# Dynamical and chemical modeling of terrestrial planet accretion

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## The "Grand Tack" dynamical model

The classic dynamical models of terrestrial planet formation, starting from a disk of planetesimals extended from the Sun to the current orbit of Jupiter, typically produce in ~ 100 Ma a few planets in the terrestrial zone on orbits comparable to the real ones [1], but the synthetic planets located near 1.5 AU are systematically more massive than Mars. The large Earth/Mars mass ratio seems to require a strong depletion of solid mass beyond ~1 AU [2]. The "Grand Tack" model [3] explains such a depletion by coupling the early orbital migration of the giant planets with the terrestrial planets accretion process. More precisely, the model assumes that, when the giant planets formed in a proto-planetary disk still dominated by gas, Jupiter first migrated towards the Sun and then, as a consequence of the formation of Saturn, reversed its migration and spiralled outwards. This possibility is supported by hydro-dynamical simulations [4]. If the reversal (or tack) of Jupiter's migration occurred when the planet was at ~ 1.5 AU, the region beyond 1 AU would have been strongly depleted by the passage of Jupiter. The simulations in [3] show that this model is consistent with the existence and the structure of the asteroid belt between 2 and 4 AU, it produces in 30-50 Ma terrestrial planets on orbits consistent with the real ones and, in particular, it explains why Mars is 10 times smaller than the Earth and formed 10 times faster [5]. Thus, the Grand Tack model is so far the most successful model of terrestrial planet formation from the dynamical point of view.

## Chemical modelling

To test the Grand Tack model further, we are now applying geochemical constraints. The model is consistent with the delivery of 2000 ppm of water to the Earth from planetesimals of chondritic composition, which agrees with recent estimates of the Earth's water budget and its isotopic composition [6]. Moreover, we are modeling core-mantle differentiation [7] using the accretion history of the planets obtained in the Grand Tack simulations. Assuming that the material originally inside ~1.5 AU had a reduced composition and that beyond this threshold was oxidized, our chemical models result in a FeO content of 8 wt% for the Earth's mantle and ~18 wt% for the Martian mantle, results that are consistent with observed concentrations [8,9]. In the future we will extend our analysis to include more elements (e.g. sulphur, volatile elements, HSEs and water) and we will use more than two initial bulk compositions for accreting material.

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# Interaction between Eu(III), phenolic acids and $Al_2O_3$ nanoparticles.

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## Introduction

Natural colloid-borne transport of metal ions in ground water is known to occur. The implications of this kind of transport are especially important in the context of radionuclide migration in subsurface water to evaluate risks of pollutants migration in contaminated soils [1,2]. Furthermore, dissolved organic matter plays a crucial role on metal ions transport. In particular, phenolic acids, resulting from lignin degradation, may be involved in the process of metal ion adsorption onto mineral nanoparticles, as it is the case for aliphatic acids [3]. Our aim is to investigate the sorption of Eu(III) (rare earth and analogue of trivalent actinides) onto $Al_2O_3$ nanoparticles in the presence of a hydroxybenzoic acid series (4-hydroxybenzoic, 3,4-dihydroxybenzoic, and 3,4,5-trihydroxybenzoic acids).

## Results

First, the binary systems were characterized. Eu(III) was shown to have a high sorption capacity on our $Al_2O_3$ sample, as already described elsewhere [4,5]. Combining sorption data analysis with time-resolved luminescence spectroscopy (TRLS) for Eu(III), at least 2 sorption sites of different energies were evidenced, as in *Rabung et al*. [5]. Complexation constants between Eu(III) and acids were determined using TRLS. It appears that the complexation constant increases from $\log_{10}K°$ = 2.1 to 5.3 with the number of phenoxy groups on the benzoic ring. As expected, the sorption isotherms of the $Al_2O_3$-phenolic acid binary systems show different sorption capacities that cannot be explained by the hydrophobicity of the acids Indeed 4-hydroxybenzoic acid, which is the most hydrophobic compound of the series, has the lowest sorption capacity on $Al_2O_3$. These results are consistent with published data, demonstrating that increasing the number of phenoxy groups on the benzoic ring of analogue compounds increases sorption on alumina [6]. Besides, the sorption isotherm of 3,4,5-trihydroxybenzoic acid at pH 5 can only be fitted using sequential Langmuir isotherms, which evidences different sorption sites for this acid on $Al_2O_3$.

The same strategy was applied to study the ternary systems. Sorption isotherms were obtained as well as the TRLS spectra which permit to discuss the pertinency of mixed-surface complexes that involves Eu(III), hydroxybenzoic acids and aluminol sites.

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