# Quantitative Reasoning Assessment Report

# December 2011

## Quantitative Reasoning Pilot Group

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On December 15, 2011 the group met to pilot the assessment of quantitative reasoning. The group used randomly selected student responses for two questions from chemistry 147 exams taken during the Fall 2011 semester.

## Quantitative Reasoning Criteria

The group started by discussing criteria they would use to evaluate student’s quantitative reasoning and developed the following scale that was used for the assessment.

### Goal: A liberally educated graduate uses quantitative methods effectively.

a) Solves problems using mathematical methods

4 – Carry out multi-step calculations correctly

3 – Identify, rearrange and solve equation correctly

2 – Identify and rearrange equation, solve with mathematical errors

1 – Identify equation to use

0 - Nothing

b) Interprets, makes inferences, and draws conclusions from data.

 4 – Create and use tables and graphs correctly

3 – Create a table or graph with correct and useful information

2 – Identify what table or graph is needed and use information to solve a problem

1 – Given a graph or table can report result

0 - Nothing

c) Determines whether numerical results are reasonable.

4 – Can use statistics to analyze error

3 – Understand what error tells you (looking at magnitude or direction)

2 – Compare experimental results with known (calculate the error)

1 – Can recognize if calculated error is absurd

0 - Nothing

## Assessment of Chemistry 147 Exam 1, Question 1, Fall 2011

The full text of this question is provided in Appendix 1. From a class of 240 students, 22 students were randomly selected. The student name was removed and their response to this question was photocopied. The assessment team reviewed three papers as a group to calibrate scoring and then one member of the group scored each of the remaining papers. A summary of the results is listed in Table 1. The full results are listed in Appendix 1.

Table . Chemistry 147, Fall 2011, Exam 1, Question 1 Quantitative Reasoning Assessment

|  |  |  |  |
| --- | --- | --- | --- |
|  | Math Methods | Interprets Data | Reasonable Results |
| Maximum score possible for question | 3 | 2 | 3 |
| Average Score | 2.95 | 1.41 | 0.54 |
| Standard Deviation | 0.21 | 0.80 | 1.06 |
|  Scoring 4 (%) | 0 | 0 | 0 |
|  Scoring 3 (%) | 95 | 0 | 9 |
|  Scoring 2 (%) | 2 | 59 | 14 |
|  Scoring 1 (%) | 0 | 24 | 0 |
|  Scoring 0 (%) | 0 | 20 | 85 |

## Assessment of Chemistry 147 Exam 2, Question 2, Fall 2011

The full text of this question is provided in Appendix 2. From a class of 240 students, 21 students were randomly selected. The student response to this question was photocopied. The assessment team reviewed three papers as a group to calibrate scoring and then one member of the group scored each of the remaining papers. A summary of the results is listed in Table 2. The full results are listed in Appendix 2.

Table 2. Chemistry 147, Fall 2011, Exam 2, Question 2 Quantitative Reasoning Assessment

|  |  |  |  |
| --- | --- | --- | --- |
|  | Math Methods | Interprets Data | Reasonable Results |
| Maximum score possible for question | 4 | 2 | 3 |
| Average Score | 2.38 | 0.28 | 0.57 |
| Standard Deviation | 1.36 | 0.56 | 0.97 |
|  Scoring 4 (%) | 33 | 0 | 0 |
|  Scoring 3 (%) | 5 | 0 | 10 |
|  Scoring 2 (%) | 38 | 5 | 5 |
|  Scoring 1 (%) | 14 | 19 | 19 |
|  Scoring 0 (%) | 10 | 76 | 67 |

## Summary of Results

### Math Methods

The assessment found that on exam 1 Question 1, which was a mathematically simple question, students scored quite well on the math methods objective. However students had much more difficulty with the math methods on exam 2 Question 2, where they were required to carry out a calculation that involved multiple steps to reach the answer. This increase in difficulty is reflected in the increase of the possible maximum score from 3 to 4. One third of the students evaluated were able to complete question 2 at a 4 level, however 38% of the students made mathematical errors in this multi-step calculation. It is not clear what the source of confusion was, students in this course certainly have sufficient practice with multi-step problems that they should be able to solve this without making any mathematical errors. Common items noted include: rounding errors, not completing all steps of the calculation, not correctly identifying the equations to use.

### Interprets Data

To assess student’s ability to interpret data the evaluators looked at student use of graphical information to solve the problem. In both of these questions students were required to use a graph on the first page of the exam to obtain information required to solve the problem. On both questions, students are explicitly referred to the Figure. As a result the maximum possible score on this scale that a student could have on this question is a 2, which requires that they identify that they need this information and they get it from the graph. On exam 1 it was more obvious that students needed this information and 59% of the students did this successfully. On exam 2 students needed the information from the graph to correctly carry out the multi-step calculation. Without the information on the graph they were unable to complete one of the steps. The same graph was used by the students in lab and for a written discussion; however 76% of the students failed to use the graph on the exam question. It is unclear if this is a problem with reading comprehension, a problem with reading graphs, or a problem with understanding the experiment. The question will be revised next time to try and clarify why so many students missed this step.

### Reasonable Results

The most troubling part of this assessment is the student scores on determining whether their numerical results are reasonable. In both exams students are provided with additional information and explicitly asked to use this information to evaluate their calculated results. For exam 1 they are expected to compare the results for DI water with the expected results. This sample should be used as a standard to test that the experiment works correctly and that the results are reliable. The importance of including known samples to validate experimental procedures is incorporated into almost every experiment in this course. However, 85% of the students taking this exam ignored the prompt to address this. Again, it is not clear if the problem is students failure to carefully read the question and respond to this prompt, if the students intentionally overlooked this result, if students still do not understand the significance of this step, or if they lack the critical thinking disposition to use this information. We plan to make some revisions to the layout and wording of this question to try and identify the source of the problem.

Failure of 67% of the students to deal with this issue on exam 2 is more troubling because the question is much more explicit. Here students have much more experience in lab with error analysis. Only 10% of the students taking the exam identified the magnitude and direction of the error in their results and were able to use that to comment on the consistency of possible sources of experimental error. 20% of the students obtained absurd results and failed to recognize that there was a problem.

Failure to recognize absurd results is something that we commonly observe in student work. It is clear that students need to confront absurd answers on a more regular basis so that they can develop the critical thinking dispositions required to identify when this occurs.

## Recommendations

Based on student outcomes for these two exams, it is clear that we have a significant amount of work ahead. The students in this class should be among the better prepared students for quantitative reasoning and in this class they are repeatedly exposed to these objectives. The chemistry department will review these findings in departmental meetings during the spring of 2012 and discuss possible solutions. A number of revisions will be made in the test questions to try and identify why students are not meeting our expectations.

# Appendix 1, Chemistry 147 Fall 2011 Exam 1, Question 1

1. (20 pts) Density. See Figure 1 on Page 1. You have two suspects for a murder committed on the Chesapeake Bay. You have obtained the following data shown in Table 1.
	1. Use this information to identify the approximate location of each suspect and circle it on the map.
	2. Use all the data available to support your claim.
	3. Make sure you use the data for DI Water to support your claim.

Table . Data on samples from murder suspects.

|  |  |  |  |
| --- | --- | --- | --- |
| Sample | Volume Pipetted (ml) | Mass of Beaker (g) | Mass Beaker and solution (g) |
| DI Water | 10.00 | 124.5486 | 134.6065 |
| Suspect 1 | 10.00 | 134.4879 | 144.5079 |
| Suspect 2 | 10.00 | 136.4729 | 146.6729 |

From: http://www.seakayak.ws/kayak/kayak.nsf/1/22AA9E20E30450F685256B4600563764

DI Water

m(H2O) = 134.6065 g −124.5486 g = 10.0579 g

d(H2O) = 1.0058 g/mL

Salinity = 10 +/- 2 ppt (from graph))

Suspect 1

m = 144.5079 g − 134.4879 g = 10.0200 g

d = 1.0020 g/mL

Salinity = 5 +/- 2 ppt (2 points (from graph))

Suspect 2

m = 10.2000 g

d = 1.0200 g/mL

Salinity = 28 +/- 2 ppt (2 points (from graph))

The salinity was 5 ppt for suspect 1 and 28 ppt for suspect 2. This places suspect 1 at the top of the bay or one of the tributaries and suspect 2 at the entrance to the bay. (It is acceptable if they circle the region on the map and indicate where each suspect is based on their data).

The salinity of D.I. water was 10 ppt. This raises questions about the technique.

-State results from DI water questions process

-Suspect 1 is at the top of the bay or near tributary

-Suspect 2 is at the entrance to the bay

-Make sure they have a reason supported by their evidence.

Table of Results for Fall 2011, Chem 147, Exam 1, Question 1

|  |  |  |  |
| --- | --- | --- | --- |
| Student | Math Methods | Interprets Data | Reasonable Results |
| 1 | 3 | 2 | 0 |
| 2 | 3 | 0 | 0 |
| 3 | 3 | 0 | 0 |
| 4 | 3 | 2 | 2 |
| 5 | 3 | 1 | 0 |
| 6 | 3 | 1 | 0 |
| 7 | 3 | 2 | 3 |
| 8 | 3 | 2 | 0 |
| 9 | 3 | 1 | 0 |
| 10 | 3 | 2 | 0 |
| 11 | 3 | 1 | 0 |
| 12 | 3 | 2 | 0 |
| 13 | 3 | 1 | 0 |
| 14 | 3 | 2 | 3 |
| 15 | 3 | 0 | 0 |
| 16 | 3 | 2 | 2 |
| 17 | 3 | 2 | 0 |
| 18 | 3 | 2 | 0 |
| 19 | 3 | 2 | 0 |
| 20 | 2 | 2 | 2 |
| 21 | 3 | 2 | 0 |
| 22 | 3 | 0 | 0 |
| AVG | 2.954545 | 1.409091 | 0.545455 |
| STD | 0.213201 | 0.796366 | 1.056827 |

# Appendix 2, Chemistry 147 Fall 2011 Exam 2, Question 2

1. **Gas Law Experiment** (20 points)

A student carries out an experiment to identify an unknown metal. Use the experimental results to calculate the atomic mass of the metal – assume a +2 charge on the metal ion in solution. See Figure on page 1 of the exam

 M (*s*) + 2 HCl (*aq*) -> H2 (*g*) + MCl2 (*aq*)

0.2446 g of metal – the metal is a silvery color

8.0 mL of 16 M HCl

Water temperature 23.0 ºC

After the tube is flipped, bubbles form

After 5 minutes the silvery colored solid is gone and no more bubbles are formed

Volume of H2 gas 94.56 mL

Barometric Pressure 763.51 mm Hg

* 1. (10 pts) Calculate the atomic weight of the unknown metal based on the data.

P = 763.51 – 21.0 = 742.51 mm Hg (-4 pts. if they fail to correct for water vapor)

P = 742.51 mm Hg = **0.9770 atm** (1 point)

 V = 94.56mL = **0.09456 L** (1 point)

 T = 23.0 + 273.15 = **296.15 K** (1 point)

n = 3.799 x 10-3 moles (3 pts)

Atomic mass = 64.39 (3 pts)

* 1. (5 pts) Identify the unknown metal and clearly explain how you determined your claim.

Zn. (3 pts)

Atomic mass between Cu and Zn, but metal is silver colored (2 pts)

* 1. (5 pts) One possible source of error is that there was not sufficient HCl added for the reaction.
		1. Is this source of error consistent with the direction of the error observed in this experiment? Explain your answer

(2 pts) Not consistent. Insufficent HCl would cause incomplete reaction so volume would be smaller, so number of moles would be smaller than expected, so atomic mass would be larger.

* + 1. Use the information from above to critique the possible claim that there was insufficient HCl for the reaction.

(3 pts must include)

-Observation was made that all the solid was gone

Table of Results for Fall 2011, Chem 147, Exam 1, Question 1

|  |  |  |  |
| --- | --- | --- | --- |
| Student | Math Methods | Interprets Data | Reasonable Results |
| 1 | 4 | 0 | 3 |
| 2 | 2 | 0 | 0 |
| 3 | 2 | 1 | 0 |
| 4 | 1 | 0 | 0 |
| 5 | 2 | 0 | 0 |
| 6 | 3 | 0 | 0 |
| 7 | 1 | 0 | 0 |
| 8 | 2 | 2 | 1 |
| 9 | 4 | 0 | 0 |
| 10 | 4 | 0 | 0 |
| 11 | 0 | 0 | 0 |
| 12 | 2 | 0 | 1 |
| 13 | 2 | 0 | 0 |
| 14 | 4 | 1 | 1 |
| 15 | 2 | 1 | 0 |
| 16 | 0 | 0 | 0 |
| 17 | 2 | 0 | 0 |
| 18 | 1 | 0 | 0 |
| 19 | 4 | 0 | 2 |
| 20 | 4 | 1 | 3 |
| 21 | 4 | 0 | 1 |
| AVG | 2.380952 | 0.285714 | 0.571429 |
| STD | 1.359272 | 0.560612 | 0.978337 |