2009 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.

2009 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

You have been given six numbered pipets containing 0.50M solutions of the sodium salts Na_2CO_3, $NaHCO_3$, $NaHSO_3$, NaH_2PO_4, Na_2HPO_4, Na_3PO_4, not necessarily in this order, a 50-mL beaker containing 0.40M HCl, and a pipet containing methyl orange indicator. Devise and carry out an experiment to determine to contents of each pipet, providing both *qualitative* and *quantitative* data to justify your conclusions.

Lab Problem 2

You have been given a thermometer, styrofoam cup with lid, a beaker, a graduated cylinder, and access to room temperature water, heated water and ice cubes. Using these materials, design and carry out an experiment to determine the heat of fusion, H_f, for water.

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.

(data and observations – continued)

3. Based on your observations, write the relevant equations that led to your conclusions:

4. Conclusions

Pipet #	**Contents**	**Justification**

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. Calculations and Conclusions.

4. Conclusions: The H_f for water is: _____________

5. Sources of Error in this experiment (please number)

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Examiner's Instructions

Directions to the Examiner:

Thank you for administering the 2009 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 hints whatsoever to the students once they begin work. As in the international competition, the students are not 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. National Chemistry Olympiad 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 its results. Do not touch any of the equipment in front of you until you are instructed to do so.

You will be asked to complete two laboratory problems. Students are to work alone. All the materials and equipment you may want to use to solve each problem has been set out for you and is grouped by the number of the problem. Students can use all materials for both lab problems, but each experiment is designed to work best with equipment and materials provided specifically for each lab problem. You will have ***one hour and thirty minutes*** *to complete the* ***two problems****. 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, raise your hand.*

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. There is a periodic table and constants on the last 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. There is a periodic table on the last page of the booklet. 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 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** in the UPS return envelope you were provided to this address:

ACS DivCHED Exams Institute Department of Chemistry Iowa State University0213 Gilman Hall Ames, IA 50011

The label on the envelope should have this address already, you will need only to include your return address and call United Parcel Service -UPS (1-800-742-5877) for it to be picked up (or it can be dropped in a UPS collection box). The cost of shipping will be billed to the Exams Institute. You can write down the tracking number on the label to allow you to track your shipment.

Wednesday, April 29, 2009, is the ***absolute*** deadline for ***receipt*** of the exam materials at the Examinations Institute. Materials received after this deadline CANNOT be graded. Be sure to have your envelope picked up no later than April 28, 2009 for it to arrive on time.

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

Examiner's List: 2009 USNCO Lab Practical Equipment and Chemicals

USNCO 2009 PART III: EXAMINER'S NOTES

Lab Problem #1: Materials and Equipment

Lab Problem #1 Each *student will have:*

Materials

- Six Beral-style pipets to be filled with the unknown sodium salts.
- One 150-mL or 250-mL beaker for holding the six pipets containing the unknown solutions.
- A twelve-hole clear well plate
- Several toothpicks for stirring
- Two empty Beral-style pipets
- One Beral-style pipet to be filled with methyl orange indicator.
- Access to sink and running tap water.

Chemicals

- Six filled Beral-style transfer pipets each containing 0.50M solution of the following sodium salts: Na_2CO_3, $NaHCO_3$, $NaHSO_3$, NaH_2PO_4, Na_2HPO_4, Na_3PO_4

IMPORTANT: Use this key to number the pipets:

	Na_3PO_4	$NaHSO_3$	Na_2CO_3	NaH_2PO_4	$NaHCO_3$	Na_2HPO_4
Vial	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**

- A single Beral-style transfer pipet of methyl orange indicator, filled and labeled 'methyl orange'. Methyl Orange Indicator: 0.1% aqueous solution.
- Approximately 20-30 mL of 0.40M HCl, in a 50-mL beaker labeled '0.40M HCl'.

Notes to Coordinators

- Place the numbered pipets upside down in the small beaker at the student's desk.
- Make sure the solutions are freshly made (especially the $NaHSO_3$ solution) prior to the lab.
- Obviously, do NOT label the pipets with the chemical formulas.

Lab Problem #2 *Each student will have:*

Materials

- One Celsius thermometer (-20 °C to 100 °C range is sufficient)

- One standard size (8 oz.) styrofoam cup with tight-fitting lid.

- One 25-mL graduated cylinder

- One 250-mL beaker

Chemicals

- Access to tap water, ice cubes, and hot water.

Notes to Coordinators

- Make sure that students can easily access the ice cubes and hot water. Ideally, they can obtain each and return to their work areas using their 250-mL beakers. The hot water should be heated to approximately 60-70 °C.

- Students might inquire about the need for an electronic balance to determine the mass of the water, but assuming that the density of water is 1 g/mL eliminates the need for determining masses here. Do NOT tell students this – it is for them to figure out.

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.

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 examination site. Please check and follow procedures appropriate for your site.

Lab Problem #1

Key:

	Na_3PO_4	$NaHSO_3$	Na_2CO_3	NaH_2PO_4	$NaHCO_3$	Na_2HPO_4
Vial	#1	#2	#3	#4	#5	#6

This problem tests students' understanding of acids and bases, titration, differentiation of mono-protic, di-protic, and tri-protic acids in titration, and some qualitative observations in acid-base neutralization.

A sample data table quantifying the HCl added might look like this:

sample	# drops HCl	Justifications / Observations
Na_3PO_4	33	No bubbles, color Δ from red to orange-yellow
Na_2HPO_4	18	No bubbles, color Δ from red to orange-yellow
NaH_2PO_4	1	No bubbles, color Δ from red to orange -yellow
$NaHSO_3$	8	Sharp, biting odor, very slight bubbling
$NaHCO_3$	15	Bubbles, red to orange-yellow color change
Na_2CO_3	29	Bubbles, red to orange-yellow color change

Excellent Student Results:

- Student presented an organized plan to add a fixed number of drops of each of the unknowns, a fixed number of drops of the methyl orange indicator to each unknown, and then add HCl drop wise until a color change occurs. Student planned to note the color changes, drops added, and a detectable odor for the sulfite ______ solution.
- Student showed a carefully constructed data table OR written account of data collected including all color changes, number of drops added to reach color changes, extent of bubbling including size of bubbles, and odor produced. Multiple trials were performed.
- Student included each of the six ionic equations that correlated to the reactions performed from data table, correctly indicating ion charges, states symbols, and stoichiometric relationship.
- Student correctly identified each of the six unknowns and gave justifications that were consistent with the data taken in this experiment.

Average Student Results:

- Student presented a plan but might not have indicated the odor to identify the sulfite or was not clear about how to distinguish the bisulfite from the sulfite.
- Student might have written most of the equations correctly but neglected to include ion charges or states symbols. One trial was performed.
- Most of the identifications were correct; most of the justifications were valid.

Below Average Student Results:

- Student did not connect the procedure with the conclusions. Plan was vague or unclear about how the added HCl would be used to conclude unknowns. Plan was difficult to follow.
- Data was unorganized or difficult to follow.

- Student neglected to include or incorrectly wrote chemical equations.
- A majority of the unknowns were incorrectly identified.

Notes: The sulfite solution should have been made fresh. Bisulfite is easily oxidized in water and older solutions that were used take little or no acid added to cause the color change and distinguishing odor.

Lab Problem # *2*

This is a calorimetry problem. The novelty in this question was the intended lack of access to a balance. Students were to make assumptions about the mass of ice based on measured volumes of water prior to adding ice, and the final volume after the ice had been added. Students also had to account for the heat required to increase the temperature of the cold water from the melted ice.

Conservation of energy applies such that *q*(ice) + *q*(cold water) = *q*(hot water). Once the ice begins to melt (don't spill, and put the cap on quickly to minimize heat loss) in the calorimetry cup, the hot water becomes colder. Since you don't end at 0 ^{o}C, the equation breaks into:

$[m_{ice} \times H_{fus}] + [m_{ice\text{-}water} \times C_p \times T_{final - initial}] = [m_{hot\ water} \times C_p \times T_{final - initial}]$.

Then solve for H_{fus}

Below are sample student data:

$10.0\ g_{ice}\ H_{fus} + 10.0\ g_{ice\text{-}water}\ (4.184)\ 27.0 - 0.0) = -[\ 100 g_{hotwater}\ (4.184)\ (27.0 - 40.0)$

$10.0\ g_{ice}\ H_{fus} + 1130\ J = 5440\ J$

$10.0\ g_{ice}\ H_{fus} = 4310\ J$

$H_{fus} = 431$ J/g, about a 30% error based on 334 J/g as a correct value.

The question did not specify the units for the reported answer. Other acceptable values include: 80.0 cal/g, 6.01 J/mol, 1440 cal/mol, 6.01 kJ/mol, or 1.44 kcal/mol.

Excellent Student Results:

- Student included initial and final temperatures, determined quantity of ice used, water used, carried out replicate determinations. The coffee cup/lid were constructed as a calorimeter in this experiment.
- Data and calculations clearly used the overall heat lost-heat gained equations.
- Students provided a cogent discussion of the major sources of error such as heat lost or gained by the system, inaccuracies of the measuring equipment used.

Average Student Results

- Student did not perform multiple determinations.
- Student *did* perform more than one trial, but averaged observations rather than results.
- Student might have neglected the heating of the water from the melted ice to the T_{final} in their calculations.

Below Average Student Results

- Student neglected to provide any measure (volume or converted mass) for ice used.
- Student did not clearly use the heat lost-heat gained equation to solve for heat of fusion.
- Student did not provide 'heat loss' or uncertainty in temperature measurement as sources of error, or provided frivolous sources such as 'spilled water'.