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Mini Review

Layered Double Hydroxide

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Layered double hydroxides (LDHs) or hydrotalcites are inorganic clay materials with many promising properties. LDHs are represented in the general formula: $[M^{II}_{1-x}M^{III}_{x}(OH)_2.[A^{n-}_{x/n}.mH_2O]$, where M^{II} and M^{III} are divalent and trivalent metal ions within the brucite-like layers and A^{n-} represents an interlayer anion. The flexibilities of the chemical composition (combination of various M(II) and M(III)) and excellent anion exchange tendency make them highly efficient and potential materials for wastewater treatment, drug deliver and catalysis. The M(II)/ M(III) LDH category (M(II): Mg^{2+}, Fe^{2+}, Co^{2+}, Ni^{2+}, Zn^{2+} , etc.; M(III): Al^{3+}, Fe^{3+}, Cr^{3+}, etc.). M^+ and M^{4+} cations can also be incorporated in the layers but examples are limited to specific cations such as Li^+, Ti^{4+}, and Zr^{4+}. In the layers of LDH hosts, the M^{2+} and M^{3+} cations are orderly distributed. The positive charge is balanced by inorganic or organic anions (Cl^-, NO_3^-, ClO_4^-, CO_3^{2-}, SO_4^{2-}, RCO_2^-, etc.) located in the interlayer with variable amounts of interlayer hydration water molecules. The first property inherent to this structure is the anion exchange capacity that occurs through the reaction represented by Equation below.

$$[M^{II}_{1-x}M^{III}_{x}(OH)_2.[A^{n-}_{x/n}.mH_2O] + {}_{x/m}B^{n-} \rightarrow [M^{II}_{1-x}M^{III}_{x}(OH)_2.[B^{n-}_{x/n}.mH_2O], +_{(x/m)}A^{n-}$$

Anion affinity for the LDH interlayer has been found to be based on the size of the ion and its associated charge. Monovalent anions have lower affinities than divalent anions and they are therefore more likely to precipitate in anion-exchange reactions. The ease of exchange of monovalent anions is in the order $OH^- > F^- > C1^- > Br^- > NO_3^-$. Divalent anions such as SO_4^{2-} and CO_3^{2-}, have higher selectivity than monovalent anions. Therefore, the most suitable LDH for anion-exchange syntheses are those that have monovalent anions in the interlayer due to the relative ease of exchange [1-4].

LDH compounds have been synthesized by direct methods, which include coprecipitation [5-8], sol-gel synthesis [9-12], chimie douce [13], salt oxide reaction [14-16], hydrothermal growth [17,18] and electrochemical synthesis [19-24]. Indirect methods include all syntheses that use an LDH as a precursor. Examples of these are all anion exchange based methods such as direct anion exchange, anion exchange by acid attack with elimination of the guest species in the interlayer region and anion exchange by surfactant salt formation [25,26]. The non-anion exchange methods include the delamination-restacking method [27-30] and LDH reconstruction method [31,32].

LDHs are reported as very efficient drug nanovehicles [33,34]. In comparison to other inorganic nanovehicles, including silica and gold nanoparticles, quantum dots, and carbon nanotubes, they are featured with excellent biocompatibility [35], high drug loading capacity [36], and pH-responsive property [37], with biodegradability in the cellular cytoplasm [38]. Such outstanding properties make LDHs an efficient non-viral drug delivery vehicle, and also a reservoir for bioactive or bio-fragile molecules. Note that the intercalated drugs can be released either by deintercalation through anionic exchange with the surrounding anions (such as Cl^- and phosphate), or through the acidic dissolution of LDH hydroxide layers.

LDHs are regarded as a valuable adsorbent for removal of heavy metals and wastewater treatment arising from their unique properties including their high stability and other physicochemical properties [39]. Environmental problems associated with the use of highly mobile herbicides are of current concern because of the increasing presence of the agrochemicals in ground and surface waters. Anionic herbicides are of particular concern because they are weakly retained by most of the components of soil sediment, so they remain dissolved in the soil solution and can rapidly move around [40]. One approach to minimizing such transport losses is to use controlled release formulation in which the herbicides and drugs are incorporated in a matrix or carrier before application, thereby limiting the amount available for unwanted processes [41-43]. LDHs were widely used in the removal of Cr (VI) ions from solutions as reported in many studies [44,45] and, recently, they are used in Cr (VI) soil remediation [46].

Conclusion

Layered double hydroxide is an inorganic materials with the surface positive charge that can be synthesized by different techniques and highly applicable for environmental remediation and drug delivery.

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