Topic variation in performance testing:

The case of the Chemistry TEACH test for international teaching assistants

by

Dean S. Papajohn

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ABSTRACT

Test method facets are particularly important in the design, development, and use of language tests because these allow for a certain amount of control in testing (Bachman 1990). Topic of input is an important feature within the framework of test method facets. Recent studies have focused on general topics versus field specific topics (Douglas and Selinker 1992, Smith 1992). Yet, field specific performance tests for international teaching assistants often provide different topics for each examinee, assuming equivalency between topics. The comparison of general topics versus field specific topics is unable to capture the full effect of topic. This study reports research into topic features and the effect topic variation has on a performance test for international teaching assistants, the chemistry TEACH test. Results indicate a relationship between topic of input as defined by the topic features of concepts, math, and calculations and test scores on the chemistry TEACH.

1. INTRODUCTION

People from all over the world come to study at universities in the United States. As the numbers of American graduate students has decreased, the number of international graduate students has increased. Along with these changes in enrollment, there has been an increase in the number of international teaching assistants (ITAs). The placement of international students as teaching assistants has not been without some problems and complaints. The "ITA problem" is the breakdown of communication between ITAs and their students. This problem has often been perceived by students, parents and administrators as a language problem stemming from the fact that the ITA uses a non-native variety of English. As universities investigated the ITA problem, often prompted by state mandates, it was discovered that more than accent or English ability was involved. ITAs are often uncertain how to effectively teach in an American classroom of American undergraduates. Culture as well as language are the culprits of the ITA problem (Kaplan 1989). Despite the fact that problems extend beyond language, tests of oral language ability are now used on many campuses in order to screen potential ITAs and reduce the "ITA problem".

ITA assessment is important for many groups including ITAs, departments, and undergraduates. Iowa State University (ISU) developed and uses a performance test for ITAs called the TEACH test. The version of the TEACH test given to chemistry majors will be referred to as the chemistry TEACH test in this paper. The chemistry TEACH test is a high stakes test for prospective ITAs because it affects their work assignments as well as their salaries. If chemistry ITAs do not pass the TEACH test, there are few research assistantships available for them. So, they are generally assigned less desirable duties such as lab preparations for demonstrations and lectures, until they improve their English, pass the TEACH test, and can fulfill their teaching responsibilities. Even if prospective ITAs pass the TEACH test and are allowed to teach, their salaries will be based on how high of a score they receive. The worse scenario is for an ITA to lose his assistantship and the financial means to continue his graduate education. On the other side, departments rely on international graduate students to economically fill teaching needs. Undergraduates rely on their ITAs for instruction and help. Because of these valid concerns from many sides, it is important to accurately assess the oral English ability of prospective ITAs prior to placement in teaching assignments.

ISU, and particularly the Chemistry Department at ISU, assign ITAs a number of teaching positions in undergraduate classes. This is true of many departments at many campuses across the United States. In Spring 1994, for example, there were eighty teaching assistants in the Chemistry Department at ISU. Of these, twenty-seven were ITAs. The ISU Graduate College administers two tests that screen for oral English ability, the modified SPEAK test and the TEACH test. The modified SPEAK test is a version of the retired Test of Spoken English (TSE) produced by Educational Testing Service (ETS). ISU has modified some of the questions and has made it a live interview format rather than using audio taped input like the TSE. The TEACH test was developed at ISU in 1985 in order to supplement the evidence of language ability provided by the modified SPEAK test. The TEACH test is an English language performance test that uses field specific topics with a classroom teaching task and context. Examinees receive test topics related to their major. Within a given major there are a number of different topics. For example, prospective ITAs from the Chemistry Department are randomly assigned one of fifteen chemistry topics. These fifteen topics have been chosen by the Chemistry Department to be used for the TEACH test to exemplify typical chemistry lessons in a beginning undergraduate chemistry class. The topics may be appropriate in the sense that they are typical chemistry lessons found in a freshman chemistry class, but it has not been shown that the different topics provide an equivalent type of input for a language test and require an equivalent expected response. In other words, the test topics have not been shown empirically to produce parallel forms of the test. The fifteen topics used for the chemistry TEACH test appear to vary in terms of topic length, degree of contextualization, distribution of new information, and type of new information. In particular, the topic and type of new information leads to the identification of the topic features of concepts, math, and calculations as potentially affecting the scores obtained by examinees. Do certain topics provide input that is easier or harder for an examinee in terms of language competencies? The research question for this paper is specifically:

Do differences in the fifteen chemistry TEACH topics affect test scores?

Bachman invites us to research further the facets that compose his framework of test method facets (Bachman 1990). As of yet the effect of topic on language performance testing has not been thoroughly studied. As test developers are delving further into the areas of context and topic, as can be seen in the current revising of the Test of Spoken English (TSE), a better understanding of topic is urgently needed. This investigation aims to provide evidence of the effect of topic variation in performance testing which will be useful to language performance test developers.

2. LITERATURE REVIEW

The ITA problem has been documented in a number of sources (e.g., Smith et al. 1992). The awareness of the ITA problem has prompted many universities to institute ITA assessment. Performance testing has been widely used for ITA assessment. However, performance testing, like any other testing, has its limitations, and criteria to evaluate performance testing need to be carefully considered. Bachman (1990) offers his theories of communicative competence and test method facets as guides in language testing research. This includes the topic material or the nature of the language of the input. Language researchers have studied the effect of topic variation in performance testing while chemistry educators have studied the effect of topic presentation on communication of chemistry knowledge.

The ITA Problem

The communication problem between ITAs and their students has concerned many people and universities including ISU. For a long time the "ITA problem" was blamed on the ITA's accent and flawed English ability. Other factors contributing to the ITA's problem are a non-standard variety of English, and the ITA's unfamiliarity with American classroom register, teaching strategies, and classroom management (Kaplan 1989). Undergraduates have also been cited for contributing to the ITA problem (vom Saal 1987). Certain areas of the United States, particularly rural areas, do not have much contact with intercultural communication. This is true for many parts of Iowa and for many of the undergraduates at ISU.

The seriousness of the ITA problem is reflected in the suit brought against the University of Pittsburgh. An ITA was blamed for inadequately explaining safety procedures in a lab. One student spilled concentrated nitric acid on both legs of another student causing second degree burns. The injured student blamed the problem on the ITA's lack of English ability (Schmitz 1993). Although the case was settled out of court, universities have taken notice of their responsibility in the assessment and placement of ITAs.

Accurate assessment of ITAs is a challenge that test developers are still struggling with. Errors in assessment affect ITAs, departments, and undergraduates. Bailey (1985) identifies two possible errors in the assessment of ITAs. The first is not allowing a qualified ITA to teach. The second is allowing an unqualified ITA to teach. By not allowing a qualified ITA to teach the ITA suffers financial loss often without the opportunity to obtain work off campus. Prohibiting a qualified ITA from teaching could also affect the ITA's graduate education, for without an assistantship, the cost of graduate school may be insurmountable. Not allowing a qualified ITA to teach also affects the department's instructional agenda by removing a possible staff person. By allowing an unqualified ITA to teach the quality of undergraduate education suffers as well as the reputation of the department. In addition to these potential consequences stemming from inadequate assessment, cited by Bailey, it can be a demoralizing experience for an ITA to teach a class before the ITA is adequately prepared. Departments, on the other hand, often suffer financially as they pay for ITA training before their prospective ITAs are allowed to teach. It can be seen that ITA assessment is serious business from a number of perspectives including those of the ITAs, their departments, undergraduates and the administration.

Performance Testing for ITAs

Because ITA assessment has important consequences for ITAs, departments and undergraduates, test developers have used a number of types of measurement instruments in assessing ITAs. The three major types of ITA assessment discussed in the literature (Plakans and Abraham 1990) include tests of general language ability, like the Test of Spoken English (TSE) and the Speaking Proficiency English Assessment Kit (SPEAK), oral interview tests, like the Interagency Language Roundtable/American Council on the Teaching of Foreign Languages (ILR/ACTFL) Oral Proficiency Interview, and performance tests, like the Taped Evaluation of Assistants' Classroom Handling (TEACH). Because this investigation focuses on the chemistry version of the TEACH test, performance testing will be defined along with a discussion of their advantages and disadvantages.

Performance tests for language testing have been described by Wesche (1985) as tests where

> *language knowledge must be demonstrated in the context of tasks and situations which represent or simulate those for which the examinees are preparing to use their second language.*

Performance tests go beyond assessing general language competence to evaluate the performance of examinees in a particular context and endeavor to replicate the tasks and settings of that context.

Teaching simulation tests are performance tests where the task and setting are teaching oriented, whether it be classroom teaching, tutoring in a helproom, conferencing during office hours, or leading a lab. Barrett has outlined four advantages and five disadvantages of teaching simulation testing. Teaching simulations offer high face validity, opportunity for examinees to demonstrate question handling and compensation techniques, and the use of raters from the ITA's specific department. Some of the disadvantages are asking an examinee to teach if he has never taught before, rater training, video equipment, misuse of test results and errors due to nerves, fatigue, or health (Barrett 1987) . Yet some of these disadvantages are disadvantages for other test forms as well, such as rater training, misuse of results, and errors due to nerves, fatigue, or health.

The TEACH test offers additional advantages and disadvantages to the ones outlined above for teaching simulation tests in general. The TEACH test endeavors to identify and rate culture and communication problems. The examinees feel more comfortable talking about topics from their field rather than general topics and to have twenty-four hours to prepare. Live ratings allow raters a better opportunity to evaluate teacher presence and compensation strategies. Live ratings provide for rapid reporting of results, while the videotaped performances allow for reviewing decisions and further diagnosis (Plakans and Abraham 1990).

Disadvantages of the TEACH test relate to time, money, questioning, and the raters. The TEACH test is time consuming and expensive. It is often difficult to schedule all the necessary examinees, raters, questioners, rooms, and video equipment. Because of the brevity of the test, it may be hard to rate particular features such as overall organization and use of examples. Plakans and Abraham (1990) warn that questioners might "contaminate" the output if they "confuse, intimidate, or interrupt the examinee." The time is also short for raters to rate four categories (overall language comprehensibility, cultural ability, communication skills, and interaction with students) with a total of fourteen subcategories (Appendix B). Raters without field specific knowledge may find it difficult to judge the clarity of explanations. It is also possible for raters to tire after a few hours of rating. Additionally, a lecture format may not authenticate the teaching required of ITAs in lab settings (Plakans and Abraham 1990).

Many universities utilize a battery of tests to assess ITA performance. ISU administers both the SPEAK and the TEACH tests to prospective ITAs. Since no single test has been shown to be completely reliable for ITA assessment, utilizing a battery of tests provides a broader basis for making decisions about the language competency of prospective ITAs.

Language Testing

Performance tests are complex and require complex throries to evaluate and interpret them. When a performance test is administered, the communicative competence of the examinee and the facets of the test itself are brought together. Bachman's (1990) theoretical framework for communicative competence attempts to describe the abilities people use in order to communicate. Bachman's (1990) theoretical framework of test method facets attempts to describe the components of a test. These two theories are described briefly in this chapter and are used as a means of evaluating the effect of topic material on chemistry TEACH test scores in Chapter 4. Theoretical frameworks like Bachman's communicative competence and test method facets are valuable tools in evaluating performance testing because they endeavor to predict and explain the effects of topic variation in performance testing. Teaching simulation tests offer face validity to the degree that they reflect particular settings and tasks; yet without identifying communicative competencies and test method facets, test scores will be open to misinterpretation.

Communicative competence is composed of language competence, strategic competence and psychophysiological mechanisms (Bachman 1990). Psychophysiological mechanisms describe physical aspects of actualizing competencies. Strategic competence relates a person's knowledge structure with their language competence. Language competence consists of fourteen components that are organized in a "hierarchical relationship." Vocabulary, morphology, syntax, and phonology/graphology are all grouped under grammatical competence. Cohesion and rhetorical organization are grouped under textual competence. The components of grammatical competence and textual competence are grouped under organizational competence. Ideational functions, manipulative functions, heuristic functions, and imaginary functions are grouped under illocutionary competence. Sensitivity to dialect or variety, sensitivity to register, sensitivity to naturalness, and cultural references and figures of speech are grouped under sociolinguistic competence. The components of illocutionary competence and sociolinguistic competence are grouped under pragmatic competence. Organizational competence and pragmatic competence compose the two main branches of this theory of language competence.

The theory of communicative competence is only the first part of Bachman's theory of factors that affect performance on language tests. The second part is his theory of test method facets. Bachman's (1990) framework for test method facets is composed of five parts. The first part is the testing environment which includes familiarity with place and equipment, personnel, time of testing, and physical conditions. The second part is test rubric which includes test organization, time allocation, and instructions. The third part is test input which includes format and the nature of the language. The fourth part is expected response which includes format, the nature of the language, and restrictions on response. The fifth part is the relationship between input and response which could be reciprocal, nonreciprocal, or adaptive.

Topic fits into the framework of test method facets as an element of the nature of the language of input and expected response. Bachman (1990) defines topic as, "...the subject matter of the discourse." Bachman expands upon this general definition of topic by discussing the test writer's goal of choosing topics that are relevant and neutral. Topics are supposed to be relevant so as to engage the examinee while being neutral so as not to give unfair advantage or disadvantage to examinees with particular background knowledge. The chemistry TEACH test provides relevant topics in the sense that they represent typical topics an ITA might have to teach an undergraduate class. The chemistry TEACH topics can be considered neutral since all the topics cover basic chemistry and should be well known by all chemistry graduate students.

Bachman (1990) states the purpose of his two theories, communicative competence and test method facets,

> *...as a means for describing performance on language tests, and I would reiterate that they are intended as a guide for both the development and use of language tests and for research in language testing.*

This investigation does exactly that by drawing upon Bachman's theories of communicative competence and test method facets in analyzing chemistry TEACH topics. When topic material is referred to in this investigation, it refers to what Bachman calls the nature of the language of the input which includes topic among other things. An analysis applying Bachman's framework to two of the chemistry TEACH topics can be found in Chapter 4 under Topic Analysis.

Topic of Input

The test method facet of topic is one of the many test method facets that the communicative competence of an examinee of a language test must deal with. A number of language testing researchers have sought to understand how topic interacts with performance. Yet, writing tests and oral language proficiency tests have not provided much evidence as to how topic variation affects performance. Other work in language research has investigated the relationship of topic with background knowledge of illocuters. Topic has also been of interest to chemistry educators as they have sought to better communicate chemistry knowledge to students. Topic features such as examples, definitions, problem solving, practical applications and the degree of abstractness of concepts have been considered. This analysis of chemistry TEACH topics provides an opportunity to combine what has been learned about topic by language researchers with what has been learned about topic by chemistry professionals.

Topics of prompts used in the writing portion of the Michigan English Language Assessment Battery (MELAB) were analyzed by Spaan (1993). The two types of input prompts used were labeled NP and AI. NP prompts were described as "rhetorically narrative, personal content topics." An example of this type of prompt is, "What is your favorite time of day? Why?" AI prompts were described as "rhetorically argumentative, impersonal content topic." An example of this type of prompt is, "What is your opinion of mercenary soldiers (those who are hired to fight for a country other than their own)? Discuss." Although Spaan identified these two prompts as having different cognitive demands, the different topics did not predict the holistic scores from her sample.

Another second language test that has been studied regarding the effects of topic is the SPEAK test. The original SPEAK test is a test of general oral language ability which researchers have used to investigate the effect of altering the facet of topic of input by producing a number of field specific tests such as CHEMSPEAK, MATHSPEAK AND PHYSICSSPEAK. None of these SPEAK offshoots has shown consistently that ITAs will perform better on an oral proficiency test with field specific topics, rather than on an oral proficiency test with general topics. Douglas and Selinker's (1992) research involving thirty-one chemistry ITAs, however, indicated that the CHEMSPEAK was more difficult than the SPEAK. Yet, the CHEMSPEAK comprehensibility score did have a higher correlation with the recommendations for teaching assignment of the TEACH raters than did the SPEAK comprehensibility score. Additionally, rater comments on the CHEM-SPEAK which referred to topic, rather than language raised concerns about the effect of raters without field specific knowledge. Their research suggested that topic may influence examinee output as well as the rater's assessments.

Smith's (1992) research with chemistry, math, and physics versions of the SPEAK test did not show consistent differences between field specific and general oral proficiency scores. Additionally, Smith reports on the possible negative effects on the accuracy of examinee performance with "emotionally invested" topics. "Emotionally invested" topics are those topics that raise intense feelings in an individual. Because the chemistry TEACH test relates to the careers of the examinees, Smith suggests that their emotional involvement in the subject or desire to be accurate with their topic material might produce a less accurate language performance than they might otherwise with a general topic. On the other hand, perhaps the "emotionally invested" topics would produce a more accurate language performance. It cannot be said for sure either way from her study.

Research into the effects of shared background of illocuters also relates to topic. Examinees of the chemistry TEACH test bring a wealth of chemistry knowledge to the topic of input they receive. However, raters do not necessarily share this technical background. Raters of the TEACH test at ISU have been, in general, ESL and language professionals. Departments have not been required to provide raters for the testing. Although some of the raters have technical backgrounds and experience studying chemistry, most do not. Therefore, when an examinee needs to or chooses to assume a certain chemistry knowledge from his audience, this may affect the level of communication. Assumptions that are not shared can be the cause of communication breakdowns (Crookes 1986). Certain chemistry topics may require more assumptions of shared chemistry knowledge than other topics of the TEACH test. Because the topic material comes from a variety of chapters of actual chemistry textbooks, topics from earlier chapters may rely on less shared background knowledge than topics taken from later chapters. A breakdown in communication may affect a rater's score of language ability when the breakdown may be due in part to the lack of shared assumptions.

Language testing researchers are not the only professionals concerned with topic effect on performance. Chemistry professionals have been looking at the effect of topic presentation over the last decade. Chemistry textbooks have been scrutinized with the idea that specific examples are useful in developing generalizations and that new definitions should be introduced slowly (Herron 1983). Others have discussed how much integration should occur between concepts, problem solving, and practical application (Pearson 1988). Practical applications for chemistry topics have been thought to be critical in the transfer of chemistry knowledge to students. For example, Western Kentucky University developed a series of one-page papers for its freshman chemistry classes. The papers show how a chemistry concept from the textbook applies to a current issue in the news (Pearson 1988).

In addition to the features of chemistry topics dealing with definitions and practical applications, problem solving has been investigated. Problem solving is an important part of many chemistry topics. Chemistry educators have differentiated topics based on the degree of complexity of physical properties, the level of abstractness, and the level of mathematical difficulty (Genyea 1983). Herron (1975) studied Piaget's framework for intellectual development and applied it to the way students understand chemistry topics and how chemistry topics should be taught. Herron (1984) developed the framework for the level of abstractness of chemistry concepts by utilizing a continuum stretching from surface level knowledge to deep level knowledge. Surface level knowledge deals with knowledge understood from environmental stimuli. The continuum progresses to direct sensory perception, inferences based on observation, inferences based on inferences, theoretical frameworks, values and beliefs. Deep level knowledge is at the top of the continuum and is defined as higher level abstractions. Herron believed that many students did not have experience with deep level thinking and, therefore had problems understanding chemistry, since much of chemistry involves abstract concepts. The chemistry TEACH topics include a wide variety of chemistry concepts and these may vary on the surface level/deep level continuum. Examinees language performance may vary when the topic of input has varying degrees of abstractness. Raters may also be affected when rating topics with varying degrees of abstractness.

This investigation takes a fine-tuned look at topic variation in comparison to those studies involving SPEAK and its offshoots that took a broad perspective of topic by comparing general topics to field specific topics. Topic features identified by chemistry professionals, such as the level of abstractness of concepts and problem solving, can be used to compare field specific chemistry topics with each other.

Summary

ITAs are an established part of higher education in the United States with their numbers growing all the time. Placing ITAs as teachers in undergraduate classrooms has created communication problems and concern for those involved in undergraduate education. Performance testing for ITAs aims at reducing the "ITA problem." The "ITA problem" then becomes the "ITA assessment problem." Performance tests have been widely used in ITA assessment because performance testing endeavors to reflect the tasks and settings of the placement the examinee is preparing for. Performance tests, including the TEACH test, have their advantages and disadvantages. Bachman's (1990) theories of communicative competence and test method facets have been proposed as a means of evaluating performance on language tests. Of the many test method facets in Bachman's framework, this investigation is focused on the facet of topic. Although writing tests and oral language tests have not shown consistent variation in performance with variation in topic, chemistry educators have identified particular features of topics and methods of presentation they believe to be important in effectively communicating various topics. This investigation of the chemistry TEACH test draws upon the theories of Bachman (1990) and the work of language researchers and chemistry educators to evaluate the effect of topic variation on test scores.

3. METHOD

This chapter provides information on the ITA subjects, the five materials or data sources, the procedures used for collecting data, and the method of data analysis. A unique aspect of this investigation is the number of materials available to help analyze topic variation and its effect on performance. In addition to test scores and a review of topic material, examinee and rater perceptions of topic were collected. These multiple data sources aided in the analysis of topic material and the identification of topic features that may influence performance. The use of chemistry professionals as assessors of topic features provided a means of validating the author's identification of topic features. Test scores subjected to a multiple regression analysis were used to quantify the effect of topic variation.

The Subjects

The subjects involved in this project are 102 international graduate students in the chemistry department at Iowa State University from 1989 to 1994. These students have all taken the TEACH test. Many of the examinees did not pass the first time and ended up taking the TEACH test a number of times. In order to control for the effect of familiarity with the test, only the scores from first time test takers were used.

Of the 102 subjects, 75% are native speakers of Chinese. Sixty-eight of the subjects came from the People's Republic of China, six came from Taiwan, and three came from Hong Kong. The twenty-five non-Chinese speakers came from a variety of countries with a variety of native languages including Arabic, Czech, Indonesian, Konaki, Korean, Nepali, Romanian, Serbo-Croatian, Sinhalese, Spanish, Tamil, Thai, Vietnamese, and Zulu. The students generally express unhappiness about taking the TEACH and SPEAK exams, but were cooperative in releasing data for research purposes.

Materials

The SPEAK Test

The SPEAK test (Speaking Proficiency English Assessment Kit) is a retired form of the Test of Spoken English (TSE). SPEAK is used at ISU and many other universities to test the oral language abilities of ITAs. A thorough description of the SPEAK test can be found in Plakans and Abraham (1990). Although the term SPEAK test is used here, ISU actually uses a modified version of the SPEAK test. The SPEAK test at ISU is a live interview between an ITA and two raters that lasts approximately twenty minutes. The test begins with a few minutes of small talk that is not rated. The examinee is asked to read a paragraph out loud, tell a story from a series of pictures, answer questions about a picture, answer description and opinion questions, and role-play a TA giving a class announcement. Raters judge the language produced according to pronunciation, fluency and comprehensibility, although only comprehensibility scores are used to calculate the final SPEAK score. The rating scale extends from O to 300, with O indicating no control over language and 300 indicating intelligibility close to that of a native speaker. The final score is an average of the two raters' scores. When raters' scores have a spread that is greater than thirty points, or if only one rater passes the examinee with a score of 220 or higher, then a third rating is done using the audio tape of the interview.

In this study the SPEAK test scores are used as a measure of general oral English ability. In order to compare TEACH scores by topic while taking into account the general oral English ability of the examinee, the TEACH scores were adjusted for the variation in SPEAK scores.

The TEACH Test

The TEACH test is a performance test requiring examinees to speak about field specific topics within a classroom teaching context. It is designed to provide evidence of oral English proficiency of ITAs as well as diagnostic information on communication problems. The topics are field specific and the context is classroom teaching. A thorough description of the TEACH test can be found in Plakans and Abraham (1990). Iowa State University uses the TEACH test scores in conjunction with the scores from the modified SPEAK test to evaluate ITAs for teaching assignments.

Topic material in this study refers to what Bachman (1990) calls the form of the input or the nature of the language of the input. The nature of the language includes the length, the propositional content (i.e. vocabulary, degree of contextualization, distribution of new information, type of information, topic, and genre), organizational characteristics, and pragmatic characteristics. The topic material for the chemistry TEACH test was chosen by the Chemistry Department at the SPEAK/TEACH administrator's request. Instructions for choosing TEACH topics were as follows:

> Please select ten topics from the above textbook and write a short description and the page numbers for each. These topics should be of average difficulty (neither too easy nor too difficult for a fair and reliable test) and more or less of equivalent difficulty. Each should be brief, since the assigned mini-lectures will be only five minutes long. *In addition, please do not select topics from the first chapter of the textbook.* The evaluation procedure for the mini-lectures assumes examinees will be giving an "ordinary" lesson during the semester...a simulation more easily achieved if topics are not drawn from the first chapter. Topics should also require some use of a blackboard.

As the above instructions indicate, the test developers wanted to choose topic material that was fair and reliable. Because the SPEAK/TEACH administrators were developing so many versions of the TEACH test, each with a number of different topics, if was impractical to verify equivalency of topics. Now there are test data which have been produced using these various topics that can aid in the analysis of topic material. This study picks up where the test developers were forced to leave off by using test score data and other sources of data to analyze the topic material.

Twenty-four hours before the test, examinees come to the SPEAK/TEACH office to pick up topic material. There are fifteen topics used in the chemistry TEACH test. In practice, all of the topics are assumed to be equivalent. The topic material was provided to the SPEAK/TEACH office by the Chemistry Department. Topic material consists of two to seven photocopied pages from two chemistry textbooks that have been used for beginning courses in chemistry at Iowa State, namely Chemistry by Gillespie and Chemistry by Chang. The fifteen topics are listed in Table 1.

Table 1 Chemistry TEACH Test Topics

Topic No.	Topic Name	Page No.*
1	Molar Concentrations	70-73
2	Molar Volume of Gas: Avogadro's Law	105-108
3	Balancing Oxidation-Reduction Equations	329-334
4	Equilibrium Constant	502-506
5	Calculation of Equilibrium Concentrations	508-510
6	Equilibria in Aqueous Solutions of Acids and Bases	516-522
7	Acid-Base Properties of Anions, Cations, and Salts	529-533
8	Mole Method (Stoichiometry)	65-69
9	Concentration of Solutions (Solution Stoichiometry)	71-73
10	Ionic Bonds	181-183
11	Enthalpy	238-242
12	Bond Energies	247-251
13	Heat of Solution	301-304
14	Molar Mass Determination	324-325
15	Balancing Redox Reactions	338-344

* Topics 1-7 are found in Chemistry by Gillespie and topics 8-15 are found in Chemistry by Chang.

The exam itself consists of three parts. During the first minute or two the examinee is allowed to write a few notes on the chalkboard. Then the examinee is allotted five minutes to explain his assigned topic as if he were teaching an undergraduate class. At the end of five minutes a timer sounds and the mock class of students ask questions about what was presented and at least one question about classroom or course procedures like, "Do you give pop quizzes?"

Among the mock class are at least two trained raters that score the test. The examinee's language is rated for pronunciation, grammar, and fluency with an overall rating of comprehensibility used in the final scoring. Other communicative abilities are also rated, such as use of chalkboard and non-verbal behavior, but these are used for diagnostic and placement purposes. The overall language comprehensibility scores of the two raters are averaged to determine the examinee's language score. If a gap of more than thirty points exists between the two raters, or if only one rater passes the examinee with a score of 220 or higher, then the videotaped test is given to a third rater for final scoring. Scores range from zero, no English language proficiency, to three, fluent and always comprehensible. Because the TEACH tests are videotaped, the tapes are available for use in studying the subjects' language output. Examinee instructions for the TEACH test are shown in Appendix A and the rating criteria for the TEACH test are found in Appendix B.

Test results are divided into four categories, namely *certified*, *conditional*, *partial*, and *not certified*. Although TEACH is scored from zero to three, these scores will be multiplied by one hundred for ease of discussion in comparison to the SPEAK test. An examinee is *certified* for a teaching assistantship if he scores 220 or above on both the SPEAK and TEACH tests. An examinee is given a *conditional pass* if he scores 220 or above on either the SPEAK or the TEACH, but not on both of the tests. A *conditional pass* means that the examinee is allowed to teach a discussion or recitation section while taking an ITA training course. No further testing is required of a *conditional pass*. An examinee is given a *partial pass* when both the SPEAK and the TEACH scores are between 180 and 210. The examinee with a *partial pass* must take an ITA training course, but may hold a lab assistantship, tutor in help rooms, grade homework, or do other tasks not requiring much stand-alone teaching. At the end of the training course he is required to retake the SPEAK and TEACH tests to see if he can become *certified* or *conditionally certified*. An examinee receives a *not certified* when both the SPEAK and TEACH tests are scored between 0 and 170. He can still be on appointment, but his duties will be limited to grading, setting up labs, or other tasks that require little speaking proficiency.

Topic Grouping Criteria

Determining criteria for the grouping of topics that might reflect existing variance in examinee performance is one of the key elements in this investigation. Operationally, the fifteen topics have been assumed to be equivalent, however, an initial review of the topic material indicates a number of differences. Topics one through seven come from the text Chemistry by Gillespie and topics eight through fifteen come from the text Chemistry by Chang. The number of pages of material varies between two and seven. The topic material includes example problems which are given an example number and provide a step by step solution to the problem. The number of example problems included among the fifteen topics varies between zero and six. Since topic material comes from different sections of the book, material from the latter half of the book may require more chemistry knowledge than material from the earlier chapters.

Are certain topics of the chemistry TEACH test easier or harder for examinees to talk about and teach? If topics do have different degrees of difficulty, do features of a topic contribute significantly to test outcome? In order to investigate how topic of input affects chemistry TEACH scores, the author reviewed the topic material and identified three features that may contribute to differences in performance. The topic features identified are **concepts, math,** and **calculations. Concepts** is a feature that reflects how cognitively demanding a topic is for a general audience to understand. **Math** is a feature that reflects the level of mathematics required for problem solving. **Calculations** is a feature that reflects the number of steps involved in problem solving.

For example, topic one, Molar Concentrations, deals with concentrations of solutions. This concept could be considered not cognitively demanding because most people are familiar with concentrations or can visualize a solution having more or less of a particular component. The math involved in solving example problems for this topic could also be considered simple multiplication and division. The calculations for the example problems given in this topic can also be considered simple because they can be performed in one step. For example, converting grams to moles by multiplying by the molecular weight and multiplying this by the mole ratio is the extent of the calculations. Topic twelve, Bond Energies, has a concept that could be considered more cognitively demanding because it is not familiar to most people and it is hard to visualize the internal energy of molecules that cannot be seen. Topic twelve also contains math that could be considered difficult like quadratic equations and logs. The calculations for topic twelve can also be considered more involved because they require more than three steps, including writing a balanced reaction, writing the expression for the equilibrium constant, writing expressions for the concentration of each species in solution, substituting concentrations into the formula for the equilibrium constant, and calculating pH with logs.

The topic features of concepts, math, and calculations were chosen for a number of reasons. First of all, they are present in what seems to be a variety of levels across the topics. Secondly, research in chemistry education has studied the features of concepts and calculations as to how they affect learning. Thirdly, some examinees and raters perceive the level of abstractness of topic concepts as affecting test performance.

The author of this study divided these topic features into three levels in order to create three groups of topics. Table 2 lists the differences in features between groups one, two, and three. Group one includes concrete concepts, simple math, and simple calculations. Therefore, if topic does affect TEACH scores, group one would be hypothesized to give mean TEACH scores that are higher than the other two groups. Group two includes somewhat unfamiliar and abstract concepts, simple to moderate difficulty of math, and calculations of two or three steps. If topic does affect TEACH scores, it would be hypothesized that the mean TEACH scores for group two will be lower than group one, but higher than group three. Group three includes unfamiliar and abstract concepts, difficult math, and calculations of three or more steps. If topic does affect TEACH scores, group three would be hypothesized as containing features most difficult for the test takers, thereby expecting to have the lowest mean TEACH scores.

Examinee Interview Questions

Examinee perceptions of TEACH test topics provide qualitative data for investigating what features of topic influence examinee performance. Twelve questions were composed by the author to be used in understanding the examinees' perceptions of chemistry TEACH topics (Appendix D). These questions were designed to elicit information about how the examinee interacts with the assigned topic. Ability to understand the topic, use of other sources, preparation time, and topic preference were areas to be probed in the examinee interviews.

Table 2 Topic Grouping Criteria

Group	Feature	Feature Characteristics
1	Concepts:	Familiar, clearly presented Not cognitively demanding to understand Convenient break points Adequate background information complemented with problem solving
	Math:	Simple - multiplication, ratios, fractions
	Calculations:	Simple Multiple step solution could possibly be condensed into one step
2	Concepts:	Unfamiliar to a general audience Somewhat cognitively demanding to understand May lack adequate background information before beginning problem solving
	Math:	Simple - multiplication, fractions, ratios or Moderate difficulty - like solving for an unknown quantity
	Calculations:	Multiple steps cannot be condensed into one step
3	Concepts:	Unfamiliar to a general audience Presentation of material complex Cognitively demanding to understand Numerous features to discuss Too much material to cover without convenient break points
	Math:	Simple - multiplication, fractions, ratios or Moderate difficulty - like solving for an unknown quantity or Difficult - quadratic equations
	Calculations:	Three or more steps required to solve problems

Rater Survey

Rater perceptions of TEACH test topics provide qualitative data for investigating what features of topic influence performance ratings. The pool of raters used to rate the TEACH and SPEAK tests at Iowa State consists of ESL teachers and graduate students or other language teachers who have been trained at Iowa State to rate these tests. Raters have different backgrounds, some with technical backgrounds, others without. Each year the raters are given refresher training.

Surveys were developed to determine rater perceptions of chemistry TEACH topics. The raters were asked to rate the degree of difficulty in rating the various topics in terms of easy to rate, average to rate, and hard to rate. A copy of the survey can be found in Appendix C.

Procedures

The SPEAK and TEACH Tests

The TEACH and SPEAK tests are administered at Iowa State four times each year. Test records are kept on file on campus. Examinees generally sign a release form which allows their test information to be used for research purposes. The Human Subjects Review Committee granted approval for the participation of ISU students in this research project.

The SPEAK/TEACH office at ISU maintains written records of all examinees. Audio tapes of SPEAK tests and videotapes of TEACH tests are kept on file for approximately four years. A record of past testing schedules, including what topic was tested, are also kept on file. These records were used to compile a list of first time chemistry TEACH test takers along with their SPEAK scores, TEACH scores and chemistry TEACH topic. These are shown in Appendix F.

Fifteen videotapes of examinees taking the chemistry TEACH test were observed. Ten of the fifteen chemistry TEACH topics were included in the sample of fifteen videotapes. The tapes were viewed in order to determine if variations in the examinees' responses related to variations in the test input. Transcriptions were not done on the tapes, but general observations were noted, such as the use of descriptive language in conjunction with the chalkboard. Observations from the taped performances are discussed in Chapter 4.

Topic Assessment

The topic material provided to examinees as test input is a primary focus in this investigation. The author's judgments were used in identifying topic features that affect examinee performance. The topic features that were chosen were then divided to create three groups (Table 2). Finally, each topic was analyzed and placed into one of the three groups based on the topic grouping criteria. However, there was a need to establish reliability of the author's topic groupings. Therefore, three independent assessors were asked to place each of the fifteen chemistry TEACH topics into one of the three groupings based on the group criteria from Table 2. Each of the three assessors have advanced degrees in chemistry. One has a Ph.D. in chemistry, another has a master's in chemistry, and the third is finishing his Ph.D. in chemistry education. The assessors were familiarized with the purpose and format of the TEACH test and then asked to study the topic grouping criteria (Appendix E). Next, the assessors were given three sample topics to practice applying the criteria. These sample topics came from the same textbooks as the fifteen chemistry TEACH topics. The assessors were able to compare their grouping judgments with those of the author. Then each assessor individually grouped each of the fifteen topics. These assessments are summarized in Table 3. The assessors' groupings were averaged across topic and rounded to the nearest whole number to determine the final grouping to be used for analysis.

Examinee Interviews and Rater Survey

Seven interviews were conducted individually with examinees within twenty-four hours of the chemistry TEACH tests in December 1993. All of these examinees had taken the chemistry TEACH test for at least the second time. This meant they were familiar with at least two of the fifteen chemistry TEACH topics. Often they were familiar with more topics because of practicing and preparing with classmates who were also taking the test. The questions were asked orally and the interviews were tape recorded. A copy of the interview questions can be found in Appendix D.

Table 3 Topic Groupings by Assessors

Topic Number	Topic Name	Groupings by Assessors[a] 1	2	3	4	Final Grouping[b]
1	Molar Concentrations	1	1	1	1	1
2	Molar Volume of Gas	2	2	2	3	2
3	Balancing Oxidation-Reduction Equations	3	2	3	3	3
4	Equilibrium Constant	3	2	3	1	3
5	Calculation of Equilibrium Concentrations	2	2	3	2	2
6	Equilibria in Aqueous Solutions of Acids and Bases	3	3	3	3	3
7	Acid-Base Properties of Anions, Cations, and Salts	3	3	3	3	3
8	Mole Method	1	2	2	1	2
9	Concentration of Solutions	1	1	1	1	1
10	Ionic Bonds	3	2	1	3	2
11	Enthalpy	2	3	2	2	2
12	Bond Energies	2	2	2	2	2
13	Heat of Solution	1	2	2	2	2
14	Molar Mass Determination	3	2	1	2	2
15	Balancing Redox Reactions	2	2	3	3	2

[a] Assessors 1, 2, and 3 are chemistry professionals. Assessor 4 is the author.

[b] This final grouping was determined based on the rounding of the average of the assessment of the three chemistry professionals. This grouping was used in the regression analysis of chemistry TEACH scores.

During the December 1993 SPEAK/TEACH testing at ISU, nineteen surveys (Appendix C) were distributed to raters. Twelve raters responded with ratings for the topics and/or with written comments about their perceptions of the degree of difficulty in rating chemistry TEACH topics.

Data Analysis

The key component of this investigation into the effect of topic variation in performance testing is the analysis of topic material. Three sources were used to analyze the chemistry TEACH topics, namely the literature review, examinee interviews, and rater surveys. The literature review provided insights into what chemistry educators have identified as important aspects in communicating chemistry knowledge. The examinees provided insight into their perceptions of what makes a topic easy or difficult to talk about and teach. The raters provided insight into shared background. These three sources helped the author to choose three key features of the topics that may influence examinee performance. The three features identified are concepts, math, and calculations. These three features were then used to determine three groupings for topics. The grouping criteria was given to chemistry professionals who placed each topic into a group. Reliability estimates were performed on the assessors' groupings to assess the degree of agreement among raters. Final topic groupings were based on an average of these assessors' grouping of topics. A MANOVA analysis was run on the TEACH scores while using the SPEAK scores to control for the general language ability of the examinees. A multiple regression analysis was computed on the topic groupings to determine which groups were significantly different from each other. These statistics reveal a relationship between topic of input and the TEACH test score. Figure 1 shows a summary of the research procedures and data sources.

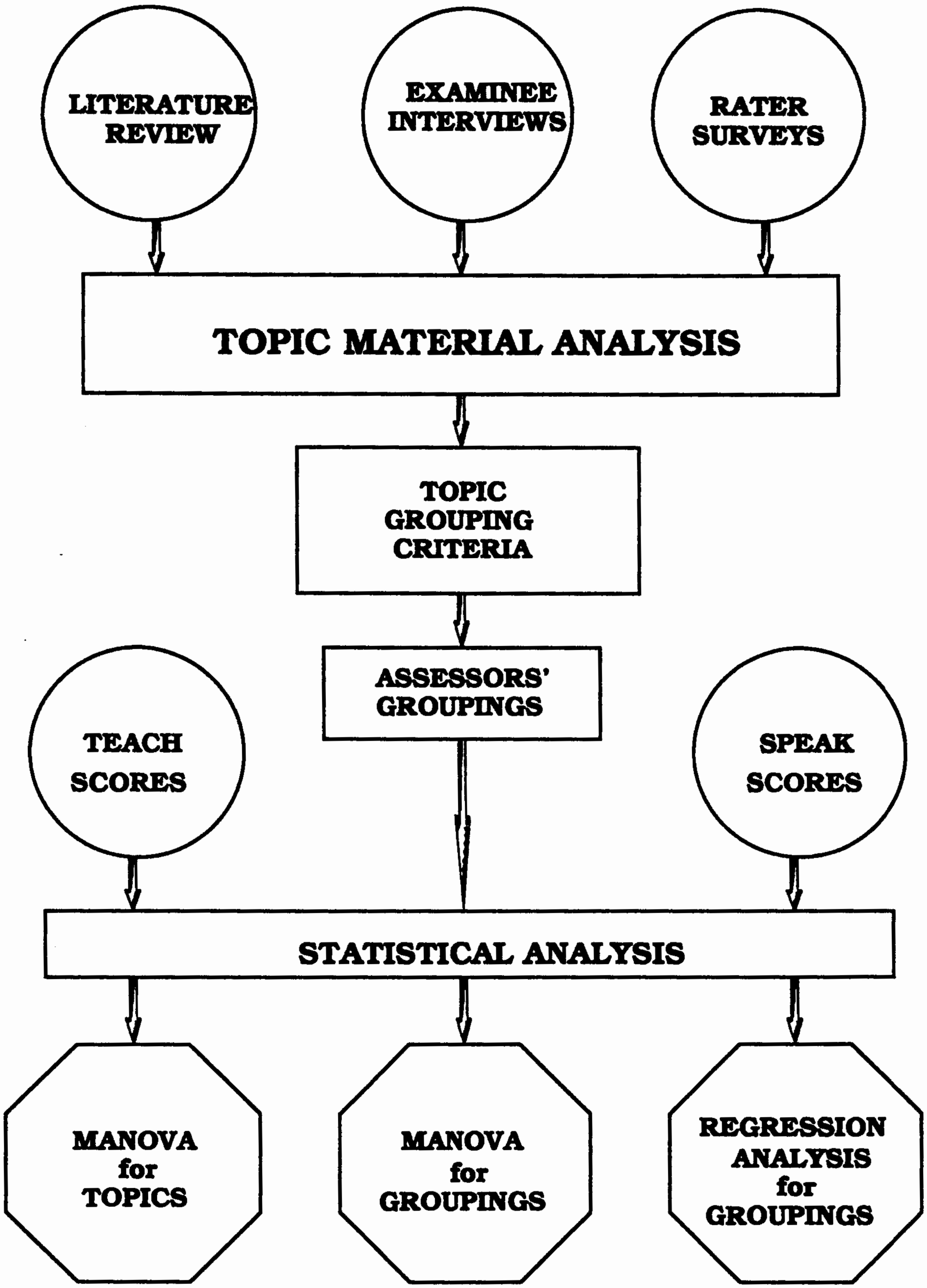

Figure 1. Summary of Research Procedures and Data Sources

4. RESULTS AND DISCUSSION

The chemistry TEACH test topics are all appropriate in the sense that they cover general chemistry from a freshman class, yet the equivalency between individual topics has yet to be established. It is not enough to say that the fifteen topics are equally likely to appear in a freshman chemistry class. The concern for testing is whether the fifteen topics call for the same language competencies and therefore produce results that should be considered equivalent from one topic to the next. The data analysis from examinee perceptions, rater perceptions, topic assessment and TEACH score statistics all indicate that topics are different.

Examinee Perceptions

One way to gain insight into how a test topic and an examinee interact is to interview the examinee. All seven examinees that were interviewed felt the topics that they had were basic, general chemistry topics which all graduate students in chemistry would understand. However, the perceptions of some examinees interviewed as part of this investigation indicate that the level of abstractness of a test concept or the focus on calculations or the inclusion of practical applications may influence the examinee's test performance.

Do abstract topics, or topics with difficult math or involved calculations cause examinees to prepare longer than for simpler topics? Preparation time for the seven examinees varied from less than a half hour to more than six hours. This range in preparation time may be one consequence of variation in topics; however, the data from this study is insufficient to answer this question. Nevertheless, it is interesting to consider the possibility of preparation time as compensating for variances in topic.

One examinee had definite opinions about various topics, from his experience of having taken the chemistry TEACH test twice and having seen the test topics assigned to his classmates. When queried about the differences in topics, this examinee explained,

Entropy [enthalpy] ...I think that concept is more difficult than this one [topic 4, Equilibrium Constant]...for it is a more dynamic concept...I can't give a-a better way to explain that concept - it will take a long time to *understanding that concept...it is more abstract - so I think that's - that's a difficult one...the Equilibrium Constant is easier to understand for the student.*

This examinee made a distinction between abstract theory, a general concept, and a problem to solve. He felt Enthalpy (topic 11) was a difficult topic to teach and talk about because he labeled it as an abstract theory. He felt that Equilibrium Constant (topic 4) was a more concrete concept and therefore easier to teach. He felt a calculation like Calculation of Equilibrium Concentrations (topic 5) would be easiest to teach. This examinee's perceptions align favorably with Bachman's theory of type of information of the input. Bachman (1990) writes, "We might hypothesize that input consisting of abstract information will be more demanding of the test taker than will input containing largely concrete information." The preference for teaching how to solve calculations over teaching concepts may be a preference of genre. The various types of genre found in the chemistry TEACH test topic material include concept discussion, problem solving, and historical development of theory. Some examinees expressed preferences for concrete topics, topics with practical applications, problem solving, or topics related to lab procedures. These all seem to be preferences in genre.

Practical applications of chemistry concepts is another way to make topics more concrete. One examinee felt that a topic without a practical application provided in the topic material was hard to introduce. The examinees are not required to stick to the topic material, but are required to keep the assigned topic. They are free to supplement their presentation with information from other sources. However, most examinees seem to stick closely to the topic material provided. Therefore, topic material that provides practical applications, such as Heat of Solution (topic 13) that discusses hot and cold packs, may provide advantages over topics that don't include practical applications.

All examinees interviewed felt a high level of stress regarding the test because their teaching appointment and level of salary depended on their scores. Many examinees thought the topics used were reasonable and that the random assignment of topics was fair. Yet the perceptions of other examinees indicate an inequivalency of topics based on the level of abstractness of the concepts or the focus on calculations or the practical application of the topic concept. These perceptions relate to the type of information (concrete/abstract) and the genre that are included in Bachman's nature of language of the input.

Rater Perceptions

Ideally the test administrators would like all the raters to perceive all fifteen topics as average to rate as compared with the other departmental versions of the TEACH test. In fact, some of the raters do feel this way since they focus on language, not content. However, a number of raters perceive that their own understanding of a specific TEACH topic affects the degree of difficulty in rating that topic. This relates to the concept of communication breakdowns caused by assumptions or background that are not shared. Raters may rate examinees' language skills lower if their understanding is inhibited by their own lack of background knowledge. On the other hand, a rater with background knowledge of chemistry may overlook some language problems if the rater understands the examinee in part based on the shared knowledge. If a topic is more difficult for a rater to comprehend, perhaps it is more difficult for the examinee to talk about and teach.

Of the twelve rater responses received, five of the raters evaluated all the topics as average to rate. A number of these who commented contended that their job as a rater is to focus on language, not content, so they do not feel that topic affects the TEACH test scoring. One rater rated all the topics as hard to rate. She commented that she was somewhat intimidated by rating a test involving the presentation of chemistry knowledge. This does not necessarily mean that she rated higher, or lower, or less consistently than the other raters. Perhaps she just has to concentrate more than when rating other versions of the TEACH test. The six remaining raters gave different degrees of difficulty for the rating of the various topics. These raters do sense some type of effect on topic in the rating process. No clear consensus materialized between the raters as to which topics are hard, average or easy to rate. What was considered to be a hard topic to rate by one rater was often considered average or easy to rate by another rater.

The background of raters may affect their ability to rate. A shared background with the examinees may increase the raters comprehensibility of a TEACH presentation. One rater commented, "I have taken two chemistry classes recently, so I don't find these as difficult to rate as I used to." This rater perceived knowledge in a content area as advantageous in rating. Another rater felt that her unfamiliarity with chemistry prevented her from checking the pronunciation of chemistry vocabulary.

The degree of contextualization that is part of the nature of language of the input in Bachman's test method facet framework deals with the idea of prior content schemata on the part of the examinee, but does not address the aspect of prior content schemata on the part of the raters. Although it is hoped that rater training will teach a rater how to appropriately score an exam given his shared or unshared background with regard to topic, this may be in reality hard to do as evidenced by the responses of some raters. Undergraduate students that an ITA will teach may have a variety of backgrounds, some sharing knowledge of chemistry, others without prior knowledge. So raters with diverse backgrounds may emulate a typical classroom setting, but raters are to do more than provide setting. They are to evaluate language performance. The prior content schemata a rater brings to the performance rating may affect the examinee's final score.

One problem with collecting information about rater perceptions of the degree of difficulty in rating topics is that the rater may not have seen or may not remember very well all the various chemistry topics. The raters see topics from many departments in an intense one or two days of rating four times per year. Due to the relatively small number of chemistry majors taking the test each semester, it may have been some time before the survey since a particular rater may have seen a particular topic used in the chemistry TEACH test.

Topic Analysis

The topic material used as input for the chemistry TEACH test covers a variety of chemistry concepts. The topic material consists of a packet of photocopied pages taken from various sections of two chemistry textbooks, Chemistry by Gillespie and Chemistry by Chang. Topic material for topic seven, Acid-Base Properties of Anions, Cations, and Salts, and for topic nine, Concentration of Solutions, are included in Appendix G. The topic material referred to in this investigation is what Bachman (1990) labels the nature of language of the input. A discussion of the nature of the language of the input for topic seven and topic nine is included here.

Topic 7, Acid-Base Properties of Anions, Cations and Salts

Topic seven, Acid-Base Properties of Anions, Cations, and Salts, was judged to be a group three topic by all three chemistry professionals and the author. The length of the topic material is three and a half pages. The propositional content can be analyzed by examining vocabulary, degree of contextualization, distribution of new information, topic and genre. The vocabulary is field specific for chemistry. It assumes a knowledge of vocabulary such as *acidic, neutral, basic, anions, cations,* and *salts.* It also assumes familiarity with symbols for elements and compounds. The topic material can be described as highly contextualized because of the information it prompts examinees to recall. The examinees are graduate students in chemistry and therefore have a strong content schemata to draw from. The distribution of information for topic seven can be considered compact because of the large amount of information presented in a small space. Two types of anions, two types of cations, and three types of salts are discussed. The type of information presented can be considered abstract, positive, and factual. It is abstract because acidic or basic properties are not something that can be determined through observation. Dissociation constants need to be calculated and compared to determine acidic or basic properties. The discussion of ions is abstract because ions are not visible to us. The material is presented positively and is factual according to current scientific theory. The topic is field specific to chemistry, namely Acid-Base Properties of Anions, Cations, and Salts. The genre is that of a science textbook with discussion and example problems.

Organizational characteristics can be analyzed by examining grammar, cohesion, and rhetorical organization. The grammar used in topic seven is typical of introductory science textbooks. Present tense is used to describe natural phenomena. The first person, plural pronoun *we* is used in the discussion. Cohesion is provided by numerous words such as t*hus, although,* and *because.*

Referential cohesion is present in references to tables and previous chapters. Rhetorical organization is marked in numerous ways. First, the section title is given in bold letters, **Acid-Base Properties of Anions, Cations, and Salts.** Three subsections, **Anions, Cations**, and **Salts,** are separated and given bold titles. Under each subsection various conditions are discussed, each condition marked by an italicized word, such as *metal ions* or *neutral salts*. Numerous examples are included throughout the discussion, usually marked by the expression, *for example*. If - then statements are also used such as, *"But if the base dissociation constant of the anion is larger than its acid dissociation constant, the anion is a base."* In the solution to the first example problem, the solution steps are labeled in italics *first step, second step*, and *third step*. Because of the compact nature of the text, the use of rhetorical organizers is very important to insure comprehensibility.

Pragmatic characteristics include illocutionary force and sociolinguistic characteristics. The illocutionary force or the language function of the topic material is basically ideational, but not in the sense that it is providing new information to the chemistry TEACH test examinee. These examinees are very familiar with the topic and the other topics used for the chemistry TEACH test. The topic material is ideational in the sense that it provides basic guidelines to the examinee about what he should present in his TEACH performance and how to explain it to an undergraduate student.

Sociolinguistic characteristics include dialect or variety, register, and naturalness. The variety of English used in the topic material is standard for introductory science textbooks. The register is formal written English and natural for American English science authors. Prospective ITAs will need to be able to read this type of material and explain it to undergraduate students. However, the variety of English in the input an ITA gets from an undergraduate student will be quite different from the variety of English in a textbook. Undergraduate students have a tendency to talk fast and use idioms. This type of informal spoken input is not present in the written topic material, but the question time of the TEACH test contains this type of input.

Topic 9, Concentration of Solutions

Topic nine, Concentration of Solutions, was judged to be a group one topic by all three chemistry professionals and the author. The length of the topic material is two and a half pages. The propositional content consists of vocabulary, degree of contextualization, distribution of new information, topic, and genre. The vocabulary is field specific for chemistry, but definitions are provided for numerous terms including *aqueous solution, solute, solvent, concentration, molarity, volumetric flask,* and *meniscus.* It contains terms which are not defined, such as *glucose, moles,* and *molar mass.* The topic material can be described as highly contextualized because of the information it prompts examinees to recall. The examinees are graduate students in chemistry and therefore have a strong content schemata to draw from. The distribution of information for topic nine is compact regarding definitions for new terms, but all of this focuses on the one basic concept of concentration of solutions. Since there is only one basic concept discussed over the two and a half pages, the topic material is neither compact or diffuse, but somewhere between. The type of information presented can be considered concrete, positive, and factual. It is concrete because most people are familiar with dissolving a solid in a liquid, and the weights and volumes of solids and liquids can be seen and measured. The material is presented positively and is factual according to current scientific theory. The topic is field specific to chemistry, namely Concentration of Solutions and the discussion of solution stoichiometry. The genre is that of a science textbook with discussion and example problems.

Organizational characteristics consist of grammar, cohesion, and rhetorical organization. The grammar used in topic nine is typical of introductory science textbooks. Present tense is used to describe the chemistry principles and terms. The pronouns *you* and *we* are used in the discussion. Cohesion is provided in terms like *thus* and *of course.* Rhetorical organization is marked in numerous ways. First, the section title is given in bold letters, **Concentration of Solutions.** Because there are so many definitions of terms in the topic material, the author provides definitions as the words are introduced. Examples of this format include, "...water solutions or, more properly, aqueous solutions", and "...molarity (also called molar solution), abbreviated M, which is defined as the number of moles of solute in a liter of solution (soln)." Examples are introduced with the phrases, *for example* and *that is*. An if - then statement is also used, "If one of the components is a solid and the other is a liquid, then the solid is called the solute and the liquid the solvent." In the solution to the example problems brief statements introduce the step, and each step is indented.

Pragmatice characteristics (illocutionary force and sociolinguistic characteristics) are the same as described for topic 7.

From this analysis of topics, it can be seen that topic materials share some common characteristics and differ in others. Material for topics seven and nine are similar according to: length, degree of contextualization, type of information, genre, grammar, cohesion, illocutionary force, and sociolinguistic characteristics. Material for topics seven and nine are different according to : vocabulary, distribution of new information, topic, and rhetorical organization. Table 4 contains a summary of this comparison of topics seven and nine.

Reliability of Topic Assessment

The grouping of topics according to features hypothesized to influence examinee performance plays a central role in this investigation. Rather than rely on the author's grouping of topics based on the selected criteria (Table 2), a panel of three chemistry professionals were asked to group the fifteen chemistry TEACH topics. An estimate of the reliability for the topic groupings of the three assessors was obtained using Cronbach's Alpha in the SPSSx-reliability program. To use Cronbach's Alpha each of the assessors' judgments was treated as a separate item on a scale for each of the fifteen topics, which were treated like subjects. A Cronbach's Alpha of 0.73 was calculated. This indicates an acceptable level of reliability for the composite grouping which was calculated by averaging the 3 assessors' judgments and rounding off to the nearest whole number. This final grouping was used to designate a group number for each topic.

When the author's groupings were combined with the three assessors, the Cronbach's Alpha increased to 0.79. This indicates that the three chemistry professionals perceived topic features in a similar manner as the author. The

Table 4 Nature of Language Facets of Chemistry TEACH Topics 7 and 9

	Topic 7 Acid-Base Properties of Anions, Cations, and Salts	Topic 9 Concentration of Solutions
LENGTH	3 1/2 pages	2 1/2 pages
PROPOSITIONAL CONTENT		
Vocabulary	field specific vocabulary without definitions	field specific vocabulary with definitions
Degree of Contexualization	highly contexualized, prompts recall	highly contexualized, prompts recall
Distribution of new information	compact	not compact, not diffuse
Type of Information	abstract, positive, factual	concrete, positive, factual
Topic	field specific, Acid-Base Properties of Anions, Cations, and Salts	field specific, Concentration of Solutions
Genre	Science textbook, discussion and example problems	Science textbook, discussion and examples problems
ORGANIZATIONAL CHARACTERISTICS		
Grammar	Introductory science textbook, present tense descriptions, use of pronoun ***we***	Introductory science textbook, present tense descriptions, use of pronouns ***you*** and ***we***
Cohesion	transition words, reference to tables and chapters	transition words
Rhetorical organization	bold heading, bold subheadings, italicized sub-sub-headings, marked examples, if-then statements, solution steps labeled and italicized	bold heading, definitions following new vocabulary, marked examples, if-then statements, solution steps indented
PRAGMATIC CHARACTERISTICS		
Illocutionary Force	ideational	ideational
Sociolinguistic	formal, written American English for for science	formal, written American English for science

high correlation between the author's groupings and the three assessors' groupings indicate that the topic features identified by the author establish a framework that is usable by others. However, all three assessors commented that it was difficult for them to distinguish varying cognitive levels because of their familiarity with the concepts, whereas the author as a non-chemistry professional perceived stronger distinctions in cognitive levels. The assessors did draw from their teaching experiences in applying the topic grouping criteria by considering the topics that have been most troublesome for students.

Topic Variation and TEACH Scores

The TEACH and SPEAK scores provide quantitative data for analyzing the effect of topic variation in this performance test. Score data for each examinee is listed in Appendix E and is organized by topic. The SPEAK and TEACH scores were grouped by the chemistry TEACH topic assigned to the examinee and SPSSx-MANOVA was used to report descriptive statistics in Table 5. The SPEAK scores, considered a measure of general language ability, were used to adjust the mean scores for TEACH.

Topic nine has the highest adjusted mean TEACH score of 2.18 and topic thirteen has the lowest adjusted mean TEACH score of 1.77. It is interesting to note that topics nine and one show the highest adjusted mean scores for TEACH and both these topics were the only ones placed into group one by all the assessors. It can be seen in Table 4 that the number of subjects for each topic varies from four to ten.

Descriptive statistics for topic groupings were calculated using SPSSx-MANOVA and are shown in Table 6. Although it was hypothesized that topic groupings would become progressively more difficult to talk about and teach going from group one to group three, the adjusted mean TEACH score for group two is the smallest. Yet are the observed differences between the groups statistically significant?

Two multiple regression analyses were computed using SPSSx to determine which, if any, topic groupings contributed to significant variance in test scores beyond that which is accounted for by speaking ability. TEACH scores were used as the dependent variable while SPEAK score and topic groupings were used as independent variables. The first step of the multiple regression computes the correlation between TEACH scores and SPEAK scores. The second step of the multiple regression computes the correlation between TEACH with both independent variables, SPEAK and topic groupings. Topics are coded by group. In order to compare the effects of group on TEACH score, dummy variables were created, D1, D2, and D3. D1 compares groups one and three. D2 compares groups two and three, and D3 compares groups one and two. Since the multiple regression analysis uses only two dummy variables for three groupings, the first multiple regression analysis computed the t value and significance of t for D1 and D2. A second multiple regression analysis computed the t value and significance of t for D3. The results from the two multiple regression analyses are summarized in Table 7. In order to determine which topic groupings are providing significant variance to the TEACH score, the t values and the significance of t values need to be examined. When a certainty level of $p<0.05$ is chosen, the t values and the significance of t values from Table 7 show that SPEAK, D1, and D3 account for significant variance in TEACH scores for these subjects.

SPEAK scores and topic grouping are both significant predictors of TEACH scores. SPEAK is the main predictor of TEACH in this study and has a correlation with TEACH of 0.820 as seen in Table 7 under multiple R. SPEAK and topic groupings together have a correlation with TEACH of 0.848 as seen in Table 7 under multiple R. The difference between the above two correlations is 0.028. This is the correlation between topic grouping and TEACH, with the SPEAK/TEACH correlation partialled out. Topic grouping affects TEACH scores as seen through the multiple R values. The t values and significance of t values in Table 7 show which groups are significantly different from each other. Group one accounts for significant variance of TEACH scores in comparison to groups two and three as shown by the significance of t values of 0.0436 and 0.0001 for D1 and D3. However, groups two and three do not show significant variance of TEACH scores in comparison to each other as shown by the significance of t value of 0.0658 for D2. Therefore, the observed differences between the adjusted means for group two and for group three are not statistically significant. In other

Table 5 Descriptive Statistics for SPEAK/TEACH Scores

TEACH Topic	Final Grouping[e]	n[a]	SPEAK[b] $\bar{x}$	SPEAK[b] S.D.	SPEAK[b] Range	TEACH[c] $\bar{x}$	TEACH[c] S.D.	TEACH[c] Range	$\bar{x}$ Adj.[d]
1	1	10	223	60	170	2.24	0.55	1.7	2.12
2	2	6	198	57	190	1.85	0.50	1.6	1.90
3	3	8	211	48	150	2.06	0.41	1.2	2.02
4	3	7	223	41	130	2.10	0.19	0.7	1.98
5	2	9	207	47	170	1.90	0.36	1.2	1.89
6	3	5	210	42	100	2.10	0.36	0.8	2.07
7	3	5	210	64	160	2.06	0.38	0.9	2.03
8	2	5	180	31	90	1.82	0.36	1.0	1.99
9	1	1	219	24	80	2.77	0.26	0.8	2.18
10	2	7	210	33	120	2.10	0.33	1.0	2.04
11	2	6	220	30	90	2.05	0.42	1.1	1.95
12	3	9	207	47	170	1.90	0.36	1.2	1.89
13	2	4	202	54	130	1.75	0.40	1.0	1.77
14	2	4	185	78	200	1.80	0.33	0.9	1.93
15	2	8	210	41	140	1.91	0.30	1.0	1.88

a number of subjects, n=102
b The SPEAK test is rated on a scale from 0 to 300.
c The TEACH test is rated on a scale from 0 to 3.
d Mean TEACH scores while controlling for general speaking ability (SPEAK scores).
e The final grouping was determined by rounding the average of the assessment of three chemistry professionals.

Table 6 Descriptive Statistics for Topic Groupings

Group	Topic	n[a]	SPEAK[b] $\bar{x}$	SPEAK[b] S.D.	SPEAK[b] Range	TEACH[c] $\bar{x}$	TEACH[c] S.D.	TEACH[c] Range	TEACH[c] $\bar{x}$ Adj[d]
1	1,9	19	221	45	170	2.25	0.40	1.7	2.19
2	2,5,8,10-15	58	198	44	190	1.89	0.34	1.6	1.97
3	3,4,6,7	25	214	46	160	2.08	0.32	1.2	2.06

a n=102

b The SPEAK test is rated on a scale from 0 to 300.

c The TEACH test is rated on a scale from 0 to 3.

d The mean TEACH scores are adjusted by the SPEAK scores.

Table 7 Multiple Regression Analyses of TEACH Considering Topic Variation

Dependent Variable	n	Independent Variable	Step	Multiple R	R^2	t Value	Sig. of t
TEACH	102	SPEAK	1	0.820	0.672	14.131	0.0000
		Groups 1,2,&3	2	0.848	0.719		
		D1				2.044	0.0436
		D2				-1.861	0.0658
		D3				3.984	0.0001

Note: D1 is the dummy variable used to compare group 1 and group 3.
D2 is the dummy variable used to compare group 2 and group 3.
D3 is the dummy variable used to compare group 1 and group 2.

words, this analysis justifies categorizing group one topics as separate from group two and three topics, but does not justify separating group two from group three topics.

The statistics from this study show that the SPEAK score is a strong, positive, and significant indicator of the TEACH score. This correlation is not unexpected since both the SPEAK and TEACH tests rate comprehensibility of oral language ability. Although the TEACH test provides the opportunity for the examinee to use teaching skills and non-verbal skills to communicate with his audience, the TEACH test is not necessarily an easier test for examinees. The score data in Appendix E shows that the TEACH score exceeded the SPEAK score for only thirty-five of the one hundred and two subjects. The TEACH test introduces challenges different from the SPEAK test. Many of the examinees do not have teaching experience or at least do not have teaching experience in English or in the United States. Furthermore, because of having to communicate specialized knowledge, standing in front of a group, and being videotaped, there is a lot of stress involved in taking the TEACH test for most examinees. The focus on comprehensibility of oral language for both tests seems to override these differences and the correlations from this study suggest that the SPEAK score is a strong predictor of the chemistry TEACH score.

The multiple regression analysis from this study shows that topic is also an indicator of the TEACH score. This corresponds with the perceptions of those examinees and raters who perceive an effect of topic on TEACH scores. Topic accounts for statistical significance in TEACH scores (R=0.028) beyond that accounted for by SPEAK. This shows that chemistry TEACH topics are not equivalent forms of input as test users had assumed. Specifically, topics one and nine have been providing a systematic advantage for examinees. This finding also suggests that the assessment of topics to establish groups based on topic criteria such as concepts, math, and calculations was useful in revealing empirical differences.

The effect of topic goes further than the degree of familiarity. Reseach in reading comprehension tests has compared topics on how familiar or unfamiliar they were to examinees (Bachman 1990). Yet in a field specific performance test like the chemistry TEACH test, the topics are all familiar and easily understandable to the examinees. It is not a question of whether the topics are familiar or unfamiliar. The effect of topic includes the topic features of concepts, math, and calculations for the subjects in this study. Specifically, topics that consist of concrete concepts, simple math, and simple calculations provide input that helps examinees score higher than if they were given topics with abstract concepts, complex math, and complex calculations

Videotaped Performances

Examinee interviews and rater surveys prove valuable in identifying topic features. Test score data prove valuable in determining statistically significant differences between topic groupings. The videotaped performances provide a means to determine what kind of linguistic features vary because of variation in topic material. For this investigation videotapes were studied for general observations only. It was learned that examinees generally use present tense to describe information they have written on the chalkboard. Most of the examinees spend a lot of their time using descriptive language. That is, they use language to describe what they have written on the chalkboard. For example, one examinee said as he referred to an equation on the chalkboard, "As we can see right away chlorine is a diatomic molecule. We have two atoms of chlorine on the left of the equation and roughly we should have two on - on the right of the equation." Another examinee pointed to a problem on the chalkboard and said, "I have the molarity. I have the volume of solution. I need to find out moles. How do I do that?" Another examinee pointed to a table he had put on the chalkboard and said, "We can see from the table that the experimental value is really close to the theoretical value. They are close. This is the first thing - the first thing we can see." These examples show how the examinees rely on descriptive language when using the chalkboard in the TEACH test.

It was also noted that examinees talk in the present tense for most of the exam. An exception occurred with an examinee of topic two. Topic two material contains information about the history and development of certain chemistry theories. The examinee said, "This statement if in fact is known as Avogadro's Law, Avogadro's Law is suggested - was suggested by - uh - Italian scientist

Avogadro in 1811 and this law was suggested earlier than ideal gas equation - and - a - now let's see, what's the use of this law?" This examinee switches from present tense, to past, to present again. This appears to be linguistically more challenging than remaining in the present tense as other examinees do with their descriptive language. Only topic two material contains historical information. An examinee for topic two may choose not to talk about the historical development of the chemistry theories and focus on example problems; in fact another examinee did just that.

In Chapter 5, it is recommended that a more detailed study of the video-taped performances be done in order to more specifically determine how variation in topic affects the language output of examinees.

Summary

In this chapter, both qualitative and quantitative data have been presented to establish the effect of topic variation on chemistry TEACH test scores. Qualitative data includes examinee perceptions, rater perceptions, analysis of topic material, and analysis of videotaped performances. Quantitative data includes TEACH and SPEAK scores along with the MANOVA and Multiple Regression Analyses and the reliability of assessors' topic groupings. Each of these sources helps to confirm that the specific topic features of concepts, math, and calculations do effect chemistry TEACH test scores.

5. CONCLUSIONS

Summary

Do variations in the chemistry TEACH topics affect the TEACH test scores? Data from examinee interviews, rater surveys, and test score statistics indicate that topic does play a role in TEACH test scores. Specifically, chemistry TEACH test scores tend to be higher when the topic of input contains features of concepts, math, and calculations that are at a lower level such as defined in group one criteria. Group one concepts are defined as being familiar, clearly presented, not cognitively demanding to understand, having convenient break points, and including adequate background information complemented with problem solving. Group one math is defined as simple, such as multiplication, ratios, and fractions. Group one calculations are defined as simple solutions or multiple step solutions that could be condensed into one step. The concrete concepts and simple math and calculations of group one topics provide a systematic advantage for examinees of the chemistry TEACH test.

In this chapter the implications and recommendations stemming from this research are presented. Implications from the effect of topic variation in performance testing extends into the areas of test development as well as testing research. Recommendations are made regarding the TEACH test, future research of performance tests, and the utility of the TEACH test.

Implications for Test Development and Research

The effect of topic variation in performance testing has implications for performance tests like the chemistry TEACH test and for the framework of test method facets. Topic equivalency should not be assumed in the chemistry TEACH test or other similar performance tests. Effort should be made to consider topic features such as concepts, math, and calculations. In the framework of test method facets, topic and the nature of language does deserve serious consideration by test developers and researchers as this investigation confirms.

Bachman (1990) wrote,

> *These characteristics, or 'facets', of test methods constitute the 'how' of language testing, and are of particular importance for designing, developing, and using language tests, since it is these over which we potentially have some control.*

Because topic has an effect on performance, and because topic is a test facet that test developers have control over, special attention should be granted to topic by test developers and researchers. Using field specific tests for examinees of specific fields does not automatically take care of making topics equivalent. Test developers should analyze topic features and compare topics not only regarding the theme of the topic, like chemistry, but also compare topic features, like concepts, math, and calculations. The topic feature of concept should be considered in relation to the rater and the examinee. The background knowledge and the ease of which a topic is understood by both the examinee and the rater are important. The already complex task of test development is made more complex when it is realized that what constitutes important topic features for one field specific test is not what may be the important topic features of another field specific test. Likewise, research on topics needs to go beyond the task and context to develop an understanding of topic features and their relationship to performance.

Recommendations for the TEACH Test

Examinee Instructions

In order to obtain a comparable language sample from one examinee to the next, considering the differences in the fifteen chemistry topics, the examinees could be given more specific instructions on what they are supposed to do during their five minute presentation. Currently the instructions say to "explain" the topic. Because of the difficulty of separating language ability and teaching ability, and because ITAs should not be tested on teaching ability when native speaking TAs are not, the TEACH examinees should be given more specific instructions about how to present their topic. What is expected in an explanation in an American classroom may not be understood yet by the examinees. When one examinee was questioned about how he chose what to include from the topic material for his TEACH test presentation he responded,

> *I have no time to use a example-I think the test perhaps is too short for-for explaining a conception and then you give them an example...what you can do--or you explain a concept or you get-give the student an example--you have time to do one of them--but you don't have time to do both of them.*

The use or absence of examples or practical applications may effect communication and the ultimate rating. For example, the examinees could be asked to show how to solve a problem, or to explain a topic while including a practical example. In this way the presentation style would have less effect on the language sample from one examinee to the next.

Topic Selection

Recommendations regarding TEACH topics stress the equivalency between topics. It is difficult for TEACH topics to reflect the varied placement of the ITAs such as tutors in help rooms, lab assistants, and recitation leaders. Since most chemistry ITAs are assigned to work in a lab, the chemistry TEACH test should reflect this. Instruction for the chemistry TEACH test could ask the examinee to explain the topic as it relates to a specific lab procedure. With these instructions, topic material would need to be supplemented with appropriate lab procedure materials. Due to time constraints of the TEACH test, showing how to solve a problem might be a more practical assignment. In order to produce equivalent topics, the topic material could be simplified. Choosing to focus on an explanation of problem solving could aid in the equivalency of the topic of input. For example, rather than providing the examinee with a few pages from a test that includes both discussion and example problems, the examinee could be given one page with a problem clearly stated along with the steps required to solve the problem. Problems with similar difficulty level should be chosen, such as problems with solutions of three or four steps. The exclusion of material that discusses concept would leave the examinee to determine for himself how to communicate the concept involved in solving the given problem and any other practical applications associated with the problem. This may make the test harder for examinees by requiring them to come up with their own discussion of concept and practical application. Yet it may also provide a better measure of strategic competence in teaching a problem solution. Some proposed topic materials are shown in Appendix H.

Because it is hard to establish equivalency between topics, it is recommended to keep the twenty-four hour preparation time for the TEACH exam. A twenty-four hour period allows examinees to interact with the topic of input for the length of time they choose. Individual variation in preparation time may reduce the effect of variation in topic of input on TEACH scores.

Recommendations for Future Research

Analysis of Topic Features

In this investigation the author identified the three topic features of concepts, math, and calculations. In future studies, it may be beneficial to obtain input from international professors as well when determining topic features that influence examinee performance. International professors could contribute their cultural perspective of topic, teaching, and language performance. The alternative perspective from another culture may reveal relevant topic features that have not yet been considered. Furthermore, in future research regarding grouping of topics based on selected features, it would be valuable to ask topic assessors to rate each feature of a topic, rather than only an overall rating of the topic. This would help to identify if certain features contribute more to an assessor's topic grouping than others. For example, the three topic asessors all commented on the difficulty they had in distinguishing differences in cognitive levels between topics because of their familiarity with the topics. Perhaps the feature of concept is not as significant as the complexity of a problem solution. This author hypothesizes that the topic feature of calculations affects performance more than concepts or math.

Analysis of Performance

Another recommendation for further topic analysis is to do a discourse analysis from the videotapes that record the TEACH test performances. The advantage of producing transcripts of the TEACH test videotapes is comparing the features of language production across topics. It has already been noted, that topic 2, Molar Volume of Gas: Avogadro's Law, seems to prompt some examinees to shift tense between past and present because of the discussion of the historical development of chemistry theories. If transcripts were produced, they could be checked for linguistically challenging forms such as dependent clauses, relative clauses, and others in addition to tense shift. A discourse analysis may provide insight into the effect topic has on rhetorical organization, cohesion, and other areas of grammatical, textual, illocutionary, and sociolinguistic competencies. Perhaps a better understanding of how topic variation affects language output could be gained. This could lead to a better understanding of the origin of differences in performance based on the distinctions of topic features as defined by topic groupings.

Examinee Perceptions

The interviews recording examinee perceptions of the TEACH topics after they took the exam were a unique part of this research. The examinees that perceived differences in topic confirmed some of the author's perceptions of difference in the level of abstractness of concepts and the inclusion or absence of practical applications. The amount of effort required to interview examinees does not seem comparable to the limited insight gained into topics. However, the examinees did provide a wealth of information regarding test taking and test preparation strategies. One of the strategies mentioned was using whole numbers that are easily divisible for example problems. Another strategy included making reference to practical applications. Yet another strategy included preparing three minutes of material for a five minute lecture to help insure finishing the mini-lecture before being cut off by the questioning time. Examinee interviews seem to be very valuable in researching test taking strategies.

Recommendations for ITA Assessment

Should TEACH testing for ITAs be continued in addition to SPEAK testing given the high correlation between chemistry TEACH scores and SPEAK scores? This author believes it should because of the importance of the decisions made based on ITA assessment and the difficult nature of assessing language competency. This concept of test batteries has been supported by others who work in ITA assessment (Plakans and Abraham 1990).

The results of ITA assessment are important for individual ITAs, for students, and for University departments. ITAs are affected financially by assessment decisions. The education of students is affected by ITA placement and department reputations are either enhanced or deteriorated by the quality of education provided by their ITAs. In chemistry labs in particular, safety is an important issue. The ability of an ITA to communicate safety procedures and warnings is of vital importance. For these reasons it is wise not to rely on SPEAK test results alone. Performance tests like TEACH are short and provide only a limited window on language proficiency. It is a limited window because of constraints on the test method facets. The settings, tasks, topics, and roles provided for in a test are only a sampling of the variety of communicative challenges that face an ITA. The SPEAK test provides an assessment in a sit-down interview format. The TEACH test provides an assessment in a stand-up presentation in front of a classroom. Since the focus of both of these tests is comprehensibility, it is expected that the scores of SPEAK and TEACH are strongly related. Yet, they do provide differing perspectives on comprehensibility based on their different settings, tasks, topics, and roles. Because ITA assessment has important consequences and because language competency is hard to measure, it is valuable to utilize as much information as possible, including both SPEAK and TEACH scores, when assessing ITAs.

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APPENDIX A

IOWA STATE UNIVERSITY INSTRUCTIONS FOR PREPARING FOR THE TEACH TEST

IOWA STATE UNIVERSITY
INSTRUCTIONS FOR PREPARING FOR THE TEACH TEST

Examinee's No._____ - _________

Videotaping session will be held on ________________________ at ________ p.m.

in ____________________________. Please be on time and bring some form of picture identification (such as your passport, student ID card, or driver's license).

COURSE:____

Assigned topic:____

pages_________________ in the textbook by___________________________________

TEACH is a test designed to supplement SPEAK and to provide evidence of prospective teaching assistants' oral English skill in a classroom in their own field of study. TEACH attempts to identify what specific communication problems the new international teaching assistant (ITA) may have.

TESTING PROCEDURES

The test lasts 10 minutes. TEACH consists of three parts: (1) A minute or two to allow you to become familiar with the physical surroundings, meet your "class" (5 or 6 people who will listen to your presentation), and write a few terms, formulae, etc. on the chalkboard before you begin your presentation. (2) You then have 5 minutes to explain some aspect of your assigned topic clearly and in words that an undergraduate class could understand. Then a timer will sound. (3) The "class" will ask you questions about the topic for 3 minutes.

The topic assigned to you has been suggested by a professor in the department in which you hope to teach. We will lend you a copy of the pages from the textbook or laboratory manual in which the assigned topic appears. These pages must be returned to one of the test supervisors immediately after your videotaping session.

When you prepare for your presentation you must assume several things:

1. You are giving an explanation or mini-lecture to an ordinary class of undergraduates.

2. Your lesson is happening sometime in the middle of the semester rather than at the beginning. You should not begin your presentation by saying, "Welcome to this course. My name is...."

3. Since this lesson is part of an imaginary course, the students in your audience may ask you questions about quizzes, tests, etc. related to the topic you will explain to them. They will be familiar with the textbook and will know what your topic is beforehand, and have been told to ask questions about it and about classroom procedure.

A typical university classroom will be used for TEACH videotaping. The room will have a chalkboard. You are encouraged to use it to help in the explanation of your topic. (But remember: Talk to your audience, not to the board; write high on the board and in large enough letters and numbers so that students in the back of the room can see what you have written.) You may use notes for your presentation, as well as a copy of the textbook. However, reading from notecards or the textbook is not a good way to present material to a class and will lower your score. Although overhead transparencies and computer printouts can be excellent teaching aids, they may not be used for this test because (1) they may not be seen on videotape and (2) TEACH focuses on your ability to communicate in the spoken language.

A table microphone will record the audio portion of your presentation. It is important to speak loudly enough for students in the back of the room to hear you. Remember to speak clearly, and do not rush through your topic. It takes time for students to absorb new material. It would be better to cover only part of your topic thoroughly than to go quickly through the entire topic and confuse your audience.

RATING YOUR PERFORMANCE

Although several students will be used as questioners at the videotape session, the evaluators of your performance will be a team of professionals in the field of teaching English as a second language. They also rate SPEAK test tapes. Two or three of these evaluators will rate each TEACH performance; if they cannot agree, another evaluator will view the videotape and make a decision.

Evaluators will rate your performance in five categories:

1. overall comprehensibility of your spoken English

2. your ability to understand and answer students' questions

3. your ability to explain a topic clearly, using supporting evidence and/or examples

4. your skill as a teacher addressing a class, using the chalkboard, showing interest in the subject and in the students as learners

5. indications of your awareness of the appropriate teacher-student relationship in a U.S. university classroom setting

REPORTING TEST RESULTS

TEACH is designed for internal use at Iowa State University and will not be considered proof of oral English proficiency by other institutions. Results of your performance on

TEACH will be considered along with your score on SPEAK in determining whether you have met the English speaking proficiency requirement for international teaching assistants. If your performance reveals some skill areas in which you may have some deficiencies, TEACH will be useful in recommending what training is needed. A composite of the results of TEACH and SPEAK will be reported to you and to the department that is considering you for a teaching assistantship as soon as results can be determined.

WOULD YOU LIKE TO SEE YOUR PERFORMANCE?

The developers of TEACH hope that the experience of preparing and performing a classroom presentation will be useful to prospective teaching assistants. If you would be interested in seeing your performance on videotape after it has been evaluated and your results have been reported to you, the Graduate College Office would be happy to offer you this opportunity. Please contact Barbara Plakans (213 Beardshear, 294-7996) after you have received your results and she will lend you the tape so that you can view it privately in the Media Room at the Parks Library.

APPENDIX B
TEACH RATING SHEET

TEACH Rating Sheet

Exam No. ______________ Rater ______________

Rating Done: LIVE VIDEO Date ______________

Topic ______________

	(Low)						(High)
1. OVERALL LANGUAGE COMPREHENSIBILITY	0	•	1	•	2	•	3
A. Pronunciation	0	.	1	.	2	.	3
B. Grammar	0	.	1	.	2	.	3
C. Fluency	0	.	1	.	2	.	3

2. CULTURAL ABILITY 0 . . . . • . . . . 1 . . . . • . . . . 2 . . . . • 3

A. Familiarity with cultural code

B. Appropriate nonverbal behavior

C. Rapport with class

3. COMMUNICATION SKILLS 0 . . . . • . . . . 1 . . . . • . . . . 2 . . . . • 3

A. Development of explanation
B. Clarity of expression
C. Use of supporting evidence
} 0 . . . . • . . . . 1 . . . . • . . . . 2 . . . . • 3

D. Eye contact
E. Use of chalkboard
F. Enthusiasm/presence
} 0 . . . . • . . . . 1 . . . . • . . . . 2 . . . . • 3

4. INTERACTION WITH STUDENTS 0 . . . . • . . . . 1 . . . . • . . . . 2 . . . . • 3

A. Basic listening ability

B. Question handling and responding

5. OVERALL IMPRESSION 0 1 2 (poor) 3 / 4 5 (average) 6 / 7 8 (excellent) 9

Recommendation: Subject's overall English and classroom ability is good enough to be:

6. Instructor with Minimal Supervision YES NO

7. Leading a Recitation Section of a Course Taught by a Faculty Member YES NO

8. Conducting a Laboratory Section YES NO

Language ______________

Culture ______________

Communication ______________

Listening ______________

APPENDIX C
RATER SURVEY

December 7, 1993

Dear Rater,

As part of my thesis research, I am investigating the various topics used for the Chemistry TEACH test. Please take a few minutes to read over the following list of topics used for the Chemistry TEACH test. Are certain topics easier or harder to rate than others? Next to each topic mark E, H, or A based on the difficulty of rating the topic where,

E = easy to rate,
H = hard to rate,
A = average to rate.

The various chemistry TEACH topics include:

Molar Concentrations
Molar Volume of Gas
Balancing Oxidation - Reduction Equations
Equilibrium Constant
Calculation of Equilibrium Concentration
Equilibria in Aqueous Solutions of Acids and Bases
Acid - Base Properties of Anions, Cations, and Salts
Mole Method
Ionic Bonds
Enthalpy
Bond Energies
Heat of Solution
Molar Mass Determination

When you have completed your markings you may leave this page in your rater envelope. Thank you for your help with this project.

Sincerely,

Dean Papajohn

APPENDIX D
QUESTIONS FOR EXAMINEES OF THE CHEMISTRY TEACH TEST

Questions for Examinees of the Chemistry TEACH test

1. Was there enough information to prepare from? too much?
2. Did you have any problems understanding the material you were given to prepare from?
3. Did you use the examples provided in the material? If not, where did you get your examples/extra material from?
4. Did anyone help you prepare?
5. How much time did you spend preparing for the exam?
6. What do the raters think is most important about this test?
7. Does your department take this test seriously?
8. Did you like this topic?
9. If you could choose a topic, what would it be?
10. Did you notice any differences between this test and any previous Chemistry Teach tests you have taken?
11. How did you do on today's test?
12. Did you cover as much as you wanted?

APPENDIX E

INSTRUCTIONS TO ASSESSORS FOR GROUPING CHEMISTRY TEACH TOPICS

Chemistry Topic Groupings

The TEACH test is used at Iowa State University to evaluate the English ability of prospective international teaching assistants. Please read over the instructions that the examinees are given before the test in order to familiarize yourself with the testing process. Your task is to place each of the fifteen chemistry topics into one of three groups. Please read over the criteria for these three groups. The descriptions of the groups include general characteristics. Place each topic into just one of the three groups. A topic may not fit all descriptions of a group perfectly. For example, a problem that requires only simple math, but has a number of steps that cannot be condensed and has a cognitively demanding topic should be placed in group 3, not in group 1 or 2 just because the math is simple. Use your best judgment in placing topics into appropriate groups. Three sample topics have been provided for you to practice applying the group criteria. Please read all three sample topics and decide which group to put them in. Then read the explanation of sample groupings to familiarize yourself with the application of the group criteria. If you have any questions about the application of the group criteria, give me a call (233-1994 or 294-6131). Next, please read the material for the fifteen Chemistry topics used in the TEACH test and place them into one of the three groups. Thank you for your help with this project.

APPENDIX F
SCORE DATA

Examinee	Topic	TEACH Score	SPEAK Score	Native Country	Native Language
90-074	1	1.5	140	457	315
90-074	1	1.4	140	457	315
90-008	1	3.0	240	743	478
90-060	1	2.2	170	319	315
92-111	1	2.9	300	343	501
92-146	1	1.9	210	457	315
92-144	1	2.3	280	328	328
93-046	1	2.1	210	688	467
93-060	1	2.8	300	325	370
93-033	1	2.3	240	349	340
90-078	2	1.8	200	457	315
90-077	2	1.8	200	457	315
91-061	2	2.8	290	394	361
92-112	2	1.3	110	457	315
93-013	2	1.8	200	457	315
93-061	2	1.6	190	457	315
93-133	3	1.8	200	616	413
90-075	3	1.6	150	457	315
90-072	3	2.7	230	457	315
90-061	3	1.7	190	457	315
91-062	3	1.8	170	457	315
92-113	3	2.0	190	319	315
93-062	3	2.4	290	671	464
93-048	3	2.5	270	325	50
90-062	4	2.0	220	457	315
91-063	4	2.0	190	457	315
92-114	4	2.2	280	322	315
93-017	4	1.8	160	457	315
93-049	4	2.2	240	457	315
93-023	4	2.4	260	692	470
93-063	4	2.1	210	457	315
90-134	5	1.8	160	457	315
90-132	5	1.7	180	457	315
91-011	5	1.6	160	457	315
91-064	5	2.1	200	394	361
92-115	5	1.7	150	457	315
92-088	5	1.7	170	457	315
92-116	5	1.7	180	457	315
93-050	5	2.2	250	457	315
93-064	5	1.7	140	457	315

Examinee	Topic	TEACH Score	SPEAK Score	Native Country	Native Language
89-067	6	1.9	190	457	315
90-064	6	1.8	180	457	315
93-051	6	2.4	250	457	315
93-042	6	1.9	170	457	315
93-065	6	2.5	260	457	315
90-129	7	2.5	290	457	315
90-065	7	1.7	140	457	315
91-066	7	1.7	160	457	315
93-066	7	2.4	260	319	315
93-052	7	2.0	200	322	315
90-074	8	2.0	180	457	315
90-066	8	1.3	130	319	315
91-067	8	2.0	200	457	315
92-118	8	1.6	180	457	315
93-067	8	2.2	210	457	315
90-067	9	2.3	220	457	315
91-034	9	2.4	200	457	315
91-068	9	2.6	220	457	315
92-119	9	1.8	190	457	315
92-168	9	2.2	240	319	315
93-054	9	2.5	260	692	470
93-018	9	1.9	200	616	413
93-068	9	2.3	200	340	331
94-038	9	2.4	240	688	467
90-068	10	2.2	200	322	315
91-033	10	1.7	160	457	315
91-069	10	2.1	190	457	315
92-069	10	1.9	190	457	315
92-124	10	2.3	270	325	370
93-069	10	2.4	200	457	315
93-055	10	1.5	200	319	315
90-069	11	1.6	210	457	315
91-070	11	1.6	170	457	315
92-120	11	2.6	250	671	464
92-149	11	2.4	250	328	328
93-073	11	2.2	230	457	315
93-056	11	1.9	210	457	315

Examinee	Topic	TEACH Score	SPEAK Score	Native Country	Native Language
89-144	12	2.0	190	457	315
90-151	12	1.5	140	457	315
90-124	12	2.6	300	370	351
90-070	12	1.8	180	457	315
93-015	12	1.5	190	457	315
92-125	12	1.9	200	457	315
93-071	12	1.6	190	457	315
93-070	12	2.2	260	457	315
93-020	12	2.0	210	349	340
90-071	13	1.4	170	457	315
91-072	13	1.5	150	457	315
92-122	13	2.3	270	671	464
93-072	13	1.8	220	457	315
90-072	14	1.8	170	457	315
91-073	14	1.8	180	457	315
92-110	14	1.4	100	457	315
92-151	14	2.2	290	408	388
90-073	15	1.4	180	457	315
91-074	15	1.8	200	457	315
91-031	15	2.0	190	457	315
92-117	15	2.3	250	457	315
92-023	15	1.9	200	401	276
92-170	15	1.6	160	457	315
92-148	15	2.1	290	204	191
92-123	15	2.2	210	457	315

NATIVE COUNTRY CODES

204	South Africa
319	Taiwan
322	Hong Kong
325	India
328	Indonesia
343	Jordan
349	Korea
370	Nepal
394	Sri Lanka
401	Thailand
407	Vietnam
457	Peoples Republic of China
616	Czech Republic
671	Romania
692	Serbia
743	Mexico

NATIVE LANGUAGE CODES

50	Konaki
191	Zulu
315	Chinese (all dialects)
328	Indonesian
340	Korean
351	Nepali
361	Sinhalese
370	Tamil
376	Thai
388	Vietnamese
413	Czech
464	Romanian
470	Serbo-Croatian
478	Spanish
501	Arabic

APPENDIX G
EXAMPLES OF CHEMISTRY
TEACH TOPIC OF INPUT

Chem. (7)

If we now multiply K_a(HA) and $K_b(A^-)$, we have

$$K_a(HA)K_b(A^-) = \frac{[H_3O^+][A^-]}{[HA]} \times \frac{[HA][OH^-]}{[A^-]} = [H_3O^+][OH^-]$$

Hence,

$$K_a(HA)K_b(A^-) = [H_3O^+][OH^-] = K_w = 10^{-14}\ \text{mol}^2\ \text{L}^{-2} \text{ at } 25°\text{C}$$

In general, for any acid

$$K_a(\text{acid})K_b(\text{conjugate base}) = K_w = 10^{-14}\ \text{mol}^2\ \text{L}^{-2}$$

Taking negative logarithms of both sides gives

$$pK_a(\text{acid}) + pK_b(\text{conjugate base}) = pK_w = 14$$

where we have written pK_w for $-\log K_w$. Thus the larger the K_a (that is, the stronger the acid), the smaller the K_b (that is, the weaker the conjugate base).

We do not need to list values of both K_a and K_b, because one can always be obtained from the other. But for convenience we have listed some common K_a and K_b values in Tables 14.3 and 14.4.

Example 14.17 What is the base dissociation constant for the fluoride ion, F^-? From Table 14.3 $K_a(HF) = 3.5 \times 10^{-4}$ mol L^{-1}.

Solution

$$K_a(HF)K_b(F^-) = K_w$$

$$K_b(F^-) = \frac{1.0 \times 10^{-14}\ \text{mol}^2\ \text{L}^{-2}}{K_a(HF)}$$

$$= \frac{1.0 \times 10^{-14}\ \text{mol}^2\ \text{L}^{-2}}{3.5 \times 10^{-4}\ \text{mol L}^{-1}} = 2.9 \times 10^{-11}\ \text{mol L}^{-1}$$

14.6 ACID-BASE PROPERTIES OF ANIONS, CATIONS, AND SALTS

When an acid reacts with a base to give a salt, the acid is often said to neutralize the base. Thus we might think that the solution of the salt that is formed is neutral, that is, that it has a pH of 7. Although many salts do give neutral solutions in water, a large number do not, because some cations and anions are acids or bases. The acid-base properties of some common anions and cations are summarized in Table 14.6.

Table 14.6 Acid-Base Properties of Some Common Ions

	CATIONS	ANIONS
Acidic	NH_4^+, H_3O^+, $Al(H_2O)_6^{3+}$, $Fe(H_2O)_6^{3+}$	HSO_4^-, $H_2PO_4^-$
Neutral	Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Li^+, Na^+, K^+, Rb^+, Cs^+, Ag^+	NO_3^-, ClO_4^-, Cl^-, Br^-, I^-
Basic	None	SO_4^{2-} (very weak, almost neutral), PO_4^{3-}, CO_3^{2-}, SO_3^{2-}, F^-, CN^-, OH^-, S^{2-}, $CH_3CO_2^-$, HCO_3^-

Anions

Anions (conjugate bases) of strong acids such as Cl^- have no basic properties in water. They give neutral solutions.

Anions (conjugate bases) of weak acids such as CN^- and CO_3^{2-} are weak bases. They give basic solutions in water. For example,

$$CN^- + H_2O \rightleftharpoons HCN + OH^-$$

Anions containing hydrogen that are derived from polyprotic acids may be either acids or bases. For example, HSO_4^- and $H_2PO_4^-$ are acids:

$$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$$

$$H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$$

But HPO_4^{2-} and HCO_3^- are bases:

$$HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$$

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$$

If the acid dissociation constant of the anion is larger than the base dissociation constant (see Tables 14.3 and 14.4), then the anion is an acid. But if the base dissociation constant of the anion is larger than its acid dissociation constant, the anion is a base.

Cations

Metal ions are generally hydrated, as we have described in Chapters 9 and 13. Many hydrated metal ions behave as acids, particularly when the metal has a positive charge of 2 or greater. For example,

$$Al(H_2O)_6^{3+} + H_2O \rightleftharpoons H_3O^+ + Al(OH)(H_2O)_5^{2+}$$

The charge on the metal ion attracts electrons from the OH bonds, making the hydrogens considerably more acidic than they are in the free water molecule. The only common hydrated metal ions that do *not* behave as acids are Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Ag^+. They give neutral solutions in water. All other hydrated metal ions give acidic solutions in water.

Cations (conjugate acids) of weak bases are weak acids. The most common example is the ammonium ion,

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

Most other acidic cations are derived from ammonia, for example, methylammonium, $CH_3NH_3^+$, anilinium, $C_6H_5NH_3^+$, and hydrazinium, $H_2NNH_3^+$.

Salts

We can now classify aqueous solutions of salts according to their acid-base properties (see Table 14.7).

Neutral salts contain a neutral cation and a neutral anion. They include salts of Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Ag^+, with anions of strong acids, such as Cl^- and NO_3—for example, KCl, $BaCl_2$, and $AgNO_3$.

Acidic salts contain an acidic cation and a neutral anion or a neutral cation and an acidic anion. They include the following:

- Salts of metal cations, except Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Sr^{2+}, Ba^{2+}, and Ag^+, with anions of strong acids, for example, $AlCl_3$ and $Fe_2(SO_4)_3$.

Table 14.7 Acid-Base Properties of Aqueous Solutions of Some Common Salts

BASIC SOLUTIONS, pH > 7	NEUTRAL SOLUTIONS, pH = 7	ACIDIC SOLUTIONS, pH < 7
Neutral cation Basic anion	Neutral cation Neutral anion	Acidic cation Neutral anion
$NaCN$	KCl	NH_4Cl
KF	$BaCl_2$	$Al(H_2O)_6Cl_3$
$Na(CH_3CO_2)$	$Ca(NO_3)_2$	$Fe(H_2O)_6(NO_3)_3$
Na_2CO_3	$Mg(ClO_4)_2$	$C_6H_5NH_3{\cdot}Cl$
		Neutral cation Acidic anion
		$KHSO_4$

- Ammonium salts of strong acids, for example, NH_4Cl.
- Some salts of polyprotic acids, for example, $NaHSO_4$.

Basic salts contain a neutral cation and a basic anion. They include salts of Li^+, Na^+, K^+, Rb^+, Cs^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, and Ag^+, with anions of weak acids, such as CN^-, F^-, and CO_3^{2-}—for example, NaCN, KF, and Na_2CO_3.

For a salt of an acidic cation, such as NH_4^+, and a basic anion, such as CN^-, we cannot predict whether the solution will be acidic, basic, or neutral without knowing their acid and base dissociation constants.

Example 14.18 Predict whether the following salts give acidic, basic, or neutral solutions when dissolved in water: NaBr, K_2CO_3, $AlCl_3$, NH_4ClO_4, and $(NH_4)_2S$.

Solution

NaBr	Neutral cation, neutral anion	Therefore the solution is neutral.
K_2CO_3	Neutral cation, basic anion	Therefore the solution is basic.
$AlCl_3$	Acidic cation, neutral anion	Therefore the solution is acidic.
NH_4ClO_4	Acidic cation, neutral anion	Therefore the solution is acidic.
$(NH_4)_2S$	Acidic cation, basic anion	We cannot make a prediction without information on $K_a(NH_4^+)$ and $K_b(S^{2-})$.

Rather than just predict whether the solution of a salt is acidic or basic, we can calculate the pH of the solution, as the following examples show.

Example 14.19 What is the pH of a 0.10*M* solution of sodium cyanide?

Solution ***The first step*** is to write the equation for the equilibrium reaction. Because CN^- is the conjugate base of a weak acid, HCN, it is a weak base:

$$CN^- + H_2O \rightleftharpoons HCN + OH^-$$

The Na^+ ion is neither an acid nor a base.

The second step is to write the expression for the equilibrium constant and to look up the value of $K_b(CN^-)$ in Table 14.4 or to calculate it from $K_a(HCN)$:

$$K_b = \frac{[HCN][OH^-]}{[CN^-]} = 2.0 \times 10^{-5} \text{ mol L}^{-1}$$

The third step is to write an expression for the concentration of each of the species in solution. Because NaCN is a salt and is fully dissociated in aqueous solution, the initial concentrations of Na^+ and CN^- are both 0.10M. If we let $[OH^-] = x$ mol L^{-1}, we have

	CN^-	$+ H_2O \rightleftharpoons$	HCN	$+ OH^-$	
Initial concentrations	0.10		0	0	mol L^{-1}
Equilibrium concentrations	$0.10 - x$		x	x	mol L^{-1}

Hence

$$\frac{x^2}{0.10 - x} \text{ mol L}^{-1} = 2.0 \times 10^{-5} \text{ mol L}^{-1}$$

Since K_b is small, we assume that $x \ll 0.10$ and hence $0.10 - x \simeq 0.10$. Thus we have

$$\frac{x^2}{0.10} = 2.0 \times 10^{-5}$$

$$x^2 = 2.0 \times 10^{-6}$$

$$x = 1.4 \times 10^{-3}$$

$$[OH^-] = 1.4 \times 10^{-3} \text{ mol L}^{-1}$$

Since x is less than 5% of the initial concentration of CN^-, the assumption that $0.10 - x \simeq 0.10$ was justified. Thus

$$[H_3O^+] = \frac{1.0 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}}{[OH^-]} = \frac{1.0 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}}{1.4 \times 10^{-3} \text{ mol L}^{-1}}$$

$$= 7.1 \times 10^{-12} \text{ mol L}^{-1}$$

$$\text{pH} = 11.15$$

Example 14.20 What is the pH of a 0.20M solution of NH_4Cl?

Solution Ammonium chloride, NH_4Cl, is an ionic solid consisting of ammonium ions, NH_4^+, and chloride ions, Cl^-. The chloride ion is neither an acid nor a base, but the ammonium ion is a weak acid. We follow exactly the same steps as in Example 14.19. First, we write the equation for the reaction of ammonium ion with water:

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

The equilibrium constant is the acid dissociation constant, $K_a(NH_4^+)$. From Table 14.3 we see that $K_a(NH_4^+) = 5.6 \times 10^{-10}$ mol L^{-1}. Thus

$$K_a(NH_4^+) = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = 5.6 \times 10^{-10} \text{ mol L}^{-1}$$

Now we obtain an expression for each of the concentrations by letting $[H_3O^+] = x$ mol L^{-1}:

	NH_4^+	$+ H_2O \rightleftharpoons$	H_3O^+	$+ NH_3$	
Initial concentrations	0.20		0	0	mol L^{-1}
Equilibrium concentrations	$0.20 - x$		x	x	mol L^{-1}

Therefore

$$\frac{x^2}{0.20 - x} \text{ mol L}^{-1} = 5.6 \times 10^{-10} \text{ mol L}^{-1}.$$

Making the usual approximation that $x \ll 0.20$, we have

$$\frac{x^2}{0.20} = 5.6 \times 10^{-10}$$

Solving for x gives

$$x = 1.1 \times 10^{-5} \text{ and } [H_3O^+] = 1.1 \times 10^{-5} \text{ mol L}^{-1}$$

Therefore

$$pH = -\log(1.1 \times 10^{-5}) = 4.96$$

14.7 pH: APPLICATIONS AND MEASUREMENT

The measurement of the pH of aqueous solutions has many important applications. The rates of chemical reactions involved in biochemical processes are often very sensitive to the hydronium ion concentration of the medium. In fermentation, for example, control of the pH is very important. In fact, the concept of pH was invented in 1909 by the Danish chemist Søren Sørensen (1868–1939) while he was working at the Carlsberg Brewery in Copenhagen on problems connected with the brewing of beer. Many body fluids have well-defined pH's that must be maintained at these values if the body is to function in a normal way. For example, the fluid in the stomach has a pH of approximately 1.4. This rather high acidity is important for the proper digestion of food. But if the stomach fluid becomes much more acidic, we are soon made aware of it by the pain and discomfort. Blood has a constant pH of 7.4.

Pure water has a pH of 7.0. Ordinary rainwater and drinking water are normally very slightly acidic (pH < 7.0), mainly because they contain a small amount of dissolved CO_2. This dissolved CO_2, which reacts with water to some extent, produces H_3O^+ and hydrogen carbonate ion, HCO_3^-:

$$CO_2(aq) + 2H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

Rainwater also contains very small amounts of sulfuric and nitric acids. These acids are formed from SO_2 emitted by volcanoes and NO formed in lightning discharges. However, when we speak of *acid rain*, we mean rain that is much more acidic than it has normally been in the past or than it is in areas where the atmosphere is not polluted with SO_2 and other acid-producing substances resulting from industrial processes and automobile emissions (see Box 14.1).

Our sense of taste is remarkably sensitive to pH. Indeed, taste was one of the earliest ways in which acids and bases were distinguished. We are able to detect a sour, tart, or acidic taste in a solution with a pH between 4 and 5. Soda water, which is a solution of carbon dioxide in water, has a pH of about 4 and tastes quite definitely acidic. Most fruit juices and soft drinks have a pH in the range of 2–3. Their familiar acid taste arises from the weak acids that they contain. For example, lemon juice contains citric acid (see Chapter 19). A solution with a pH of 1 or less is not only unpleasant to taste but is dangerous because it burns the skin.

Basic solutions with a pH greater than 7 have a bitter taste and a characteristic slippery or soapy feel. They cause a characteristic wrinkling of the skin. A 2% solution of sodium hydrogen carbonate, $NaHCO_3$, is an effective mouthwash, but it has a very unpleasant taste. Very basic solutions of pH 12 or 13 are dangerous because they attack the skin quite rapidly. Some drain cleaners are a concentrated NaOH solution with added scent and coloring. They have a pH as high as 14 or 15 and should be handled with great care.

Indicators

A convenient way of determining the approximate pH of a solution is by the use of indicators. ***An* indicator *is a weak acid that has a conjugate base with a different color from that of the acid.*** Some naturally occurring colored substances

Chem. #9

$$\text{theoretical yield of DDT} = 2.00 \text{ mol DDT} \times \frac{355 \text{ g DDT}}{1 \text{ mol DDT}} = 710 \text{ g DDT}$$
$$= 7.10 \times 10^2 \text{ g DDT}$$

(b) To find the percent yield, we write

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$
$$= \frac{654 \text{ g}}{710 \text{ g}} \times 100\% = 92.1\%$$

3.5 Solution Stoichiometry

Concentration of Solutions

Many chemical reactions occur in solutions, particularly in water solutions or, more properly, aqueous solutions. Certainly most, or perhaps all, of the experiments you will be carrying out in the laboratory in an introductory chemistry course will involve the use of aqueous solutions.

A solution is made up of at least two different components. If one of the components is a solid and the other a liquid, then the solid is called the *solute* and the liquid the *solvent*. For example, in an aqueous glucose solution, the glucose is the solute and water is the solvent. Of course, a solution may contain more than one solute. The solvent is normally present in the greatest amount in a solution and its physical state is unchanged.

If both components of a solution are liquids—for example, ethanol and water—the terms solute and solvent still apply if one component is present in considerably larger amounts than the other. The smaller component is called the solute and the larger component the solvent.

A solution is defined by the nature of its solute and solvent, and by its *concentration*, that is, the amount of solute present in a given quantity of solution. One of the most common units of concentration used in chemistry is *molarity* (also called molar solution), abbreviated M, which is defined as *the number of moles of solute in a liter of solution* (soln).

$$\text{molarity} = \frac{\text{moles of solute}}{\text{liters of soln}}$$

Thus, a 2.60 molar sodium chloride solution, expressed as 2.60 M NaCl, contains 2.60 moles of the solute (NaCl) in one liter of the solution; a 1.85 molar glucose solution, expressed as 1.85 M glucose, contains 1.85 moles of $C_6H_{12}O_6$ in one liter of the solution; and so on. Of course, we do not need to work with solutions of exactly one liter in all cases. Thus, a 500 mL solution containing 1.30 moles of NaCl still has the same concentration of 2.60 M, that is

$$\text{molarity} = \frac{\text{moles of solute}}{\text{liters of soln}}$$
$$= \frac{1.30 \text{ mol}}{0.500 \text{ L}} = 2.60\ M$$

One advantage of expressing concentration in molarity is that solutions of known concentration can be conveniently prepared in a *volumetric flask*. A volumetric flask is designed to contain an exact volume of liquid when the bottom of the meniscus—the curved surface—of the liquid just reaches the etched line on the neck of the flask. The steps for preparing a solution with a known molarity are illustrated in Figure 3.5.

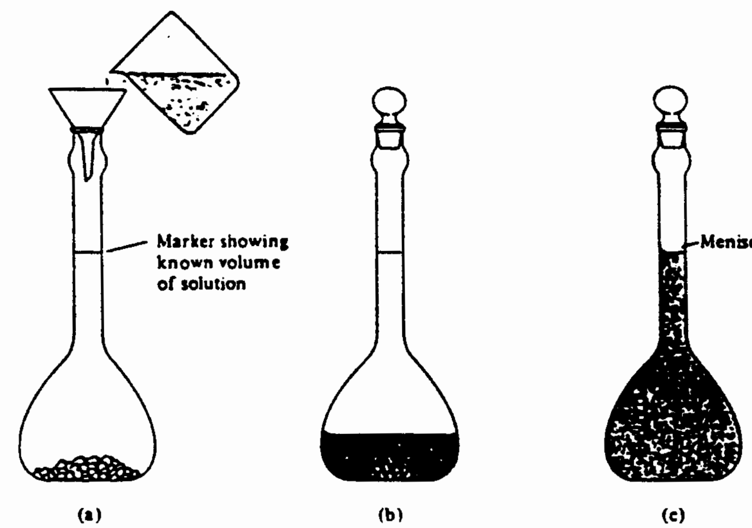

FIGURE 3.5 *Preparation of a solution of known molarity. (a) A known amount of substance (the solute) is added to the volumetric flask, followed by the addition of water through a funnel. (b) The solid is slowly dissolved by gently shaking the flask. (c) After the solid has completely dissolved, more water is added to bring the level of the solution to the mark. Knowing the volume of the solution and the amount of the substance added, we can calculate the molarity of the prepared solution.*

EXAMPLE 3.16

A quantity of 6.98 g of sucrose ($C_{12}H_{22}O_{11}$) is dissolved in enough water to form 67.8 mL of solution. What is the molarity of this solution? The molar mass of sucrose is 342 g.

Answer

To change 6.98 g of sucrose to moles of sucrose we write

$$\text{moles of } C_{12}H_{22}O_{11} = 6.98 \text{ g } C_{12}H_{22}O_{11} \times \frac{1 \text{ mol } C_{12}H_{22}O_{11}}{342 \text{ g } C_{12}H_{22}O_{11}}$$

$$= 0.0204 \text{ mol } C_{12}H_{22}O_{11}$$

The molarity of the sucrose solution is given by

$$\text{molarity} = \frac{\text{moles of } C_{12}H_{22}O_{11}}{\text{liters of soln}}$$

$$= \frac{0.0204 \text{ mol } C_{12}H_{22}O_{11}}{67.8 \text{ mL soln}} \times \frac{1000 \text{ mL soln}}{1 \text{ L soln}}$$

$$= 0.301\ M$$

EXAMPLE 3.17

How many grams of NaCl are present in 50.0 mL of a 2.45 *M* NaCl solution?

Answer

The first step is to find out the number of moles of NaCl present in 50.0 mL of the solution.

$$\text{moles of NaCl} = 50.0\text{ mL NaCl soln} \times \frac{2.45\text{ mol NaCl}}{1000\text{ mL NaCl soln}}$$
$$= 0.123\text{ mol NaCl}$$

The molar mass of NaCl is 58.4 g, so we have

$$\text{grams of NaCl} = 0.123\text{ mol NaCl} \times \frac{58.4\text{ g NaCl}}{1\text{ mol NaCl}}$$
$$= 7.18\text{ g NaCl}$$

EXAMPLE 3.18

How many grams of potassium nitrate (KNO_3) are required to prepare exactly 250 mL of solution whose concentration is 0.700 *M*?

Answer

The first step is to determine the number of moles of KNO_3 in 250 mL of solution.

$$\text{moles of KNO}_3 = 250\text{ mL KNO}_3\text{ soln} \times \frac{0.700\text{ mol KNO}_3}{1000\text{ mL KNO}_3\text{ soln}}$$
$$= 0.175\text{ mol KNO}_3$$

The molar mass of KNO_3 is 101 g, so we have

$$\text{grams of KNO}_3 = 0.175\text{ mol KNO}_3 \times \frac{101\text{ g KNO}_3}{1\text{ mol KNO}_3}$$
$$= 17.7\text{ g KNO}_3$$

Dilution

We often find it convenient to prepare a solution of a certain concentration from a more concentrated solution. This is called *dilution*. For example, suppose we wish to prepare a liter of 0.20 *M* KCl solution from a solution of 1.0 *M* KCl. This requires the use of 0.20 mole of KCl from the 1.0 *M* KCl solution. Since there is 0.20 mole of KCl in 200 mL of a 1.0 *M* KCl solution, we must withdraw 200 mL from the 1.0 *M* KCl solution (using a pipet) and dilute it to 1000 mL with water (in a one-liter volumetric flask). This gives us the desired solution of one liter of 0.20 *M* KCl. In carrying out a dilution process, it is useful to remember that adding more solvent to a solution changes (decreases) the concentration of the solution without changing the number of moles of solute present in the solution (Figure 3.6).

$$\text{moles of solute before dilution} = \text{moles of solute after dilution}$$

Since the number of moles of solute equals molarity of solution × volume of solution (from the definition of molarity), we can conclude that

$$M_{\text{initial}}V_{\text{initial}} = M_{\text{final}}V_{\text{final}}$$

where M_{initial} and M_{final} are the initial and final concentrations of the solution in molarity, and V_{initial} and V_{final} are the initial and final volumes of the solution, respectively. Of course, the *units* of V_{initial} and V_{final} must be the same.

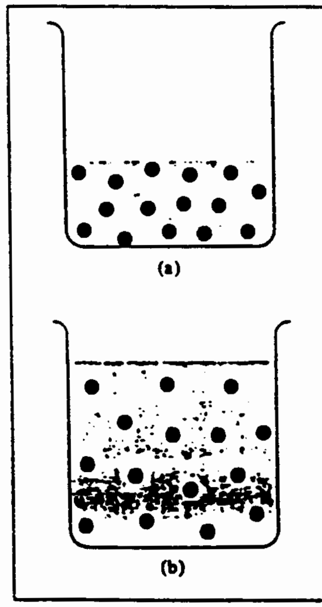

FIGURE 3.6 *The dilution of a more concentrated solution (a) to a less concentrated one (b). Note that the total number of solute particles in (b) is the same as that in (a).*

APPENDIX H
PROPOSED TOPIC MATERIAL

CHEMISTRY — Topic No. 3

Balancing oxidation-reduction equations, Gillespie, 329-334.

Please explain how to solve the problem, including an explanation of the chemistry concept and any relevant practical applications for this type of problem.

Example 9.1 Copper reacts with dilute nitric acid to give nitrogen monoxide, NO. Write a balanced equation for the reaction.

Solution

$$\underbrace{Cu + H_3O^+ + NO_3^-}_{\text{Reactants}} \longrightarrow \underbrace{Cu^{2+} + NO}_{\text{Products}}$$

We have

$$\text{Oxidation} \quad \overset{0}{Cu} \longrightarrow \overset{+2}{Cu^{2+}}$$

$$\text{Reduction} \quad \overset{+5}{N}O_3^- \longrightarrow \overset{+2}{N}O$$

Adding electrons, we have

$$\text{Oxidation} \quad \overset{0}{Cu} \longrightarrow \overset{+2}{Cu^{2+}} + 2e^-$$

$$\text{Reduction} \quad \overset{+5}{N}O_3^- + 3e^- \longrightarrow \overset{+2}{N}O$$

and the oxidation equation is balanced. But the reduction equation is not balanced.

We first balance charges by adding H^+:

$$NO_3^- + 3e^- + 4H^+ \longrightarrow NO$$

We then balance atoms by adding $2H_2O$ to the right-hand side of the equation:

$$NO_3^- + 3e^- + 4H^+ \longrightarrow NO + 2H_2O$$

The equations for both half-reactions are now balanced.

We add three times the first equation to twice the second equation to eliminate the electrons:

$$\begin{array}{lcl}
3Cu & \longrightarrow & 3Cu^{2+} + 6e^- \\
2NO_3^- + 6e^- + 8H^+ & \longrightarrow & 2NO + 4H_2O \\
\hline
3Cu + 2NO_3^- + 8H^+ & \longrightarrow & 3Cu^{2+} + 2NO + 4H_2O
\end{array}$$

This equation is the balanced equation for the oxidation-reduction reaction between Cu and dilute HNO_3 to give Cu^{2+} and NO.

Finally, we check for atoms and charges:

Left side	*Right side*
3Cu	3Cu
2N	2N
6O	6O
8H	8H
6+	6+

And we check for oxidation number changes:

$$2N(+5) \longrightarrow 2N(+2) = -6 \quad \text{and} \quad 3Cu(0) \longrightarrow 3Cu^{2+}(+2) = +6$$

Calculation of equilibrium concentrations, Gillespie, 508-510.

Please explain how to solve the problem, including an explanation of the chemistry concept and any relevant practical applications for this type of problem.

Example 14.3 Suppose we introduce 0.100 mol of H_2 and 0.100 mol of I_2 into a 10.0-L flask at 698 K. What are the concentrations of H_2, I_2, and HI at equilibrium?

Solution *The first step in solving any equilibrium problem* is to write the equation for the equilibrium reaction. In this case the reaction is

$$H_2 + I_2 \rightleftharpoons 2HI$$

The second step is to write the expression for the equilibrium constant and look up its value at the temperature of the reaction if the value is not given with the data for the problem. In this case the value $K_c = 54.4$ at 698 K has been given on page 503. Thus we can write

$$K_c = \left(\frac{[HI]^2}{[H_2][I_2]}\right)_{eq} = 54.4$$

The third step is to write expressions for the concentrations of each of the molecules present at equilibrium. We do not know these concentrations, but they are all related to each other through the balanced equation for the reaction. Suppose that when equilibrium is reached, x moles of H_2 have reacted. Then the equation shows that they must have combined with x moles of I_2 to form $2x$ moles of HI. We can conveniently write this information under the equation for the reaction:

	H_2	+ I_2	$\rightleftharpoons$ 2HI
Initial amounts	0.100 mol	0.100 mol	0 mol
Equilibrium amounts	$(0.100 - x)$ mol	$(0.100 - x)$ mol	$2x$ mol
Equilibrium concentrations	$\frac{(0.100 - x)\text{ mol}}{10.0\text{ L}}$	$\frac{(0.100 - x)\text{ mol}}{10.0\text{ L}}$	$\frac{2x\text{ mol}}{10.0\text{ L}}$

The fourth step is to substitute these concentrations in the expression for K_c and to solve for x. We have

$$\frac{(2x/10)^2\text{ mol}^2\text{ L}^{-2}}{[(0.100 - x)/10\text{ L}][(0.100 - x)/10\text{ L}]\text{ mol}^2\text{ L}^{-2}} = 54.4$$

Taking the square root of both sides of the equation and multiplying numerator and denominator by 10, we have

$$\frac{2x}{0.100 - x} = 7.38$$

Solving for x gives

$$x = 0.0787$$

Substituting this value of x in the equilibrium concentrations gives

$$[H_2] = \frac{(0.100 - 0.0787)\text{ mol}}{10.0\text{ L}} = 0.002\,13\text{ mol L}^{-1}$$

Similarly,

$$[I_2] = 0.002\,13\text{ mol L}^{-1} \qquad [HI] = 0.0157\text{ mol L}^{-1}$$

We can check these results by calculating K_c:

$$K_c = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.0157)^2}{(0.002\,13)^2} = 54.3$$

CHEMISTRY Topic No. 6

Equilibria in aqueous solutions of acids and bases, Gillespie, 516-522.

Please explain how to solve the problem, including an explanation of the chemistry concept and any relevant practical applications for this type of problem.

Example 14.8 What is the H_3O^+ concentration in a 0.20*M* solution of hydrocyanic acid, HCN? What is the percent dissociation of the acid?

Solution *First*, we write the equation for the equilibrium:

$$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$$

Second, we write the expression for the equilibrium constant and find the value of K_a from Table 14.3:

$$K_a = \left(\frac{[H_3O^+][CN^-]}{[HCN]}\right)_{eq} = 4.9 \times 10^{-10} \text{ mol L}^{-1}$$

Third, we let x mol $L^{-1} = [H_3O^+]$ at equilibrium. Then we have

	$HCN(aq) + H_2O \rightleftharpoons$	$H_3O^+(aq) +$	$CN^-(aq)$	
Initial concentrations	0.20	0	0	mol L^{-1}
Equilibrium concentrations	$0.20 - x$	x	x	mol L^{-1}

Substituting into the expression for K_a, we have

$$K_a = \frac{x^2}{0.20 - x} \text{ mol L}^{-1} = 4.9 \times 10^{-10} \text{ mol L}^{-1}$$

Since K_a is very small, HCN is only very slightly dissociated and the concentration of H_3O^+ will be very small. Therefore we assume that x is much smaller than 0.20 and can be neglected with respect to 0.20. In other words, $0.20 - x \simeq 0.20$. We then have

$$\frac{x^2}{0.20} = 4.9 \times 10^{-10}$$

$$x^2 = 0.98 \times 10^{-10} = 98 \times 10^{-12}$$

Taking the square roots of both sides, we obtain

$$x = 9.9 \times 10^{-6}$$

Therefore $$[H_3O^+] = 9.9 \times 10^{-6} \text{ mol L}^{-1}$$

We see that our assumption that $x \ll 0.2$ is certainly justified.

Since the concentration of HCN that is dissociated is equal to the concentration of $[H_3O^+]$ that is formed, 9.9×10^{-6} mol L^{-1}, the percent dissociation of the acid is

$$\frac{9.9 \times 10^{-6} \text{ mol L}^{-1}}{0.20 \text{ mol L}^{-1}} \times 100\% = 0.005\%$$

At a concentration of 0.20*M*, HCN is ionized to only a very small extent, namely, 0.005%. Thus it is an extremely weak acid. Only 5 molecules in 100.000 are ionized; the rest remain as unionized HCN molecules.

CHEMISTRY Topic No. 7

Acid-base properties of anions, cations, and salts, Gillespie, 529-533.

Please explain how to solve the problem, including an explanation of the chemistry concept and any relevant practical applications for this type of problem.

Example 14.20 What is the pH of a 0.20*M* solution of NH_4Cl?

Solution Ammonium chloride, NH_4Cl, is an ionic solid consisting of ammonium ions, NH_4^+, and chloride ions, Cl^-. The chloride ion is neither an acid nor a base, but the ammonium ion is a weak acid. We follow exactly the same steps as in Example 14.19. First, we write the equation for the reaction of ammonium ion with water:

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

The equilibrium constant is the acid dissociation constant, $K_a(NH_4^+)$. From Table 14.3 we see that $K_a(NH_4^+) = 5.6 \times 10^{-10}$ mol L^{-1}. Thus

$$K_a(NH_4^+) = \frac{[H_3O^+][NH_3]}{[NH_4^+]} = 5.6 \times 10^{-10} \text{ mol L}^{-1}$$

Now we obtain an expression for each of the concentrations by letting $[H_3O^+] = x$ mol L^{-1}:

	$NH_4^+ + H_2O$	$\rightleftharpoons H_3O^+$	$+ NH_3$	
Initial concentrations	0.20	0	0	mol L^{-1}
Equilibrium concentrations	$0.20 - x$	x	x	mol L^{-1}

Therefore

$$\frac{x^2}{0.20 - x} \text{ mol L}^{-1} = 5.6 \times 10^{-10} \text{ mol L}^{-1}.$$

Making the usual approximation that $x \ll 0.20$, we have

$$\frac{x^2}{0.20} = 5.6 \times 10^{-10}$$

Solving for x gives

$$x = 1.1 \times 10^{-5} \text{ and } [H_3O^+] = 1.1 \times 10^{-5} \text{ mol L}^{-1}$$

Therefore

$$pH = -\log(1.1 \times 10^{-5}) = 4.96$$

CHEMISTRY Topic No. 8

Mole method, Chang, 65-69.

Please explain how to solve the problem, including an explanation of the chemistry concept and any relevant practical applications for this type of problem.

EXAMPLE 3.14

The chief ingredient of milk of magnesia is magnesium hydroxide, $Mg(OH)_2$. Being a base, it neutralizes the excess acid—largely hydrochloric acid (HCl)—in our stomachs. The reaction is

$$Mg(OH)_2(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + 2H_2O(l)$$

If 16.1 g of $Mg(OH)_2$ is treated with 11.0 g of HCl, how many grams of $MgCl_2$ could be produced? Which compound is the limiting reagent? Calculate the mass of the excess reagent remaining at the end of the reaction.

Answer

As in Example 3.13, our first step is to convert the masses of the reactants into number of moles. The molar masses of $Mg(OH)_2$ and HCl are 58.3 g and 36.5 g, respectively. Thus

$$\text{moles of } Mg(OH)_2 = 16.1 \text{ g } Mg(OH)_2 \times \frac{1 \text{ mol } Mg(OH)_2}{58.3 \text{ g } Mg(OH)_2} = 0.276 \text{ mol } Mg(OH)_2$$

$$\text{moles of HCl} = 11.0 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}} = 0.301 \text{ mol HCl}$$

From the balanced equation we see that 1 mol $Mg(OH)_2 \simeq 2$ mol HCl. We now divide the actual number of moles of $Mg(OH)_2$ and of HCl by the coefficients shown in the equation:

$$\frac{0.276 \text{ mol } Mg(OH)_2}{1} = 0.276 \text{ mol } Mg(OH)_2 \qquad \frac{0.301 \text{ mol HCl}}{2} = 0.151 \text{ mol HCl}$$

Thus HCl must be the limiting reagent because a smaller proportionate amount of this substance was supplied in the reaction (0.151 mole is smaller than 0.276 mole). The number of moles of $MgCl_2$ produced is

$$\text{moles of } MgCl_2 = 0.301 \text{ mol HCl} \times \frac{1 \text{ mol } MgCl_2}{2 \text{ mol HCl}}$$
$$= 0.151 \text{ mol } MgCl_2$$

Next, the amount in grams of $MgCl_2$ produced is given by

$$\text{mass of } MgCl_2 = 0.151 \text{ mol } MgCl_2 \times \frac{95.3 \text{ g } MgCl_2}{1 \text{ mol } MgCl_2}$$
$$= 14.4 \text{ g } MgCl_2$$

The number of moles of the reagent $Mg(OH)_2$ left over is found as follows:

$$\text{moles of } Mg(OH)_2 \text{ left over} = 0.276 - 0.151 = 0.125 \text{ mol } Mg(OH)_2$$

The mass of $Mg(OH)_2$ left over can now be calculated:

$$\text{mass of } Mg(OH)_2 \text{ left over} = 0.125 \text{ mol } Mg(OH)_2 \times \frac{58.3 \text{ g } Mg(OH)_2}{1 \text{ mol } Mg(OH)_2}$$
$$= 7.29 \text{ g } Mg(OH)_2$$