

G E O C H E M I S T R Y

Measurements on the D/H-ratio in H<sub>2</sub>-gas and  
water vapour collected at the volcanic  
island Surtsey during the year 1964.

by

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Introduction:

During the year 1964 four visits were made to the volcanic island Surtsey.

The reason for these visits was to attempt to collect samples of volcanic gases and water vapour, escaping from the molten lava, for D/H-measurements.

The visits were made on May 21st, August 19th, October 15th and November 25th.

On the first visit, May 21st, it was impossible to approach the crater, but both water and gas samples were collected from fissures in the lava field. The temperature in the bottom of the fissures was about 840°C.

The gas analysis showed almost atmospheric gas containing no hydrogen<sup>1)</sup> and the condensed water vapour measured for its D/H-ratio showed almost the same deuterium content as oceanic water.

On the visit on August 19th it was again impossible to approach the crater and only samples of gas from a fissure in the lava field were collected.

These showed almost the same results as previously<sup>1)</sup>.

On October 15th it was possible to get much closer to the crater and a chimney was found from which the gas was escaping with great force.

Chemical analysis of this gas indicated that it was mostly magmatic gas, which contained about 23% hydrogen and about 1% nitrogen + inert gases<sup>1)</sup>.

On November 25th it was also possible to come quite close to the crater, but the conditions had changed, so that it was impossible to collect as good gas samples as on the previous occasion. The gas samples contained so much atmospheric oxygen that the hydrogen was completely burned to water<sup>1)</sup>.

Despite this, the D/H analysis on the water gave a D/H-ratio that was not far from the D/H-ratio in the water collected on October 15th (see tab. 1).

#### Method of collection:

A stainless steel tube of about 8 mm diameter was put in the fissure and connected to a trap, which was used to condense the water vapour. 250 ml gas sample tubes made from pyrex glass were connected to the trap.

On October 15th the stainless steel tube acted as a condenser but on November 25th and all other occasions a trap of pyrex glass cooled to  $-80^{\circ}\text{C}$  was used. (See fig. 1).

#### Analysis:

The water was converted to hydrogen gas as described by Friedman<sup>2)</sup>, and analysed for its D/H-ratio in a specially constructed mass spectrometer<sup>2)</sup>.

The results are expressed as deuterium enrichment (plus  $\delta$  value) or depletion (negative  $\delta$  value) relative to SMOW (Standard Mean Ocean Water, having a D/H-ratio of about  $158.10^{-6}$ )<sup>3)</sup>.

The gas analysis was made as follows: The gas was first passed through a liquid air cooled trap, to condense the heavy components. The residual gas containing nitrogen, hydrogen and inert gases was then passed through a copper oxide oven at about

500°C, where the hydrogen was completely burned to water. The resulting water vapour was then allowed to pass into a liquid air cooled trap, whereby it was frozen out.

The residual gas, now containing nitrogen and inert gases, was then pumped away and the condensed water allowed to reevaporate and passed through a uranium oven in the usual way, as described by Friedman<sup>2)</sup>.

The hydrogen gas was then analysed in the same mass spectrometer as the water samples.

The accuracy of the measurements is within 0.2%. Tab. 1 shows the results.

#### Discussion:

Although the number of measurements is limited, they may give some indications.

For example, if we use the values from October 15th,  $\delta_{\text{H}_2\text{O}} = -5.0\%$  and  $\delta_{\text{H}_2} = -14.38\%$ , and say that the hydrogen and water is in equilibrium at  $t^\circ\text{C}$ , we can calculate the equilibrium constant,  $K = 1.11^{\text{xx}}$  and use the theoretically estimated equilibrium constants for various temperatures<sup>4)</sup>. Then we will obtain  $t = 1010^\circ\text{C}$ , which is not far from the measured gas temperature (ca.  $1140^\circ\text{C}$ )<sup>5)</sup>.

Fig. 2 shows the theoretically calculated equilibrium constant for the reaction  $\text{H}_2\text{O} + \text{HD} \rightarrow \text{HDO} + \text{H}_2$  (vapour phase)<sup>4)</sup>.

$$\text{xx } K = \frac{(\text{H}_2)/(\text{HD})}{(\text{H}_2\text{O})/(\text{HDO})_{\text{vapour}}}$$

#### References:

1. G. Sigvaldason and G. Elisson, this report.
2. I. Friedman (1953) Deuterium content of natural water and other substances. *Geochim. et Cosmochim. Acta*, 4, pp. 89-103.

3. H. Craig (1961) Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. *Science*, vol. 133, No. 3467, pp.1833-1834.
4. Kirschenbaum (1951) Physical properties and analysis of heavy water, p. 48, McGraw-Hill 1951.
5. Th. Sigurgeirsson, this report.

TABLE 1  
Measurements on the D/H-ratio in H<sub>2</sub>-gas and water  
vapour collected at Surtsey during 1964.

Date of sampling	Sample no.	Water ‰ δ	H <sub>2</sub> - gas ‰ δ
May 21st	1	+ 2.18	
"	2	+ 1.73	
"	3	+ 1.90	
"	4	+ 1.90	
"	5	+ 1.90	
"	6	+ 1.76	
"	7	+ 1.31	
"	8	+ 2.22	
"	9	+ 1.90	
"	10	+ 1.68	
October 15th	11	- 5.00	- 14.38
"	12	- 5.07	
November 25th	13	- 5.59	
"	14	- 5.57	
"	15	- 6.06	

FIG I

Gas and water collecting apparatus.

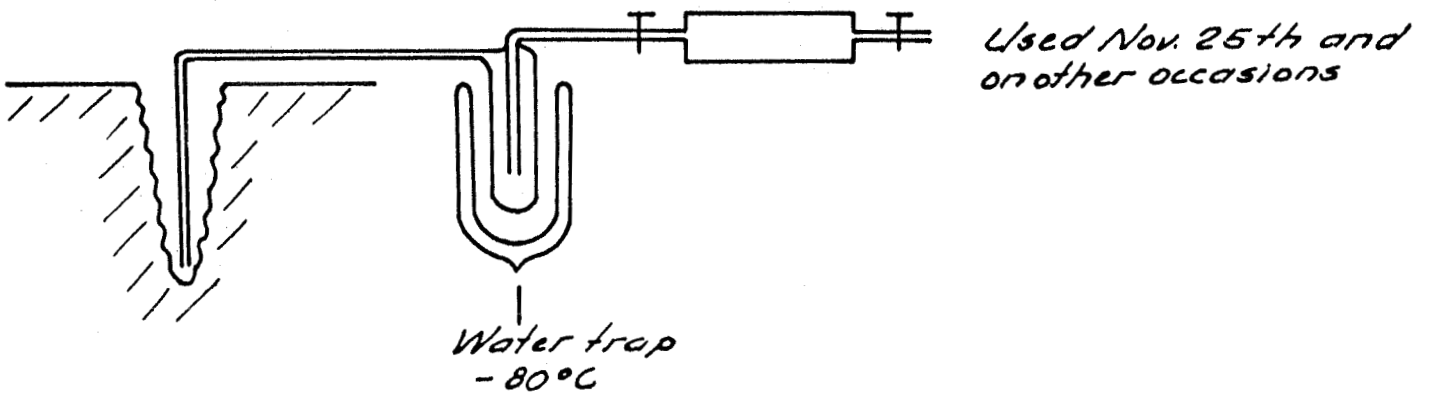
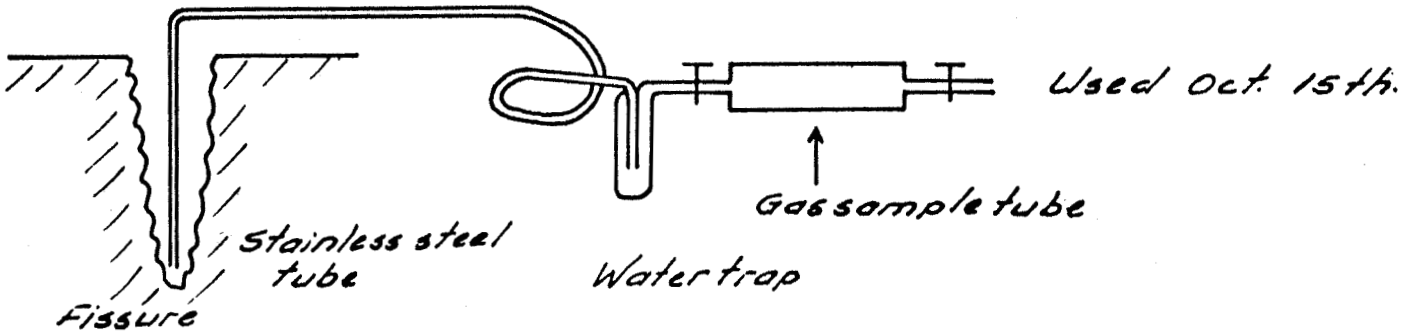


FIG. 2.

