THE HEAT OF COMBUSTION OF δ-PLUTONIUM

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THE HEAT OF COMBUSTION OF 6-PLUTONIUM

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ABSTRACT

Precise measurements have been made of the heat of combustion of 8-plutonium metal. The heat of combustion of 1.01% gallium-stabilized 8-plutonium alloy was 4513.0 ± 7.2 joules/g at an oxygen pressure of 25 atm.

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I. The Heat of Combustion of 8-Plutonium 6
Introduction

This report describes the measurements made with an oxygen combustion calorimeter, described earlier,\(^1\) to determine the heat of combustion of gallium-stabilized \(\delta\)-plutonium metal.

Method

The procedures used to handle the \(\delta\)-plutonium metal and combustion products were identical to those employed for the combustion of \(\alpha\)-plutonium metal.\(^2\) The energy equivalent of the calorimeter with 25 atm. oxygen was 10,017 \(\pm\) 4.2 joules/\(^\circ\)C as determined with NBS benzoic acid. All runs were made at an oxygen pressure of 25 atm.

\(\delta\)-Plutonium Metal

The \(\delta\)-plutonium metal was analyzed at this Laboratory with the following results: Mg, 0.003\%; Al, 0.01\%; Si, 0.011\%; Fe, 0.027\%; Ca, 0.005\%; Ni, 0.009\%; Ga, 1.01\%; C, 0.0115\%; H, 0.000\%; and O, 0.0015\%. The metal was thus about 98.91\% plutonium. If we assume that the carbon and oxygen were combined with the plutonium and not with the metallic impurities, the material was 96.01 mole \% \(\delta\)-plutonium metal.
Combustion of \(\delta\)-Plutonium

The combustions were performed on sintered discs of plutonium dioxide as described earlier.\(^2\) Seven runs were made. Combustion was complete in each run except one in which 98.82\% of the metal burned. X-ray patterns of the combustion products showed the lattice constant of the cubic unit cell, CaF\(_2\) type, to be \(a = 5.3949 \pm 0.0003\) Å. The average initial temperature was 25.3°C. The results are listed in Table I.

The heat of combustion of the 10 mil diameter \(\delta\)-plutonium fuse wire used to ignite the main mass of the alloy was not determined separately. Its weight was only about 3\% of the total weight and its heat of combustion could not have been sufficiently different to introduce a significant error.

Table I

<table>
<thead>
<tr>
<th>Mass (\delta)-Pu Burned, g.</th>
<th>Wt. PuO(_2), g.</th>
<th>Joules/total</th>
<th>(\Delta T), K.</th>
<th>Firing, Joules</th>
<th>Pu, Joules/g.</th>
<th>Dev. from Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0109</td>
<td>124.6</td>
<td>10051.8</td>
<td>1.3527</td>
<td>8.1</td>
<td>4513.3</td>
<td>10.2</td>
</tr>
<tr>
<td>3.0668</td>
<td>122.3</td>
<td>10051.3</td>
<td>1.3814</td>
<td>8.6</td>
<td>4524.7</td>
<td>1.2</td>
</tr>
<tr>
<td>3.0071</td>
<td>121.6</td>
<td>10051.1</td>
<td>1.3547</td>
<td>6.8</td>
<td>4525.8</td>
<td>2.3</td>
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<tr>
<td>2.9777</td>
<td>117.8</td>
<td>10050.2</td>
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<td>6.7</td>
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<tr>
<td>3.0402</td>
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<td>10049.9</td>
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<td>10053.1</td>
<td>1.3655</td>
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<td>12.6</td>
</tr>
<tr>
<td>3.0243</td>
<td>124.2</td>
<td>10051.7</td>
<td>1.3604</td>
<td>5.1</td>
<td>4519.8</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Av.** 4523.5

**2 x St. Dev.** 5.6

\(\text{APPROVED FOR PUBLIC RELEASE}\)
The average value of 4523.5 joules/g. for the combustion of the alloy must be corrected for the impurities present.

Correction for Impurities

The calculated percentage composition of the $\delta$-plutonium by weight is $\delta$-Pu metal, 98.91%; Ca metal, 1.01%; PuO$_2$, 0.013%; Mg, 0.003%; Al, 0.01%; Si, 0.011%; Ca, 0.005%; Ni, 0.009%; Fe, 0.027%; C, 0.0115%. The carbon may be combined with the plutonium as PuC but the amount is small. The heats of combustion of graphite (to CO$_2$), Mg (to MgO), Si (to SiO$_2$), Al (to Al$_2$O$_3$), Fe (to Fe$_2$O$_3$), Ca (to CaO), and Ni (to NiO$_2$) are taken as 33,000, 24,670, 30,100, 30,970, 7,320, 15,825, and 4,095 joules/g., respectively. The heat of combustion of the 1.01% gallium-stabilized $\delta$-plutonium alloy, corrected for the presence of the impurities, becomes 4513.0 ± 7.2 joules/g., or 0.23% lower than the uncorrected value. If this value is now corrected for the presence of the gallium, taking 7710 joules/g. as its heat of combustion, the heat of combustion of $\delta$-plutonium metal becomes 4480.3 joules/g. The heat of combustion of $\alpha$-plutonium is 4413.4 ± 4.1 joules/g. The difference between these two values may be attributed to (1) the heats of the $\alpha$-$\beta$, $\beta$-$\gamma$, and $\gamma$-$\delta$ phase changes, (2) the heat of solution of gallium in plutonium, and (3) the heat of solution of Ga$_2$O$_3$ in PuO$_2$ (both X-ray and microscopic examination of the combustion product showed no separate Ga$_2$O$_3$ phase). Until additional data are obtained, perhaps from solution calorimetry, it will not be possible to calculate the heat of combustion of pure $\delta$-plutonium metal.
Bibliography
