2013 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART III

Prepared by the American Chemical Society 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 may carry out the two tasks in any order they wish and move directly from one to the other within the allotted time. Each procedure must be approved for safety by the examiner before the student begins that procedure.

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

Students should be permitted to use **non-programmable** scientific 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.

2013 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

One way of using solar energy is to capture heat from the sun in a reservoir to be released later. You have been provided with about 10 g of each of two different metals and several pieces of laboratory equipment.

Devise and carry out a procedure to determine the specific heat capacity of each metal and use these values to calculate the mass of each metal that would be needed to capture 5.00 kilojoules of thermal energy with a 1.0 °C temperature increase.

Lab Problem 2

You have been given six colorless aqueous solutions labeled A - F and various pieces of laboratory equipment. The combination of the correct two solutions will produce a yellow color, which will turn blue when the correct third solution is added. Finally the addition of the correct fourth solution will turn the mixture colorless again. Two of the solutions will have no effect no matter when they are added.

Devise and carry out a procedure that will yield these colors in the order specified. You should keep detailed notes so that you can specify the identity and quantity of each solution needed to produce the specified changes.

Answer Sheet for Laboratory Practical **Problem 1**

Student's Name: _____

Student's School: _____ **Date:** _____

Proctor's Name: _____

ACS Local Section Name: _____ **Student's USNCO ID #:** _____

1. Give a brief description of your experimental plan.

2. Data and Observations.

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

3. Calculations.

4. Analysis and Conclusions.

Answer Sheet for Laboratory Practical **Problem 2**

Student's Name: _____

Student's School: _____ **Date:** _____

Proctor's Name: _____

ACS Local Section Name: _____ **Student's USNCO ID #:** _____

1. Give a brief description of your experimental plan.

2. Data and Observations.

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

3. Analysis and Conclusions.

Solutions mixed to produce the yellow color _____

Solution added to produce the blue solution _____

Solution added to turn blue solution colorless _____

4. Use your chemical knowledge to answer the following questions:

a. Identify a substance that could undergo the change from colorless to yellow and then to blue.

_____

b. What type of reaction is illustrated by this activity? _____

ABBREVIATIONS AND SYMBOLS					
amount of substance	n	Faraday constant	F	molar mass	M
ampere	A	free energy	G	mole	mol
atmosphere	atm	frequency	ν	Planck's constant	h
atomic mass unit	u	gas constant	R	pressure	P
Avogadro constant	N_A	gram	g	rate constant	k
Celsius temperature	°C	hour	h	reaction quotient	Q
centi– prefix	c	joule	J	second	s
coulomb	C	kelvin	K	speed of light	c
density	d	kilo– prefix	k	temperature, K	T
electromotive force	E	liter	L	time	t
energy of activation	E_a	measure of pressure	mm Hg	vapor pressure	VP
enthalpy	H	milli– prefix	m	volt	V
entropy	S	molal	m	volume	V
equilibrium constant	K	molar	M		

CONSTANTS

$R = 8.314\ \text{J•mol}^{-1}\text{•K}^{-1}$

$R = 0.0821\ \text{L•atm•mol}^{-1}\text{•K}^{-1}$

$1\ F = 96{,}500\ \text{C•mol}^{-1}$

$1\ F = 96{,}500\ \text{J•V}^{-1}\text{•mol}^{-1}$

$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$h = 6.626 \times 10^{-34}\ \text{J•s}$

$c = 2.998 \times 10^{8}\ \text{m•s}^{-1}$

$0\ ^\circ\text{C} = 273.15\ \text{K}$

$1.00\ \text{atm} = 760\ \text{mm Hg}$

EQUATIONS

$$E = E^\circ - \frac{RT}{nF}\ln Q \qquad \ln K = \left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T}\right) + \text{constant} \qquad \ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

PERIODIC TABLE OF THE ELEMENTS

1 1A																	18 8A
1 **H** 1.008	2 **2A**											13 **3A**	14 **4A**	15 **5A**	16 **6A**	17 **7A**	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3 **3B**	4 **4B**	5 **5B**	6 **6B**	7 **7B**	8 **8B**	9 **8B**	10 **8B**	11 **1B**	12 **2B**	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.8	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (281)	111 **Rg** (272)	112 **Cn** (285)	113 (Uut) (284)	114 (Uuq) (289)	115 (Uup) (288)	116 (Uuh) (293)	117 (Uus) (294)	118 (Uuo) (294)

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** 231.0	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

AMERICAN CHEMICAL SOCIETY

U.S. National Chemistry Olympiad

2013 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART III — EXAMINER'S INSTRUCTIONS

Prepared by the American Chemical Society Chemistry Olympiad Laboratory Practical Task Force

Directions to the Examiner:

Thank you for administering the 2013 USNCO laboratory practical on behalf of your Local Section. It is essential that you follow the instructions provided, in order to ensure 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 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.

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.

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. 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. You may use equipment from one problem to work on the other problem, but the suggested ideal equipment and chemicals to be used for each problem has been grouped for you. 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, please raise your hand.*

*Safety is an important consideration during the lab practical. **You must wear goggles at all times.** Please 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 they 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 to fill out all of the information at the top of the answer sheets. Are they 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 portion of the exam.

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 might wish to take a few 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 USNCO subcommittee as they prepare for 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 Next Day return envelope you were provided to this address:

American Chemical Society
U.S. National Chemistry Olympiad
1155 16th Street, NW – Room 831D
Washington, DC 20036

The label on the UPS Express Pak envelope should have this address and your return address already. The cost of the shipping is billed to ACS USNCO. You can keep a copy of the tracking number to allow you to track your shipment.

Wednesday, April 17, 2013, is the ***absolute*** deadline for ***receipt*** of the exam material. Materials received after this deadline **CANNOT** be graded. Be sure to have your envelope sent no later than ***Tuesday, April 16, 2013*** for it to arrive on time.

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

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 POTENTIAL UNSAFE PRACTICES.

Lab Problem #1: Materials and Equipment

Each student should have available the following equipment and materials:

Materials

- 25 mL Graduated cylinder (1 mL graduations)
- 3 – 25 × 150 mm Test tubes
- Styrofoam coffee cup calorimeter
- Thermometer (1 °C divisions) (Only – Celsius, glass, alcohol, at least 0 – 100 °C range)
- Access to balance weighing to 1 mg
- Access to boiling water bath (hot plate, 400 mL beaker) – See note below.
- Access to deionized water
- 1 set – Test tube tongs

Chemicals

- About 10 g of Al shot (provided by ACS) **Label as Al**. Dispense material in a small Ziploc plastic bag or small beaker.

- About 10 g of Cu shot (provided by ACS) **Label as Cu**. Dispense material in a small Ziploc plastic bag or small beaker.

Note:

Share Hot Plates. We recognize that individual hot plates may be impractical for larger sections. If this is the case, it is recommended that students share hot plates in the following way: each hot plate would have 3–4 400 mL beakers on it to serve as boiling water baths. Each beaker should be labeled with the student's USNCO I.D. # for their personal use. On the day of the exam, you will have to make it clear to the students that although the hot plates will be shared; they each have their own hot water bath to use.

Lab Problem #2: Materials and Equipment

Each student should have available the following equipment and materials:

Materials:

- 8 – Beral pipets (Do not use JUMBO or MICRO-PIPETS)
- Stirrers – e.g., a dozen simple wooden toothpicks
- 1 – 24 Well-plate

Chemicals:

- 6 – Capped vials, 5 mL of each solution

THE CONTENTS OF THE VIALS MUST BE AS GIVEN BELOW AND VIALS SHOULD BE LABELED A, B, C, D, E, F BUT THE CHEMICAL CONTENTS OF EACH SHOULD NOT BE GIVEN.

A. Deionized H_2O
B. 1% Soluble starch – See note below.
C. 1M Sodium thiosulfate ($Na_2S_2O_3$)
D. 0.2 M Potassium iodide (KI)
E. Deionized H_2O
F. 3% Hydrogen peroxide (H_2O_2)

Notes:

The identity of the chemicals used in this exercise should NOT be revealed to the participants in any way. The vials should be labeled ONLY with the letters A - F with the contents of each as specified above.

1% Soluble starch preparation (Flinn Scientific Catalog/Reference Manual)
Prepare a 1% starch solution by first making a smooth paste with 10 g of soluble (potato) starch and 100 mL of distilled or deionized water. Pour the starch paste into 1 L of boiling water while stirring. Stir until dissolved and the solution is clear.
Allow the solution to cool to room temperature before use. Starch solutions have a poor shelf life and will form mold if kept too long. Fresh solutions work best. Use within one or two months.

3% Hydrogen peroxide (H_2O_2) can be bought from a store, because the H_2O_2 may lose strength if has been on the store shelf for a long time (or is stored near a heat source) it is recommended to make sure that the H_2O_2 to be used gives a yellow color with the KI solution.

Safety Instructions for Lab Problem #1 and #2:

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.

If you have any questions regarding Part III, please contact USNCO office immediately at USNCO@acs.org.

2013 USNCO Part III Key

Lab Problem 1

Plan 3 points
Data 8 points
- Mass of metal (1 pt.)
- Mass of H_2O (1 pt.)
- Units (labels) (1 pt.)
- Temperatures (1 pt.) (initial metal, initial H_2O, final)
- Duplicates (1 pt.)
- Organized table (1 pt.)
- Quality (2 pts.)
  (instruments used appropriately, mass H_2O vs. volume)

Calculations 6 points
- Specific heat of H_2O (1 pt.)
- Correct equation (2 pts.)
- Correct substitution (2 pts.)
- Solution (1 pt.)

Analysis 8 points
- Answers to questions posed in lab (2 pts.)
- Calculation of mass required to absorb 5000 J (4 pts.)
- Error analysis (2 pts.)
  (identification of error and its impact on the answer)

Lab Problem 2

Plan 3 points
Data and Observations 12 points
Matrix set-up

A	B	C	D	E	F
B	--------				
C		----------			
D			----------		
E				---------	
F					----------

D + F yellow solution / bubbles
+ B blue
+ C colorless
-2 for each miss-observation
-2 for not completing table

Analysis and Conclusions 8 points

solutions to produce yellow color	D + F	(2 + 2)
solution added to produce blue color	B	(2)
solution to turn colorless	C	(2)
comments about precipitate formation		(-2)

Questions

Substance that could change from colorless to yellow to blue - iodine (1 pt.)

Reaction type - redox (1 pt.)