The square well potential

The square well potential u between two spheres at separation r has the form

$$u(r) = \begin{cases} \infty, & r < 2\rho \\ \varepsilon, & 2\rho \leq r \leq s \\ 0, & r > s \end{cases}$$

(S1)

where the parameters ε and s defines the depth and outer limit of the potential well, respectively. With a mean-field approximation the square well contribution to the free energy density becomes

$$w_{el} = k_{SqW} C_s \phi_s$$

(S2)

where we have combined the two parameters into a single square well interaction parameter $k_{SqW} \equiv 4\varepsilon \left(\left(\frac{s}{2\rho} \right)^3 - 1 \right)$. With equation (S2) in place of (5) we get the following in place of figure 7, which is qualitatively identical to what results from the capacitor model. Thus, our conclusions are not sensitive to the exact form of the attractive potential.
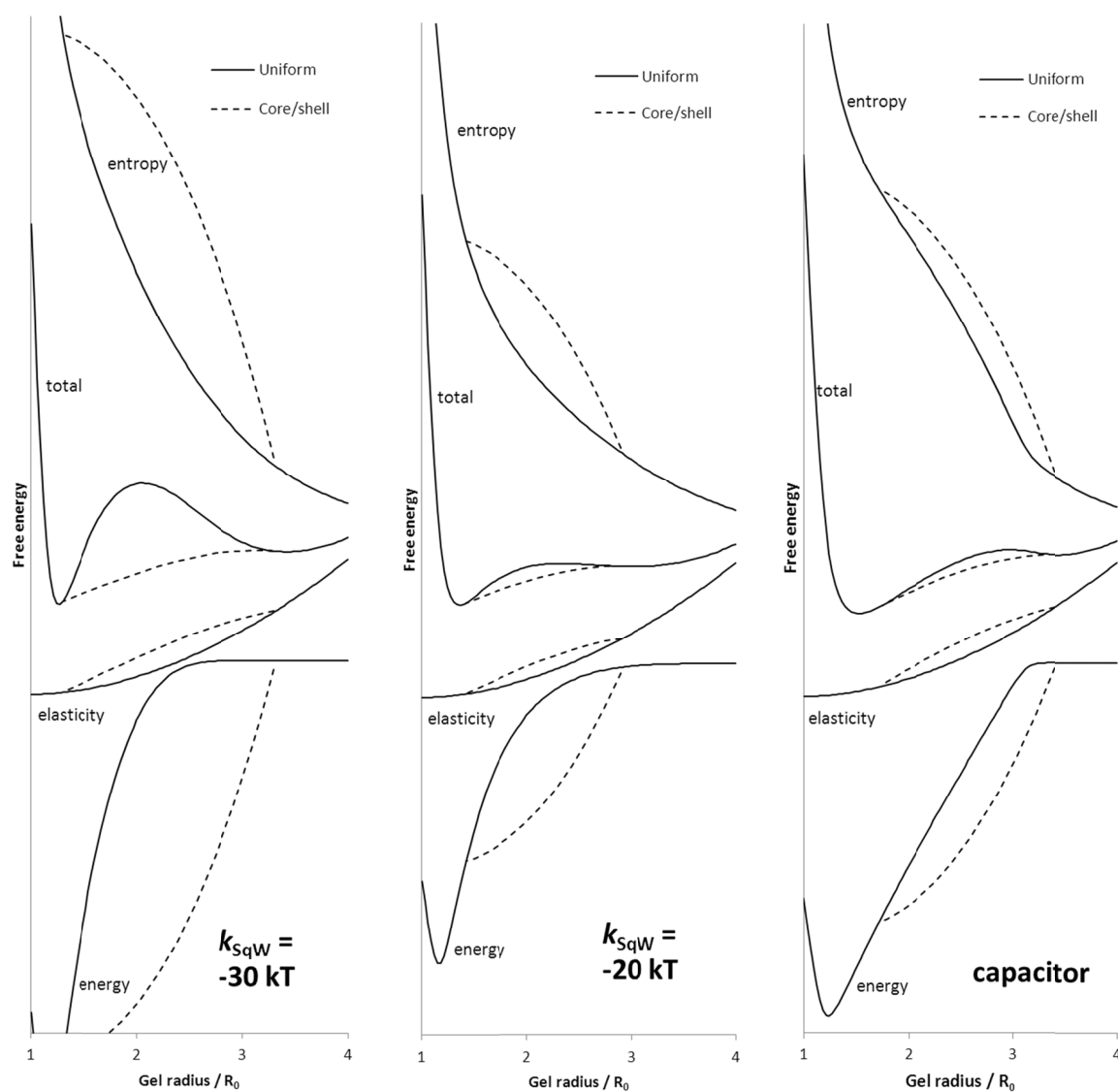
Figure S1: The free energy and its components with a square well potential instead of the capacitor energy. The interaction parameters correspond roughly to a well width of one sphere radius and depth of -3 and -2 kT, respectively. Taken at their respective shell formation concentrations.