DOCUMENT RESUME

ED 081 203 EM 011 373

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TITLE Chemical Calculations; An Audiotutorial Approach.
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PUB DATE 73
NOTE 5p.

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS Audiovisual Aids; Audiovisual Instruction; Calculation; Chemistry; *Chemistry Instruction; Higher Education; *Individualized Instruction; Problem Sets; *Problem Solving; Program Descriptions; Review (Reexamination); *Tape Recordings; *Tutorial Programs; Tutoring

ABSTRACT

An audiotutorial approach to problem-solving in college chemistry relying upon audio tapes is available. The program is designed to increase the teacher's effectiveness by providing individualized attention to student difficulties related to problem-solving. Problem solutions are recorded on audio tapes (designed for use with Sony TC-160 cassettes or Sony TC-630 reels) and accompanying notes presenting visual and written material are prepared. The following topics are covered: units and conversion factors, weights, equations and stoichiometry, reactions, solutions, gases, equilibrium, solubility product calculations, acids and bases, ionic solutions, energetics, thermodynamics, galvanic cells and electrodes, dynamics, kinetics, nuclear chemistry, and radioactivity. The individual units are arbitrarily arranged but within units there is an ascending order of problem complexity and the units are structured to teach chemistry rather than problem-solving per se. These units are not designed as a priori introductions to problem solutions; students are first expected to do required reading and attempt to solve problems on their own, using the tapes for review and for tutorial assistance on troublesome matters. (For related document, see EM 011 372.) (PB)

chemical calculations

AN AUDIOTUTORIAL APPROACH

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An audio-tutorial approach to problem solving

How does one go about teaching a problems-based course in introductory chemistry to a group of students whose apparent abilities to understand, analyze and solve problems range from perfect to almost non-existent? While I do believe that problem solving is an ideal way to bring the student into intimate contact with the chemical principles that form the basis for most modern introductory-level courses, I have always wanted my students to feel that they are taking a course in chemistry, not in problem solving. And yet, it seemed that an undue amount of time had to be expended on the mechanics of explaining and analyzing problems, both in the lecture period itself, and especially in the smaller once-a-week tutorial sessions.

In any event, I have never been convinced that the classroom discussion of problems constitutes a very efficient learning situation for the majority of the class members; each student comes to the class with his own deficiencies, his own difficulties, and a certain amount of individual attention by the instructor is required in order to resolve them. Meanwhile, the class effectively comes to a halt for the other students who have no immediate interest in the problem being discussed.

Although a good teacher does try to generalize his comments in the hope that the other members of the class can benefit from them, the problem-tutorial class still tends to become more like a series of one-to-one dialogues in which the majority of the students are not actively participating at any given time. The slower students are up against another problem: being already sensitive to their inferior standing, they are forced to flaunt their ignorance publicly each time they seek help; it is hardly surprising that they soon gravitate to the rear of the room where they seek to remain as inconspicuous as possible for the remainder of the semester.

Several years ago, in an attempt to cope with this situation, I started making tape-recorded commentaries on each problem in the weekly problem sets. My object here was not to simply dictate the solution of the problem to the student, but rather to explain what the problem is *about*, and to place it in the context of the principles that have been developed in the course. I tried to outline the strategy behind the solution without actually giving it away, so that the student would always be required to participate actively in the process and thereby be more likely to derive some real value from the exercise.

The CHEMICAL CALCULATIONS audiotapes

The *CHEMICAL CALCULATIONS* materials are essentially a development and generalization of this concept. The topics covered span the range of subjects common to most Freshman courses (chemical bonding and atomic structure being the principal exception). The materials are

organized into eighteen problem units, each covering a different general topic. The order of topics is rather arbitrary, and only in a few rather obvious cases does one problem unit presuppose some exposure to a previous one. In some cases a given topic will appear in more than one unit. For example, Problem 3-11 and Problem 8-9 (in the units on stoichiometry and gases, respectively) both involve concepts of chemical energetics which are treated more thoroughly in Unit 14, which is entirely devoted to that subject.

Within any given problem unit, some attempt is made to build up a concept by presenting problems of increasing complexity. The student should therefore be encouraged to commence with the simplest problems and then work up to whatever level is required by the course. On the other hand, there is no point in using the audiotapes on any but the problems that present difficulty, unless the student merely wishes to review and confirm his understanding of the material.

Each of the eighteen problem units is contained on a separate audiotape reel or cassette. In order to enable students to access the specific problems they desire, some means of cueing is necessary. We do this by providing with each tape a list of problem numbers and the corresponding number of the index counter on the tape machine. These counters are not always uniform between machines of different types, so it is best to prepare a new list when our tapes are to be used on machines other than the Sony TC-160 (cassette) or TC-630 (reel). In our own tapes, we provide a gap of about one minute between successive problem sections so that the student can more easily locate the beginning of a problem. This gap is filled with music to make it more readily identifiable.

The audiotape notes

A set of audiotape notes accompanies, and must be used with, each of the eighteen audiotapes. The purpose of these notes is twofold:

First, they afford a medium for the presentation of visual material such as equations, graphs, and the like, as well as for printed matter that reinforces or helps to organize the audio commentary.

The second function of the notes is to prevent the student from becoming merely a passive listener. The tapes in themselves can teach the student very little; he can only learn if he responds, doing some thinking and reasoning of his own, and participating actively in the exercise. For this reason the recorded commentaries are tied very closely to the notes, and the student is expected to fill in the shaded blanks as he goes along. In doing this, he will frequently have to stop the tape and perhaps occasionally back up; this is desireable, because it means that the student is making active use of the tape as a learning aid- he is not simply listening to a lecture.

Once the sheet or portion of a sheet relevant to a given problem has been completed, the student has prepared what amounts to a permanent

set of notes that forms the groundwork for the solution of the problem. It should be emphasized that the series of blanks on the audiotape notes are not necessarily meant to represent the logical sequence of steps in the direct solution of the problem; the object of the exercise is to help the student learn chemistry, not to simply "work" the problem. Much of what appears in the audiotape notes is designed to help the student visualize and understand the principles involved, and then apply them to the problem. The actual solution of the problem, which should be carried out on a separate sheet, can usually be much more succinct.

The audiotape notes are divided into "frames" (I regret the resemblence to the terminology of programmed instruction!) to which reference is made at appropriate points in the audio commentary. The frames are numbered according to the corresponding problem number within the unit. When more than one frame is required for a given problem, the additional frames are denoted by a letter following the number. In a few units, some introductory remarks are made that pertain to the entire subject area of the unit; the frames for these portions of the units are designated by letters only.

Using the audiotapes

The CHEMICAL CALCULATIONS materials are intended to increase the teacher's effectiveness in presenting a course in introductory chemistry. This increase in effectiveness will depend very strongly on the role the teacher wishes to assign these tapes in the context of the overall course. At a minimum, they can be made available as "enrichment" or "remedial" materials to supplement a traditional lecture-based course. They will probably be much more effective, however, for those teachers who are able to regard these (and other) "individual study" materials as integral parts of the course. Ideally, the audio-tutorial should be one component of a total learning system in which a variety of activities such a formal lectures, group discussions, reading assignments, and computer-assisted instruction are combined in a comprehensive manner.

Teachers will differ on the question of whether to assign the problems contained in CHEMICAL CALCULATIONS as "required" work, to be turned in for marking. My own experience is that this is a practical thing to do, and that one can expect a higher standard of performance from the students; for example, you can actually insist on a clear and legible (if not literate) explanation of the solution to a problem. At the same time, it is important to provide other problems so that the student can reinforce what he has already learned, and eventually wean himself away from the audiotapes.

One thing that must be continually emphasized to the students is that the audio commentaries are not intended to serve as a priori introductions to either the theory or the problems. Students must be encouraged to do the necessary reading beforehand, and to attempt as many of the problems as possible before listening to the tapes. On the other hand, the tapes can serve as effective means of reviewing the course material at a later date, and of checking one's understanding of a problem that has already been solved.

Unit 1	*Units and conversion factors, significant figures, temperature and density.
Unit 2	*Atomic and molecular weights, combining weights, formulas.
Unit 3	*Chemical equations and stoichiometry
Unit 4	*Chemical reactions: ionization, acids and bases, combining powers, oxidation number
Unit 5	*Solutions: concentration, dilution, and titration
Unit 6	Physical- and colligative properties of solutions
Unit 7	Balancing oxidation-reduction equations
Unit 8	*Calculations involving gases
Unit 9	Chemical equilibrium: equilibrium quotients and equilibrium constants, multiple equilibria, Le Châtelier's principle
Unit 10	*Solubility product calculations
Unit 11	*Acids and bases: concepts, definitions, simple pH calculations
Unit 12	Acids and bases: hydrolysis, buffers, indicators, competing equilibria, polyprotic acids
Unit 13	Electrical properties of ionic solutions: conductivity and electrolysis, activity series
Unit 14	Chemical energetics and dynamics: the First Law
Unit 15	Thermodynamics and equilibrium: the Second Law
Unit 16	Galvanic cells, electrode potentials and chemical equilibrium
Unit 17	Chemical dynamics and kinetics
Unit 18	Nuclear chemistry and radioactivity

* *these units are also covered by the computer-assisted instruction program CHEMEX*