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ABSTRACT

This research study was conducted to investigate the interactions of specific student aptitudes with their ability to solve chemistry problems of varying structure and information. Fourteen classroom quizzes were validated and a number of in-task variables were identified for analysis. These variables included: the nature of information given (implicit or explicit); the type of information provided in the questions (relevant or irrelevant); the algebraic format required to solve the problems; and the ability/inability to demonstrate reversibilities, negation, and reciprocity. Results (based on responses of 77 high school chemistry students) indicate: (1) that field independent students were significantly better at solving proportional reasoning problems containing relevant and irrelevant information and/or implicit information than field dependent students; (2) that the degree of formal reasoning and proportional reasoning were significantly correlated with success in chemistry, independent of item in-task conditions; (3) a significant difference between the sexes favoring males on the ability to solve proportional reasoning problems; and (4) no significant interactions between sex and chemistry achievement. (Author/JN)

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The Ability of High School Chemistry Students to Solve Computational Problems Requiring Proportional Reasoning as Affected by Item In-Task Variables

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Abstract

This research study was conducted to investigate the interactions of specific student aptitudes with their ability to solve chemistry problems of varying structure and information. Fourteen classroom quizzes were valided and a number of in-task variables were identified (Piagetian logical structure - reversibility, algebraic format, type of information - relevant only or relevant and irrelevant, and the nature of the information - explicit or implicit) for analysis. All measures were administered to 77 high school chemistry students. Results of the study indicated: (1) field independent students were significantly better at solving proportional reasoning problems containing relevant and irrelevant information and/or implicit information; (2) degree of formal reasoning and proportional reasoning were significantly correlated with success in chemistry, independent of item in-task conditions; (3) a significant difference between the sexes favoring males on the ability to solve proportional reasoning problems; and (4) no significant interactions were found between sex and chemistry achievement.

A vast majority of research studies in chemistry education have focused upon the relationships of student aptitudes to achievement in secondary and college chemistry classes. Studies by Gabel and Sherwood (1983, 1984) have researched student difficulties with mole concept tasks. Niaz and Lawson (1985) researched the role of developmental level and mental capacity on student ability to balance chemical equations. These studies indicated that chemical problem solving ability is highly correlated with students' mathematical skills and their developmental level. Mixed results were reported regarding the usefulness of using algorithms to teach various chemical concepts. Herron (1975) summarized research on chemistry achievement and student aptitude by recommending that teachers either vary instructional techniques to provide concrete experiences or not teach specific concepts altogether. Relatively few studies have investigated the effects of in-task variables. The content and the nature of the questions used to assess achievement, as well as their structure, are important in instances where advanced logic is required (Lunzer, 1965).

In a recent edition of the Encyclopedia of Educational Research, Mitzel (1982) expressed the need to investigate several classes of variables: (1) task variables (i.e., factors that affect a problem's difficulty, such as content, format, context, or logical structure), and (2) subject variables (i.e., student subject attributes that affect problem solving achievement such as previous knowledge, cognitive style, and attitudes). Thus there is a need to analyze the evaluative instruments used for assessing student achievement. The nature of the exams and exam questions should be taken into consideration before major changes in pedagogy or course content take place.

The type of examination questions (i.e., multiple choice, computational) affect student performance; therefore, desired outcomes will affect an instructors choice of format for any given test. However, student achievement is also dependent upon their ability to discern the question, and the instructors ability to set the question. When achievement is measured via examinations requiring successful solution of problems emphasizing proportional reasoning, it is important to know whether there are any interactions of students' aptitudes with the specific characteristics and cognitive demands of the questions themselves. Piaget's (1972) suggestion that persons with expertise may achieve higher than those without expertise, implies that aptitudes are important. Inhelder and Piaget (1958) referred to differences in the problem solving ability of transitional students (substage IIB) as affected by relevant and irrelevant information. Ronning, McCurdy, & Ballinger (1984) concluded that field independent students were more likely to attack problems by keying on relevant information. Similar findings by Linn (1978), Nummedal and Collea (1981), and Wormack (1979) further clarified the abiltiy of field independent subjects to disembed relevant information from irrelevant.

A study conducted by Shyers and Cox (1978) showed the significance of the INRC group on the ability of students to solve proportionality problems. Their research found significant effects on a student's ability to solve proportionality problems due to an intervention program on reversibilities of the INRC group. The concept of reversibility is, therefore, particularly relevant to the ability to apply proportional reasoning. As outlined by Wheeler and Kass (1977) the reversibilities, negation and inversion, have particular relevance to chemistry. However, given the ability to solve problems requiring proportional reasoning, it may be hypothesized that subjects have acquired the skills represented by the INRC group (Flavell, 1963). Therefore, problems representing reversibility situations should pose no greater difficulty. In the process of formulating the dependent measures to tease out any effect in problem solving due the INRC group, it became apparent that the algebraic format of the solution was different in each case. To appropriately measure any effect, solution formats were controlled, while at the same time analyzed for any relevant interaction effects of their own.

Many aptitude factors have been attributed to male-female differences in scientific reasoning; however, a clear and definitive answer has yet to emerge as to the causal variable. Therefore, sex was included as an independent variable in this study.

The task variables identified consisted of an application of Piaget's INRC group (logical structure), the problems' algebraic format, and the nature and type of information given. Specifically, questions were analyzed for the: (1) effects of students' ability/inability to demonstrate the reversibilities, negation and reciprocity; (2) effects due to the algebraic format ($A = KB$, $B = A/K$, $A/A' = X/B'$, $X/A' = B/B'$) required to solve the problems; (3) effects of the type of information provided in the questions, being either relevant only or relevant and irrelevant; and (4) effects of the nature of information given, either explicit or implicit.

Purpose

The purpose of this study was to investigate the interactions of selected student aptitudes with their ability to solve chemistry problems, requiring proportional reasoning, but also of varying structure and information. A secondary purpose was to investigate the relationships of sex with chemistry problem solving and student aptitudes. The research sought to answer the following questions:

(1) Is there a relationship between proportional reasoning ability to solve computational chemistry problems as a function of the in-task variables?

(2) Is there a relationship between the degree of field dependence-independence and the ability to solve

computational chemistry problems as a function of the in-task variables?

(3) Is there a relationship between the degree of cognitive development and the ability to solve computational chemistry problems as a function of the in-task variables?

(4) Is there a relationship between gender and the ability to solve computational chemistry problems?

(5) Is there a relationship between gender and the degree of cognitive development as measured by the Inventory of Piaget's Developmental Tasks (IPDT)?

(6) Is there a relationship between gender and the degree of field dependence-independence as measured by the Find a Shape Puzzle (FASP) test?

(7) Is there a relationship between gender and the ability to solve proportionality problems as measured by the Balance Puzzle and a subtest of the IPDT?

Procedures and Design

Sample

The sample consisted of 77 (41 males, 36 females) chemistry students enrolled in three Chem Study classes of a suburban, southeastern Michigan high school. The subjects ages ranged from 15 years 7 months to 18 years 0 months ($\bar{X}$ = 16.59, SD = 0.65 years).

Procedures

The aptitude measures were given on subsequent days, randomizing the order for the various classes. The dependent variable, chemistry problem solving, was assessed by classroom quizzes. These measures were a part of the regular classroom testing program and were administered over a period of fourteen weeks during the first semester of the 1983-84 school year. Instruction in problem solving essentially followed a combination of factor-label and proportional reasoning approaches. Each quiz contained four questions similar to those assigned from the student textbook during each instructional period. All students were administered fourteen study specific quizzes, covering five different chemistry concepts.

Instruments

Degree of Formal Reasoning. The Inventory of Piaget's Developmental Tasks is a 72-item multiple choice paper and pencil instrument developed by H. Furth (1970). It is an untimed test designed to inventory students' cognitive development skills and is divided into five problem areas: classification, relations, images, laws (proportional reasoning), and conservation. Patterson and Milakofsky (1980) established the reliability of the IPDT, reporting test-retest correlation coefficients of 0.67 - 0.95. The general conclusion concerning the validity is that the IPDT shows the developmental progression of reasoning found by Piaget in the five major areas included in the inventory, and it yields a result similar to the traditional individually administered Piagetian tasks.

Field Dependence-Independence (FDI). The Find a Shape Puzzle (FASP) is a version of the Embedded Figures Test where the simple and complex shapes are on the same page. It is a test designed to measure a subject's cognitive restructuring ability, and was developed by S. Pulos and M. Linn (1979a). The reported reliability estimate for this test is 0.86 - 0.90. The validity of the FASP as a measure of FDI has been established by the authors.

Proportional Reasoning. Two measures of the proportional reasoning ability of students were used: the subtest of the IFDT on proportionality; and the Balance Puzzle, developed by S. Pulos and M. Linn (1979b). The Balance Puzzle is a paper and pencil test. It is a sixteen item multiple-choice test. The reported reliability for this test is 0.64, indicating moderate reliability. Validity has been established by the authors.

Dependent Measures. The fourteen quizzes covered molar conversion problems and introductory stoichiometric problems. The molar conversion problems were of three types, mole/mass, mole/molecule, and mole/volume conversions. The stoichiometric problems covered mole/mole and mass/mass relationships of composition, decomposition, and replacement reactions. Each quiz contained four problems. Each question was independently evaluated and validated as to it's conditions by two separate and discrete panels of chemistry instructors. Using a measure of response agreement (Light, 1971) a range of G-scores, 3.359 to 8.832 were obtained. All values were significant at the 0.05 level indicating no disagreement of the judges as to a set standard. Therefore, a measure of validity was established within the limitations of the evaluating judges' knowledge and expertise. An estimate of reliability was determined by computing Cronbach's alphas for the concept area quizzes. The alpha coefficients ranged from 0.80 to 0.89.

At the conclusion of the data gathering process a random sampling of student quizzes were exactly transcribed and independently scored by four high school chemistry teachers. The reliability of scoring checks yielded correlations ranging from 0.667 to 0.982.

Results and Findings

The major statistical procedures used for the analyses were correlations and analyses of variance (Statistical Package for the Social Sciences). A significance level of 0.05 was selected for the acceptance of the statistical tests.

Prior to discussing the results specific to each research question, a brief description of the overall data analysis and results for the entire sample is presented. Descriptive data for students' proportional reasoning ability and FDI were dicotomized at the median for use in the analyses of variance studies. An analysis of the frequency distribution of the IPDT scores lead to dichotomizing the scores into upper third and lower third groupings for the analyses of variance. This grouping produced a significant difference in the degree of formal reasoning for each group. The t-statistic was 10.44 (df = 55) with a probability level of 0.00. A summary table of tests used to assess student aptitudes in given in Table I.

Table I

Summary of Independent Measures
(N = 77)

Aptitude/Sex Measures	Number of Items	Median	Mean	Standard Deviation
Proportional Reasoning				
Balance Puzzle	13	7.00	6.96	2.25
IPDT Proportional Reasoning	16	12.00	12.04	2.38
Total	29	19.00	19.00	3.02
Field Dep-Independence				
FASP	20	10.00	10.46	4.47
Developmental Reasoning				
IPDT				
Relations	12		11.43	1.15
Imagery	12		10.78	1.70
Conservation	16		13.00	1.79
Classification	16		13.77	1.69
Proportional	16		12.04	2.38
Total	72		61.01	6.35

Table II shows the interrelations of the independent measures. The correlations indicate fairly strong relationships between the aptitudes; however, there exists a measure of uniqueness within each.

Table II

Pearson Correlation Coefficients for Proportiontional Reasoning, IPDT, FASP, and Sex

Measure	Proportional Reasoning	IPDT	FASP
Proportional Reasoning	-	-	-
IPDT	0.76 *	-	-
FASP	0.25 ***	0.27 **	-
Sex	-0.31 **	-0.06	0.03

* p 0.001
** p 0.01
*** p 0.05

The first information sought was to determine the relationships between student's proportional reasoning ability, FDI, degree of cognitive development, gender and their ability to solve computational chemistry problems. Significant results were obtained between the first three and problem solving ability (See Table III). A stepwise multiple regression analysis was run to summarize the predictive power and degree of relationship between the independent and dependent variables. The independent variables, where possible, were entered in their component parts to help further clarify any relationships. The results of the test are presented in Table IV.

Table III

Pearson Correlation Coefficients for Student Aptitudes and Computational Chemistry Problem Solving

Measure	Proportional Reasoning	Field Dependence-Independence	Cognitive Development	Sex
Problem-Solving Ability	0.45 (0.000) *	0.23 (0.022)	0.52 (0.000)	0.03 (0.395)

* Probability Level

Table IV

Stepwise Multiple Regression for Problem Solving Ability

Variable	F-Ratio	Pearson Correlation	Beta	R	Percent Explained Variance
IPDT Proportional Reasoning	21.57 (0.00) *	0.47	0.284	0.47	22
IPDT Relations	15.97 (0.00)	0.43	0.287	0.55	30
IPDT Classification	12.22 (0.00)	0.41	0.193	0.58	34
Age	9.87 (0.00)	9.13	0.141	0.60	36

* Probability Level

Cognitive development as measured by three problem areas of the IPDT accounted for 34% of the variance in student problem solving ability. Age added an additional 2% of the variance. To further aid analysis of the research questions, a number of analyses of variance (ANOVA) were conducted. Table V provides a summary of these statistics.

Table V

Analysis of Variance of Student Aptitudes Related to Chemistry Problem Solving Ability

Aptitude	F	Probability	Percent Variance
Proportional Reasoning	8.91	0.004	10.6
Cognitive Development	13.12	0.000	19.3
Field Dependence Independence	3.68	0.06	-
Gender	0.07	0.79	-

Research Question 1. The findings indicate a significant relationship between all in-task conditions and a subject's proportional reasoning ability. The proportion of explained variance ranged from 5.3% to 15.4% (See Table VI). This range indicates differences in students' ability to deal with the various conditions, but overall, the problem solving ability of students is more dependent on their proportional reasoning ability than the effects of the in-task variables.

Research Question 2. A significant interaction between the in-task conditions and FDI was found. Field independent students were more capable of deciphering the relevant information in a question containing both relevant and irrelevant, than field dependent students. The accounted for variance was 5.3% in their problem solving ability (See Table VI). Additionally, field independent students were better able to solve problems where information was assumed to be general knowledge and not provided in the quiz format (implicit information). This finding would seem to support Ronning, et al. (1984), wherein they state "that FD students' ability to analyze...tasks...interacts with their inability to bring past experience to bear on them" (p. 80). This interaction was compounded when both conditions were combined in the implicit relevant and irrelevant questions. A total of 7. % of the variance in the problem solving ability of students was accounted for by this variable. These questions provided no explicit relevant information but did contain irrelevant information.

Two other interactions were found for FDI and the in-task variables. Field independent students were able to significantly out-perform field dependent students on problems containing a direct logic task and on problems requiring the algebraic format A = KB. These findings were not anticipated and pose difficulty in interpretation. To date, no research has been found correlating FDI measures to Piagetian reversibility concepts, only correlation of FDI and cognitive development - specifically formal reasoning. However, it is assumed that the significance of the interaction is not a result of a common factor between direct relationships and FDI. Analysis of the direct quiz questions indicated that they were evenly split with respect to the type of information provided, 50% containing relevant only and 50% relevant and irrelevant. There was, however, an uneven distribution with respect to implicit and explicit information. Sixteen questions used implicit information while twelve questions contained explicit information. The same was true for the questions requiring the algebraic format A = KB, which is a direct relationship. Ten of the questions used implicit information while the other eight contained explicit information. It is hypothesized that part of the variance due to the direct relationship and A = KB format is a result of the imbalance of implicit and explicit information. However, this did not explain all the variance encountered. Field independent students were significantly better at solving these problems than field dependent students. Whether this is due to some common ability, a combination of the effect of implicit information or chance, the study was not able to isolate the variable.

Research Question 3. The findings indicate a significant relationship between all in-task variables and subjects' degree of cognitive development. Table VI shows the proportion of explained variance ranged from 14.0% to 19.6%. Small differences due to the in-task conditons exist; however, overall the results indicate that the problem solving ability of students is more dependent on their degree of cognitve development than the effects of the in-task conditions.

Table VI

Analyses of Variance for Proportional Reasoning, FDI, Degree of Cognitive Development and In-Task Conditions

In-Task Condition	Proportional Reasoning F	p	Percent Variance	FDI F	p	Percent Variance	Cognitive Development F	p	Percent Variance
Direct	6.54	0.01	8.0	5.46	0.02	6.8	10.98	0.00	16.6
Reverse	10.89	0.00	12.7	2.59	0.11	-	13.38	0.00	19.6
A = KB	6.31	0.01	7.8	4.78	0.03	6.0	8.97	0.00	14,0
B = A/K	13.65	0.00	15.4	2.82	0.10	-	10.84	0.00	16.5
A/A'=X/B'	4.24	0.04	5.3	1.39	0.24	-	11.42	0.00	17.2
X/A'=B/B'	4.69	0.03	5.9	3.30	0.09	-	11.92	0.00	17.8
Relevant only	8.98	0.00	10.7	2.74	0.10	-	11.79	0.00	17.7
Relevant & Irrelevant	8.27	0.01	9.9	4.10	0.04	5.3	13.26	0.00	19.4
Explicit	6.42	0.01	7.9	1.50	0.22	-	10.62	0.00	16.2
Implicit	9.05	0.00	10.8	4.76	0.03	6.0	12.44	0.00	18.5
Exp Relevant only				1.94	0.17	-			
Imp Relevant only				2.61	0.11	-			
Exp Rel & Irrelevant				1.11	0.29	-			
Imp Rel & Irrelevant				6.17	0.02	7.6			

Research Questions 4-7. Sex interactions with chemistry problem solving and the independent measures showed mixed results. No significant results were obtained for the interacton between male-female differences and the ability to solve computational chemistry problems. This finding supports that of Ridgeway (1980), wherein no significant sex difference in overall achievement in chemistry was found. Where research studies have identified male-female differences, males proved to be better problem solvers. This has been attributed to both cognitive and affective factors centering on mathematical problem solving. No significant results were obtained between sex, degree of cognitive development and FDI. However, significant results were found between sex and two of the IPDT subtests. Females out performed males on the classification subtest, while males out performed females on the proportionality subtest. Milakofsky & Bender (1982) found that on the IPDT males out performed females in conservation and proportional reasoning. Lawson (1975, 1978) found male-female performance difference depended on how the tasks were presented, either in a written or manipulative format.

No definitive results have been obtained with respect to FDI. Witkin (1962, 1971) has reported that males tend to be more field-independent while Linn & Pulos (1983a, 1983b) report a lack of sex differences on their version of the EFT, the FASP. The results of this study, using the FASP, support Linn's findings. This may imply either sex differences for FDI is not universal, or the FASP test measures students' restructing ability differently than the EFT.

The results obtained between the ability to solve proportional reasoning problems and sex were significant. The explained variance in problem solving ability was 9.5% favoring males. This finding is similar to the findings of Linn & Pulos (1983a, 1983b) using the Balance Puzzle as measure of proportional reasoning. Interestingly, the interaction between sex and chemistry problem solving (all problems required proportional reasoning) was not significant ($F = 0.07$, $p = 0.79$).

These measures must tap different abilities, or sex differences are problem-specific and should not be generalized. Table VII provides a summary of gender effects.

Table VII

Analysis of Gender Effects

	Sex				Pearson Correlation (N=77)		Maximum			
	Males		Females							
	Mean	SD	Mean	SD	R	P	Score	z-Score	F	Alpha
Chemistry Problem Solving	137.92	22.07	139.44	27.55	0.03	0.40	168	1.2	0.07	0.79
Degree of Cognitive Development (IPDT Total)	61.37	5.92	60.61	6.88	-0.06*	0.30	72	1.7	0.27	0.61
IPDT										
Relations					-0.03	0.39				
Imagery					-0.06	0.29				
Conservation					-0.09	0.22				
Classification					0.22	0.03				
Proportional					-0.19	0.04				
Degree of Field Dep-Independence Total	10.34	4.88	10.58	4.03	0.03	0.41	20	2.1	0.06	0.81
Proportional Reasoning Total	20.10	3.82	17.75	3.47	-0.31	0.00	29	2.6	7.89	0.01
IPDT Proportional					-0.19	0.04				
Balance Puzzle					-0.32	0.00				

*negative correlation favoring males

Implications

Ronning's, et al. (1984) thesis - "the assertion that a viable theory of problem solving must consider at least three dimensions: domain knowledge, problem-solving methods, and characteristics of problems solvers," should be expanded to include task variables. Results of the current study support continued research on the interactions of student aptitudes and problem solving, but also the need to account for variance due to

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the task variables students encounter. In conjunction with these emphases it is highly recommended that the research be conducted in natural settings using regular classroom examinations. This would aid classroom teachers in applying scientific research to their daily instructional activities.

The dependent measures used in this study were limited to introductory chemistry concepts and problems requiring only one or two step problem solutions. Future research should be conducted using more difficult multistepped chemistry problems, i.e., equilibrium, molarity. Continued study should be given to the relationships of FDI with task conditions which vary in the type and nature of information given. Instruction, however, should try to aid students to recognize the critical aspects of chemistry problem solving that require proportional reasoning and to help them learn to isolate relevant information. Additional emphasis should be placed on providing students with the background information that is needed in solving problems requiring implicit information. Teachers should avoid over usage of implicit and/or irrelevant information in their exam questions.

The importance of proportional reasoning to the study of chemistry suggests that emphasis be placed on identifying students of low ability and providing them a balance between problem solving and concept learning. Research indicates that students who are deficient in proportional reasoning ability will be unable to go beyond an algorithmic approach in solving chemistry problems (Gabel, Sherwood & Enochs; 1984). By providing more balanced evaluative instruments these students may achieve at a higher than present rate.

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Dependent Measures

The dependent quizzes are presented with clarifying statements as to the in-task conditions of each question.

Name ____________

Date ____________

QUIZ

1. What is the mass of 4.0 moles of nitrogen gas at a temperature of 80'C? (Gram-molecular weight of N_2 is 28)

   (Direct, A = KB, relevant and irrelevant information, explicit information)

2. How many moles of carbon dioxide are present in 100 grams carbon dioxide? (Gram-molecular weight of CO_2 is 44)

   (Reverse, B= A/K, relevant only, explicit)

3. What is the mass, in grams, of 3 moles of carbon dioxide? (Gram-molecular weight of CO_2 is 44)

   (Direct, A =KB, relevant only, explicit)

4. At 100'C, how many moles of sulfur dioxide are present in 112 grams of sulfur dioxide? (Gram-molecular weight of of SO_2 is 96.1)

   (Reverse, B = A/K, relevant and irrelevant, explicit)

Date ___________

Name ___________

QUIZ

1. How many moles of sulfuric acid are present in 100 grams of sulfuric acid? (Gram-molecular weight of H_2SO_4 is 98.1)

   (Reverse, B = A/K, relevant only, explicit)

2. At 0′C, how many moles of water are present in 20 grams of water? (Gram-molecular weight of H_2O is 18)

   (Reverse, B = A/K, relevant and irrelevant, explicit)

3. What is the mass, in grams, of 2.5 moles of sodium hydroxide? (Gram-molecular weight of NaOH is 40)

   (Direct, A = KB, relevant only, explicit)

4. At 100′C, what is the mass of 1.5 moles of water? (Gram-molecular weight of H_2O is 18)

   (Direct, A = KB, relevant and irrelevant, explicit)

Name ____________

Date ____________

QUIZ

1. Given the following balanced equation,

$$Zn + 2HCL \text{ --- } ZnCl_2 + H_2$$

how many moles of Zn are required to produce 0.75 moles of $ZnCl_2$?

(Reverse, X/A′ = B/B′, relevant only, explicit)

2. Given the following balanced equation

$$Fe_2O_3 + 3H_2 \text{ --- } 2Fe + 3H_2O$$

how many moles of hydrogen would be required to produce 1.5 moles of Fe at a temperature of 500′C?

(Reverse, X/A′ = B/B′, relevant and irrelevant, explicit)

3. Given the following balanced equation,

$$Zn + 2HCl \text{ --- } ZnCl_2 + H_2$$

at 0′C, calculate how many moles of $ZnCl_2$ will be produced by the complete reaction of 1.5 moles of HCl.

(Direct, A/A′ = X/B′, relevant and irrelevant, explicit)

4. Given the following balanced equation,

$$Fe_2O_3 + 3H_2 \text{ --- } 2Fe + 3H_2O$$

how many moles of Fe will be produced by the complete reaction of 4 moles of H_2?

(Direct, A/A′ = X/B′, relevant only, explicit)

Name ____________

Date ____________

QUIZ

1. Given the following balanced equation,

$$2Na + 2H_2O \text{ --- } 2NaOH + H_2$$

how many moles of Na must react to produce 0.75 moles of H_2 gas measured at 100′C and 2 atm pressure?

(Reverse, X/A′ = B/B′, Relevant and irrelevant, explicit)

2. Chlorine gas can be produced by passing an electric current through molten KCl as represented by the following balanced equation,

$$2KCl \text{ --- } 2K + Cl_2$$

At 1000′ and a pressure of 1 atm, how many moles of chlorine can be produced from the complete reaction of 2.5 moles of KCl?

(Direct, A/A′ = X/B′, relevant and irrelevant, explicit)

3. Given the balanced equation in question 2, how many moles of KCl are required to produce 1.5 moles of K metal?

(Reverse, X/A′ = B/B′, relevant only, explicit)

4. Given the following balanced equation,

$$2Na + 2H_2O \text{ --- } 2NaOH + H_2$$

how many moles of NaOH will be produced from the complete reaction of 1.5 moles of Na?

(Direct, A/A′ = X/B′, relevant only, explicit)