# MASSES OF LEAD ISOTOPES

1958

SovietRxiv

## Abstract

## Full Text

## PHYSICS

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# MASSES OF LEAD ISOTOPES

*(Presented by Academician L. A. Artsimovich on 26 IX 1957)*

In the present communication we set forth the results of measurements of the masses of the lead isotopes $Pb^{204}$, $Pb^{206}$, $Pb^{207}$, and $Pb^{208}$. These measurements were undertaken in connection with the determination of the binding energy of nucleons in the nucleus in the region of magic numbers for protons 82 and neutrons 126, and with the need to refine the mass of the isotope $Pb^{208}$, used as the reference value for calculating the masses of heavy isotopes with $z \geq 82$ from nuclear-reaction data. The measurements were carried out on the mass-spectrographic apparatus described in paper ([1]). The resolving power of the instrument, determined from doublet lines, in this range was of the order of 60,000-80,000. To increase the accuracy of the measurements, determination of the masses of the lead isotopes was carried out by direct comparison with the corresponding mass of hydrocarbons containing the isotopes $H^1$, $C^{12}$, and $O^{16}$. The masses of the isotopes $H^1$ and $C^{12}$ had previously been measured with sufficient accuracy ([1]). The obtained values were checked by determining the mass of a lead isotope from different doublets and by obtaining lead ions from various compounds, including such cases when the molecular weight of the hydrocarbon compound was equal to the atomic weight of the lead isotope. This completely eliminated possible systematic errors associated with dissociation of molecules ([2]).

Each value of $\Delta M$ of a doublet was obtained as a result of processing 18-20 mass spectrograms photographed on different plates. The results of the measurements are given in Table 1. From comparison of the data of this

**Table 1**

| Doublet | Value of $\Delta M$ in $10^{-3}$ m.u. | Value of the mass of the lead isotope | Mean value of the mass of the Pb isotope | Product from which the ions were obtained |
|---|---|---|---|---|
| $Pb^{208}$–$C_{14}H_8O_2$ | 75.998 ± 59 | 208.042618 ± 63 | 208.042658 ± 35 | $Pb^{208}$ from $Pb(CH_3)_4$ |
| $Pb^{208}$–$C_{14}H_8O_2$ | 75.919 ± 47 | 208.042697 ± 51 | 208.042658 ± 35 | $Pb^{208}$ from metal vapor |

| Doublet | Value of $\Delta M$ in $10^{-3}$ m.u. | Value of the mass of the lead isotope | Mean value of the mass of the Pb isotope | Product from which the ions were obtained |
|---|---|---|---|---|
| $Pb^{207}$–$C_{14}H_7O_2$ | 68.938 ± 110 | 207.041546 ± 112 | 207.041574 ± 35 | $Pb^{207}$ from $Pb(CH_3)_4$; $C_{14}H_7O_2$ from $C_{14}H_8O_2$ |
| $Pb^{207}$–$C_{14}H_7O_2$ | 68.887 ± 50 | 207.041587 ± 54 | 207.041574 ± 35 | $Pb^{207}$ from metal vapor; $C_{14}H_7O_2$ from $C_{14}H_8O_2$ |
| $Pb^{207}$–$C_{15}H_{11}O$ | 105.273 ± 35 | 207.041589 ± 40 | 207.041574 ± 35 | $Pb^{207}$ from metal vapor; $C_{15}H_{11}O$ from $C_{15}H_{12}O$ |
| $Pb^{206}$–$C_{16}H_{14}$ | 135.000 ± 66 | 206.040108 ± 69 | 206.040184 ± 76 | $Pb^{206}$ from $Pb(CH_3)_4$ |
| $Pb^{206}$–$C_{16}H_{14}$ | 134.849 ± 33 | 206.040259 ± 39 | 206.040184 ± 76 | $Pb^{206}$ from metal vapor |
| $Pb^{204}$–$C_{16}H_{12}$ | 120.472 ± 44 | 204.038352 ± 48 | 204.038352 ± 48 | $Pb^{204}$ from metal vapor; $C_{16}H_{12}$ from $C_{16}H_{14}$ |

table it is seen that, within the measurement errors, there is satisfactory "internal" agreement among the values of the isotope masses determined from different doublets. The values of $\Delta M$ for each of the doublets $Pb^{208}$–$C_{14}H_8O_2$, $Pb^{207}$–$C_{14}H_7O_2$, and $Pb^{206}$–$C_{16}H_{14}$, within the measurement errors, coincide with one another independently of the origin of the lead ions—atomic or dissociative. Good agreement of the values of the masses of the lead isotopes also occurs in the case when the doublet pair for

of the given lead isotope was formed with the aid of various hydrocarbon compounds. All this may serve as confirmation of the absence of systematic measurement errors and of the reliability of the data obtained.

As can be seen from Table 2, the values of the masses of the lead isotopes obtained in the present work differ from the corresponding values measured earlier by the mass-spectrographic method [3] by approximately 1 mmu.

**Table 2**

| Source | $Pb^{208}$ | $Pb^{207}$ | $Pb^{206}$ | $Pb^{204}$ |
|---|---|---|---|---|
| [4] | $208,041640 \pm 0^*$ | $207,040580 \pm 10^*$ | $206,038826 \pm 10^*$ | $204,036859 \pm 130^*$ |
| [3] | $208,041600 \pm 1000$ | $207,042900 \pm 1600$ | – | – |
| Data of the present work (1957) | $208,042658 \pm 35$ | $207,041574 \pm 35$ | $206,040184 \pm 76$ | $204,038352 \pm 48$ |

* All errors marked with an asterisk are equal to 1000 on the basis of the error obtained from the mass-spectrographic values [3].

At the same time, the mass differences of the isotopes $Pb^{208}$—$Pb^{207}$, $Pb^{207}$—$Pb^{206}$, $Pb^{206}$—$Pb^{204}$ (see Table 3), calculated from the data of the present work, differ from the corresponding data obtained from nuclear reactions [4] by less than 0.3 mmu.

**Table 3**

| | $Pb^{208}$—$Pb^{207}$ | $Pb^{207}$—$Pb^{206}$ | $Pb^{206}$—$Pb^{204}$ |
|---|---|---|---|
| Nuclear reactions* | $1,001060 \pm 1400$ | $1,001754 \pm 1400$ | $2,001967 \pm 1500^{**}$ |
| According to the data of the present work | $1,001084 \pm 30$ | $1,001390 \pm 80$ | $2,001832 \pm 90$ |

* For the measurement errors, see the footnote to Table 2.

The authors express their gratitude to E. E. Baroni and his coworkers T. V. Lebsadze, K. A. Kovyrzina, and V. M. Shonia for preparing the organometallic compounds and heavy hydrocarbons.

Received
5 VI 1957

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*Note: Figure translations are in progress. See original paper for figures.*