



Colloidal phenomena and aggregation mechanisms of cerium oxide nanoparticles in aqueous systems: effects of monovalent and divalent cations, and Suwanee River humic and fulvic acids

Linlin Mu · Christophe J. G. Darnault

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Abstract This study examines the interfacial interactions of cerium oxide nanoparticles (CeO_2 NPs) with average particle size below 25 nm in aqueous environment in the presence of monovalent cations (Na^+) and divalent cations (Ca^{2+}) and humic substances (humic acid (HA) and fulvic acid (FA)). Characterization of the dynamic growth of nanoaggregate- CeO_2 -complexes formed, and assessment of the colloidal stability of these nanoaggregate- CeO_2 -complexes in such aqueous environments were performed in order to determine possible risks to their environmental surroundings. Hydrodynamic diameter and zeta potential of CeO_2 NPs were measured over time in these aqueous environments. Results indicated that Ca^{2+} was more efficient than Na^+ in enhancing the homoaggregation of CeO_2 NPs. The critical coagulation concentration (CCC) of Na^+ (30 mM) was twice as large as the CCC of Ca^{2+} (15 mM) at pH 5 (pH below pH value of point of zero charge, pH_{PZC}). The heteroaggregation of CeO_2 NPs and HA was enhanced at higher Na^+ concentrations

(> 100 mM NaCl) due to electrostatic attraction and at higher Ca^{2+} concentrations (> 1 mM CaCl_2) due to bridging effect. Furthermore, HA was more efficient than FA in enhancing CeO_2 NPs heteroaggregation in the presence of Ca^{2+} , and FA was more efficient than HA in enhancing CeO_2 NPs heteroaggregation in the presence of Na^+ .

Keywords Metal-oxide nanoparticles · Aggregation · Stability · Monovalent cations Na^+ · Divalent cations Ca^{2+} · Humic acid · Fulvic acid · Aqueous environments · Nanomaterials transport in environment

Introduction

The development of nanoscience and technology has created an increasing demand for applications and products of engineered nanoparticles [1]. However, the intentional or unintentional release of engineered nanoparticles into the environment during their production, application, and waste disposal adversely impacts the environment [2, 3].

Cerium oxide nanoparticles (CeO_2 NPs) are used in industrial and consumer products due to their small size and specific physico-chemical properties. CeO_2 NPs serve as catalyst additives in the combustion process for storing and donating oxygen [4], and are used as UV blocking agents in sunscreen applications for absorbing ultraviolet radiation [5]. They also

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Colloidal Phenomena Ernst A. Hauser, 1954 Colloidal Phenomena Ernest Alfred Hauser, 1935 **Fundamentals of Interface and Colloid Science** J. Lyklema, 2005-03-30 Volume IV 2005 covers preparation characterization of colloids stability and interaction between pairs of particles and in concentrated systems their rheology and dynamics This volume contains two chapters written or co authored by J Lyklema and edited contributions by A P Philipse H P van Leeuwen M Minor A Vrij R Tuinier and T van Vliet The volume is logically followed by Vol V but is equally valuable as a stand alone reference Combined with part V this volume completes the prestigious series Fundamentals of Interface and Colloid Science Together with volume V this book provides a general physical chemical background to colloid science Covers all aspects of particle colloids Colloidal Suspension Rheology Jan Mewis, Norman J. Wagner, 2012 Presented in an accessible and introductory manner this is the first book devoted to the comprehensive study of colloidal suspensions *Basic Principles of Colloid Science* Douglas H Everett, 2007-10-31 This book provides an introduction to colloid science based on the application of the principles of physical chemistry Early chapters assume only an elementary knowledge of physical chemistry and provide the basis for more thorough discussion in later chapters covering specific aspects of colloid science The widespread occurrence of colloids is stressed and the more important industrial applications of colloid technology are outlined The final chapter deals with the future of colloid science and indicates the directions in which further developments are likely to take place The book is ideal for undergraduate courses and supplemented by further reading for postgraduates too It will also be useful to industrial research workers who wish to become familiar with the basic ideas and their many important applications to industry **Colloid Science** Terence Cosgrove, 2010-04-26 Colloidal systems are important across a range of industries such as the food pharmaceutical agrochemical cosmetics polymer paint and oil industries and form the basis of a wide range of products eg cosmetics toiletries processed foodstuffs and photographic film A detailed understanding of their formation control and application is required in those industries yet many new graduate or postgraduate chemists or chemical engineers have little or no direct experience of colloids Based on lectures given at the highly successful Bristol Colloid Centre Spring School Colloid Science Principles Methods and Applications provides a thorough introduction to colloid science for industrial chemists technologists and engineers Lectures are collated and presented in a coherent and logical text on practical colloid science Colloid Chemistry Theodor Svedberg, 1924 Computational Methods in Surface and Colloid Science Malgorzata Borowko, 2019-04-23 This volume presents computer simulation methods and mathematical modelling of physical processes used in surface science research It offers in depth analysis of advanced theoretical approaches to behaviours of fluids in contact with porous semiporous and nonporous solid surfaces The book also explores interfacial systems for a wide variety of p **Principles of Colloid and Surface Chemistry, Third Edition, Revised and Expanded** Paul C. Hiemenz, Raj Rajagopalan, 1997-03-18 This work aims to familiarize students with the fundamentals of colloid and

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