Neutron-induced activity studies of the ATLAS SCT strip detector module, glues and paint

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1. Motivation

- The neutrons arising during the interactions on the ATLAS detector will be moderated by environment matter of this detector.
- 60% of the all moderated neutrons will have their energy in thermal region.
- Two aims of activation studies are:
  - to specify the radiation protection of workers and
  - to study of background signal.
- The main goal of this work is:
  - to find out a neutron-induced activity in several components of the ATLAS detector.
2. Experimental setup for thermal-neutron activation study of the module

- The ATLAS SCT silicon strip end-cap detection module was activated.
- VR-1 CTU Prague training reactor was used.
- Two gold foils were used as neutron flux monitors.
- The module was situated \(\sim 3\) cm from fuel elements.
- The activation time was 165 min. and the neutron flux was \((7.2\pm0.2)\times10^8\) cm\(^{-2}\).s\(^{-1}\).
3. Data analysis

- The delayed gamma-ray spectra were measured by shielded HPGe detector.
- 8 spectra with increasing sequence of real-time periods (1, 2, 4, ..., 120 min.) and 22 spectra with fixed duration of 240 min. have acquired due to record of decreasing activity.
- Two parameters (gamma-ray energy and half-life) have been verified to obtain proper identification of the radioisotopes.
- For every identified radioisotope, its activity at the end on the activation was counted up.
## 5. Results

<table>
<thead>
<tr>
<th>#</th>
<th>(^X)</th>
<th>t(_{1/2})</th>
<th>Activity</th>
<th>#</th>
<th>(^X)</th>
<th>t(_{1/2})</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(^{24})Na</td>
<td>15.0 h</td>
<td>37.0 ± 5 kBq</td>
<td>14</td>
<td>(^{110})Mg</td>
<td>250.0 d</td>
<td>318.0 ± 32 Bq</td>
</tr>
<tr>
<td>2</td>
<td>(^{27})Mg</td>
<td>9.5 m</td>
<td>79.0 ± 8 kBq</td>
<td>15</td>
<td>(^{116})In</td>
<td>54.3 m</td>
<td>4.2 ± 0.4 kBq</td>
</tr>
<tr>
<td>3</td>
<td>(^{28})Al</td>
<td>2.2 m</td>
<td>5.2 ± 0.5 MBq</td>
<td>16</td>
<td>(^{117})Sn</td>
<td>13.6 d</td>
<td>59.0 ± 7 Bq</td>
</tr>
<tr>
<td>4</td>
<td>(^{38})Cl</td>
<td>37.2 m</td>
<td>1.6 ± 0.3 kBq</td>
<td>17</td>
<td>(^{123})Sn</td>
<td>40.1 m</td>
<td>2.0 ± 0.2 kBq</td>
</tr>
<tr>
<td>5</td>
<td>(^{42})K</td>
<td>12.4 h</td>
<td>5.5 ± 0.6 kBq</td>
<td>18</td>
<td>(^{125})Sn</td>
<td>9.5 m</td>
<td>11.0 ± 1 kBq</td>
</tr>
<tr>
<td>6</td>
<td>(^{51})Ti</td>
<td>5.8 m</td>
<td>4.8 ± 0.7 kBq</td>
<td>19</td>
<td>(^{122})Sb</td>
<td>2.7 d</td>
<td>2.9 ± 0.3 kBq</td>
</tr>
<tr>
<td>7</td>
<td>(^{56})Mn</td>
<td>2.6 h</td>
<td>7.1 ± 0.9 kBq</td>
<td>20</td>
<td>(^{124})Sb</td>
<td>60.2 d</td>
<td>73.0 ± 7 Bq</td>
</tr>
<tr>
<td>8</td>
<td>(^{65})Ni</td>
<td>2.5 h</td>
<td>1.2 ± 0.1 kBq</td>
<td>21</td>
<td>(^{131})Ba</td>
<td>11.5 d</td>
<td>120.0 ± 12 Bq</td>
</tr>
<tr>
<td>9</td>
<td>(^{64})Cu</td>
<td>12.7 h</td>
<td>2.0 ± 0.2 MBq</td>
<td>22</td>
<td>(^{135})Ba</td>
<td>28.7 h</td>
<td>840.0 ± 100 Bq</td>
</tr>
<tr>
<td>10</td>
<td>(^{66})Cu</td>
<td>5.1 m</td>
<td>3.8 ± 0.5 MBq</td>
<td>23</td>
<td>(^{137})Ba</td>
<td>2.6 m</td>
<td>10.0 ± 2 kBq</td>
</tr>
<tr>
<td>11</td>
<td>(^{69})Zn</td>
<td>13.8 h</td>
<td>496.0 ± 51 Bq</td>
<td>24</td>
<td>(^{139})Ba</td>
<td>83.1 m</td>
<td>79.0 ± 8 kBq</td>
</tr>
<tr>
<td>12</td>
<td>(^{82})Br</td>
<td>35.3 h</td>
<td>377.0 ± 38 Bq</td>
<td>25</td>
<td>(^{182})Ta</td>
<td>114.4 d</td>
<td>227.0 ± 23 Bq</td>
</tr>
<tr>
<td>13</td>
<td>(^{108})Ag</td>
<td>2.4 m</td>
<td>4.3 ± 0.4 MBq</td>
<td>26</td>
<td>(^{198})Au</td>
<td>2.7 d</td>
<td>35.0 ± 4 kBq</td>
</tr>
</tbody>
</table>
6. Experimental setup for the fast-neutron activation studies

- Fast neutrons were produced from a cyclotron by means of \((p,n)\) reaction on a thick beryllium target (right upper figure).
- Energy spectrum of the neutrons arising in the beryllium target is practically same as in the case of \(D_2O\) target (right lower figure).
- The target is roughly a point source of neutrons, and therefore, the distance between the target and the activated samples defines the neutron flux.
- The analysis was done by same way as in case of the thermal-neutron induced activity.
7. Description of samples

- The ATLAS SCT silicon strip end-cap detection module (pictured on the right side)
- Two samples of glue are:
  i. Araldite AW106/HV953,
     - which is an epoxide adhesive glue of the sample weight of 34.3 mg, and
  ii. Eotite P102,
     - which is a special adhesive glue comprising silver sawdust of the sample weight of 21.3 mg.
- One candidate of fireproof white paint for the JM shielding
  - of the sample weight of 146.4 mg.
9. Preliminary results

- All samples have been activated. The total fluence of the SCT module is \(1.54 \times 10^{12} \text{ cm}^{-2}\); the total fluence of the other samples is \(1.73 \times 10^{14} \text{ cm}^{-2}\).
- For every sample, five delayed gamma-ray spectra were measured.
- The radioisotopes were produced by means of nuclear reactions the likes of \((n,\gamma)\), \((n,p)\), \((n,2n)\), \((n,np)\), ...
- The main peaks in the spectrum of the SCT module activated by fast neutrons are related to \(^{27}\text{Mg}\), \(^{29}\text{Al}\), and \(^{24}\text{Na}\) radioisotopes arising by neutron reactions on Si, Al, and Mg elements.
- All spectra are still in processing.
10. Conclusion

- The activations by means of thermal as well as fast neutrons were done. The activated samples were:
  - i. the ATLAS SCT silicon strip end-cap detection module,
  - ii. two samples of glue (Araldite AW106/HV953 and Eotite P102), and
  - iii. a candidate of fireproof white paint for the JM shielding.
- These experiments proved the necessity of taking into account the activation of ATLAS detector components.
- The results of the activation of the SCT module by the thermal neutron flux showed that 26 radioisotopes, some of them long lived, are generated.
- The data from the activation by means of the fast neutrons are in processing.
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