Measurement of the Specific Gravity of the Radioactive Fallout Particles produced by the Third Chinese Nuclear Test, May, 1966

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ABSTRACT

The measurement of the specific gravity of the highly radioactive fallout particles from the third Chinese nuclear test explosion was made. The specific gravity ranged from 5.2 to 6.5 and there was a tendency that the specific gravity increased with increasing darkness of the particle color. In connection with the results obtained by the electron microprobe analyses made previously, it was assumed that the specific gravity increased with increasing ratio of iron to aluminium in the matrix materials.

INTRODUCTION

Hot particles from the third Chinese nuclear test explosion on May 9, 1966 were found and collected on May 10 and 11 on roofs of the buildings in our laboratory. Particles having beta-activity higher than a few mCi were distributed at a density of about 50 particles per m². These hot particles were assumed to have fallen on the ground mainly with the rain on May 10, because at that time the activity in the atmosphere was not so high and many large spots were found on an autoradiograph of the filter paper through which the rain water sample on May 10 was filtered, while no large spots were found on autoradiographs of the filter papers through which a large volume of air was passed. More than forty hot particles were isolated from dust particles under a microscope. The shape and the color were examined and the relation between the particle size and the activity was studied, in the same ways as were reported in the preceding papers1,2. Then the specific gravity was determined by measuring the falling velocity of particles in a liquid.

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MEASUREMENT OF THE SPECIFIC GRAVITY OF FALLOUT PARTICLES

EXPERIMENTAL RESULTS AND DISCUSSION

1. Relation between the particle size and the beta-activity  
   Forty-five hot particles were isolated and examined under a microscope and their microphotographs were taken in order to measure their diameters precisely. They were variously colored in yellow, brown or black. Some of them were colorless. The gamma-counting rate of each particle was measured with a NaI (TI1) scintillation counter. Among the forty five particles six particles were chosen and their beta-counting rates were measured with a G.M. counter, while care was taken so that they might be accompanied with no dust particles. The ratios of beta- to gamma-counting rate were determined for the six particles, and the average ratio in the six particles was used as the conversion factor to estimate beta-counting rate from gamma-counting rate. Fig. 1 shows the relation between the particle diameter and the beta-activity thus obtained, which suggests that the activity was nearly proportional to the third power of the diameter, namely to the volume, and that the specific activity at a young stage was nearly constant, regardless of the particle color. Such proportionality between the activity and the volume was found by many researchers on hot particles produced in several past explosions\(^3\text{-}^5\). We also observed the same relation in hot particles originated from a large scale air burst by U.S.S.R. in autumn 1961\(^1\).

The hot particles from the first Chinese explosion on October 16, 1964 which was believed to be a land surface burst showed some different features from ones now under study. Among the former samples were found some particles which were mottled with more than two colors or consisted of two different parts with different colors. Proportionality between the activity and the volume was not so clear and the specific activity was much lower\(^2\).

This time, a considerable radionuclide fractionation was found in hot particles and the result of a detailed study revealed that the initial atom numbers per unit

![Graph](image-url)

**Fig. 1.** The relation between the particle diameter and the beta-activity
volume of the nuclides such as $^{95}$Zr, $^{97}$Zr, $^{147}$Nd, $^{237}$U and $^{239}$Np were more or less related with the particle color. The results of the study on the radionuclide fractionation will be reported elsewhere in near future.

2. Measurement of the specific gravity  

The specific gravity of the hot particles was estimated by measuring the falling velocity of them in a liquid, using the following equation of Stokes' law.

$$\eta = \frac{2}{9} \frac{d - d'}{v} \frac{g}{r^2},$$

where $\eta$: the viscosity of a liquid,
$d$: the density of a spherical particle falling down in a liquid,
$d'$: the density of a liquid,
g: the gravity acceleration,
v: the falling velocity of a spherical particle,
r: the radius of a spherical particle.

The equation (1) is modified as follows, where $D$ denotes the diameter of a spherical particle.

$$d = d' + \frac{18 \nu \eta}{gD^2}$$

The schematic view of the apparatus for this experiment is shown in Fig. 2. A glass tube of 2 cm in diameter whose bottom was closed with a film thinner than 0.1 mm (PARAFILM "M") was filled with 99% ethanol 20 cm in depth. The glass tube was mounted vertically on an end window type G.M. tube as closely as possible. The G.M. tube was connected with a rate meter and a recording millivolt meter. When a particle reached the thin film at the bottom, the counting rate increased abruptly. The time required for a particle to settle down through 20 cm ethanol column was determined by reading the record on the chart. The sample particles were so fine that they often floated on the liquid surface due to the surface tension of the liquid. In such cases particles would not reach the bottom. Sometimes an unreasonably long transit time was recorded, possibly because of the interference by the impact on the glass wall on the way to the bottom. However, when measurements were successfully repeated, nearly the equal transit time could be reproduced.
in each run. Measurements were made at a room temperature of about 25°C. In each run the temperature of the ethanol column was measured and the viscosity and the density of 99% ethanol at the measured temperature were estimated by interpolating the values shown in a table of physico-chemical constants⁹).

In Table 1 are shown some experimental results, where successful measurements were made three times each for ten particles. The specific gravity was within a narrow range from 5.2 to 6.5. It is noted that light-colored particles had smaller specific gravity than dark ones.

Table 1. Results of the measurements of the specific gravity of hot particles produced by the third Chinese nuclear test explosion on May 9, 1966

<table>
<thead>
<tr>
<th>Particle no.</th>
<th>Color</th>
<th>Mean diameter (μ)</th>
<th>Measured specific gravity values</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>colorless</td>
<td>14.9</td>
<td>5.06 5.29 5.27</td>
<td>5.2</td>
</tr>
<tr>
<td>2</td>
<td>colorless</td>
<td>13.8</td>
<td>5.25 5.36 5.27</td>
<td>5.3</td>
</tr>
<tr>
<td>3</td>
<td>yellowish brown</td>
<td>13.2</td>
<td>5.38 5.79 5.85</td>
<td>5.7</td>
</tr>
<tr>
<td>4</td>
<td>yellow</td>
<td>17.4</td>
<td>5.65 5.73 5.74</td>
<td>5.7</td>
</tr>
<tr>
<td>5</td>
<td>yellow</td>
<td>11.1</td>
<td>5.56 5.67 5.91</td>
<td>5.7</td>
</tr>
<tr>
<td>6</td>
<td>yellowish brown</td>
<td>14.5</td>
<td>5.57 5.60 5.89</td>
<td>5.7</td>
</tr>
<tr>
<td>7</td>
<td>yellowish brown</td>
<td>13.0</td>
<td>5.65 5.80 6.28</td>
<td>5.9</td>
</tr>
<tr>
<td>8</td>
<td>yellow</td>
<td>14.1</td>
<td>5.77 5.91 6.22</td>
<td>6.0</td>
</tr>
<tr>
<td>9</td>
<td>black</td>
<td>16.3</td>
<td>6.04 6.49 6.75</td>
<td>6.4</td>
</tr>
<tr>
<td>10</td>
<td>reddish black</td>
<td>13.8</td>
<td>6.26 6.44 6.74</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Kobayashi and Sasaki made a similar measurement on a hot particle with dark brown color which originated from an air burst carried out in autumn 1962 by U.S.S.R. and obtained a specific gravity value of 5.4—6.7⁹), which agreed well with our present values.

According to the previous results of the electron microprobe analyses of hot particles produced by air bursts, it was found that metallic elements in the matrix materials were mainly iron and aluminium⁷—⁹), and the composition ratio of iron to aluminium increased with increasing darkness of the particle color⁹). We have not yet made electron microprobe analysis on the hot particles now under study; it, however, may not be unreasonable to assume that they are also mainly composed of oxide of iron and aluminium. It is therefore concluded that the specific gravity increases with increasing ratio of iron to aluminium in the matrix materials. The specific gravities of iron oxides and aluminium oxide are as follows: Fe₂O₃: 5.18, Fe₃O₄: 5.24, FeO: 5.7, Al₂O₃: 3.99. According to our result of observation on the specific gravity it seems that the hot particles which were subjected to the measurement were mainly composed of iron oxides of lower oxidation state and mixed with some metallic state iron and aluminium.
REFERENCES