher IS. Furthermore, CH3 was predicted to have a larger influence on colloid retention and release than CH1 or CH2. However, predicted interaction energy profiles were demonstrated to be mainly dominated by NR, which tended to lower the energy barrier height and the depths of both the secondary and primary minima, especially when the roughness fraction was small. This dramatically increased the relative importance of primary to secondary minima interactions on net electrostatically unfavorable surfaces, especially when roughness occurred on both surfaces and for conditions that produced small energy barriers on smooth surfaces. Energy balance calculations indicate that the combined influence of roughness and Born repulsion produced a shallow primary minimum that was susceptible to diffusive or hydrodynamic removal, even in the presence of significant amounts of CH.

References

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