ABSTRACT

It is known that apatite contains radioactive elements since fission tracks can be seen on polished surfaces under high magnification. One of the techniques that can be used to determine the concentration of these radioactive elements is neutron activation analysis (NAA). In this paper, we report on the use of NAA to determine the concentration of rare earth elements in natural apatites.

Introduction

Apatite belongs to a group of minerals that contains appreciable amount of radioactive elements uranium and thorium. These elements decay either by spontaneous fission or by $\alpha$ decay and results in damage to the crystal structure. Luminescence from solids results mainly from two types of centers or activators. These are impurity centers and defect centers. Most transition metal ions and rare earth ions impurity are known to produce luminescence. Emission from rare earth ions was observed in apatites and their emissions gave rise to several peaks [1,2]. Laser emission at 1.0629 $\mu m$ was observed from neodymium ($\text{Nd}^{3+}$) doped and at 2.075 $\mu m$ in holonium ($\text{Ho}^{3+}$) doped apatite [3].
**Experimental Method**

Neutron activation analysis was carried out at a Research Reactor (RTP) TRIGA MkII at MINT with a thermal neutron flux of about $4 \times 10^{12}$ n/cm$^2$/s. Samples were in powder form, were placed into pre-cleaned polythene vials (2/5 drum). The net weight of the sample in each vial was approximately 0.1g. Materials with known concentrations of the elements investigated which act as standards were also weighed. Samples and standards were then irradiated for six hours. After irradiation the samples and standards were left to cool for ten days in order to reduce the background radiation. Activities of samples and standards were measured with a horizontal hypergermanium detector coupled to a pulse height analyser. The counting was done 10 days after irradiation and counting period was 1 hour.

**Results and discussions**

A plot of the energy of $\gamma$-rays detected after irradiating the apatite samples with neutrons is shown in figure 1. These curves were obtained after a long irradiation process. A list of the elements detected is given in table 1. It is evident that the natural apatites investigated contained considerable number of rare-earth impurities. The radioactive elements uranium and thorium and lanthanum were also found in high proportions. The presence of radioactive elements can introduce lattice defects when they decay. These defects are called fission tracks and can be observed under a microscope after delineating them with mild nitric acid [5]. The occurrence of radioactive elements U and Th in blue apatite correlates with its high natural fission track density. This is in agreement with Knutson et. al. [7] which reported that the natural fission track density is proportional to the U concentration. Other elements detected include Sm, Lu, Yb, Eu and As. Our findings is similar to that reported by Hughes et. al. [6]. They found that 95% of the rare earth elements present in natural apatite are from the series La to Sm. In agreement with our observation, they also reported that La is one of the major impurity elements in natural apatite.
A number of the rare earth elements emit luminescence under photons or electron excitation. The main characteristic of their emission is the presence of sharp peaks in the emission spectrum. Emission spectrum from our samples also contain sharp peaks in the visible region and these peaks has been associated with the presence of rare earth impurities. [7]

<table>
<thead>
<tr>
<th>Element</th>
<th>Blue (ppm)</th>
<th>Yellow</th>
<th>Yellow -Green</th>
<th>Brown (ppm)</th>
<th>Green (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>55.8</td>
<td>n.d</td>
<td>8.7</td>
<td>13.3</td>
<td>7.8</td>
</tr>
<tr>
<td>Th</td>
<td>806</td>
<td>244</td>
<td>89</td>
<td>135</td>
<td>73</td>
</tr>
<tr>
<td>Sm</td>
<td>68</td>
<td>212</td>
<td>195</td>
<td>257</td>
<td>85.5</td>
</tr>
<tr>
<td>Lu</td>
<td>1.8</td>
<td>5.4</td>
<td>2.6</td>
<td>4.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Yb</td>
<td>4.0</td>
<td>39.8</td>
<td>20.2</td>
<td>37.3</td>
<td>7.7</td>
</tr>
<tr>
<td>As</td>
<td>5.1</td>
<td>274</td>
<td>15.9</td>
<td>8.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Sb</td>
<td>0.2</td>
<td>7.1</td>
<td>0.03</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>La</td>
<td>331</td>
<td>3389</td>
<td>1164</td>
<td>1430</td>
<td>482</td>
</tr>
<tr>
<td>Fe</td>
<td>n.d</td>
<td>n.d</td>
<td>n.d</td>
<td>665</td>
<td>174</td>
</tr>
<tr>
<td>Eu</td>
<td>5.6</td>
<td>15.1</td>
<td>29.7</td>
<td>35.8</td>
<td>10.4</td>
</tr>
</tbody>
</table>

n.d - not detected

Table 1. Concentrations of various elements detected using Neutron Activation Analysis.

**Conclusions**

Neutron activation analysis of the natural apatites showed that they contain rare earth elements and the radioactive elements uranium and thorium. The element lanthanum is one of the major impurity.
Acknowledgements

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References


Yellow

Blue

Energy (keV)

Intensity

Energy (keV)

Intensity
Figure 1. $\gamma$-ray energy spectrum of the various apatite investigated.