2002 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM—PART III

Prepared by the American Chemical Society Olympiad Laboratory Practical Task Force

OLYMPIAD LABORATORY PRACTICAL TASK FORCE

Lucy Pryde Eubanks, Clemson University, Clemson, SC
Chair

Robert Becker, Kirkwood High School, Kirkwood, MO

Nancy Devino, Coordinating Board for Higher Education, Jefferson City, MO

Sheldon L. Knoespel, Michigan State University, East Lansing, MI

Steve Lantos, Brookline High School, Brookline, MA

Jim Schmitt, Eau Claire North High School, Eau Claire, WI

Robert G. Silberman, SUNY-Cortland, NY

Christie B. Summerlin, University of Alabama-Birmingham, Birmingham, AL

DIRECTIONS TO THE EXAMINER–PART III

The laboratory practical part of the National Olympiad Examination is designed to test skills related to the laboratory. Because the format of this part of the test is quite different from the first two parts, there is a separate, detailed set of instructions for the examiner. This gives explicit directions for setting up and administering the laboratory practical.

There are two laboratory tasks to be completed during the 1 hour, 30 minutes allotted to this part of the test. Students do not need to stop between tasks, but are responsible for using the time in the best way possible. Each procedure must be approved for safety by the examiner before the student begins that procedure.

Part III	**2 lab problems**	**laboratory practical**	**1 hour, 30 minutes**

Students should be permitted to use non-programmable calculators.

DIRECTIONS TO THE EXAMINEE–PART III

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO. WHEN DIRECTED, TURN TO PAGE 2 AND READ THE INTRODUCTION AND SAFETY CONSIDERATIONS CAREFULLY BEFORE YOU PROCEED.

There are two laboratory-related tasks for you to complete during the next 1 hour, 30 minutes. There is no need to stop between tasks or to do them in the given order. Simply proceed at your own pace from one to the other, using your time productively. You are required to have a procedure for each problem approved for safety by an examiner before you carry out any experimentation on that problem. You are permitted to use a non-programmable calculator. At the end of 1 hour, 30 minutes, all answer sheets should be turned in. Be sure that you have filled in all the required information at the top of each answer sheet. Carefully follow all directions from your examiner for safety procedures and the proper disposal of chemicals at your examining site.

2002 UNITED STATES NATIONAL CHEMISTRY OLYMPIAD
PART III — LABORATORY PRACTICAL

Student Instructions

Introduction

These problems test your ability to design and carry out laboratory experiments and to draw conclusions from your experimental work. You will be graded on your experimental design, on your skills in data collection, and on the accuracy and precision of your results. Clarity of thinking and communication are also components of successful solutions to these problems, so make your written responses as clear and concise as possible.

Safety Considerations

You are required to wear approved eye protection at all times during this laboratory practical. You also must follow all directions given by your examiner for dealing with spills and with disposal of wastes.

Lab Problem 1

Design and carry out an experiment to investigate a relationship between the surface area of a piece of raw potato and the rate of decomposition of hydrogen peroxide. You may use only those materials available at your experimental station. You will be asked to describe the method you developed to carry out this investigation.

Lab Problem 2

Design and carry out an experiment to determine the equilibrium constant, K_{eq}, for this reaction at room temperature.

$$\text{urea}_{(s)} + H_2O_{(l)} \rightleftharpoons \text{urea}_{(aq)}$$

You will be asked to describe the method you developed to solve this problem.

Given: molar mass of urea, $CO(NH_2)_2$ = 60.0 g·mol^{-1}
molarity of pure H_2O = 55.5 mol·L^{-1}

Answer Sheet for Laboratory Practical **Problem 1**

Student's Name: ____________________

Student's School: ____________________ **Date:** ____________________

Proctor's Name: ____________________

ACS Section Name : ____________________ **Student's USNCO test #:** ____________________

1. Give a brief description of your experimental plan.

Before beginning your experiment, you must get approval (for safety reasons) from the examiner.	Examiner's Initials:

2. Record your data and other observations.

3. What relationship did you have find between the surface area of a raw potato and the rate of decomposition of hydrogen peroxide? Support your conclusion with your experimental evidence.

Answer Sheet for Laboratory Practical Problem 2

Student's Name: ____

Student's School: _________________________ **Date:** ____________________

Proctor's Name: ____

ACS Section Name : ____________________ **Student's USNCO test #:** __________

1. Give a brief description of your experimental plan.

Before beginning your experiment, you must get approval (for safety reasons) from the examiner.	**Examiner's Initials:**

2. Record your data and other observations.

3. What value did you calculate for the equilibrium constant? Show your methods clearly.

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Examiner's Directions

Thank you for administering the 2002 USNCO laboratory practical on behalf of your Local Section. It is essential that you follow the instructions provided, in order to insure consistency of results nationwide. There may be considerable temptation to assist the students after they begin the lab exercise. It is extremely important that you do not lend any assistance or provide any hints whatsoever to the students once they begin work. As is the case with the international competition, students should not be allowed to speak to anyone until the activity is complete.

The equipment needed for each student for both lab exercises should be available at his/her lab station or table when the students enter the room. The equipment should be initially placed so that the materials used for Lab Problem 1 are separate from those used for Lab Problem 2.

After the students have settled, read the following instructions (in italics) to the students.

Hello, my name is ________. Welcome to the lab practical portion of the U.S. Chemistry Olympiad National Examination. In this part of the exam, we will be assessing your lab skills and your ability to reason through a laboratory problem and communicate your results. Do not touch any of the equipment in front of you until you are instructed to do so.

Both of this year's problems use some small-scale chemistry equipment. Small-scale chemistry techniques help to minimize the amount of materials you use, thereby increasing safety and minimizing waste. Specialized equipment for small-scale chemistry that you will use today include Beral-type pipets.

Show the Beral-type pipets being used at your site. If you substituted droppers in the first problem, show those as well.

You may be unfamiliar with the graduated centrifuge tubes available in both parts of this lab practical exam. This is the type we will be using.

Show the type of centrifuge tube being used at your site.

The watertight caps will be an advantage in at least one of the problems.

You will be asked to complete two laboratory problems. The materials and equipment needed to solve each problem has been set out for you and is grouped by the number of the problem. You also may use distilled (or deionized) water. You must limit yourself to this equipment and materials for each problem. A balance is not needed for either problem. You may choose to start with either problem. You are required to have a procedure for each problem approved for safety by an examiner. (Remember that approval does not mean that your procedure will be successful–it is a safety approval.) When you are ready for an examiner to come to your station for each safety approval, please raise your hand.

You will have ***one hour and thirty minutes*** *to complete* ***both problems****.*

Safety is an important consideration during the lab practical. ***You must wear goggles at all times.*** *Wash off any chemicals spilled on your skin or clothing with large amounts of tap water. The appropriate procedures for disposing of solutions at the end of this lab practical are:*

We are about to begin the lab practical. Please do not turn the page until directed to do so, but read the directions on the front page. Are there any questions before we begin?

Distribute **Part III** booklets and again remind students not to turn the page until the instruction is given. **Part III** contains student instructions and answer sheets for both laboratory problems. Allow students enough time to read the brief cover directions.

> *Do not turn to page 2 until directed to do so. When you start to work, be sure that you fill out all information at the top of the answer sheets. Are there any additional questions?*

If there are no further questions, the students should be ready to start **Part III**.

> *You may begin.*

After **one hour and thirty minutes**, give the following directions.

> *This is the end of the lab practical. Please stop and bring me your answer sheets. Thank you for your cooperation during this test.*

Collect all the lab materials. Make sure that the student has filled in his or her name and other required information on the answer sheets. At this point, you may want to take five or ten minutes to discuss the lab practical with the students. They can learn about possible observations and interpretations and you can acquire feedback as to what they actually did and how they reacted to the problems. After this discussion, please take a few minutes to complete the Post-Exam Questionnaire; this information will be extremely useful to the Olympiad Laboratory Practical subcommittee as they prepare next year's exam.

Please remember to return the post-exam Questionnaire, the answer sheets from **Part III**, the Scantron sheets from **Part I**, and the "Blue Books" from **Part II** to this address:

ACS DivCHED Exams Institute
Clemson University
223 Brackett Hall
Clemson, SC 29634-0979

Wednesday, April 24, 2002 is the ***absolute*** deadline for ***receipt*** of the exam materials at the Examinations Institute. Materials received after this deadline ***CANNOT*** be graded.

THERE WILL BE NO EXCEPTIONS TO THIS DEADLINE DUE TO THE TIGHT SCHEDULE FOR GRADING THIS EXAMINATION.

EXAMINER'S NOTES

Lab Problem #1: Materials and Equipment. Each student will need:

1 stopwatch, timer, or access to clock with second hand

6 25-mL or 15-mL graduated cylinders, with bases

Note: If providing this many graduated cylinders per student is not possible, 6 13 x 100 test tubes and a test tube rack may be substituted.

2 small beakers (100 mL or 250 mL); one labeled "water", one labeled "3% hydrogen peroxide"

2 1-mL Beral-style pipets (eye droppers may be substituted)

2 15-mL graduated centrifuge tubes (see lab problem #2 for specifications; caps not needed for this lab problem)

1 6-in plastic ruler

1 100-mL or larger wash bottle, labeled "distilled water" or "deionized water"

1 25-mL dropping bottle labeled "liquid detergent"

1 kitchen cutting board (or suitable clean hard surface on lab bench)

1 sharp kitchen paring knife, non-serrated edge

1 plastic container (such as a margarine tub or a Deli salad container); capable of holding approximately 200 mL

1 plastic tub for disposal of liquid wastes (or easy access to sinks)

supply of paper towels

1 pair safety goggles

1 lab coat or apron (optional)

Lab Problem #1: Chemicals . Each student will need:

1 8-fluid oz (237 mL) bottle of 3% hydrogen peroxide

Note: Hydrogen peroxide antiseptic is sold in the first aid section in most supermarkets and drug stores. Provide each student with an unopened bottle to emphasize the use of a consumer product. The cheapest brand, so long as it is fresh and unopened, will work.

1 white potato (Russet potatoes work well and are generally available; provide potato whole and unpeeled)

10 mL liquid detergent

100 mL of distilled or deionized water

Quick Check to be sure this lab problem will work for your examinees:

1) Are the bottles of hydrogen peroxide ***fresh and unopened?***

2) Is the knife capable of making ***clean cuts*** in the potato?

3) Have all detergent or soap residues ***been removed*** from the glassware?

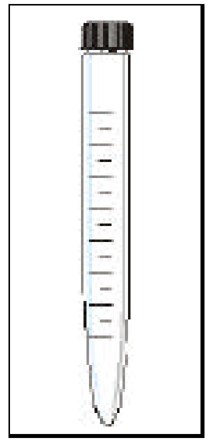
Lab Problem #1: Notes

1. Note that the examiner will need to initial each student's experimental plan. Please do not comment on the plan other than looking for any potentially unsafe practices.

2. Safety: It is your responsibility to ensure that all students wear safety goggles during the lab practical. A lab coat or apron for each student is desirable but not mandatory. You will also need to give students explicit directions for handling spills and for disposing of waste materials, following approved safety practices for your examining site. Please check and follow procedures appropriate for your site.

Lab Problem #2: Materials and Equipment. **Each student will need:**

4 15-mL centrifuge tubes with 0.1 mL or 0.5 mL graduations. The centrifuge tubes should have conical bottoms and screw caps. 2 tubes labeled "~9.0 mL"; 2 tubes labeled "4.0 g urea"



Note: Polystyrene, polypropylene, or Pyrex® centrifuge tubes are widely used in biology, chemistry, and biochemistry departments. The dome-seal screw cap prevents loss of any liquid, important for this experiment. The conical-bottom tubes are preferred to the round bottom tubes. It is not necessary to use the far more expensive borosilicate centrifuge tubes.

1 100-mL or larger wash bottle, labeled "distilled water" or "deionized water"
1 10-mL graduated Beral-style pipet
1 small beaker (100 mL or 250 mL), labeled "water"
1 plastic tub for disposal of liquid wastes (or easy access to sinks)
supply of paper towels
1 pair safety goggles
1 lab coat or apron (optional)

Lab Problem #2: Chemicals. Each student will need:

2 4.0 g samples of urea, $(NH_2)_2CO$, provided in closed, labeled conical-bottom graduated centrifuge tubes. The samples should be prepared in advance.

100 mL of distilled or deionized water

Quick Check to be sure this lab problem will work for your examinees:

1) Have the correct centrifuge tubes been ***obtained and labeled***?

2) Have two 4.0 g urea samples ***been prepared*** and placed in the labeled centrifuge tubes for each student?

3) Have two other centrifuge tubes been labeled "~9.0 mL H_2O" for each student? These should ***not*** be filled in advance.

Lab Problem #2: Notes

1. Note that the examiner will need to initial each student's experimental plan. Please do not comment on the plan other than looking for any potentially unsafe practices.

2. Be sure that the labels on the centrifuge tubes do not obscure any graduations.

3. Safety: It is your responsibility to ensure that all students wear safety goggles during the lab practical. A lab coat or apron for each student is desirable but not mandatory. You will also need to give students explicit directions for handling spills and for disposing of waste materials, following approved safety practices for your examining site. Please check and follow procedures appropriate for your site.

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KEY for NATIONAL EXAM—PART III

Lab Problem 1

Part 1. Experimental Plan

A good plan included a detailed description of a method to observe the rate of reaction. It would also include a plan for varying the surface area of the potato. Finally, the plan needed to account for the importance of controlling the volume of peroxide.

For example, a good plan might consist of these steps.

1) Cut the potato into different size cubes, such as 2 cubes of 0.5 cm on a side and 2 cubes of 1.0 cm on a side.

2) Measure 2.0 mL of H_2O_2 into a test tube or graduated cylinder and add 3 drops of detergent..

3) Shake to generate a small amount of foam for a starting point. Measure the height of the foam column or read the volume of the foam directly if using a graduated cylinder.

4) Drop in one cube of potato and start a timer.

5) At appropriate intervals, measure the height of the foam column or read the volume of the foam directly if using a graduated cylinder.

6) Repeat steps 2-5 for other potato pieces.

An average plan was either missing one of these three components or had less detail in two or more of these components.

A weak plan had minimal detail about how the experiment would be conducted.

Part 2. Experiments and Observations

A good experimental section included these points.

1) Appropriate measurements of

- **a.** reaction rate or progress.
- **b.** dimensions of the potato pieces used.
- **c.** time.
- **d.** volume of H_2O_2 used.

2) Multiple (at least two) trials for each different surface area of the potato piece.

3) Appropriate quantitative detail such as

- **a.** precision in the trials.
- **b.** averaging trial data.
- **c.** description of any calculation methods used, such as for determining the surface area of the potato piece.

An average experimental section was either missing one of these three components or had less detail in two or more of these components.

A weak experimental section had minimal detail about how the experiment was conducted and what observations were made.

Part 3. Discussion

A good discussion included these points.

1) Calculations or graphical determinations of the relationship between surface area and rate of decomposition of hydrogen peroxide.

2) An appropriate description of the scientific reasoning utilized.

3) An accurate conclusion supported by the experimental observations and data reported.

Note: Points were *not* deducted for correct and reasoned discussion of an experiment with seemingly anomolous results.

Lab Problem 2

Part 1. Experimental Plan

A good plan recognized that it was necessary to determine how much water was required to completely dissolve 4.0 g of urea.

For example, a good plan might consist of these steps.

1) Add water in small increments to 4.0 g of urea in the graduated centrifuge tube.

2) Cap the tube and shake after each addition.

3) If any solid remains, add another small portion of water. Cap and shake the tube.

4) Continue to add water until all the urea is dissolved.

5) Record the total volume of solution and/or the total volume of water added.*

6) Repeat with the second 4.0 g sample of urea.**

An average plan was either missing one of these components or had less detail in two or more of these components.

A weak plan had minimal detail about how the experiment would be conducted.

Part 2. Experiments and Observations

Sample Data

	Total Volume of Solution*	**Mass Urea****
Trial 1	7.3 mL	4.0 g
Trial 2	7.5 mL	4.0 g

Many students also observed that as the urea dissolved, the tube felt cool to the touch. Some allowed time for the tube to return to room temperature before making final observations of volume.

Part 3. Calculation of Equilibrium Constant

Sample calculations for Trial 1

1) Moles of urea = $4.0 \text{ g urea} \times \dfrac{1 \text{ mol urea}}{60.0 \text{ g urea}} = 0.067 \text{ mol urea}$

2) Molarity of urea solution = $\dfrac{0.067 \text{ mol urea}}{0.0073 \text{ L solution}} = 9.2 \text{ M}$

3) Calculation of K_{eq} if assume that the concentration of water is in standard state.

$$\text{urea}(s) + H_2O(l) \rightleftharpoons \text{urea}(aq)$$

$$K_{eq} = [\text{urea}(aq)]$$

$$K_{eq} = 9.2$$

* A **superior** plan recognized that because there is a high concentration of urea in the saturated solution, the solution cannot be treated as a dilute solution in which the concentration of the solvent is the same as that of pure water. Points were awarded to students who realized this and adjusted their experimental approach. This requires knowing the volume of water added, not just the volume of the resulting solution. For example, if 4.3 mL of water was added, the final volume of the solution was reported as 7.3 mL. The molarity of water in the saturated solution can then be calculated, as shown in this example.

$$\frac{4.3 \text{ mL } H_2O}{7.3 \text{ mL solution}} \times 55 \text{ M} = 32 \text{ M} \quad \text{and} \quad K_{eq} = \frac{[\text{urea}(aq)]}{[\text{urea}(s)][H_2O(l)]} \quad \text{and} \quad K_{eq} = \frac{(9.2 \text{ M})}{(1)(32 \text{ M}/55.5 \text{ M})} = 16$$

** Some students elected to obtain more samples by dividing the given mass of urea. The mass of smaller samples of urea was estimated by calculating the density of urea, given the known mass and the volume markings on the graduated centrifuge tube.