

GEOCHEMISTRY

Dry Synthesis of Feldspathoids by
Feldspar - Carbonate Reactions

THERE is a well-known petrogenetical theory that rock-types, undersaturated in silica, can form from saturated magmas by limestone-syntexis¹⁻⁴, or by the physico-chemically equivalent process of granite-assimilation by carbonatite magma⁵. Nobody, however, seems to have tried to verify experimentally such proposed processes. This may have been due to the fact that the shadow of the all-embracing crystallization-differentiation theory⁶ loomed large over the then still extremely small world of experimental petrologists. Petrographers, on the other hand, may have felt that their evidence (partial replacement of limestone- and dolomite-inclusions with concomitant formation of feldspathoids in lavas) was just as good as laboratory proof. Interesting evidence by McLintock⁷, who published an account of the generation of leucite and aegirite with melilite, wollastonite and diopside in a Persian marl, heated by the combustion of hydrocarbons underground, seems to have got little attention.

This communication shows how easily normal granitic or rhyolitic magma would produce leucite and/or nepheline-bearing rocks on reaction with limestones and dolomites, provided sufficient heat is available.

As starting materials for our experiments we used microcline and albite from Amelia Court House (Virginia), dolomite from Tuckahoe, New York, and calcium carbonate prec. pro anal. (Merck).

Stoichiometric mixtures of the powdered starting materials of reactions (1)-(4) were heated in crucibles for 25 h at 1,000° C and 1 atm. (air). X-ray analysis of the products of these runs showed that reaction has gone to completion.

An interesting point in the experiments is that these reactions proceeded entirely in the absence of water; no melt had formed, and the powders came as a loose powder again out of the crucibles, giving at first sight the impression that no reaction has occurred, although in fact a complete reconstitution has taken place, and at least SiO₂ must have been transferred from the feldspar grains towards the calcite or dolomite grains.

Although rate-studies and the determination of the equilibrium-curves are under way, these preliminary runs indicate already that these reactions proceed rather rapidly, even in the dry state. It seems only logical to suppose that the reactions will run at an even more rapid pace in Nature with molten rocks, containing volatiles. It may well be that in natural circumstances the reaction rate is mainly determined by the rate of escape of the carbon dioxide which is produced by these reactions.

A major objection which has often been raised to the theory of the origin of leucite- and nepheline-bearing rocks by limestone-syntexis is that limestones or dolomites are lacking in several areas, where these rocks are found, especially in Pre-Cambrian terranes. Apart from the fact that our geological knowledge in many cases is insufficient to make such stringent statements, one might point out that syntexis has possibly been so complete

as to wipe out any trace of pre-existing carbonate rocks. Even so, there are certainly a number of occurrences of alkaline rocks for which the theory of limestone-syntexis appears less likely. As many of these seem to be associated with carbonatites (for example, Fen area, Rift valley, Kaiserstuhl), the explanation given by Holmes⁵ looks more promising, that is, silic material assimilated by carbonatite magma. From a physico-chemical point of view, there is no essential difference between the two processes.

Only in rare cases the incongruent melting of orthoclase may cause precipitation of leucite in a silica-saturated rock, its subsequent preservation depending on rapid cooling (quenching). Some examples are cited in Bowen⁶. In these examples, however, the chemical composition of the whole rock shows it to be silica-saturated, so that these occurrences have no direct bearing on the problem of the formation of undersaturated magmas.

In conclusion, then, it may be stated that:

(1) Production of leucite and nepheline from (silica-saturated) feldspars by reaction with carbonates is an experimentally proved possibility. It occurs rapidly in the laboratory, even without the interference of a melt.

(2) Small-scale petrological evidence of the limestone-syntexis theory for the production of leucite- or nepheline-bearing associations is very convincing.

(3) Large-scale evidence is less direct, but the regional association of alkaline rock-types with carbonatites, or the presence of many partly assimilated limestone- or dolomite-inclusions, is highly suggestive.

R. D. SCHULING

Vening Meinesz Laboratory of
Geophysics and Geochemistry,
Utrecht, Holland.

¹ Rittmann, A., *Z. Vulk.*, **15** (1933).

² Daly, R. A., *Igneous Rocks and the Depths of the Earth* (McGraw-Hill, 1933).

³ Shand, S. J., *Eruptive Rocks*, second ed. (John Wiley and Sons, 1943).

⁴ Brouwer, H. A., *Proc. Kon. Akad. Wetensch.*, **48** (1945).

⁵ Holmes, A., *Amer. Min.*, **35** (1950).

⁶ Bowen, N. L., *The Evolution of the Igneous Rocks* (Dover Pub., 1956).

⁷ McLintock, W. F. P., *Min. Mag.*, **23** (1932).

PHYSICS

High-temperature Hydrogen Isotope Targets

FOR neutron sources using the D(*d,n*)He³ and the T(*d,n*)He⁴ reactions targets consisting of deuterium or tritium impregnated zirconium or titanium films have been widely used. The methods of preparation and some of their limitations have been described¹⁻⁵. One limitation of these targets is that the maximum temperature to which they may safely be raised for long periods is about 300° C. This sets an upper limit to the bombarding ion current density in particle accelerators and neutron tubes and hence to the continuous neutron output which may be obtained in long periods of operation.

We have investigated the possible use of rare-earth metal deuterides and tritides for targets. Initial investigations were confined to neodymium and praseodymium but generally similar behaviour is expected with other rare-earth metals.

The maximum safe temperature to which a hydrogen isotope target may be raised is mainly dependent on the dissociation pressure of the hydride. The neodymium-hydrogen and praseodymium-hydrogen systems have been investigated by Mulford⁶. In Fig. 1 Mulford's results of dissociation pressure as a function of composi-

- (1) $2\text{CaCO}_3 + \text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \rightarrow 2\text{CaSiO}_3 + \text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 + 2\text{CO}_2$
(calcite) (microcline) (wollastonite) (leucite)
- (2) $\text{CaCO}_3 \cdot \text{MgCO}_3 + \text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \rightarrow \text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2 + \text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 + 2\text{CO}_2$
(dolomite) (microcline) (diopside) (leucite)
- (3) $4\text{CaCO}_3 + \text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \rightarrow 4\text{CaSiO}_3 + \text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 + 4\text{CO}_2$
(calcite) (albite) (wollastonite) (nepheline)
- (4) $2\text{CaCO}_3 \cdot \text{MgCO}_3 + \text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \rightarrow 2\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2 + \text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 + 4\text{CO}_2$
(dolomite) (albite) (diopside) (nepheline)