Chemical Possibility and Modal Semantics

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ABSTRACT

In the course of their work, chemists sometimes judge particular chemical processes to be possible or impossible. In this note I examine the semantics of the notion of possibility implicit in these judgments. I argue that standard possible worlds semantics does not allow an adequate analysis of this notion, and I suggest a modification of possible worlds semantics that may overcome this limitation.

1. Introduction. Philosophers have long recognized that there are many different notions of possibility. The best known among these notions are logical, conceptual, and physical possibility. Because chemistry is the study of certain aspects of the physical world, chemistry is concerned with what is physically possible. However, there is no *a priori* guarantee that all statements about possibility found in the discourse of chemistry can be understood simply as statements about physical possibility.[1]

In this paper I will examine a notion of possibility commonly used in chemistry -- the notion to which chemists resort when they claim that a particular chemical reaction, or other chemical process, is either possible or impossible. I will argue that this chemical notion of possibility cannot be reduced in a simple way to physical possibility. Further, I will suggest that the familiar idiom of possible worlds, in its unmodified form, might not be the most natural conceptual framework for the formalization of the semantics of this chemical notion of possibility. I will point out a way in which one might extend possible worlds semantics to arrive at a more adequate analysis of chemical possibility.

2. Chemical possibility. Chemists sometimes use the words "possible" and "impossible" in a manner peculiar to the discourse of chemistry. For example, a chemist might say that it is impossible to synthesize a particular drug from a specified set of raw materials. What the chemist means by this statement is that it impossible to produce the drug from the raw materials *by chemical means alone*. This notion of possibility most often crops up in informal discussions of chemistry; for example, a change in the composition of matter is labeled "impossible" because that change is unattainable by way of chemical processes. We will call this informal notion of possibility *chemical possibility*.

Chemical possibility is not the same as physical possibility. A particular change in the composition of matter may be physically possible, and yet chemically impossible. An example is the changing of one element into another, which occurs routinely during nuclear reactions but cannot be accomplished through chemical changes alone. Thus, chemical and physical possibility do not coincide. There also is a deeper difference between these two notions of possibility. Chemical possibility appears to differ *semantically* from the standard notions of possibility, such as physical and logical possibility. The following paragraph explains what I mean by this.

In standard modal semantics,[2] the truth conditions for statements like "It is possible that P" are formulated in terms of possible worlds. According to standard possible worlds semantics, "It is possible that P" is true at the actual world if and only if P is true at some possible world accessible from the actual world. (There are different relations of accessibility for different kinds of possibility; for example, in the case of physical possibility, a world accessible from w is taken to be a world in which the laws of physics in w hold.) However, this kind of analysis looks unnatural when applied naively to statements about chemical possibility. If we try to treat chemical possibility along the same lines as physical possibility, then we might try saying that "It is chemically possible that P" is true if and only if P is true in some chemically possible world -- that is, in some world in which the actual laws of chemistry hold. (We take the laws of chemistry to include the laws of physics as a proper subset.) But this analysis of chemical possibility is wrong. If we take P to be the statement "Hydrogen sometimes changes into helium," then P is true in some chemically possible world -- namely, the actual world, in which all the laws of chemistry hold, and in which hydrogen constantly changes into helium through nuclear fusion in the stars. But according to the intuitive notion of chemical possibility that we introduced earlier, it is not chemically possible that P. The fusion of hydrogen into helium is a nuclear process involving the change of one element into another, and therefore is chemically impossible under the intuitive notion of chemical possibility. The mere fact that this change occurs in a world in which the laws of chemistry hold does not count in favor of the chemical possibility of the change. What would count is the physical possibility of the change occurring *by way of chemical processes alone*. The processes that convert hydrogen to helium in the sun are not chemical processes; hence the physical possibility of those processes does not count for the chemical possibility of anything.

3. The semantics of chemical possibility. It appears that one obvious possible worlds analysis of chemical possibility is inadequate. A more natural analysis of chemical possibility might not use possible worlds alone, but might also use a domain of *possible chemical processes*. Possible chemical processes are chemical processes that are physically possible. Once we have settled on a domain of possible chemical processes, we can say that (roughly speaking) a state of affairs is chemically possible if and only if that state of affairs that can be brought about by way of possible chemical processes alone.

Before I try to make the last statement precise, I will make some remarks on the notion of a possible chemical process. The condition that these processes be "chemical" recognizes the intuitive difference, familiar to chemists, between processes that are chemical and processes that are merely physical. The neutralization of an acid by a base is a chemical process. A nuclear reaction is not a chemical process; neither is the generation of radio waves by an antenna. Roughly speaking, a chemical process is one that results in a change in the molecular structure of matter and does not involve nuclear change. We will not try to precisify this concept further at this time. No matter how one precisifies this notion, the domain of possible chemical processes should coincide at least roughly with the domain of those physically possible processes that chemists typically regard as chemical rather than merely physical.

Once we decide on a domain of possible chemical processes, the suggested analysis of chemical possibility would run something like this:

> "It is chemically possible that P" is true at world w if and only if: at world w, for some possible chemical process K, if K occurs then P.

For example, "It is chemically possible that some sample of sodium bicarbonate neutralizes some sample of acetic acid" is true if and only if there is a possible chemical process K such that if K occurs then some sample of sodium bicarbonate neutralizes some sample of acetic acid. (Such a process K could be, for example, a process in which a drop of acetic acid lands on a chunk of sodium bicarbonate.) As another example, "It is chemically possible for aspirin to be synthesized" is true if and only if there is a possible chemical process K such that if K occurs then aspirin is synthesized. (Such a process K could be any process of organic synthesis that creates aspirin.)

As it stands, this definition is incomplete, because it is not clear what the "if...then..." really amounts to in the clause "if K occurs then P." Intuitively, it seems reasonable to suppose that this implication is *physically necessary* implication. That is, "if K occurs then P" means that in any physically possible world, K materially implies P.

We arrive at the following rigorization of the notion of chemical possibility:

> "It is chemically possible that P" is true at world w if and only if: at world w, for some possible chemical process K, it is physically necessary that if K occurs then P.

(Here the final "if...then..." expresses material implication.)

This semi-formalized notion of chemical possibility still involves possible worlds, but possible chemical processes now play a prominent role.

We note that the domain of possible chemical processes may, in principle, vary from world to world. To best reflect the intuitive notion of chemical possibility, we might want to take the domain of possible chemical processes in the preceding rigorization to be the domain of possible chemical processes in the actual world.

4. Closing remarks. We have arrived at a preliminary sketch for a semantics of the notion of chemical possibility. In doing so, we have introduced a special semantical device: a domain of possible processes, which plays a role in the semantics along with the domain of possible worlds. It is well known that the domain of possible worlds may have a nontrivial internal structure; for example, one usually defines an accessibility relation upon that domain. We may ask whether the space of possible chemical processes has any internal structure relevant to the semantics of chemical possibility, and whether giving this space more (or less) internal structure might lead to interesting alternatives for the semantics.

We note first that the space of chemical processes has a nontrivial *algebraic* property: that of closure under a certain binary operation. Two possible chemical processes, performed one after the other, constitute a single possible chemical process. Hence the set of possible chemical processes has a binary operation * defined as follows: a*b is the process consisting of process b followed by process a. (I have defined "a*b" to mean b followed by a, instead of a followed by b, to conform to the mathematicians' convention for multiplication of operators.) If we count the *empty* process (a process in which nothing happens) as a possible chemical process, then the binary operation * has an identity element, and the chemical processes form an algebraic structure known as a *monoid*.

One might ask what the algebraic properties of the "real" set of possible chemical processes are like -- and whether different choices for those properties might lead to substantively different notions of chemical possibility, in much the same way that different choices for the accessibility relation lead to different notions of possibility in conventional modal semantics.

References

1. In an earlier preprint, I argued something similar about a notion of possibility used in phonetics. (Mark F. Sharlow, "Phonetic Possibility and Modal Logic," preprint, 2003.)

2. Modal semantics is discussed in textbooks on modal logic. See, for example, Brian F. Chellas, *Modal Logic: An Introduction*, Cambridge, UK: Cambridge University Press, 1980. I have used background information on modal semantics and logic on a level comparable to that found in textbooks in the field.