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Zeta Potential - Applications

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Abstract. The utilization of zeta potential measurements for characterization of different kinds of particles was presented. On wide spectra of materials practical utilization for industry was showed, e.g. producing of pigments, catalysts, waste water treatment or coal flotation. Knowledge of the zeta potential values and possibilities how to influence it could be used in various subjects of human activities. The zeta potencial can be used for economical benefit and also for environmental protection.

Keywords: Zeta potential; Adsorption; Applications

1. Introduction

The zeta potential is the important factor to describe various particles. The value of the zeta potential indicates possible behavior of the dispersion. Particles which have got the zeta potential between minus 30 to plus 30 mV show tendency to the coagulation. This fact is the most expressive at the isoelectric point, when the zeta potential equals zero mV. There are many factors impact zeta potential, such as type of particles, the concentration of particles, the background electrolyte, addition of other substances (heavy metals, surfactants etc.). The pH has got the main impact of the value of zeta potential. With the change of pH we can reach stable or unstable system. Sometimes we want the stable dispersion, for example paints, polymers or a blood. Unstable system is useful for water purification or flotation of minerals or coals.

The measurement of the zeta potential is also a method which provides us to obtain imagination about the character of particle surface itself and then also about the processes running on this surface (e.g. adsorption, ion exchange, modification). The experiments connected to zeta potential measuring are the other factor which helps us to explain the principles of the particle surface and its surroundings interactions. As example we can mention heavy metals adsorption on clay minerals (heavy metals removing) or surfactant adsorption on carbonaceous materials (flotation of coals). There are many other areas where we can use knowledge of the zeta potential, e.g. oxidative catalysts, pigments, waste slurries, etc.

The main aim of this work is to present wide possibilities of using zeta potential in focus on practical applications.

2. Materials

2.1. Pigments

One of the areas where the zeta potential measuring plays an important role is producing of pigments, e.g. titanium dioxide. The pigments are consequently used for paints manufacturing and it is obvious that the paint must be homogenous for long time. The influence of pH on zeta potential of different types of commercially produced titanium dioxide (rutile, anatase) was carried out, figure 1. [1]

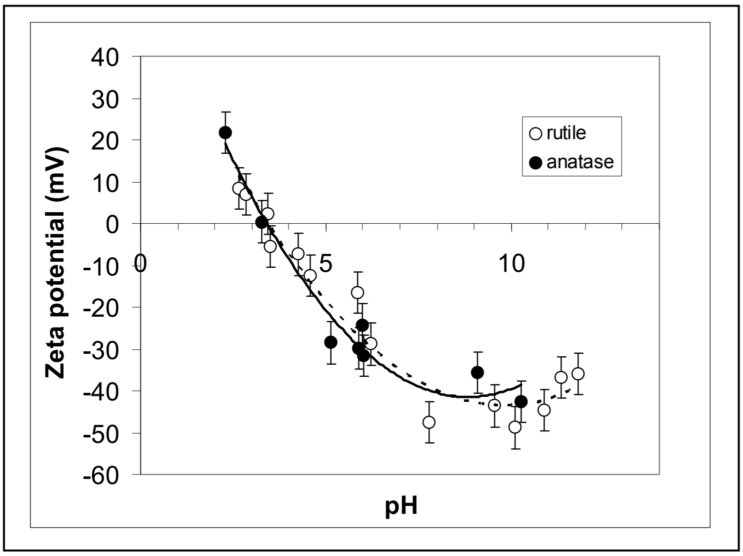

Fig. 1: The influence of pH on TiO_2 zeta potential

The picture shows a typical dependence of zeta potential on pH. The zeta potential goes to positive values in aid range. In this concrete case the isoelectric point lies in between pH 3.3-3.5.

The zeta potential can be influenced by many factors. One of these is of course the type of particle (pigment, clay, coal, etc.), pre-treatment of these particles (e.g. oxidation) followed by concentration of dispersions, concentration of bulk solutions, addition of "third" compound (heavy metal, surfactant), temperature, etc. Despite these factors the influence of the pH on the zeta potential is always being followed. Generally it can be said that hydrogen ions and also hydroxylic ions are easily adsorbed on article surface. In the case of hydrogen ions the small diameter is the cause. On the other hand the high dipole moment causes the good affinity for hydroxylic ions.

On the basis of these measurements it is possible to recommend the paint manufacturers to adapt the pH so that it lies out of the isoelectric point area.

2.2. Clays

Clay minerals are other materials which the zeta potential is measured very often by. In one work authors titrated dispersions of montmorillonite, illite and chlorite by hydrochloric acid and sodium hydroxide. Trend of the zeta potential change was the same as in the case of the titanium dioxide mentioned in the previous chapter. Among individual minerals there were differences however, arising from the structure and chemical composition of studied samples. The most significant change of pH came out in the case of chlorite and that was also the only one clay mineral which we were able to set the isoelectric point by (pH=5). [2]

The adsorption of heavy metals, metal oxides on the surface of clay minerals respectively plays an important role as well. Sorption of iron and aluminium on the surface of illite, montmorillonite and kaolinite lead to reduction of negative charges on the surface of the particles so that the isoelectric point of these minerals was moved to higher values of pH. [3]

The zeta potential of zeolites was examined in connection to the sorption of heavy metals on these adsorption materials. Dependence of the zeta potential on the pH was being influenced by concentration of bulk electrolyte ($NaNO_3$). As the concentration of $NaNO_3$ was increasing the value of the zeta potential was increasing as well. That fact is explained by change of thickness of double-layer caused by ionic strength of the solution. These changes consequently influenced the adsorption of heavy metals (Pb, Cu, Cd and Zn). The highest adsorption capacity was found in water. [4]

We also studied zeta potential and its changes during adsorption process. As an example we can mention adsorption of copper on clay mineral montmorillonite. As usual we followed the dependence of the zeta potential on suspension pH. The addition of base caused the increase of the zeta potential in this concrete case we were not able to determine the isoelectric point. Finally we determined the zeta potential of montmorillonite particles in copper solutions. We compared values of the zeta potential before and after the adsorption process. The adsorption of copper ions caused the change of the zeta potential of clay particles. The zeta potential became more positive. [5]

2.3. Zn-Fe slurries

From the economical point of view it is not surprising that new and cheap adsorbents are studied. Natural and waste materials can be shown as typical examples. Waste sludge from zinc chloride manufacturing was studied as a material for immobilization of various compounds or pollutants from waste waters. Sludge were different in elementary composition and in texture parameters as well. Temperature, pH and contact time were conditions which effected properties of waste sludge. Charges on the surface were again examined by measuring of the zeta potential and final values were correlated with adsorption capacities of individual slurries. [6]

In this case it is possible to say that through suitable modification of adsorbent surface (clay, slurries, etc.) higher adsorption capacity can be reached. These materials can be used as an alternative to commercial adsorbents for waste water treatment.

2.4. Carbonaceous materials

The great attention is devoted to the zeta potential of carbonaceous particles. The motivation can be for example to describe the influence of coal surface charge on the flotation process. The oxidation of bituminous coal has negative affect on floatability. The negative charge increased during oxidation and the zeta potential decreased. [7]

We can also try to modify the coal particle surface leading by effort to rich the isoelectric points. Particles are without charge, they are attracted and there are not repulsive forces in between them. This fact can be used for producing of briquettes, pellets or during agglomeration process. Shortly this is useful everywhere where we need to connect the small particles to bigger pieces. This modification leads to lower expenses of such technological operations. [8]

The surfactants are closely bound up to carbonaceous materials:

- The first possible application is using carbonaceous materials as adsorbents for removing surfactants from the solutions.
- Sometimes carbons or clays are modified by surfactants with aim to increase their adsorption capacities to catch other pollutants, e.g. heavy metals.
- The third option is to use of surfactants as collectors and foamers during flotation of coals and minerals.

These days it is still not clear if the surfactants are connected to the carbon surfaces by hydrophilic head or hydrophobic tail. Cationic, anionic and also non-ionic surfactants were added to three types of Australian coals. Authors published that surfactants are adsorbed by hydrophilic end. Cationic surfactant (CTAB) and non-ionic surfactant (G12A8) increased values of zeta potential against measuring of zeta potential in water without these surfactants. The anionic surfactant (SDS) had the opposite effect. [9] The fact that we are not still sure in orientation of surfactant molecules on coal surface can be documented by other paper where authors declared that cationic surfactant is adsorbed by hydrophobic tail. [10, 11]

We also followed interactions between various kinds of coals and different surfactants. It can be assumed that the adsorption of the surfactant on the coal surface causes a change in the coal surface charge and then a change in the zeta potential. The adsorption of the cationic surfactant (CTAB) causes an increase in the values of the zeta potential. Oxidative altered bituminous coal is typical of a high proportion of dissociated negative oxygen functional groups. These functional groups in particular contribute to the fact that the zeta potential of oxidative altered bituminous coal in distilled water shows values of approximately – 50 mV. The situation changed significantly after the cationic surfactant was added. After adding the 0.5 mmol/l-solution of CTAB, the zeta potential reaches zero value and keeps increasing with the rising concentration. The changes of zeta potential correspond with the adsorption isotherm. The driving force for adsorption in the negative range of zeta potential is the mentioned chemisorption. This "chemisorption" period is relatively fast and it is accompanied by significative change of zeta potential as the previous study showed. When adsorption places are occupied by surfactant molecules the zeta potential approaches zero. Consequential adsorption to the second layer shifts the zeta potential to positive values. A similar trend was also found in bituminous and subbituminous coals and there is a relationship between the adsorption capacity and the change in the zeta potential. In the case of oxidative altered bituminous coal, the change in the zeta potential is about 160 mV (compared to distilled water) in the equilibrium state. From this point of view, it can be assumed that the CTAB adsorption takes place mainly on the coal surface. Hence, the adsorbed molecules of CTAB significantly influence the surface charge and consequently the zeta potential. The same results were achieved for other adsorption systems. [5,12].

Also the molecules of anionic surfactant definitely affect the surface charge of adsorbent´s particles and also the values of zeta potential. The following findings can be deduced from experimental data:

- addition of the anionic surfactant (SDS) affects the value of ξ- potential, making the zeta potential values more negative,
- the most significant change of the ξ- potential in the presence of SDS was observed for bituminous coal, i.e. for sample of the most hydrophobic surface;
- there is relationship between oxygen content of the coal, its adsorption capacity for SDS and change in the zeta potential of (adsorption) suspension. Decrease in oxygen content (= increase in hydrophobicity) of the coal leads to the *increase* in its adsorption capacity for SDS, the adsorption being accompanied by the most significant changes in the zeta potential values of the suspensions. [13]

The zeta potential significantly helps to increase effectiveness of flotation of coal and minerals. Detailed knowledge about interactions between mineral grain and flotation collector has direct technological, economical a ecological effect.

2.5. Catalysts

The zeta potential measuring has also practical application in the case of oxidative catalysts. A new method for preparation of both eggshell and uniformly distributed MoO_3 in titania and zirconia supported catalysts was studied. The uniformly saturated catalysts MoO_3/TiO_2 and MoO_3/ZrO_2 were tested in hydrodesulfurization of thiophene and benzothiophene in their sulfidic states. They exhibited the same hydrodesulfurization activity and relative selectivity hydrogenation/hydrogenolysis as theirs counterparts prepared by conventional impregnation from solution of ammonium heptamolybdate, which confirmed good dispersion of Mo species achieved by water-assisted spreading method. By all the new catalysts made by this new method the zeta potential was measured. [14]

Well the zeta potential can be utilized for development of new methods for production of catalysts and for evaluating of their effectiveness.

3. Conclusions

The aim of this work was to show the zeta potential not only as an “academic” quantity but as an efficient help to understand the processes on interface. We believe that laboratory experiments can be used in industry and can help with developing new, innovated productions. The list of applications in this paper is obviously not final, let us mention pharmaceutical industry, cement producing or in the Czech Republic popular beer producing. Our final wish is the successful cooperation between universities and industry sector.

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