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Geophysics

GENESIS OF THE ABUNDANCE OF HELIUM FORMATION IN NATURAL GAS EMANATING FROM THERMAL SPRINGS

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The origin of helium in thermal spring gases has been considered in relation to the isotopic constitution of two other associated gaseous elements, nitrogen and argon. It has been observed that the helium enrichment is associated with increase in ^{38}A content in argon associated with natural gas emanating from thermal springs.

INTRODUCTION

THE quest for the origin of helium in thermal spring gases has been the subject matter of lively debates. Chatterjee (1972) has reviewed the various hypotheses leading to the origin of natural gases emanating from some Indian thermal springs. In order to correctly appraise the essential factors responsible for the formation and occurrence of helium, a detailed analysis of the isotopic composition of natural gases emanating from some hot springs located in Eastern India was undertaken.

RESULTS AND DISCUSSION

Table I gives the analyses of the percentage composition by volume of the natural gases emanating from a few thermal springs located in the Eastern Zone of India. The results are the average of several measurements carried over two years—1975 and 1976. The analyses were made on MS III type massspectrometer supplemented by analysis with modified Orsat apparatus.

TABLE I

Percentage composition of natural gas constituents

Location	H_2 (%)	He (%)	N_2 (%)	O_2 (%)	Ar (%)	CO_2 (%)	CH_4 (%)
Agnikunda (Bakreswar, W. Bengal)	Nil	1.88	91.45	0.85	1.80	1.20	2.82
Suraj Kunda (Hazaribagh, Bihar)	0.21	0.94	94.34	1.40	2.30	0.67	0.14
Tantloi (Santhal Pargana, Bihar)	Nil	1.25	91.38	2.65	1.92	Nil	2.80

It is evident that the gas composition given above substantiates the well-known hypothesis regarding the occurrence of a high percentage nitrogen as a prelude to the possibility of helium enrichment in natural gases. Lind (1925) suggested that probably the radio-chemical decomposition, caused by α-particles, of a nitrogenous compound simultaneously generates both helium and nitrogen. This was actually verified by Geslin (1935) who found that there was a rapid liberation of nitrogen from animal and vegetable proteins when radium was added to flasks filled with water, organic matter and soil. The isotopic abundance ratio of the nitrogen isotopes $^{14}N/^{15}N$ of the spontaneously emitted natural gas from thermal springs was determined by Chatterjee *et al.* (1973). Their results, recalculated in terms of $\delta(^{15}N)$ per thousand, the difference per thousand, between the $^{15}N/^{14}N$ ratios of the sample and the standard atmospheric nitrogen is given in Table II.

TABLE II

Deviation of abundance of ^{15}N from normal (air)

Location	Isotopic constitution (^{15}N) ‰ (per thousand)
Agnikunda (Bakreswar, W. Bengal)	—22.8
Suraj Kunda (Hazaribagh, Bihar)	—22.8
Tantloi (Santhal Pargana, Bihar)	— 9.6

It is observed that $\delta(^{15}N)$ is negative in the thermal spring gases which corresponds to a decrease in the ^{15}N content in comparison with atmospheric nitrogen. This is in agreement with the negative $\delta(^{15}N)$ values generally obtained in nitrogen derived from coal, peat, petrol and petroligenic natural gas, Rankama (1963). The high nitrogen content of the thermal spring gases cannot possibly be therefore attributed to trapped atmospheric nitrogen which is released fortuitiously along with thermal spring waters. Rather, one may expect the nitrogen content to be indicative, to an approximate measure, of the organic matter originally present in the sediment.

The concentration of helium in thermal spring gases was expressed by a factor $R = \frac{He}{Ar}\text{ (source)}\Big/\frac{He}{Ar}\text{ (air)}$, by Moureu, Lepape and Geslin (1930). The variation of R with the argon isotopes ^{38}A and ^{36}A of the thermal spring gases as obtained in the present investigation is shown in Table III.

TABLE III

Relative isotopic abundances of Argon in emitted natural gas

Location	R	^{38}A (%)	^{36}A (%)	$^{38}A/^{36}A$
Agnikunda (Bakreswar, W. Bengal)	1865	0.182	0.411	0.443
Tantloi (Santhal Pargana, Bihar)	1162	0.094	0.362	0.254
Suraj Kunda (Hazaribagh, Bihar)	730	0.089	0.370	0.241
Air (standard)	—	0.075	0.335	0.198

It is seen that there is an increase in the ^{38}A content with increase in R. The occurrence of large excess of ^{38}A has also been observed in uranium and thorium minerals. The excess ^{38}A was eventually confirmed by Wetherill (1954) as to be due to the two reactions, viz., $^{35}Cl\ (\alpha, p)\ ^{38}A$ and $^{35}Cl\ (\alpha, n)\ ^{38}K \xrightarrow{\beta^+} {}^{38}A$.

Accordingly, it is most likely that the helium from the thermal springs is really of radioactive origin, wherefrom both helium and argon are released simultaneously from the grain boundaries of the minerals and rocks within which they are confined.

The distribution of helium in the earth's crust is essentially controlled by the following two factors : (*a*) the distribution of α-emitters in the minerals and rocks; (*b*) the ability of those minerals to retain helium once it has been produced within them by α-decay. From the estimated average content of radioactive substances in the rocks of the earth's crust, Rogers (1921) calculated that from 282 to 1060 million cubic feet of helium is generated annually. Much of this helium escapes to the atmosphere, but a significant fraction of it is retained within the radioactive minerals in the crystal lattice. The gradual accumulation of helium causes high pressures to develop within the mineral. The helium is released either spontaneously on account of the fractures and mechanical disintegration caused by the high pressures or it may be assisted in its escape from the minerals by the solvent action of hot waters which may react chemically with the metallic (alkali) ions which usually contribute to the trapping of the gas within the lattice structures and grain boundaries of sedimentary rocks.

The waters of the thermal springs are characterised by their comparatively low mineral content, which usually rises upto a few hundred ppm. Of the many thermal springs investigated by us, it has been observed that helium is, in general, associated with thermal springs having alkaline waters. It has been found that gases emanating from acidic springs (such as those at Rajgir, Tapoban etc.) do not contain any significant amount of helium.

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