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Insight into the use of ion beam based techniques for energy related issues in earth sciences

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Ion Beam Analysis (IBA) has been proved to be original and interesting to study geological processes from fundamental geoscience to mineral exploration as well as for environmental and waste management issues. IBA has the advantage to be non-destructive, allowing the analysis of buried structures, profiling light elements (H, He…) to elements as heavy as U and permitting discriminating diffusion from surface processes. Thus, IBA techniques like Rutherford Backscattering Spectrometry (RBS) or Nuclear Reaction Analysis (NRA) used individually or in a coupled way, appear as methods of choice to probe impurities in the geoscience context. In particular, considering the nuclear fuel cycle from uranium mining to waste disposal, these techniques may provide useful information to evaluate the environmental impact of the industrial facilities. In this presentation, we shall illustrate through three examples how IBA can be used in the context of oil recovery as well as to help anticipating the long term environmental consequences due to the release of radiotoxic impurities in the context of deconstruction of industrial facilities or long term geological disposal. In the first example [1] we show how IBA can be applied to characterize organic matter/mineral interactions at a microscopic scale in the purpose of oil recovery which is strongly influenced by the wettability of the reservoir rock. We studied the distribution of some heavy fractions of crude oil and nitrogen molecules on model minerals of sandstone reservoir rocks such as silica and clays. Using the Proton Elastic Scattering Analysis (PESA) on ^{12}C, $^{12}C(p,p)^{12}C$, and the $^{14}N(\alpha,p)^{17}O$ nuclear reaction, the results pointed out the important role played by nitrogen in the retention of the organic matter especially at the organic matter/mineral interface and how the nature of the mineral substrate and the organic compound affect the thickness of the organic films. Another example [2] is related to the management of graphite issued from the dismantling of the first generation graphite moderated nuclear reactors. These reactors are currently under dismantling. In France, the current management option is direct disposal into clay. As a result of reactor neutron irradiation it contains ^{3}H which has a short half-life (12.3 years) and contributes significantly to the initial activity. In order to anticipate its behaviour at the early stage of disposal, information regarding its inventory and speciation at the reactor shutdown must be determined. We used ^{2}H implantation to simulate the presence of ^{3}H and mapped ^{2}H thanks to the $^{2}H(^{3}He,p)^{4}He$ nuclear reaction. Extrapolating to ^{3}H, the results revealed that ^{3}H located at the edge of the coke grains was labile at reactor temperatures resulting in the impoverishment of part of the ^{3}H inventory. On the contrary, ^{3}H located inside the coke grains trapped at high energy sites is stable at reactor temperatures. This latter ^{3}H should therefore be far less labile during dismantling and at the early operational stage of disposal. Another example [3] is devoted to calcite, the main secondary alteration product formed during the degradation of cement over geological time scales in the waste repository. We investigated the retention on calcite of Europium (as fission product or actinide analogue) and Nickel (as activation product) using RBS. RBS performed on single crystals reveal distinct sorption behaviour of Eu and Ni. We showed that Ni accumulates at the calcite surface without being incorporated whereas Eu precipitates at the surface and is also incorporated into calcite and the amount of incorporated Eu increases with time. This kind of information could be also useful to study the environmental impact of rare earth element mining operation.

References:

[1] Mercier F et al. (1999) Nuclear Instruments and Methods in Physics Research B 152 122-128

[2] Le Guillou M et al. (2015) Journal of Nuclear Materials 461 72–77

[3] Sabau A et al. (2014) Nuclear Instruments and Methods in Physics Research B 332 111–116