pH-Dependent Phase Behaviour of Carbohydrate-based Gemini Surfactants. The Effects of Carbohydrate Stereochemistry, Head Group Hydrophilicity and Nature of the Spacer.

Supplementary Information

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Effects of the number of hydroxy groups in the carbohydrate head group

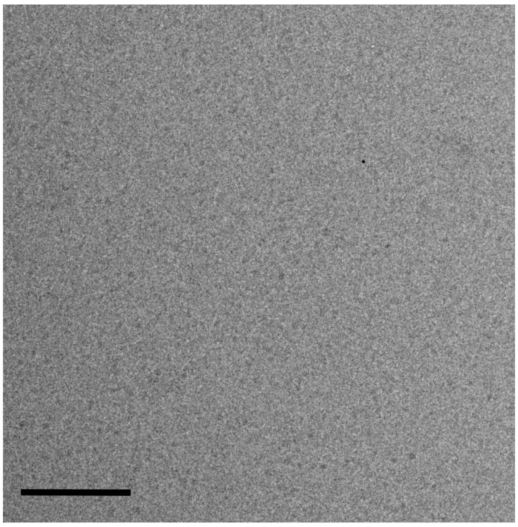

Figure 1. Cryo-electron microscopy pictures of **2** equilibrated over night at pH 2.88. Bar represents 100 nm.

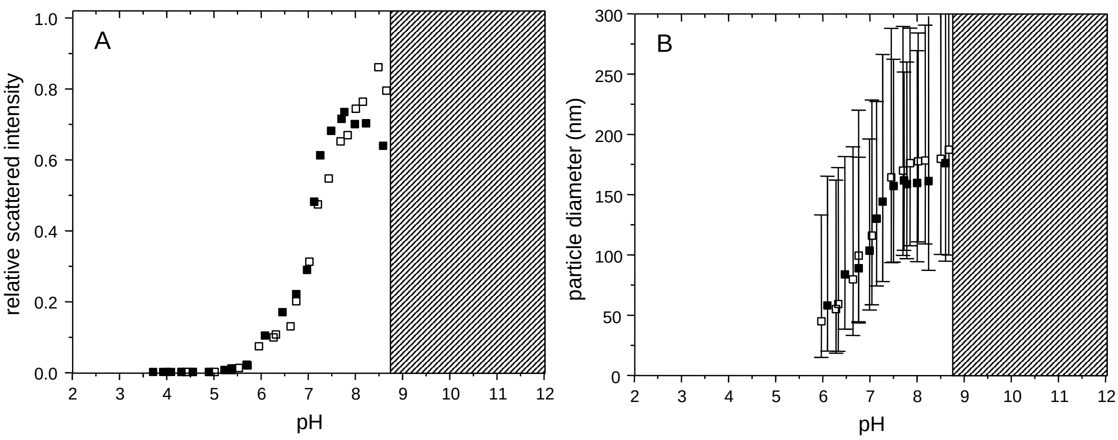

Figure 2. Relative scattered intensity (A) and size distributions (B) of solutions containing gemini amphiphile **3** as a function of pH. Error bars denote the width of the size distribution.[1] Different symbols represent independent experiments starting from stock solutions prepared at near neutral pH. Lined bar denotes the pH region where data could not be obtained due to flocculation.

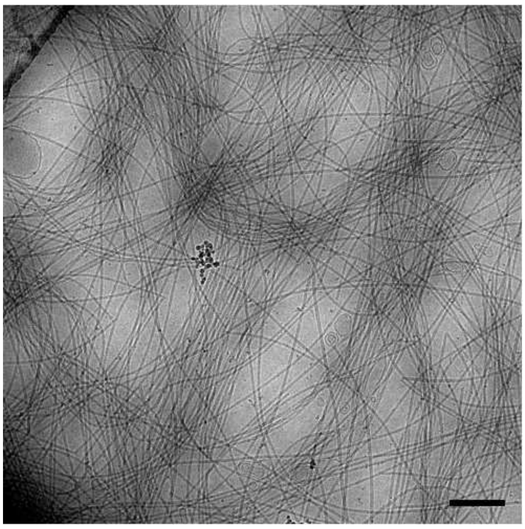

Figure 3. Cryo-electron microscopy pictures of **3** equilibrated over night at pH 8.6. Bar represent 100 nm.

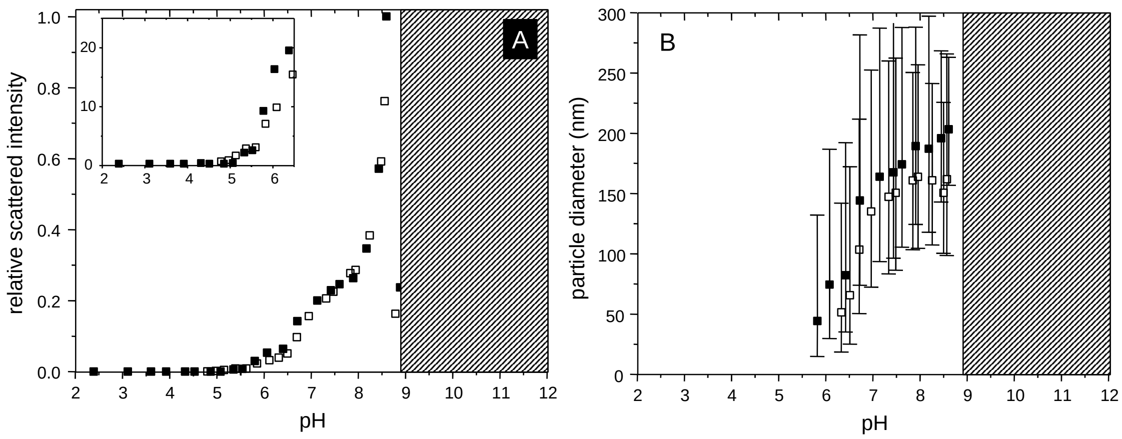

Figure 4. Experimental data for solutions containing **4**. For legend details see Figure 2.The insert in A displays the absolute scattered intensity clearly showing the onset of wormlike micelle formation and vesicle formation.

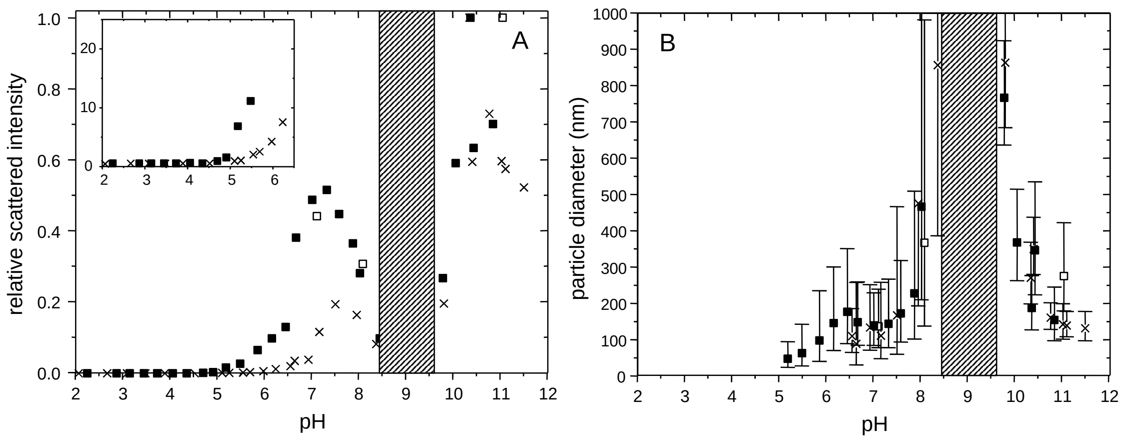

Figure 5. Experimental data for solutions containing **5**. For legend details see Figure 2. One experiment was performed starting from pH 2.7 (×). The insert in A displays the absolute scattered intensity.

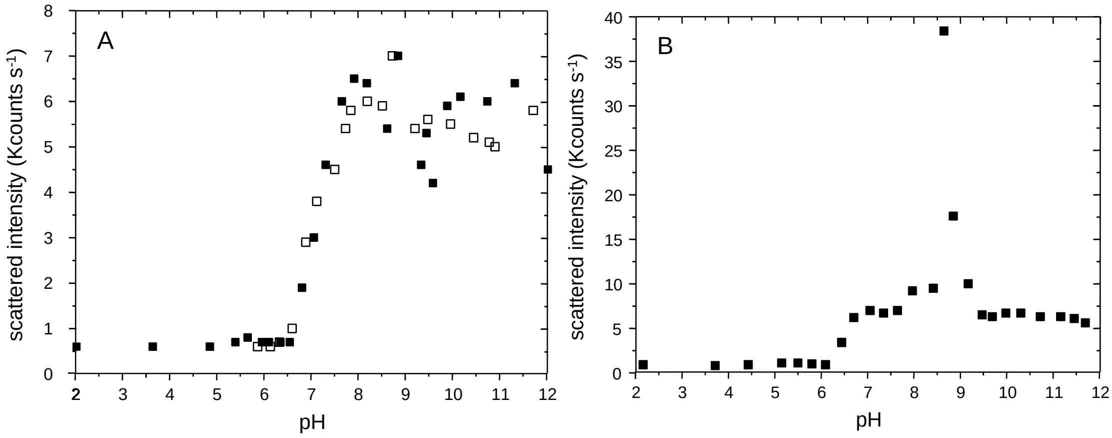

Figure 6. Scattered intensity of solutions containing gemini amphiphile **7** (A) and **8** (B) as a function of pH. Different symbols represent independent experiments starting from stock solutions prepared at near neutral pH.

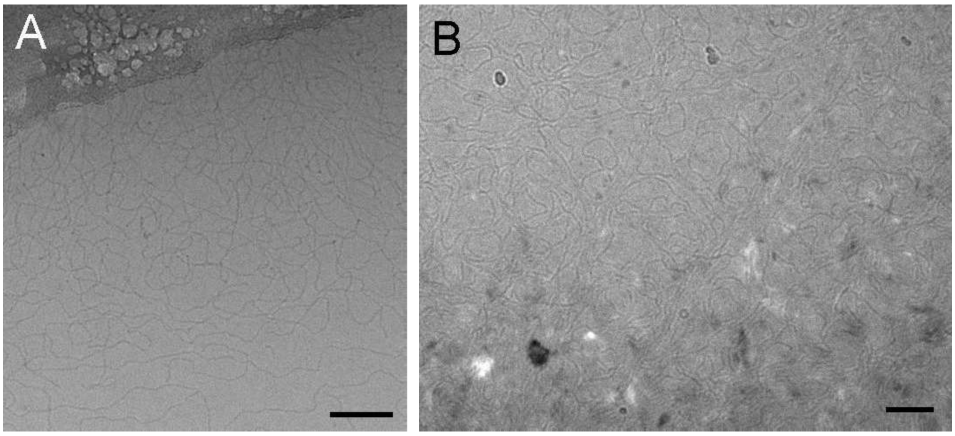

Figure 7. Cryo-electron microscopy pictures of **7** equilibrated over night at pH 8.5 (A) and pH 10.3 (B). Bar represents 100 nm

Effects of Carbohydrate Stereochemistry

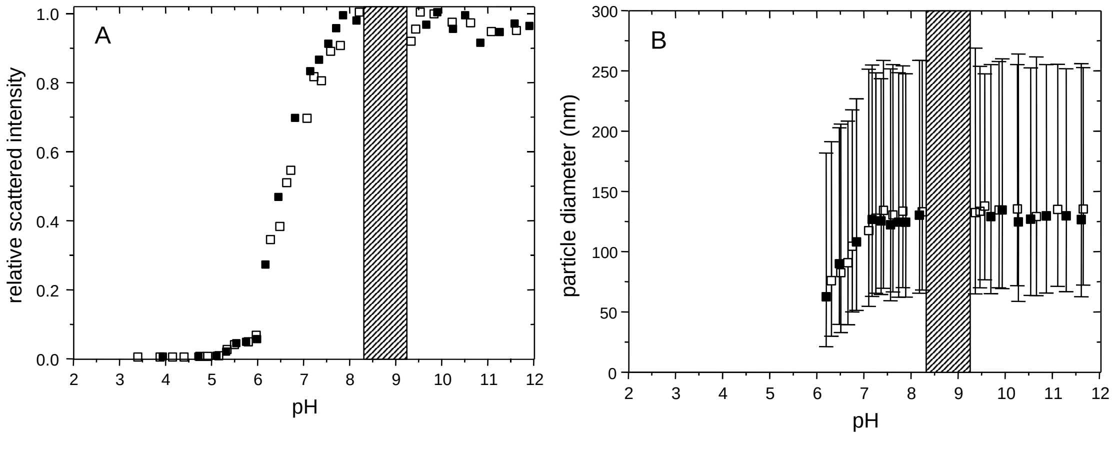

Figure 8. Experimental data for solutions containing **9**. For legend details see Figure 2.

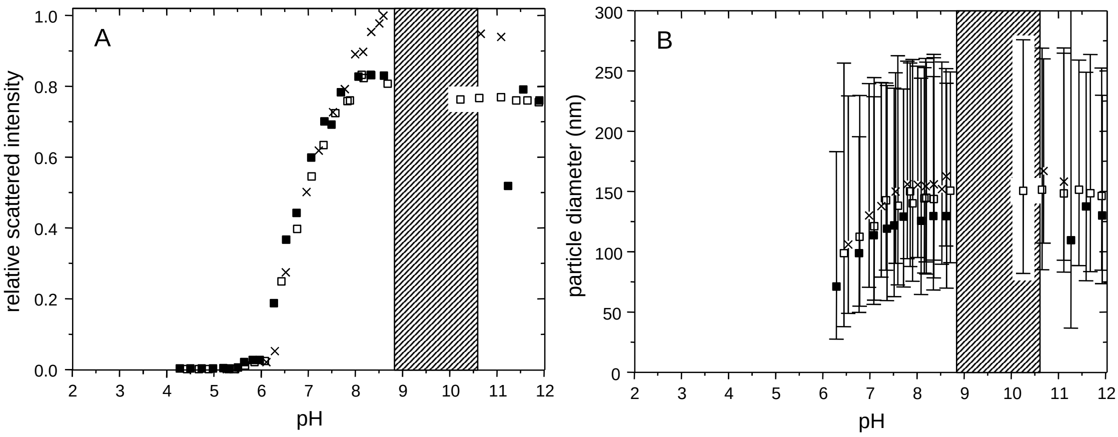

Figure 9. Experimental data for solutions containing **11**. For legend details see Figure 2.

As can be seen the pH of redispersion could not be reproduced very well for **11**. This is the reason that the pH of redispersion has a relatively large error (0.6 pH units versus otherwise typically around 0.3 pH units). **11** only weakly adsorbs hydroxide ions (high pH of redispersion), suggesting that the interface containing **11** is more sensitive for small variations at the interface than interfaces formed from more strongly hydroxide-ion adsorbing gemini surfactants.

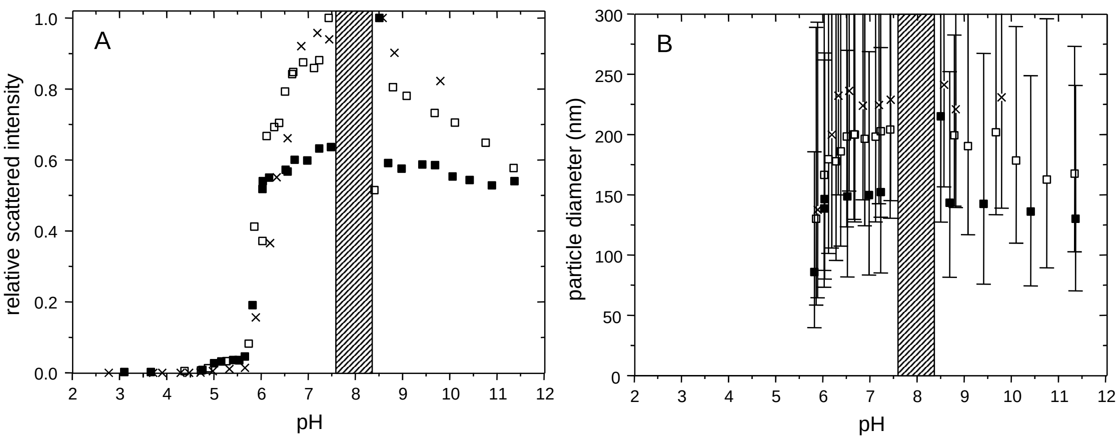

Figure 10. Experimental data for solutions containing **12**. For legend details see Figure 2, except for the symbol × (see text).

In Figure 10 it can be seen that the first experiment of **12**, represented by the symbol ■, is different from the second (□) and third (×) experiment. For the first experiment the stock solution was prepared at pH 6.0 leading to relatively small vesicles. This behaviour is common when vesicles are prepared at a significantly lower pH than the pH of flocculation. The low size is due to the presence of wormlike micelles. The analysis algorithm CONTIN cannot adequately handle such polydisperse samples and reports an average size. Upon increasing the pH of such a solution the wormlike micelles are transformed into bilayer fragments of which the measured size is more or less similar to that of wormlike micelles. Hence, a relatively low size is observed.[2]

In the second and third experiment it was attempted to prepare the vesicles closer to the pH of flocculation (pH 7.6). However, this turned out to be impossible, since when it was attempted to hydrate lipid films with a buffer solution of pH 7.4 the film did not dissolve. Therefore the pH had to be lowered to about pH 6.8. Then a very milky, but homogeneous, solution appeared, whereas for **2** at 5 mM solutions were bluish, but transparent.

Looking at the particle size distributions it can be seen that vesicles are larger than usually observed using the standard preparation protocol (Experimental section). Therefore cryo-electron microscopy pictures of vesicles made at pH 6.8, after which the pH was adjusted to pH 6.2, pH 7.3 and pH 8.8, were taken (Figure 11). Much to our surprise no unilamellar vesicles can be seen, instead multilamellar vesicles are observed. This is unexpected since the vesicle preparation protocol applied here leads in the case of phospholipids to solutions containing unilamellar vesicles with a monodisperse size distribution. Possibly the poor fit of galactose into the three-dimensional hydrogen-bond network of water promotes the formation of multilamellar vesicles. Due to an increased surface charged density at pH 6.2 the lamellae are not so densely packed as those at the other pH values

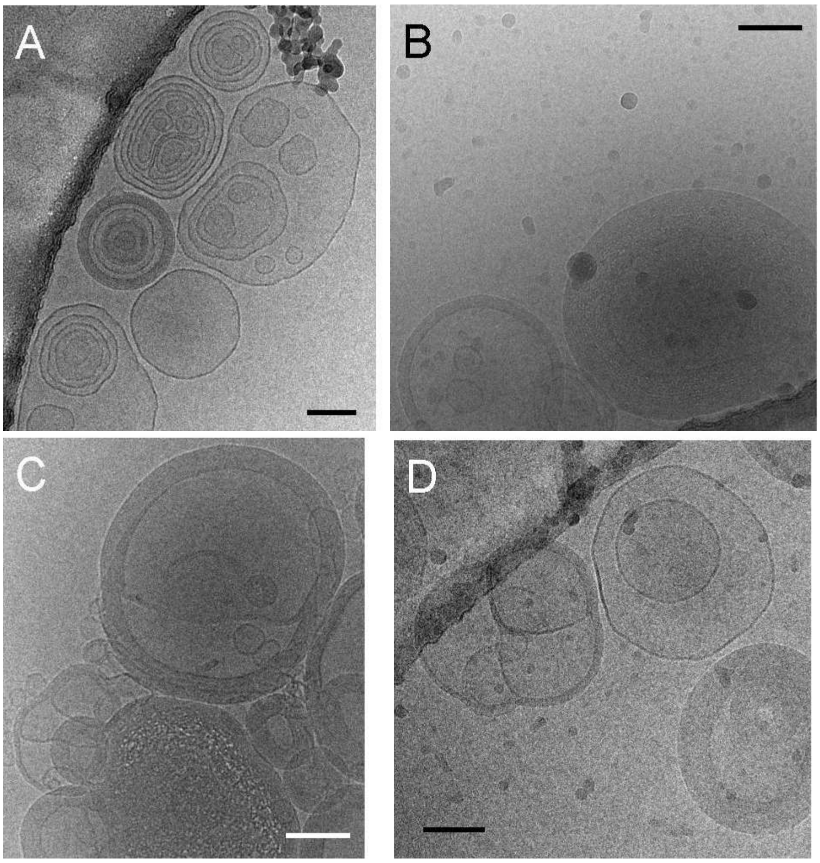

Figure 11. Cryo-electron microscopy pictures of **12** equilibrated over night at pH 6.2 (A), pH (6.8), pH 7.3 (C) and pH 8.8 (D). Bar represents 100 nm.

Effects of the nature of the spacer

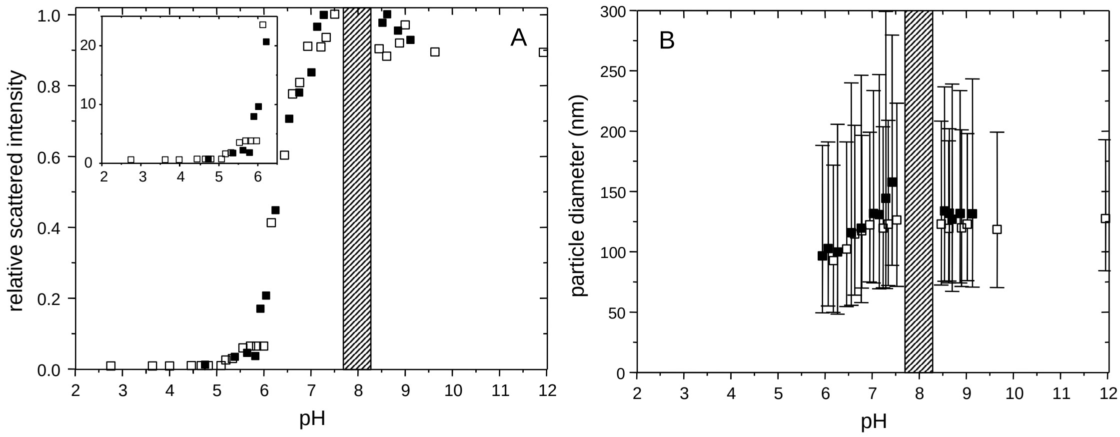

Figure 12. Experimental data for solutions containing **10**. For legend details see Figure 2.

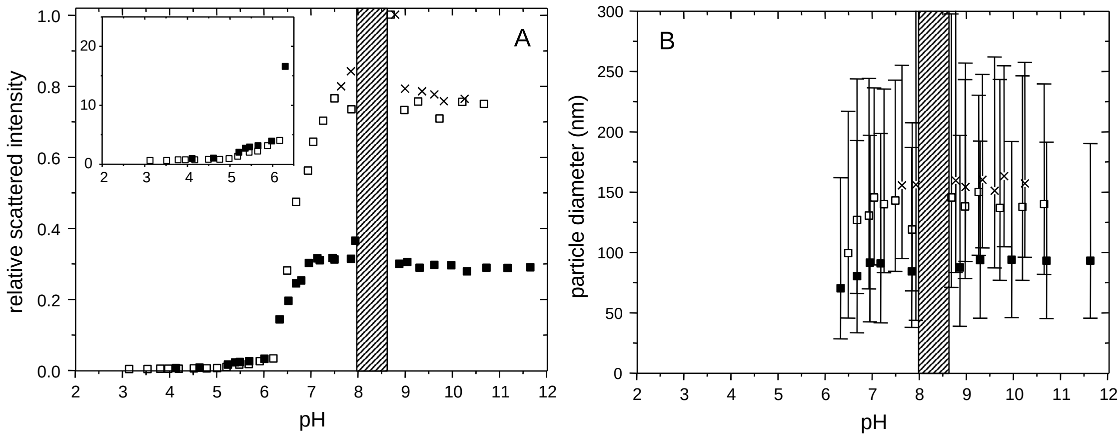

Figure 13. Experimental data for solutions containing **13**. For legend details see Figure 2, except for the symbol ×, which represents a triplo experiment.

For the first experiment of **13** (■) vesicles were prepared at a pH, which was too low. This was done for similar reasons as in the case of **12**.

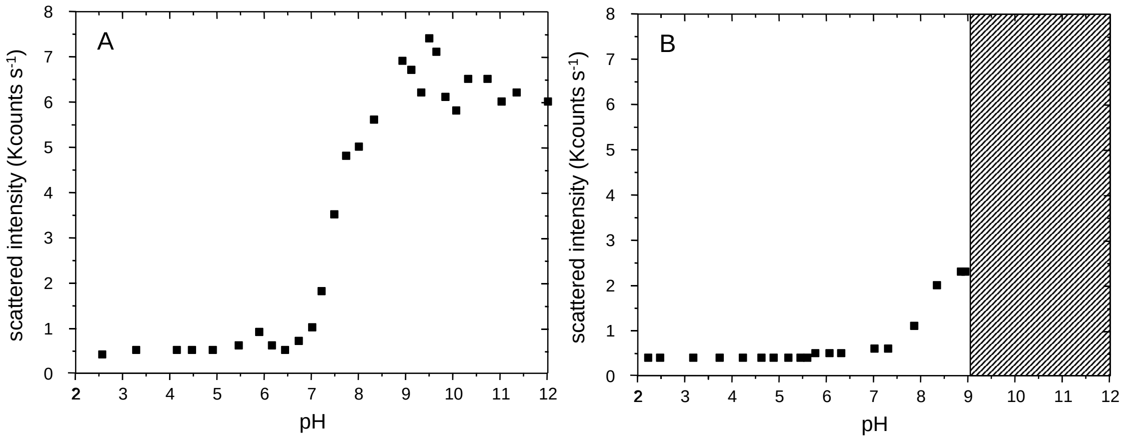

Figure 14. Scattered intensity of solutions containing gemini amphiphile **14** (A) and **15** (B) as a function of pH.

References

(1) Size distributions were obtained by fitting a Gaussian function to intensity as function of the logarithm of the particle diameter. The width of the size distribution is then the width at half height.

(2) For more details about dynamic light scattering and its limitations see: Klijn, J.E. *Ph.D. Thesis*, University of Groningen, Groningen, **2004**. The thesis can be downloaded from http://irs.ub.rug.nl/ppn/267171021