ACS Chemistry for Life®

STUDENT USNCO ID:

2018 U. S. NATIONAL CHEMISTRY OLYMPIAD
NATIONAL EXAM PART III

Prepared by the American Chemical Society Chemistry 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 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**

A periodic table and other useful information are provided on page two for student reference.
Students should be permitted to use non-programmable calculators. The use of a programmable calculator, cell phone, watch, or any other device that can access the internet or make copies or photographs during the exam is grounds for disqualification.

Students are permitted to request one replacement or refill of a chemical during the laboratory period. Please indicate on the exam sheet the item replaced or refilled.

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.

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 J mol^{-1} K^{-1}
R = 0.08314 L bar mol^{-1} K^{-1}
F = 96,500 C mol^{-1}
F = 96,500 J V^{-1} mol^{-1}
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$h = 6.626 \times 10^{-34}$ J s
$c = 2.998 \times 10^{8}$ m s^{-1}
0 °C = 273.15 K
1 atm = 1.013 bar = 760 mm Hg
Specific heat capacity of H_2O = 4.184 J g^{-1} K^{-1}

EQUATIONS

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

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** 78.97	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** 95.95	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 **Nh** (286)	114 **Fl** (289)	115 **Mc** (289)	116 **Lv** (293)	117 **Ts** (294)	118 **Og** (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)

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, tie back long hair into a ponytail, and wear close-toed shoes 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

Ethylenediaminetetraacetic acid or EDTA forms a 1:1 complex with calcium and magnesium cations at pH 10. The indicator Eriochrome Black T forms a red colored complex with metal ions and is blue/black in their absence. Using the provided materials, devise and carry out an experiment to determine the total combined concentration of calcium and magnesium in milk.

Lab Problem 2

You are provided with two vials, each containing a different flavor of Kool-Aid® drink mix dissolved in water. Devise and carry out a procedure to rank the polarity of the artificial coloring found in both samples.

STUDENT USNCO ID:

Answer Sheet for Laboratory Practical P**roblem 1**

Student's Name: _____

Student's School:_____

Proctor's Name:_____

ACS Local Section Name:_____

1. Give a brief description of your experimental plan.

2. Record your data/observations.

For safety reasons before beginning your experiment, you must get Approval from the examiner. **Examiner's Initials:**_____

3. Show all calculations.

4. The total combined concentration in mol/L of calcium and magnesium in milk is _____.

Examiner please indicate the item replaced or refilled provided:

STUDENT USNCO ID:

Answer Sheet for Laboratory Practical **Problem 2**

Student's Name: _____

Student's School:_____

Proctor's Name:_____

ACS Local Section Name:_____

1. Give a brief description of your experimental plan.

2. Record your data and other observations.

For safety reasons, before beginning your experiment, you must get approval from the examiner **Examiner's Initials:**_____

3. How many dyes are present in each sample? Specify the number and color(s) of the dye(s) in each sample.

   Kool-Aid 1 flavor: _____(record information from label of vial)

   Kool-Aid 1 number of dye(s) and colors of the dye(s) in the sample: _____
   _____

   Kool-Aid 2 flavor: _____(record information from label of vial)

   Kool-Aid 2 number of dye(s) and colors of the dye(s) in the sample: _____
   _____

4. Does/Do the same dye(s) exist(s) in more than one sample(s) of Kool-Aid? If yes, please specify which dye(s) and the sample that contain the same dye(s).

5. Rank the dyes in order of increasing polarity

   Least polar **Most polar**

Examiner please indicate the item replaced or refilled provided:

2018 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 2018 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 and separated the materials used for both Lab Problem #1 and Problem #2, for Lab Problem #1 and for Lab Problem #2.

Students are permitted to request one replacement or refill of a chemical during the laboratory period. Please indicate on the exam sheet the item replaced or refilled.

It is your responsibility to ensure that all students wear approved eye protection at all times, tie back long hair into a ponytail, and wear close-toed shoes during this laboratory 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* 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 safety 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 page two of the booklet. Allow students enough time to read the brief cover directions.

Do not turn to page 3 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 811
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 25, 2018, 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 ***Monday, April 23, 2018*** 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.

Each student should have available the following equipment and materials:

Materials needed for Problem #1:

- One (1) graduated cylinder, 10 mL
- Three (3) Erlenmeyer flasks or beakers, 25 or 50 mL
- One (1) stirring rod
- One (1) well plate, 12- or 24-wells per plate
- Six (6) graduated Beral pipets, with 0.25 mL graduations

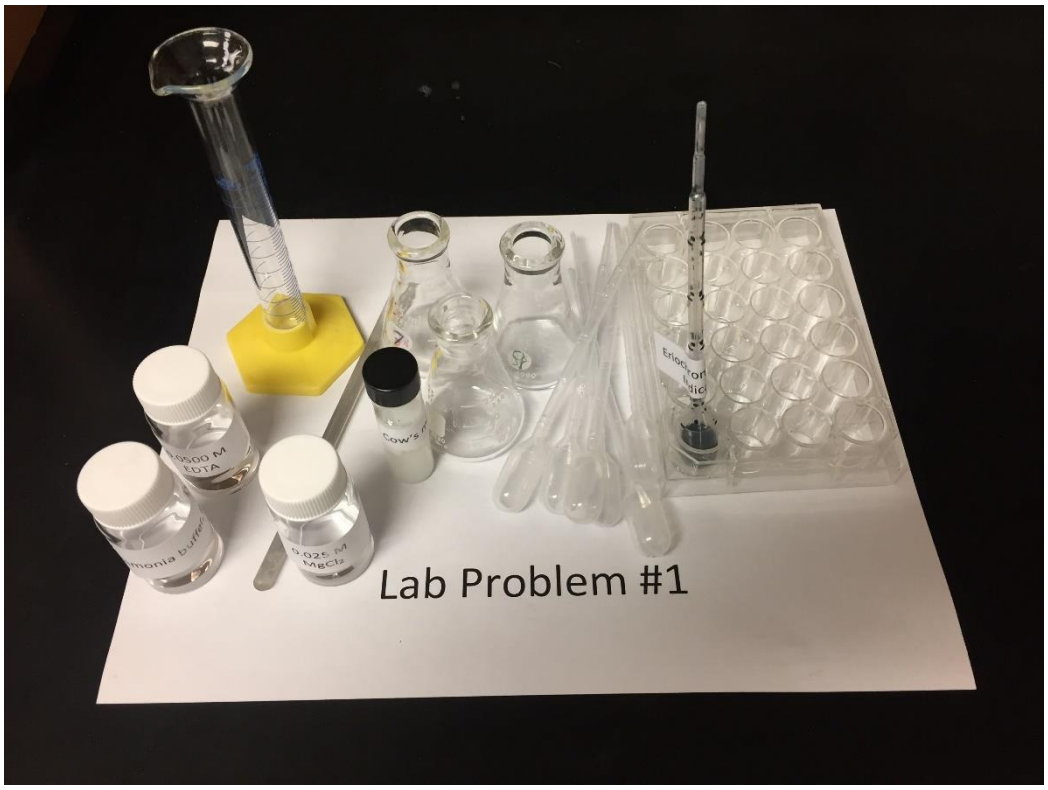
  Suggested Beral pipets are:

  - Fisherbrand catalog# 13-711-9AM
  - Samco Scientific – Thermo Fisher catalog number 212

Chemicals for Problem #1:

- 0.0500 M EDTA, 10 mL per student
  Weigh 9.306 g of disodium EDTA salt and dissolve it in enough water to make 500 mL of solution.
- Ammonia buffer, pH~10, 10 mL per student
  Dissolve 7.0 g of ammonium chloride in 57 mL of concentrated ammonia. Dilute to 100 mL with water. The pH of the buffer should be between 10 and 11.
- 0.025M $MgCl_2$ solution, 10 mL per student
  Dissolve 2.54 g of magnesium chloride hexahydrate in enough water to make 500 mL of solution.
- Eriochrome Black T indicator (made fresh), 1 mL in a Beral pipet, one (1) per student
  Dissolve 0.2 g of Eriochrome Black T indicator in 15 mL of concentrated ammonia solution and 5 mL of 95% ethanol. Do not store more than one to two days before use.
- cow's milk, skim (0% fat), 5 mL per student

Suggested Laboratory Set-up for Problem 1



Materials needed for Problem #2:

- Four (4) Beral style pipets
- Four (4) cotton swabs
- Four (4) toothpicks
- Three (3) watch glasses, large enough to cover the top of a 250 mL beaker
- Three (3) beakers, 250 mL
- One (1) graduated cylinder, 25 or 50 mL
- Twelve (12) strips, 2 cm x 10 cm, Whatman 3MM Chromatography paper (Cat No: 3030 614), in a plastic bag to keep dry

- One (1) ruler
- One (1) set of tweezers or forceps
- One (1) pencil

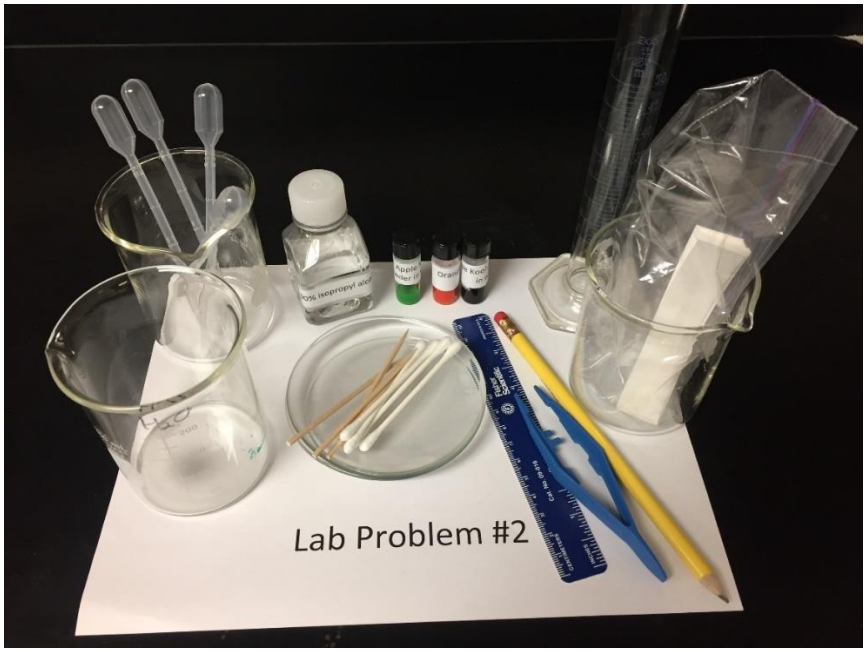
Chemicals for Problem #2:

- Isopropyl alcohol, 90%, 50 mL
- Two of the following Kool-Aid® samples should be provided to each student. Please clearly indicate on the label the flavor of the Kool-Aid®. Please do not substitute alternative flavors of Kool-Aid®.
  - Kool-Aid® green apple, powder dissolved in water no sugar added, 0.4 g/mL, 1 mL
  - Kool-Aid® orange, powder dissolved in water no sugar added, 0.4 g/mL, 1 mL
  - Kool-Aid® grape, powder dissolved in water no sugar added, 0.4 g/mL, 1 mL

Note: if left over night, a white substance settles out of solution. Upon shaking, the substance redissolves.

- 

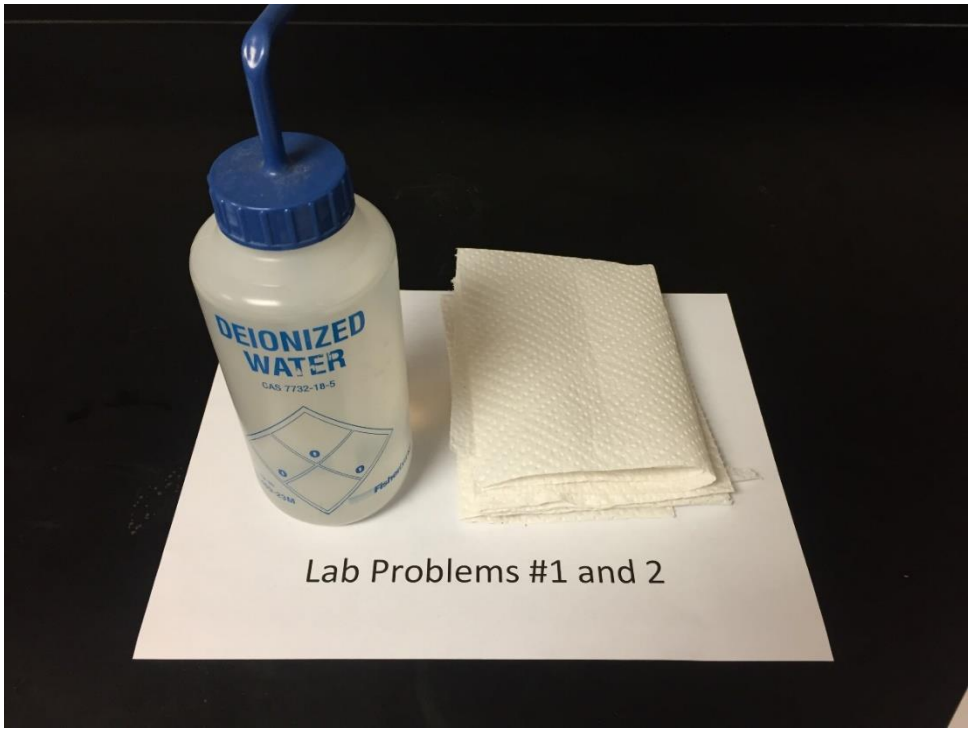
Suggested Laboratory Set-up for Problem 2



Note: the image for suggested lab set-up contains all three Kool-Aid® samples – the set-up for students will only have two (2) samples per student.

Materials for both Problem #1 and 2:

- Distilled water, at least 500 mL, in a wash bottle labelled "Distilled water"
- Access to paper towels and a sink with running water



Safety Instructions for Lab Problems #1 and #2:

It is your responsibility to ensure that all students wear safety goggles at all times, tie back long hair into a ponytail, and wear close-toed shoes 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.

U.S. National Chemistry Olympiad

PART III – LABORATORY PRACTICAL RUBRIC
Lab Problem 1

Ethylenediaminetetraacetic acid or EDTA forms a 1:1 complex with calcium and magnesium cations at pH 10. The indicator Eriochrome Black T forms a red colored complex with metal ions and is blue/black in their absence. Using the provided materials, devise and carry out an experiment to determine the total combined concentration of calcium and magnesium in milk.

Answer Sheet Questions

1. Give a brief description of your experimental plan. (7 points)
   - Indication that titration will be used to solve the problem
   - Students may plan to test titration (observation of the endpoint) with the magnesium chloride solution, indicator, buffer, and EDTA.
   - Excellent plan indicates a strategy for determining volume added
   - Experimental details on titration
     - One possible approach – mix buffer, indicator, and milk. Titrate with EDTA solution until indicator changes from red to blue.
     - Another possible approach – mix buffer, indicator, milk, and set volume of EDTA – solution must be blue/black in color. Back titrate with magnesium chloride solution until color changes from blue to red.
   - Detailed equipment to use for the titrations.
   - Replicate measurements

2. Record your data/observations (6 points)
   - Clear data table indicating starting volumes of each solution used (i.e. milk, magnesium chloride solution, EDTA, buffer, indicator – specific solutions depends on method of titration) and the volume of titrant (EDTA or $MgCl_2$) used – minimum of duplicate trials
   - Observations – color changes observed in the titrations
   - Clear indication of how number of drops are converted to volume or how the volume of solutions used was determined

3. Show all calculations (6 points)
   The calculations will depend upon the method of titration selected by the student.
   a) Titration of milk directly with EDTA:
      - Calculate moles of EDTA added to the solution
      - Calculate based on a 1:1 ratio the moles of Mg^{2+} or Ca^{2+} in the milk
      - Determine the total concentration (mol/L) of Mg^{2+} and Ca^{2+} in milk by dividing moles of divalent cations by the volume of milk used

b) Back-titration with magnesium chloride solution
   - Calculate moles of EDTA added to the milk
   - Calculate the moles of Mg^{2+} added to reach the endpoint = moles of excess EDTA
   - Calculate the moles of divalent cation complexed with the EDTA = moles of divalent cations in milk
   - Determine the total concentration (mol/L) of Mg^{2+} and Ca^{2+} in milk by dividing moles of divalent cations by the volume of milk used
   - Average value – from duplicate trials

4. The total combined concentration in mol/L of calcium and magnesium in milk is _____. (5 points)

   USDA reports the following values for Skim milk

Calcium	122 - 143 mg/ 100 g
Magnesium	11 - 16 mg/100 g

   The density of milk is reported to be between 1.03-1.04 g/mL

   The total combined concentration in mol/L of calcium and magnesium in milk ranges from 0.036 – 0.044 mol/L.

   Accuracy of value

0.03-0.045 M	full credit
0.02-0.03 or 0.045-0.06 M	3 points
0.015-0.02 or 0.06 – 0.07 M	2 points

Lab Problem 2

You are provided with two vials, each containing a different flavor of Kool-Aid® drink mix dissolved in water. Devise and carry out a procedure to rank the polarity of the artificial coloring found in both samples.

Answer Sheet for Laboratory Practical Problem 2

1. Give a brief description of your experimental plan. (7 points)
   - Indication that paper chromatography will be used to solve the problem
   - Excellent plan would indicate trying different eluents (isopropanol, water, and mixtures of isopropanol and water)
   - Students should provide details about set-up – a sketch is an excellent way to provide information about the set-up, indicate start and end point, spot above solvent line

2. Record your data/observations. (11 points)

- Qualitative observations: numbers of spots and colors of the spots, degree of migration in the eluent
- Quantitative observations: providing R_f or a sketch to scale demonstrating the migration distance

3. How many dyes are present in each sample? Specify the number and color(s) of the dye(s) in each sample (3 points)

   Answer depends on the Kool-Aid samples provided to the student.

   The ingredients on the packages of Kool-Aid are as follows:

Green Apple:	Yellow 5 and Blue 1
Grape:	Red 40 and Blue 1
Orange:	Red 40 and Yellow 5

4. Does/Do the same dye(s) exist(s) in more than one sample(s) of Kool-Aid? If yes, please specify which dye(s) and the samples that contain the same dye(s). (2 points)

   Answer depends on the Kool-Aid samples provided to the student.

   The ingredients on the packages of Kool-Aid are as follows:

Green Apple:	Yellow 5 and Blue 1
Grape:	Red 40 and Blue 1
Orange:	Red 40 and Yellow 5

5. Rank the dyes in order of increasing polarity (2 points)

least polar			most polar
water as eluent:	blue	yellow	red
isopropanol as eluent:	blue	red	yellow