**Ion-exchange Analysis for water solution:** Batch experiments were performed by introducing functionalized MOFs and MOFs@magnetic core particles in a solution with known concentration of REE. For unbound MOFs, initial ion-exchange studies were carried out by immersing MOFs (MIL-101-SO3, In-MOF or DETA-In-MOF) into a 5 ml standard solution of individual (or mixed) REE cations in water in 1:2 molar ratio (typically 5-8 mg of MOF powder into ~0.0005M REE cation solution). For ion-exchange involving core-shell magnetic microspheres, a similar experimental approach was taken. In a typical ion-exchange process, ~5-8 mg of core-shell magnetic microsphere was added to a 5 ml standard REE solution. The solution pH is close to ~4-5. REE uptake was determined by comparing ICP-OES analysis of blank reference solution samples where no sorbent was present with solution samples extracted after 5 min exposure to functionalized MOFs and MOFs@magnetic core particles. The extraction capacity, *qe* (mg g-1), %REE removal, and distribution coefficient Kd (mL g-1) for functionalized MOFs and MOFs@core shell are calculated using the equations below:

$$\% removal =\frac{\left(c\_{0}-c\_{a}\right)×100}{c\_{0}}$$

$$q\_{e}=\frac{\left(c\_{0}-c\_{a}\right)×V}{m}$$

$$K\_{d}=\frac{\left(c\_{0}-c\_{a}\right)V}{c\_{e}×m}$$

where *c0* and *ca* are respectively the initial and equilibrium concentration of metal ions (mg L-1). *V* denotes the volume of the solution (mL) and *m* corresponds to the quantity of material used (g).

**Ion exchange Analysis from Brine Solution:** Similar batch experiments were performed on MOFs@magnetic core particles (MIL-101-SO3@Fe3O4 and DETA-In-MOF@Fe3O4) in brine solution spiked with a known concentration (0.0005 M) of all five REE elements. A known quantity (5 – 10 mg) of MOFs@magnetic core particles were immersed in a brine solution (5 ml) spiked with REE. After 5 minutes of exposure, the solutions were filtered to remove MOF@mgnetic core particles. ICP-OES analysis was again performed on the brine solution samples before and after exposure to the sorbents. The amount of REE adsorption on MOF@magnetic core particles was calculated using the same equations noted above. The pH of the brine solution with REE was found to be between 6 and 7. Raw solution analysis data and calculated adsorbed REE concentration are provided in Tables 1 and 2, respectively.

Table . Raw ICP-OES Data from Batch Adsorption Tests with Functionalized Core-Shell Sorbents

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | ICP Results:ppm | Moles: M/L |
| Sample ID# | Dilution | Nd | Eu | Y | Dy | Ce | Nd | Eu | Y | Dy | Ce |
| A Stock | 10 | 9.179 | 8.612 | 6.33 | 8.646 | 9.092 | 0.000636 | 0.000567 | 0.000712 | 0.000532 | 0.0006489 |
| A1 | 10 | 7.334 | 6.803 | 5.556 | 6.912 | 7.489 | 0.000508 | 0.000448 | 0.000625 | 0.000425 | 0.0005345 |
| A2 | 10 | 7.268 | 6.403 | 5.5 | 6.465 | 7.52 | 0.000504 | 0.000421 | 0.000619 | 0.000398 | 0.0005367 |
|   |   |   |   |   |   |   |   |   |   |   |   |
| B stock  | 10 | 9.663 | 9.446 | 5.252 | 8.399 | 8.249 | 0.00067 | 0.000622 | 0.000591 | 0.000517 | 0.0005887 |
| B1 | 10 | 9.369 | 8.779 | 5.161 | 7.728 | 8.198 | 0.00065 | 0.000578 | 0.00058 | 0.000476 | 0.0005851 |
| B2 | 10 | 7.477 | 6.716 | 4.403 | 6.124 | 6.394 | 0.000518 | 0.000442 | 0.000495 | 0.000377 | 0.0004563 |
|  |  |  |   |  |  |  |  |  |  |  |  |
| **1 = MIL-101SO3@Fe3O4** |  |  |  |  |  |  |  |  |  |  |
| **2 = DETA-In-MOF@Fe3O4** |  |  |  |  |  |  |  |  |  |  |
| **A = REE in Water**  | **REE concentration = 0.0005 Molar solution** |   |  |  |  |  |  |
| **B = REE in Brine Solution** |  |  |  |  |  |  |  |  |  |  |

Table . REE Adsorption on Core Shell MOFs

|  | **Difference (M/L)** | **g/L** | **mg-REE/g-MOF** |
| --- | --- | --- | --- |
| **Nd** |  |  |  |
| **A1** | 1.28E-04 | 0.0185 | 36.9 |
| **A2** | 1.32E-04 | 0.0191 | 38.2 |
|  |  |  |  |
| **B1** | 2.04E-05 | 0.0029 | 5.9 |
| **B2** | 1.31E-04 | 0.0189 | 37.8 |
|  |  |  |  |
| **Eu** |  |  |  |
| **A1** | 1.19E-04 | 0.0181 | 36.2 |
| **A2** | 1.45E-04 | 0.0221 | 44.2 |
|  |  |  |  |
| **B1** | 4.39E-05 | 0.0067 | 13.3 |
| **B2** | 1.80E-04 | 0.0273 | 54.6 |
|  |  |  |  |
| **Y** |  |  |  |
| **A1** | 8.71E-05 | 0.0077 | 15.5 |
| **A2** | 9.34E-05 | 0.0083 | 16.6 |
|  |  |  |  |
| **B1** | 1.02E-05 | 0.0009 | 1.8 |
| **B2** | 9.55E-05 | 0.0085 | 17.0 |
|  |  |  |  |
| **Dy** |  |  |  |
| **A1** | 1.07E-04 | 0.0173 | 34.7 |
| **A2** | 1.34E-04 | 0.0218 | 43.6 |
|  |  |  |  |
| **B1** | 4.13E-05 | 0.0067 | 13.4 |
| **B2** | 1.40E-04 | 0.0228 | 45.5 |
|  |  |  |  |
| **Ce** |  |  |  |
| **A1** | 1.14E-04 | 0.0160 | 32.1 |
| **A2** | 1.12E-04 | 0.0157 | 31.4 |
|  |  |  |  |
| **B1** | 3.64E-06 | 0.0005 | 1.0 |
| **B2** | 1.32E-04 | 0.0186 | 37.1 |