Characterisation and dissolution studies on the uranium pyrochlore mineral betafite $(Ca,U)_2(Nb,Ti,Ta)_2O_7$

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The pyrochlore group mineral, betafite (nominally $(Ca,U)_2(Nb,Ti,Ta)_2O_7$); is a refractory uranium mineral found in many ore deposits, including the currently mined deposit at Rössing, Namibia and the currently unmined deposit at Saima Massif, China. The decreasing abundance of "easy to leach" uranium minerals (i.e. uraninite), has led to interest in the extraction of uranium from refractory uranium minerals such as betafite. In the current study, three naturally occurring betafite mineral samples (obtained from Ambatofotsky and Miarinarivo, Madagascar (BAM and BMM respectively) and Silver Crater Mine, Canada (BSC)) were characterised using ex-situ high temperature X-Ray Diffraction (XRD), multi acid digestion / ICP-MS analysis (composition) and X-Ray Photoelectron Spectroscopy (XPS). Dissolution of the three samples was also investigated under conditions similar to those used in commercial tank based uranium leaching processes.

XRD analysis showed that all three samples were highly metamict. Samples BMM and BSC showed no assignable diffraction lines before heat treating, whereas the XRD pattern obtained for sample BAM contained diffraction lines that confirmed the presence of crystalline anatase (TiO_2). Heat treatment studies on the samples showed that the betafite in the samples was converted into a crystalline form at 700°C in all 3 samples. Gangue minerals, rutile, Nb-rutile, $UTiNb_2O_{10}$, and studitite were also found to be present in the heat treated samples. Multi acid digestion ICP-MS analysis showed the natural samples contained between 16 and 26% w/w uranium as well as all the major elements present typically in betafite. XPS analysis was conducted on the unheated betafite samples. XPS analysis showed that the uranium in the samples was predominately in U^{5+} oxidation state. Some U^{6+} was also identified though this was most likely restricted to the outer surface of the samples.

Dissolution studies (batch mode) were conducted under the following conditions: $[H_2SO_4]$ between 0 and 100 g/L, $[Fe_{TOT}]$ between 0 and 12 g/L, Redox potential (Fe^{3+}:Fe^{2+} Ratio), between 1:0 to 0:1, Temperature (35-95°C) and crystallinity (pre heat treated and heat treated). The results of the dissolution studies showed similar trends between the 3 samples studied. Increasing the temperature had the most significant effect on dissolution. Similar trends between the samples were seen with the effect of $[Fe_{TOT}]$ and Redox potential. All studies completed looking at these two parameters showed very minor changes in dissolution concentration as these parameters were changed. The maximum uranium dissolution for BAM, BMM and BSC was 70, 34 and 45% respectively. This was achieved with; 3g/L Iron (100% as Fe^{3+}); 50g/L H_2SO_4; 95°C temperature after 24 hrs.