2001 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

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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 90 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 90 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 the 90 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.

2001 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 determine the density of the plastic object you have been given. You may use water and the alcohol solution provided at your lab station, as well as the equipment you will find there, but you may ***not*** use a balance. You will be asked to describe the method you developed to solve this problem.

Given: density of water = 1.00 $g \cdot mL^{-1}$
density of alcohol solution = 0.85 $g \cdot mL^{-1}$

Lab Problem 2

Design and carry out an experiment to determine the specific identity of the compound in each of eight numbered vials. Each vial contains one of these ionic compounds.

$BaCl_2$, $CaCO_3$, $Ca(OH)_2$, KI, NaCl, $NaHCO_3$, Na_2SO_4, $Pb(NO_3)_2$

In addition to the equipment you will find at your lab station, you may use distilled water. You also have the option of choosing ***ONE*** additional reagent from this list. You may do this either before or during your experimentation.

6 M H_2SO_4, 6 M HCl, 6 M NaOH, phenolphthalein indicator solution

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

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 is the density of the plastic object? Show your methods clearly.

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:**

When you wish to request the optional reagent, return to the Examiner with this sheet.

I request this additional reagent: _____	**Examiner's Initials:**

2. Record your data and other observations.

2. Record your data and other observations. (continued)

3. Identify the substance in each numbered vial, giving a brief justification for that choice.

Vial #	Contains	Justification
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

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NATIONAL EXAM—PART III

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Examiner's Directions

Thank you for administering the 2001 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.

One of this year's problems uses this type of plastic screw anchor as the object being investigated.

> Show the type of plastic screw anchors being used at your site. (See picture on page 3 of these instructions for approximate size of the anchors.)

Another of this year's problems uses 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 and reaction plates.

> Show a 1-mL, 3-mL, or a 5-mL Beral-type pipet, and show a 6-well or a 12-well reaction plate. (If your testing site has substituted 50-mL or 100-mL beakers, show those instead.)

*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 may **not** be used 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.*

*In the second problem, you have the option of choosing **ONE** additional reagent, either **before** or **during** your experimentation. Again, when you are ready to make this choice, please **write** the formula*

*of the reagent being requested on your report sheet, and 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
Box 340979
Clemson, SC 29634-0979

Wednesday, April 25, 2001 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

Note: Students will ***NOT*** be allowed to use a balance for this lab problem. Be sure none are available in the testing area or secure them so they may not be used.

Each student will need:

2 10-mL graduated cylinders

2 small beakers (100 mL or 250 mL)
one labeled "water", one labeled "alcohol solution"

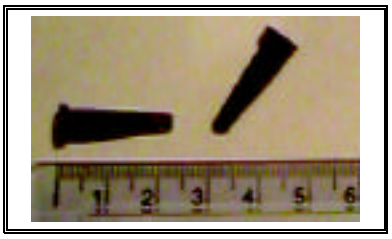
2 1-mL Beral-style pipets (Eye droppers may be substituted.)

4 to 6 test tubes, 13 x 100 mm or larger

1 test tube rack

1 250-mL squeeze bottle, labeled "distilled water" or "deionized water"

2 plastic screw anchors (Check your local hardware store for No. 8-10 x 7/8". These are 2 cm long with a maximum diameter of approximately 0.5 cm. Other sizes varying from No. 4-6 to 10-12 may be used but be sure to check that these sizes fit easily into the test tubes being used.)



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

250 mL of distilled or deionized water

250 mL of 70% isopropyl alcohol

Note: This is sold as "rubbing alcohol" in most stores or pharmacies. You may wish to provide each student with an unopened bottle to emphasize the use of a consumer product. Choose the cheapest brand and check there are no additives such as dyes or perfumes that will change the density. Do ***not*** purchase 91% or 99% isopropyl alcohol; these are often available as well. A less desirable alternative, one that does not emphasize the use of a consumer chemical, is to prepare a 70% by volume solution from pure isopropyl alcohol and water, and provide the solution in a 250-mL labeled squeeze bottle.

Quick Check to be sure lab problem #1 will work for your examinees:

1) Does the screw anchor ***fit*** into the size test tubes being provided?

2) Does the screw anchor ***float*** in water, and ***sink*** in the alcohol solution?

3) Have you planned to ***prevent access to all balances*** in the working area?

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:**

8 numbered small vials with tops (30-mL plastic vials work well)
1 100-mL or larger wash bottle, labeled "distilled water" or "tap water"
1 24-well reaction plate or 2 12-well plates. If reaction plates cannot be obtained or borrowed, 6 50-mL or 100-mL beakers can be substituted.
stirring sticks such as wooden or plastic toothpicks, or coffee stirers
8 1-mL Beral-style pipets, cut to use as scoops (or 8 small spatulas or scoops)
2 1-mL Beral-style pipets (Eye droppers may be substituted.)
1 1-mL Beral-style pipet with label (This will contain 6 M H_2SO_4, 6 M HCl, 6 M NaOH, or phenolphthalein indicator solution)
1 container designated for disposal of heavy metal waste of Pb^{2+} and Ba^{2+}
supply of paper towels
1 pair safety goggles
1 lab coat or apron (optional)

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

1 set of filled, numbered vials. Each numbered vial will contain about 1 g of one of these dry solids.

Note: This is the order for filling the numbered vials. ***Please keep this list secure***.

1. NaCl
2. $CaCO_3$
3. Na_2SO_4
4. $BaCl_2$
5. $NaHCO_3$
6. $Ca(OH)_2$
7. $Pb(NO_3)_2$
8. KI

Please have available 100 mL of each of these reagents: 6 M H_2SO_4, 6 M HCl, 6 M NaOH, and phenolphthalein indicator solution. Students will be asked to choose ***ONE*** of these reagents for use with lab problem #2, either before starting experimentation or during their work. You may find it convenient to pre-fill a set of labeled Beral-style pipets for each student but they must ***not*** be supplied at the lab station.

Supply of distilled water, if available; deionized water may also be used

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

1) Are all the solids ***dry***?

2) $CaCO_3$ needs to be provided in ***powdered form***, not as marble chips that are sometimes used.

3) Are you prepared to ***dispense*** H_2SO_4, HCl, NaOH, or phenolphthalein indicator solution quickly and safely when the students have made their choice?

4) Are you prepared to ***collect*** all solutions containing Pb^{2+} and Ba^{2+} metal ions?

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. The examiner also will need to initial each student's choice of additional reagent.

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.

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Lab Problem 1

Either of two general plans might be used to solve this problem. Multiple trials are expected for either plan used.

Plan A: Make a solution of water and alcohol in which the object is suspended. Using the measured volumes of the water and alcohol, and their given densities, the density of the solution can be found. The density of the solution and the object will be the same.

Plan A Sample Data:	**Trial #1**	**Trial #2**
Volume water to suspend object	2.21 mL	2.23 mL
Volume alcohol to suspend object	3.02 mL	3.03 mL

Plan A Calculations:

$$\text{Mass of solution} = \left(V_{H_2O} \times \text{density}_{H_2O}\right) + \left(V_{\text{alcohol}} \times \text{density}_{\text{alcohol}}\right)$$

$$\text{Volume of solution} = \left(V_{H_2O}\right) + \left(V_{\text{alcohol}}\right) \text{ (assuming volumes are additive)}$$

$$\text{Density of solution} = \frac{\text{Mass of solution}}{\text{Volume of solution}}$$

Plan A Sample Results:	**Trial #1**	**Trial #2**
Mass of solution (g)	4.78	4.81
Volume of solution (mL)	5.23	5.26
Density of solution (g/mL)	0.91	0.91

Plan B: Using Archimedes' principle, determine the volume of the object by displacing the alcohol. Determine the mass of the object by displacing water, and multiplying the volume of the water displaced by the density of water. Determine the density of the object by dividing the mass of the object by its volume.

Plan B Sample Data:	**Trial #1**	**Trial #2**
Initial volume water	5.02 mL	5.14 mL
Final volume water	5.83 mL	5.94 mL
Initial volume alcohol	6.01 mL	6.02 mL
Final volume alcohol	6.88 mL	6.89 mL

Plan B Calculations:

$$\text{Mass of object} = V_{H_2O \text{ displaced}} \times \text{density}_{H_2O}$$

$$\text{Density of object} = \frac{\text{Mass of object}}{\text{Volume of object}}$$

Plan B Sample Results:	**Trial #1**	**Trial #2**
Mass of object (g)	0.81	0.80
Volume of object (mL)	0.87	0.87
Density of object (g/mL)	0.93	0.92

Conclusion: The determined density should be between 0.85 g/mL and 1.00 g/mL, because the object sinks in alcohol and floats in water. The density determination must be supported by data gathered and calculations performed.

Lab Problem 2

Credit was awarded for alternate, logical pathways that achieved identification of the compounds. The identifications depend on developing a logical sequence of tests that will lead to the identifications. Some type of tabular form organizes the data for clear presentation, even if a formal flow chart is not included.

Sample Plan: Many students started by adding water to each compound. Most often, H_2SO_4 was chosen as the extra reagent Those tests were followed by adding selected solutions of the unknown to each other to help with identification.

Sample Data:

FIRST TESTS	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**
H_2O	sol	insol	sol	sol	sol	insol	sol	sol
H_2SO_4	no rxn	dissolves, bubbles	no rxn	white ppt	bubbles	dissolves	white ppt	yellow

The first set of tests allows identification of **#2** as $CaCO_3$, **#5** as $NaHCO_3$, and **#6** as $Ca(OH)_2$.

SECOND TESTS	**#1**	**#3**	**#4**	**#7**	**#8**
#1	**–**	no rxn	no rxn	white ppt	no rxn
#3		–	white ppt	white ppt	no rxn
#4			–	white ppt	no rxn
#7				–	yellow ppt
#8					**–**

The second set of tests allows identification of **#1** as NaCl, **#7** as $Pb(NO_3)_2$, and **#8** as KI. There is still ambiguity about #3 and #4 at this point.

THIRD TESTS	**#3**	**#4**
H_2SO_4	no rxn	white ppt

The third set of tests allows identification of **#3** as Na_2SO_4 and **#4** as $BaCl_2$.

Conclusion:

Identification	**Substance**	**Supporting Evidence**
#1	**NaCl**	Second tests: forms a white precipitate with #7, $Pb(NO_3)_2$
#2	**$CaCO_3$**	First tests: insoluble in water, dissolves and bubbles in acid
#3	**Na_2SO_4**	Third tests: no reaction with H_2SO_4
#4	**$BaCl_2$**	Third tests: white precipitate forms
#5	**$NaHCO_3$**	First tests: soluble in water, dissolves and bubbles in acid
#6	**$Ca(OH)_2$**	First tests: insoluble in water, dissolves in acid
#7	**$Pb(NO_3)_2$**	Second tests: forms three white precipitates and one yellow precipitate
#8	**KI**	Second tests: forms one yellow precipitate