A COMPARISON OF THREE LEVELS OF DIAGNOSTIC-PRESCRIPTIVE REMEDIATION OF STUDENT MISCONCEPTIONS RELATING TO STOICHIOMETRIC CALCULATIONS

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A Comparison of Three Levels of Diagnostic-Prescriptive Remediation of Student Misconceptions Relating To Stoichiometric Calculations

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by

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ABSTRACT

The purpose of this study was to compare three levels of diagnostic-prescriptive treatment for the remediation of students' misconceptions relating to a hierarchy for stoichiometric calculations. This hierarchy was validated by a previous researcher (Whelan, 1982).

The sample consisted of 220 subjects drawn from 13 intact Level II chemistry classes in five Newfoundland high schools. Following regular classroom instruction in stoichiometry, a diagnostic test was administered. Three treatment groups were formed in each class by stratified random assignment based on ranked scores from this test. Each student was remediated on skills which he/she had failed on the pretest. Remediation was through an individualized student booklet, a different version of which was administered to each group. One level of remediation (treatment A) consisted of instructional content sequenced in the order that skills in the hierarchy appeared on the pretest (non-hierarchical arrangement). A second level of remediation (treatment B) involved an instructional booklet in which direct reference to the learning hierarchy was made throughout, and instructional content was sequenced in the order of skills in the hierarchy. The third level of remediation (treatment C) consisted of the hierarchical arrangement of treatment B, with an additional feature - the identification of specific student misconceptions as part of the remediation. A posttest,

parallel in construction and content to the first, was administered 1-3 days after the remedial session.

Two null hypotheses were tested. Hypothesis 1 relates to hierarchical versus non-hierarchical arrangement of remedial content, in effect comparing treatments A and B with regard to achievement gains following remediation. Hypothesis 2 relates to remediation employing the identification of specific student misconceptions versus remediation not employing student misconceptions, in effect comparing treatments B and C. Analysis of covariance revealed that there was no significant difference in achievement gains among the three treatment groups ($p > .05$). However, post hoc analysis yielded a group of non-remediated students whose achievement gains were significantly less than those of the treatment groups.

Patterns of responses on the pretest and post-test were also analyzed and reported with regard to misconceptions and overall improvement on specific skills. Again no significant differences in treatment groups were found, but group C consistently showed the greatest gains in the analyses based on treatment.

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This thesis is dedicated to my father, Angus Cooke, who devoted his life to education and taught me to value learning, to my children, Sandra and David, and to God, the Ultimate Source of all strength and knowledge.

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CHAPTER 1

The Problem

Introduction

Despite the most conscientious efforts of teachers, students often fail to exhibit the intended outcomes of instruction. While individual differences in ability and learning styles are generally recognized, the limitations of time and human resources have tended to perpetuate the practice of group instruction, with only incidental attention given to individual needs and abilities. Within such a framework individual differences are exhibited most notably through differential achievement. As test scores reveal learning deficiencies, corrective measures can be employed to attempt to remedy these inadequacies, again subject to the constraints mentioned earlier. Such corrective action constitutes remediation.

Remediation may be defined as any effort at correcting partially or totally recognized deficiencies in learning. Remedial teaching is generally identified with the treatment of serious learning disabilities, especially in the basic skills of reading and arithmetic. Outside this specialist domain exist more general remediation activities employed by classroom teachers in the normal course of teaching in the content areas. Such remediation strategies may vary from a mere reteaching of content, to individually prescribed remediation schedules based upon diagnosed student errors. This latter case forms the focus of this study. In particular, the use of Gagné's learning hierarchy model for this purpose is investigated.

Theoretical Background

Teachers in all educational settings are concerned with the progress of individual students toward a desired standard of competence in any given subject area or unit of study. In all but prohibitively large classes, the teacher monitors the progress of each individual by informal and formal measures, the most common form of the latter being the examination. Characteristically the teacher finds that few, if any, of the students have mastered all of the required elements of the content. In view of the fact that much of the content of teaching is cumulative in nature, some attempt at correction of student misconceptions is desirable before proceeding to the next topic.

Corrective strategies employed by teachers represent a broad spectrum which may be characterized by three general levels. At one extreme is the practice that might be termed 'general remediation', or simply reteaching or reviewing the content with an entire class. A second level involves more specific remediation with smaller groups of students exposed to specific aspects of the content where difficulties were exhibited. The third level is represented by specific remediation applied individually and to the individual's unique pattern of misconceptions relating to the topic in question. This is the realm of diagnostic-prescriptive remediation (DPR).

Diagnostic-Prescriptive Remediation

Diagnostic-Prescriptive Teaching (DPT) is generally associated with individualized instruction formats. Charles (1980) suggests that DPT consists of four parts:

> 1. Establishing objectives ... groups of behavioral statements describing educational interests.
> 2. Diagnosis ... ascertaining which objectives the student has reached and which he has not.
> 3. Prescription ... describing activities to be undertaken that will lead to objectives as yet unreached.
> 4. Criterion measurement ... determining whether the student, after completing the prescribed activities, has reached intended objectives. (p. 95)

Furthermore, according to Charles, the first three aspects "give DPT its unique quality as a method of individualizing instruction" (p. 95).

The components of a mastery teaching strategy outlined by Okey (1974) and termed a 'diagnostic/remedial instructional system' by Yeaney and Miller (1983) are as follows:

STEP 1: Specify performance objectives.

STEP 2: Develop diagnostic measures for objectives.

STEP 3: Teach using any preferred procedures.

STEP 4: Test achievement of objectives using diagnostic measures.

STEP 5: Remediate and rediagnose, if desired.

STEP 6: Administer summative test.

(Yeaney & Miller, 1983, p. 19).

The difference between diagnostic-prescriptive teaching as described by Charles (1980) and diagnostic-prescriptive remediation as represented above, is essentially at what point and for what purpose diagnosis takes place. In DPT diagnosis takes place prior to instruction and becomes the basis for the placement of students in an instructional setting. In DPR, diagnosis takes place following normal instruction and becomes the basis for determining appropriate remediation activities for an individual or a group. There is some similarity in the two models outlined above; Steps 1 and 4 of both strategies are identical. Steps 5 and 6 of the diagnostic/remedial system could logically follow after Step 4 of Charles' DPT system. Indeed, most individualized instruction strategies, including the Personalized System of Instruction (PSI) and the Individually Prescribed Instruction (IPI) System, employ diagnostic-prescriptive remediation cycles within a diagnostic-prescriptive teaching format. For the purposes of the present study, however, the diagnostic-prescriptive strategy is applied only to remediation following regular group instruction. This is consistent with many of the studies involving diagnostic/remedial instruction in science reported by Yeaney and Miller (1983). A comparison of the DPT, DPR, and Mastery models is presented in Figure 1.

Hierarchies of Intellectual Skills

Many scientific concepts belong to the domain of learning referred to by Gagné (1970) as 'intellectual skills'. Gagné suggests that learning of such skills requires prior learning of prerequisite tasks and that analysis of the prerequisite or subordinate skills related to the acquisition of a target intellectual skill would yield a hierarchical organization. Such structures constitute learning hierarchies which may serve as the basis for sequencing content and instruction (Gagné, 1970).

A learning hierarchy is derived by asking the question, "What must the learner be able to do if he is to achieve a particular new intellectual skill?" Beginning with the target skill, the answer to this question reveals a prerequisite or subordinate skill necessary for the learning of the target skill. Successively asking the same question for each new intellectual skill produced results in a learning hierarchy. A hierarchy may be linear or branched, any branch implying that several skills may be considered directly prerequisite to the next higher one.

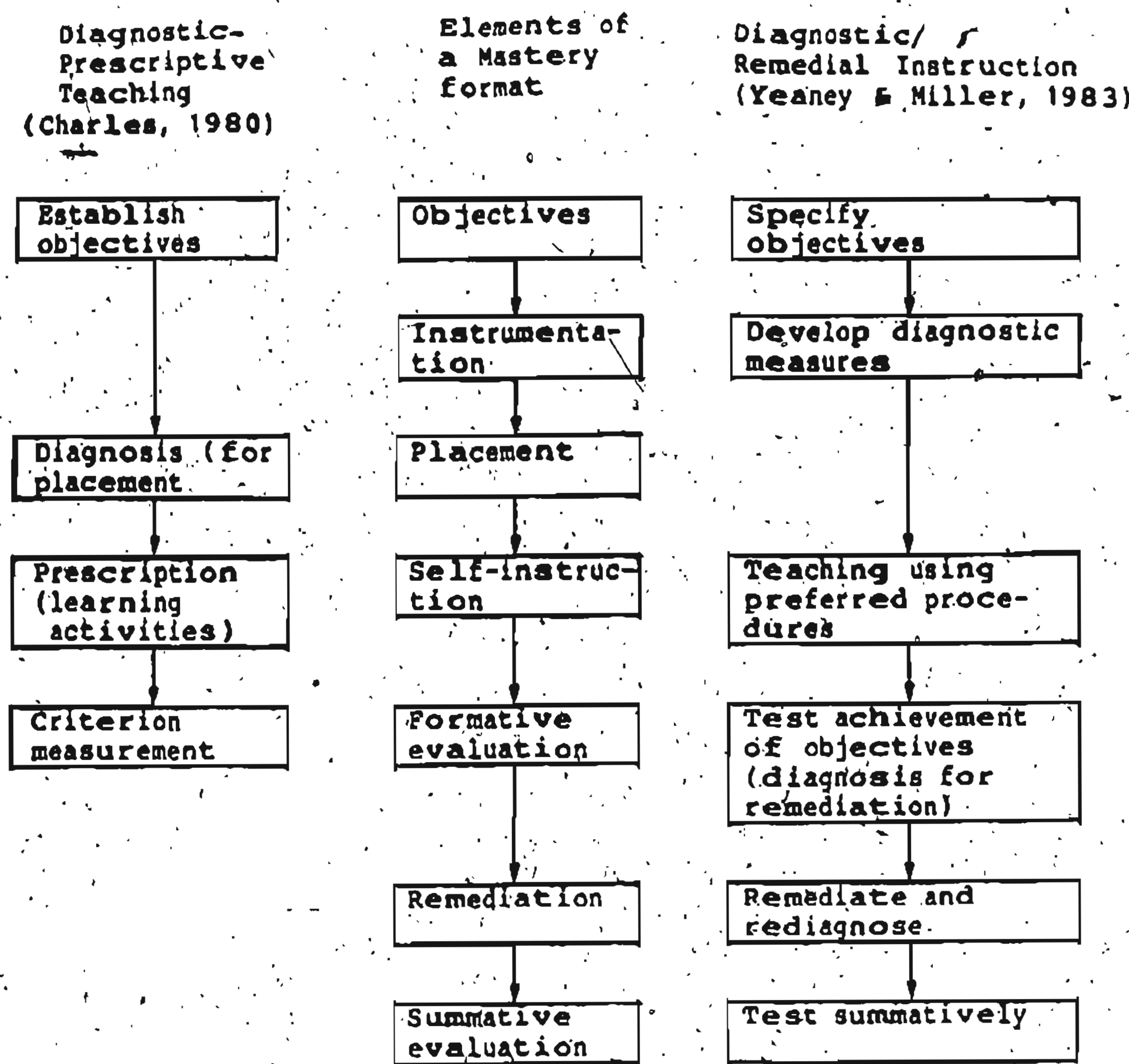

Figure 1. A comparison of diagnostic-prescriptive teaching according to Charles (1980) and diagnostic/remedial instruction according to Yeaney and Miller (1983), showing how elements of both are integrated into an individualized mastery format.

An example from Okey and Gagné (1970) serves to illustrate the learning hierarchy model (See Figure 2). In this example, the target skill (Skill I) was "Solve solubility product problems." By asking the hierarchy generating question, "What must the learner be able to do ...?", three directly prerequisite skills (Skills IIa, b, c) were identified. Each exists in a subordinate-superordinate relationship with the terminal skill. Asking the same question of each subordinate skill yields further skills which are subordinate to it. In the example cited above, four skills were found to be prerequisite to skill IIa, as depicted in Figure 2. Such an analysis continues until one has identified the capacities that can be assumed to be present in the learners to whom the hierarchy is applicable (Gagné, 1970).

Task analysis of this sort followed by diagnostic testing can be used as the basis for placement of students within a learning sequence. Diagnostic testing following instruction, or 'formative' testing (Bloom, Hastings, and Madaus, 1971), serves to identify areas of weakness or difficulty within the learning sequence, and can suggest appropriate corrective or remedial action.

Some research has been conducted in the remediation of subordinate skills in a learning hierarchy (Piel & Okey, 1975; Griffiths, 1979, 1982; Grant, 1983; Pottle, 1982; Whelan, 1982). However, the extent of the diagnosis

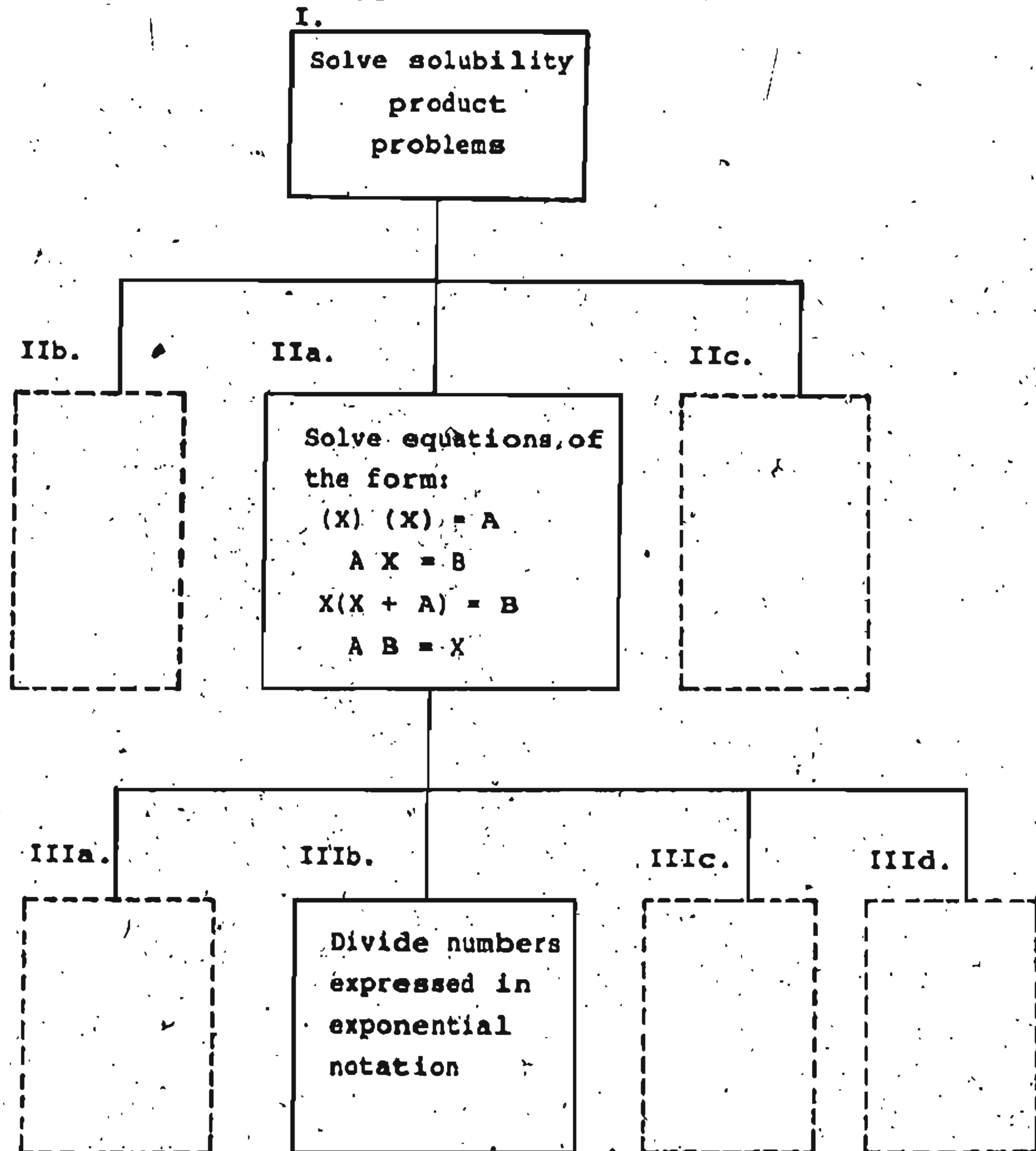

Figure 2. Part of the learning hierarchy for 'Solubility product calculations' from Okey and Gagné (1970, p. 323). (Pairs of intellectual skills in a Superordinate-Subordinate relationship are Skills I and IIa, I and IIb, I and IIc, IIa and IIIa, IIa and IIIb, etc.)

has generally been limited to the identification of those sub-skills which required remediation. No research has investigated the remediation of specific student misconceptions within each failed sub-skill.

Misconceptions Remediation

The identification of students' specific misconceptions in science has recently become a major focus of attention in the science education literature. However, much of the research has been concerned with misconceptions of rather broad concepts, such as heat (Erickson, 1979, 1980), gravity (Gunstone & White, 1981), earth (Nussbaum & Novak, 1976; Nussbaum, 1979), and life (Brumby, 1982). In science education an important class of concepts appears to be different from those listed above, concepts belonging to a domain of learning referred to earlier, namely, 'intellectual skills' (Gagné, 1970). According to Griffiths, Pottle, and Whelan (1983), "such concepts are more narrowly defined in terms of specific operations, and are typically encountered for the first time in school learning" (p. 5). Examples of such concepts are the 'mole' in chemistry, 'density' in physics, and the 'food web' in biology.

According to Gagné (1970) the critical factor in successful learning of intellectual skills is the learner's ability to recall and apply the subordinate skills which are necessary for, and/or facilitate, the learning of the superordinate skill. As suggested earlier, intellectual skills, when analysed in terms of their prerequisite sub-skills, can be represented in learning hierarchies. Such a hierarchy suggests an ideal sequencing of instruction in subordinate skills for the acquisition of the target intellectual skill. Misconceptions in performing the target skill may be related to inadequate learning of subordinate skills. Further analysis of student responses on tests of subordinate skills may yield misconceptions which inhibit the acquisition of these skills. Some misconceptions may thread through a number of subordinate skills, some may be unique to the skill in question, and others may be outside the scope of the hierarchy. Examples of each are described in Griffiths and Grant (1983) and Griffiths, Pottle, and Whelan (1983). Such data represent a potentially valuable resource for the remediation of student misconceptions in specific topics in science.

Statement of the Problem

For the purposes of this study, three levels of diagnostic-prescriptive remediation were identified. These represent three treatment levels for the remediation of learning deficiencies identified by a diagnostic pretest. The extent of the diagnosis, and hence the nature of the prescribed remediation, varies among the treatment groups. The remediation in each case is conducted via an individualized student booklet. Level A involves non-hierarchical organization of content in the student booklet. Skills covered are arranged in the same sequence as corresponding test items appear on the pretest. Level B involves remediation based on a learning hierarchy. Skills in the student booklet for this treatment are arranged hierarchically and reference to the hierarchy is made throughout. The remediation for Level C is identical to that for Level B above, but in addition, specific student misconceptions are identified for each student, and these become the focus of the remediation. A detailed discussion of the three remedial treatments is presented in Chapter 3.

The problem is to investigate which, if any, of the diagnostic-prescriptive approaches to the remediation of failed skills relating to a particular topic in science, namely, stoichiometry, will result in greater gains in student achievement. The unique feature of this study is the diagnosis and remediation of specific student misconceptions relating to failed skills, which constitutes one of the levels of treatment.

The foregoing discussion suggests the testing of the following null hypotheses:.

With reference to the remediation of failed skills in a learning hierarchy related to stoichiometric calculations, Hypothesis 1: There will be no significant difference in achievement gains between students who receive diagnostic-prescriptive remediation hierarchically arranged and students who receive similar remediation non-hierarchically arranged.

Hypothesis 2: There will be no significant difference in achievement gains between students who receive diagnostic-prescriptive remediation in which specific student misconceptions are identified and students who receive diagnostic-prescriptive remediation in which misconceptions are not identified.

Need for the Study

An understanding of stoichiometry and the correct performance of stoichiometric calculations are central to success in introductory chemistry courses. These are integrally related to an understanding of the mole concept, a major theme of modern high school chemistry courses. Yet this is an area of difficulty for many students. Johnstone (1980) reports that stoichiometry was one of the main areas of difficulty identified by students entering first-year chemistry in two Scottish universities. Novick and Menis (1976) suggest that students cannot use the mole concept effectively in solving problems based on it. Others including Hudson (1976) and Bleam (1981) report similar findings.

A variety of approaches has been proposed for teaching stoichiometry, from the 'fruit basket analogy' (Bleam, 1981) to the 'mole triangle' (Ruda, 1978), none of which have met with much success. Whatever strategy is employed it seems that students require some degree of remediation in this topic. Chiappetta and McBride (1980) investigated a general remediation strategy for correcting deficiencies related to stoichiometry, again with little success. Whelan (1982) validated a learning hierarchy for stoichiometric calculations; in the course of his study he found the hierarchy to be a moderately effective tool in remediating failed skills. This remediation strategy deserves further investigation and serves as the framework for the present study.

Student misconceptions in any learning situation are a major source of concern for educators. While recent studies have attempted to identify misconceptions, little research has focused on their remediation. This study, while recognizing that misconceptions may be an inevitable consequence of group instruction, addresses a need widely identified by teachers - the need for manageable remediation strategies that focus on individual student misconceptions.

Definition of Terms

Chemistry Pretest: an instrument which tests the seven intellectual skills in a validated learning hierarchy for stoichiometric calculations. The test consists of fourteen items, two items per intellectual skill tested. This test is reproduced in Appendix 1.

Chemistry Posttest: a test identical in structure to the Chemistry Pretest, containing items parallel to those used in the Chemistry Pretest. This test is reproduced in Appendix 2.

Instructional Booklet A: a written booklet containing instruction and practice questions representing each intellectual skill in the learning hierarchy, and arranged in the same sequence as skill test items appear on the Chemistry Pretest/Posttest. No reference is made to the learning hierarchy in this booklet. This booklet is reproduced in Appendix 3.

Instructional Booklet B: a written booklet containing instruction and practice questions representing each intellectual skill in the learning hierarchy, and arranged in the same sequence as the skills in the learning hierarchy. Reference to the hierarchy is made throughout the booklet. This booklet is reproduced in Appendix 4.

Instructional Booklet C: a written booklet identical in content and sequence to Booklet B. In addition, a page is inserted at the beginning of each skill failed by the particular student which identifies the student's specific misconception in that skill as diagnosed by the Chemistry Pretest.

Learning Hierarchy: an arrangement of intellectual skills which are related to others in subordinate-superordinate relationships wherein each subordinate skill is logically and empirically necessary for the learning of the superordinate skill and exhibits transfer of learning to its immediately superordinate skill. The learning hierarchy upon which this study is based was validated by Whelan (1982) and relates to the skills involved in stoichiometric calculations. Minor revisions have been made in that validated hierarchy, as will be discussed in Chapter 3.

Misconception: an error or misunderstanding related to the incorrect assimilation or application of formally taught rules or concepts, generated during, or as a result of, instruction.

Diagnosis: the process of identifying an individual's areas of difficulty, and/or the underlying causes of difficulty, for a particular learning topic.

Prescription: the process of delivering to an individual or a group a learning strategy designed to rectify the deficiencies identified by a diagnosis.

Remediation: any corrective action aimed at the improvement of student achievement following normal instructional procedures in a course of study.

Diagnostic-Prescriptive Remediation (DPR): any remediation strategy prescribed for an individual or a group on the basis of diagnosed areas of difficulty or underlying misconceptions in a topic of study, following regular instructional procedures.

Stoichiometry: quantitative relationships between all reactants and products in a chemical reaction. In the present study only mass and mole quantities are considered.

Mole: the amount of substance which contains as many elementary entities as there are carbon atoms in 0.012 kilogram of carbon-12.

Delimitations of the Study

A major delimitation of this study is the content area and topic, namely, stoichiometry, which formed the basis of the research. Any effects identified as a result of the remedial treatments may not be generalizable to other concepts in chemistry, in science, or in other subject areas.

The test items represent another delimitation as they were designed for this study by the author. It is possible that more effective test items could have been constructed, although every effort was made to ensure that the test was valid and reliable. A further delimitation was the choice of distractors in the multiple choice items. While five or six choices were given for each item, it is possible that other misconceptions or errors occurred which did not appear in the respondents' item choice selection.

Limitations of the Study

The open-ended, free-response questions represent a limitation of this study. In one level of treatment, the researcher was required to interpret the students' written problem-solving methods recorded on the test paper, and to diagnose specific student misconceptions. It is possible that where uncertainty occurred, a student may have been diagnosed, and thus remediated, incorrectly, though such cases were analysed by other science educators in an attempt to ensure an objective assessment of the students' work.

A major limitation of this study was the constraints of time available for in-class testing and remediation. If a student did not complete the pretest, his/her performance on those skills represented in the latter items on the test could not be assessed nor diagnosed. This might have made the prescribed remediation less effective. With regard to the remedial class period, students who were remediated for a high number of skills (three or more) may not have had time to complete the required remediation. This might have affected performance on the posttest, although it must be noted that, given the stratified design of this research, these effects should be equal for all groups.

One further limitation concerns the variation in response pattern observed in some respondents. Ideally for a given skill, except for guessing, a student should get both items correct or both incorrect. However, because individual test items representing the same skill may not have been identical in structure and presentation, some variation in response pattern was evident. Again, the stratified design of the research should minimize the effect of this factor on the dependent variable. In any case the differences in these test items were not major.

Summary

The general problem of remediation of intellectual skills has been discussed. A method of treatment based on a validated learning hierarchy and diagnostic-prescriptive remediation has been proposed for overcoming students' misconceptions in the learning of stoichiometry.

CHAPTER 2

Related Research

Since this study investigates a diagnostic-prescriptive approach to the remediation of student misconceptions utilizing a learning herarchy, three terms - remediation, hierarchy, and misconceptions - provide the framework for the review of literature presented below. Studies related to general remediation are summarized first, including studies of pure and modified mastery-type formats with their built-in remediation cycles. Research on various types of diagnostic-prescriptive remediation strategies completes the review of general remediation literature. Studies on remediation related to learning hierarchies are reviewed next, followed by a summary of misconceptions studies, particularly those dealing with misconceptions identification through learning hierarchies. Remediation in this latter context is the concluding focus of this chapter, and is the setting for the current study.

Remediation in Science Teaching

There exists a substantial body of research which supports the hypothesis that remediation of some sort has a positive effect on student achievement in science. Swanson and Denton (1977) reported significant increases in student achievement among 53 high school chemistry students when remediation treatments patterned on mastery strategies (PSI and Learning-for-Mastery) were employed. Yeaney, Dost, and Matthews (1980) studied differences in achievement between two groups of undergraduate biology students, one of which received remedial assignments when necessary, and one group which acted as a control and received no remediation. Overall achievement was significantly higher ($p = .04$) for the remediated group. Dillashaw and Okey (1983) compared two remediation strategies with a control group which received no remediation and reported findings in favor of remediation. Other researchers, including Thompson (1941), Fiel and Okey (1975), Kulik, Kulik, and Hertzler (1977), and Long, Okey, and Yeaney (1978), have reported studies in support of the value of remediation in student achievement.

Several studies do not concur with this general finding. Chiappetta and McBride (1980) found that general remediation did not significantly increase student achievement among 9th grade physical science students (N = 99). Leuckemeyer and Chiappetta (1981) reported insignificant differences between remediation versus no-remediation strategies in a high school human physiology unit. Fiel and Okey (1975) cited several studies which failed to support the value of remedial instruction, but concluded, "Those studies which failed to produce significant improvement employed additional practice (more of the same instruction) as remediation," (p. 253) and that the form of the remedial instruction was the critical factor.

Yeaney and Miller (1983), in a meta-analysis of diagnostic/remedial studies, found that student achievement was significantly and positively influenced by remediation, but that feedback alone accounted for a considerable portion of the effect. It would seem then that remediation per se is not always effective in enhancing student achievement and that other factors may be influential in the effectiveness of remedial instruction. Research on some of these factors will be considered below.

Remediation in Mastery-type Formats

A significant portion of the research in remediation has taken place within the context of mastery-type instructional formats, such as Bloom's Learning-for-Mastery (LFM) (Bloom, 1968) and Keller's Personalized System of Instruction (PSI) (Keller, 1968), more particularly the former. In such strategies, diagnosis usually takes place prior to instruction for the purpose of placement of students, and additionally, diagnostic tests, or formative tests, are administered following instruction to determine whether the student has mastered the instructional objectives, and hence to prescribe remedial activities where necessary. This suggests a "unit-perfection requirement for advancement, which lets the student go ahead to new material only after demonstrating mastery of that which preceded it" (Keller, 1968, p. 7).

Bloom (1968) postulated that through a mastery strategy 90% of students could achieve criterion mastery in a given unit of study. This is effected by unlimited opportunity for correction of errors, thus ensuring mastery before proceeding. While mastery formats have been generally effective, their success has not been to the extent expected and their results have sometimes been inconsistent. Swanson and Denton (1977) found that subjects in both Learning-for-Mastery and PSI groups had significantly greater retention gains when compared with a non-remediated control group, although immediate achievement was not significantly different. Kulik, Kulik, and Hertzler (1977) found that, in PSI modular college biology, required remediation raised student achievement and reduced variation in end of course achievement, though differences in ability were reflected in rate of course work. Dillashaw and Okey (1983) found that a modified mastery learning strategy was effective in increasing student achievement, though the effect of increased on-task behavior was also noted. Okey (1973) reported that mastery-taught students achieved higher than non-mastery students, but differences were significant in only one of twenty-one units of study. Merrill (1970) studied various mastery formats with no significant differences reported for test efficiency and accuracy. Chiappetta and McBride (1980) and Leuckemeyer and Chiappetta (1981) reported studies employing mastery learning formats with limited remediation opportunities, but acknowledged no significant differences when compared with control groups. While most of the studies cited above are supportive of the hypothesis of greater student achievement through mastery strategies, the observed gains are often inconsistent with those predicted.

Remediation in Modified Mastery Formats

In reference to Bloom's Mastery learning strategy, Dillashaw and Okey (1983) suggest that the reason that such strategies have not gained wide acceptance is "perhaps because of the time inherent in cycling students through the diagnosis-remediation loop until complete mastery of instruction is accomplished" (p. 203). They further suggest that limiting the number of diagnostic-remediation loops may make the mastery format more feasible. While Dunkleberger and Heikkinen (1983) claim that "the single most important component in Bloom-type mastery learning strategies is the feedback/correction procedures" (p. 556), Chiappetta and McBride (1980) maintain that "one element of this strategy, that of feedback and correctives, needs modification" (p. 609). Swanson and Denton (1977) express a similar reservation: "The additional time necessary for recycling may be considered a limitation of remediation strategies and mastery learning in general" (p. 522).

Some of the research in remediation has utilized just such a modified mastery format, usually involving some limitation of the diagnostic/remediation cycling process. Thompson (1941) reported significant gains in mathematics achievement among 7th grade students who were given 3 opportunities to remediate and re-test. Dillashaw and Okey (1983) found that two cycles of diagnosis/remediation were sufficient to significantly increase achievement in grade 9 chemistry (N = 156), though the interactive effect of increased on-task behavior was recognized. Merrill (1970) compared a strategy with only one opportunity for diagnosis/remediation recycling, with a remediation format requiring mastery. He found that the greater opportunity for remediation supported greater achievement. Chiappetta and McBride (1980) modified the mastery format by providing general rather than objective-specific remediation, but reported that no significant difference in achievement was effected. Leuckemeyer and Chiappetta (1981) compared a limited remediation treatment with a traditional no-remediation treatment. They found only a small degree of improvement in student achievement and no reduction in variation among students in end-of-course achievement.

Diagnostic-Prescriptive Remediation (DPR)

Many of the studies cited above are consistent with a diagnostic-prescriptive remediation strategy outlined by Yeaney, Dost, and Matthews (1980) as follows:

1. The instructor defines expectations in terms of student postinstruction outcomes (i.e., instructional objectives).
2. Test items are prepared that correspond to the instructional objectives.
3. Instruction is planned and carried out to help students achieve the objectives. Any materials may be used and any appropriate teaching procedures may be followed.
4. Diagnostic tests related to the objectives are given either before or after instruction, or both. The tests are short and are given frequently so that learning problems are quickly identified.
5. Students are provided feedback on how they performed on the diagnostic tests. Remedial work is prescribed for students who do not achieve an objective.
6. Additional cycles of instruction-diagnostic testing-remediation may be carried out with either individuals or groups (conditions may preclude taking all students to mastery). (pp. 537-538).

A diagnostic-prescriptive activities model (Yeaney, et al., 1980, p. 538) further elaborates the spectrum of cases that may fall under the umbrella of DPR. Such cases may vary on both the dimensions of diagnosing and remediating (prescribing). Studies dealing specifically with diagnostic-prescriptive remediation will be reviewed below.

Long, Okey, and Yeaney (1978) studied DPR with student-directed versus teacher-directed remediation, finding that the latter yielded significant differences over the control group. However, no consistency in favor of student- or teacher-directed remediation was found in three units of study. A similar study by Long, et al. (1979) was similarly inconclusive. Dillashaw and Okey (1983) also investigated DPR comparing student-directed and teacher-directed remediation, but found no significant difference between the results of the two treatments.

Several studies investigated the effect of different levels of remediation on student achievement. Piel and Okey (1975) found that remediation which consisted of additional instruction on missed skills was significantly more effective than remediation consisting of practice on the skill itself. Merrill (1970) investigated repeat presentations as remediation compared with specific review, but found no significant difference in efficiency or accuracy in test taking as a result. Chiappetta and McBride (1980) opted for general rather than objective-specific remediation. "The idea was that general remediation over a unit's objectives for students who do not achieve at the prescribed level of mastery would be easier for teachers to implement than over specific objectives." (p. 612). However, even with two remediation opportunities, there was no significant difference in achievement between the treatment and control groups.

Required versus optional remediation assignments was the focus of a study by Sundberg, Malott, Ober, and Wysocki (1978) within the context of a PSI psychology course. While the required remediation, with its mastery criterion, tended to produce higher student performance, in all treatment groups it seems that the criterion requirement of an A grade controlled performance considerably. Thus, remediation per se was not a critical component of the PSI course under study. Initial quiz performance was generally high, perhaps related to the "potentially aversive events involved with remediation" (p. 96), such as students having to take a remedial quiz and thus slowing their course progress.

The inability of DPR studies to produce consistent results is evident from the foregoing discussion. Many of these studies were among those 'meta-analysed' by Yeaney and Miller (1983); their conclusions are illustrative of the kind of general direction and qualification of the DPR research:

> On the basis of the available research findings, it appears that achievement can be significantly and positively influenced through diagnostic/remedial instruction. The magnitude of this influence can be expected to be about 0.55 standard deviation units of achievement when compared to an instructional strategy that does not employ diagnosis and remediation. The surprising result in this study is the source of the impact: It does not appear to be the remediation but rather the diagnostic feedback. (pp. 24-25)

Remediation Related to Learning Hierarchies

Several studies have incorporated a learning hierarchy as the basis for a remediation strategy. Wiegand (1969) studied subordinate skills in science problem-solving and found that students who attained required subskills following an initial test which indicated that these skills were absent, were then able to perform the final task successfully. Fiel and Okey (1975) compared two remediation strategies. The first consisted of additional instruction on prerequisite skills in a learning hierarchy, while the second consisted of additional practice on the final skill. Using a sample of 90 eighth-grade general science students, Fiel and Okey reported a significant gain in achievement for those subjects receiving additional instruction on prerequisite skills.

They concluded that "the results support Gagné's hypothesis that learning intellectual skills requires the mastery of prerequisite tasks and that additional study on the prerequisites will be more effective than additional practice of the final tasks themselves" (p. 255).

Okey and Gagné (1970) investigated the use of a learning hierarchy in the revision of a science topic. Instructional materials, followed by a diagnostic test to identify failed skills, were administered to one group of subjects. Revised instructional materials, with additional instruction on the skills failed by Group 1, were given to a second treatment group. Significant differences in student achievement were reported for Group 2 as compared to Group 1. Though remediation based on specific skills was not involved in this study, the research reported by Okey and Gagné supports the utility of a learning hierarchy in the improvement of instruction, and hence in the improvement of student achievement.

Whelan (1982) used a proposed learning hierarchy for stoichiometric calculations as the basis for remediation of failed skills, in an attempt to validate the hierarchy by a 'transfer of learning' criterion. A diagnostic test was administered to 180 grade 10 chemistry students following normal classroom instruction on stoichiometry. The diagnosis was followed by a remedial session in which each student was given an individualy prepared version of a remedial booklet keyed to those skills in the hierarchy diagnosed as not mastered, and designed to give additional instruction on those skills. A parallel achievement measure was administered to all students following the remedial period. Whelan did not report his results as overall achievement gains, but he did report significant gains between tests for each skill in several of the hierarchical links. Grant (1983) and Pottle (1982) carried out similar studies, the former using a 'food web' hierarchy, and the latter, a 'conservation of mechanical energy' hierarchy. Similar results were obtained.

Whelan (1982), Grant (1983), and Pottle (1982) also identified student misconceptions associated with each of the skills in their respective hierarchies. These misconceptions were not the direct focus of the remediation activities. However, the potential value of the misconceptions data for remediation is noted by Griffiths, Pottle, and Whelan (1983) who suggest that "the difficulties experienced by particular students may be more readily remedied if they can be specifically identified and related to the context of the overall hierarchy" (p. 16). Since the present study takes this direction, that of identification and remediation of specific student misconceptions, attention will now be directed to the misconceptions literature.

Misconceptions Identification

A considerable body of research dealing with student misconceptions in science has emerged recently. The bulk of this work concerns "naive conceptions" (Champagne, Gunstone, and Klopfer, 1983), which are "descriptive and explanatory systems for scientific phenomena that develop before [students] experience formal study of science", and which are "remarkably resistant to change by exposure to traditional instructional methods" (p. 174). The term 'alternative frameworks' has been used to describe such "autonomous frameworks for conceptualizing ... experience of the physical world" (Driver and Easley, 1978, p. 62) and "beliefs which differ from the currently accepted view and from the intended outcomes of learning experiences" (Driver, 1981, p. 94). While the term 'misconceptions' has been used synonymously with 'alternative frameworks', 'preconceptions', 'naive conceptions', or 'alternative conceptions' in some contexts (e.g., Nussbaum and Novick, 1982), a distinction can be made between those terms described above, and those "misunderstandings of concepts which are typically encountered for the first time in formal learning" which may be more definitively called 'misconceptions' (Griffiths, et al., 1983, p. 2). Driver and Easley (1978) distinguish between 'alternative frameworks' and 'misconceptions' in that the latter is a term that "tends to be used in studies where pupils have been exposed to formal models or theories, and have assimilated them incorrectly" (p. 62). For the purposes of this study, these delimiters on the term 'misconceptions' will apply.

Much of the research investigating students' misconceptions and alternative frameworks in science has dealt with concepts that fall into the latter category. Erickson (1979, 1980) used clinical interviews to investigate children's 'patterns of beliefs' concerning heat. A similar 'naturalistic' study relating to air pressure was conducted by Séré (1982). Nussbaum and Novak (1976) and Nussbaum (1979) studied children's concepts of the earth, the former utilizing structured interviews, and the latter using a multiple-choice test format. Other concepts investigated include 'gravity' (Gunstone & White, 1981), 'electric current' (Osborne & Gilbert, 1980), and 'life' (Brumby, 1982).

A number of studies have investigated the use of group-administered, structured-response testing formats for identifying student misconceptions, similar to the format used in the present study. Doran (1972) developed a test relating to the particulate nature of matter. Items were of the alternate response type, with distractors representing some of the possible misconceptions related to the concepts being tested. Johnstone and Mahmoud (1980) developed a true-false test relating to water potential, with distractors generated from misconceptions identified in preliminary small-group interviews.

Wheeler and Kass (1978) developed a Misconceptions Identification Test consisting of 30 multiple choice items. Distractors were keyed to six hypothesized misconceptions relating to chemical equilibrium. Za'róur (1975) administered a 40-item multiple choice test to 1444 high school and university students in Beirut. Distractors represented "erroneous science statements or potential misconceptions" (p. 386) in physics, biology, chemistry, and earth and space science. Misconceptions in science were investigated also using a multiple-choice format by Duncan and Johnstone (1973) on the mole concept, and by Helm (1980) on a variety of physics concepts.

Misconceptions Identification through Learning Hierarchies

As noted earlier, the studies reviewed above are typically concerned with conceptions that belong to the 'alternative frameworks' category, though the term 'misconceptions' is used freely in many of these studies. The research reviewed below deals with conceptions that are more representative of the 'misconceptions' category as defined above, and hence these studies will be presented in more detail.

Griffiths, et al. (1983) reported on studies in which a learning hierarchy model was applied to the identification of specific student misconceptions for two science concepts. These concepts ('stoichiometry' and 'conservation of mechanical energy') differ significantly from those in the studies reviewed above. Such concepts belong to the domain of learning referred to by Gagné (1970) as 'intellectual skills' - concepts which are relatively narrow, are usually encountered for the first time during formal instruction, and typically may be represented in the form of rules. Following the theoretical framework of Gagné (1970) a hierarchy was hypothesized for each of the concepts under investigation. Two free-response test items for each skill in a hierarchy were generated and the composite test was administered to a number of intact classes following normal classroom instruction in the particular concepts (for 'stoichiometry' N = 180; for 'conservation of mechanical energy', N = 156). Tests were scored by the researchers and particular note was made of the misconceptions held by each student whenever a wrong answer was obtained. Frequency of occurrence of misconceptions on each skill was tabulated. Griffiths and Grant (1983) also applied a learning hierarchy to the identification of misconceptions in a biological concept, namely, 'food webs'. They maintain that for intellectual skills, such as those referred to above, "the underlying source of misconceptions causing inadequate representation of the overall concept may be traced to inadequate learning of subordinate skills" (p. 4), and therefore that the identification and testing of subordinate skills can lead to identification of the underlying misconceptions which might otherwise elude detection. Once the misconceptions have been uncovered, then appropriate action can be carried out to correct them. The present study follows this model.

Misconceptions Remediation

Little research has investigated the remediation of specific misconceptions within a hierarchical context. Whelan (1982) remediated students' deficiencies in subordinate skills in his study investigating a learning hierarchy for stoichiometric calculations. Additional instruction on failed skills was the basis of the remediation; no attempt was made to address directly specific misconceptions, although misconceptions were identified.

The present study is based upon the learning hierarchy validated by Whelan's study and the misconceptions identified therein. It investigates the remediation of specific misconceptions within the context of a treatment based on the hierarchy.

Summary

A review of the literature relating to remediation in science teaching has been presented. More particularly, the review has focused on diagnostic-prescriptive remediation. Studies relating to the use of a learning hierarchy in remediation have been surveyed and literature relating to misconceptions identification has been summarized to provide the framework for the present study. It has been shown that diagnostic-prescriptive remediation applied to specific student misconceptions is a relatively unresearched area of study.

Particular details of the methods used in the present study follow from a consideration of the studies reviewed in this Chapter. These details are described in Chapter three.

CHAPTER 3

Research Design and Procedures

The methodology used in this study is described by considering each of the following: the sample of subjects used and the population from which it was drawn; the experimental design of the research; the instruments and materials utilized; the procedures employed; and the analyses performed on the data. A description of each of these aspects constitutes this Chapter.

Population and Sample

The sample consisted of thirteen intact Level II chemistry classes enrolled in Chemistry 2202 in Newfoundland schools. The program of study relies heavily on Alchem 10 (Jenkins, et al., 1978), and contains a substantial component on the topic of stoichiometry. The classes in the sample were located in five schools in or near St. John's; all classes were heterogeneously grouped with respect to ability and sex. Class sizes ranged from 12 to 35 students, with an average size of 24. Within each school, all chemistry classes used were taught by one teacher.

The intake of the schools used in the study represents a wide socioeconomic background which appears to be quite representative of North American urban and sub-urban areas. However, the schools, classes, and students may not represent accurately the rural situation.

The ideal population from which the sample is taken is all Newfoundland high school students enrolled in Chemistry 2202, but any findings may be justifiably generalized only to schools of similar size and similar demographic and geographic characteristics.

Research Design

The study was conducted using a multiple treatment/single factor design involving pretest and posttest with matching. Subjects were exposed to the experimental conditions following regular classroom instruction in stoichiometry according to the objectives for Chemistry 2202. Teachers were asked not to vary in any way from their normal teaching pattern.

For each class involved in the study, three class sessions of 40-45 minutes each were made available to the researcher. During the first session, a diagnostic test covering seven hierarchically related skills in stoichiometry was administered. Incorrect responses on this test were used as the basis for prescribing a remediation strategy for each student. Remediation was in the form of a remedial booklet, of which there were three versions representing three levels of remedial treatment.

Within each class, each student was placed in one of the treatment groups through stratified random assignment on the basis of the pretest scores. These scores were rank ordered and subjects were then randomly assigned to treatment groups, beginning with the highest pretest score. This effected a matching of students in each treatment level with respect to pretest scores, taken as an indication of initial knowledge in stoichiometry.

During the second class session, one to three days later, each student received a remedial booklet appropriate to the treatment level to which he/she had been assigned. These treatment levels may be summarized as follows:

> <u>Treatment A</u> - remediation of failed skills presented in the order that the skills appeared on the diagnostic test.
>
> <u>Treatment B</u> - remediation of failed skills presented in the context of a learning hierarchy.
>
> <u>Treatment C</u> - remediation of failed skills presented in the context of a hierarchy and focused directly on individual student misconceptions within each failed skill.

These treatments and the student booklets used for each are described in detail below.

During the final class session one to three days later, a second chemistry test parallel to the chemistry pretest was administered. This posttest was scored and the answers were coded as for the pretest. Pretest and posttest scores for each group from each class were pooled and the data was subjected to statistical analysis.

A graphic representation of the research design is presented in Figure 3.

Materials and Instruments

The materials used in this study were of two kinds: chemistry pre- and posttests, and student instructional booklets. All of these materials were based on the work of a previous researcher (Whelan, 1982) who proposed and validated a learning hierarchy relating to stoichiometric calculations. Whelan also constructed a chemistry pretest and posttest and a student instructional booklet covering the skills in the hierarchy. In addition, he identified a number of misconceptions for each skill from students' test answers.

A first step in this research involved Whelan's validated hierarchy for stoichiometric calculations (Whelan, 1982, p. 109). This hierarchy is reproduced in Figure 4. For the present study one skill, namely Skill 6, was removed. This skill which involves direct application of the law of conservation of mass, represents the fundamental basis of stoichiometric calculations, but is not actually necessary to the correct performance of them. Further, Whelan found that this skill did not significantly enhance learning of related superordinate skills. For this reason it was decided, in consultation with other

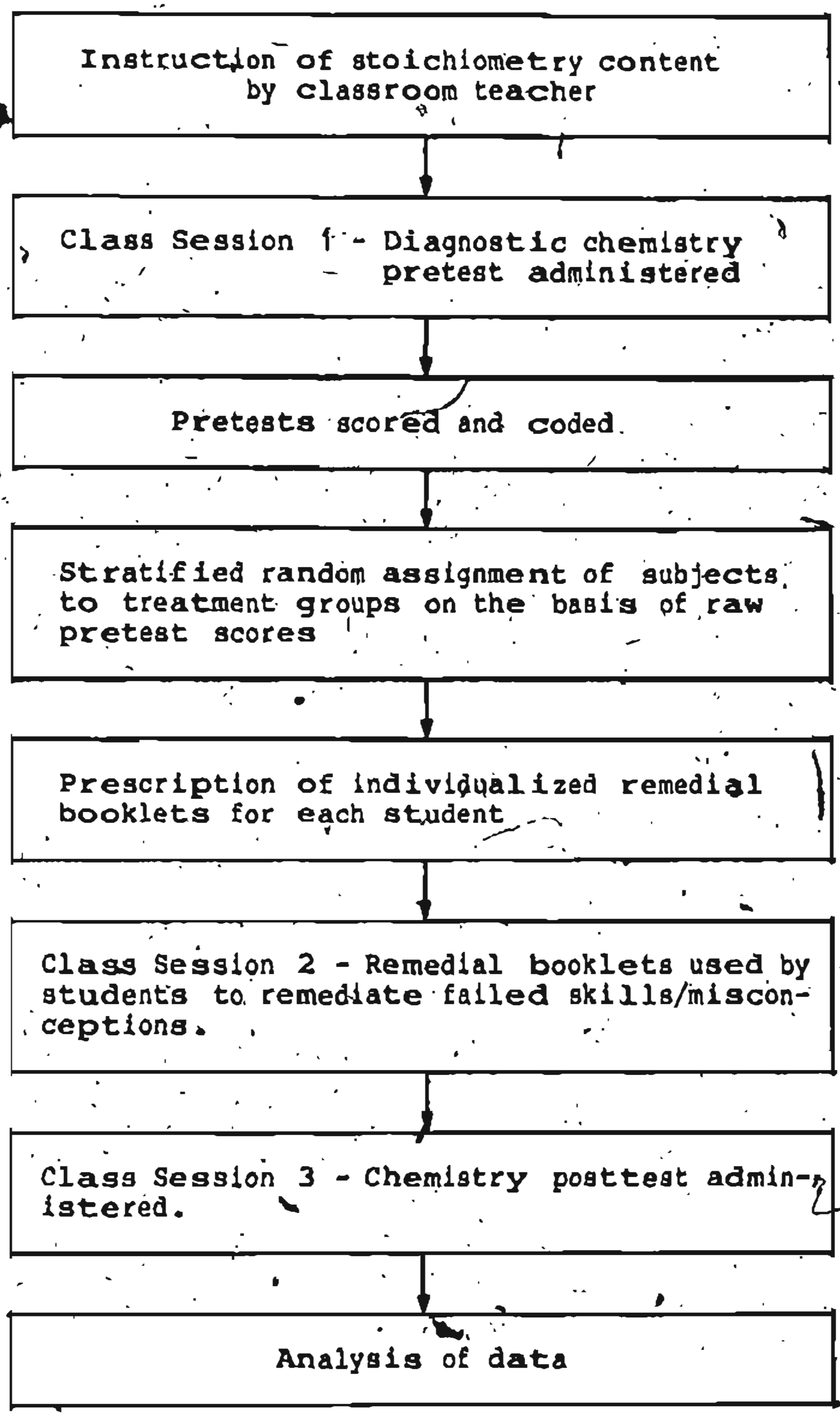

Figure 3. Design of the Study.

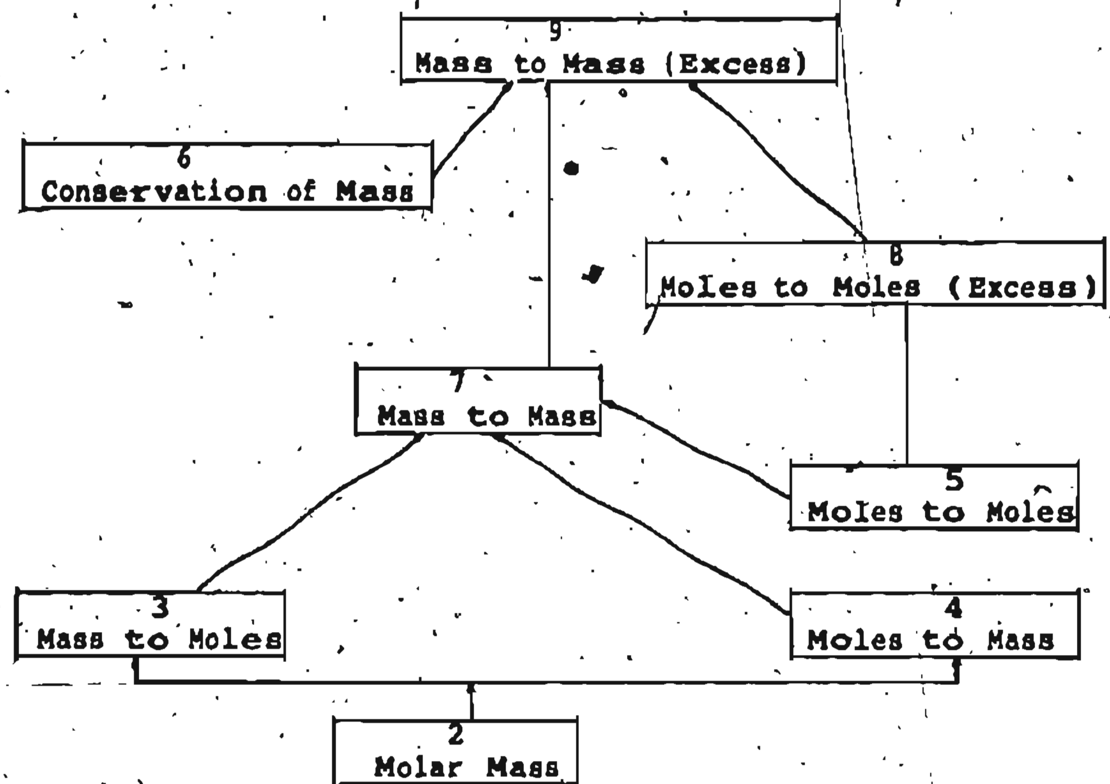

Figure 4. Hierarchy for Stoichiometric Calculations (Whelan, 1982)

science educators, to exclude this skill from the hierarchy for the purposes of this study. The revised hierarchy was adopted and the skills were renumbered as per Figure 5.

The Instruments

The chemistry pretest and posttest were identical in format and sequencing. Items testing a particular skill in pretest and posttest, respectively, were different but closely matched.

The first step in the construction of the chemistry tests was the listing of possible student misconceptions for each of the seven skills in the stoichiometry hierarchy. Those identified by Whelan (1982) were used as the primary source. Additional possible misconceptions for each skill were generated by the author in consultation with a panel of science educators.

Next, a battery of test items covering all seven skills in the hierarchy was constructed, following closely the test item format used by Whelan (1982). For test items on Skills 1-5, multiple choice distractors were generated to test as validly as possible the array of possible misconceptions students could exhibit on each skill. A total of 20 test items for Skills 1-5 (4 items per skill) were prepared in this manner. The number of distractors for each test item, including the correct answer, was five, except that for items testing Skill 5 an

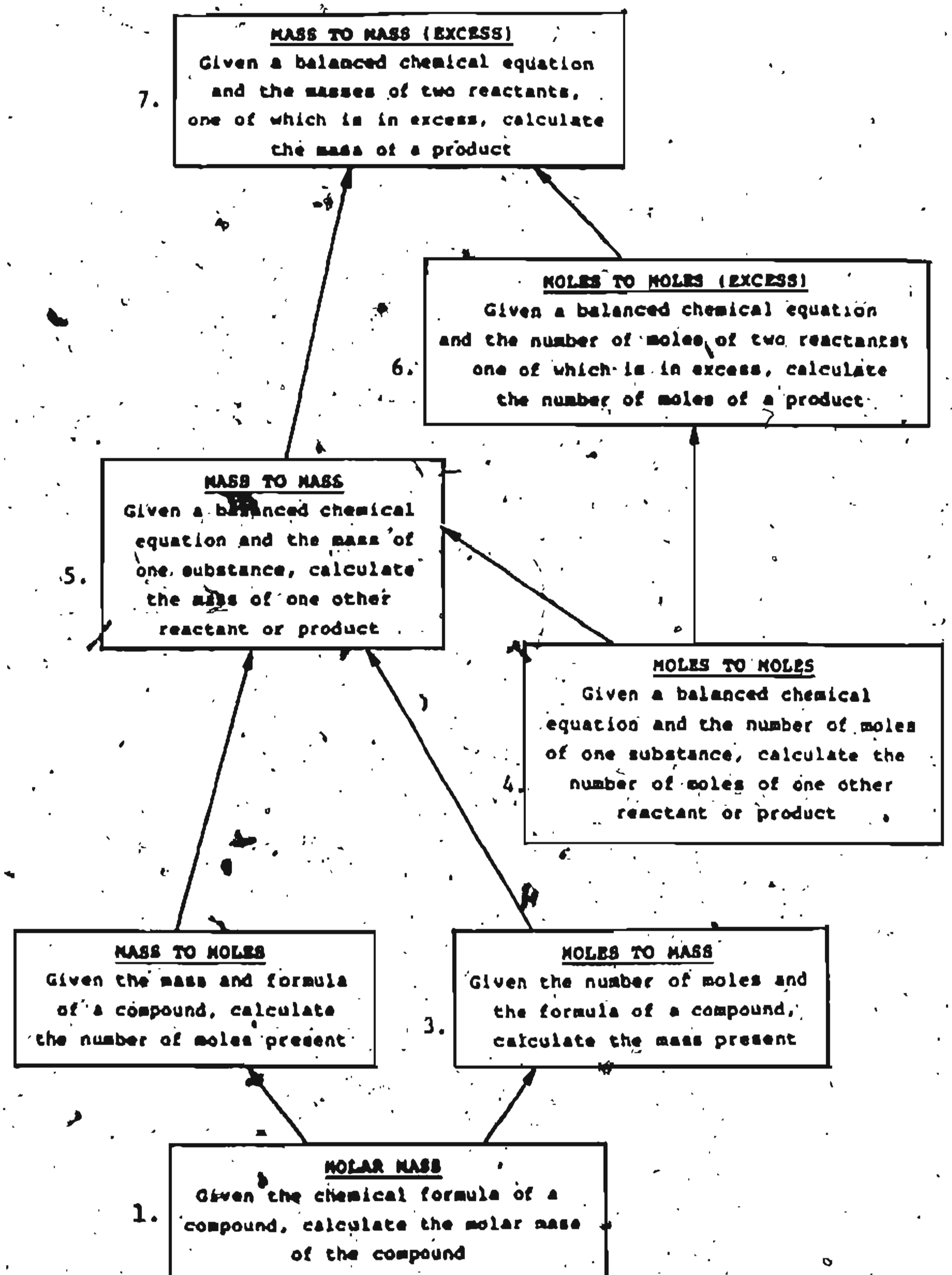

Figure 5. Revised hierarchy for stoichiometric calculations used in present study.

additional distractor was added following pilot testing.

Progression up a learning hierarchy is accompanied with increasing complexity of the skills involved. Hence, more types of student errors are possible, and so the multiple choice format becomes unsuitable because the number of distractors is too large. Thus for Skills 6 and 7, a written free-response test item format was used. For items testing these skills students were asked to show their calculations. An additional 8 test items were prepared to test Skills 6 and 7 (4 items per skill).

The purpose of choosing a multiple-choice format for items testing Skills 1-5 was to speed up the process of correcting tests and diagnosing student misconceptions. For the present research this was deemed necessary because of the relatively short 'turn around' time between diagnostic pretest and remediation session, but possible future use of the instruments by teachers was also considered. It was felt that this format would also contribute to a shorter testing time since students would not have to record any of their calculations for ten of the fourteen items on a test. The dangers that this introduces however are:

1. The student may calculate an answer that does not correspond to one of the available choices. This may lead to:

(a) rechecking and spending extra time on a particular test item; or

(b) guessing in the absence of a suitable distractor.

2. The student may arrive at a correct answer by an incorrect method, or vice versa.

However, the research design effectively distributes any of these effects throughout the treatment levels.

The free-response format for test items on Skills 6 and 7 has the advantage of providing a record of the students' problem solving strategy for each test item. However, an inherent danger is the researcher's subjectivity in correcting answers and in diagnosing misconceptions on these items.

The battery of test items thus constructed (28 items) was divided into two groups so that two items per skill appeared in each group. Group 1 became the chemistry pretest and group 2 became the chemistry posttest. For each test, the items were arranged randomly by skills tested. Care was taken to ensure that the item sequence did not closely parallel the order of skills in the learning hierarchy. After pilot testing, it was decided to alter slightly the item sequence on the test. This was effected by making two clusters of test items for each test. Questions 1-10 on each test would reflect skills 1-5, randomly sequenced. Questions 11-14 on each test would test Skills 6 and 7, inversely sequenced. This change was deemed necessary because the free-response items testing Skills 6 and 7 generally took students longer to complete than the multiple choice items. It was felt that students would have a better chance of completing the test if they encountered the multiple choice items first. The chemistry pretest and posttest are reproduced in Appendix 1 and Appendix 2, respectively.

The Instructional Booklets.

The remediation for each of the three treatment levels consisted of a student booklet containing instruction on each of the seven skills in the hierarchy for stoichiometric calculations. For all levels, the instructional content for each skill was identical. However, significant differences existed in the organization of the content in each of the treatment groups, as will be discussed below.

The three different remedial booklets were prepared by first drafting a basic booklet and then adapting this booklet to the different treatment levels. This basic booklet was patterned on the remedial booklet produced by Whelan (1982), and contained instruction arranged skill by skill and in the order of the skills in the revised hierarchy (Figure 5). Each skill was introduced by a graphic representation of that skill in relation to other skills in the hierarchy. The introductory pages of the booklet also contained a complete breakdown of the hierarchy for stoichiometric calculations.

The booklet was then adapted for the three levels of treatment as follows:

Treatment A: For this treatment level the instructional material in the basic booklet was rearranged so that it appeared in the order in which skills appeared on the chemistry pre/post tests. The actual order of items by skill tested on the chemistry tests was as follows:

Item Number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Skill Tested:	3	1	4	2	1	5	2	3	5	4	7	6	7	6

Thus the order of the skills in the instructional booklet for treatment A was: 3, 1, 4, 2, 5, 7, 6. The numbers of the skills in the actual booklet were changed to correspond with their occurrence in the booklet. Thus, for treatment group A, Skill 3 was renamed Skill 1, Skill 1 was renamed Skill 2, etc. In booklet A the graphic representation of the hierarchy at the beginning of each skill was eliminated, as was the introductory page outlining the hierarchy in detail.

The remediation which group A received was essentially the same instructional content as for groups B and C, but such content was non-hierarchically arranged, and no reference was made to a hierarchy or to particular misconceptions. This represents the major difference between remediation for group A compared to that for groups B and C. Instructional booklet A is reproduced in Appendix 3.

Treatment B: For this group, the basic booklet was adopted wholesale. The remediation which students in this treatment level received consisted of a hierarchical arrangement of instructional content on each of the skills in the hierarchy. Booklet B is reproduced in Appendix 4.

Treatment C: Again for group C the basic booklet was adopted wholesale, except that pages were renumbered so that a page could be inserted at the beginning of any or each skill. Such a page would identify for the student the particular misconception(s) which he/she exhibited in the answer(s) given for the corresponding item(s) on the chemistry pretest. Thus subjects in this treatment group were alerted to their previously demonstrated misconceptions, in addition to receiving hierarchically arranged instructional content on the skills.

A set of misconception pages was prepared for each skill, corresponding to the misconceptions represented by the distractors in the multiple choice questions (Skills 1-5), or to those misconceptions identified by Whelan (1982) or suggested by the author for Skills 6 and 7. Each page consisted of a statement of the skill being tested and the particular error or misconception which the student exhibited on that skill in the pretest. These were carefully constructed so as not to include any extra instruction on the skill, but merely to point the student to the particular area of the skill in which the error occurred. The complete set of pre-prepared misconception pages is reproduced in Appendix 5.

From the foregoing discussion, it is obvious that the instructional content which made up the remedial treatment for the three levels of remediation was essentially identical. However, significant differences in the treatment groups existed in the sense that group A received a remedial booklet in which the skills covered were non-hierarchically sequenced, group B received the same instructional content but in a hierarchical arrangement and context, and group C received hierarchically arranged content plus non-instructional misconception pages alerting subjects to their previous errors.

Procedures

In a previous section, it was noted that in the collection of research data, three visits were made to each class in the sample. During the first session, the students were informed that they were taking part in a study conducted by the University and that, though their performance would not count toward their final grade, their participation could prove to be quite beneficial to them in their understanding of stoichiometry. Following this, the chemistry pretest was administered and completed by the students during that same class session.

The tests were collected by the researcher and were later scored and coded for particular misconceptions on each incorrect answer. For the multiple choice items, this was done quite easily since each incorrect choice represented a particular misconception. For the free-response test items, student calculations were studied carefully to determine the student's misconception(s) where an incorrect answer was obtained, or to determine whether a correct answer was arrived at by an incorrect method. Every effort was made to ensure an objective assessment of student responses on these questions, and uncertain items were reviewed by a panel of science educators and the opinions of the majority were adopted. Though misconceptions were used in only one of the treatment levels, they were identified for all subjects in order to determine frequency of occurrence and in order to facilitate comparisons.

Students in each class were assigned to one of the three treatment levels by stratified random assignment on the basis of pretest scores, as described in a previous section. Once the class was divided up in this manner, an appropriate instructional booklet was prepared for each student. For subjects in groups A and B, this preparation consisted of recording in the front of each booklet the student's name and the skills which that student failed on the pretest. The booklets would provide remediation on those skills, booklet A containing non-hierarchically arranged content and booklet B containing hierarchically arranged content on the skills tested by the pretest. A skill was considered 'failed' if the student incorrectly answered at least one of the two test items on that skill, except where it was obvious that an incorrect answer was obtained through a simple arithmetic error.

For group C, in addition to recording in each booklet the skills requiring remediation, a misconception page was inserted at the beginning of each failed skill. As indicated earlier, each misconception page was intended to alert the student to the particular misconceptions which he/she exhibited on that skill in the pretest. To this end, within the instructional content of each failed skill, those sections relating directly to the student's misconception(s) in that skill were noted by an asterisk. The purpose of the asterisk was explained to the student in the misconception page.

The prescribed remediation for treatment C may be illustrated by examining a hypothetical student response to the following test item from the chemistry pretest:

Test Item: Calculate the number of moles in 145 g of butane (C_4H_{10}):

a) 2.50 mol
b) 0.400 mol
c) 11.2 mol
d) 8.41×10^3 mol
e) 10.4 mol

Calculations: (Hypothetical)

Molar Mass of C_4H_{10} = (4 x 12.0g/mol) + (10 x 1.0g/mol) = 58.0g/mol

$$\text{Moles} = \frac{\text{Molar Mass}}{\text{Mass}} = \frac{58.0\text{g/mol}}{145\text{g}}$$

= 0.400 mol Answer: b

Distractor 'b' in the example above represents a particular student misconception. The student in treatment group C who chose this answer would receive the following information inserted immediately before the instructional content on the skill in question:

Skill 2: Converting Mass to Moles

On a previous test, you were asked to change a given mass of a compound to its corresponding number of moles. The answer you selected indicates that you used an incorrect method for changing mass to moles. Instead of dividing the given mass by the molar mass of the compound, you reversed the operation and divided the molar mass by the given mass.

The following pages contain a review of mass to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

As the student read through the instructional content of Skill 2, he would find sections marked by an asterisk as indicated on the misconception page. A section from booklet C containing instruction on Skill 2 so marked is included in Appendix 6.

Where more than one misconception per skill was identified for a student, two misconception pages were included or the contents of one page were hand written onto the other. Where no particular misconception could be identified for a skill, a general misconception page was included. In cases where new misconceptions were identified at the time of scoring the pretest, a new misconception page was prepared at that time.

The students were given their individualized booklets during the next visit of the researcher to the class, one to three days later. They were given some simple directions in using the booklets and were directed to work individually on the sections of the booklet indicated. Students were required to read the prescribed sections of the booklet and to do the appropriate sample questions. The fact that the booklets were individualized was stressed, and comparison of booklets was discouraged. The subjects were not told that three versions of the booklet were in use in the class at the same time.

At the end of the class period, the booklets were collected by the researcher. The chemistry posttest was administered during the final class session. It was scored and coded as for the pretest, and the pretest and posttest scores were subjected to the analysis described below.

Analysis of the Results

The mean scores for pretest and posttest performance were calculated for each of the treatment groups. One way analysis of covariance was used to determine whether or not there was a significant difference between treatment groups with respect to posttest performance.

Frequency tabulations were also made with respect to the occurrence of misconceptions in students' answers on the pretest and posttest. Comparisons between the three treatment groups with regard to changes in misconception frequencies following remediation were also conducted.

Summary

A complete breakdown of the stages involved in this study has been presented in this Chapter, including a discussion of the sample, the research design, the instruments and other materials used, the procedures employed in collecting the data, and the analyses applied to the results. The next chapter focuses on the analysis of the data collected according to the experimental design outlined above.

CHAPTER 4

Results

Test Reliability

This chapter deals with the statistical analysis of the data obtained on the chemistry pretest and posttest. Since these tests represent the chief instruments through which data on the dependent variable was collected, some measure of the reliability of the tests is appropriate. The measure chosen was the split-half estimate of reliability, especially relevant to these instruments because of their parallel construction. Each test (pre- and post-) consists of 14 items, 2 items testing each of 7 different skills in a hierarchy for stoichiometric calculations. The split-half of each test was obtained by selecting one test item for each skill for each half. Particular attention was paid to the order of items on the test so that each split-half contained a balance of earlier and later test items. The split-half separation with test item sequence and skills tested are presented in Table 1. The separation was identical for both the pretest and the posttest.

In the application of the split-half reliability measure, the correlation coefficient (r) between the scores on each half of the test is first calculated. Since this estimate of reliability represents the reliability of a test only half as long as the original test, a correction formula is applied to the coefficient to estimate the reliability of the actual test. The formula used

TABLE 1

Test Item Split for Split-half Estimate of Reliability

Skill Tested	Test Item Numbers	
	Half test I	Half test II
1	5	2
2	4	7
3	1	8
4	10	3
5	9	6
6	12	14
7	13	11

was the Spearman-Brown formula: $r_{xx} = \frac{2r_{hh}}{r_{hh} + 1}$.

The correlation coefficients and corrected estimates of reliability for the chemistry pretest and posttest are presented in Table 2. A split-half estimate of reliability of .84 was obtained for the pretest and a corresponding value of .86 for the posttest. These values suggest a high degree of internal consistency for the instruments in this study.

Statistical Analysis

Descriptive statistics on the data collected in this study were obtained using the SPSS statistical package. A comparison of the three treatment groups A, B, and C on several descriptive measures is summarized in Table 3. This table indicates that all groups gained from pretest to posttest and that the gain scores show a gradual increase through groups A to C. The significance of this difference was investigated as follows.

An important aspect of the research design in the present study was the stratified random assignment of subjects to three treatment groups based on ranked pretest scores. This was designed to create three groups with equal pretest means. However, because of attrition the pretest means were not identical, though they were similar. Attrition occurred because certain subjects missed one or both of the in-class sessions following the initial session in which the pretest was administered. The three

TABLE 2

Correlation Coefficients (r) and Split-half Estimates of Reliability for the Chemistry Pretest and Posttest.

	r between halves	Estimate of reliability
Pretest	0.72	0.84
Posttest	0.75	0.86

TABLE 3

Test Means, Standard Deviations, and Mean Gains for Treatment Groups A, B, & C

Treatment Group	N	Pretest Mean $(X_1)^a$	Pretest SD	Posttest Mean $(X_2)^a$	Posttest SD	Mean Gain $(X_2 - X_1)$
A	69	8.49	2.89	10.17	2.65	1.68
B	77	8.16	2.93	9.90	2.94	1.74
C	74	8.43	2.81	10.49	2.90	2.06

[a] Total possible score = 14

treatment groups were established immediately following this initial session. Thus any subject absent for subsequent session(s) had to be dropped from the sample with consequent effects on the pretest mean of the group from which he/she was eliminated.

The effect of attrition on the pretest means was not significant; however, a statistical procedure was employed to allow for these initial differences. An analysis of covariance with pretest mean as covariate and posttest mean as the dependent variable, was carried out to determine whether there was a significant difference between the adjusted means of the three treatment groups, at the .05 level of significance. The analysis of covariance data is reported in Table 4.

Hypothesis 1 of this study states that there will be no significant difference in achievement gains between students who receive diagnostic-prescriptive remediation hierarchically arranged and students who receive similar remediation non-hierarchically arranged. These two conditions of remedial instruction are represented by treatments B and A respectively. The analysis of covariance of the adjusted means of all treatment groups shows that there was no significant difference between posttest means of any of the groups ($p = .42$). On the basis of this analysis null hypothesis 1 is accepted. Thus no significant difference has been demonstrated in the effects of hierarchical versus non-hierarchical

TABLE 4

Analysis of Covariance by Treatment Groups A, B, and C With Pretest Mean as Covariate

Source of Variation	df	SS	MS	F-value	p
covariate	1	863.48	863.48	210.47	0.00
treatment	2	7.09	3.54	0.86	0.42

remediation procedures.

The second hypothesis investigated in this study was that there would be no significant difference in achievement gains between students who received diagnostic-prescriptive remediation in which specific student misconceptions were identified and students who received similar remediation in which misconceptions were not identified. These two remedial conditions are represented by treatments C and B respectively. On the basis of the analysis of covariance of posttest means of all treatment groups, this second null hypothesis is to be accepted also, namely, that no significant difference has been demonstrated in the effects of remediation involving identified misconceptions versus remediation not employing identified misconceptions.

In retrospect several possible reasons for the absence of an expected difference between the groups may be identified. The first of these relates to the difference in treatment between the three groups. At the time of designing the study it was felt that treatment C (remediation hierarchically arranged and incorporating diagnosed student misconceptions) would be more advantageous to the subjects than either of the other two treatments, especially treatment A. However, because for treatment C some students' misconceptions could not be diagnosed by the written answers they submitted, and hence could not be addressed directly in remediation, some of the subjects in group C in fact represent a subset which parallels group B (remediation hierarchically arranged but without reference to misconceptions). This would tend to decrease the potential effect of treatment C.

A second reason relates to the nature of the material chosen for the study. In many cases where mathematical formulae are involved, students may simply manipulate variables and "plug in" values to obtain the desired result, while neither truly understanding nor misunderstanding. Thus misconceptions identified may not be considered relevant by some students. Hence the remedial instruction given such students in any of the three groups may not be as discriminating as was anticipated.

It must be noted clearly, however, that the research design is such that the effects of extraneous variables such as those described above are minimized. The three groups were equal with regard to all variables other than treatment, within the limitations of random assignment. Hence if no significant difference is recorded through statistical analysis, the null hypotheses are to be retained.

A third point is that, though the remedial content for each treatment group was similar, the differences in remedial procedures may have generated different demands on students in the different treatment groups. In treatment A skills were reviewed in the order that corresponding test items appeared on the pretest. In effect this parallels the typical teaching situation and thus represents very little departure from procedures to which students are generally accustomed. In treatment B, students encountered not only the remedial material but also a learning hierarchy around which the remedial content was focused. This may constitute a greater informational demand on students in this treatment as compared with treatment A. Treatment C may represent an even greater informational demand with the addition of specific misconceptions identified for each skill remediated. Conversely, since appropriate sections of the remedial content of treatment C were annotated by an asterisk to point out the student's area(s) of weakness as diagnosed by the pretest, subjects in this treatment level may have given too little attention to the careful reading of the remedial material, perhaps opting to attend only to those sections marked by the asterisk. The net effect of these confounding factors may have been to decrease the effectiveness of treatments B and C.

Post Hoc Analysis

As indicated above, natural attrition resulted in elimination of some of the original subjects from the final sample in this study. The number eliminated by attrition from each treatment group was similar, as indicated by the number of subjects in each group in the final sample (Group A: n = 69; Group B: n = 77; Group C: n = 74). The group n's were originally equal. Those subjects lost through attrition fell into one of two categories. Certain subjects missed one of the tests (pre- or post-) and so a measure of achievement gain could not be obtained for these. However, other subjects missed only the remedial session, and were present for the writing of the pretest and posttest. It was realized post hoc that this latter group represented a nonremediated control group whose achievement gains could be compared with those of the established treatment groups. Accordingly, a further 32 subjects were identified who received no remediation, but did complete a pretest and a posttest.

This nonremediated group (group D) was added to the analysis for the other three groups. As Table 5 indicates, it was found to be equivalent to the remediated groups with regard to pretest mean, but showed considerably less gain from pretest to posttest. The significance of this difference in mean gain was investigated by applying the same covariance procedure that was employed earlier with the experimental groups only.

Analysis of covariance of the three treatment groups and the nonremediated group yielded a significant difference between posttest means at the .05 level of significance (Table 6). To determine the source of this difference, separate analyses of covariance were performed on pairs of adjusted means as follows: Group A with Group D; Group B with Group D; Group C with Group D. The results of these analyses are presented in Table 7. In

TABLE 5

Test Means, Standard Deviations, and Mean Gains for Treatment Groups A, B, and C and Post hoc Group D

Treatment Group	N	Pretest Mean (X_1)[a]	Pretest SD	Posttest Mean (X_2)[a]	Posttest SD	Mean Gain $(X_2 - X_1)$
A	69	8.49	2.89	10.17	2.65	1.68
B	77	8.16	2.93	9.90	2.94	1.74
C	74	8.43	2.81	10.49	2.90	2.06
D	32	8.56	3.16	9.31	3.14	0.75

[a] Total possible score = 14.

TABLE 6

Analysis of Covariance by Group Including Post Hoc Nonremediated Group

Source of variation	df	SS	MS	F-value	p
Covariate	1	1029.76	1029.76	250.69	0.00
Treatment	3	38.35	12.78	3.11	0.027

TABLE 7

Analysis of Covariance for each Treatment Group With Post Hoc Nonremediated Group

Source of Variation	df	SS	MS	F-value	p
Groups A & D					
Covariate	1	368.63	368.63	96.99	0.00
Treatment	1	19.71	19.71	4.94	0.028
Groups B & D					
Covariate	1	506.25	506.25	121.38	0.00
Treatment	1	19.38	19.38	4.65	0.033
Groups C & D					
Covariate	1	474.54	474.54	112.38	0.00
Treatment	1	38.68	38.68	9.16	0.003

each case, there was a significant difference between the posttest mean of the treatment group and the posttest mean of the post hoc nonremediated group. The magnitude of the difference was greatest between Groups C and D ($p = .003$) while the differences for the other two pairs were similar (for Groups A and D, $p = .028$; for Groups B and D, $p = .033$). These results suggest that diagnostic-prescriptive remediation significantly enhances student achievement. This is consistent with other recent studies on the effects of similar remediation strategies.

Yeaney and Miller (1983) conducted a meta-analysis of diagnostic-remedial studies in which an effect size in standard deviation units was calculated for each study. The average effect size for diagnostic-remedial strategies when compared with instructional strategies without diagnosis or remediation was reported to be 0.55 standard deviation units. Similar effect sizes were calculated for the three treatment groups in the present study using adjusted posttest means. Comparisons were made with nonremediated group D. Values of 0.30, 0.29, and 0.42 were obtained for groups A, B and C respectively. While these achievement gains are somewhat less than the average gain reported by Yeaney and Miller, there is ample evidence of a positive influence on student achievement by diagnostic-prescriptive remediation in all treatment levels, with a more pronounced effect in the misconceptions remediated group C. The additional feedback on misconceptions which characterized treatment *e* may have influenced the effect size for this group, consistent with the finding of Yeaney and Miller that the main impact on the achievement appeared to be diagnostic feedback rather than remediation itself.

Subjects' Misconceptions

The final discussion in this section concerns the identification and prevalence of misconceptions observed among the subjects in this study. This part of the analysis does not relate directly to the hypotheses stated in Chapter One. However, it was performed in an attempt to uncover the particular difficulties encountered by subjects within and between experimental groups. As indicated earlier, the pretest and posttest were composed of two types of test items: items testing skills 1-5 of the hierarchy for stoichiometric calculations were in a multiple choice format where alternatives other than the correct one represented specific misconceptions relating to the skill involved; items testing skills 6 and 7 were in a free-response format. When those latter items were scored by the investigator, incorrect solutions were examined critically for types of conceptual errors. Where no specific miconception could be identified, the data were coded accordingly.

First to be examined are the frequencies of specific misconceptions on each of the skills in the learning hierarchy for stoichiometric calculations. For each skill the misconceptions are described and then listed, but no breakdown of the frequencies of misconceptions by treatment group is given. While comparisons between the groups with regard to possible reduction or extinction of misconceptions following remedial treatment were examined, no consistent pattern was found. This may be attributed to the confounding effects of (a) subjects exhibiting different misconceptions on the posttest than were exhibited on the pretest for a given skill; and (b) a decrease from pretest to posttest in the number of subjects for whom no specific misconception could be identified on incorrect answers. Some subjects for whom no misconception(s) could be identified on a particular skill on the pretest exhibited identifiable misconception(s) on the posttest, thus inflating posttest misconception frequencies. In any case, the present summary is intended to describe the kinds of misconceptions exhibited by subjects, and to highlight any notable changes in raw frequencies from pretest to posttest. A more specific analysis of misconceptions by treatment groups is found later in this chapter.

It must be noted that since there were two questions per skill on each of the tests, it is possible that any subject may have exhibited more than one misconception per skill. Furthermore, when the same misconception was exhibited by a subject on both questions testing a skill on a test, that misconception was recorded only once for the summaries below. The general patterns of misconceptions identified by skill tested are examined in the paragraphs following.

Misconceptions Exhibited on Each Skill

Skill 1 - Given the chemical formula of a compound, calculate the molar mass of the compound.

Only a small percentage of subjects exhibited misconceptions on this skill. Those test item distractors which represented misconceptions were related to the incorrect use of subscripts in calculating the molar mass. Subjects either ignored subscripts altogether, or otherwise applied them incorrectly, such as by adding them. The frequencies of this misconception on the pretest and posttest are presented in Table 8.

Skill 2 - Given the mass and formula of a compound, calculate the number of moles present.

Three misconceptions were identified in relation to this skill. Two of these arose from the incorrect recall or application of the required algorithm. Instead of dividing the given mass by the molar mass of the compound, some subjects reversed the division operation, dividing the molar mass by the given mass, while others multiplied the given mass by the molar mass. This suggests the rote memorization of the algorithm without an understanding of its components. A third misconception was the incorrect calculation of molar mass. The frequencies of misconceptions identified for skill 2 are presented in Table 9. It might be noted that the two misconceptions related to the algorithm for converting mass to moles were reduced in frequency by approximately 50% between the pretest and the posttest.

TABLE 8

Frequencies of Misconceptions Exhibited on Skill 1

	Raw Frequency		Frequency (%)	
Misconception	Pretest	Posttest	Pretest	Posttest
Used subscripts incorrectly	19	11	8.6	5.0

TABLE 9

Frequencies of Misconceptions Exhibited on Skill 2

	Raw Frequency		Frequency (%)	
Misconception	Pretest	Posttest	Pretest	Posttest
1. Divided molar mass by mass.	27	14	12.3	6.4
2. Multiplied molar mass by mass.	13	6	5.9	2.7
3. Incorrectly calculated molar mass.	11	8	5.0	3.6

Skill 3 - Given the number of moles and the formula of a compound, calculate the mass present.

As in the previous skill, a number of subjects recalled or applied the required algorithm incorrectly. Instead of multiplying the given number of moles of the named compound by its molar mass, some subjects divided either the given number of moles by the molar mass, or vice versa. Again, this suggests an incomplete understanding of the algorithm for converting moles to mass. Another misconception exhibited was the incorrect calculation of the molar mass of the named compound. The misconceptions identified and their frequencies for skill 3 are presented in Table 10.

Skill 4 - Given a balanced chemical equation and the number of moles of one substance, calculate the number of moles of one other reactant or product.

Most of the misconceptions exhibited on this skill related to the incorrect use of the stoichiometric relationships in the balanced chemical equation. Some subjects tried to employ the molar mass of one or more of the substances represented in the equation, either quoting a molar mass as the answer or manipulating the molar mass with stoichiometric ratios. Others simply multiplied or divided the given number of moles by the coefficient of the 'required' substance. Still others ignored the stoichiometric relationship and simply quoted the number of moles given in the problem as the answer, or

TABLE 10

Frequencies of Misconceptions Exhibited on Skill 3

Misconception	Raw Frequency		Frequency (%)	
	Pretest	Posttest	Pretest	Posttest
1. Divided moles by molar mass, or vice versa.	43	33	19.5	15.0
2. Incorrectly calculated molar mass.	16	18	7.3	8.2

alternatively quoted the coefficient of the 'required' substance as the answer. These misconceptions indicate a basic misunderstanding of the relationships among the coefficients in a balanced chemical equation and their application to the calculation of the actual numbers of moles of the substances involved in complete reaction.

The frequencies of the misconceptions identified for skill 4 are presented in Table 11. Notable reductions in the total frequencies of all misconceptions between the pretest and the posttest were observed for this skill.

Skill 5 - Given a balanced chemical equation and the mass of one substance, calculate the mass of one other reactant or product.

The misconceptions identified on this skill again were generally related to the inappropriate interpretation of the stoichiometric ratios in the equation, or to failure to use these ratios. Some subjects combined mass and mole quantities in forming a proportion, assuming that the coefficients in the balanced chemical equation represent mass amounts. Thus students used a correct mole ratio from the equation but equated it with a ratio of the masses of 'given' and 'required' substances. Other subjects correctly calculated the molar mass of the 'required' substance and simply quoted this quantity as the answer, or multiplied the molar mass by the coefficient of that substance in the equation. No reference to

TABLE 11

Frequencies of Misconceptions Exhibited on Skill 4

	Raw Frequency		Frequency (%)	
Misconception	Pretest	Posttest	Pretest	Posttest
1. Used molar mass to calculate answer.	22	15	10.0	6.8
2. Multiplied or divided given moles by coefficient of 'required' substance.	16	7	7.3	3.2
3. Quoted given no. of moles as answer.	12	4	5.5	1.8
4. Quoted coefficient of 're-quired' substance as answer.	10	1	4.5	0.5

the given mass was made.

Another misconception identified was the assumption of a 1:1 ratio of masses in the chemical equation. Subjects quoted the mass given as the answer for the mass of the 'required' substance, without performing a mass-to-moles conversion and without reference to the stoichiometric ratios. Other subjects correctly calculated the mole amount of 'required' substance but failed to convert this quantity to a mass amount, perhaps indicating an oversight or a slight misreading of the question. Still others correctly changed the given mass to a mole quantity but then multiplied this mole quantity by the molar mass of the 'required' substance without reference to the stoichiometric ratio. Finally, some subjects exhibited misconceptions related to skills 1, 2, or 3, either calculating the molar mass incorrectly or using an incorrect algorithm for converting mass to moles or moles to mass. These misconceptions and their frequencies are presented in Table 12.

Several notable differences between the pretest and posttest frequencies are evident here. There were significant reductions in the frequencies of misconceptions 1 and 2 and the complete extinction of misconception 3 ("Assumed a 1:1 ratio of masses"). However, there was also a notable increase in the frequencies of misconceptions 4, 5, and 6. One possible explanation for this is that some subjects who previously held misconceptions 1,

TABLE 12

Frequencies of Misconceptions Exhibited on Skill 5

	Raw Frequency		Frequency (%)	
	Pretest	Posttest	Pretest	Posttest
1. Combined mass and mole quantities.	47	27	21.4	12.3
2. Did not use mole ratios-calculation on 'required' substance only.	29	14	13.2	6.4
3. Assumed a 1:1 ratio of masses.	9	0	4.1	0.0
4. Correct mole quantity not changed to mass.	9	21	4.1	9.5
5. Multiplied or divided molar mass of 'required' substance by calculated moles of 'given' substance.	12	18	5.5	8.2
6. Incorrectly calculated molar mass.	17	30	7.7	13.6

2, or 3 on the pretest, were exhibiting misconceptions 4, 5, or 6 on the posttest. This seems reasonable since there was only a slight increase (12.3%) in the number of subjects who correctly answered questions on skill 5 on the posttest as compared with the pretest.

Skill 6 - Given a balanced chemical equation and the number of moles of two reactants, one of which is in excess, calculate the number of moles of a product.

Misconceptions identified on this skill related to a misunderstanding of the concept of the limiting reagent. Some subjects chose one reactant (usually the first appearing in the reaction, or the one for which the greater or lesser mole quantity was given) and calculated an amount of product based on this choice. There was no evidence of manipulation of the stoichiometric ratio between the two 'given' substances. For some of the subjects in this category the errors may indicate failure to recognize an 'excess'-type problem.

Another group of subjects converted the given mole quantities to mass and then combined mass and mole quantities in a proportion. A similar misconception was noted in skill 4. Others added the two given mole quantities to arrive at an answer, or calculated two mole quantities of product and either added these quantities or quoted two answers. Finally some subjects chose the wrong reactant as the limiting reagent, inappropriately manipulating the stoichiometric ratio between the two reactants. These misconceptions and their frequencies for skill 6 are reported in Table 13.

A significant reduction in the frequency of misconception 1 ("Failed to determine limiting reagent") was noted between pretest and posttest. However, there was a corresponding increase in the frequency of misconception 4 ("Selected wrong substance as limiting reagent"). Apparently a number of subjects recognized the need to use stoichiometric ratios to determine the limiting reagent, but were unsuccessful in performing the calculation correctly.

Skill 7 - Given a balanced chemical equation and the masses of two reactants, one of which is in excess, calculate the mass of a product.

A variety of misconceptions was exhibited on this skill, many similar to those identified on the two previous skills (skill 5 and skill 6). A prevalent misconception was the selection of one reactant (usually the first or the reactant for which the greater mass was given) as the limiting reagent without performing any calculations related to the stoichiometric ratio between the reactants. As in skill 6, this error may stem from an incorrect reading of the problem, failure to recognize the question as an 'excess'-type problem, or a misunderstanding of the concept of the limiting reagent.

TABLE 13

Frequencies of Misconceptions Exhibited on Skill 6

Misconceptions	Raw Frequency Pretest	Raw Frequency Posttest	Frequency (%) Pretest	Frequency (%) Posttest
1. Calculated product based on one reactant - failed to determine limiting reagent.	56	11	25.5	5.0
2. Confused mass and mole quantities.	27	21	12.3	9.5
3. Added mole quantities of reagents or product.	12	13	5.1	5.9
4. Selected wrong substance as limiting reagent.	6	33	2.7	15.0

Other subjects added the given mass amounts in an effort to arrive at an answer, or converted the given masses to moles and then added the calculated mole amounts. Some subjects found two mass amounts or two mole amounts of product and then added. Still others incorrectly manipulated the stoichiometric ratio between the two reactants and thus chose the wrong reactant as the limiting reagent. A small number of subjects failed to use any information from the balanced chemical equation in calculating their answers. Some subjects incorporated mass and mole ratios together inappropriately in a proportion, while others incorrectly calculated molar mass or used an incorrect algorithm for mass-to-moles or moles-to-mass conversions. Because correct performance of skill 7 involves a complex procedure, combinations of several misconceptions in student answers were fairly common. The frequencies of the misconceptions identified for skill 7 are presented in Table 14.

As with skill 6, there was a significant reduction in the frequency of misconception 1 ("Failed to determine limiting reagent") between the pretest and the posttest, but there was also an increase in the frequency of misconception 4 ("Selected wrong substance as limiting reagent"). The explanation for this pattern may be that a number of subjects after remediation recognizd the need to use stoichiometric ratios in determining the limiting reagent, but were unable to use them successfully.

TABLE 14

Frequences of Misconceptions Exhibited on Skill 7

Misconceptions	Raw Frequency		Frequency (%)	
	Pretest	Posttest	Pretest	Posttest
1. Calculated product based on one reactant - failed to determine limiting reagent.	86	19	39.1	8.6
2. Added mass or mole amounts of reagents.	29	17	13.2	7.8
3. Added mass or mole amounts of product.	5	4	2.3	1.8
4. Selected wrong substance as limiting reagent.	15	51	6.8	23.2
5. Failed to use balanced chemical equation.	6	2	2.7	0.9
6. Confused mass and mole quantities.	13	15	5.9	6.8
7. Incorrectly calculated molar mass.	29	30	13.2	13.6

It should be noted also that for skills 6 and 7, because of the free-response nature of the test items on these skills, specific misconceptions could not be identified for a substantial number of subjects. Some subjects showed no calculations whatsoever and merely quoted an answer, while others had indecipherable workings for the problems. Still others had neither calculations nor answers.

The number of subjects for whom no misconceptions could be identified was significantly reduced between the pretest and the posttest. For 61.4% of subjects, no specific misconceptions could be identified on one or both of the questions for skill 6 on the pretest, as compared to 34.1% on the posttest. For skill 7 the figures were 55.0% on the pretest and 30% on the posttest. These decreases may be accounted for in the fact that students writing the posttest knew what to expect in terms of test items and could allot their time accordingly. Also, it is possible that because of remediation, subjects were able to complete earlier test items more quickly and hence would have more time and possibly more prerequisite knowledge to attempt the test items on skills 6 and 7. As noted earlier, this may have contributed to increased frequencies of misconceptions on the posttest.

Analysis of Misconceptions by Treatment Group

A second analysis investigated the effectiveness of various remedial treatments in reducing the frequencies of specific misconceptions from pretest to posttest. Subjects who exhibited a particular misconception on the pretest were selected by treatment group, and the frequencies of that misconception on the posttest were determined for the subsamples. Tabulations were made for each misconception on each skill, but in most cases the frequencies were too small for meaningful comparisons. However, combining the frequencies so calculated for all misconceptions on a given skill yielded numbers more suitable for comparison. The results of this analysis are presented in Table 15.

In 4 of the 7 skills in the hierarchy for stiochiometric calculations, including the top 3 skills, the greatest decrease in the frequency of misconceptions among subjects who exhibited these misconceptions on the pretest was in treatment C. In two skills (skills 3 and 4) treatment A showed the greatest decrease in the frequency of misconceptions. In the final skill (skill 1) the frequencies are quite small, but in both treatments A and C there was a 100% decrease in the frequency of misconceptions on this skill. Totalling all of the pretest and posttest frequencies for each treatment group reveals that the overall effect in diminishing the frequencies of misconceptions favors treatment C (86.0%), followed by treatments B (82.0%) and A (79.0%). The statistical significance of the differences between pretest and posttest proportions (Ferguson, 1976, p. 174) was tested for each

TABLE 15

Frequencies of Total Misconceptions by Skill for Selected Subjects Exhibiting Specific Misconceptions on Pretest

Skill	Treatment Group	Frequency Pretest	Frequency Posttest	% decrease
1	A	6	0	100
	B	9	2	77.8
	C	4	0	100
2	A	19	5	73.7
	B	20	4	80.0
	C	12	1	91.7
3	A	15	3	80.0
	B	25	6	76.0
	C	19	7	63.2
4	A	15	0	100
	B	22	2	90.0
	C	22	3	86.4
5	A	40	8	80.0
	B	44	11	75.0
	C	38	4	89.5
6	A	29	7	75.9
	B	35	4	88.6
	C	37	4	89.2
7	A	52	14	73.1
	B	73	12	83.6
	C	47	6	87.2
TOTAL	A	176	37	79.0
	B	228	41	82.0
	C	179	25	86.0

skill and for the totals, but no significant differences were found at the .05 level of significance.

As noted above, the subjects exhibiting a given misconception on the pretest were selected for analysis by treatment group. The extent to which the frequencies decreased on the posttest for these selected subjects was examined. A number of these misconceptions and their corresponding frequencies by treatment group are reported in Table 16. Only misconceptions which were exhibited with an average pretest frequency of nine or greater per treatment group are presented here, since smaller frequencies make comparisons less meaningful.

For five of the nine misconceptions reported in Table 16, the greatest percentage decrease in frequency on the posttest was found for the treatment C group. For two others (misconceptions 6a and 7b), treatments B and C showed virtually equal percentage decrease, both greater than that for treatment A. For the final two misconceptions (3 and 5a), reductions were greatest for treatment A and treatments A and B respectively, though only for the former misconception is the distinction between the treatment groups notable. Tests of significance of the differences between pretest and posttest proportions for each misconception revealed that the differences were not statistically significant for any of the misconceptions ($p > .05$).

<u>Improvement on Failed Skills</u>

A final analysis of the data concerns the

TABLE 16

Pretest and Posttest Frequencies for Most Frequent Misconceptions[a]

Misconception	Group	Frequency Pretest	Frequency Posttest	% Decrease
Skill 2 - Divided molar mass by mass.	A	10	4	60.0
	B	10	4	60.0
	C	7	1	85.7
Skill 3 - Divided moles by molar mass, or vice versa.	A	12	2	83.3
	B	18	6	66.7
	C	13	5	61.5
Skill 5(a) - Did not use mole ratios - calculation on 're-quired' substance only.	A	7	0	100
	B	10	0	100
	C	12	1	100
Skill 5(b) - Combined mass and mole quantities.	A	18	6	66.7
	B	16	7	56.2
	C	13	3	76.9
Skill 6(a) - Chose one reactant without using stoichiometric ratios.	A	15	3	80.0
	B	24	1	95.8
	C	17	1	94.1
Skill 6(b) - Confused mass and mole quantities.	A	7	2	71.4
	B	8	3	62.5
	C	12	2	83.3
Skill 7(a) - Added mass or mole quantities of reagents.	A	12	5	58.3
	B	9	2	77.8
	C	8	1	87.5
Skill 7(b) - Chose one reactant without using stoichiometric ratios.	A	21	5	76.5
	B	34	3	91.2
	C	22	2	90.9
Skill 7(c) - Incorrectly calculated molar mass.	A	7	2	71.4
	B	14	4	71.4
	C	7	0	100

[a] for selected subjects exhibiting specific misconceptions on the pretest.

posttest performance of subjects who answered incorrectly both questions for a given skill on the pretest. These subjects were selected for comparisons between the three treatment groups with regard to correct performance of the skill in question on the posttest. For this analysis, correct performance of a skill is defined as answering correctly both questions for a given skill. A summary of the data is presented in Table 17.

First to be noted is that data on Skill 1 is not included in the summary since only 3 subjects answered both questions on this skill incorrectly on the pretest. The number of subjects is also small for skills 2-4, and thus any generalizations based on these skills may not be meaningful. For skills 5-7, however, the numbers of subjects are relatively large. The percentage column of Table 17 shows that for each of skills 5-7, the highest percentage of subjects who failed a skill on the pretest and subsequently passed the skill on the posttest was in treatment C. Though the differences are only slight in each case and are not statistically significant, the data suggest that students who were remediated according to treatment C (hierarchical arrangement of remedial content with remediation of specific misconceptions) improved slightly more than students in either of the other two treatment levels. A similar general trend in favor of treatment C was noted in earlier analyses.

TABLE 17

Percentages of Subjects Who Failed Pretest Skills and Passed Posttest Skills by Group

Skill	Group	Failed Pretest (n_1)[a]	Passed Posttest (n_2)[b]	% of change ($\frac{n_2}{n_1}$ x 100%)
2	A	11	7	63.6
	B	12	7	58.3
	C	7	6	85.7
3	A	8	6	75.0
	B	8	4	50.0
	C	11	6	54.5
4	A	9	7	77.8
	B	9	3	33.3
	C	13	8	61.5
5	A	22	5	22.7
	B	27	4	14.8
	C	26	8	30.8
6	A	56	12	21.4
	B	56	16	28.6
	C	52	16	30.8
7	A	58	11	19.0
	B	72	13	18.1
	C	57	12	21.1

[a] Answered both questions on a skill incorrectly.

[b] Answered both questions on a skill correctly.

SUMMARY

This chapter has described the results of this study with regard to the reliability of the instruments, the statistical significance of the data and the implications for the hypotheses under study, and the patterns of pretest and posttest performance with regard to misconceptions and overall improvement on skills. The next and final chapter will include a summary of the study, its implications, and a list of recommendations for further research arising from the present study.

CHAPTER 5

Summary, Implications and Recommendations

Summary

This study has investigated the efficacy of three different levels of remedial treatment in addressing student misconceptions in the correct performance of skills in a learning hierarchy for stoichiometric calculations. This particular topic in chemistry is problematic for many high school students, so that remedial instruction is often required following regular teaching of the topic.

The three levels of treatment explored in this study were as follows:

Treatment A - remediation of failed skills with remedial instruction presented in the same sequence as questions testing these skills appeared on a pretest (non-hierarchical arrangement).

Treatment B - remediation of failed skills with remedial instruction sequenced according to the order of these skills in a learning hierarchy.

Treatment C - remediation of failed skills with remedial instruction presented in the order that skills appear in a learning hierarchy, along with reference to individual student misconceptions throughout the remedial material. The study was carried out in a modified individualized format wherein all students in all treatment groups received the same remedial content, but each treatment group was characterized by a unique arrangement and/or feature of the instructional content, and each student in each group was provided with a unique prescription based on his/her performance on a pretest.

A validated learning hierarchy for stoichiometric calculations (Whelan, 1982) served as the basis for the study described herein. A pretest and a parallel posttest were composed to test each of seven skills in the hierarchy. Each test contained two items per skill and questions on five of the seven skills were keyed to specific student misconceptions through multiple choice distractors. The chemistry pretest was administered to all subjects during a normal class period, following which the pretest scores were rank ordered and students were randomly assigned to treatment levels in order of decreasing pretest scores. This effected a matching of groups with regard to pretest performance and allowed the investigator to use intact classes of students with the three levels of treatment represented in each class. In scoring the pretest (and later the posttest) individual student misconceptions on each skill were identified and recorded.

During a later class session, each student was given a version of an individualized remedial booklet containing remedial instruction on all seven skills in the hierarchy. Which version of the booklet a student received depended upon which treatment group he/she had been assigned to following the pretest. Each student's booklet was annotated so that the student could identify those skills on which he/she required remediation. In addition, for treatment C an annotation was made for each subject for each failed skill which identified the student's specific misconception(s) on that skill in the pretest. Subjects were exposed to the remedial booklets for one class period, and during a later class session a posttest was administered to determine whether significant gains in achievement had occurred in any of the treatment groups.

Posttest scores were adjusted through analysis of covariance but this statistical analysis revealed that there were no significant differences in achievement among the treatment groups following remediation. Thus, two null hypotheses were accepted - one relating to hierarchical versus non-hierarchical arrangement of remedial content, and one relating to remediation with reference to misconceptions versus remediation with no reference to misconceptions. Post hoc comparison with an equivalent nonremediated group of subjects yielded a significant difference between posttest means of the post hoc group and each of the three treatment groups.

The patterns of misconceptions which were evident on pretest and posttest answers were also investigated. Some general differences in the frequency of misconceptions between the pretest and the posttest were noted, but no consistent patterns relating to specific treatment groups could be identified. However, several analyses of pretest and posttest responses favored treatment C over the other treatment groups.

Implications

1. Diagnostic-prescriptive remediation (DPR) in this topic (stoichiometry) has been shown to be significantly effective in improving student achievement. Furthermore, DPR in all levels was shown to have a positive effect in decreasing the frequency of student misconceptions relating to the skills in question. This implies that DPR is potentially an important tool in increasing student achievement.

2. The method of remediation has not been shown to have a significant effect on student achievement. Though a general trend in favor of treatment C was noted in the data analyses, the implication for educational practice is that the additional effort required for diagnosis of student misconceptions and for subsequent remediation based on these misconceptions may not translate into increased student achievement.

3. The method of misconceptions identification through keyed distractors in multiple choice questions has implications for the diagnosis of difficulties in a learning sequence, as well as for preparation of instructional and/or remedial materials. The present study illustrates the feasibility of this.

Recommendations

While the method of remediation has not been shown to have a significant effect on student performance following remediation, several recommendations for further study in this area are suggested below.

1. The basic remedial content of the individualized student booklet used in the present study should be revised somewhat in format. A longer period of time should be allowed for testing and for the remedial session. A replication study incorporating these changes could prove fruitful.

2. Diagnosis and remediation should be incorporated together in a computer program to investigate various remedial treatments. Following a response to a diagnostic question, the student would receive immediate remediation in various forms corresponding to the treatment levels investigated in this study. The effect of mastery of earlier skills on subsequent performance of later skills in a learning hierarchy could also be studied in a similar format.

3. The misconceptions relating to stoichiometric calculations identified herein should be considered in curriculum design related to this topic.

4. A "misconceptions feedback" treatment should be investigated wherein feedback consisting of the identification

of a misconception, but no remedial content, is provided. This could be compared with other levels of feedback and/or remedial treatments in order to investigate the conditions for most effective use of feedback for improving student achievement (Yeaney and Miller, 1983).

5. Any study investigating the effects of remediation should strive to ensure control over the remediation, perhaps through computerization, so that the investigator can be confident that subjects are actually being remediated according to prescription.

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APPENDIX 1

NAME ____________________

SCHOOL ____________________

CLASS ____________________

DATE ____________________

Please do not write in this space.

A

CHEMISTRY TEST

This is a test of your ability to do certain kinds of problems in chemistry. Please work through the test as directed.

For the multiple choice questions, <u>first</u> solve the problem using the space provided for calculations; <u>then</u> pick the corresponding answer from the choices provided and write its <u>letter</u> in the answer space. Choose only <u>one</u> answer in each question.

In the other types of questions, PLEASE SHOW ALL OF YOUR CALCULATIONS ON THE PAPER. <u>YOU WILL NOT BE GIVEN ANY CREDIT FOR CORRECT ANSWERS FOR THESE QUESTIONS IF CALCULATIONS ARE NOT SHOWN</u>.

If you have difficulty with any one item, don't spend too much time on it; go on to the next item. Attempt as many questions as you can even if you cannot complete the whole test.

Table of Atomic Molar Masses

Element	Atomic Molar Mass (g/mol)
aluminum (Al)	27.0
boron (B)	11.0
bromine (Br)	80.0
carbon (C)	12.0
calcium (Ca)	40.0
chlorine (Cl)	35.5
chromium (Cr)	52.0
copper (Cu)	63.5
fluorine (F)	19.0
iron (Fe)	56.0
hydrogen (H)	1.00
lithium (Li)	7.00
nitrogen (N)	14.0
oxygen (O)	16.0
potassium (K)	39.0
sodium (Na)	23.0
sulfur (S)	32.0
silver (Ag)	108
zinc (Zn)	65.5

1. How many grams of aluminum oxide (Al_2O_3) are present in 2.50 mol of Al_2O_3?

a) 0.025 g

b) 255 g

c) 108 g

d) 40.8 g

e) 525 g

Answer: ____________

2. The molar mass of hydrogen peroxide (H_2O_2) is:

a) 34.0 g/mol

b) 4.00 g/mol

c) 17.0 g/mol

d) 36.0 g/mol

e) 68.0 g/mol

Answer: ____________

3. Boron (B) reacts with hydrochloric acid (HCl) according to the reaction:

$$2B + 6HCl \longrightarrow 2BCl_3 + 3H_2$$

How many moles of hydrogen (H_2) will be produced if 6.00 mol of boron (B) are completely reacted?

a) 12.0 mol

b) 0.333 mol

c) 18.0 mol

d) 9.00 mol

e) 2.00 mol

f) 6.00 mol

Answer: ____________

4. Calculate the number of moles in 126 g of nitric acid (HNO_3):

a) 1.35 mol

b) 0.500 mol

c) 7.94×10^3 mol

d) 2.00 mol

e) 4.06 mol

Answer: ____________________

5. The mass of one mole of calcium carbonate ($CaCO_3$) is:

a) 204 g

b) 100 g

c) 5.00 g

d) 68.0 g

e) 124 g

Answer: ____________________

6. Sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) react according to the equation:

$$H_2SO_4 + 2NaOH \longrightarrow 2H_2O + Na_2SO_4$$

What mass of sodium sulfate (Na_2SO_4) will be produced if 160 g of NaOH are completely reacted?

a) 284 g

b) 142 g

c) 160 g

d) 35.5 g

e) 4.00 g

f) 80.0 g

Answer: ____________________

7. Calculate the number of moles in 145 g of butane (C_4H_{10}):

a) 2.50 mol

b) 0.400 mol

c) 11.2 mol

d) 8.41 X 10^3 mol

e) 10.4 mol

Answer: ____________

8. How many grams of hydrogen sulfide (H_2S) are contained in 2.00 mol of H_2S?

a) 17.0 g

b) 66.0 g

c) 68.0 g

d) 0.059 g

e) 132 g

Answer: ____________

9. Sodium peroxide (Na_2O_2) reacts with water (H_2O) according to the equation:

$$2Na_2O_2 + 2H_2O \longrightarrow 4NaOH + O_2$$

If 312 g of Na_2O_2 are completely reacted, what mass of sodium hydroxide (NaOH) would be produced?

a) 40.0 g

b) 8.00 g

c) 312 g

d) 320 g

e) 160 g

f) 624 g

Answer: ____________

10. For the reaction: $N_2H_4 + 2H_2O_2 \longrightarrow N_2 + 4H_2O$

How many moles of H_2O_2 would be required in order to completely react 0.500 mol of N_2H_4?

a) 68.0 mol

b) 4.00 mol

c) 17.0 mol

d) 0.500 mol

e) 1.00 mol

f) 2.00 mol

Answer: ______________

11. Carbon disulfide (CS_2) reacts with chlorine gas (Cl_2) according to the equation:

$$CS_2 + 3Cl_2 \longrightarrow CCl_4 + S_2Cl_2$$

If 228 g of CS_2 and 426 g of Cl_2 are mixed and allowed to react until no further reaction occurs, what mass of carbon tetrachloride (CCl_4) will be produced?

<u>*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED</u>

Answer: ______________

12. Zinc sulfide (ZnS) reacts with oxygen (O_2) according to the equation:

$$2ZnS + 3O_2 \longrightarrow 2ZnO + 2SO_2$$

If 5.00 mol of ZnS and 6.00 mol of O_2 are mixed together and allowed to react until no further reaction occurs, how many moles of sulfur dioxide (SO_2) will be produced?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ______________

13. Ammonia (NH_3) and oxygen (O_2) react to produce nitric oxide (NO) and water (H_2O) according to the equation:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

What mass of nitric oxide (NO) will be produced from a reaction between 85.0 g of NH_3 and 128 g of O_2?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ______________

14. Consider the reaction between lithium fluoride (LiF) and sodium sulfide (Na_2S) according to the equation:

$$Na_2S + 2LiF \longrightarrow Li_2S + 2NaF$$

If 4.00 mol of Na_2S and 6.00 mol of LiF are mixed together, and allowed to react until no further reaction occurs, how many moles of lithium sulfide (Li_2S) will be produced?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ____________________

APPENDIX 2

NAME ____________________

SCHOOL ____________________

CLASS ____________________

DATE ____________________

Please do not write in this space.

CHEMISTRY TEST

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chromium (Cr)	52.0
copper (Cu)	63.5
fluorine (F)	19.0
iron (Fe)	56.0
hydrogen (H)	1.00
lithium (Li)	7.00
nitrogen (N)	14.0
oxygen (O)	16.0
potassium (K)	39.0
sodium (Na)	23.0
sulfur (S)	32.0
silver (Ag)	108
zinc (Zn)	65.5

- 1 -

1. What mass of carbon tetrachloride (CCl_4) is present in 1.40 mol of CCl_4?

   a) 216 g

   b) 110 g

   c) 9.00×10^{-3} g

   d) 266 g

   e) 66.5 g

   Answer: ________

2. The molar mass of sulfuric acid (H_2SO_4) is:

   a) 49.0 g/mol

   b) 7.00 g/mol

   c) 196 g/mol

   d) 98.0 g/mol

   e) 200 g/mol

   f) 8.00 g/mol

   Answer: ________

3. Silver (Ag) reacts with nitric acid (HNO_3) according to the equation:

   $$Ag + 2HNO_3 \longrightarrow NO_2 + AgNO_3 + H_2O$$

   How many moles of water (H_2O) would be produced by this reaction if 4.00 mol of HNO_3 are completely reacted?

   a) 72.0 mol

   b) 2.00 mol

   c) 4.00 mol

   d) 18.0 mol

   e) 1.00 mol

   f) 36.0 mol

   Answer: ________

4. How many moles of sodium sulfate (Na_2SO_4) are contained in 284 g of Na_2SO_4?

a) 4.03×10^4 mol

b) 0.500 mol

c) 4.00 mol

d) 1.00 mol

e) 2.00 mol

Answer: ______________

5. The mass of one mole of ammonia (NH_3) is:

a) 45.0 g

b) 17.0 g

c) 4.00 g

d) 15.0 g

e) 51.0 g

Answer: ______________

6. Consider the reaction between hydrogen sulfide (H_2S) and potassium hydroxide (KOH):

$$H_2S + 2KOH \longrightarrow 2H_2O + K_2S$$

If 102 g of H_2S are completely reacted, what mass of water (H_2O) would be produced?

a) 6.00 g

b) 18.0 g

c) 108 g

d) 54.0 g

e) 204 g

f) 51.0 g

Answer: ______________

7. How many moles of calcium bromide ($CaBr_2$) are contained in 100 g of $CaBr_2$?

a) 2.00 mol

b) 0.500 mol

c) 2.00×10^4 mol

d) 0.833 mol

e) 1.20 mol

Answer: ____________

8. What mass of calcium fluoride (CaF_2) is present in 3.00 mol of CaF_2?

a) 26.0 g

b) 354 g

c) 177 g

d) 234 g

e) 0.038 g

Answer: ____________

9. Butene (C_4H_8) reacts with oxygen (O_2) according to the equation:

$$C_4H_8 + 6O_2 \longrightarrow 4CO_2 + 4H_2O$$

If 28.0 g of C_4H_8 are completely reacted, what mass of oxygen (O_2) would be required (consumed)?

a) 192 g
b) 96.0 g
c) 48.0 g
d) 3.00 g
e) 16.0 g
f) 168 g

Answer: ____________

10. Copper (Cu) reacts with silver nitrate ($AgNO_3$) according to the equation:

$$Cu + 2AgNO_3 \longrightarrow 2Ag + Cu(NO_3)_2$$

How many moles of silver (Ag) would be produced if 0.800 mol of copper (Cu) undergoes complete reaction?

a) 1.60 mol

b) 0.800 mol

c) 86.4 mol

d) 135 mol

e) 0.400 mol

f) 2.00 mol

Answer: ____________________

11. Iron (Fe) reacts with hydrogen chloride (HCl) according to the equation:

$$Fe + 2HCl \longrightarrow FeCl_2 + H_2$$

If 168 g of Fe and 146 g of HCl are mixed and allowed to react until no further reaction occurs, what mass of iron (II) chloride ($FeCl_2$) would be produced?

<u>*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED</u>

Answer: ____________________

12. Hydrogen gas (H_2) and chromium chloride ($CrCl_3$) react according to the equation:

$$2CrCl_3 + 3H_2 \longrightarrow 2Cr + 6HCl$$

If 6.00 mol of chromium chloride ($CrCl_3$) and 8.00 mol of hydrogen (H_2) are allowed to react until no further reaction occurs, how many moles of hydrogen chloride (HCl) will be produced?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ______________

13. The reaction for the oxidation of pentane (C_5H_{12}) is as follows:

$$C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$$

If 144 grams of pentane (C_5H_{12}) and 128 grams of oxygen (O_2) are mixed and allowed to react until no further reaction occurs, what mass of carbon dioxide (CO_2) will be produced?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ______________

14. The formation of ammonia (NH_3) may be represented by the equation:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

If 3.00 mol of nitrogen (N_2) and 6.00 mol of hydrogen (H_2) are mixed and allowed to react until no further reaction occurs, how many moles of ammonia (NH_3) will be produced?

*PLEASE SHOW ALL OF YOUR CALCULATIONS IN THE SPACE PROVIDED

Answer: ____________________

APPENDIX 3 (Booklet A)

Name: ____________________

School: ____________________

Class: ____________________

Date: ____________________

M O L / STOICHIOMETRY / A S S

INSTRUCTION BOOKLET

Introduction:

The material covered in this booklet is related to the use of the mole concept in determining reacting amounts of unknown substances. This aspect of chemistry is known as stoichiometry. Here, as in the test you wrote a short while ago, the amounts of substances will be expressed in moles or in mass units (grams).

Purpose of this Booklet:

You have already dealt with stoichoimetric calculations in class; you also wrote a test of stoichiometric problems a short while ago. Your test results indicate that you are having difficulty with some of the types of problems on the test. This instructional booklet is intended to help you overcome these difficulties.

This booklet consists of a number of "lessons", or skills, which review the types of problems which were represented on the test. The lessons are arranged in the order in which the problems appeared on the test. Please turn the page for further directions on how to use this booklet.

Directions

Note carefully the chart below. The first column indicates those skills that you had difficulty with. It is necessary for you to do only those sections of the booklet which deal with these difficulties. Beginning at the lowest skill for which you have an (X) mark, turn to the appropriate page and read through the instructional material for that skill. Once you have completed a skill, please turn back to this page to see which skill you should do next.

In each skill that you do, please follow the steps carefully and do all of the exercises suggested. Remember, your success in overcoming your weaknesses will depend upon how much effort you are willing to put in. Remember also that a thorough understanding of stoichiometry is necessary for any further work in chemistry.

Do These Skills	Skill Number	Pages
	1	5
	2	9
	3	12
	4	18
	5	22
	6	28
	7	35

Table of Atomic Molar Masses

Element	Atomic Molar Mass (g/mol)
Aluminum (Al)	27.0
Boron (B)	11.0
Carbon (C)	12.0
Calcium (Ca)	40.0
Chlorine (Cl)	35.5
Iron (Fe)	56.0
Hydrogen (H)	1.00
Magnesium (Mg)	24.3
Nitrogen (N)	14.0
Oxygen (O)	16.0
Sodium (Na)	23.0
Silicon (Si)	28.0
Sulfur (S)	32.0

SKILL 1 - MOLES TO MASS: Given the number of moles and the formula of a compound, calculate the mass present.

If you are given the chemical formula of a compound, you should be able to convert any given number of moles of the compound to its corresponding mass. This skill involves the use of the molar mass of the compound (Skill 1 in the diagram above).

The mass of one mole of a compound is called the molar mass. It follows then that n moles of a compound have a mass of n times the molar mass. In other words, the given number of moles of the compound is multiplied by the molar mass to give the mass present. This may be summarized as follows:

Mass present (g) = Moles present (mol) x Molar mass (g/mol)

A Sample problem and its solution are given below.

EXAMPLE:

Before the mid 1800's the two most common anaesthetics used by dentists were whiskey and a blow on the head. Later nitrous oxide (N_2O) became widely used.

If a dental patient inhaled 6.50 moles of N_2O, what mass of N_2O would he have inhaled?

The approach to this type of problem is to find the mass of one mole (molar mass) of N_2O, and then multiply that mass by the number of moles given (6.50 mol).

STEP 1: Calculate the molar mass of the compound.

Molar mass of N_2O:

(a) 2 mol of N + 1 mol of O

(b) from Table p. 4, atomic molar mass of:

N ⟶ 14.0 g/mol
O ⟶ 16.0 g/mol

(c) Molar mass of N_2O

= (2 mol x 14.0 g/mol) + (1 mol x 16.0 g/mol)
= 28.0 g + 16.0 g
= 44.0 g/mol of N_2O

STEP 2: Multiply given number of moles by the molar mass

$$\text{Mass present} = \text{Moles present} \times \text{Molar mass}$$
$$= 6.50 \text{ mol} \times 44.0 \text{ g/mol}$$
$$= 286 \text{ g}$$

The dental patient would have inhaled 286 g of nitrous oxide.

NOTE: If the given number of moles is greater than 1, the mass present is greater than the molar mass. If the given number of moles is less than 1, the mass present is less than the molar mass.

Moles > 1, Mass > Molar Mass
Moles < 1, Mass < Molar Mass

You can use this "rule" to check your answer to see whether it is a logical one.

EXERCISES:

1. Calculate the mass present in one half mole of propane (C_3H_8).

STEP 1: Molar mass of C_3H_8:

?

STEP 2: Mass present = Moles present x Molar mass.

Check: ??? Moles present < 1, Mass < Molar mass
Moles present > 1, Mass > Molar mass

2. How many grams of sodium nitrate ($NaNO_3$) are present in 5.00 mol of $NaNO_3$?

____

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

SKILL 2 - MOLAR MASS: Given the chemical formula of a compound, calculate the molar mass of the compound.

The molar mass of a compound is the mass of one mole (6.02×10^{23} molecules) of a compound. If you know the chemical formula of a compound, you should be able to calculate its molar mass.

In order to calculate molar mass you need to know:

A. The number of moles of each element in one mole of the compound.

This information is immediately available from the chemical formula. The subscript directly following the chemical symbol for each element in the formula indicates the number of moles of that element in one mole of the compound.

B. The atomic molar mass of each element in the compound.

This information can be obtained from a standard periodic table. In this booklet a table of atomic molar masses of selected elements is provided (see page 4).

The steps involved in the calculation of molar mass are outlined in the example following.

EXAMPLE:

Nicotine, a poisonous substance found in tobacco leaves, and thus in cigarettes, has the chemical formula C_5H_7N. What is the molar mass of nicotine?

STEP 1: Write the number of moles of each element in one mole of the compound.

$$C_5H_7N$$

$$\underline{5\ \text{mol of C}} + \underline{7\ \text{mol of H}} + \underline{1\ \text{mol of N}}$$

STEP 2: Multiply each number from STEP 1 by the corresponding atomic molar mass (see page 4).

In C_5H_7N:

for C ⟶ 5 mol x 12.0 g/mol = 60.0 g

for H ⟶ 7 mol x 1.00 g/mol = 7.00 g

for N ⟶ 1 mol x 14.0 g/mol = 14.0 g

STEP 3: Add together the total masses of the elements in the compound (the answers in STEP 2)

Molar mass of C_5H_7N = 60.0 g + 7.00 g + 14.0 g = 81.0 g/mol

EXERCISE:

1. Calculate the molar mass of aluminum oxide (Al_2O_3).

STEP 1: Write the number of moles of each element in one mole of the compound.

for Al = ____ for O = ____

STEP 2: Multiply each number in STEP 1 by the atomic molar mass of the element concerned (see table page 4).

for Al ⟶

for O ⟶

STEP 3: Add the answers in STEP 2 to find the molar mass of Al_2O_3.

Molar mass of Al_2O_3 = ____

2. Calculate the molar mass of each of the following:

a) sodium sulfide (Na_2S)

b) magnesium chloride ($MgCl_2$)

c) glucose ($C_6H_{12}O_6$)

Turn to page 42 to check your answers. Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

SKILL 9 - MOLES TO MOLES: Given a balanced chemical equation and the number of moles of one substance, calculate the number of moles of one other reactant or product.

The calculations involved in this type of problem require the use of the balanced chemical equation for the reaction. All further skills in this booklet will also require that you understand and be able to use balanced chemical equations.

Consider the following situation involving a chemical reaction:

Two waste gases produced by industrial processes are sulfur dioxide (SO_2) and hydrogen sulfide (H_2S). One way to deal with the pollution caused by such wastes is to recover them in a usable form. SO_2 and H_2S may be recovered in the form of elemental sulfur (S) according to the equation:

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

Such a balanced chemical equation contains important information about the relative amounts of substances involved in the reaction. The numerical coefficient (the number directly in front of the formula of each substance in the reaction) indicates the relative number of <u>moles</u> of that substance involved in the reaction. The coefficients give the <u>simplest mole relationships</u> between reactants and products. These relationships may be written in the form of ratios.

For example, in the equation below, the mole ratio of H_2S to S will always be:

<u>2 mol of H_2S</u> to <u>3 mol of S</u>

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

<u>1 mol of SO_2</u> to <u>2 mol of H_2O</u>

Similarly, the ratio of SO_2 to H_2O (water) will always be 1:2, as indicated above.

Such mole relationships can be written in the form of fractional ratios. In the examples above:

(i) $$\frac{2 \text{ mol of } H_2S}{3 \text{ mol of S}} = \frac{2}{3}$$

This means that for each 2 mol of H_2S reacted, 3 mol of S will be produced in this reaction.

$$\text{(ii)} \quad \frac{1 \text{ mol of } SO_2}{2 \text{ mol of } H_2O} = \frac{1}{2}$$

This means that for each mol of SO_2 reacted, 2 mol of H_2O will be produced in this reaction.

This information can be used to solve problems of the type given below.

EXAMPLE:

In the reaction: $2H_2S + SO_2 \longrightarrow 3S + 2H_2O$

how many moles of sulfur dioxide (SO_2) would be required to completely react with 16 mol of hydrogen sulfide (H_2S)?

The solution to this type of problem involves three steps.

STEP 1: Determine from the equation the mole relationship of Known to Unknown and write this as a ratio.

NOTE:

Known	=	Substance for which information is given.
Unknown	=	Substance for which information is required.

In the problem above: Known = H_2S

Unknown = SO_2

From the equation we see that the ratio of Known to Unknown is:

$$\frac{2 \text{ mol of } H_2S}{1 \text{ mol of } SO_2} = \frac{2}{1}$$

STEP 2: Let X = the required number of moles of Unknown (SO_2).

Write a second ratio using the given number of moles of Known and using X for the Unknown amount.

$$\frac{\text{Known (given)}}{\text{Unknown (X)}} = \frac{16 \text{ mol of } H_2S}{X \text{ mol of } SO_2} = \frac{16}{X}$$

STEP 3: Write the two ratios in a proportion and solve for X.

Since the mole ratio of any two substances in a reaction will always be the same in a complete reaction, the two ratios above are equal.

$$\frac{2 \text{ mol of } H_2S \text{ (from equation)}}{1 \text{ mol of } SO_2 \text{ (from equation)}} = \frac{16 \text{ mol of } H_2S \text{ (given)}}{X \text{ mol of } SO_2 \text{ (required)}}$$

Thus: $\frac{2}{1} = \frac{16}{X}$

Solve for X by cross multiplying: $\frac{2}{1} = \frac{16}{X}$

$2X = 16$

$X = 8 \text{ mol of } SO_2$

We can now conclude that 8 mol of SO_2 are required to completely react with 16 mol of H_2S in this reaction.

NOTE: The two ratios are equal.

$\frac{2}{1}$ (from equation) = $\frac{16}{8}$ (from calculation)

The steps in a <u>Mole to Mole</u> calculation may be summarized as follows:

STEP 1:	Determine the mole relationship of Known to Unknown from the balanced chemical equation, and write this as a ratio.
STEP 2:	Write a second ratio of Known to Unknown using the given number of moles of Known and using X to represent the required number of moles of Unknown.
STEP 3:	Write the two ratios in a proportion and solve for X.

EXERCIES:

Aluminum oxide (Al_2O_3) reacts with carbon (C) to produce aluminum (Al) and carbon dioxide (CO_2) according to the reaction:

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

1. Calculate the number of moles of Al produced by 6 moles of Al_2O_3.

STEP 1: Ratio of Known (Al_2O_3) to Unknown (Al) from equation.

STEP 2: Ratio of Known (given) to Unknown (required - X).

STEP 3: Write as a proportion and solve for X.

2. Calculate the number of moles of CO_2 produced by 12 moles of C in the reaction:

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

SKILL 4 – MASS TO MOLES: Given the mass and formula of a compound, calculate the number of moles present.

If you are given the chemical formula of a compound you should be able to convert any given mass of the compound to its corresponding number of moles. This skill involves the use of the molar mass of the compound.

The molar mass of a compound is defined as the mass of one mole of the compound. It follows then that any given mass can be coverted to moles by dividing the given mass by the molar mass. This may be summarized as follows:

$$\text{Number of Moles Present} = \frac{\text{Mass Present (g)}}{\text{Molar Mass (g/mol)}}$$

A sample problem and its solution are given below.

EXAMPLE:

Silicosis is a lung disease contracted by inhaling dust formed in sandblasting or in silicon mining. The dust consists of a compound of silicon and oxygen called silicon dioxide (SiO_2).

If a man inhales 180 grams of SiO_2, how many moles of SiO_2 has he inhaled?

The approach to this type of problem is to calculate the mass of one mole (molar mass) of the compound, and then to divide the given mass by the molar mass.

STEP 1: Calculate the molar mass of the compound.

<u>Molar mass of SiO_2</u>

(a) In SiO_2 :

<u>1 mol of Si + 2 mol of O</u>

(b) From Table p. 4, atomic molar mass of:

Si ⟶ 28.0 g/mol

O ⟶ 16.0 g/mol

(c) <u>Molar mass of SiO_2</u> =

(1 mol x 28.0 g/mol) + (2 mol x 16.0 g/mol)

= 28.0 g + 32.0 g

= 60.0 g/mol of SiO_2

STEP 2: Divide the given mass of the compound by the molar mass.

$$\text{Moles Present} = \frac{\text{Mass Present}}{\text{Molar Mass}}$$

$$= \frac{180\ g}{60.0\ g/mol} = 3.00\ mol$$

The man inhales 3.00 mol of SiO_2

A USEFUL CHECK:

If the given mass is greater than the molar mass, the number of moles will be greater than 1. If the given mass is less than the molar mass, the number of moles will be less than 1.

Given mass > molar mass, moles > 1

Given mass < molar mass, moles < 1

You can use this "RULE" to check your answer to see whether it is a logical one.

EXERCISES:

1. Calculate the number of moles of sodium oxide (Na_2O) in 124 g of Na_2O.

STEP 1: Molar mass of Na_2O:

STEP 2: Moles present = $\frac{\text{Given mass}}{\text{Molar mass}}$

CHECK: ??? Given mass > molar mass; moles > 1
Given mass < molar mass; moles < 1

2. Calculate the number of moles present in 162 g of nitrogen pentoxide (N_2O_5).

Turn to page 42 to check your answers. Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

<u>SKILL 5 - MASS TO MASS</u>: Given the balanced chemical equation for a reaction and the mass of one substance, calculate the mass of one other substance.

In this skill you are required to calculate the mass of one substance in a reaction if you are given the mass of one other substance and the balanced chemical equation for the reaction. This skill is a combination of three other skills.

Here is a sample problem involving a mass to mass calculation.

One of the problems of space travel is the build up of carbon dioxide (CO_2) produced by the astronauts in the space vehicle. One proposal for solving this problem was to use sodium hydroxide (NaOH) to remove CO_2 as in the reaction:

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

If the average human body discharges 924 g of CO_2 per day, what mass of NaOH would be required to remove the daily output of CO_2 by one astronaut?

The approach to solving this type of problem is to first convert the given mass to moles. Then using the mole relationship from the balanced chemical equation, determine the number of moles of Unknown substance produced (Moles to Moles calculation). This calculated number of moles is then converted to mass.

STEP 1: Convert given mass to moles.

Given mass = 924 g of CO_2

To convert mass to moles, divide mass by molar mass.

$$\text{Moles present} = \frac{\text{Mass Present}}{\text{Molar mass}}$$

a) Molar mass of CO_2

$= (1 \text{ mol} \times 12.0 \text{ g/mol}) + (2 \text{ mol} \times 16.0 \text{ g/mol})$
$= 44.0 \text{ g/mol}$

b) $\text{Moles present} = \frac{924\text{g}}{44.0\text{g/mol}} = 21.0 \text{ mol}$

STEP 2: Calculate the number of moles of Unknown substance (NaOH) that are required to react with the number of moles of Known substance calculated above (21 mol of CO_2).

This is a Moles to Moles calculation involving these three steps:

(a) Determine the ratio of Known (CO_2) to Unknown (NaOH) from the equation.

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

Known =	Substance for which information is given.
Unknown =	Substance for which information is required.

$$\frac{\text{Known}}{\text{Unknown}} = \frac{1 \text{ mol of } CO_2}{2 \text{ mol of NaOH}} = \frac{1}{2}$$

(b) Write a second ratio using the calculated number of moles of Known from Step 1 and using X to represent the required number of moles of Unknown.

$$\frac{\text{Known (given)}}{\text{Unknown (required)}} = \frac{21 \text{ mol of } CO_2}{X \text{ mol of NaOH}} = \frac{21}{X}$$

(c) Write the two ratios from (a) and (b) in a proportion and solve for X.

$$\frac{1 \text{ mol of } CO_2}{2 \text{ mol of NaOH}} = \frac{21 \text{ mol of } CO_2}{X \text{ mol of NaOH}}$$

$$\frac{1}{2} = \frac{21}{X}$$

$X = 42$ mol of NaOH

STEP 3: Convert calculated number of moles of unknown (42 mol of NaOH) to mass.

To change from Moles to Mass, we multiply as follows:

Mass present = Moles Present x Molar mass

a) <u>Molar mass of NaOH</u>:

$= (1 \text{ mol} \times 23.0 \text{ g/mol}) + (1 \text{ mol} \times 16.0 \text{ g/mol}) + (1 \text{ mol} \times 1.00 \text{ g/mol})$

$= 40.0 \text{ g/mol}$

b) <u>Mass present (NaOH)</u> $= 42 \text{ mol} \times 40.0 \text{ g/mol}$

$= 1680 \text{ g} = 1.68 \times 10^3 \text{ g}$

Thus 1.68×10^3 g of NaOH would be required to remove the daily output of CO_2 of one astronaut.

A review of the Steps in this Skill reveal that a Mass to Mass calculation is essentially a combination of three skills.

STEP 1: Convert given mass of Known substance to its corresponding number of moles.

(Mass to Moles)

STEP 2: Calculate the <u>number of moles of Unknown substance</u> corresponding to the calculated number of moles of Known from STEP 1.

(Moles to Moles)

STEP 3: Convert calculated number of <u>moles</u> of Unknown substance (STEP 2) to its corresponding mass.

(Moles to Mass)

EXERCISES:

1. Methane (CH_4) reacts with oxygen gas (O_2) according to the equation:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

If 8.00 g of CH_4 are reacted, what mass of water (H_2O) would be produced?

STEP 1: Convert given mass of Known (CH_4) to moles.

a) Molar mass of Known substance:

b) Moles = $\frac{\text{Mass}}{\text{Molar Mass}}$

STEP 2: Calculate moles of Unknown (H_2O) produced by calculated moles of Known (____ mol of CH_4).

(a) Write the ratio of Known to Unknown from the equation:

$$\frac{\text{Known } (CH_4)}{\text{Unknown } (H_2O)} =$$

(b) Write a ratio using the calculated number of moles of Known from Step 1, and using X to represent the required number of moles of Unknown.

$$\frac{\text{Known (given)}}{\text{Unknown (required)}} =$$

(c) Write the two ratios in a proportion and solve for X.

STEP 3: Convert moles of Unknown from STEP 2 (____ mol of H_2O) to its corresponding mass.

a) Molar mass of Unknown substance :

b) Mass present = Moles x Molar mass

Turn to page A2 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

SKILL 6 - MASS TO MASS (EXCESS): Given a balanced chemical equation and the masses of two reactants, one of which is in excess, calculate the mass of a product.

In some problems (and in some chemists' actual situations) the mass of each of two reactants is known, but one of them may be in excess. The question is: How much product will be produced if the given amounts of reactants are mixed and allowed to react? The expected amount of product can be calculated using a combination of several skills.

An example of this type of problem and the procedure for working it out are given below.

When iron is made in a blast furnace the main reaction which occurs is:

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

If 320 g of iron (II) oxide (Fe_2O_3) and 252 g of carbon monoxide (CO) are present in the reaction chamber of the blast furnace, what mass of iron (Fe) would result according to the reaction above?

The approach to this type of problem is to convert the given masses to moles, then using the Moles to Moles (Excess) calculation the number of moles of product can be determined. This mole quantity of product is then converted to mass.

The STEPS in a mass to mass (excess) calculation may be summarized as follows:

STEP A: Convert given masses of reactants to moles.

STEP B: Do a moles to moles (Excess) calculation.

1. Find the number of moles of Unknown (in this case, Fe) which might be produced by the calculated number of moles of Known A (Fe_2O_3) and the number of moles of Unknown which might be produced by the calculated number of moles of Known B (CO).

2. Determine the Limiting Reagent.

3. Write the number of moles of Unknown produced by Limiting Reagent.

STEP C: Convert calculated moles of Unknown (from STEP B-3) to its corresponding mass.

Back to the original problem:

For the reaction: $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

we want to answer the question:

320 g of Fe_2O_3 + 252 g of CO → __?__ g of Fe

STEP A: Convert given masses to moles

$$\text{Moles Present} = \frac{\text{Mass Present}}{\text{Molar Mass}}$$

Known A: Fe_2O_3 - Mass present = 320 g

Molar mass = (2 x 56.0) + (3 x 16.0)
= 160 g/mol

$$\text{Moles Present} = \frac{320\ g}{160\ g/mol} = 2.00\ mol$$

Known B: CO - Mass present = 252 g

Molar mass = (1 x 12.0) + (1 x 16.0)
= 28.0 g/mol

$$\text{Moles Present} = \frac{252\ g}{28\ g/mol} = 9.00\ mol$$

STEP B: Moles to Moles (EXCESS) Calculation

1. a) Ratio of Known A (Fe_2O_3) to Unknown (Fe) from equation.

$$\frac{\text{Known A}}{\text{Unknown}} = \frac{1 \text{ mol of } Fe_2O_3}{2 \text{ mol of } Fe} = \frac{1}{2}$$

b) Ratio of calculated number of moles of Known A (Step A) to required number of moles of Unknown (X).

$$\frac{\text{Known A (given-calculated)}}{\text{Unknown (required - X)}} = \frac{2 \text{ mol of } Fe_2O_3}{X \text{ mol of } Fe} = \frac{2}{X}$$

c) Write ratios in (a) and (b) as a proportion and solve for X.

$$\frac{1}{2} = \frac{2}{X}$$

X = 4 mols of Fe could be produced.

d) Ratio of Known B (CO) to Unknown from equation.

$$\frac{\text{Known B}}{\text{Unknown}} = \frac{3 \text{ mol of CO}}{2 \text{ mol of Fe}} = \frac{3}{2}$$

e) Ratio of Known B (moles calculated in Step A) to required number of moles of Unknown (y).

$$\frac{\text{Known B (given-calculated)}}{\text{Unknown (required-y)}} = \frac{9 \text{ mol of CO}}{y \text{ mol of Fe}} = \frac{9}{y}$$

f) Write ratios in (d) and (e) in a proportion and solve for y.

$\frac{3}{2} = \frac{9}{y}$ 3y = 18 y = <u>6 mol of Fe could be produced</u>

2. Determine Limiting Reagent (see discussion on page 35).

Limiting Reagent is Fe_2O_3 because the given amount of Fe_2O_3 will yield fewer moles of product (Fe) than the given amount of CO, if both were fully reacted.

Note that in STEP B - 1, two possible amounts of product (Fe) were calculated. But the actual amount of product which could form is determined by the reagent which is used up first in the reaction - Fe_2O_3. Once this reagent - the limiting reagent - is used up, no futher reaction can occur. The other reagent (CO) was in excess; there will be some CO remaining after the reaction is complete.

3. Moles of Unknown (Fe) actually produced = 4 mol

320 g (2 mol) of Fe_2O_3 + 252 (9 mol) of CO ⟶ 4 mol of Fe

STEP C: Convert calculated moles of Unknown to Mass

Mass Present = Moles Present x Molar Mass

Molar Mass of Fe = 56.0 g/mol

Mass Present = 4.00 mol x 56.0 g/mol
= 224 g of Fe

We can now conclude that the reaction of 320 g of Fe_2O_3 and 252 g of CO will yield 224 g of Fe.

EXERCISE: Consider the reaction between acetylene (C_2H_2) and oxygen (O_2) according to the equation

$$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$$

If 52.0 g of C_2H_2 and 32.0 g of O_2 are mixed together and allowed to react until no further reaction occurs, what mass of carbon dioxide (CO_2) will be produced?

STEP A: Convert given masses to moles.

52.0 g of C_2H_2 = _____ mol of C_2H_2

32 g of O_2 = _____ mol of O_2

STEP B: Moles to moles (EXCESS) calculation.

1. a) $\frac{\text{Known A (Equation)}}{\text{Unknown (Equation)}} = \frac{\text{Known A (calculated in Step A)}}{\text{Unknown (required-X)}}$

$$\frac{\_\_\_\_}{\_\_\_\_} = \frac{\_\_\_\_}{X}$$

X =

b) $\frac{\text{Known B (Equation)}}{\text{Unknown (Equation)}} = \frac{\text{Known B (calculated Step A)}}{\text{Unknown (required-y)}}$

$$\frac{\_\_\_\_}{\_\_\_\_} = \frac{\_\_\_\_}{y}$$

y =

STEP B:

2. Limiting Reagent:

3. 52.0 g (___ mol) of C_2H_2 + 32.0 g (___ mol) of O_2 $\rightarrow$
_____ mol of CO_2

STEP C: Change moles of Unknown (STEP B-3) to mass.

52.0 g of C_2H_2 + 32.0 g of O_2 $\rightarrow$ _____ g of CO_2

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, turn to page 3 and follow the directions there.

SKILL 7 - MOLES TO MOLES (EXCESS): Given a balanced chemical equation and the number of moles of two reactants, one of which is in excess, calculate the number of moles of a product.

In this skill you are given the number of moles of two reactants, one of which may be In Excess, and you are asked to calculate the number of moles of a product in the reaction. When amounts of two reactants are given in a problem, this is a clue that an excess-type calculation is involved.

First you have to decide which of the reactants is In Excess and which of the two is the Limiting Reagent. Let's start with a non-chemical example first.

The concept of the limiting reagent may be likened to the following situation:

A craftsman needs 2 metres of wooden dowel and 5 metres of plastic binding in order to make one footstool. If the craftsman receives a shipment containing 10 metres of dowel and 20 metres of plastic binding, how many footstools can he make from these materials?

With 10 metres of dowel he can make $10 \div 2 = 5$ stools
With 20 metres of binding he can make $20 \div 5 = 4$ stools

Obviously with the material in the shipment he can make only 4 complete stools. The amount of binding limits the number of stools that can be made. It is the limiting agent. There is an excess amount of dowel that will be left over after the 4 stools are completed.

How does this apply to a moles to moles (excess) problem? An example of this type of problem and the procedure for solving it are given below.

EXAMPLE:

The fuel oxidizer combination used in the Apollo 11 lunar module was as follows:

The fuel was Aerozine 50, approximately half of which was hydrazine (N_2H_4), while the oxidizer was nitrogen tetroxide (N_2O_4). The principal exhaust product was water (H_2O). One of the reactions leading to the formation of water was:

$$2N_2H_4 + N_2O_4 \longrightarrow 3N_2 + 4H_2O$$

If 12 moles of hydrazine (N_2H_4) and 10 moles of nitrogen tetroxide (N_2O_4) were reacted together in the combustion chamber until no further reaction occurred, how many moles of water (H_2O) would be produced?

In this type of problem you are given amounts of two substances:

Known A = N_2H_4
Known B = N_2O_4

The procedure is to determine which of the given quantities (12 mol of N_2H_3 or 10 mol of N_2O_4) produces the lesser amount of Unknown substance (in this case, H_2O). Whichever produces the lesser amount of product will be the <u>limiting reagent</u>.

It is necessary then to do <u>two</u> Mole to Mole calculations to answer these two questions:

For the reaction: $2N_2H_4 + N_2O_4 \longrightarrow 3N_2 + 4H_2O$

(i) How many moles of H_2O could be produced by 12 mol of N_2H_4?

(ii) How many moles of H_2O could be produced by 10 mol of N_2O_4?

Whichever of the two answers is the lesser will be the answer to the original problem.

STEP 1: Two "Mole to Mole" calculations

a) <u>For Known A (N_2H_4)</u>

(i) Ratio of Known A to Unknown from Equation:

$$\frac{\text{Known A}}{\text{Unknown}} = \frac{2 \text{ mol of } N_2H_4}{4 \text{ mol of } H_2O} = \frac{2}{4}$$

ii) Let X = number of moles of Unknown that could be produced by given amount of Known A.

Ratio of Known A (given) to Unknown (required):

$$\frac{12 \text{ mol of } N_2H_4}{X \text{ mol of } H_2O}$$

iii) Write the two ratios in a proportion and solve for X.

$$\frac{2 \text{ mol of } N_2H_4}{4 \text{ mol of } H_2O} = \frac{12 \text{ mol of } N_2H_4}{X \text{ mol of } H_2O}$$

$$\frac{2}{4} = \frac{12}{X}$$

$$2X = 48$$

$$X = 24 \text{ mol of } H_2O$$

b) <u>For Known B (N_2O_4)</u>:

i) Ratio from equation: $\frac{\text{Known B}}{\text{Unknown}} = \frac{1 \text{ mol of } N_2O_4}{4 \text{ mol of } H_2O}$

ii) Let y = number of moles of Unknown which could be produced by given amount of Known B.

Ratio of given to required: $\frac{10 \text{ mol of } N_2O_4}{y \text{ mol of } H_2O}$

iii) Write as a proportion and solve for y.

$$\frac{1}{4} = \frac{10}{y}$$

$$y = 40 \text{ mol of } H_2O$$

From the two mole to mole calculations we find:

12 mol of N_2H_4 produces 24 mol of H_2O

10 mol of N_2O_4 produces 40 mol of H_2O

Which of these two amounts (24 mol or 40 mol) is correct?

Only one amount of product will be produced from the reaction of 12 mol of N_2H_4 and 10 mol of N_2O_4. Once one of the reactants is all used up, it doesn't matter how much of the other is left — it will have nothing left to react with. The amount of product is limited by whichever reactant can produce the least amount of product. Hence it is called the Limiting Reagent.

In the problem above, the N_2H_4 will be used up first; it is therefore the limiting reagent. There isn't enough N_2H_4 to react with all 10 moles of N_2O_4. The amount of product is limited by the quantity of N_2H_4 present; the other reactant (N_2O_4) is in excess.

We can conclude that 12 mol of N_2H_4 and 10 mol of N_2O_4 produced 24 mol of H_2O when the reaction was completed. All of the N_2H_4 was used up, but some of the N_2O_4 was unreacted.

The STEPS in a Moles to Moles (Excess) Calculation

Preliminary STEP: Recognizing an EXCESS problem.

Rule:	Mole quantities of two Reactants Given	→	Do steps in "EXCESS"-type problem.
	Mole quantity of only one substance given	→	Do straight Moles to Moles Calculation (Skill 3)

FURTHER STEPS:

STEP 1: a) Determine number of moles of Unknown substance which might be produced by given amount of Known A.
b) Determine number of moles of Unknown substance which might be produced by given amount of Known B.

STEP 2: Determine which reactant (Known A or Known B) is the <u>Limiting Reagent</u>.

STEP 3: From STEP 1 write the number of moles of Unknown produced by the Limiting Reagent as your answer.

<u>EXERCISE</u>:

Consider the reaction between aluminum oxide (Al_2O_3) and hydrogen gas (H_2) according to the equation

$$Al_2O_3 + 3H_2 \longrightarrow 2Al + 3H_2O$$

If 2 mol of Al_2O_3 and 7 mol of H_2 are mixed together and allowed to react until no further reaction occurs, how many moles of water (H_2O) will be produced?

<u>Preliminary STEP</u>: Is this an "Excess" problem?

Ask Yourself: Are amounts of <u>two</u> reactants given?
Answer: Yes.
Conclusion: This could be an "excess" problem.
Do steps in "excess"-type calculation.

STEP 1: a) Moles of Unknown (H_2O) produced by given moles of Known A (2 mol of Al_2O_3).

b) Moles of Unknown (H_2O) produced by given moles of Known B (7 mol of H_2).

???? - What if the two answers in a) and b) above are the same? No problem!
This indicates that there is no excess and that the amount of product will be what you have calculated in a) or b). Both amounts of reactants will be completely consumed.

STEP 2: Determine Limiting Reagent
- Which given amount of Known - A or B - produces the smaller amount of Unknown?

STEP 3: 2 mol of Al_2O_3 + 7 mol of H_2 $\longrightarrow$ ___ mol of H_2O

Amount produced by given amount of Limiting Reagent

Turn to page 42 to check your answers.

You have now completed all of the skills with which you had difficulty on your previous test. If you have any time left, please turn to page 43 and work on the additional exercises there. Feel free to do any of the other skills in this booklet as time permits.

Page	Exercise No.	Answer
8	1	22.0 g
8	2	425 g
11	1	102 g/mol
11	2 a)	78.0 g/mol
	b)	95.3 g/mol
	c)	180 g/mol
16	1	12 mol of Al
17	2	12 mol of CO_2
21	1	2.00 mol
21	2	1.50 mol
27	1	18.0 g of H_2O
34	1	35.2 g of CO_2
41	1	6.00 mol of O_2

Additional Exercises

1. How many moles of hydrogen chloride (HCl) are there in 80.3 g of HCl?

2. Calculate the molar mass of each of the following:
   a) carbon monoxide (CO)
   b) hydrogen borate (H_3BO_3)

3. In the reaction $2B + 6HCl \longrightarrow 2BCl_3 + 3H_2$
How many moles of HCl would be required to completely react 5 moles of boron (B)?

4. What is the mass present in 4.5 mol of sodium chloride (NaCl)?

5. Nitrogen gas (N_2) reacts with water (H_2O) according to the reaction $2N_2 + 6H_2O \longrightarrow 4NH_3 + 3O_2$
What mass of oxygen gas (O_2) would be produced from 54 g of H_2O?

6. In the reaction $2NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + 2HCl$
If 234 g of NaCl and 245 g of H_2SO_4 are mixed and allowed to react until no further reaction occurs, what mass of HCl will be produced?

7. 20 mol of ammonia (NH_3) and 20 mol of oxygen (O_2) are mixed and allowed to react until no further reaction occurs, the reaction which takes place is

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

How many moles of water (H_2) will be produced?

Turn the page to check your answers.

Answers to Additional Exercises

No.	Answer
1	2.2 mol of HCl
2 a)	28.0 g/mol
b)	62.0 g/mol
3	15.0 mol of HCl
4	.263 g of NaCl (3 significant figures)
5	48.0 g of O_2
6	146 g of HCl
7	24.0 mol of H_2O

APPENDIX 4 (Booklet B)

Name: ______________________

School: ______________________

Class: ______________________

Date: ______________________

STOICHIOMETRY

MOLE

MASS

INSTRUCTION BOOKLET

Introduction

The material covered in this instruction booklet is related to the use of the mole concept in determining reacting amounts of unknown substances. This aspect of chemistry is known as stoichiometry. Here, as in the test you wrote a short while ago, the amounts of substances will be expressed in moles or in mass units (grams).

In order to do stoichiometric calculations you need to develop basic skills and then build upon these as you encounter more and more complex problems. The skills involved and their relationship to each other are summarized in the diagrammed flowchart on the following page (page 2).

Note that skills 1, 2 and 3 are concerned with chemical compounds alone, and that the remaining skills 4-7, deal with chemical reactions and the reactants and/or products in these reactions.

Purpose of this Booklet

You have already dealt with these skills in class; you also wrote a test of these skills a short while ago. Your test results indicate that you are having difficulty with some of the types of problems listed in the flowchart on the following page. This instructional booklet is intended to help you overcome these difficulties.

After you have studied the flowchart on the next page, please turn to page 3 and note carefully the directions you are to follow in using this booklet.

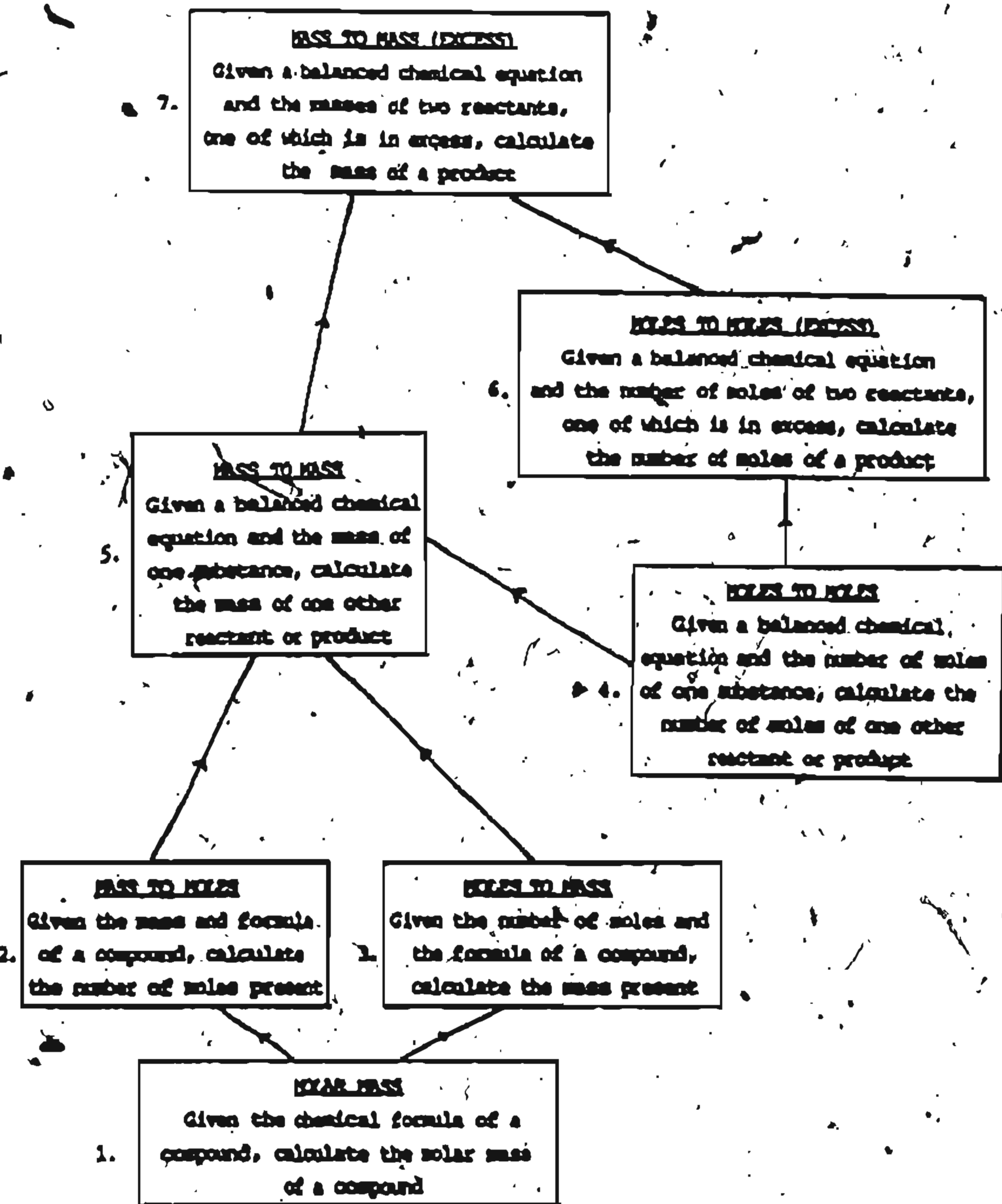


Figure 1-

Flowchart of Skills Involved in Stoichiometric Calculations

Directions

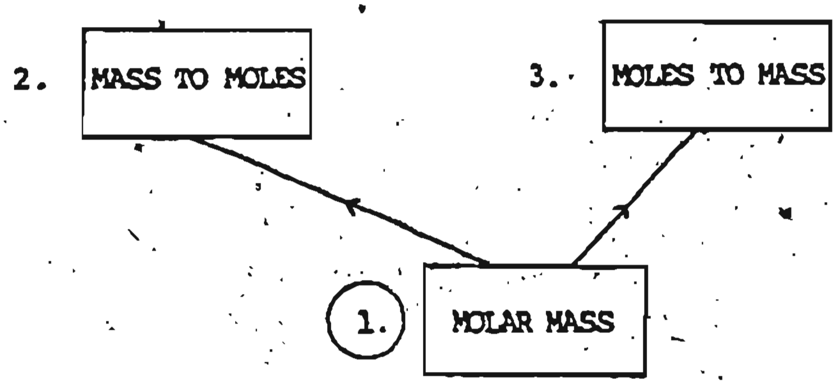
Note carefully the chart below. The first column indicates those skills that you had difficulty with. It is necessary for you to do only those sections of the booklet which deal with these difficulties. Beginning at the lowest skill for which you have an (X) mark, turn to the appropriate page and read through the instructional material for that skill. Once you have completed a skill, please turn back to this page to see which skill you should do next.

In each skill that you do, please follow the steps carefully and do all of the exercises suggested. Remember, your success in overcoming your weaknesses will depend upon how much effort you are willing to put in. Remember also that a thorough understanding of stoichiometry is necessary for any further work in chemistry.

Do These Skills	Skill Number	Pages
	1	5
	2	8
	3	12
	4	16
	5	22
	6	28
	7	35

Table of Atomic Molar Masses

Element	Atomic Molar Mass (g/mol)
Aluminum (Al)	27.0
Boron (B)	11.0
Carbon (C)	12.0
Calcium (Ca)	40.0
Chlorine (Cl)	35.5
Iron (Fe)	56.0
Hydrogen (H)	1.00
Magnesium (Mg)	24.3
Nitrogen (N)	14.0
Oxygen (O)	16.0
Sodium (Na)	23.0
Silicon (Si)	28.0
Sulfur (S)	32.0



SKILL 1 - MOLAR MASS: Given the chemical formula of a compound, calculate the molar mass of the compound.

The molar mass of a compound is the mass of one mole (6.02×10^{23} molecules) of a compound. If you know the chemical formula of a compound, you should be able to calculate its molar mass.

In order to calculate molar mass you need to know:

A. The number of moles of each element in one mole of the compound.

This information is immediately available from the chemical formula. The subscript directly following the chemical symbol for each element in the formula indicates the number of moles of that element in one mole of the compound.

B. The atomic molar mass of each element in the compound.

This information can be obtained from a standard periodic table. In this booklet a table of atomic molar masses of selected elements is provided (see page 4).

The steps involved in the calculation of molar mass are outlined in the example following.

EXAMPLE:

Nicotine, a poisonous substance found in tobacco leaves, and thus in cigarettes, has the chemical formula C_5H_7N. What is the molar mass of nicotine?

STEP 1: Write the number of moles of each element in one mole of the compound.

C_5H_7N

5 mol of C + 7 mol of H + 1 mol of N

STEP 2: Multiply each number from STEP 1 by the corresponding atomic molar mass (see page 4).

In C_5H_7N:

for C ⟶ 5 mol x 12.0 g/mol = 60.0 g

for H ⟶ 7 mol x 1.00 g/mol = 7.00 g

for N ⟶ 1 mol x 14.0 g/mol = 14.0 g

STEP 3: Add together the total masses of the elements in the compound (the answers in STEP 2)

Molar mass of C_5H_7N = 60.0 g + 7.00 g + 14.0 g = 81.0 g/mol

EXERCISE:

1. Calculate the molar mass of aluminum oxide (Al_2O_3).

STEP 1: Write the number of moles of each element in one mole of the compound.

for Al = ____ for O = ____

STEP 2: Multiply each number in STEP 1 by the atomic molar mass of the element concerned (see table page 4).

for Al →

for O →

STEP 3: Add the answers in STEP 2 to find the molar mass of Al_2O_3.

Molar mass of Al_2O_3 = ____

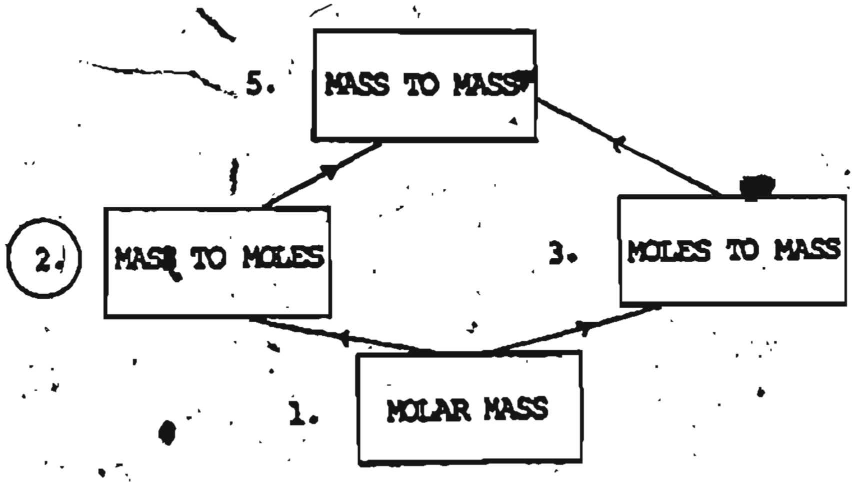
2. Calculate the molar mass of each of the following:

a) sodium sulfide (Na_2S)

b) magnesium chloride ($MgCl_2$)

c) glucose ($C_6H_{12}O_6$)

Turn to page 42 to check your answers. Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.



SKILL 2 - MASS TO MOLES: Given the mass and formula of a compound, calculate the number of moles present.

If you are given the chemical formula of a compound you should be able to convert any given mass of the compound to its corresponding number of moles. This skill involves the use of the molar mass of the compound.

The molar mass of a compound is defined as the mass of one mole of the compound. It follows then that any given mass can be coverted to moles by dividing the given mass by the molar mass. This may be summarized as follows:

$$\text{Number of Moles Present} = \frac{\text{Mass Present (g)}}{\text{Molar Mass (g/mol)}}$$

A sample problem and its solution are given below.

EXAMPLE:

Silicosis is a lung disease contracted by inhaling dust formed in sandblasting or in silicon mining. The dust consists of a compound of silicon and oxygen called silicon dioxide (SiO_2).

If a man inhales 180 grams of SiO_2, how many moles of SiO_2 has he inhaled?

The approach to this type of problem is to calculate the mass of one mole (molar mass) of the compound, and then to divide the given mass by the molar mass.

STEP 1: Calculate the molar mass of the compound.

Molar mass of SiO_2

(a) In SiO_2

1 mol of Si + 2 mol of O

(b) From Table p. 4, atomic molar mass of:

Si ⟶ 28.0 g/mol

O ⟶ 16.0 g/mol

(c) Molar mass of SiO_2 =

(1 mol x 28.0 g/mol) + (2 mol x 16.0 g/mol)

= 28.0 g + 32.0 g

= 60.0 g/mol of SiO_2

STEP 2: Divide the given mass of the compound by the molar mass.

$$\text{Moles Present} = \frac{\text{Mass Present}}{\text{Molar Mass}}$$

$$= \frac{180\ g}{60.0\ g/mol} = 3.00\ mol$$

The man inhales 3.00 mol of SiO_2

A USEFUL CHECK:

If the given mass is greater than the molar mass, the number of moles will be greater than 1. If the given mass is less than the molar mass, the number of moles will be less than 1.

Given mass > molar mass, moles > 1
Given mass < molar mass, moles < 1

You can use this "RULE" to check your answer to see whether it is a logical one.

EXERCISES:

1. Calculate the number of moles of sodium oxide (Na_2O) in 124 g of Na_2O.

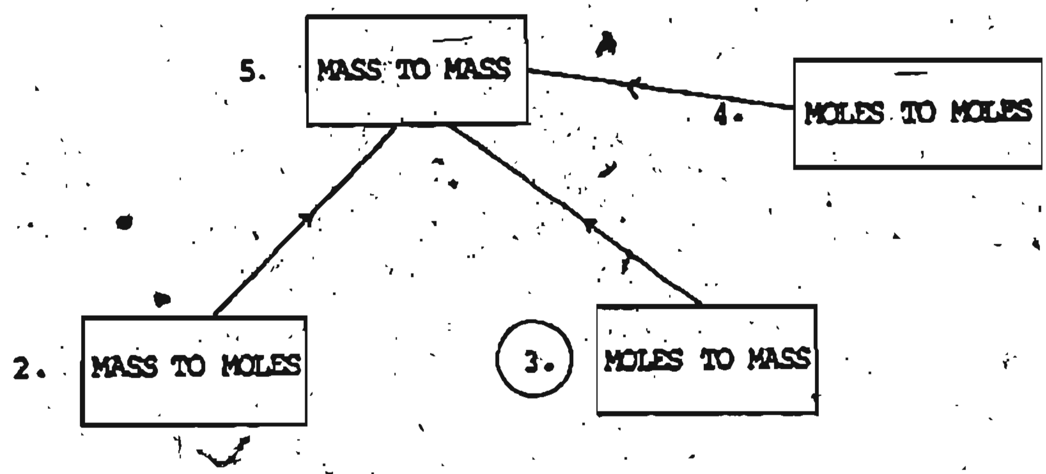
STEP 1: Molar mass of Na_2O:

STEP 2: Moles present $= \frac{\text{Given mass}}{\text{Molar mass}}$

CHECK: ??? Given mass > molar mass; moles > 1
Given mass < molar mass; moles < 1

2. Calculate the number of moles present in 162 g of nitrogen pentoxide (N_2O_5).

Turn to page 42 to check your answers. Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.



SKILL 3 - MOLES TO MASS: Given the number of moles and the formula of a compound, calculate the mass present.

If you are given the chemical formula of a compound, you should be able to convert any given number of moles of the compound to its corresponding mass. This skill involves the use of the molar mass of the compound.

The mass of one mole of a compound is called the molar mass. It follows then that n moles of a compound have a mass of n times the molar mass. In other words, the given number of moles of the compound is multiplied by the molar mass to give the mass present. This may be summarized as follows:

Mass present (g) = Moles present (mol) x Molar mass (g/mol)

A sample problem and its solution are given below.

EXAMPLE:

Before the mid 1800's the two most common anaesthetics used by dentists were whiskey and a blow on the head. Later nitrous oxide (N_2O) became widely used.

If a dental patient inhaled 6.50 moles of N_2O, what mass of N_2O would he have inhaled?

The approach to this type of problem is to find the mass of one mole (molar mass) of N_2O, and then multiply that mass by the number of moles given (6.50 mol).

STEP 1: Calculate the molar mass of the compound.

<u>Molar mass of N_2O:</u>

(a) 2 mol of N + 1 mol of O

(b) from Table p. 4, atomic molar mass of:

N ⟶ 14.0 g/mol
O ⟶ 16.0 g/mol

(c) <u>Molar mass of N_2O</u>

= (2 mol x 14.0 g/mol) + (1 mol x 16.0 g/mol)
= 28.0 g + 16.0 g
= 44.0 g/mol of N_2O

STEP 2: Multiply given number of moles by the molar mass

$$\text{Mass present} = \text{Moles present} \times \text{Molar mass}$$
$$= 6.50 \text{ mol} \times 44.0 \text{ g/mol}$$
$$= 286 \text{ g}$$

The dental patient would have inhaled 286 g of nitrous oxide.

NOTE: If the given number of moles is greater than 1, the mass present is greater than the molar mass. If the given number of moles is less than 1, the mass present is less than the molar mass.

Moles > 1, Mass > Molar Mass
Moles < 1, Mass < Molar Mass

You can use this "rule" to check your answer to see whether it is a logical one.

EXERCISES:

1. Calculate the mass present in one half mole of propane (C_3H_8).

STEP 1: Molar mass of C_3H_8:

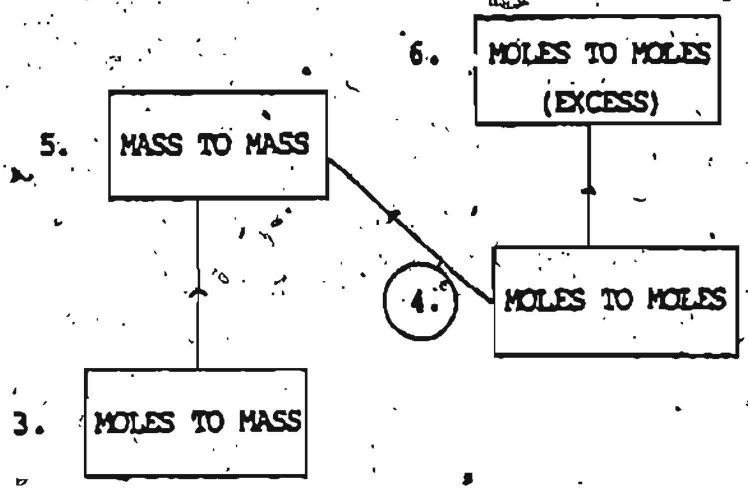
STEP 2: Mass present = Moles present x Molar mass

Check: ??? Moles present < 1, Mass < Molar mass
Moles present > 1, Mass > Molar mass

2. How many grams of sodium nitrate ($NaNO_3$) are present in 5.00 mol of $NaNO_3$?

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.



SKILL 4 - MOLES TO MOLES: Given a balanced chemical equation and the number of moles of one substance, calculate the number of moles of one other reactant or product.

The calculations involved in this type of problem require the use of the balanced chemical equation for the reaction. All further skills in this booklet will also require that you understand and be able to use balanced chemical equations.

Consider the following situation involving a chemical reaction:

Two waste gases produced by industrial processes are sulfur dioxide (SO_2) and hydrogen sulfide (H_2S). One way to deal with the pollution caused by such wastes is to recover them in a usable form. SO_2 and H_2S may be recovered in the form of elemental sulfur (S) according to the equation:

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

Such a balanced chemical equation contains important information about the relative amounts of substances involved in the reaction. The numerical coefficient (the number directly in front of the formula of each substance in the reaction) indicates the relative number of moles of that substance involved in the reaction. The coefficients give the simplest mole relationships between reactants and products. These relationships may be written in the form of ratios.

For example, in the equation below, the mole ratio of H_2S to S will always be:

2 mol of H_2S to 3 mol of S

$$2H_2S + SO_2 \longrightarrow 3S + 2H_2O$$

1 mol of SO_2 to 2 mol of H_2O

Similarly, the ratio of SO_2 to H_2O (water) will always be 1:2, as indicated above.

Such mole relationships can be written in the form of fractional ratios. In the examples above:

(1)
$$\frac{2 \text{ mol of } H_2S}{3 \text{ mol of } S} = \frac{2}{3}$$

This means that for each 2 mol of H_2S reacted, 3 mol of S will be produced in this reaction.

(ii) $$\frac{1 \text{ mol of } SO_2}{2 \text{ mol of } H_2O} = \frac{1}{2}$$

This means that for each mol of SO_2 reacted, 2 mol of H_2O will be produced in this reaction.

This information can be used to solve problems of the type given below.

<u>EXAMPLE:</u>

In the reaction: $2H_2S + SO_2 \longrightarrow 3S + 2H_2O$

how many moles of sulfur dioxide (SO_2) would be required to completely react with 16 mol of hydrogen sulfide (H_2S)?

The solution to this type of problem involves three steps.

STEP 1: Determine from the equation the mole relationship of Known to Unknown and write this as a ratio.

<u>NOTE:</u> Known = Substance for which information is given.
Unknown = Substance for which information is required.

In the problem above: <u>Known</u> = H_2S

<u>Unknown</u> = SO_2

From the equation we see that the ratio of Known to Unknown is:

$$\frac{2 \text{ mol of } H_2S}{1 \text{ mol of } SO_2} = \frac{2}{1}$$

STEP 2: Let X = the required number of moles of Unknown (SO_2).

Write a second ratio using the given number of moles of Known and using X for the Unknown amount.

$$\frac{\text{Known (given)}}{\text{Unknown (X)}} = \frac{16 \text{ mol of } H_2S}{X \text{ mol of } SO_2} = \frac{16}{X}$$

STEP 3: Write the two ratios in a proportion and solve for X.

Since the mole ratio of any two substances in a reaction will always be the same in a complete reaction, the two ratios above are equal.

$$\frac{2 \text{ mol of } H_2S \text{ (from equation)}}{1 \text{ mol of } SO_2 \text{ (from equation)}} = \frac{16 \text{ mol of } H_2S \text{ (given)}}{X \text{ mol of } SO_2 \text{ (required)}}$$

Thus: $\frac{2}{1} = \frac{16}{X}$

Solve for X by cross multiplying: $\frac{2}{1} = \frac{16}{X}$

$$2X = 16$$
$$X = 8 \text{ mol of } SO_2$$

We can now conclude that 8 mol of SO_2 are required to completely react with 16 mol of H_2S in this reaction.

NOTE: The two ratios are equal.

$$\frac{2}{1} \text{ (from equation)} = \frac{16}{8} \text{ (from calculation)}$$

The steps in a <u>Mole to Mole</u> calculation may be summarized as follows:

STEP 1:	Determine the mole relationship of Known to Unknown from the balanced chemical equation, and write this as a ratio.
STEP 2:	Write a second ratio of Known to Unknown using the given number of moles of Known and using X to represent the required number of moles of Unknown.
STEP 3:	Write the two ratios in a proportion and solve for X.

EXERCIES:

Aluminum oxide (Al_2O_3) reacts with carbon (C) to produce aluminum (Al) and carbon dioxide (CO_2) according to the reaction:

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

1. Calculate the number of moles of Al produced by 6 moles of Al_2O_3.

STEP 1: Ratio of Known (Al_2O_3) to Unknown (Al) from equation.

STEP 2: Ratio of Known (given) to Unknown (required - X).

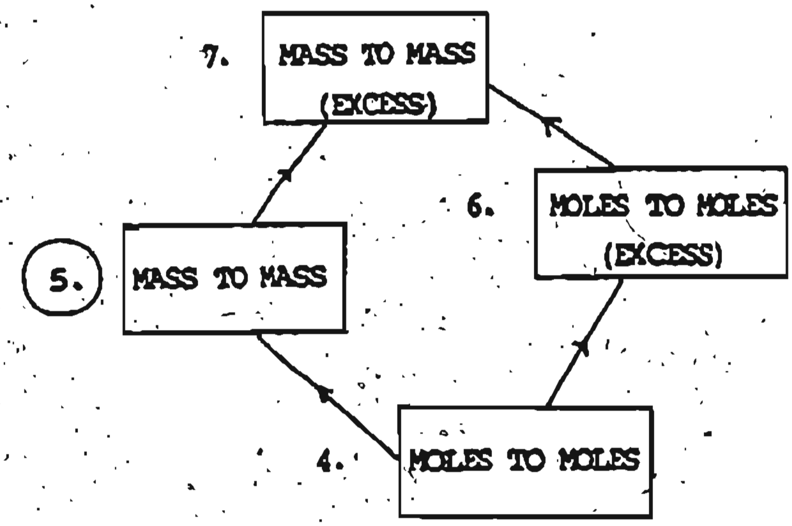
STEP 3: Write as a proportion and solve for X.

4. Calculate the number of moles of CO_2 produced by 12 moles of C in the reaction:

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.



SKILL 5 - MASS TO MASS: Given the balanced chemical equation for a reaction and the mass of one substance, calculate the mass of one other substance.

In this skill you are required to calculate the mass of one substance in a reaction if you are given the mass of one other substance and the balanced chemical equation for the reaction. This skill is a combination of three other skills.

Here is a sample problem involving a mass to mass calculation.

One of the problems of space travel is the build-up of carbon dioxide (CO_2) produced by the astronauts in the space vehicle. One proposal for solving this problem was to use sodium hydroxide (NaOH) to remove CO_2 as in the reaction:

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

If the average human body discharges 924 g of CO_2 per day, what mass of NaOH would be required to remove the daily output of CO_2 by one astronaut?

The approach to solving this type of problem is to first convert the given mass to moles. Then using the mole relationship from the balanced chemical equation, determine the number of moles of Unknown substance produced (Moles to Moles calculation). This calculated number of moles is then converted to mass.

STEP 1: Convert given mass to moles.

Given mass = 924 g of CO_2

To convert mass to moles, divide mass by molar mass.

$$\text{Moles present} = \frac{\text{Mass Present}}{\text{Molar mass}}$$

a) Molar mass of CO_2

$= (1 \text{ mol} \times 12.0 \text{ g/mol}) + (2 \text{ mol} \times 16.0 \text{ g/mol})$
$= 44.0 \text{ g/mol}$

b) $\text{Moles present} = \frac{924\text{g}}{44.0\text{g/mol}} = 21.0 \text{ mol}$

STEP 2: Calculate the number of moles of Unknown substance (NaOH) that are required to react with the number of moles of Known substance calculated above (21 mol of CO_2).

This is a Moles to Moles calculation involving these three steps:

(a) Determine the ratio of Known (CO_2) to Unknown (NaOH) from the equation.

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

Known =	Substance for which information is given.
Unknown =	Substance for which information is required.

$$\frac{\text{Known}}{\text{Unknown}} = \frac{1 \text{ mol of } CO_2}{2 \text{ mol of NaOH}} = \frac{1}{2}$$

(b) Write a second ratio using the calculated number of moles of Known from Step 1 and using X to represent the required number of moles of Unknown.

$$\frac{\text{Known (given)}}{\text{Unknown (required)}} = \frac{21 \text{ mol of } CO_2}{X \text{ mol of NaOH}} = \frac{21}{X}$$

(c) Write the two ratios from (a) and (b) in a proportion and solve for X.

$$\frac{1 \text{ mol of } CO_2}{2 \text{ mol of NaOH}} = \frac{21 \text{ mol of } CO_2}{X \text{ mol of NaOH}}$$

$$\frac{1}{2} = \frac{21}{X}$$

$$X = 42 \text{ mol of NaOH}$$

STEP 3: Convert calculated number of moles of unknown (42 mol of NaOH) to mass.

To change from Moles to Mass, we multiply as follows:

Mass present = Moles Present x Molar mass

a) Molar mass of NaOH:

$$= (1 \text{ mol} \times 23.0 \text{ g/mol}) + (1 \text{ mol} \times 16.0 \text{ g/mol}) + (1 \text{ mol} \times 1.00 \text{ g/mol}) = 40.0 \text{ g/mol}$$

b) Mass present (NaOH) = 42 mol x 40.0 g/mol

$$= 1680 \text{ g} = 1.68 \times 10^3 \text{ g}$$

Thus 1.68×10^3 g of NaOH would be required to remove the daily output of CO_2 of one astronaut.

A review of the Steps in this Skill reveal that a Mass to Mass calculation is essentially a combination of three skills.

STEP 1: Convert given mass of Known substance to its corresponding number of moles.

(Mass to Moles)

STEP 2: Calculate the number of moles of Unknown substance corresponding to the calculated number of moles of Known from STEP 1.

(Moles to Moles)

STEP 3: Convert calculated number of moles of Unknown substance (STEP 2) to its corresponding mass.

(Moles to Mass)

EXERCISES:

1. Methane (CH_4) reacts with oxygen gas (O_2) according to the equation:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

If 8.00 g of CH_4 are reacted, what mass of water (H_2O) would be produced?

STEP 1: Convert given mass of Known (CH_4) to moles.

a) Molar mass of Known substance:

b) Moles = $\frac{\text{Mass}}{\text{Molar Mass}}$

STEP 2: Calculate moles of Unknown (H_2O) produced by calculated moles of Known (____ mol of CH_4).

(a) Write the ratio of Known to Unknown from the equation:

$$\frac{\text{Known } (CH_4)}{\text{Unknown } (H_2O)} =$$

(b) Write a ratio using the calculated number of moles of Known from Step 1, and using X to represent the required number of moles of Unknown.

$$\frac{\text{Known (given)}}{\text{Unknown (required)}} =$$

(c) Write the two ratios in a proportion and solve for X.

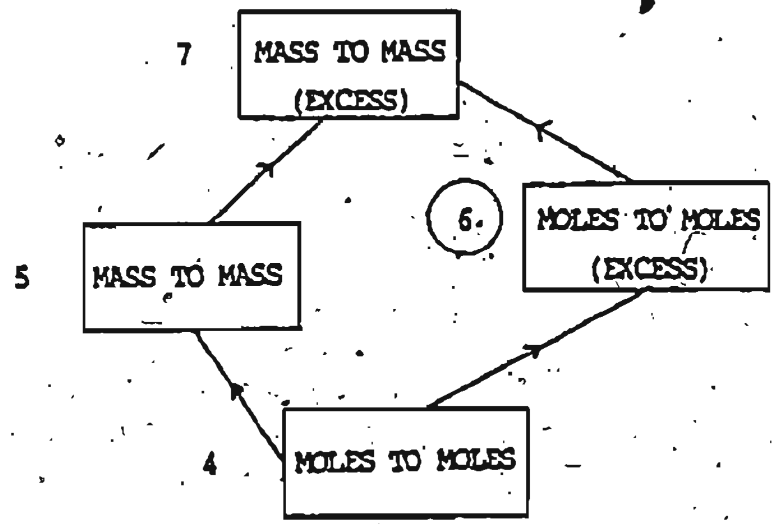
STEP 3: Convert moles of Unknown from STEP 2 (____ mol of H_2O) to its corresponding mass.

a) Molar mass of Unknown substance :

b) Mass present = Moles x Molar mass

Turn to page 42 to check your answers.

Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.



<u>SKILL 6 - MOLES TO MOLES (EXCESS)</u>: Given a balanced chemical equation and the number of moles of two reactants, one of which is in excess, calculate the number of moles of a product.

In this skill you are given the number of moles of <u>two</u> reactants, one of which may be <u>In Excess</u>, and you are asked to calculate the number of moles of a product in the reaction. When amounts of two reactants are given in a problem, this is a clue that an excess-type calculation is involved.

First you have to decide which of the reactants is In Excess and which of the two is the <u>Limiting Reagent</u>. Let's start with a non-chemical example first.

The concept of the limiting reagent may be likened to the following situation:

A craftsman needs 2 metres of wooden dowel and 5 metres of plastic binding in order to make one footstool. If the craftsman receives a shipment containing 10 metres of dowel and 20 metres of plastic binding, how many footstools can be make from these materials?

With 10 metres of dowel he can make 10 ÷ 2 = 5 stools
With 20 metres of binding he can make 20 ÷ 5 = 4 stools

Obviously with the material in the shipment he can make only 4 complete stools. The amount of binding limits the number of stools that can be made. It is the limiting agent. There is an excess amount of dowel that will be left over after the 4 stools are completed.

How does this apply to a moles to moles (excess) problem? An example of this type of problem and the procedure for solving it are given below.

EXAMPLE:

The fuel oxidizer combination used in the Apollo 11 lunar module was as follows:

The fuel was Aerozine 50, approximately half of which was hydrazine (N_2H_4), while the oxidizer was nitrogen tetroxide, (N_2O_4): The principal exhaust product was water (H_2O). One of the reactions leading to the formation of water was:

$$2N_2H_4 + N_2O_4 \longrightarrow 3N_2 + 4H_2O$$

If 12 moles of hydrazine (N_2H_4) and 10 moles of nitrogen tetroxide (N_2O_4) were reacted together in the combustion chamber until no further reaction occurred, how many moles of water (H_2O) would be produced?

In this type of problem you are given amounts of two substances:

$$\text{Known A} = N_2H_4$$
$$\text{Known B} = N_2O_4$$

The procedure is to determine which of the given quantities (12 mol of N_2H_3 or 10 mol of N_2O_4) produces the lesser amount of Unknown substance (in this case, H_2O). Whichever produces the lesser amount of product will be the <u>limiting reagent</u>.

It is necessary then to do <u>two</u> Mole to Mole calculations to answer these two questions:

For the reaction: $2N_2H_4 + N_2O_4 \longrightarrow 3N_2 + 4H_2O$

(i) How many moles of H_2O could be produced by 12 mol of N_2H_4?

(ii) How many moles of H_2O could be produced by 10 mol of N_2O_4?

Whichever of the two answers is the lesser will be the answer to the original problem.

STEP 1: Two "Mole to Mole" calculations

a) <u>For Known A (N_2H_4)</u>

(i) Ratio of Known A to Unknown from Equation:

$$\frac{\text{Known A}}{\text{Unknown}} = \frac{2 \text{ mol of } N_2H_4}{4 \text{ mol of } H_2O} = \frac{2}{4}$$

ii) Let X = number of moles of Unknown that could be produced by given amount of Known A.

Ratio of Known A (given) to Unknown (required):

$$\frac{12 \text{ mol of } N_2H_4}{X \text{ mol of } H_2O}$$

iii) Write the two ratios in a proportion and solve for X.

$$\frac{2 \text{ mol of } N_2H_4}{4 \text{ mol of } H_2O} = \frac{12 \text{ mol of } N_2H_4}{X \text{ mol of } H_2O}$$

$$\frac{2}{4} = \frac{12}{X}$$

$$2X = 48$$

$$X = 24 \text{ mol of } H_2O$$

b) <u>For Known B (N_2O_4)</u>:

i) Ratio from equation: $\frac{\text{Known B}}{\text{Unknown}} = \frac{1 \text{ mol of } N_2O_4}{4 \text{ mol of } H_2O}$

ii) Let y = number of moles of Unknown which could be produced by given amount of Known B.

Ratio of given to required: $\frac{10 \text{ mol of } N_2O_4}{y \text{ mol of } H_2O}$

iii) Write as a proportion and solve for y.

$$\frac{1}{4} = \frac{10}{y}$$

$$y = 40 \text{ mol of } H_2O$$

From the two mole to mole calculations we find:

12 mol of N_2H_4 produces 24 mol of H_2O

10 mol of N_2O_4 produces 40 mol of H_2O

Which of these two amounts (24 mol or 40 mol) is correct?

Only one amount of product will be produced from the reaction of 12 mol of N_2H_4 and 10 mol of N_2O_4. Once one of the reactants is all used up, it doesn't matter how much of the other is left — it will have nothing left to react with. The amount of product is limited by whichever reactant can produce the least amount of product. Hence it is called the Limiting Reagent.

In the problem above, the N_2H_4 will be used up first; it is therefore the limiting reagent. There isn't enough N_2H_4 to react with all 10 moles of N_2O_4. The amount of product is limited by the quantity of N_2H_4 present; the other reactant (N_2O_4) is in excess.

We can conclude that 12 mol of N_2H_4 and 10 mol of N_2O_4 produced 24 mol of H_2O when the reaction was completed. All of the N_2H_4 was used up, but some of the N_2O_4 was unreacted.

The STEPS in a Moles to Moles (Excess) Calculation

Preliminary STEP: Recognizing an EXCESS problem.

Rule:	Mole quantities of two Reactants Given	⟶	Do steps in "EXCESS"-type problem.
	Mole quantity of only one substance given	⟶	Do straight Moles to Moles Calculation (Skill 4)

FURTHER STEPS:

STEP 1:	a) Determine number of moles of Unknown substance which might be produced by given amount of Known A.
	b) Determine number of moles of Unknown substance which might be produced by given amount of Known B.
STEP 2:	Determine which reactant (Known A or Known B) is the <u>Limiting Reagent</u>.
STEP 3:	From STEP 1 write the number of moles of Unknown produced by the Limiting Reagent as your answer.

<u>EXERCISE</u>:

Consider the reaction between aluminum oxide (Al_2O_3) and hydrogen gas (H_2) according to the equation

$$Al_2O_3 + 3H_2 \longrightarrow 2Al + 3H_2O$$

If 2 mol of Al_2O_3 and 7 mol of H_2 are mixed together and allowed to react until no further reaction occurs, how many moles of water (H_2O) will be produced?

<u>Preliminary STEP</u>: Is this an "Excess" problem?

Ask Yourself:	Are amounts of <u>two</u> reactants given?
Answer:	Yes.
Conclusion:	This could be an "excess" problem.
	Do steps in "excess"-type calculation.

STEP 1: a) Moles of Unknown (H_2O) produced by given moles of Known A (2 mol of Al_2O_3).

b) Moles of Unknown (H_2O) produced by given moles of Known B (7 mol of H_2).

???? – What if the two answers in a) and b) above are the same? No problem!

This indicates that there is <u>no excess</u> and that the amount of product will be what you have calculated in a) or b). Both amounts of reactants will be completely consumed.

STEP 2: Determine Limiting Reagent

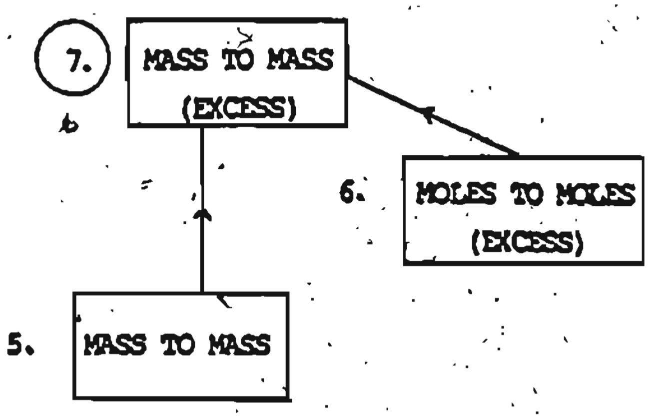
- Which given amount of Known – A or B – produces the smaller amount of Unkhown?

STEP 3: 2 mol of Al_2O_3 + 7 mol of H_2 $\longrightarrow$ ____ mol of H_2O

↑ Amount produced by given amount of Limiting Reagent

Turn to page 42 to check your answer(s).

Once you are satisfied that you understand this skill, turn to page 3 and follow the directions there.



<u>SKILL 7 – MASS TO MASS (EXCESS)</u>: Given a balanced chemical equation and the masses of two reactants, one of which is in excess, calculate the mass of a product.

In some problems (and in some chemists' actual situations) the mass of each of <u>two</u> reactants is known, but one of them may be in excess. The question is: How much product will be produced if the given amounts of reactants are mixed and allowed to react? The expected amount of product can be calculated using a combination of several skills.

An example of this type of problem and the procedure for working it out are given below.

When iron is made in a blast furnace the main reaction which occurs is:

$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

If 320 g of iron (II) oxide (Fe_2O_3) and 252 g of carbon monoxide (CO) are present in the reaction chamber of the blast furnace, what mass of iron (Fe) would result according to the reaction above?

The approach to this type of problem is to convert the given masses to moles, then using the Moles to Moles (Excess) calculation the number of moles of product can be determined. This mole quantity of product is then converted to mass.

The STEPS in a mass to mass (excess) calculation may be summarized as follows:

STEP A: Convert given masses of reactants to moles.

STEP B: Do a moles to moles (Excess) calculation.

1. Find the number of moles of Unknown (in this case, Fe) which might be produced by the calculated number of moles of Known A (Fe_2O_3) and the number of moles of Unknown which might be produced by the calculated number of moles of Known B (CO).

2. Determine the Limiting Reagent.

3. Write the number of moles of Unknown produced by Limiting Reagent.

STEP C: Convert calculated moles of Unknown (from STEP B-3) to its corresponding mass.

Back to the original problem:

For the reaction: $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

we want to answer the question:

320 g of Fe_2O_3 + 252 g of CO ⟶ _?_ g of Fe

STEP A: Convert given masses to moles

$$\text{Moles Present} = \frac{\text{Mass Present}}{\text{Molar Mass}}$$

Known A: Fe_2O_3 - Mass present = 320 g

Molar mass = (2 x 56.0) + (3 x 16.0)
= 160 g/mol

$$\text{Moles Present} = \frac{320\text{ g}}{160\text{ g/mol}} = 2.00\text{ mol}$$

Known B: CO - Mass present = 252 g

Molar mass = (1 x 12.0) + (1 x 16.0)
= 28.0 g/mol

$$\text{Moles Present} = \frac{252\text{ g}}{28\text{ g/mol}} = 9.00\text{ mol}$$

STEP B: Moles to Moles (EXCESS) Calculation

1. a) Ratio of Known A (Fe_2O_3) to Unknown (Fe) from equation.

$$\frac{\text{Known A}}{\text{Unknown}} = \frac{1 \text{ mol of } Fe_2O_3}{2 \text{ mol of Fe}} = \frac{1}{2}$$

b) Ratio of calculated number of moles of Known A (Step A) to required number of moles of Unknown (X).

$$\frac{\text{Known A (given-calculated)}}{\text{Unknown (required - X)}} = \frac{2 \text{ mol of } Fe_2O_3}{X \text{ mol of Fe}} = \frac{2}{X}$$

c) Write ratios in (a) and (b) as a proportion and solve for X.

$$\frac{1}{2} = \frac{2}{X}$$

X = 4 mols of Fe could be produced.

d) Ratio of Known B (CO) to Unknown from equation.

$$\frac{\text{Known B}}{\text{Unknown}} = \frac{3 \text{ mol of CO}}{2 \text{ mol of Fe}} = \frac{3}{2}$$

e) Ratio of Known B (moles calculated in Step A) to required number of moles of Unknown (y).

$$\frac{\text{Known B (given-calculated)}}{\text{Unknown (required-y)}} = \frac{9 \text{ mol of CO}}{y \text{ mol of Fe}} = \frac{9}{y}$$

f) Write ratios in (d) and (e) in a proportion and solve for y.

$\frac{3}{2} = \frac{9}{y}$ $3y = 18$ $y =$ 6 mol of Fe could be produced

2. Determine Limiting Reagent (see discussion on page 35).

Limiting Reagent is Fe_2O_3 because the given amount of Fe_2O_3 will yield fewer moles of product (Fe) than the given amount of CO, if both were fully reacted.

Note that in STEP B – 1, two possible amounts of product (Fe) were calculated. But the actual amount of product which could form is determined by the reagent which is used up first in the reaction – Fe_2O_3. Once this reagent – the limiting reagent – is used up, no futher reaction can occur. The other reagent (CO) was in excess; there will be some CO remaining after the reaction is complete.

3. Moles of Unknown (Fe) actually produced = 4 mol

320 g (2 mol) of Fe_2O_3 + 252 (9 mol) of CO $\longrightarrow$ 4 mol of Fe

STEP C: Convert calculated moles of Unknown to Mass

Mass Present = Moles Present x Molar Mass

Molar Mass of Fe = 56.0 g/mol

Mass Present = 4.00 mol x 56.0 g/mol
= 224 g of Fe

We can now conclude that the reaction of 320 g of Fe_2O_3 and 252 g of CO will yield 224 g of Fe.

EXERCISE: Consider the reaction between acetylene (C_2H_2) and oxygen (O_2) according to the equation

$$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$$

If 52.0 g of C_2H_2 and 32.0 g of O_2 are mixed together and allowed to react until no further reaction occurs, what mass of carbon dioxide (CO_2) will be produced?

STEP A: Convert given masses to moles.

52.0 g of C_2H_2 = _____ mol of C_2H_2

32 g of O_2 = _____ mol of O_2

STEP B: Moles to moles (EXCESS) calculation.

1. a) $\frac{\text{Known A (Equation)}}{\text{Unknown (Equation)}} = \frac{\text{Known A (calculated in Step A)}}{\text{Unknown (required-X)}}$

$$\frac{\_\_\_\_}{\_\_\_\_} = \frac{\_\_\_\_}{X}$$

X =

b) $\frac{\text{Known B (Equation)}}{\text{Unknown (Equation)}} = \frac{\text{Known B (calculated Step A)}}{\text{Unknown (required-y)}}$

$$\frac{\_\_\_\_}{\_\_\_\_} = \frac{\_\_\_\_}{Y}$$

Y =

STEP B:

2. Limiting Reagent.

3. 52.0 g (___ mol) of C_2H_2 + 32.0 g (___ mol) of O_2 →
_____ mol of CO_2

STEP C: Change moles of Unknown (STEP B-3) to mass.

52.0 g of C_2H_2 + 32.0 g of O_2 → _____ g of CO_2

Turn to page 42 to check your answers.

You have now completed all of the skills with which you had difficulty on your previous test. If you have any time left, please turn to page 43 and work on the additional exercises there. Feel free to do any of the other skills in this booklet as time permits.

Page	Exercise No.	Answer
7	1	102 g/mol
7	2 a)	78.0 g/mol
	b)	95.3 g/mol
	c)	180 g/mol
11	1	2.00 mol
11	2	1.50 mol
15	1	22.0 g
15	2	425 g
20	1	12 mol of Al
21	2	12 mol of CO_2
27	1	18.0 g of H_2O
34	1	6.00 mol of H_2O
41	1	35.2 g of CO_2

Additional Exercises

1. How many moles of hydrogen chloride (HCl) are there in 80.3 g of HCl?

2. Calculate the molar mass of each of the following:
   a) carbon monoxide (CO)
   b) hydrogen borate (H_3BO_3)

3. In the reaction $2B + 6HCl \longrightarrow 2BCl_3 + 3H_2$
How many moles of HCl would be required to completely react 5 moles of boron (B)?

4. What is the mass present in 4.5 mol of sodium chloride ($NaCl$)?

5. Nitrogen gas (N_2) reacts with water (H_2O) according to the reaction $2N_2 + 6H_2O \longrightarrow 4NH_3 + 3O_2$
What mass of oxygen gas (O_2) would be produced from 54 g of H_2O?

6. In the reaction $2NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + 2HCl$
If 234 g of NaCl and 245 g of H_2SO_4 are mixed and allowed to react until no further reaction occurs, what mass of HCl will be produced?

7. 20 mol of ammonia (NH_3) and 20 mol of oxygen (O_2) are mixed and allowed to react until no further reaction occurs, the reaction which takes place is

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

How many moles of water (H_2) will be produced?

Turn the page to check your answers.

Answers to Additional Exercises

No.	Answer
1	2.2 mol of HCl
2 a)	28.0 g/mol
b)	62.0 g/mol
3	15.0 mol of HCl
4	263 g of NaCl (3 significant figures)
5	48.0 g of O_2
6	146 g of HCl
7	24.0 mol of H_2O

APPENDIX 5

SKILL 1: Calculation of Molar Mass

On a previous test you were asked to calculate the molar mass of a compound, given the chemical formula of the compound. The answer you chose indicates that you used the subscripts incorrectly in calculating the molar mass. It seems that you either failed to use the subscripts altogether, or you applied the subscripts incorrectly in your calculations.

The following pages contain a review of molar mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 1: Calculation of Molar Mass

On a previous test you were asked to calculate the molar mass of a compound, given the chemical formula of the compound. The answer you chose indicates that you failed to use the atomic molar mass of each element in calculating the molar mass of the compound. Molar mass is not found by simply adding the subscripts in the chemical formula.

The following pages contain a review of molar mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 2: Converting Mass to Moles

On a previous test you were asked to change a given mass of a compound to its corresponding number of moles. The answer you selected indicates that you used an incorrect method for changing mass to moles. Instead of dividing the given mass by the molar mass of the compound, you reversed the operation and divided the molar mass by the given mass.

The following pages contain a review of mass to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 2: Converting Mass to Moles

On a previous test you were asked to change a given mass of a compound to its corresponding number of moles. The answer you selected indicates that you used an incorrect method for converting mass to moles. Instead of dividing the given mass by the molar mass of the compound, you multiplied the given mass by the molar mass.

The following pages contain a review of mass to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 2: Converting Mass to Moles

On a previous test you were asked to change a given mass of a compound to its corresponding number of moles. The answer you selected indicates that you incorrectly calculated the molar mass of the compound. The following pages contain a review of a mass to moles calculation. Please pay careful attention to those sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 3: Converting Moles to Mass

On a previous test you were given a certain number of moles of a compound and were asked to change this quantity to mass. The answer you selected indicates that you divided instead of multiplying to find the answer. Once you find the molar mass of the compound you must multiply the molar mass by the given number of moles to find the mass present.

The following pages contain a review of the moles to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 3: Converting Moles to Mass

On a previous test you were given a certain number of moles of a compound and were asked to change this quantity to mass. The answer you selected indicates that you incorrectly calculated the molar mass of the compound. The following pages contain a review of a moles to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 4: Moles to Moles

On a previous test you were given the balanced chemical equation for a reaction. You were also given the number of moles of one substance in the reaction, and you were asked to determine the corresponding number of moles of one other substance. The answer you selected indicates that you used the molar mass of one or both of the substances in trying to calculate the required number of moles. This type of calculation <u>does not</u> involve the use of molar mass at all.

The following pages contain a review of the moles to moles calculation. Please read carefully through this skill and note that molar mass does not enter into any of the steps in the calculation.

SKILL 4: Moles to Moles

On a previous test you were given the balanced chemical equation for a reaction. You were also given the number of moles of one substance in the reaction, and you were asked to determine the corresponding number of moles of one other substance. The answer you selected indicates that you neglected to consider the relationship between the number of moles of the two substances in question, as indicated by the numerical coefficients of these substances in the balanced chemical equation. You assumed a 1:1 ratio between the given and required substances in the problem and quoted the given number of moles as your answer.

The following pages contain a review of the moles to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as they appear to be the areas where your errors occurred.

SKILL 4: Moles to Moles

On a previous test you were given the balanced chemical equation for a reaction. You were also given the number of moles of one substance in the reaction, and you were asked to determine the corresponding number of moles of one other substance. The answer you selected indicates that you neglected to consider the relationship between the number of moles of the two substances in question, as indicated by the numerical coefficients of these substances in the balanced chemical equation. You simply quoted the coefficient of the required substance.

The following pages contain a review of the moles to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 4: Moles to Moles

On a previous test you were given the balanced chemical equation for a reaction. You were also given the number of moles of one substance in the reaction, and you were asked to determine the corresponding number of moles of one other substance. The answer you selected indicates that you neglected to consider the relationship between the number of moles of the two substances in question, as indicated by the numerical coefficients of these substances in the balanced chemical equation. You simply multiplied the given number of moles by the coefficient of the required substance.

The following pages contain a review of the moles to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 4: Moles to Moles

On a previous test you were given the balanced chemical equation for a reaction. You were also given the number of moles of one substance in the reaction, and you were asked to determine the corresponding number of moles of one other substance. The answer you selected indicates that you neglected to consider the relationship between the number of moles of the two substances in question, as indicated by the numerical coefficients of these substances in the balanced chemical equation. You simply divided the given number of moles by the coefficient of the required substance.

The following pages contain a review of the moles to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you did not use correctly the information from the balanced chemical equation in your calculations. You simply found the molar mass of the desired substance, or multiplied the molar mass of this substance by its coefficient, without reference to the given substance.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you confused moles and mass in your calculations.

You set up a proportion using the correct mole ratio from the equation, but using a ratio of masses as well. The coefficients of the substances in a balanced chemical equation do not indicate mass relationships; they indicate relative numbers of moles of substances in the reaction.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you did not use correctly the information from the balanced chemical equation in your calculations. You assumed a 1:1 ratio between the masses of the given and required substances. Thus you quoted the mass given as your answer.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you confused moles and mass in your calculations. Once you found the correct number of moles of required substance, you failed to convert this mole quantity to mass.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you did not use correctly the information from the balanced chemical equation in your calculations. Once you converted the given mass to moles, you simply multiplied this mole quantity by the molar mass of the required substance. You failed to consider the ratio of given and required from the balanced chemical equation.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you did not use correctly the information from the balanced chemical equation in your calculations. Once you converted the given mass to moles, you simply divided the molar mass of the required substance by the calculated number of moles. You failed to consider the ratio of given and required from the balanced chemical equation.

The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 5: Mass to Mass

On a previous test you were given the balanced chemical equation for a reaction and the mass of one substance in the reaction. You were then asked to calculate the mass of one other substance in the reaction. The answer you selected indicates that you incorrectly calculated the molar masses of the substances involved. The following pages contain a review of the mass to mass calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 6: Moles to Moles (Excess)

On a previous test you were given the number of moles of two reactants along with the balanced chemical equation for the reaction. You were asked to calculate the number of moles of a product that would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you confused mass and mole quantities in your calculations. Note that in a straight moles to moles calculation, in which given quantities are in moles and the answer is required in moles, there is no need to use mass quantities at all. Please note this as you read carefully through the following pages which contain a review of the moles to moles (excess) skill.

SKILL 6: Moles to Moles (Excess)

On a previous test you were given the number of moles of two reactants along with the balanced chemical equation for the reaction. You were asked to calculate the number of moles of a product that would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you tried to add the given mole quantities in some way, or converted the mole quantities to mass and then tried to add. This is incorrect.

The following pages contain a review of a moles to moles calculation where one reactant may be in excess. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 6: Moles to Moles (Excess)

On a previous test you were given the number of moles of two reactants along with the balanced chemical equation for the reaction. You were asked to calculate the number of moles of a product that would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you did a straight Moles to Moles calculation (Skill 4) by choosing one of the given amounts of reactants and calculating the corresponding amount of product. You did not indicate any reason for choosing one reactant over the other. It seems that you did not realize that one of the reagents was in excess.

The following pages contain a review of a moles to moles calculation where one reactant may be in excess. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 6: Moles to Moles (Excess)

On a previous test you were given the number of moles of two reactants along with the balanced chemical equation for the reaction. You were asked to calculate the number of moles of a product that would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you selected the wrong substance as the limiting reagent. This then led to your calculating an incorrect amount of product.

The following pages contain a review of a moles to moles (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 6: Moles to Moles (Excess)

On a previous test you were given the number of moles of two reactants along with the balanced chemical equation for the reaction. You were asked to calculate the number of moles of a product that would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you failed to choose one of the reagents as the limiting reagent. You gave two quantities of product as your answer. This is incorrect, as there can be only one final amount of a product after a reaction is complete.

The following pages contain a review of the moles to moles (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you did a simple Mass to Mass (Skill 5) calculation by choosing one of the given masses of reactants and calculating the corresponding amount of product. You did not indicate any reason for choosing one reactant over the other. It seems that you did not realize that one of the reactants was in excess.

The following pages contain a review of the mass to mass (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you tried to add the given mass quantities in some way to arrive at your answer. This is incorrect as you will notice in the following pages which contain a review of the mass to mass (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you selected the wrong substance as the limiting reagent. This then led to your calculating an incorrect amount of product.

The following pages contain a review of the mass to mass calculation where one reactant is in excess. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you failed to use important information from the balanced chemical equation in doing your calculations. This information concerns the mole quantities of reactants and products involved in the reaction, as indicated by the numerical coefficients.

The following pages contain a review of the mass to mass calculation where one reactant is in excess. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you confused mass and mole quantities in your calculations. Note that all given masses are converted to moles, and these mole quantities are used in further calculations. Only in the final step is the mole quantity converted to mass to give the answer.

The following pages contain a review of the mass to mass (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you incorrectly calculated the molar mass of one or more substances. This led to errors in further calculations.

The following pages contain a review of the mass to mass d to (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL 7: Mass to Mass (Excess)

On a previous test you were given the masses of two reactants and the balanced chemical equation for a reaction. You were asked to calculate the mass of a designated product which would result from a reaction involving the given quantities of reactants.

The answer that you calculated indicates that you failed to choose one of the reagents as the limiting reagent. You gave two quantities of product as your answer. This is incorrect since there can be only one final amount of a product after a reaction is complete.

The following pages contain a review of the mass to mass (excess) calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.

SKILL __

From an answer you gave on a previous test, it seems that you are having some difficulty with this skill in stoichiometry. Your error could not be identified clearly. However we have prepared a lesson that is designed to teach you how to do this skill. It consists of instructions on the skill, a representative question much like the one on the test, and a practice problem.

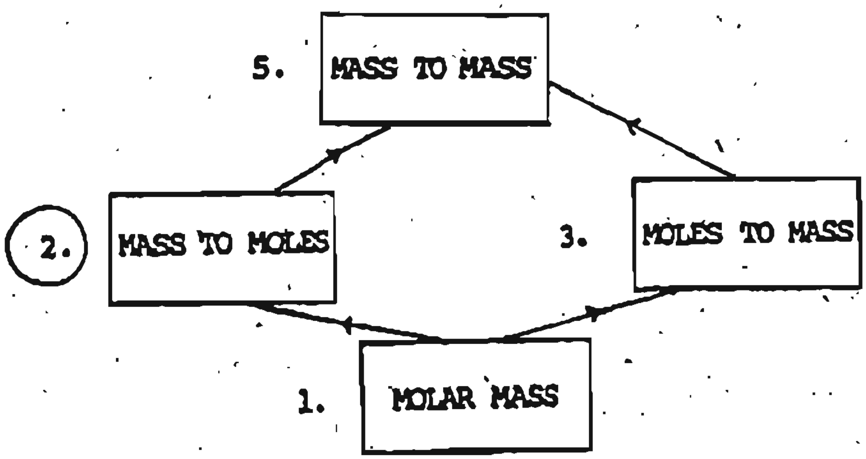
Please turn the page, read the lesson on this skill, and try the practice problem.

APPENDIX 6

SKILL 2: Converting Mass to Moles

On a previous test you were asked to change a given mass of a compound to its corresponding number of moles. The answer you selected indicates that you used an incorrect method for changing mass to moles. Instead of dividing the given mass by the molar mass of the compound, you reversed the operation and divided the molar mass by the given mass.

The following pages contain a review of mass to moles calculation. Please pay careful attention to the sections marked * as you read through this skill, as these appear to be the areas where your errors occurred.



SKILL 2 - MASS TO MOLES: Given the mass and formula of a compound, calculate the number of moles present.

If you are given the chemical formula of a compound you should be able to convert any given mass of the compound to its corresponding number of moles. This skill involves the use of the molar mass of the compound.

The molar mass of a compound is defined as the mass of one mole of the compound. It follows then that any given mass can be coverted to moles by dividing the given mass by the molar mass. * This may be summarized as follows:

$$\text{Number of Moles Present} = \frac{\text{Mass Present (g)}}{\text{Molar Mass (g/mol)}}$$ *

A sample problem and its solution are given below.

EXAMPLE:

Silicosis is a lung disease contracted by inhaling dust formed in sandblasting or in silicon mining. The dust consists of a compound of silicon and oxygen called silicon dioxide (SiO_2).

If a man inhales 180 grams of SiO_2, how many moles of SiO_2 has he inhaled?

The approach to this type of problem is to calculate the mass of one mole (molar mass) of the compound, and then to divide the given mass by the molar mass.

STEP 1: Calculate the molar mass of the compound.

<u>Molar mass of SiO_2</u>

(a) In SiO_2 :

<u>1 mol of Si</u> + <u>2 mol of O</u>

(b) From Table p. 4, atomic molar mass of:

Si ⟶ 28.0 g/mol

O ⟶ 16.0 g/mol

(c) <u>Molar mass of SiO_2</u> =

(1 mol x 28.0 g/mol) + (2 mol x 16.0 g/mol)

= 28.0 g + 32.0 g

= 60.0 g/mol of SiO_2

STEP 2: Divide the given mass of the compound by the molar mass.

$$\text{Moles Present} = \frac{\text{Mass Present}}{\text{Molar Mass}} \quad *$$

$$= \frac{180\ g}{60.0\ g/mol} = 3.00\ mol$$

The man inhales 3.00 mol of SiO_2

A USEFUL CHECK:

If the given mass is greater than the molar mass, the number of moles will be greater than 1. If the given mass is less than the molar mass, the number of moles will be less than 1.

Given mass > molar mass, moles > 1
Given mass < molar mass, moles < 1

You can use this "RULE" to check your answer to see whether it is a logical one.

EXERCISES:

1. Calculate the number of moles of sodium oxide (Na_2O) in 124 g of Na_2O.

STEP 1: Molar mass of Na_2O :

STEP 2: Moles present = $\frac{\text{Given mass}}{\text{Molar mass}}$

CHECK: ??? Given mass > molar mass; moles > 1
Given mass < molar mass; moles < 1

2. Calculate the number of moles present in 162 g of nitrogen pentoxide (N_2O_5).

Turn to page 42 to check your answers. Once you are satisfied that you understand this skill, return to page 3 and follow the directions there.

APPENDIX 7

Test Scores for Skills 1-7 on

the Chemistry Pretest and Posttest

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
ID	GROUP	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
1	A	1	1	1	1	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
2	A	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
3	A	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
4	A	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
5	B	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	B	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
7	B	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
8	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	B	1	1	0	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
10	C	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
11	C	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
12	C	1	1	0	0	0	1	1	1	0	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
13	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1
14	A	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0
15	A	1	1	1	1	1	1	1	0	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	0	0	1	0
16	A	1	1	1	1	0	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0
17	A	1	1	1	0	1	1	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	1	0	0	0	0	0	0
18	A	1	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0
19	A	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
20	B	1	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0
21	B	1	1	0	0	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	1	0	0
22	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
23	B	1	0	1	1	1	1	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	0
24	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1
25	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
26	C	1	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	0	1	1	1	0	1
27	C	1	1	0	1	0	0	0	1	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	0
28	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
29	C	1	0	0	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	0	0	0
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31	C	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0
32	A	0	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	1	0
33	A	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
34	B	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
35	B	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
36	B	1	1	0	0	1	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
37	C	1	1	1	1	1	1	0	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1
38	C	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1
39	C	1	1	1	1	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0
40	C	1	1	1	1	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	0	1	0
41	C	1	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	0	0	0	1	0
42	A	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	1	0	1	1	1
43	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
44	B	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
45	C	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	0	1	0	0	0	0	0

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
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46	C	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
47	C	1	1	1	1	0	1	0	0	0	1	0	0	0	0	1	1	1	1	1	1	0	1	1	0	0	1	0	0
48	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
49	A	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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57	B	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0
58	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	0
59	C	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
60	C	1	1	0	0	1	1	1	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
61	C	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0
62	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1
63	C	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	0	1	0	1	0	0	0	0	0	0
64	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
65	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
66	A	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	1	0
67	A	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0
68	A	1	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
69	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
70	B	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	1	0	1	1	1	1	1	0	0	0	0
71	B	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	0	0	0	0
72	B	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	0	0
73	B	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	0	0
74	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
75	B	1	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0
76	C	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
77	C	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
78	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
79	C	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
80	C	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
81	C	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
82	A	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	1	1	0	1	1	1	1	0	0	0	1	1	1
83	A	1	1	0	1	0	1	1	1	1	1	0	0	1	0	1	1	1	0	0	1	1	1	1	1	0	0	0	0
84	B	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
85	B	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1
86	C	1	0	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
87	C	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
88	A	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
89	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
90	A	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
ID	GROUP	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
91	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
92	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
93	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0
94	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	1	0
95	B	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
96	B	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
97	B	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0
98	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
99	B	1	1	0	1	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
100	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	0	0	0
101	B	1	1	1	1	1	1	0	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
102	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	1	1	0	1
103	C	0	1	0	0	0	0	1	1	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
104	C	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
105	C	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
106	C	1	1	1	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	0	0
107	C	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
108	C	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	1	0	1	1	1	1	1	1	1	1	0
109	C	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
110	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
111	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	0	1
112	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
113	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
114	A	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
115	A	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
116	B	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
117	B	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
118	B	1	1	1	1	0	1	0	1	1	1	0	0	0	0	1	1	1	0	1	1	0	0	1	1	0	0	0	0
119	B	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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121	B	1	1	1	1	1	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0
122	B	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	0	1	1	0	0	1	1	1	1
123	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
124	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
125	C	1	1	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
126	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
127	C	1	0	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
128	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
129	C	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
130	A	1	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
131	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0
132	A	1	0	1	0	0	1	0	0	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
133	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
134	A	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
135	A	1	1	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
ID	GROUP	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
136	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	0	0	1	[illegible]	1	1	1	0	1	0	0	0
137	A	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
138	B	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0
139	B	1	1	1	1	1	1	1	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
140	B	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
141	B	1	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0
142	B	1	1	0	0	1	0	0	1	1	1	0	0	0	0	1	0	1	1	0	0	1	1	0	1	0	0	0	0
143	B	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	1
144	B	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	1	0
145	B	1	1	1	1	1	1	1	0	1	0	0	0	0	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0
146	C	0	1	0	0	0	0	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1
147	C	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
148	C	1	1	1	1	0	0	0	1	0	0	1	0	0	0	1	1	1	1	0	1	0	1	1	0	0	0	0	0
149	C	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
150	C	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	0	1	1	1	0	1	1	0	0	0
151	A	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0
152	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
153	A	1	1	0	0	1	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0
154	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
155	A	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	0	1	1	1	0	1	1	1	1	1	0	0	0
156	A	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
157	A	1	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	0
158	B	1	1	1	1	0	0	[illegible]	0	0	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	1	0	0
159	B	1	0	0	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0
160	B	1	1	0	0	0	1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1	0	1	1	1	1	1	1
161	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
162	B	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
163	B	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
164	B	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
165	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1	1	1	0	1
166	C	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0
167	C	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
168	C	1	1	[illegible]	1	1	[illegible]	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0
169	C	1	1	1	0	1	1	1	1	0	0	1	0	0	0	1	1	1	1	0	1	1	1	0	0	1	0	0	0
170	C	1	1	1	1	1	0	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
171	C	1	1	0	0	1	0	1	1	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	1	0	0	0	0
172	C	0	1	1	1	0	0	0	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
173	A	1	1	1	1	0	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
174	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
175	A	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	0	1	1	1	1	0	1	1	1	0	0	0	0
176	A	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	[illegible]	1	1	1	1	1	1	1	1	1	1
177	A	1	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
178	A	1	1	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0
179	B	0	1	1	1	0	1	1	1	1	0	0	0	0	0	1	1	0	1	1	1	1	1	0	1	1	1	1	0
180	B	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
ID	GROUP	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
181	B	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
182	B	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	1	0	0	0	0	0
183	B	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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185	B	0	1	1	1	1	1	1	1	0	1	0	0	0	0	1	0	1	1	1	1	1	0	0	1	1	0	0	0
186	B	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	0	1	0	1	1	1	0	0	0	0	1
187	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1
188	C	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
189	C	1	1	1	1	1	0	1	1	0	1	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0
190	C	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	1	1	1	0	1	1	1	1	0	1	0	1	0
191	C	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
192	C	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
193	C	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	0	1	1	1	0	0	0	0
194	A	1	1	1	0	1	1	1	1	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	0	1	0	1	1
195	A	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	1
196	A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
197	A	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
198	A	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1
199	A	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1
200	A	1	0	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	1	0
201	A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
202	A	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	1	0	1	1	0	0	1	1	1	1
203	B	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1
204	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
205	B	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0
206	B	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
207	B	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
208	B	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
209	B	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
210	B	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
211	C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
212	C	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1
213	C	1	1	1	1	1	1	1	1	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	0
214	C	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
215	C	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
216	C	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1
217	C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
218	C	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
219	A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
220	C	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
221	D	1	1	1	1	0	1	1	0	1	1	0	0	0	0	1	1	1	1	1	1	0	1	0	1	0	0	0	0
222	D	1	1	1	1	1	1	1	1	0	1	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0
223	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	1	1	1	0	0	0	0
224	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	1	0
225	[illegible]	1	1	1	1	1	1	0	0	1	1	0	0	0	0	1	0	1	1	1	1	0	0	0	1	0	0	0	0

		PRETEST														POSTTEST													
		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7		SK.1		SK.2		SK.3		SK.4		SK.5		SK.6		SK.7	
ID	GROUP	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28
226	D	1	1	1	1	1	1	1	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
227	D	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	0	1	1	0	0	1	1	0	0
228	D	[illegible]	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
229	D	1	1	0	1	1	1	1	1	0	0	0	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	0	0
230	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
231	D	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
232	D	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0
233	D	1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
234	D	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
235	D	1	1	1	0	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
236	D	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1	1	1	1	1	1	0	1	1	0	0	0	0
237	D	1	1	1	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	1	0	1	1	0	0	0	1	0	0
238	D	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
239	D	1	1	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	0	1	0	0	0
240	D	1	0	1	1	0	0	0	1	0	0	0	0	0	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0
241	D	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1
242	D	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
243	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
244	D	1	1	1	1	1	0	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0
245	D	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
246	D	1	1	1	1	1	1	0	1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	0
247	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
248	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1	1	1	1	0	0	0	0
249	D	1	1	1	1	1	1	0	1	0	0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	1	0	0	0
250	D	1	1	0	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0	0
251	D	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
252	D	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1