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Research Article

Evaluation of the Possibility of Using the Helium Leak Detector TI 1-14 for the Analysis of Protium H_2, Deuterium D_2, Helium-3 ^3He and Tritium T_2

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Abstract

The characteristics of the TI 1-14 helium leak detector are given. The possibility of detecting fusion products based on the interaction of hydrogen isotopes with the TI 1-14 sensor is evaluated. The results of calibration of the leak detector by helium are given. The results of measuring hydrogen and the apparent products of nuclear fusion during the electrolysis of solid proton-conducting electrolytes in the deuterium atmosphere are described.

Keywords: TI 1-14 helium leak detector, nuclear fusion products, hydrogen isotopes, protium, deuterium, helium-3, tritium.

1. Introduction

We would like to draw your attention to one of the results of the first work of M. Fleishmann and S. Pons[2]. That is to say, tritium as an undeservedly forgotten product. One of the products of the D+D reaction of cold nuclear fusion is tritium.

$$\begin{aligned} &\mathbf{{}^2D + {}^2D \rightarrow {}^3T(1.01\ MeV) + {}^1H(3.02\ MeV)\ (v)} \\ \mathbf{or}\quad & \\ &\mathbf{{}^2D + {}^2D \rightarrow {}^3He\ (0.82\ MeV) + n\ (2.45\ MeV)\ (vi)} \end{aligned} \qquad \mathbf{(2)}$$

Use of eqn. (2) indicates that reaction (v) takes place to the extent of $1 \div 2 \times 10^4$ atoms s^{-1} which is consistent with the measurements of the neutron flux, bearing in mind the difference in radii. On the other hand, the data on enthalpy generation would require rates for reactions (v) and (vi) in the range $10^{11} \div 10^{14}$ atoms s^{-1}. It is evident those reactions (v) and (vi) are only a small part of the overall reaction scheme and that other nuclear processes must be involved.

Note that the amount of tritium in the first work significantly exceeds the number of detected neutrons. Isn't this the error in the discrepancy between the amount of detected helium-4 and the total excess heat discovered by other authors subsequently?

Confucius (an ancient thinker and philosopher of China, VI-V century BC) said:

Explore the past if you want to know the future.

In the development of this thesis, let us suggest that you consider the possibility of the TI 1-14 helium leak detector as an instrument to detect tritium, hydrogen and deuterium.

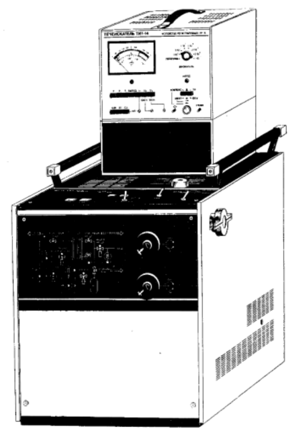

Figure 1. Leak detector produced in the 1990s.

Figure 2. Modern leak detector.

The modern upgraded helium leak detector has the ability to adjust to control gases: **helium and hydrogen**[3].

Table 1. Technical characteristics of the leak detector TI 1-14

Parameter	**Values**
Minimum helium flow recorded by the leak detector without throttling pumping	7×10^{-12} $m^3\times$ Pa/s
Minimum helium flow recorded by a leak detector with throttling pumping	7×10^{-13} $m^3\times$ Pa/s
Residual pressure in the analyzer, no more	1.3×10^{-3} Pa
Input pressure regulation P_2	$1.3\times10^{-3} \div 3\times10^{-3}$ Pa
Regulation of the accelerating voltage U_A	$(150 \div 450)$ V
Suppressor voltage regulation U_S	$(15 \div 300)$ V
The level of the output signal at the residual pressure in the analyzer and when U_A changes by 10% of the maximum value of the helium peak, no more	30%
Dynamic output range	$(0.0002 \div 100)$ V
Fluctuations of the electric zero of an electrometric DC amplifier, no more	$\pm$ 2 mV
Change in the emission current of the ion source cathode when the input pressure P_2 changes from 35 to 55 scale divisions, no more	$\pm$ 0.5 scale divisions of the linear scale of the arrow device

Minimum recorded helium flux in units of the flux of helium atoms per second according to the following formula:

$$N_{\mathrm{He}}^{\min} = \frac{\mathrm{PV}}{\mathrm{RT}} \cdot N_A$$

at a temperature T = 300 K

$N_A = 6.022 \cdot 10^{23} \mathrm{atom/mol}$ - Avogadro number,

$N_{\mathrm{He}}^{\min 1} = 1.69 \cdot 10^{9} \frac{\mathrm{atom}}{s}$ - without throttling pumping,

$N_{\mathrm{He}}^{\min 2} = 1.69 \cdot 10^{8} \frac{\mathrm{atom}}{s}$ - with throttling pumping.

1.1. Operating Principle of the Leak Detector

The leak detector is a highly sensitive magnetic mass spectrometer tuned to detect helium. The leak detector consists of a vacuum system and a recording device. The main element of the leak detector is a mass spectrometric analyzer containing an ion source, an analyzer (drift space) and an ion receiver. In the ionizer, electrons collide with gas molecules entering the leak detector from the investigated volume and cause their ionization. The resulting ions are pulled out of the ionizer by an accelerating electric field acting in a direction perpendicular to the electron beam. The flow of ions through the outlet diaphragm of the ion source enters the drift space, in which the spatial separation of ions by mass takes place. Under the action of a constant magnetic field directed perpendicular to the direction of motion, the ions move along circular trajectories. The radii of these trajectories depend on the mass of the ions.

The radius of the ion trajectory in centimeters is determined by the formula:

$$R = \frac{0.576 \cdot \pi}{H} \cdot \sqrt{M \cdot U}$$

where **R -** radius of the ion motion trajectory, cm; **H** - magnetic field strength, A/m; **U** - potential difference accelerating the ions, V; **M** - effective mass of the ion, equal to ratio of its mass number to electron charge.

1.2. Possibility of Detecting Tritium

With different ratios of the effective masses of the ions and different potential differences accelerating these ions, respectively, the ion receiver is located motionless and the radii of the trajectories of different ions (tritium and helium) during detection will be equal to

$$\boldsymbol{R_T = R_{He}} = 2.5 \text{ cm},$$

Then

$$M_T \cdot U_T = M_{\mathrm{He}} \cdot U_{\mathrm{He}}$$

$$M_T = \frac{6 \text{ amu}}{e}, \qquad M_{\mathrm{He}} = \frac{4 \text{ amu}}{e}$$

$$U_T = \frac{2}{3} \cdot U_{\mathrm{He}}$$

If the regulation range of the accelerating voltage is $\mathbf{U_A}$=150÷450 V, and the accelerating voltage when tuned to a helium leak for the helium peak is U_{He} =265 V, then with the accelerating voltage U_T=177 V, tritium **can be detected**.

1.3. What can be Analyzed With This Leak Detector?

Consider all ions and their mass numbers that can be formed during ionization in the ion source of the leak detector on account of nuclear reactions of cold nuclear fusion:

Table 2. Ions and their mass numbers

Ions	**H+**	**^{3}He++**	**H_2+**	**D+**	**^{4}He++**	**HD+**	**^{3}He+**	**T+**	**D_2+**	**HT+**	**^{4}He+**	**DT+**	**T_2+**
m, amu	1	1.5	2	2	2	3	3	3	4	4	4	5	6

Obviously, the identification of chemical elements by these mass numbers is difficult. Therefore, in order to accurately identify the measured products of nuclear reactions, in addition to direct calibration of the instrument for pure gaseous components (hydrogen - H_2, deuterium - D_2, tritium - T_2, helium-3 -$_3$He, helium-4 -$_4$He) one should apply the method of chemical separation of hydrogen from helium. This method is to oxidize the hydrogen in a special reactor on a chemically pure copper oxide, followed by analysis of the remaining gaseous helium and analysis of the resulting water for tritium content.

1.4. Ions flow

Knowing the input resistance of the electrometric amplifier of the leak detector, it is possible to calculate the ions flow of a certain effective mass by the formula

$$N = \frac{U(V)}{R(Ohm) \times e(Kl)}$$

where **U** - the intensity of the peak measured by the ion receiver (*V*), **R=1014 Ohm** - the input impedance of the electrometric amplifier (*Ohm*), and **e** is the electron charge (*Kl*).

Since the value of the input resistance of the electrometric amplifier of the leak detector R is indicated in the description as its smaller limit, its real value may differ from the accepted value.

Therefore, it must be understood that the real flow values are less than the calculated values.

However, there are also factors that increase the found ion flow values:

- not all molecules that get into the flow of ionizing electrons will be ionized;
- not all ions will join the flow directed to the collector, some of them will be scattered.

Table 3. Setting for the helium leakage

Measured component	P_2, scale divisions	U_A, V	Peak content in total, %	Ions flow, ions/s	
He	42	265	100%	9.233×10^{15}	The leakage is open

1.5. Measurement Results

Mass numbers can be calculated using the formula:

$$m = \frac{R_{\mathrm{He}}^2 \times B^2 \times e}{2 \times U_A}$$

If $R_{\mathrm{He}} = 0,025$ м$, B$ =0.187498 T - magnetic induction value of a constant magnetic field, $e = 1.6021766310^{-19}$, $U_A = 265\ V$, then

Table 4. Helium mass numbers

U_A,V	**265**
m_{He}, kg	6.64216×10^{-27}
m_{He}, amu	4.0

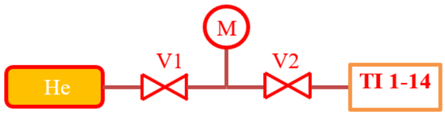

Figure 3. Connection diagram of a helium balloon to TI 1-14.

Table 5. The change in the He peak intensity depending on the pressure P_2

Measured component	P_2, scale divisions	U_A, V	Peak intensity, mV	Ions flow, ions/s
He	30	285	78	4.801×10^{14}
He	40	280	198	1.219×10^{15}
He	50	280	740	4.555×10^{15}
He	60	280	1890	1.163×10^{16}

1.6. Helium Peak Calibration

Helium peak intensity depending on the pressure P_2 has a nonlinear, close to polynomial, form.

D_2 measurements from the sample after electrolysis of solid proton-conducting electrolytes in a deuterium atmosphere.

In addition to deuterium, this sample clearly shows the presence of **tritium**, and possibly helium-3 and helium-4.

2. Conclusions

We have shown how the leak detector can be used to measure the products of nuclear reactions of hydrogen, deuterium, tritium and helium fusion. We need to develop a standard technique, combining the analysis of tritium with the transfer of all hydrogen into water and analysis of the β-activity of tritium in the resulting water. The development of this

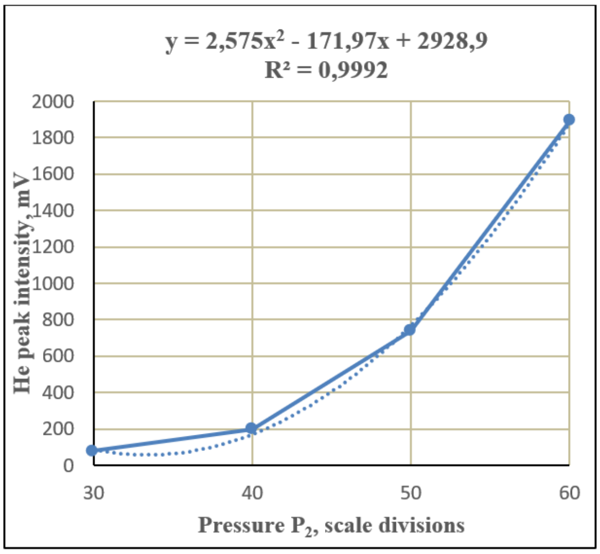

Figure 4. Helium peak intensity depending on the pressure P_2.

Table 6. Measurement results

Measured component	P_2, scale divisions	U_A, V	Peak intensity, mV	Peak content in total, %	Ions flow, ions/s	m, amu	Ions identification
D_2	45	375	55	47%	3.385×10^{14}	3.0	HD^+,$^3He^+$,T^+
		275	30	25%	1.847×10^{14}	4.1	D_2^+,HT^+,$^4He^+$
		190	33	28%	2.031×10^{14}	5.9	T_2^+
D_2	55	375	90	52%	5.540×10^{14}	3.0	HD^+,$^3He^+$,T^+
		275	40	23%	2.462×10^{14}	4.1	D_2^+,HT^+,$^4He^+$
		190	44	25%	2.708×10^{14}	5.9	T_2^+
D_2	60	375	150	34%	9.233×10^{14}	3.0	HD^+,$^3He^+$,T^+
		275	180	41%	1.108×10^{15}	4.1	D_2^+,HT^+,$^4He^+$
		190	114	26%	7.017×10^{14}	5.9	T_2^+

technique requires a strict metrological analysis of the results at all stages of such a combined hybrid method of analysis. It is necessary to modernize the leak detectors manufactured now to facilitate the detection and identification of reaction products. It is necessary to continue work on setting up a leak detector for hydrogen.

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