SEARCH FOR ANOMALOUS HYDROGEN

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An attempt is made to detect with the aid of a mass spectrometer elementary particles of mass greater than that of the proton. It is shown that in the earth's atmosphere the concentration of positively charged particles with a mass greater than that of deuterium may be smaller than 1.5×10^{-12} if the concentration is defined as the ratio of the number of sought particles to the total number of particles in a given air sample.

As already noted by Okun'[1], the presently known laws pertaining to elementary particles do not exclude the existence of anomalous stable particles (charged, neutral, or antiparticles) with mass larger than that of the proton. The possible concentration of such particles in the earth's atmosphere, according to the estimate given in [1], is on the order of 1×10^{-10}, this being the upper limit of the concentration of the "wild" particles. It is obvious that any positively charged "wild" particle capturing an electron should form heavy "wild" hydrogen which, when oxidized, could participate in the water cycle and in all other chemical reactions with ordinary hydrogen and its isotopes.

There is likewise no doubt that all processes involving enrichment of hydrogen with deuterium (for example, in the production in heavy water), should be accompanied by considerable enrichment of the sample with the anomalous heavy isotopes.

Thus, in spite of the low expected content of "wild" particles in atmospheric air, it is not senseless to make a special attempt at a mass spectrometric investigation of samples of heavy water with an aim at detecting the anomalous hydrogen (all the more since the sensitivity of modern mass spectrometric methods is sufficiently high).

The MI 1311-04 mass spectrometer was subjected to additional tests to ascertain its maximum sensitivity and best resolution. This mass spectrometer, with a 90° sector magnetic field and an analyzer chamber bent along a circular arc of 300 mm radius, is equipped with a source of ions produced by bombarding molecules of the investigated gas with 25—30 eV electrons. An electron multiplier was used as ion collector and first amplification stage of the mass spectrometer, so that ion currents on the order of 10^{-14}—10^{-18} A could be measured. (Currents larger than 10^{-14} A were measured with a dc amplifier with 100% feedback, connected directly to the collector. The measurement scales were made to continue each other.) The gain of the multiplier was measured before each ion-current measurement, and ranged from 5×10^3 to 10×10^3.

After prior conditioning of the instrument, the content of helium in atmospheric air was determined. According to the tabulated data, the content of helium in the earth's atmosphere is $\sim 5 \times 10^{-4}$ %. This is very close to the result obtained with the MI 1311-04 mass spectrometer.

Attempts to observe He^3 in the helium were not successful, since the mass spectrometer resolution was not high enough to separate the lines of He^3 and HD at the given supply of helium to the ion source of the instrument. At the same time, the lines corresponding to He^4 and D_2 were quite clearly separated, since the mass defect was sufficiently large.

Thus, at 5% of the mass-spectrum line intensity, the resolution of the MI 1311-04 mass spectrometer with a gas source was found to be 500 at a vacuum of 2×10^{-7} mm Hg in the ion source and at a background current $\sim 2 \times 10^{-18}$ A.

If we assume that a threefold excess of the ion current over the background (noise) is a line of the mass spectrum, and if we compare such a peak ($\sim 6 \times 10^{-18}$ A), which exceeds the background oscillations by a factor of three, with the maximum possible peak ($\sim 3 \times 10^{-11}$ A), we obtain for the ratio of the peaks a value of 2×10^{-7} ($\sim 2 \times 10^{-5}$%), which serves as an estimate of the sensitivity of this particular mass spectrometer [1)].

[1)]The specifications of MI 1311-04 state that its sensitivity relative to argon is 5×10^{-5}%.

Type of ion	Mass of ion	Ratio of mass-spectrum peaks to D_2^+ peak.	Type of ion	Mass of ion	Ratio of mass-spectrum peaks to D_2^+ peak.
H^+	1	$1.5 \cdot 10^{-4}$	D_2^+	4	1
H_2^+	2	$1.6 \cdot 10^{-2}$	H_2D^+	4	coincides with D_2^+
D^+	2	coincides with H_2^+	HD_2^+	5	$1 \cdot 10^{-5}$
HD^+	3	$1.2 \cdot 10^{-2}$	D_3^+	6	$2 \cdot 10^{-4}$
H_3^+	3	coincides with HD^+			

Thus, our instrument makes it possible to detect approximately one anomalous particle in 5×10^6 ordinary particles if the anomalous-particle mass differs from the mass of the known particles by more than ± 0.003 mass units.

After establishing the exact characteristics of the MI 1311-04 instrument, we undertook a search for "wild" hydrogen in samples of atmospheric air, hydrogen, and deuterium.

Since the water vapor content of atmospheric air at sea level reaches about 4% by volume[2], the concentration of the anomalous particles of a vapor sample condensed into water should increase by approximately 20—25%, and the possibility of observing "wild" isotopes of hydrogen should increase by the same token to $1:(5 \times 10^6 \times 20) = 1:10^8$.

If we consider further the case when the mass of the sought anomalous particle (and the atoms produced by it) is larger than the mass of deuterium, then the process of deuterium concentration can increase the content of "wild" hydrogen by not less than 6.6×10^3 times [2)] and accordingly increase further the possibility of observing anomalous particles in atmospheric air to a value $1:(5 \times 10^6 \times 20 \times 6.6 \times 10^3) = 1:6.6 \times 10^{11}$.

In the mass interval from 1 to 12, no "wild" hydrogen was observed in either atmospheric air, or hydrogen, or in the deuterium of 97 and 99.82% heavy water [3)]. By way of an example, the table lists the ratio of the current of ions of various masses to the current of ions with the mass of D_2^+. The data were obtained in an analysis of a sample of heavy water with 99.82% deuterium concentration.

Thus, mass spectrometry using the MI 1311-04 apparatus with sensitivity 2×10^{-5}% and resolution of 500 at the level of 5% of the peak height, has established that: (a) if the mass of the "wild" hydrogen is larger than the mass of deuterium, then its concentration in the earth's atmosphere can be less than 1.5×10^{-12}; (b) if the mass of the "wild" hydrogen is intermediate between ordinary hydrogen and deuterium, then its maximum concentration in air is estimated to range from 1×10^{-8} to 1.5×10^{-12}.

Since the efficiency of any isotopic enrichment of heavy water is determined directly or indirectly by the mass difference of the separated isotopes and increases with this difference, we can state that the observable limit of the concentration of anomalous hydrogen isotopes with mass much larger than deuterium in the atmosphere is much lower than 1.5×10^{-12}. It must be kept in mind, however, that to estimate the limits of the concentration of the anomalous particles with mass larger than two mass units it is necessary to process much larger amounts of raw water.

Sherr, Smith, and Bleaney[3], using a mass spectrograph to detect the presence of tritium in highly concentrated water, have shown that (a) "the abundance of T in ordinary hydrogen is lower than 1×10^{-12}," (later investigations have shown[4] that the T/H ratio fluctuates between 1×10^{-18} and 70×10^{-18}), and (b) the mass spectrograms contained a line corresponding to mass 5, the ratio of the intensities of the mass-5 and mass-4 lines being 3×10^{-7}. In discussing this result the authors indicated that "the presence of primary ions with mass 5 in samples is still not understood."

By now, however, it has been confirmed by estimates based on the data of Sherr et al.[5] that the mass 5 should be attributed to the HD_2^+ ions, whose number depends on the operating condition of the ion source and on the degree of purity of the D_2. Thus, there are no reasons for ascribing the mass 5 obtained in[3] to heavy anomalous hydrogen.

In conclusion, we note that the search for anomalous particles would be greatly facilitated by

[2)] At C = 99.82% and C_0 = 0.015%, the ratio is $C/C_0 \approx 6.6 \times 10^3$.

[3)] The D_2O concentration is in accordance with the specifications. In view of the hygroscopic nature of D_2O, its concentration could drop somewhat as a result of the manipulations during the preparation of the samples for the analysis, but this could not greatly influence the concentration of the anomalous hydrogen.

knowledge of the most probable mass interval in which the observation of "wild" isotopes could be expected. This would make it possible to improve the data by using a mass-spectrometric accumulation procedure during the measurements.

It is apparently not meaningless to review the mass spectrograms obtained in earlier analyses of samples of especially highly concentrated water, with an aim at observing peaks (lines) which at that time were not identified with definite masses.

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[1] L. B. Okun', Possible Types of Elementary Particles, Inst. Theoret. Exptl. Phys. Preprint No. 245, 1964.

[2] See, for example, V. I. Perel'man, Kratkiĭ spravochnik khimika (Short Handbook for Chemists), 7th Ed., 1964, p. 325.

[3] Sherr, Smith, and Bleaney, Phys. Rev. **54**, 388 (1938).

[4] W. F. Libby, J. Acad. Sci. Wash. **45**, 301 (1955).

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