CHEMICAL REACTION PROBLEM SOLVING

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Problem solving has often been described as a major component of high school chemistry classes. In many high school chemistry classes there are prerequisites - - students must have obtained a certain level or grade in mathematics classes. However, chemistry does not have to be a subject in which mathematical problems are the focus. There are many concepts and problems associated with chemistry that do not involve mathematical manipulations. Predicting products of chemical reactions is one such aspect of chemistry. Chemical equation problem solving and instructional methods will help students predict products.

Problem solving in chemistry has been related to students doing exercises which involve rote memorization and recall rather than authentic problem solving which involves process skills and reasoning skills.1 Problem solving can be defined as a process whereby someone applies previously learned rules to a novel situation in order to arrive at a solution. Predicting products of chemical reactions is a process in chemistry that is content specific. The methods for helping students learn this process must be taught to students and future teachers by using the pedagogical skills within the content.

Memorizing facts can lead to cognitive dissonance in which facts are separated entities with no relationships. Cognitive dissonance can be described as having knowledge without being able to use it. Knowledge, such as memorizing chemical formulas and specific reactions, does not help a student learn chemistry, because the knowledge is not applicable to knowledge already learned. Solving a chemical reaction should involve creative cognition. This allows for diverse and meaningful instruction and learning, because creative cognition relates new knowledge to already acquired knowledge. It is the interconnectedness of the different items that allows for creativity in problem solving.

The Problem

In predicting products for chemical reactions, students must know not only facts but how these facts interconnect with each other. The problem is to understand what the reactants will do and what products will form under certain conditions. There are some basic questions why experts (chemists) can solve chemical reaction problems and novices (students) have difficulty. The basic underlying principle is having the necessary knowledge to solve the problem.[3] Many students may know facts, but solving problems involves connecting the facts for a desired outcome. Experts can store and retrieve facts in a more logical and meaningful manner; novices have problems making those connections.

In chemistry courses students are asked to predict the products of different types of chemical reactions. Some of these reactions are acid/base, net ionic, single replacement, double replacement, synthesis, decomposition, redox, and nuclear. What are the facts and knowledge associated with all of these reactions that would help students solve them? How can we teach students to approach product predicting when many students have the knowledge, but not the reasoning ability? Table I lists some common reactions found in many chemistry textbooks. Some may recognize these as easy, while others might find them difficult.

Table I: Sample Reactions for Predicting Products
1. A solution of sodium iodide and lead nitrate is mixed.
2. A strip of magnesium is burned in oxygen.
3. Dinitrogen pentoxide is added to a solution of potassium hydroxide.

Why are some students able to predict the products of these equations and others are not? Student performance drops rapidly on problems that contain more than five pieces of information.[2] These pieces of information are the facts about chemicals and reactions. How can someone tackle a problem with more than five items? When there is too much information to process, experts chunk individual pieces of information into larger understandable pieces which are then stored. Cognitive scientists believe that information retrieval and learning are directly related to how pieces of information are learned, grouped, and stored in one's mind. Once the information pieces are available, it takes interconnectedness of these pieces to enable a student to solve many chemical reaction problems. Many chemical reactions involving product prediction involve knowing more than five pieces of information.

The reactions in Table I have different number of information pieces that are needed for understanding and solving the problems. Table II lists all the pieces of information necessary to predict the products and understand the reactions.

Table II: Pieces of Information for Chemical Reactions in Table I

1.	• the formulas of the reactants • the reaction is a double replacement or precipitation reaction • lead nitrate and sodium iodide are soluble • ionic charges for lead and iodide • lead iodide forms as an insoluble product • this should be a net ionic equation with no spectator ions
2.	• the formulas of the reactants • the reaction is a combustion or combination reaction • ionic charges for magnesium and oxide • formula of the product; magnesium oxide
3.	• the formulas of the reactants • the reaction is an acid/base reaction • dinitrogen pentoxide is an acid anhydride • acid anhydrides react with water to form acids • nitric acid forms from this reaction • nitric acid is a strong acid and is written in ionic form • potassium ion is a product • water is not written down in the equation because it is both a reactant and a product • potassium nitrate is soluble and will not form a precipitate

The first reaction in Table I might be considered difficult. If solubility rules are known in advance, then in Table II, six pieces of information will reduce to five. If this reaction were demonstrated, students might recall the bright yellow precipitate which forms. The first reaction can be learned more effectively if the teacher helps the students remember solubility rules and demonstrates the reaction.

The second reaction might be the easiest for students to predict for a number of reasons. One might be that the students saw a demonstration. When magnesium is burned, it gives off a bright light; students may have remembered the bright light, and that magnesium is sometimes used in fireworks. Another reason is that only four pieces of information are needed. Demonstrating the reaction or providing a practical application can help the students make connections.

Equation three may seem the hardest, but it can be made easier if students realize: 1) solubility rules and strong acids ionizing can be chunked together; 2) dinitrogen pentoxide is an oxy-acid; and 3) an aqueous solution contains water and the product of an acid/base reaction is water. These three chunks of knowledge would reduce the nine pieces of information needed to five.

<u>Instructional Methods for Improving Reaction Problem Solving</u>

Students need to be taught how to organize and chunk information in an efficient manner. There are instructional methods that the teacher can use to help students understand and solve reaction problems. These methods are: brainstorming, learning general reaction types, learning solubility rules or trends, demonstrations of solving techniques and strategies, demonstrations to exemplify certain types of reactions, memorizing basic facts, and learning periodic trends. Brainstorming occurs when students write down or list all the facts known about a reaction type or reactants. Students should learn general reaction types rather than specific reactions. For example, rather than memorizing that hydrochloric acid reacts with calcium hydroxide to produce calcium chloride and water, students should learn that the products of an acid/base reaction are a salt and water. There are variations of this reaction type when using weak acids and bases, but the key concept is to know general reactions rather than the specifics. Learning periodic trends does not mean memorizing trends, rather understanding why certain groups of elements react under certain circumstances. These methods help establish a foundation for students to use for product predictability.

When a student first encounters a reaction problem, he/she should brainstorm all of the related bits of information and write them down. The bits of information from the brainstorming can then be related to each other in different ways. For example, in reaction one, solubility rules would allow the student to see all possible ions and their charges. This would lead to the realization that when two of the ions combine they form a precipitate. This could lead the student to remember that a precipitate results from ions in solution in a double replacement reaction. Next, the student should chunk these relations. When chunking is finished, spectator ions should be found and eliminated from the reaction.

Teachers should use a variety of teaching strategies. A sequence of events that might happen is that the teacher demonstrates that magnesium bums in air just like gasoline bums in a carburetor. The teacher proceeds to write the reaction with reactants and products demonstrating how the products are formed and why. The student may realize that burning is a combustion reaction that was shown earlier by the teacher and may relate the demonstration and problem solving strategies shown by the teacher to the problem. Part of the demonstration should incorporate chunking information for various reasons. Students should be allowed to chunk in different ways that are relevant to understanding (as long as it is chemically correct). Teachers should use students' chunking ideas and share them with the class.

Implications for Teaching Students

The teacher should model predicting products of chemical reactions during a lecture, lab, group learning, or demonstration. General rather than specific facts related to a chemical reaction should be emphasized. Teachers need to be aware when students develop conceptual overload. This occurs when students learn too many facts and do not understand why they knew these facts are needed. Once students are shown, by chunking information, that chemicals in a reaction are related to one another then process skills for predicting reaction products become easier to teach and learn.

References

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