

**Dynamics and Thermodynamics of Water around EcoRI Bound to a Minimally Mutated  
DNA Chain**

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**SUPPLEMENTARY INFORMATION**

## TABLES

Table S1. Average number of waters in the interface and intercalating regions.

	Intercalating	Interfacial
<b>Cognate complex</b>	148 ± 10	2375 ± 9
<b>Noncognate Complex</b>	146 ± 2	2507 ± 5

Table S2. Average number of water molecules that have a minimum residence time of  $t$  ps simulation in the two regions

	Intercalating $t = \text{mean residence time}$	Interfacial $t = 2\text{ns}$
<b>Cognate complex</b>	42	65
<b>Noncognate Complex</b>	29	90

Figure S1. Second-rank dipole moment reorientational correlation function for interfacial waters

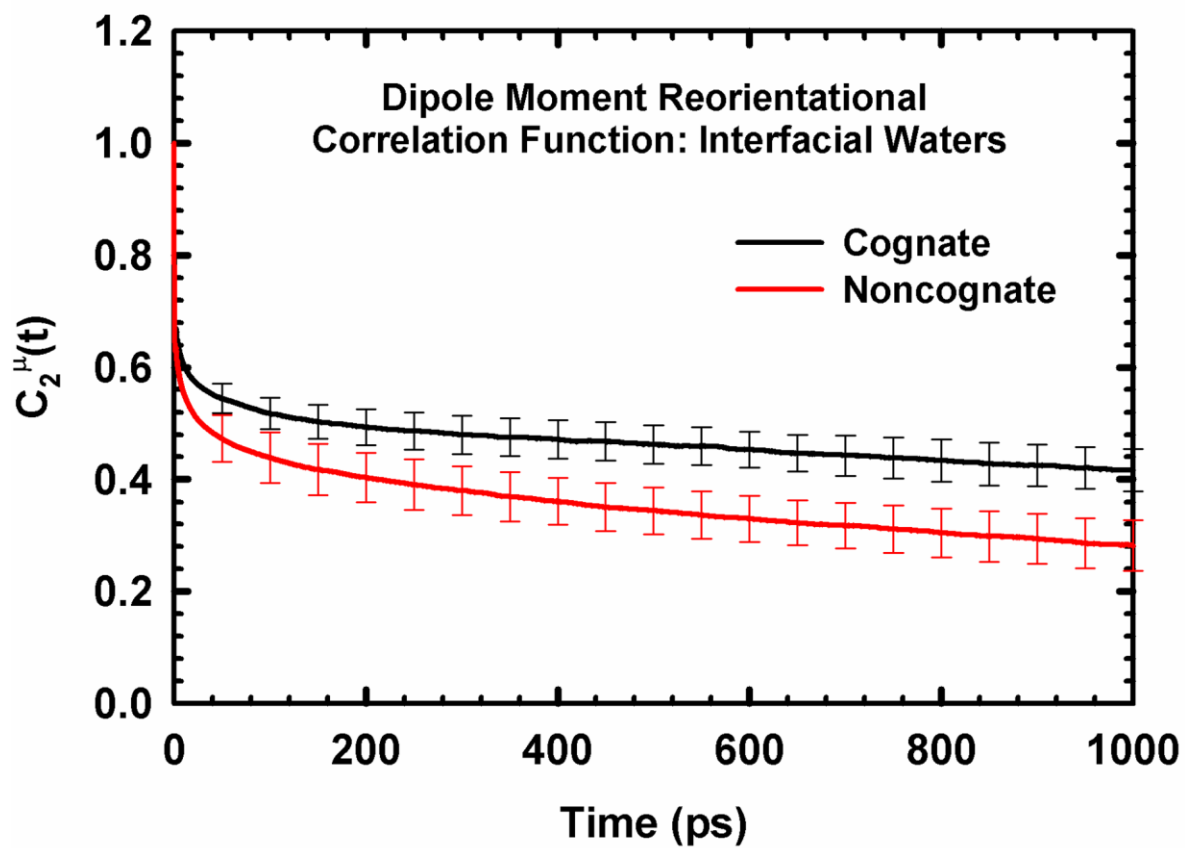


Figure S2. Second-rank dipole moment reorientational correlation function for intercalating waters

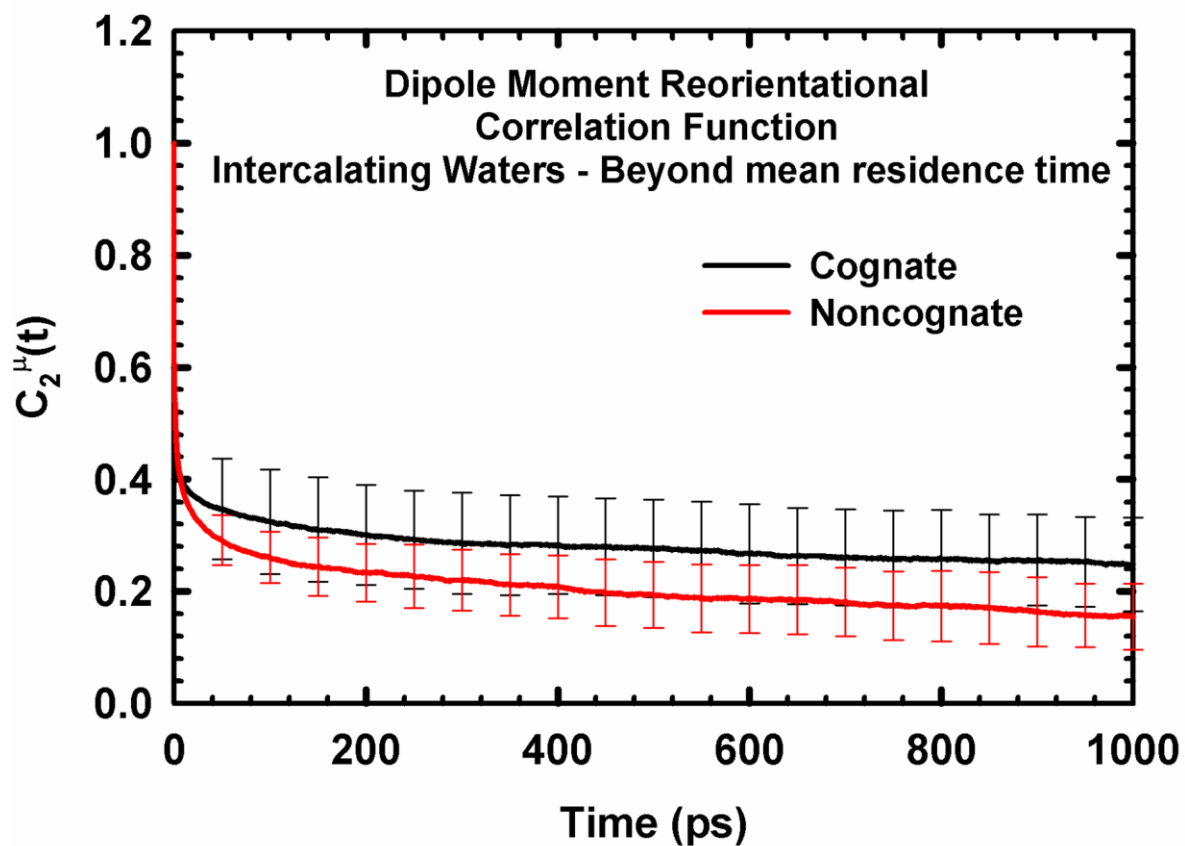
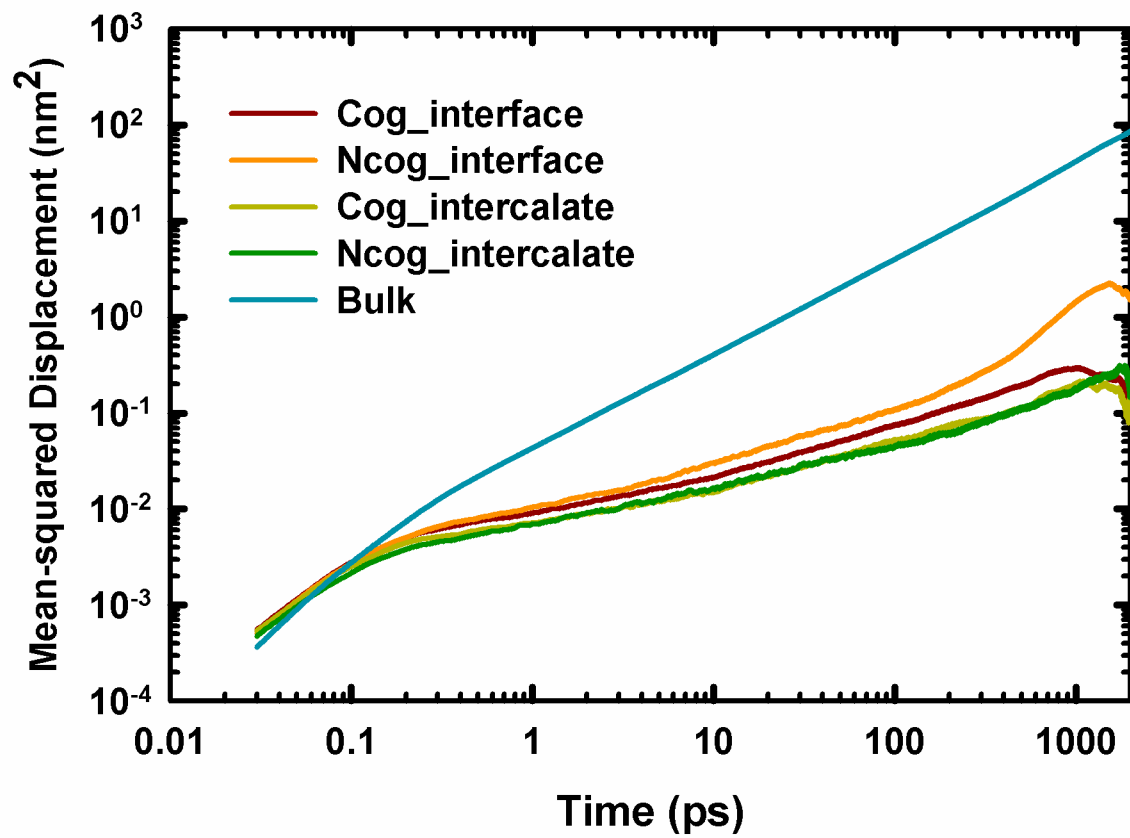


Figure S3. Mean-squared displacement of water molecules in the interfacial and intercalating regions.



## 2PT Theory for Calculating Thermodynamic properties from MD Trajectories

The density of states of a system  $g(\nu)$  is given as the Fourier transform of the velocity autocorrelation function:

$$g(\nu) = \frac{2}{kT} \lim_{\tau \rightarrow \infty} \int_{-\tau}^{\tau} C(t) e^{-i2\pi\nu t} dt \quad (1)$$

where  $C(t)$  is the mass-weighted translational velocity autocorrelation function or the moment-of-inertia-weighted angular velocity autocorrelation function (see<sup>1-3</sup>),  $k$  is the Boltzmann constant, and  $T$  is the absolute temperature. In the 2PT model, the density of state  $g(\nu)$  of a system with  $3N$  degrees of freedom is assumed to be partitioned into a gas-like component  $g^g(\nu)$  and solid-like component  $g^s(\nu)$ , i.e.,

$$g(\nu) = g^g(\nu) + g^s(\nu) \quad (2)$$

A thermodynamic property  $P$  of a system can then be determined by weighting the individual components as follows:

$$P = \int_0^{\infty} g^s(\nu) W_p^{HO}(\nu) d\nu + \int_0^{\infty} g^g(\nu) W_p^g(\nu) d\nu \quad (3)$$

where  $W_p^{HO}(\nu)$  is the weighting function for the solid phase based on the harmonic oscillator model and  $W_p^g(\nu)$  is the weighting function corresponding to the choice of gas component. The gas-like component can be taken to be a hard-sphere fluid, for which the density of states can be written as<sup>3</sup>

$$g^g(\nu) = g^{HS}(\nu) = \frac{g_0}{1 + \left[ \frac{\pi g_0 \nu}{6fN} \right]^2} \quad (4)$$

where  $g_0$  is equal to  $g(\nu=0)$ ,  $f$  is the fluidity factor and  $N$  is the number of molecules. The factor  $f$  is a measure of the “fluidity” of the system and indicates the departure of the state of system from the two extremes, namely, the gas-like and solid-like states. Thus,  $f$  needs to satisfy two conditions: (i) At high temperatures and in the low-density limit, the system behaves like a gas, here taken to be a hard-sphere gas. Hence,  $f$  should be equal to 1. (ii) At the high-density limit, the system becomes a solid, and hence,  $f = 0$ . Therefore,  $f$  determines the apportioning of the chosen property of the liquid phase in terms of the corresponding values for the solid state and the gas state. One can write  $f$  as<sup>3</sup>:

$$f = \frac{D(T, \rho)}{D_0^{HS}(T, \rho; \sigma^{HS})} \quad (5)$$

which satisfies the above two conditions. In the above equation,  $D(T, \rho)$  is the self-diffusion coefficient of the molecules and is obtained from the zero-frequency intensity of density of states as:

$$D_{Trans} = \frac{kTg(\nu = 0)}{12mN} \quad (6)$$

for translational diffusion (where  $m$  is the mass of the water molecule) and

$$D_{Rot} = \frac{kT \sum_{j=1}^3 g^j(\nu = 0)}{4N \sum_{j=1}^3 I_j} \quad (7)$$

for rotational diffusion (where  $I_j$  is the moment of inertia along the  $j$ th principal axes). The denominator in Eq. (5) is the hard-sphere diffusion coefficient in the zero-pressure limit.

Lin et al.<sup>3</sup> developed a universal equation for  $f$  which bypasses the need for estimating  $D_0^{HS}$  (and hence  $\sigma_{HS}$ ), and the equation is given as

$$2\Delta^{-9/2} f^{15/2} - 6\Delta^{-3} f^5 - \Delta^{-3/2} y^{7/2} + 6\Delta^{-3/2} f^{5/2} + 2f - 2 = 0 \quad (8)$$

where  $\Delta$ , the normalized diffusivity, is a function of the material properties and is given as

$$\Delta(T, \rho, m, g_0) = \frac{2g_0}{9N} \left( \frac{\pi kT}{m} \right)^{1/2} \rho^{1/3} \left( \frac{6}{\pi} \right)^{2/3} \quad (9)$$

Thus, once  $g_0 (= g(\nu = 0))$  and  $f$  are determined, one can determine  $g^g$  and  $g^s (g^s = g - g^g)$ .

Once the individual components of the density of states are determined, one can use Eq. (3) to obtain the thermodynamic properties. The quantum weighting functions in Eq. (3) for the solid-like component are given as follows.

$$W_E^Q(\nu) = \frac{\beta h \nu}{2} + \frac{\beta h \nu}{\exp(\beta h \nu) - 1} \quad (10)$$

$$W_S^Q(\nu) = \frac{\beta h \nu}{\exp(\beta h \nu) - 1} - \ln[1 - \exp(-\beta h \nu)] \quad (11)$$

$$W_A^Q(\nu) = \ln \left( \frac{1 - \exp(\beta h \nu)}{\exp(-\frac{\beta h \nu}{2})} \right) \quad (12)$$

The quantum weighting functions for the gas-like component are given as:

$$W_E^g(\nu) = W_E^{HS}(\nu) = 0.5 \quad (13)$$

$$W_S^g(\nu) = W_S^{HS}(\nu) = \frac{1}{3} \frac{S^{HS}}{k} \quad (14)$$

$$W_A^g(\nu) = W_A^{HS}(\nu) = W_E^{HS}(\nu) - W_S^{HS}(\nu) \quad (15)$$

The energy  $E$ , entropy  $S$ , and Helmholtz free energy  $A$  for a canonical ensemble can then be determined as

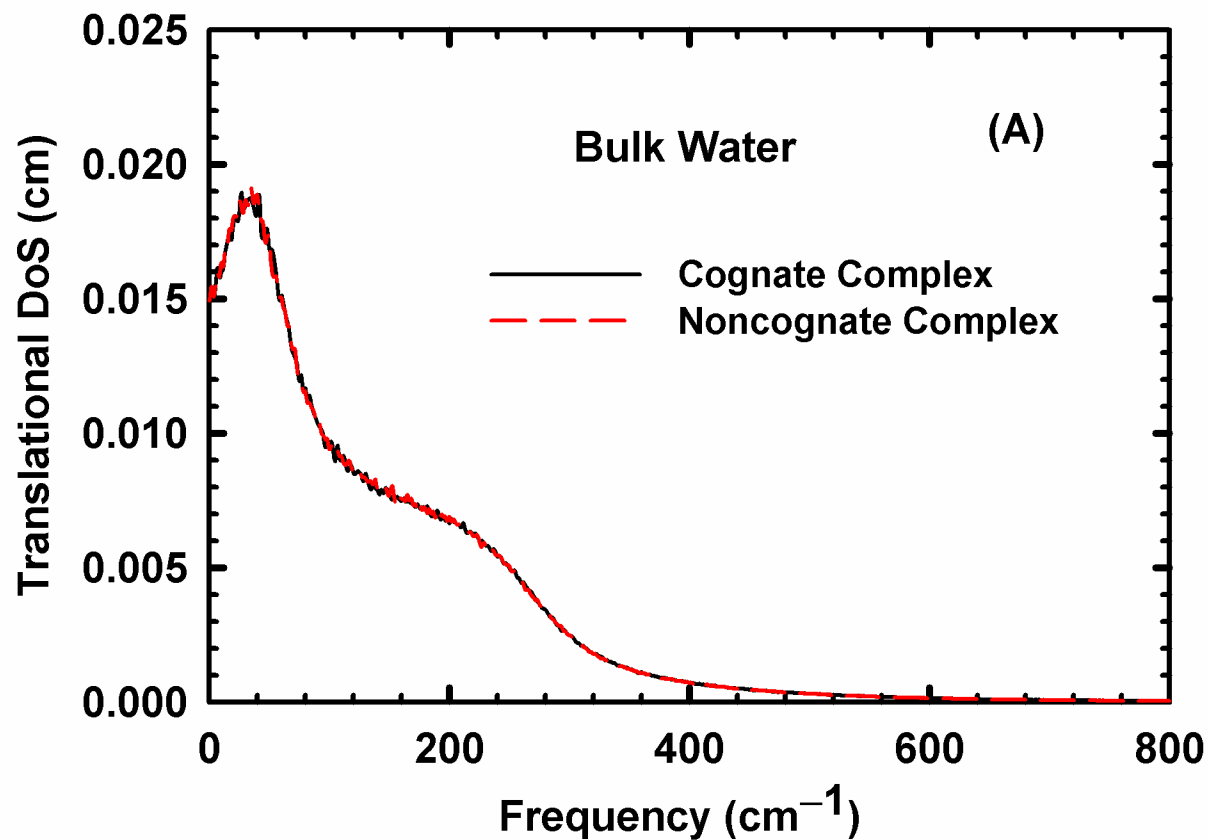
$$E = V_0 + \beta^{-1} \int_0^{\infty} g(\nu) W_E^g(\nu) d\nu \quad (16)$$

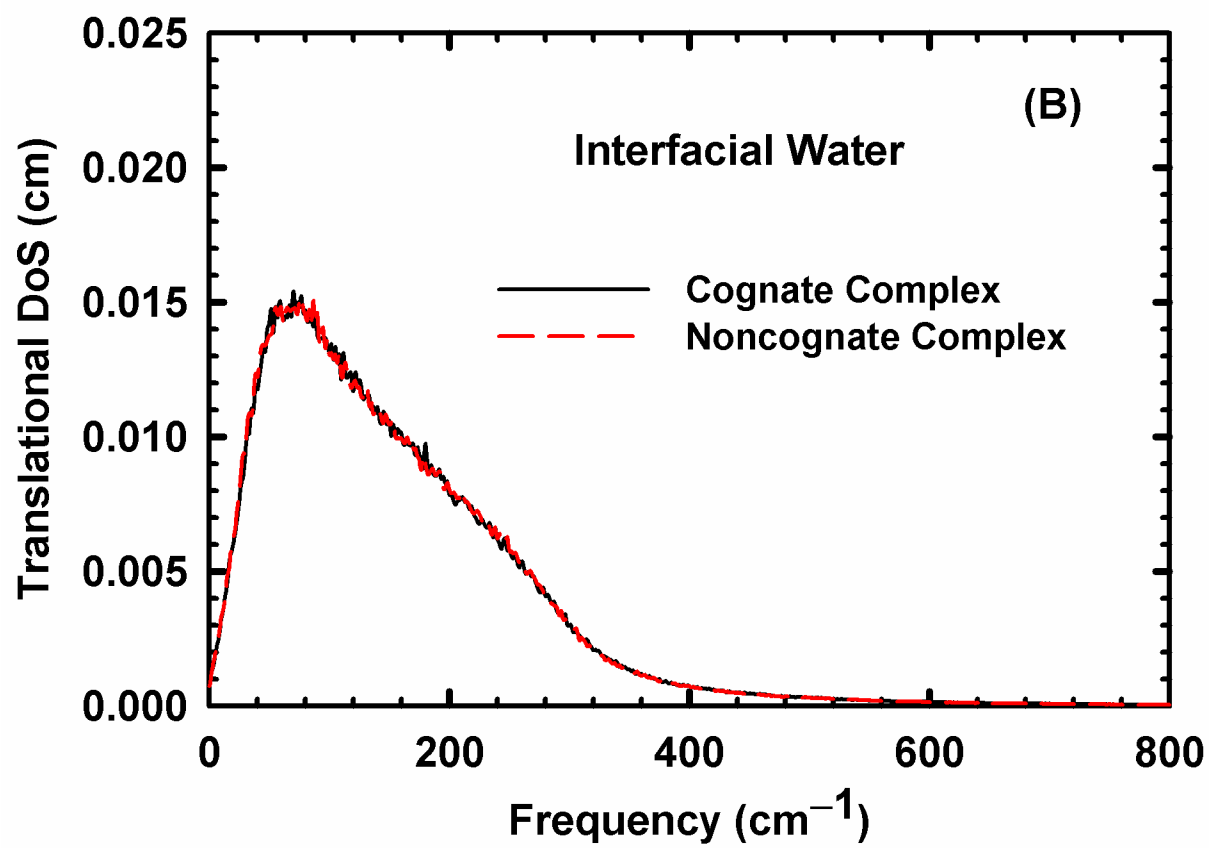
$$S = k \int_0^{\infty} g(\nu) W_S^g(\nu) d\nu \quad (17)$$

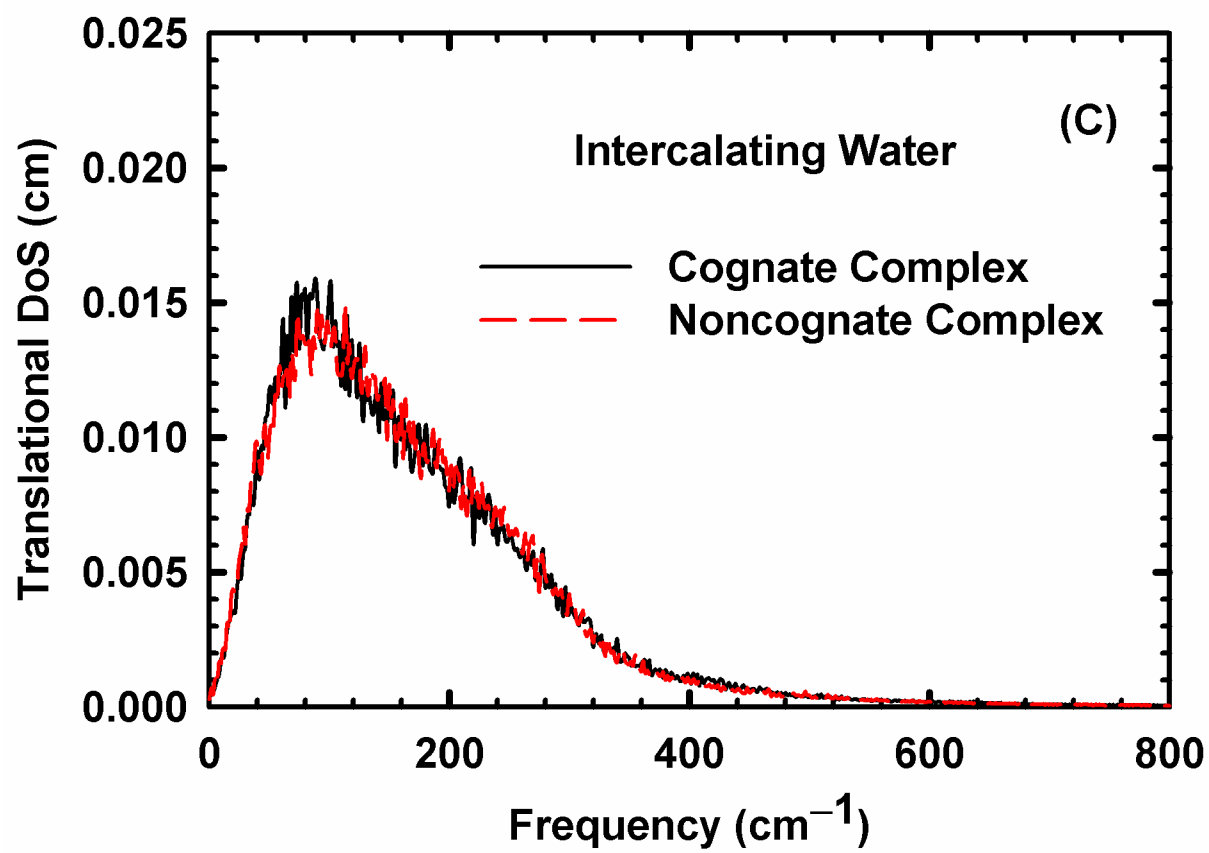
$$A = V_0 + \beta^{-1} \int_0^{\infty} g(\nu) W_A^g(\nu) d\nu \quad (18)$$



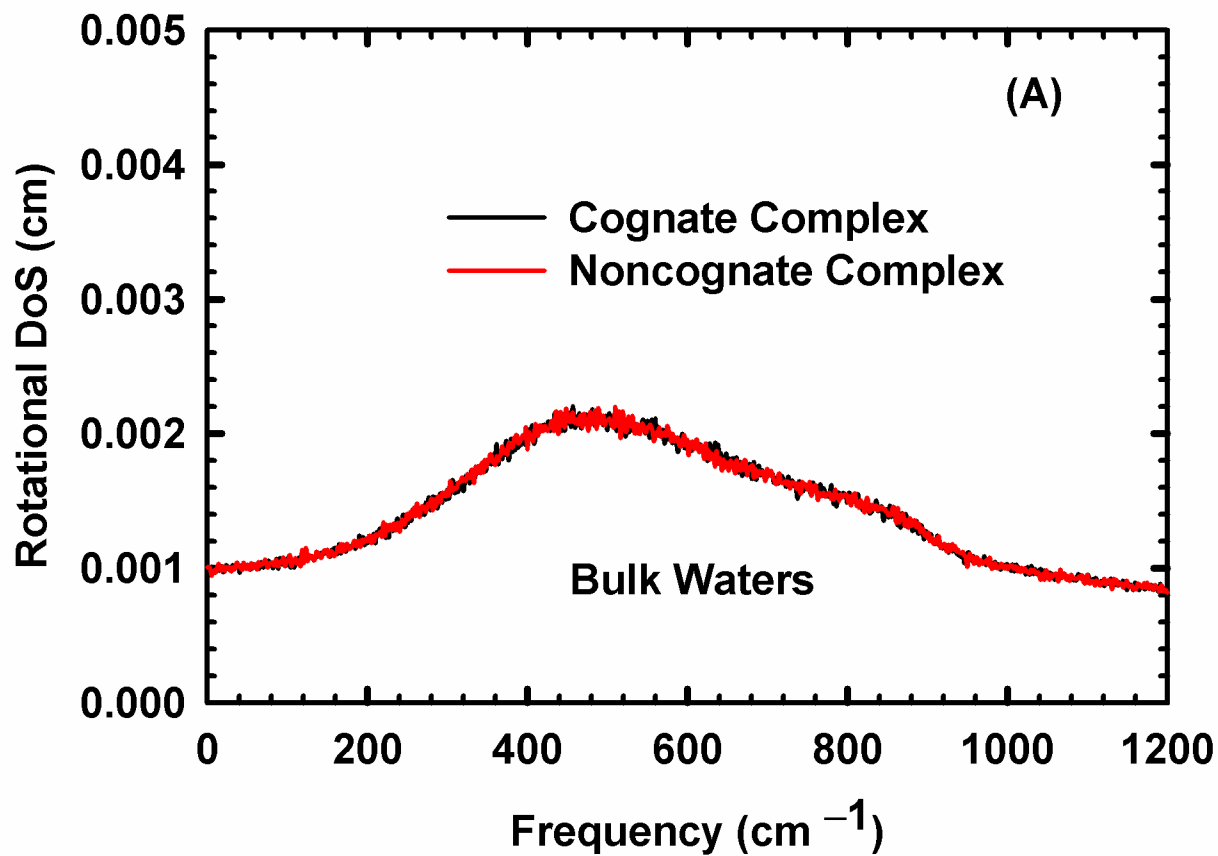
**Figure S4.** Comparison of the translational density of states spectrum of bulk (A), interface (B) and intercalating waters (C) in the cognate and noncognate complexes.

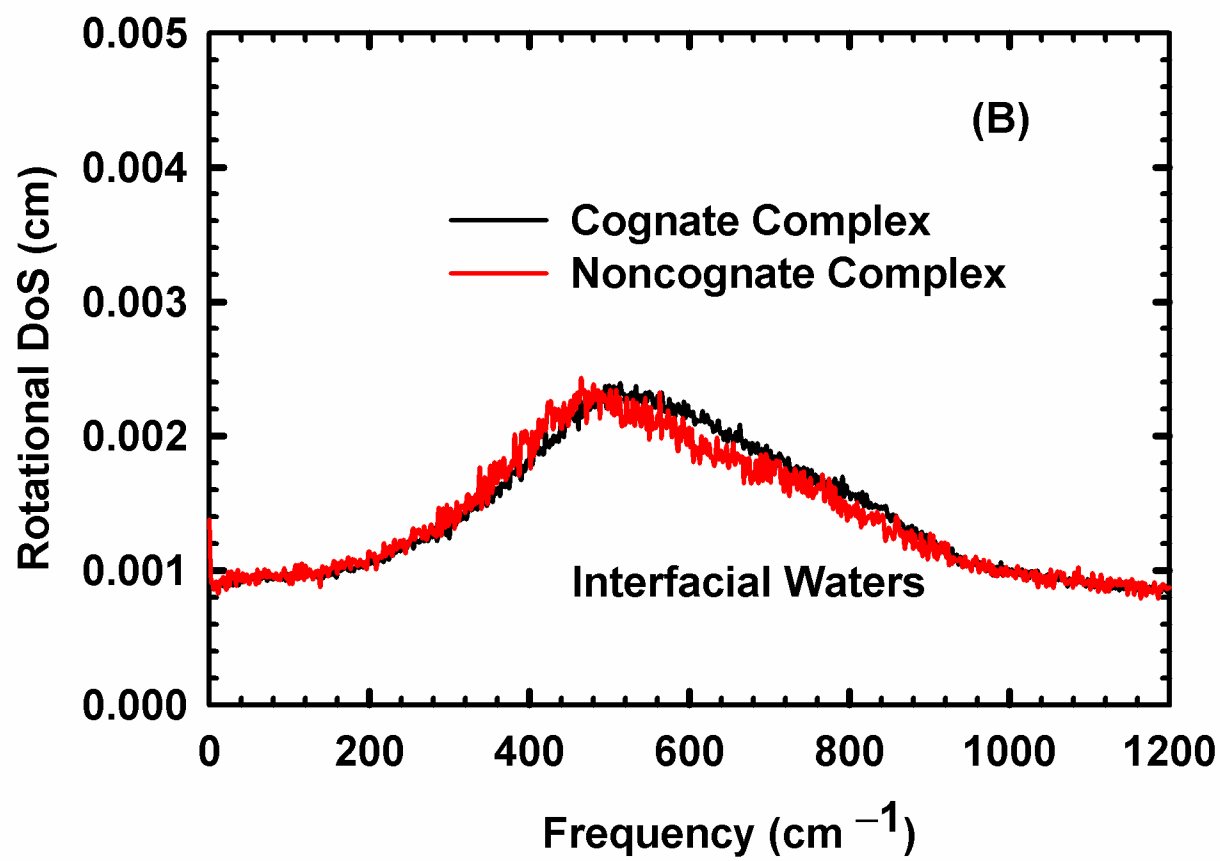


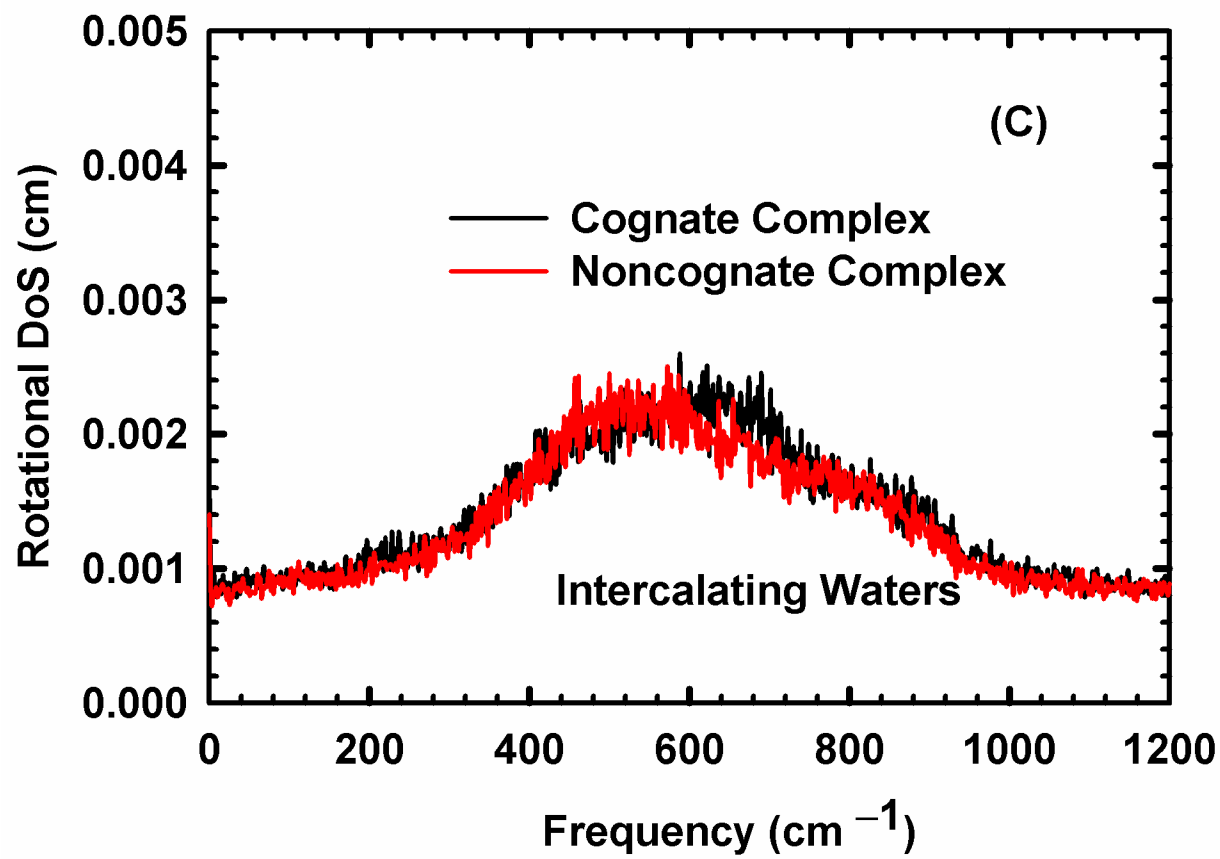




**Figure S5.** Comparison of the rotational density of states spectrum of bulk (A), interface (B) and intercalating waters (C) in the cognate and noncognate complexes.







**Table S3.** Comparison of the exponent  $\alpha$  (from mean-squared displacement of water molecules as a function of time) in the interface and the intercalating regions of the cognate and noncognate complexes show the sublinear diffusion in these regions.

		$\alpha$
Interface	Cognate	$0.58 \pm 0.07$
	Noncognate	$0.62 \pm 0.02$
Intercalate	Cognate	$0.55 \pm 0.09$
	Noncognate	$0.54 \pm 0.05$
Bulk		$1.00 \pm 0.03$

**Table S4a.** Comparison of the translational entropy (J/mol/K) of the intercalating, interfacial and bulk waters in the cognate and noncognate complexes.

	Intercalating Water	Interfacial Water	Bulk Water
GAATTC Complex	$36.68 \pm 1.42$	$40.40 \pm 0.80$	$56.62 \pm 0.24$
TAATTC Complex	$36.32 \pm 0.84$	$40.60 \pm 0.60$	$56.73 \pm 0.29$

**Table S4b.** Comparison of the rotational entropy (J/mol/K) of the intercalating, interfacial and bulk waters in the cognate and noncognate complexes.

	Intercalating Water	Interfacial Water	Bulk Water
GAATTC Complex	$6.69 \pm 0.07$	$7.06 \pm 0.04$	$7.87 \pm 0.06$
TAATTC Complex	$6.56 \pm 0.12$	$7.13 \pm 0.10$	$7.88 \pm 0.03$

**Table S4c.** Comparison of the average interaction energy (kcal/mol) of the intercalating, interfacial and bulk waters in the cognate and noncognate complexes.

	Intercalating Water	Interfacial Water	Bulk Water
GAATTC Complex	$-11.04 \pm 0.11$	$-10.05 \pm 0.06$	$-9.52 \pm 0.03$
TAATTC Complex	$-10.98 \pm 0.26$	$-10.26 \pm 0.18$	$-9.51 \pm 0.04$

## References

- 1 B. Jana, S. Pal, P. K. Maiti, S.-T. Lin, J. T. Hynes and B. Bagchi, *Journal of Physical Chemistry B*, 2006, 110, 19611-19618.
- 2 S.-T. Lin, P. K. Maiti and W. A. Goddard, *Journal of Physical Chemistry B*, 2010, 114, 8191-8198.
- 3 S.-T. Lin, M. Blanco and W. A. Goddard, *Journal of Chemical Physics*, 2003, 119, 11792-11805.