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LOS ALAMOS SCIENTIFIC LABORATORY
OF THE UNIVERSITY OF CALIFORNIA o LOS ALAMOS NEW MEXICO

THE HEAT OF COMBUSTION OF δ-PLUTONIUM

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OF THE UNIVERSITY OF CALIFORNIA LOS ALAMOS NEW MEXICO

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THE HEAT OF COMBUSTION OF δ-PLUTONIUM

(Title unclassified)

by

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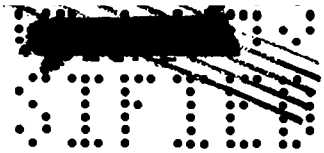

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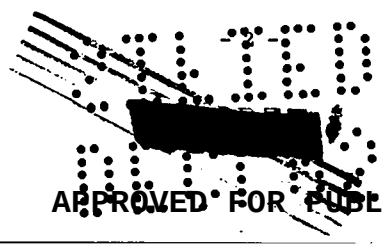

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ABSTRACT

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

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TABLE

Introduction

This report describes the measurements made with an oxygen combustion calorimeter, described earlier,[1] to determine the heat of combustion of gallium-stabilized δ-plutonium metal.

Method

The procedures used to handle the δ-plutonium metal and combustion products were identical to those employed for the combustion of α-plutonium metal.[2] The energy equivalent of the calorimeter with 25 atm. oxygen was 10,017.8 ± 4.2 joules/°C. as determined with NBS benzoic acid. All runs were made at an oxygen pressure of 25 atm.

δ-Plutonium Metal

The δ-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 % δ-plutonium metal.

Combustion of δ-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 ± 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 δ-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

THE HEAT OF COMBUSTION OF δ-PLUTONIUM

Mass δ-Pu Burned, g.	Wt. PuO_2, g.	joules/° total	ΔT, °K.	Energy from Firing, joules	Energy from Pu, joules/g.	Dev. from Mean
3.0109	124.6	10051.8	1.3527	8.1	4513.3	10.2
3.0668	122.3	10051.3	1.3814	8.6	4524.7	1.2
3.0071	121.6	10051.1	1.3547	6.8	4525.8	2.3
2.9777	117.8	10050.2	1.3393	6.7	4518.1	5.4
3.0402	116.5	10049.9	1.3701	6.5	4527.0	3.5
3.0251	129.8	10053.1	1.3655	5.4	4536.1	12.6
3.0243	124.2	10051.7	1.3604	5.1	4519.8	3.7
				Av.	4523.5	5.6
				2 x St. Dev.		5.6

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 δ-plutonium by weight is δ-Pu metal, 98.91%; Ga 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_2O_3), Fe (to Fe_2O_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 δ-plutonium alloy, corrected for the presence of the impurities, becomes 4513.0 $\pm$ 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 δ-plutonium metal becomes 4480.3 joules/g. The heat of combustion of α-plutonium is 4413.4 $\pm$ 4.1 joules/g.[2] 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_2O_3 in PuO_2 (both X-ray and microscopic examination of the combustion product showed no separate Ga_2O_3 phase). Until additional data are obtained, perhaps from solution calorimetry, it will not be possible to calculate the heat of combustion of pure δ-plutonium metal.

Bibliography

(1) Holley, C. E., Jr., and Huber, E. J., Jr., "A Precision Calorimeter for the Measurement of Heats of Combustion," LA-2084, November, 1955.

(2) Huber, E. J., Jr., Head, E. L., and Holley, C. E., Jr., "The Heat of Combustion of Plutonium." LA-2279, November, 1958.