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IN CHEMICAL COMPOUNDS

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In 1947 Fermi and Teller[1] predicted
that the mesic atom formation in chemical
compounds should be proportional to Z of
individual constituents. This thesis known
as the "Z-law" has been experimentally
verified for a number of compounds. Thus,
for muonic atoms the time distribution of
decay electrons and X-ray intensities have
been analysed.   As a result of
these   investigations the main characte-
ristics of chemical effects have been un-
derstood[2,3].

As to pionic atoms, a great deal of all
the experimental data reported up-to now
relates to hydrogenous compounds for which
mesochemical effects are usually studied
by a very special reaction of charge ex-
change. Despite its long history [4] and great
importance this class of compounds seems to
be somewhat one-sided for establishing the
general picture of "pionic chemistry". Ex-
perimental data for compounds of heavier
elements are rather poor.

Due to strong pion-nuclear interaction
neither the pion decay on the atomic orbits
nor electromagnetic transitions between
low-lying levels take place in pionic atoms.
For this reason only transitions between
high-lying levels have been used in all the
cases with heavy-atom compounds [5-7].

Because of the difference in the nature of pions and muons, and in their interactions with matter suggestion of the full analogy between the pionic and muonic chemistries without the systematic experimental study should not be quite rightful.

In this work we have studied the alkaline iodides using a new technique for mesochemistry, namely, the induced radioactivity method of pion capture identification. This method is based on the following property of negative pions: in contrast to muons they have equal probabilities of atomic and nuclear capture. As the ionic bound in these compounds is almost identical, the probability of mesic atom formation should depend only on the atomic number, i.e., the charge of the nucleus.

The targets of LiJ , NaJ , KJ , RbJ and CsJ powders were activated by stopped negative pions of the bio-medical beam of the Dubna synchro-cyclotron. Irradiation, cooling and counting times for all the targets were the same and equal to 50 min, 5 min and 40 min, respectively, with an accuracy of 10 seconds. Each target contained 10.000 ± 0.001 gram of iodine.

To aviod possible complications in the interpretation of the results crystallization water was previously removed from target material.

The relative probabilities of pion capture in iodine for compounds under investigation were extracted from the 1293.5 keV gamma ray intensity of ^{116m}Sb ($J\pi = 8-$, $T_{1/2} = 60$ min), high-spin isomer produced in the $^{127}J(\pi^-, 1p\,10n)$ reaction.

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For monitoring the thermalized pion flux fine Bi_2O_3 powder $(5.000 \pm 0.001 \ g)$ was uniformly mixed with target powders. The intensities of 899 keV and 912 keV gamma-rays from $^{204m}Pb(J^{\pi}=9^-, T_{1/2}=66 \ min)$, high-spin isomer produced in the $^{209}Bi(\pi^-,5n)$ reaction were used for this purpose.

Due to a large value of ^{116m}Sb and ^{204m}Pb gamma-ray energies their self-absorption in the targets may be neglected. All the measurements were performed with the same spectrometer under entirely identical conditions.

Figure 1 shows the parts of gamma-ray spectra in which the above-mentioned lines are located.

Figure 2 shows R and W_{exp} experimental values, where $R=S_t/S_m$ is the ratio of 1293.5 keV photopeak area to the 899 and/or 912 keV photopeak areas; W_{exp} is the same ratio but corrected by the number of π^- stops in the target and monitor powders. To obtain this correction the photopeak area is divided by the corresponding stopping power Δ_i.

On the assumption that the stopping power for chemical compounds is an additive functions and for an individual chemical element it is proportional to the electron density, the following relationship can be written:

$$W_{exp} \propto R \ \frac{1}{1 + z_1/z_2} , \tag{1}$$

where z_2 is the atomic number of iodine, z_1 is the atomic number of alkaline metal. Since target masses and time intervals were known with high accuracy the presented errors are only statistical.
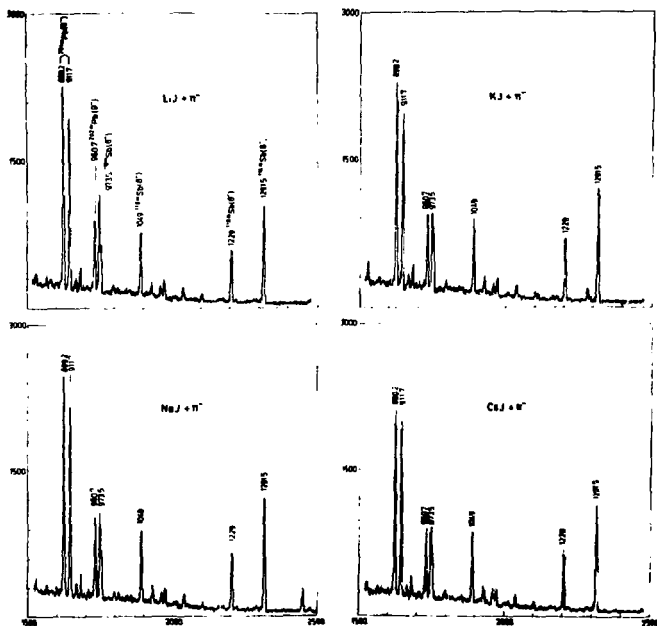
Fig. 1. Radioactive decay gammas from targets irradiated with stopped pions (1 MeV region spectra).

Assuming the validity of some generalized " Z-law": $P_i \propto Z_i^n$ we obtain the theoretical dependence of the pionic iodine formation probability on the atomic number of alkaline metal in the following form:
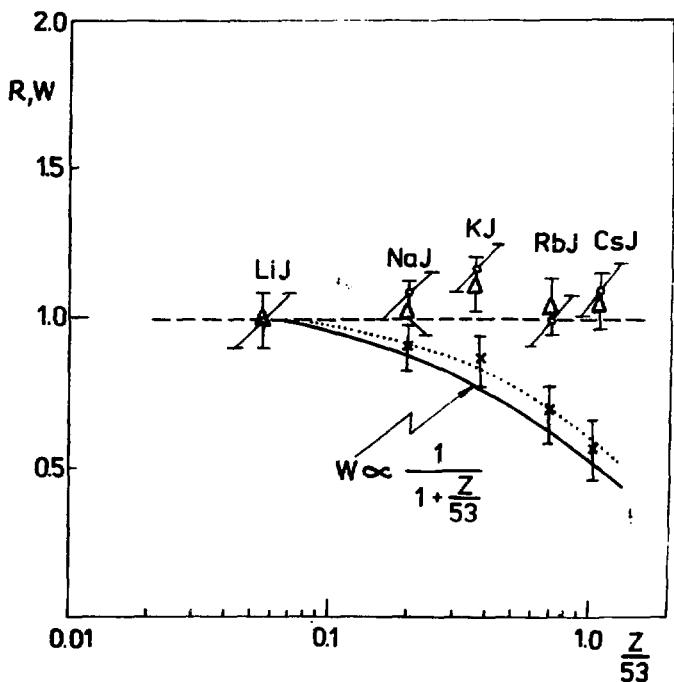
Fig. 2. Extracted experimental data versus the atomic number of the iodine chemical partner. o and Δ -target-to-monitor photo-peak ratios (R): 899/1293 and 912/1293,
× .probability of pionic iodine formation (W_{exp}) . Solid line is the prediction of the " Z-law". All the values are normalized to the lithium-iodine ones.

$$W_{th} = \frac{P_2}{P_1 + P_2} \propto \frac{1}{1 + (z_1/z_2)^n} . \qquad (2)$$

If $n = 1$, it follows from (1) and (2.

$$R = \frac{S_t}{S_m} \propto \frac{W_{exp}}{W_{th}} = const$$

Thus, we have a very satisfactory agreement of experimental results with the predictions of the " Z -law". Naturally, the extrapolation of this conclusion to other types of compounds should be incorrect.

Small disagreement between W_{exp} and W_{th} values may be connected with the inexact additivity of the stopping powers for chemical compounds and inexact proportionality of the stopping powers to the atomic number of the moderator at the very end of the pion range: $\Delta_i \propto (Z_i / E) \, \ell n \, (E/aZ_i)$; where $a \simeq 1$ keV.

On the other hand, from the fitting of the W_{th} function to the experimental data we have obtained $n = 1.1$; however, it is not known what physical origin of this result is.

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