DOCUMENT RESUME

ED 043 483 SE 008 098

AUTHOR Case, James B.
TITLE Treating Chemical Equilibrium Mathematically in Secondary Schools: A Preliminary Investigation.
INSTITUTION Nevada Southern Univ., Las Vegas.
PUB DATE 6 Mar 70
NOTE 9p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (43rd, Minneapolis, Minn., March 5-8, 1970)

EDRS PRICE EDRS Price MF-$0.25 HC-$0.55
DESCRIPTORS *Academic Achievement, *Chemical Equilibrium, *Chemistry, *Instruction, Science Units, Scientific Concepts, Secondary School Mathematics, *Secondary School Science

ABSTRACT

This report presents the procedures, results, and conclusions of a study to determine the characteristics of secondary school chemistry students who were successful in grasping a mathematical approach to learning chemical equilibrium. Subjects were eighty-nine students enrolled in chemistry at a rural-suburban high school; each student had completed at least one-year of algebra and plane geometry. An experimental mathematically based unit on chemical equilibrium developed by the investigator was taught to the students. Six daily lesson tests and a final test were administered to the students during the study. Results indicated that about one student in five was successful in understanding the quantitative presentation of chemical equilibrium while the remaining students attained varying degrees of understanding of the experimental unit. The successful students were described as highly intelligent, with more than five semesters of mathematics and science respectively. Som e implications for teaching chemical equilibrium from a mathematically based approach are considered. (LC)

Treating Chemical Equilibrium Mathematically In Secondary Schools: A Preliminary Investigation

By

James B. Case, Ph.D.
University of Nevada, Las Vegas

A Paper
Presented At The 1970 Annual Meeting Of
The National Association For Research In Science Teaching
Minneapolis, Minnesota
March 6, 1970

INTRODUCTION:

Much has been written about the many problems associated with the teaching of chemical equilibrium at both the college level and the secondary school level. Generally these writings have been descriptions of new and/or different methods or approaches to teaching the concept of chemical equilibrium. The topic of this report is the result of an investigation that represented the first recorded attempt at obtaining information about the teaching and learning of chemical equilibrium in the secondary school chemistry class. Specifically this investigation was the first recorded attempt at using a specially written and designed mathematically based approach to chemical equilibrium, for the secondary school student. The topic of this investigation evolved due to concern of the writer over the lack of mathematically based science concepts being presented in the secondary school science classes, and the lack of integrated and/or correlated mathematics-science programs at the secondary level. With the modern science teaching emphasis on the "process of science", i.e., doing what the scientist does, it would seem plausible that a quantitative relationship such as chemical equilibrium should be taught as the scientist observes it and uses it—quantitatively with mathematics.

PURPOSE

The investigation to be described in this paper was planned to be preliminary in nature, and its purpose was to determine the characteristics of secondary school chemistry students who were successful (or unsuccessful) in grasping a mathematical approach to teaching chemical equilibrium.

THE POPULATION

The population studied consisted of all the students enrolled in chemistry at a rural-suburban three-year senior high school, which could best be described as comprehensive in nature, and as having provided "traditional" science and mathematics curriculums. Of the one-hundred and fourteen students enrolled in chemistry, eighty-nine were directly involved in the study, and were considered the population. All students enrolled in chemistry were required to have completed first-year algebra and plane geometry. More than half the population was enrolled concurrently in second-year algebra. More than half the population had completed biology as sophomores, and the entire population had completed a general science course as freshmen.

The final population was identified as having taken the Terman-McNemar in 1963, and was divided into two sub-groups based upon whether the student had two years of mathematics background, or three years of mathematics background. Each of these two groups was further broken down into smaller sub-groups based on quality of mathematics grades and quality of science grades in courses previously completed, and performance on twelve key test items selected from the daily lesson tests. As a matter of interest, the final population mean I.Q. was 121 with s.d. = 12.

MATERIALS AND PROCEDURES

An experimental mathematically based unit on chemical equilibrium was developed and written by the investigator. The unit was specially designed for use with secondary school students. The experimental unit was introduced to the students during the same time period of the school year that the students would normally have been taught the "regular" approach to chemical equilibrium, as given in Modern Chemistry (Dull, Metcalf, Brooks). Each student received individual copies of the experimental unit for his personal use. The amount of class time devoted to the experimental unit was equal to that which had been allocated for the "regular" presentation of chemical equilibrium—in other words, the experimental presentation was exactly substituted for the "regular" presentation. The students had completed 7½ months of the school year at the time

5

of the study, and therefore, those students enrolled in second-year algebra had completed the bulk of this mathematics course.

The experimental unit consisted of six individual daily lessons, six individual tests over each lesson, and a final test over the entire unit. One lesson and test was given each day by the investigator. The six lessons covered the following topics, in order: (1) The Gas Laws and a Review of Required Mathematics; (2) The First Law of Thermodynamics; (3) The Second Law of Thermodynamics; (4) The Equilibrium Constant for Gas Reactions; (5) The Thermodynamic Equilibrium Constant for Aqueous Reactions and (6) Applications of the Thermodynamic Equilibrium Constant. The structure of the experimental unit was developed by the investigator after consideration of the presentation of the topic of chemical equilibrium as given in the "traditional" chemistry curriculum textbook Modern Chemistry, the CHEM Study textbook Chemistry: An Experimental Science, the CBA textbook Chemical Systems, and the literature concerning mathematics in the secondary school science curriculum, and the literature concerning concept-formation in science. Fifty-three test items over the six daily lesson tests were written to test the student's understanding of chemical equilibrium at the comprehension level of knowledge. The validity of each test was evident in that all test items in a given test could be answered directly from the material presented in the lesson corresponding to that test. Reliabilities were not calculated for each test because there were too few test items per test to give a <u>true</u> measure of the lesson test's reliability. (Reliability is directly related to the number of items—L. Nedelsky, Science Teaching & Testing, 1965, p. 93). All raw scores on these daily lesson tests were converted to standard scores for analysis of results of the study, since each test contained a different number of test items.

A final test of thirty items, which tested over the entire unit, was also used in the investigation. These thirty test items corresponded to thirty selected items from the daily lesson tests that related to the most important concepts within the unit. The final test items requested the same information asked for in the daily lesson tests, but in a different manner. The correlation between the final test items and their counterparts in the daily lesson tests was 0.8 (Pearson Product-Moment). Validity for the final test items was apparent for the same reasons as given previously for the daily lesson test items.

THE DATA

The data collected were numerous—thirteen to fifteen pieces per member of the population—depending on the student's mathematics and science background. The thirteen (or fifteen) data items collected were: the scores on each of the six daily lesson tests; the score on the final test; performance score on the twelve selected key test items; intelligence quotient; two (or three) mathematics grades; and two (or three) science grades. The latter two data items were converted from letter grades to numerical values for computer use.

The data were used to identify sub-groups within the population, and to describe the characteristics of the students who were successful (or unsuccessful) in understanding the specially designed mathematically based unit on chemical equilibrium. The six daily lesson test scores were used to measure each student's "progress" through the unit, and each individual score was a measure of the student's understanding of the particular lesson. The total of these six lesson test scores was a measure of the student's grasp of the complete unit. The final test score was a measure of retention, and the student's grasp of the unit as a whole. The student's score on the twelve selected key test items was a measure of the student's grasp of the important concepts required for understanding chemical equilibrium as presented in the mathematically based unit.

The minimum score necessary to indicate understanding of the mathematically based unit on chemical equilibrium was seventy percent on the six-lesson-test-total, the final thirty-item test, and the twelve selected key test items.

The seventy percent minimum included only those concepts absolutely necessary to an understanding of chemical equilibrium as presented in the mathematically based unit. Correlation coefficients were calculated for all possible combinations of data for the subgroups; graphs of the data also were plotted for the subgroups. Since this investigation was intended to be descriptive in nature, the data and the results are not generalizable to another population.

DISCUSSION OF RESULTS

The data indicated that about one student in five could be described as having grasped adequately the meaning of chemical equilibrium as presented in the mathematically based teaching unit. About eighty percent of the population attained varying degrees of understanding of the experimental unit on chemical equilibrium. No attempt was made to categorize these varying degrees of understanding.

Generally, within the population studied, the secondary school chemistry student who was successful in grasping the mathematical approach to chemical equilibrium as presented by the author, had these characteristics: An intelligence quotient (as measured by the Terman-McNemar) of one or more standard diviations (s.d.= 12) above the population mean of 121; more than five semesters of mathematics background, including first-year algebra, plane geometry, and second-year algebra; more than five semesters of science background, including a general science course, biology, and chemistry; and his level of performance in the described mathematics and science courses was of high enough quality to place him in the upper twenty percent of the chemistry student population in these courses.

The unsuccessful student was found not to have all the preceding described characteristics.

Although only about one student in five was experimentally described as successful in understanding the quantitative presentation of chemical equilibrium, many of the "non-successful" students were still able to attain varying levels of understanding of chemical equilibrium from the quantitative approach presented in the experimental teaching unit. Evidence for this was obtained in log form, through an open-ended comment oriented questionaire completed by the students, and through informal conversations during, and after, the experiment. Many students (including the "successful" ones) expressed amazement that chemistry was such an orderly subject that "could be figured out with math". Several were quite impressed with the power and predictability that mathematics gave to scientific inquiry. A few were completely baffled, and could discover no relationship between mathematics and scientific inquiry. This latter group was very small and was characterized by a very low performance level in all their previous mathematics and science courses, and lower levels of interest and occupational ambitions than their more successful peers.

CONCLUSIONS AND RECOMMENDATIONS

As a result of this investigation, the author has found that a mathematical approach to teaching chemical equilibrium is not beyond the ability of the secondary school chemistry student in a particular population—but in order for the topic to be most meaningful, it should be reserved for essentially the top twenty percent of the student population, as determined by quality of performance in previous mathematics and science courses.

The most difficulty in student learning when presenting a mathematically based approach to chemical equilibrium is likely to be encountered when considering the topic of entropy. The individual test scores indicated that this topic was most difficult for almost everone. With regard to the particular teaching unit developed for this study, this section will have to be revised before the study is repeated.

In addition, since the mathematical approach to presenting chemical equilibrium requires a considerable amount of "discovery" on the part of the student, and student application of mathematics as a tool as the scientist uses it in his work, more time must be used in a presentation of this type than is currently used in presenting chemical equilibrium in the three major secondary school chemistry curriculums.

Finally, in order for this approach to teaching chemical equilibrium to secondary school chemistry students to be useful on a wide basis, the study will have to be repeated using standardized tests and student samples drawn from the national student population. Recent interest in mathematics in science (or science in mathematics) indicates that this type of activity may occur in the near future. (re: Dr. Boeck, "Coordinating and Integrating Science and Mathematics Programs at the Secondary School Level", major speaker at CASMT Annual Meeting, November 28, 1969, Milwaukee).