PROPOSED NOMENCLATURE FOR

HELIUM ALLOTROPES

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The following proposal is based on an earlier recommendation by A. F. Schuch and R. L. Mills, dated September 1962, and on the considerations and agreements arrived at during a meeting held in the Queen Mary College, London, September 20, 1962, at which meeting nearly all research scientists interested in the question were in attendance. The proposal, moreover, has been approved by J. de Boer, Secretary of the Commission on Symbols, Units, and Nomenclature, of the International Union of Pure and Applied Physics.

Until 1953 it was not known that more than one allotrope of helium existed. In that year Dugdale and Simon[1] reported the existence of two solid forms of He^4. These are the α and β forms in Fig. 1. Then in 1961 Vignos and Fairbank[2] showed that a third solid phase, γ-He^4, existed in a narrow region along the melting curve. At the Los Alamos Scientific Laboratory the three allotropic forms of He^3 shown in the figure were discovered.[3,4] The structures of all these solid phases have been found by x-ray[4-8] and neutron[9] diffraction studies and are listed in Table 1.

One notes that in the present nomenclature, identical crystal forms of He^3 and He^4 are not given the same alphabetical names. The structure of α-He^3 is that of γ-He^4. A similar mismatch exists in the alphabetical names of the other corresponding structures. In order to remove the confusion which now exists we propose that a new and consistent system of names be adopted.

By custom the designation of solid phases is usually by Roman numerals or by letters of the Greek alphabet. Later, as their structures become known, the phases are also referred to by abbreviations indicating their structure. The assignment of phase names has sometimes been according to the order of discovery and sometimes according to an increas-

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Table 1. The Structures of the Helium Allotropes

He^3		*He^4*	
Form	*Structure*	*Form*	*Structure*
α	bcc	α	hcp
β	hcp	β	ccp
γ	ccp	γ	bcc

bcc = body centered cubic, hcp = hexagonal close packed, and ccp = cubic close packed.

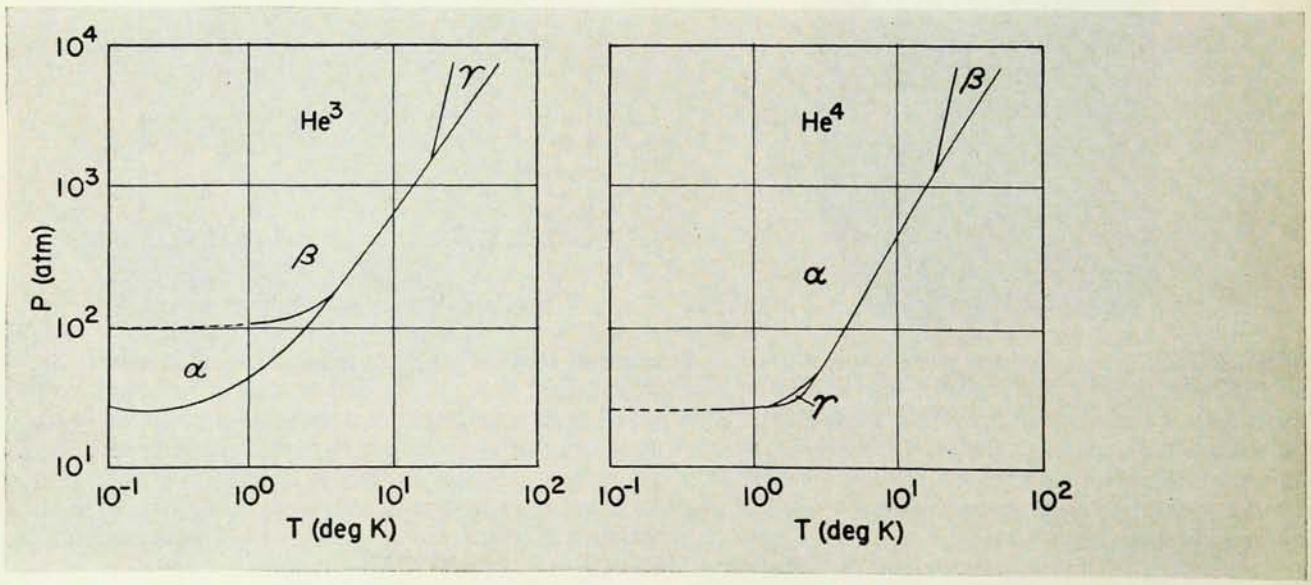

Fig. 1. Present nomenclature for allotropes of He^3 and He^4.

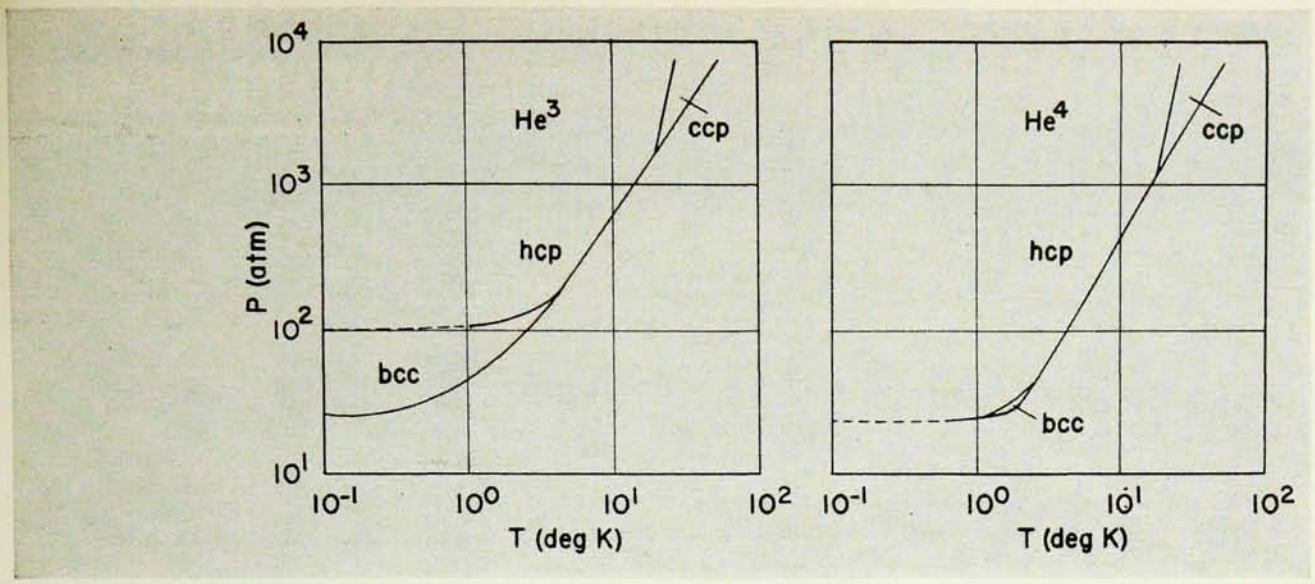

Fig. 2. Proposed nomenclature for allotropes of He^3 and He^4.

ing sequence of some property such as temperature or pressure. Often it has happened that the chronological order has been in the direction of increasing temperature.

In considering systems of nomenclature that might be used for helium, one observes that the naming of the solid phases by numerals can lead to confusion. Designations such as He I, He II, He^3, and He^4 are already in use and have particular meanings. This suggests in consequence that the solid forms might better be named by letters.

Consideration has been given to a continuation of the use of Greek letters in naming the helium allotropes with, however, a rearrangement of the designations for He^4 so that they will follow the same sequence as those currently used for He^3. This would mean for each isotope that the bcc phase be called the α, the hcp the β, and the ccp the γ phase. It was pointed out at the meeting, however, that such a choice would lead to future difficulties due to possible confusions between the old and this proposed system.

Consideration was also given to the use of letters of the Roman alphabet such that for each isotope the bcc phase be called a-helium, the hcp, b-helium and the ccp, c-helium. This suggestion was seriously considered because these letters have not previously been associated with any helium phases. It was, however, recalled during the meeting that the letters a, b, and c are already in common use by crystallographers as names for crystal axes. Thus, to avoid introducing new ambiguities, this system was rejected in favor of the one enumerated below. The main arguments evident in these considerations concern the question of solid mixtures of He^3 and He^4 which, in general, can only unequivocally be referred to in terms of their crystal structure.

The meeting therefore recommended the adoption of the system shown in Fig. 2 where the solid phases are labeled by symbols indicating their structure. This system is unequivocal, can be used at once, and its acceptance does not require a departure from what now exists in the literature. The abbreviation ccp is used in the literature for "cubic close packed" in analogy to hcp for "hexagonal close packed." Often a cubic close packed structure is referred to as face centered cubic, fcc, which it is. This latter term, however, can be ambiguous. A face centered cubic structure is close packed only when there are four atoms per unit cell. We favor ccp over fcc because it emphasizes the close packed feature of this helium form.

In summary, we propose a new system of nomenclature for the helium allotropes, based on crystal structure, which is informative, terse, and easily assimilated.

References

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