2014 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. **Cell phones and cameras should not be allowed during the exam.**

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 examination site.

2014 UNITED STATES NATIONAL CHEMISTRY OLY
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

A box of food coloring, available from a grocery store, contains one small bottle each of the color red, yellow, blue, and green. You have been given two vials, one containing some green food coloring and the other a mixture of the blue and the yellow.

Devise and carry out a procedure to determine:

1) ***Which solvent-paper combination gives the best separation of the dyes present in the mixture of the blue and yellow food coloring, and***
2) ***Which dye(s) is (are) present in both the mixture of the blue and yellow food coloring and in the green food coloring.***

Lab Problem 2

A bottle of acetic acid of unknown molarity is found in a chemical storeroom. The determination of the concentration of this acid has been assigned to you. You find some standardized sodium hydroxide solution, but there are no indicators in the storeroom. Just before giving up, you remember that you brought grape juice to drink with your lunch today. In addition to a number of other organic compounds, red and purple grapes contain multiple anthocyanins, naturally occurring compounds which can act as acid-base indicators.

Devise and carry out a procedure to determine the concentration of the acetic acid. You should keep detailed notes of your data and observations, and show all your calculations.

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. Record your data and observations.

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

3. Which solvent-paper combination gives the best separation?

4. Which dye(s) is (are) present in both a mixture of blue and yellow food coloring and in the green food coloring?

5. Provide the order in which the colors are separated with the brown paper-salt water combination. Compare that order with the order of the white paper-salt water combination. Describe a possible explanation for the difference.

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. Record your data and observations.

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

3. Show all calculations.

4. The concentration of the acetic acid = _________*M*.

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 °C = 273.15 K

1 atm = 760 mm Hg

EQUATIONS

$$E = E^{\circ} - \frac{RT}{nF}\ln Q$$

$$\ln K = \left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T}\right) + \text{constant}$$

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

PERIODIC TABLE OF THE ELEMENTS

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.008																	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											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** (271)	107 **Bh** (270)	108 **Hs** (277)	109 **Mt** (276)	110 **Ds** (281)	111 **Rg** (280)	112 **Cn** (285)	113 (Uut) (284)	114 **Fl** (289)	115 (Uup) (288)	116 **Lv** (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

Laboratory Practical Problem 1

Characteristics of Excellent Student Responses for Lab Practical **Problem 1:**

1. Experimental Plan

   An *average* response indicated that the experiment relied on paper chromatography. It gave a plan for using all six combinations (2 types of paper × 3 eluents) on the mixture of blue and yellow food coloring, then using the most effective combination to analyze the green food coloring. (Using all six combinations on each of the two types of food coloring was also reasonable.)

   An *excellent* response gave more details about the mechanics of paper chromatography, for example by drawing a sketch of the proposed setup.

2. Data and Observations

   An *average* response clearly linked sets of observations with particular conditions (eluent, paper, food coloring sample), usually in the form of a table or tables. The degree of separation was described in qualitative terms, and included the color of the spots ("blue faster than yellow"). A difference in the order of elution, with blue dye eluting faster than yellow on white paper but yellow faster than blue was observed.

   An *excellent* response described the observations both qualitatively and quantitatively (by R_f or by a quantitatively accurate sketch of the chromatogram). The presence of a red spot in the blue/yellow mixture was noted.

3. Best separation

   The white paper/salt water combination worked best.

4. Dyes in common between the samples

   An *average* response noted that blue and yellow dyes were present in both samples. An *excellent* response made the comparison with respect to elution rates (i.e., R_f values) as well as colors. A *poor* response alluded to the presence of a green dye (no green dye was present in any of the samples, but overlap between spots might produce the appearance of a green smear).

4. Changing elution order and its explanation

   An *average* response noted the inversion of order mentioned in (2) and attributed to different affinities of the dyes for the surfaces of the brown vs. white paper. An *excellent* response was concrete in connecting the change in affinity to the difference in elution times, e.g., that the greater affinity of the brown paper for the blue dye made the blue dye run more slowly on the brown paper. It might also have mentioned possible reasons for the change in affinity, e.g. different hydrophilicity of the paper surfaces. A *poor* response attributed differences to factors unrelated to paper chromatographic separation (e.g., the molecular weights of the dyes).

Laboratory Practical Problem 2

Characteristics of Excellent Student Responses for Lab Practical **Problem 2**:

1. Experimental Plan

   a. Statement that this was a titration task.
   b. Plan to use volumes of acetic acid solution, standardized NaOH solution, and grape juice indicator that seem reasonable for a titration analysis.
   c. Specific equipment used is properly described (e.g.: a 10 mL graduated cylinder).

2. Data and Observations

   a. The observation of the color of the grape juice in acidic and basic solution.
   b. At least two titration trials performed, with the final result for the molarity of the acetic acid determined by averaging the results of multiple trials.
   c. If drops were counted as part of the titration analysis, a description of how the drop count was converted into volume (if needed for the calculations) was provided.
   d. A data table, rather than a series of sentences that included data, was created that was easy to read and included units.
   e. All data required for the calculations was neatly and clearly provided. This likely included the volume of acetic acid solution used, the volume of NaOH solution used, the number of drops of grape juice used as indicator.

3. Show all calculations

   a. Student clearly indicates, either in words or by a balanced chemical equation, or as shown in the calculations, that there is a 1:1 mole:mole ratio between the moles of acetic acid and moles of sodium hydroxide reacting.
   b. Calculation of acetic acid concentration from each trial and then averaging, OR calculation of concentration from average volume of titrant used. For example: $M_A V_A = M_B V_B$ (since acetic acid and NaOH react in a 1:1 mole ratio)
   $M_A = M_B V_B / V_A$ (volumes need not be converted to L; just must both be expressed in the same unit, e.g., mL)
   Alternatively, something similar to the following (based on avg. volume; will vary based on volume of acetic acid used):

   $$8.4 \text{ mL NaOH} \times \frac{1 \text{ L NaOH}}{1000 \text{ mL NaOH}} \times \frac{0.501 \text{ mol NaOH}}{1 \text{ L NaOH}} = 4.2 \times 10^{-3} \text{ mol NaOH}$$

   $$4.2 \times 10^{-3} \text{ mol NaOH} \times \frac{1 \text{ mol HOAc}}{1 \text{ mol NaOH}} = 4.2 \times 10^{-3} \text{ mol HOAc}$$ (may not be shown explicitly)

   $$\frac{4.2 \times 10^{-3} \text{ mol HOAc}}{0.00500 \text{ L HOAc used}} = \underline{0.84}\, M$$ (steps may be shown & calc. as one sequence)

   c. The calculated value for the molarity of acetic acid fell within an acceptable range that was established by the grading team.

   d. The calculations were neatly done, easy to follow, and included appropriate units.

   e. The student chose to include a statement or statements of likely sources of error in the titration work.