Helium Isotopes from Deuterium Absorbed in $LaNi_5$

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ABSTRACT

Helium isotopes(^3He and ^4He) from D_2 or H_2 gases absorbed in $LaNi_5$ were analyzed with a noble gas mass spectrometer. The reproducible increase in ^3He, corre-sponding to a fusion probability of $>8.0 \times 10^{-24}$ d-d·s^{-1}, was observed on the D_2-experiment, whereas ^3He was not formed by the reaction of H_2 and $LaNi_5$. ^4He production was unreliable, because the reproducibility of the result has not been obtained.

1. Introduction

Helium is a suitable candidate in order to detect the cold fusion product, because helium generated can be accumulated and condensed in a closed system even if the nuclear reaction occurs instantaneously or discontinuously.

From this point of view, we have made a thorough study of the helium isotopes from the D_2 gas absorbed in $LaNi_5$ by using a noble gas mass spectrometer[1-3] since Fleischmann and Pons[4] and Jones et al.[5] reported the occurrence of cold fusion.

It is necessary to measure not only ^3He and ^4He but also other noble gases, because the elemental abundance of these gases suggests the origin of the helium isotopes. The estimation of the increase in ^4He needs the greatest care since the amount of ^4He in the closed system is easy to be affected by the atmospheric ^4He due to the air leakage. Such a work that only ^4He has been measured is out of the question.

We present the results of the precision analysis for the helium isotopes and other noble gases in the D_2 gas

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absorbed by $LaNi_5$.

2. Experimental details

The reaction vessels($3.23x10^{-5}$) sealed with a copper gasket, gas samplers and vacuum-gas connecting lines were made of stainless steel to exclude helium in air. The reaction vessels were previously degassed by heating at 1123 K for half a day in vacuo. After loading in the vessels, the $LaNi_5$ ingots(52.5 g) was heated at 1123 K for 18 h in the evacuated vessels, and then a portion of the resulting gas was collected in a sampler("Degas" in Table 1). The 99.5 % pure D_2 gas or 99.999 % pure H_2 gas were applied to the $LaNi_5$ ingots at a pressure of $7.9x10^5$ Pa. Since a large amount of helium was initially contained in the raw D_2 or H_2 gas, the helium gas was removed by evacuating while the applied hydrogen gas was absorbed in the $LaNi_5$ ingot. After removing the helium gas, a part of the residual gas was collected in a sampler("Ante-reacted gas" in Table 1).The temperature fluctuation process (77⇔300 K) to the vessel containing the hydrogenated $LaNi_5$ was repeated 135 times over a period of 130.0 days (2nd run;131 times, 120.4 days), and a portion of the gas separated from the D_2 or H_2 gas was withdrawn into another sampler("Post-reacted gas" in Table 1).

A VG5400 mass spectrometer(Operating in the "static" mode) and a noble gas purification system installed at Okayama University were used for helium isotopic analyses. The detection limit of helium with this apparatus was about 10^{-20} m^3 STP(10^5 atoms). For helium isotopic analyses, the mass resolutions necessary to separate the hydrogen and deuterium peaks are 510, 400 and 100 for ^3He-HD, ^3He-H_3 and ^4He-D_2 respectively, so that the high resolution(600) collector was used for the ^3He analyses and the low resolution(200) collector was used to separate ^4He and D_2. The helium background of the system was about less than $1x10^{-16}$ m^3 STP(<10^9 atoms) and $1x10^{-20}$ m^3 STP(<10^5 atoms) for ^4He and ^3He respectively.

Nucleonic helium may be detected as an isotopic ratio different from the ratio of helium initially contained in the D_2 gas. The helium isotopic ratio, however, can be changed by air leakage and physical processes such as diffusional transport. Therefore, to determine such an effect on the helium isotopic ratio, the elemental abundance of neon, argon, krypton and xenon was measured in addition to the helium isotopic ratios in some of the sample gases.

3. Results and Discussion

Elemental abundances of helium, neon, argon, krypton and xenon, and isotopic ratios of ^3He and ^4He are listed

Table 1. Contents and isotopic ratios of He, Ne, Ar, Kr and Xe.

	^{3}He ($\times10^{5}$)	^{4}He ($\times10^{10}$)	$^{3}He/^{4}He$ ($\times10^{-6}$)	^{20}Ne ($\times10^{9}$)	^{36}Ar ($\times10^{10}$)	^{84}Kr ($\times10^{8}$)	^{132}Xe ($\times10^{7}$)
[First run]							
D_2 Gas Experiment							
Post-reacted gas	27.6(7.53)	43.7(5.99)	6.3(1.9)	2.94(0.42)	489(69)	9.47(1.33)	25.0(3.5)
Ante-reacted gas	0.20(0.72)	2.82(0.39)	0.71(2.6)	1.34(0.20)	106(15)	3.12(0.44)	4.08(0.59)
Increment	27.4(8.3)	40.9(6.4)		1.60(0.62)	383(84)	6.35(1.77)	20.9(4.1)
H_2 Gas Experiment							
Post-reacted gas	<1	2.58(0.36)	<4	3.10(0.49)	0.734(0.104)	1.12(0.16)	0.883(0.125)
Ante-reacted gas	0.83(0.67)	0.26(0.04)	32(26)	3.77(0.55)	1.10(0.15)	3.42(0.49)	2.32(0.33)
Increment	—	2.32(0.40)		—	—	—	—
[Second run]							
D_2 Gas Experiment							
Post-reacted gas	30.8(11.2)	0.111(0.016)	2.78×10^{3} (1.09×10^{3})	56.1(7.8)	23.7(3.3)	29.0(4.1)	0.171(0.024)
Ante-reacted gas	5.58(1.25)	0.286(0.040)	195(52)	29.9(4.2)	7.31(1.01)	21.4(3.0)	3.17(0.45)
Increment	25.2(12.5)	—		26.2(12.0)	16.4(4.3)	7.6(7.1)	—
H_2 Gas Experiment							
Post-reacted gas	8.80(6.20)	1.46(0.21)	60(43)	0.577(0.0951)	1.71(0.24)	0.316(0.045)	0.171(0.024)
Ante-reacted gas	0.80(1.26)	0.0849(0.0119)	94(149)	1.12(0.16)	0.306(0.043)	0.964(0.137)	0.571(0.086)
Increment	8.00(7.46)	1.37(0.22)		—	1.40(0.29)	—	—
Degas(at 1123 K)	2(2)	14.6(2.5)	14(14)	47.7(8.2)	26.2(4.5)	26.6(4.6)	22.6(3.9)
Air			1.399(0.013)				

· The noble gas contents are given in number of atoms existing in the reaction vessel.
· The standard deviations are shown in brackets.

in Table 1. We assumed that the nuclear reaction occurs at the surface or near surface of $LaNi_5$ and that the generated helium is released from $LaNi_5$ with hydrogen. On the experiment using the D_2 gas, it is noteworthy that the amount of ^{3}He ($2.74(0.83)\times10^{6}$ atoms) increased in the gas obtained after the repeated temperature cycling, while no enrichment of ^{3}He was observed for the H_2-experiment. The phenomenon was reproduced in the second run. The increase in ^{4}He ($4.09(0.64)\times10^{11}$ atoms) was also observed in the first run. The ^{4}He production, however, was unreliable, because the reproducibility of the phenomenon was not obtained in the second run.

The enhancement of ^{3}He as well as ^{4}He may be caused by only the air leakage. If we assume that the increment of ^{4}He originated from the atmosphere, then it should be accompanied by $5.72(0.90)\times10^{5}$ atoms of ^{3}He which is derived by using the atmospheric ratio of 1.399×10^{-6}. Thus, the excess of ^{3}He is $2.17(0.92)\times10^{6}$ atoms. Assuming that the $\sim2.2\times10^{6}$ atoms ^{3}He generated by the D_2 gas(2.5×10^{22} molecules) absorbed in $LaNi_5$ during a period of the temperature fluctuation process for 1.1×10^{7} s, we obtained a lower limit of $\sim8.0\times10^{-24}$ fusion/d-d$\cdot s^{-1}$ based on the reaction $d + d \rightarrow {}^{3}He + n$. The fusion probability is comparable to that given by Jones et al.[5] and Menlove.[6]

Figure 1 shows the noble gas elemental abundance relative to that in air, expressing the following equation,

$$F(m) = (^{m}X/^{36}Ar)/(^{m}X/^{36}Ar)_{atmosphere},$$

where ^{m}X is the noble gas element with mass m and the subscript "atmosphere" means the atmospheric elemental abundance.

The elemental abundance patterns provide significant information regarding the isotopic anomaly of helium observed in this work, such as the air leakage and the diffusional transport. If the leakage of air into the vessel occurred during the temperature fluctuation process, the abundance pattern of the post-reacted gas would be close to that of air(logF(m)=0). The increase in ^3He was not significantly affected by the air contamination, because the abundance patterns for both ante- and post-reacted gases resembled each other, and were much different from those for air. The possibility of the diffusional transport was also denied due to the coincidence of the two patterns of the ante- and post-reacted gases.

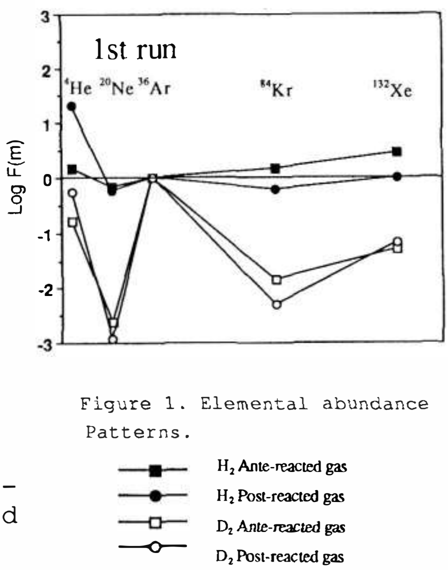

Figure 1. Elemental abundance Patterns.

4. Conclusions

The enrichment of ^3He was observed in the D_2 gas absorbed by $LaNi_5$ after the repeated temperature fluctuation cycling. The phenomenon, however, was not obtained from the H_2-experiment. The elemental abundance patterns indicate that the increase of ^3He was not obviously caused by the air leakage. The fusion probability estimated by the ^3He production was $>8.0 \times 10^{-24}$ fusion/d-d·s^{-1} which is in agreement with the value determined by Jones et al. or Menlove.

References

1. Sakaguchi, H., Nagao, K. and Adachi, G., *Proc. Topical Meet. on Cold Fusion*, Osaka, February 27-28,(1990) p.71.
2. *Sankei Shinbun*, Sangyo Keizai Shinbun, Osaka, 17077, March 8, (1990).
3. Adachi, G., Sakaguchi, H. and Nagao, N., 1992, *J. Alloys & Compd.* **181**, 469.
4. Fleischmann, M. and Pons, S., 1989, *J. Electroanal. Chem.* **261**, 301.
5. Jones, S. E. et al., 1989, *Nature*, **338**, 737.
6. Menlove, H. O., *Workshop on Cold Fusion Phenomena, Santa Fe, NM, Meeting Abstracts LA-UR-89-1974*, (1989).