Active Assessment: Small scale experiments for authentic assessment

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Individuals learn and retain information differently, and that should be taken into consideration in both the teaching and assessment in their science classes. Teaching should go beyond the traditional lecture techniques, associated homework questions, work sheets, problem sets, and occasional term projects to include a mixture of demonstrations, hands-on activities, homework investigations, and active hands-on testing.

In traditional classroom teaching, the majority of the information conveyed is through a lecture and textbook-type of approach. Information is transmitted with little physical reinforcement or visual demonstrations to provide experiential involvement of the student. There are limited resources provided to the teacher by their districts or colleges. Innovations such as *Chemistry in the Community* (*ChemCom*), and *Chemistry in Context*, developed under the direction of the American Chemical Society, provide an excellent alternative for the non-major, but does not provide material for the science major unless the science teacher can apply selected material to their majors' course. In addition, many districts and colleges utilize standardized testing that also locks the teacher into a set curriculum leaving them with an "obligation" to cover material specifically for those tests. When inquiring about expanding course topics to include more relevance and applications, this author has been told by teachers that "there is no time for it in the curriculum" and "it won't be on the (standardized) test".

In traditional testing, students encounter a range of questions such as true-false, matching, fill-in-the-blanks, multiple choice, essay, and problem sets. Most testing relies on memorization rather than active testing. Ask an individual "Can you answer every question on tests that you take?" or "Can you always solve the more difficult problems in a problem set on your first run-through?", yet, we require our students to do so and then we grade them based on what they don't know.

Classroom teaching should include a number of strategies and resources. Current issues facing society should be discussed using articles from newspapers and magazines, and information from recent television shows and movies. Such material does not replace the textbook, but enhances it. This information should be integrated into class presentations without eliminating content needed for the curriculum. Low cost demonstrations and activities should also be used as part of active teaching.

Vary assessment techniques and testing to allow students to demonstrate their individual competencies. If classroom topics include forensics, then the assessment component should have students solving a "crime", if the topic is science and science fiction, then the assessment component should be to write a science fiction story. For the more "traditional" topics, some alternative testing strategies are building questions that can test at two levels, multi-answer multiple choice questions, and interactive questions that use small-scale experiments as part of the testing process. Assessment techniques should also include laboratory testing.

In chemistry, implementing hands-on experiment testing and laboratory practical exams has long been viewed as a difficult undertaking due to amounts of materials and apparatus needed along with the formulation of questions, time for administration of the exam, and development of grading Rubrics. The first steps toward small scale chemistry experiments were taken by Hubert Alyea starting in 1961 with his TOPS overhead projection series and later with his Armchair Chemistry experiments. The availability of inexpensive and readily available materials such as Beral pipettes and well plates, along with development of suitable questions and techniques by Wilbur Berquist's "Test Cubes", Abraham and Pavelich's open inquiry experiments in their *Inquiries Into Chemistry*, and Bob Silberman's *Small-Scale Laboratory Assessment Activities* have laid a foundation for modern small-scale classroom experiments and laboratory practical exams. The experiments and techniques from classroom activities and laboratory practical exams, once set up, can be extended to hands-on testing as part of a classroom exam and have also been used as part of the 2001 and 2002 New Jersey's Rutgers Academic Challenge competition.

In the classroom exams and the laboratory practical exams, students get some choice in selecting questions to answer that involve performing experiments or activities, ranging from microscale to small scale. The small scale and microscale experiments utilize minimal amounts of substances to provide safe procedures and easy clean-up and disposal.

Some examples of different types of exams, exam questions, and laboratory practical exam questions are included on the following pages. Comments are provided in *italics.*

REFERENCES

Alyea, Hubert N., *Armchair Chemistry*, Second Edition, Hubert N. Alyea, Princeton University, 1974.

Abraham, Michael R., and Michael J. Pavelich, *Inquiries Into Chemistry*, Waveland Press, Prospect Heights, IL, 1979 (Note: Currently in 3rd Edition)

Silberman, Robert G., *ACS Small-Scale Laboratory Assessment Activities*, ACS Exams (864-656-1249 or acsxm@clemson.edu)

DIRECTIONS FOR A MENU-TYPE EXAM

This type of exam allows the students to choose among questions so that they can demonstrate what they know rather than what they don't know. They can earn more than 100 points allowing for a small amount of extra credit as well as variations in point values of different questions. Trying to answer every question, however, will penalize them as the instructor should stop grading sections as soon as the attempted point count is reached. This is an example of the directions I use on such an exam.

Chemtech College
Chemistry 100 - Exam #1
Spring 2001 - D. A. Katz

Name ____

DIRECTIONS: The following exam consists of a number of questions totaling between 124 and 136 points. You are to select questions to answer so that your total point count is no more than 105 points. Your score will be penalized for answering more than 105 points.

For each calculation, solve by dimensional analysis (factor-label method) or use the proper formula. **SHOW THE SET-UP CLEARLY**, including the formula used, conversion factors, and the proper units. Observe significant figures, show any set-ups for formula weight calculations, and circle or underline the final answer. Keep discussion-type answers brief and to the point, avoid long essays.

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. *(page 1 questions and problems go in this area)*

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**Number of points answered on this page (________) *[this is placed at the bottom of the page]*

CHALLENGE PROBLEM

Students can also choose the level of calculation they want to answer. The challenge problem is more complex and will earn extra points, thus letting them omit another question or problem elsewhere in the exam. They still must demonstrate a basic level of competency. Calculations cannot be omitted by the students, on the exam, they can only choose the level of calculations they want to answer.

6. Calculation: Complete **either** problem 6.1 **or** problem 6.2. Problem 6.1 is a *challenge* problem, that is, it is more complex than problem 6.2. DO NOT solve BOTH problems 6.1 and 6.2.

Problem 6.1 (Challenge Problem)
Urea, $(NH_2)_2CO$, ammonium nitrate, NH_4NO_3, guanidine, $HNC(NH_2)_2$, and ammonia, NH_3, are all used as fertilizers to contribute nitrogen to the soil. Which one of these is the richest source of nitrogen on a mass percentage basis? (12 points)

Problem 6.2
Calculate the percent composition of calcium arsenate, $Ca_3(AsO_4)_2$ (8 points)

CHEMICAL REACTION QUESTIONS

This is one type of what I call "Active Assessment" questions. The student must physically perform a small-scale reaction. Thus the old "complete and balance the following reactions" type of questions now have a physical significance. The materials for the reactions sets are placed in small boxes, plastic drinking cups or beakers, and labeled with an identification number. More than one set may be needed depending on the size of the class. Materials can be labeled using names or formulas of the elements or compounds in the reaction set. Note that both the symbols and the names of the reacting substances are asked for in the problem even though the materials were labeled with the names or symbols. This is to insure that the grader knows the correct set that the student selected even if the student writes an incorrect set identification number or an incorrect formula or name.

II. CHEMICAL REACTIONS (36 points total - 12 points each)

Directions: Select 3 chemical reactions from the front desk (Please take them one at a time). Run each reaction on a piece of wax paper using one or two drops of the liquid chemical solutions (or one or two drops of liquid and a piece of solid). Complete the information below for each reaction.

Please return the reaction materials to the front desk. Discard the waste materials by crumpling up the wax paper with the drops of chemical inside and place it in the trash.

Reaction Set No.: _____

a) Symbols of reacting substances:

b) Names of reacting substances:

c) Evidence of a chemical reaction:

d) Write a balanced chemical equation for the reaction that occurred.

SAMPLE CLASSROOM EXPERIMENT QUESTIONS

This is another type of what I call "Active Assessment" questions. The student must physically conduct a small-scale experiment. These experiments are aimed at testing concepts and principles rather than the old "define" or "explain" type of short-answer questions. Materials can be labeled using names or formulas of the elements or compounds in the experiment set.

These questions, letters a) through e), involve doing or observing an experiment. The materials are available on the front desk. Select an experiment, take it to your desk and answer the question. You may answer up to **two** experiment questions. (10 points each)

a) You are given three pennies, pipettes, and three liquids/solutions: water, water-detergent, ethyl alcohol. Howmany drops of each liquid can you put on a penny? Explain the differences.

b) You are given a cotton ball that is wet with some ethyl rubbing alcohol. Touch the cotton ball to the back of your hand. What sensation do you feel? Explain.

c) On the front desk is a paper cup containing water. It is being heated by a candle. Explain.

d) You are given a washable marker, a stick of porous chalk, and a cup containing a few mL of water. Draw a line on the chalk, about 1 cm from one end, using the marker. Stand the chalk up in the cup and observe the changes that are taking place (Note: the water is moving through the chalk by a process known as capillary action.):
   i) What changes are occurring?

   ii) Explain your observations using the principles of solutions and intermolecular forces.

e) The bottles labeled 1, 2 and 3 contain distilled water, a solution of acetic acid, and a solution of sodium chloride. Which is which? Explain how you determined your answer.

SAMPLE LAB QUESTIONS

These are some questions that can be used in a laboratory practical exam. Questions can be as simple as "read the volume of liquid in the graduated cylinder, buret, etc." or more complicated problems involving stoichiometry, pH, pK, equilibrium, kinetics, etc. I usually label each problem by type. Descriptions in italics are included here for the reader's information. Students must select and answer a selected number of questions during the exam period, rotating between stations in the laboratory, at random or at set time intervals. Students usually are assigned to work in pairs.

Due to the use of these questions in exams, both at my home institution and a other schools, answers or scoring Rubrics for these questions are not included in this article, leaving this information as an exercise for the reader. Please contact the author for additional information and/or assistance with scoring Rubrics for these questions.

FLOATING COKE CANS
(*coke and diet coke in a container of water*)

Can you explain what is happening here?

You may examine the system any way you desire, please DO NOT open any of the cans.

MEASUREMENT
(*liquids in measuring devices*)

Determine the volume of liquid contained in each of the measuring devices. Please DO NOT remove any liquid from any of the containers.

NAME the container and tell the volume of liquid.

LAB APPARATUS
(*Use any items of lab apparatus*)

Name the pieces of apparatus

MASS RELATIONSHIPS I
(*study the stoichiometry of a reaction*)

Investigate the mass relationship associated with heating a sample of $CoCl_2{\bullet}6H_2O$

Describe any changes that occur.

Write a chemical equation for the reaction that takes place.

Is this reaction reversible?

MASS RELATIONSHIPS II

Investigate the mass relationship associated with burning a piece of steel wool (iron).

What compound is formed?

Write a chemical equation for the reaction that takes place.

MASS RELATIONSHIPS III

Investigate the mass relationship associated with reaction of hydrochloric acid and sodium bicarbonate.

Write a chemical equation for the reaction that takes place.

HEAT/REACTION SYSTEMS

Add the following to a Zip Loc bag:

- 3 g sodium bicarbonate *(Note: measuring spoons can be used.)*
- 3 g calcium chloride
- a test tube or vial containing 10 mL of phenol red solution.

Holding the bag upright, so as NOT to spill any liquid, squeeze as much air out of the bag as possible and seal it.

Spill the phenol red solution into the bag so it mixes with the powders. Record the results.

Which component is responsible for each of the observed results?

Write chemical equations for the reaction(s) that take place.

CHEMICAL REACTIONS

Identify the 5 white powders using the solutions in the pipettes: water, vinegar, and phenolphthalein. The powders are ground up samples of chalk, alka-seltzer, washing soda (sodium carbonate), baking soda (sodium bicarbonate) and vitamin C. Explain the basis for your identification.

CHEMICAL REACTIONS

The three Beral pipettes, labeled A, B, and C, contain three separate solutions of the following compounds: calcium chloride, sodium carbonate, and dilute hydrochloric acid. Using only these three solutions, determine which pipette contains which solution. Describe how you solved the problem.

ANALYSIS

Which is the soap solution? (or detergent solution)

[*Materials: Solutions of soap, detergent, and water. Solutions with ions Fe, Ca, and Mg. Cooking oil.*]

ANALYSIS

Which water sample is hardest?

[*Materials: Solutions of soap and detergent and water samples. An alternative test uses water samples and reagenst for hardness testing can be used*]

CALORIMETRY

Which nut has the higher caloric content?

[*Burn nuts or snack food*]

CHROMATOGRAPHY

Which pen was used to make a mark below the X on this paper?

[*Ink analysis by paper chromatography. Materials and solvents are supplied.*]

DENSITY

Determine the density of ONE of these liquids.

Tell which liquid you used

[*Materials: liquids or solutions, graduated cylinders, and a balance*]

MEASUREMENT II

Determine the accuracy of the 10 mL graduated cylinder.

Note: The density of water is 1.0 g/mL

MASS RELATIONSHIPS IV LIMITING REAGENT

Investigate the reaction of aluminum with copper(II) chloride.

Which is the limiting reagent? [*If students use entire contents of containers.*]

What changes take place?

Write the balanced chemical equation for the reaction.

How much of the excess reagent should be left at the end of the reaction?

NOTES:

Use one vial of copper(II) chloride.

Use one piece of aluminum.

HEAT/REACTION SYSTEMS II

Determine ΔH in J/mole for the reaction of 2.0 M H_2SO_4 with 2.0 M NaOH.

Write the balanced equation for the reaction that occurs.

NOTES:

A well in the well plate holds 3.0 mL of solution.

The specific heat of the solutions is assumed to be 4.184 J/g°C

ELECTROLYTES: CONDUCTIVITY OF SOLUTIONS

Determine the conductivity of each of the solutions.

What information does the conductivity tell you?

[*Students are given a selection of solutions ranging from non-electrolytes to strong electrolytes, along with a safe student conductivity apparatus.*]

ACID - BASE CHEMISTRY

Determine the pH range over which the indicator changes color. The solutions you have to work with are 0.10 M HCl and water.

[*Students are given a well plate, droppers, and an indicator which changes color in the pH 1 to 7 range. This experiment can be expanded using 0.10M NaOH and indicators that change color in the pH 7 to 14 range. For a more comprehensive problem, both the HCl and NaOH can be used with a range of indicators.*]

ACID - BASE CHEMISTRY

Determine how much acid solution will be neutralized by 1.00 mL of milk of magnesia.

[*Small beaker is needed – volume too large for a well plate. Best results obtained by neutralizing the milk of magnesia and back titrating with base.*]

ACID - BASE CHEMISTRY

The six numbered pipettes contain either acidic or basic solutions. The seventh pipette contains phenolphthalein solution. Rank the acid and base solutions in order of their concentration.

[*This is a series of small titrations.*]

ACID - BASE CHEMISTRY

Determine the pH of this sample of weak acid.

ACID - BASE CHEMISTRY

Determine if the acid is weak or strong.

ACID - BASE CHEMISTRY

Determine the approximate pH of the two household products using universal indicator and the buffer solutions provided.

ACID - BASE CHEMISTRY

Using the universal indicator and the color chart provided, determine which of the five 0.10 M solutions have been prepared from strong acids and which from weak acids.

REACTION RATES

Devise an experiment and collect data to show the rate of a reaction between a solid and a liquid are related to the particle size of the solid. The chemicals you have to work with are 2.0 M HCl and a stick of chalk.

REACTION RATES

Devise an experiment to show that the rate of a reaction is related to the temperature of the reactants. The chemicals you have to work with are 2.0 M HCl and magnesium ribbon.

REACTION RATES

Devise an experiment and collect data to show that the rate of a chemical reaction is directly related to the concentration of reactants. The chemicals you have to work with are 6.0 M HCl and a stick of chalk.

REACTION RATES

When solutions A and B are mixed a white precipitate slowly forms. If the rate law for the reaction is:

$$\text{rate} = k[A]^a[B]^b$$

devise and carry out an experiment that enables you to determine the exponent in the rate equation for compound A.

SOLUBILITY

Use the 0.10 M calcium chloride and 0.10 M sodium sulfate to determine the approximate solubility of calcium sulfate in water.

EQUILIBRIUM

What factors affect the equilibrium:

$$Co(H_2O)_6^{2+} + 4\ Cl^{1-} \Longleftrightarrow CoCl_4^{2-} + 6\ H_2O$$

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The three Beral pipettes, labeled A, B, and C, contain three separate solutions of the following compounds: calcium chloride, sodium carbonate, and dilute hydrochloric acid. Using only these three solutions, determine which pipette contains which solution. Describe how you solved the problem.

This is a typical answer sheet that I use for laboratory practical exams.

CHEMISTRY 100 LABORATORY FINAL

Name(s): ____

Topic and Question Number: __________________________________

Approximate length of time needed to solve this problem: _____________minutes

How did you solve this problem? Please describe, briefly, what you did.

Results/Answer to Problem:

If you encountered any “problems” with this question, or if you have any suggestions for improving or modifying this question, please write them on the back of this paper.