INFLUENCE OF ANIONS ON THE RHEOLOGICAL PROPERTIES OF CLAY SUSPENSIONS

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Controlling the rheological properties of clay based slurries is often indispensable in ceramic processes. Liquidity at high solid contents is highly desired to reduce energy consumption during drying and constant viscosity values are necessary to obtain a stable manufacturing process. It has long been known that certain compounds have a pronounced liquefying effect on clay/water mixtures. Deflocculants like water glass, humic acids, anionic polyelectrolytes and ortho- and oligomeric phosphates are common agents for increasing the solid content of ceramic slurries. Whereas the cations and positive edge charges of the particles are responsible for coagulation of the negatively charged clay mineral surfaces, several multivalent anions counterbalance the coagulating power of the cations. Systematically influencing the rheological properties of clay/water systems either in the direction of stiffening or liquefying the system needs pronounced knowledge of the laws of clay and colloid chemistry.

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Sodium-montmorillonite from Wyoming, Kaolin from Cornwall and mixtures of both were investigated. Slurries were prepared and mixed with salt solutions of varying concentrations. We compared the effect of a large number of different anions such as sodium salts, their corresponding acids and the mixed sodium hydrogen salts. Viscosity and yield stress were determined as characteristic rheological parameters with a rotation viscometer. Mobility or zeta potential of the particles caused by the sum of edge and face charges was investigated by the electrokinetic sonic amplitude method. Additionally adsorption isotherms of all species were recorded to observe correlations between specific adsorption and colloidal properties.

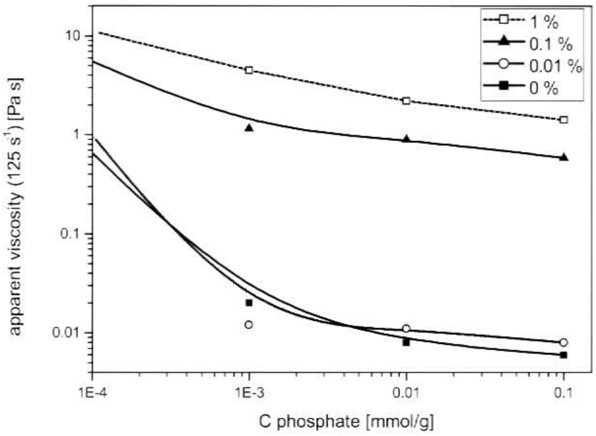
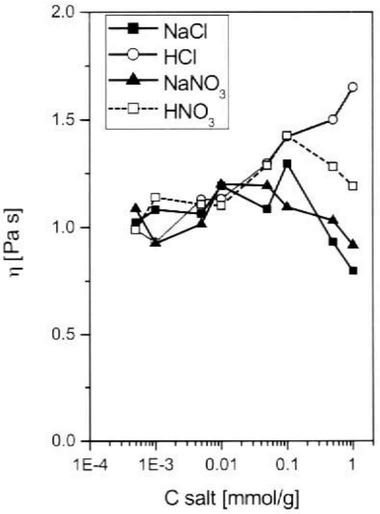


Fig. 1. Apparent viscosity of kaolin slurries with addition of 0.01 to 1 % pure sodium-montmorillonite at increasing phosphate concentrations.

Fig. 1 shows that just small amounts of swellable clays prevent effective liquefaction of kaolin slurries. Natural clays as raw materials for technical applications are usually mixtures of different clay minerals. Because each species gives rise to special reactions it is worth investigating first the pure components and then trying to sum up the results.

Pure Kaolin slurries show the pronounced liquefying effect of multivalent ions up to high salt concentrations caused by deflocculation. The rheological behaviour of kaolin with the addition of some salts is shown in figure 2.



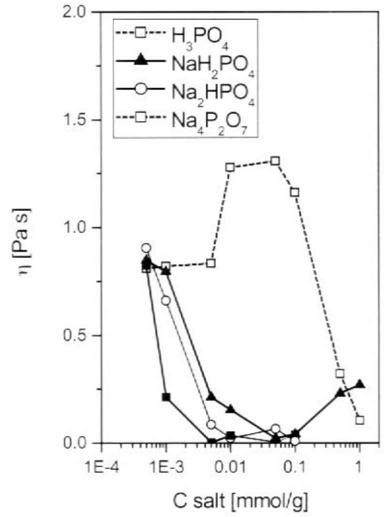
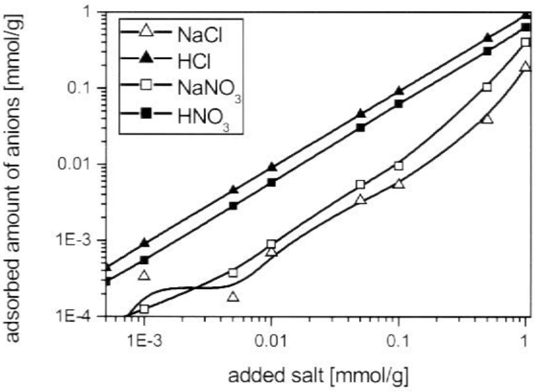


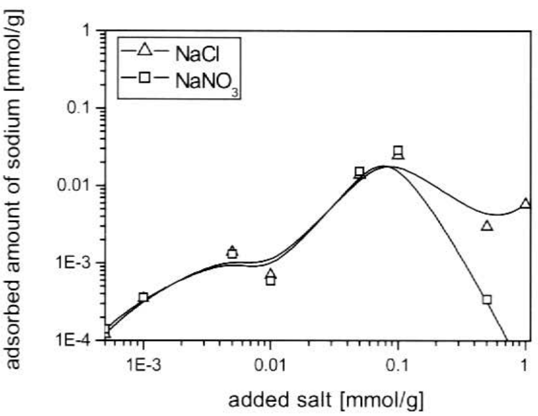
Fig 2. Viscosity η of kaolin slurries with increasing concentrations of chlorides, nitrates, phosphates and their corresponding acids and mixed salts.

In some cases, viscosity increases again at higher salt concentrations ('over-liquefying') because of coagulation of the particles. The influence of different anions is not only determined by the valency but also by the specific molecular pattern of the substance.

In the case of montmorillonite, the initial state of the highly charged particles in the slurry is already dispersed. The solid content, where gelation occurs is only 5 %. Addition of small amounts of salts leads to a weak decrease in viscosity values. This is attributed to the electroviscous effect. The addition of higher amounts at concentrations above a critical coagulation concentration gives rise to more viscous and plastic pastes or stiff gels, characterized by the development of a yield stress. Again, all these rheological effects are strongly dependent on the nature and chemical structure of the added salt and the structural state of the clay / water system.

Interactions of ions with surfaces are monitored by adsorption isotherms. The example of figure 3 demonstrates that the adsorption of anions and cations on kaolin influence each other, that anions are adsorbed over the whole concentration range and sodium ions are adsorbed until saturation is reached. There is no obvious correlation with the rheological behaviour.





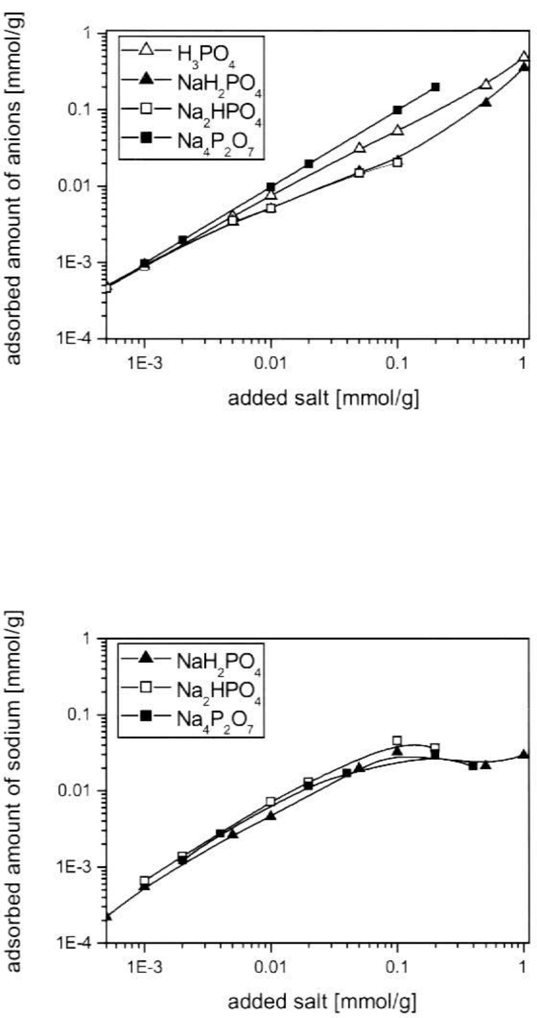


Fig. 3. Adsorption isotherms of phosphates on kaolin; left anion adsorption right cation adsorption.