# NOMENCLATURE OF PHASE TRANSITION

**JAMES E. McDONALD**
University of Arizona, Tucson

It is a somewhat curious fact, which seems to have escaped previous formal attention, that the terminology of chemistry and physics includes only *five* terms for use in describing the *six* possible types of transition between the three ordinary states of matter. We have the antonymous pair, "freezing-melting," for the solid-liquid transitions, and we have the antonymous pair, "condensation-evaporation," for the liquid-vapor transitions, but for the solid-vapor transitions, we have only the single term "sublimation."

That this asymmetric situation has been permitted to exist as long as it has would seem to argue that no revisions are needed. However, after recently making a systematic examination of present usages in the fields of chemistry, physics, and meteorology, I have concluded that improvement is, in fact, sorely needed. The physicists seem to be very consistent in employing "sublimation" *only* to denote the solid-to-vapor transition, yet they take no apparent formal notice of their lack of an inverse term. Current literature in the field of solid-state physics contains frequent passages wherein "condensation" is used to describe growth of crystals from the vapor phase, and almost as frequently crystals are spoken of as "evaporating." It is probably true that this never engenders real ambiguity since the physicist is usually dealing with simple laboratory situations. Quite different is the case of the meteorologist, who must often describe processes in active rainclouds where all six possible types of phase transition are going on simultaneously. To employ the physicists' twofold meaning for "condensation" and "evaporation" would be out of the question in such meteorological contexts, so over the past few decades the meteorologist has evolved the practice of using the single term, "sublimation," to specify *either* the solid-to-vapor *or* the vapor-to-solid transition, and much more frequently it is the latter meaning that is intended. For example, the meteorologist speaks frequently of a "sublimation nucleus," which is a direct contradiction in terms from the physicist's viewpoint.

Inasmuch as both physics and meteorology have taken over the term, "sublimation," from earlier chemical usage, one might expect that at least in the latter case uniform practices would have been adopted. However, on examining numerous texts in general chemistry and physical chemistry, I find that the chemists are about equally divided in employing two distinct usages. Many employ the definition to be found in a recently published chemical dictionary[1] which states "sublimation" to be "the transformation of a solid directly to the gaseous condition without passing through the liquid state," i.e., many use exactly the same definition that all physicists now seem to employ. However, about as many chemists use the term to mean the *cyclic* process beginning with a solid-to-vapor transition and ending with the inverse vapor-to-solid transition, as in the phrase, "purification by sublimation." Thus a widely used college chemistry text[2] defines the term as "the complete process of evaporation of a crystal and recondensation of a gas directly as crystals, without apparently passing through the liquid state."

I became clearly aware of this confusing nomenclatural position when I set about coining some term for use in my own field of cloud physics where there is pressing need for an antonym to "sublimation" as used by the physicist. Suspecting that etymology would offer helpful clues to the invention of an appropriate antonym, I consulted a number of standard references. The findings were interesting but of little immediate help. Etymology clearly argues employment of the last meaning cited above, for in the vocabulary of alchemy, *sublimation* was an emotionally tinged term denoting a cyclic process of solid-to-vapor and subsequent vapor-to-solid transition by which mystical purifying action was to be achieved. The Latin *sublimis*, meaning "high, lofty ethereal, purified," had still earlier origin that offers little in the way of clues to formulation of any new terminology of chemistry and physics, for it is apparently derived from roots connoting "reaching up to lintel," the latter being a sacred site according to early Roman familial belief. There is nothing very helpful here except the implication that the physicist has corrupted the term by restricting its original meaning to just one portion of the over-all process of "purification by sublimation."

After weighing relative advantages of the several current usages, and discussing these with colleagues in the several fields involved, I have concluded that if any solution to this peculiar terminological difficulty is to be sought it should probably consist of letting the phrase "purification by sublimation" retain its original meaning while restricting the narrow sense of the term, "sublimation" to just the solid-to-vapor transition, i.e., adopting what is already standard usage in physics and fairly common usage in chemistry; and, at the same time, finding some entirely new term to serve as an antonym to "sublimation" in this latter sense.

As the new antonym, I wish to recommend here the term, "deposition" for I have found that this word is already being informally used in exactly this sense in the literature of all three fields involved. Thus, in a re-

[1] Honig, J. M., et al., "The Van Nostrand's Chemist's Dictionary," D. Van Nostrand Co., Inc., New York, **1953**, p. 670.

[2] Pauling, L., "College Chemistry," 2d ed., W. H. Freeman, San Francisco, **1955**, p. 41.

cently published chemistry text one finds a figure whose caption refers to ". . . equilibrium between molecules evaporating from an iodine crystal and gas molecules depositing on the crystal;" while in another, the author points out that "gas may be changed into the solid again by deposition on a cold surface." The physicist speaks commonly of "vacuum deposition" of thin films, and one finds a crystal physicist's description of the growth of metal crystals from the vapor wherein reference is made to "a temperature of 1000°C. for the deposition." A meteorologist writes ". . . down to a certain temperature below 0°C., direct deposition of vapor as ice is not to be expected," while another writes "the deposition of the first few molecular layers on such a nucleus may not be in the form of ice," so we see that meteorologists are also prepared to use this term as proposed.

I believe it must be agreed that it is highly desirable to have six distinct terms unambiguously specifying the six possible types of phase transition. Although ambiguities in past and present usage of "sublimation" render any recommendations for revision less than clear-cut, I believe that the best course is to assign as the basic and most specific denotation of "sublimation" just the solid-to-vapor transition and to allow the rather infrequently used concept of purification by sublimation to retain its old sense. If this is done, then "deposition" seems to afford a quite appropriate antonym to "sublimation" that does not have already-established connotations in physics and chemistry that preclude its adoption in the proposed sense. Its geological meaning will scarcely conflict with that here urged, since there is little chance of overlap of these two contexts. I am making the present recommendation by letters to several journals in the fields of physics and meteorology as well as here, in the hope that uniform practice can be achieved and a minor, but long-standing nomenclatural difficulty thereby resolved.