# Test of the Pauli principle

V. M. Novikov, E. Nolte,[1)] and A. A. Pomanskiĭ
*Institute of Nuclear Research, Academy of Sciences of the USSR*

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The results of the mass-spectrometric experimental search in a fluorine sample of hypothetical $^{20}$Ne atoms with a deformed structure of the electronic shells can be interpreted as a constraint on the lifetime of $^{20}\overline{\text{Ne}}$ atoms relative to the violation of the Pauli principle, $T > 2 \times 10^{30}$ y, and as a constraint on the concentration of symmetrized (non-Pauli) electrons in the universe, $\delta(e^{-\prime}) < 2 \times 10^{-22}$.

Theoretical models which admit violation of the Pauli principle have recently been discussed extensively.[1-3] From the experimental standpoint, there are two ways in which this effect can be detected[2-5]: (1) detection of radiation produced as a result of a transition which violates the Pauli principle and (2) search for stable products of such transitions.

In this letter we present the results of an experiment whose arrangement was suggested by Novikov and Pomanskiĭ.[5]

As a result of a chemical evolution of matter, each element with an atomic number $z$ contains, according to these authors, an admixture of anomalous atoms, formed as a result of the violation of Pauli principle, of an element which has in the simplest case the atomic number $z+1$. It is assumed that the anomalous atom is stable and that the chemical properties of the anomalous atom $\overline{z+1}$ and the normal atom $z$ are identical. One of the most sensitive methods involves a search for anomalous $^{20}\overline{\text{Ne}}$ atoms in fluorine which has the only stable $^{19}$F isotope.

The quantity measured experimentally is thus the concentration of anomalous $^{20}\overline{\text{Ne}}$ atoms in fluorine $C(^{20}\overline{\text{Ne}})$. We will use the latter quantity to calculate the ratio $N(^{20}\overline{\text{Ne}}/N(^{20}\text{Ne})$, which is the number of anomalous $^{20}\overline{\text{Ne}}$ atoms and normal $^{20}$Ne atoms which existed in the universe before the beginning of chemical differentiation of matter (i.e., about 4.5 billion years ago)[5]:

$$N(^{20}\overline{\text{Ne}})/N(^{20}\text{Ne}) = C(^{20}\overline{\text{Ne}})\frac{P(\text{F})}{P(^{20}\text{Ne})}, \quad (1)$$

where $P(\text{F})/P(^{20}\text{Ne}) = 0.0003$ (Ref. 6). $P(\text{F})$ and $P(^{20}\text{Ne})$ are the relative cosmic abundances of fluorine and $^{20}$Ne. The appearance of a factor $P(\text{F})/P(^{20}\text{Ne})$ is a consequence of the fact that upon formation of matter and its chemical evolution the anomalous $^{20}\overline{\text{Ne}}$ atoms, which form from a relatively large number of $^{20}$Ne atoms, "dissolve" in the presence of a relatively small number of fluorine atoms.

The experiment was carried out on the accelerator of the Munich Technical University. To detect the anomalous $^{20}\overline{\text{Ne}}$ atoms, we used the method of accelerator mass spectrometry based on the time-of-flight technique.[7] The start and stop detectors were

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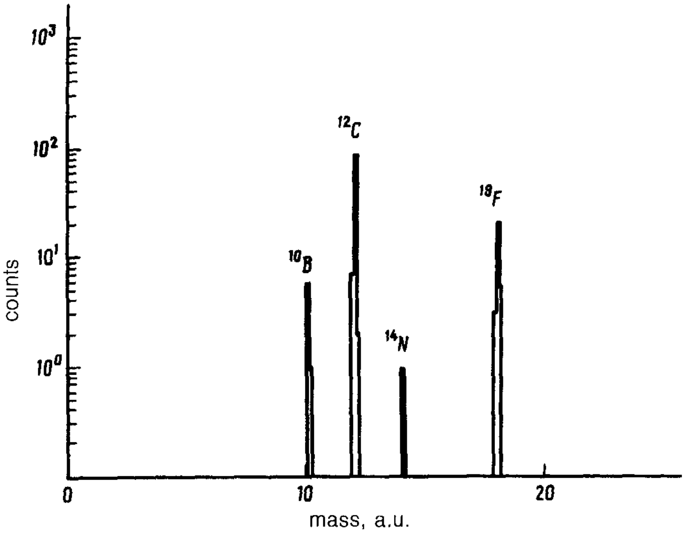


FIG. 1. Experimentally obtained mass spectrum.

spaced 2.7-m apart. As the fluorine same we used $CaF_2$, from which negative $^{19}F$ ions and hypothetical $^{20}\overline{Ne}$ ions were extracted. After magnetic and electric deflections the ions were injected in tandem, "stripped" to the charged $5^+$ state, and accelerated to 46 MeV. The $F^-$ ion current was about 10 $\mu$A in the 8% transmission from the ion source to the detector. Figure 1 shows the mass spectrum obtained after taking measurements for 10 h. As can be seen in Fig. 1, the spectrum has no events with a mass of 20. This result makes it possible to set an upper limit on the concentration of anomalous $^{20}\overline{Ne}$ atoms in fluorine:

$$C(^{20}\text{Ne}) < 6\times10^{-18}. \tag{2}$$

Using relation (1), we find

$$\frac{N(^{20}\overline{\text{Ne}})}{N(^{20}\text{Ne})} < 2\times10^{-21}. \tag{3}$$

The value in (3) can be interpreted in two ways.

1. Anomalous $^{20}\overline{Ne}$ atoms can be formed from normal $^{20}Ne$ atoms by dropping the valence electron (which violates the Pauli principle) from the $2p$ shell to a lower-lying is shell. For an exposure time $\tau\sim4.5$ billion years[5] we then find the constraint on the lifetime of a normal $^{20}Ne$ relative to the transition to $^{20}\overline{Ne}$ with three electrons in the $K$ shell to be

$$T=\frac{\tau}{N(^{20}\overline{\text{Ne}})\,/\,N(^{20}\text{Ne})} > 2\times10^{30}\ \text{yr}. \tag{4}$$

We note, however, that such a spontaneous transformation of an ordinary atom to a "non-Pauli" atom may turn out to be forbidden.[2,8]

2. Anomalous $^{20}\overline{\mathrm{Ne}}$ atoms may exist if not all of the electrons in the universe are antisymmetrized.[2] Since a $^{20}$Ne atom has ten electrons, we find the constraint on the concentration $\delta(e^{-\prime})$ of non-Pauli electrons (relative to the normal electrons) to be

$$\delta(e^{-\prime}) \doteq \frac{N(^{20}\overline{\mathrm{Ne}})\,/\,N(^{20}\mathrm{Ne})}{10} < 2\times 10^{-22}\,. \tag{5}$$

The results reported here can be refined by more than six orders of magnitude by increasing the measurement time, the ion current, and the transmission and by using a fluorine sample enriched with hypothetical $^{20}\overline{\mathrm{Ne}}$ atoms.

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[1)] Munich Technical University, Garching, FRG.

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