Modification of mesoporous silica magnetite nanoparticles by
3-aminopropyltriethoxysilane for the removal of Cr(VI) from aqueous
solution

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A R T I C L E   I N F O
Article history:
Received 25 May 2015
Received in revised form 8 July 2015
Accepted 8 July 2015
Available online 17 July 2015

Keywords:
Mesoporous silica magnetite NPs
Core-shell structure
Cr(VI) removal
Adsorption mechanism
Quantum mechanics calculations

A B S T R A C T
Silica magnetite nanoparticles (S-MNPs) as core were embedded in mesoporous silica shells by using
cetyltrimethylammonium bromide (CTAB) as a surfactant. Then, the resultant mesoporous silica-
magnetite nanoparticles (M-S-MNPs) were modified with 3-aminopropyltriethoxysilane (APTES) as a
coupling agent in dry hexane solvent. APTES-grafted mesoporous silica magnetite nanoparticles (A-M-S-
MNPs) were characterized by XRD, FTIR spectroscopy, EDX, elemental analysis, TGA/DTA technique.
Results demonstrate that the obtained A-M-S-MNPs were nearly spherical in shape with 25 nm thick
mesoporous silica shell. The adsorption behavior of the nanocomposite was examined in removing of
Cr(VI) ion with concentrations 20, 30 and 50 mg/L at optimum pH level of 2. In this study a pH swing
adsorption was observed too. The adsorption kinetic data were modeled using pseudo-second-order
kinetics and intraparticle diffusion equations. The obtained results for intraparticle diffusion model
show that the adsorption mechanisms are different in low and in high concentrations of Cr(VI) ion.
According to the parameters of the Langmuir isotherm, the maximum adsorption capacity (qm) of A-M-S-
MNPs for Cr(VI) increases as the temperature rises from 298 to 318 K. For better understanding of
adsorption mechanism, quantum mechanical methods were applied. The results indicate that the elec-
trostatic and hydrogen bond interactions between surface functional groups and HCrO 4 ions have an
important role in adsorption process. The easy separation from aqueous solution by an external magnetic
field, rapid adsorption, regeneration, and reusability of A-M-S-MNPs are interesting points as an effective
adsorbent for the removal of Cr(VI) ions.

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1. Introduction

In recent years, discharge of industrial wastewater containing
heavy metal ions in nature has become one of the main environ-
mental subjects due to the adverse effects of these ions on
ecosystem and human health. Among the heavy metal ions, Cr(VI)
with its wide application in different industries such as electro-
plating, leather tanning, and pigment industry has been extremely
considered [1,2]. Depending on pH and redox conditions, chromium
exists generally in two oxidation states Cr(VI) and Cr(III) in the
aqueous solutions [3]. Cr(VI) has more mobility and solubility than
another specie. Cr(III) is considered as a necessary element for
controlling of glucose, lipid and protein metabolism in the human
and animal body. While Cr(VI) is very dangerous to living organism
due to its toxicity, mutagenic and carcinogenic properties [4,5].
Therefore, efficient removal of Cr(VI) from wastewaters is an
important issue. Various treatment techniques have been used for
the removal Cr(VI) from aqueous solutions such as ion exchange,
precipitation, reverse osmosis and membrane processes. These
methods have major drawbacks including incomplete metal
removal, high reagents or energy requirements and generation of
toxic sludge or secondary waste [6,7]. Therefore, the adsorption
process as a high efficiency and low cost method can be used for the
treatment of wastewater containing heavy metals [8,9].

Recently magnetite nanoparticles (MNPs) are applied as useful
adsorbents for cleanup of environmental contaminants because of