ACS USNCO
U.S. National Chemistry Olympiad

2022 U.S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM PART III

Prepared by the American Chemical Society Chemistry Olympiad Examinations Task Force

OLYMPIAD LABORATORY PRACTICAL TASK FORCE

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DIRECTIONS TO THE EXAMINER

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 three parts to the National Olympiad Examination. You have the option of administering the three parts in any order, and you are free to schedule rest breaks between parts.

Part I	**60 questions**	**single-answer multiple-choice**	**1 hour, 30 minutes**
Part II	**8 questions**	**problem-solving, explanations**	**1 hour, 45 minutes**
Part III	**2 lab questions**	**laboratory practical**	**1 hour, 30 minutes**

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.

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 - DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO.

WHEN DIRECTED, TURN TO PAGE 3 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.

Do not forget to turn in your U.S. citizenship/Green Card Holder statement before leaving the testing site today.

STUDENT USNCO ID:

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 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

***Question**:* Antacids are a class of medications that neutralize acid in the stomach. Determine the moles of HCl, simulating stomach acid that can be neutralized by a tablet of commercial antacid.

Lab Problem 2

***Question**:* Design and carry out an experiment to determine the specific identity of the substance in each of six numbered vials. Each vial contains one of these substances.

baking soda (sodium bicarbonate)
borax (sodium tetraborate)
cornstarch (polysaccharide of glucose)
Epsom salts (magnesium sulfate)
powdered sugar (sucrose and corn starch)
washing soda (sodium carbonate)

Using the materials provided (including distilled water, 10% HCl, 10% NaOH, 2% iodine solution, bromothymol blue, and phenolphthalein), devise and carry out an experiment to correctly determine the contents of each vial.

STUDENT USNCO ID:

Answer Sheet for Laboratory Practical **Problem 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. A typical Tums tablet weighs 1.3 g. The amount of stomach acid that can be neutralized by the tablet 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:**_____

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

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

Unknown #	Contains	Justification
1		
2		
3		
4		
5		
6		

Examiner please indicate the item replaced or refilled provided:

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U.S. National Chemistry Olympiad

2022 U.S. NATIONAL CHEMISTRY OLYMPIAD

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EXAMINER'S INSTRUCTIONS

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Lawrence Wilkinson, *ExxonMobil*, Baton Rouge, LA

Thank you for administering the 2020 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 the materials separated 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 three 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 that was sent by e-mail through Formsite; this information will be extremely useful to the USNCO subcommittee as they prepare for next year's exam.

Please remember to return 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 834
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.

May 9, 2022 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 **May 7, 2022** 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.

Laboratory Problem #1

Materials needed for problem #1:

- One (1) graduated cylinder, 25 mL – can substitute with 10 and/or 100 mL
- Two (2) Beral pipets, with 0.25 mL graduations
    - Suggested Beral pipets are:
        - Fisher brand catalog# 13-711-9AM
        - Samco Scientific – Thermo Fisher catalog number 212
- One (1) glass stirring rod – for both problems #1 and 2
- One (1) spatula – for both problems #1 and 2
- One (1) hot plate – stirring is not needed and should not be used
- Three (3) beakers, 100 or 150 mL
- pH indicator strips range 1.0-12.0, 12 per student
    - Suggested indicator strips
        - Fluka Analytical Mat # 10184429
        - Fisher brand catalog #13-640-508
- Two (2) pieces of wax paper or glassine weigh paper – used to crush tablets
- Distilled or deionized water, at least 500 mL, in a wash bottle labeled appropriately – for both problems #1 and 2
- Access to paper towels and a sink with running water – for both problems #1 and 2

Chemicals needed for problem #1:

- Phenolphthalein indicator, 0.5% (wt in 1:1 ethanol/water), 0.5 mL in a labelled Beral pipet or a vial with a dropper – for both problems #1 and 2
- Three (3), TUMS **peppermint** antacid tablets – PLEASE remove from original packaging and place in a labelled plastic bag. These will be provided to you by ACS. DO NOT provide packaging information to the students.
- Standardized HCl, 0.5 M reported to three significant figures, 100 mL per student
- Standardized NaOH, 0.40-0.45 M reported to three significant figures, 50 mL per student

Standardization instructions for NaOH, to be standardized by the coordinator:

1. Dissolve 20 grams of solid NaOH in enough distilled or deoionized water to create one liter solution.
2. Weigh out approximately 0.8 grams of potassium hydrogen phthalate (KHP, molecular weight 204.23 g/mol) to at least 3 decimal places and dissolve in 50-75 mL of water in an Erlenmeyer flask. Record the amount of KHP used.
3. Add 2-3 drops of phenolphthalein indicator to the KHP solution.
4. Titrate the solution with prepared NaOH solution until a faint pink endpoint. Record volume of NaOH solution used in the titration.
5. Repeat.
6. Convert grams of KHP to mol NaOH noting a 1:1 mole ratio of KHP to NaOH.
7. Divide moles of NaOH by the volume of NaOH used to determine molarity.
8. Report the average molarity on the labels for the students.

Standardization instructions for HCl, to be standardized by the coordinator:

1. Dilute 83.3 mL of 6M HCl with enough distilled or deoionized water to create 1 L of 0.5 M HCl.
2. Pipet or use a buret to transfer 20.0 mL of HCl to an Erlenmeyer flask. Record the volume of HCl used.
3. Add 2-3 drops of phenolphalein.
4. Titrate the solution with the previously standardized NaOH solution, recording the volume of NaOH used in the titration. Repeat trials.
5. Convert the volume of standardized NaOH added to solution to moles of HCl (1:1 stoichiometry) using the molarity of NaOH.
6. Divide the number of moles of HCl by the volume of HCl used in the titration to determine molarity.
7. Report the average molarity to three significant figures on the label for the students.

Phenolphthalein indicator, 0.5% (wt in 1:1 ethanol/water), 0.5 mL in a labelled Beral pipet
Either purchase prepared indicator or prepare by dissolving 1.0 g of phenolphthalein in 100 mL of a mixture of ethanol and water (50 mL ethanol and 50 mL water).

Dispense approximately 0.5 mL in a Beral pipet or a vial with a dropper and place a label on the pipet/vial. For the pipet, store with the bulb end of the pipet down.

Laboratory Problem #2

Materials needed for problem #2:

- Four (4) Beral pipets – these do not need to be graduated but can have graduations
- One (1) glass stirring rod – for both problems #1 and 2
- Twelve (12) test tubes
- One (1) test tube rack or two (2) test tube racks depending on number of slots in the racks
- One (1) spatula -– for both problems #1 and 2
- One (1) plastic or ceramic well plate, 6 or 12 wells per plate
- One (1) distilled or deionized water, at least 500 mL, in a wash bottle labeled appropriately – for both problems #1 and 2
- Access to paper towels and a sink with running water – for both problems #1 and 2

Chemicals needed for problem #2:

- Phenolphthalein indicator, 0.5% (wt in 1:1 ethanol/water), 1.0 mL in a labelled Beral pipet or a vial with a dropper (same one for problem #1)
- Bromothymol blue indicator, 0.04% (wt in water), 0.5 mL in a labelled Beral pipet or a vial with a dropper
- Iodine–Potassium Iodide Solution, 5 mL per student
- HCl, 10%, 10 mL of solution (does not need to be standardized)
- NaOH, 10%, 10 mL of solution (does not need to be standardized)
- Unknowns – please label each of these samples with unknown number and not the identity of the substance
    - unknown #1: cornstarch, 2 g per student
    - unknown #2: baking soda (sodium bicarbonate), 2 g per student
    - unknown #3: epsom salts (magnesium sulfate), 2 g per student – can use anhydrous $MgSO_4$ or an available hydrated forms
    - unknown#4: powdered sugar, 2 g per student
    - unknown #5: washing soda (sodium carbonate), 2 g per student
    - unknown #6: borax (sodium tetraborate), 2 g per student – can use commercially available borax from a grocery store or pure sodium tetraborate

Bromothymol blue indicator, 0.04%, 0.5 mL in a labelled Beral pipet

- Either purchase prepared indicator or prepare by dissolving 0.04 g of bromothymol blue in 50 mL of distilled or deoinized water and then dilute to 100 mL with water.
- Dispense approximately 0.5 mL in a Beral pipet or a vial with a dropper and place a label on the pipet or vial. For the pipet, store with the bulb end of the pipet down.

Iodine–Potassium Iodide Solution

Dissolve 15 g of potassium iodide in 125 mL of distilled or deoionize water; add 3 g of iodine; stir to dissolve, then dilute to 1 L. Store in a dark bottle.

Waste disposal:

The solutions should not be disposed of down the drain. Place any waste in a designated waste container.

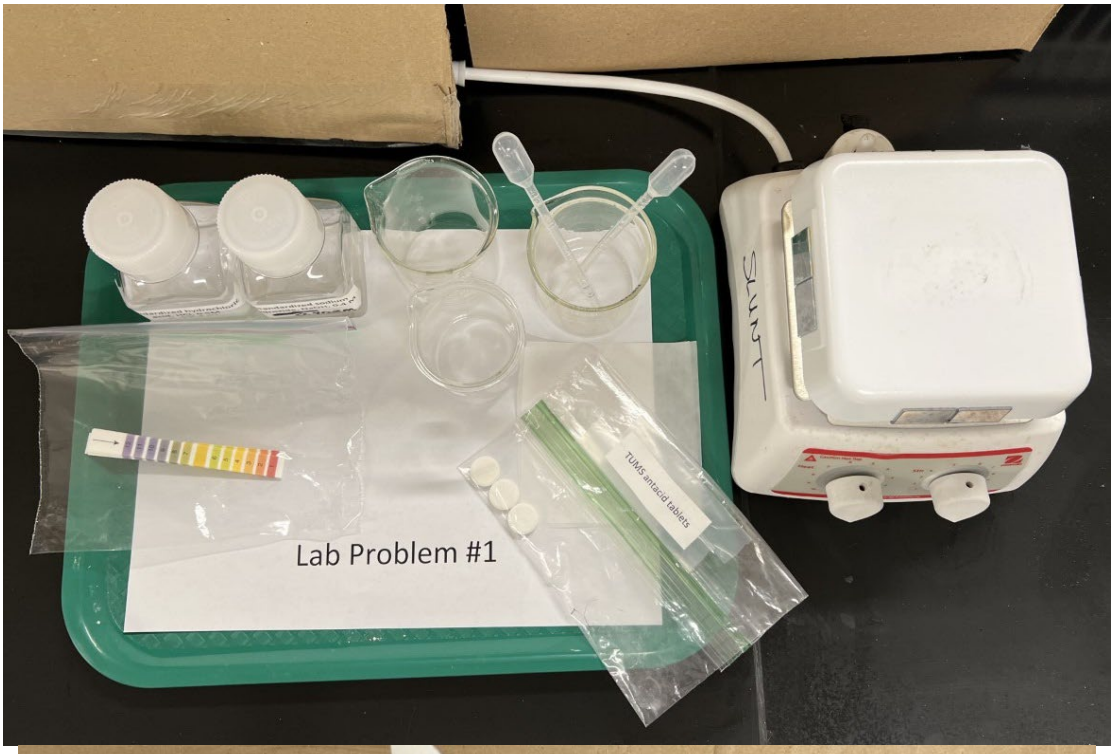
Suggested Laboratory Setup Photos

Note – phenolphalein and bromothymol blue could be provided in a labelled dispensing bottle rather than the pipet as shown.

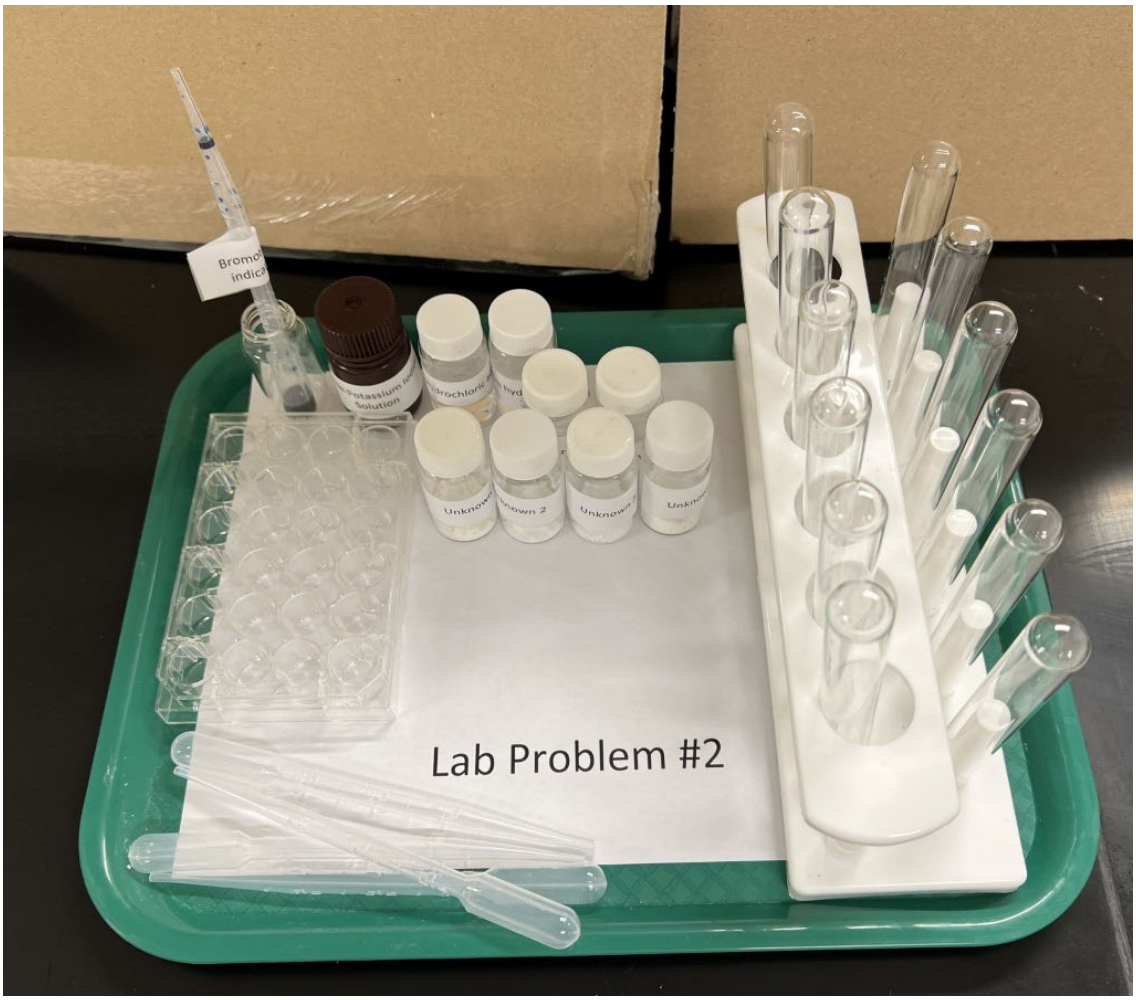
PLEASE remove TUMS tablets from original packaging and place in a labelled plastic bag. DO NOT provide TUMS packaging information to the students.

DO NOT provide names of the unknowns on the bottles of white solids.

See photos for suggested set-up on the next page.


Lab Problem #1
TUMS antacid tablets


Lab Problems #1 and


Lab Problem #2

2022 UNITED STATES NATIONAL CHEMISTRY OLYMPIAD
National Exam Part III RUBRIC

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

Lab Problem 1

Question: Antacids are a class of medications that neutralize acid in the stomach. Determine the moles of HCl, simulating stomach acid, that can be neutralized by a tablet of commercial antacid.

Answer Sheet Questions

1. Give a brief description of your experimental plan (5 points)
   One suggested approach – back titration
   - Indication that a back titration with excess HCl will be used to solve the problem
   - Students may plan to test titration (observation of endpoint) with the HCl, NaOH, and indicator
   - Experimental details on the titration
     - Mix tablet, HCl, and indicator and heat the solution to near boiling to release excess CO_2. Remove from heat, allow to cool and test with pH indicator paper to ensure excess acid is present. Titrate with NaOH until the color turns from colorless (or white due to presence of the tablet) to pink.
   - Students may attempt to titrate by dissolving the tablet in water and titrating with HCl, but this is an inaccurate method.
     - Care should be taken to prevent overheating as the fillers present in the tablet may burn when heating on the hot plate or the water can evaporate.
   - Determine the volume of a drop of liquid from a Beral pipette
   - Replicate Measurements

   Another approach – determine amount of carbon dioxide lost after neutralization

   - Indication that measurement of loss of carbon dioxide will be determined by decrease in mass
   - Experimental details
     - Mass of all items before mixing – making sure to include the glassware for the reaction
     - Mass of items after mixing
     - Allow time for the reaction to occur – stirring, heating, and waiting until no visible gas remains in the solution and the reaction between the antacid and HCl concluded. Remove from heat, allow to cool, and determine mass after reaction.

    - Ensure an excess of HCl was added to the tablet – using pH strips to check the pH.
    - Care should be taken to prevent overheating as the fillers present in the tablet may burn when heating on the hot plate or the water can evaporate.
- Replicate Measurements

2. Record your data/observations (6 points)
   Back titration
   - Recorded mass of antacid tablet used
   - Recorded volume of a drop of liquid from a Beral pipette
   - Clear data table indicating starting volume of HCl and volume of NaOH used to neutralize the solution
   - Observations- color changes observed in titrations
   - Clear indication of how number of drops are converted to volume or how the volume of solutions used was determined

   Quantification of carbon dioxide lost after neutralization

   - Clear data table including starting and ending masses of antacid, solutions, and glassware and volumes of HCl used
   - Observations- could include the expulsion of gas, the final masses were recorded after all visible gas was removed, pH of the solution after excess HCl was added
   - Clear indication of how number of drops are converted to volume or how the volume of solutions used was determined

3. Show all calculations (7 points)
   Back titration
   - Calculate the number of moles needed to dissolve the total amount of calcium carbonate in the tablet
   - Calculate the total moles of HCl that was used to completely dissolve the antacid tablet and still have excess in solution.
   - Calculate the moles of NaOH added to reach the endpoint = moles of excess HCl
   - Calculate the moles of HCl that reacted with the calcium carbonate in the antacid tablet
   - Average value – from duplicate trials

   Quantification of carbon dioxide lost after neutralization
   - Mass of carbon dioxide lost
   - Mass of calcium carbonate in the antacid tablet
   - Calculate the moles of HCl that reacted with the calcium carbonate in the antacid tablet
   - Average value – from duplicate trials

4. A typical Tums tablet weighs 1.3 g. The amount of stomach acid that can be neutralized by the tablet is: _____. (7 points)

    - Experimental range: 0.00986 mol – 0.0106 mol HCl per 1.3 g tablet

    - Accuracy of value

0.00980 – 0.0106 moles	full credit
0.00882- 0.00979 or 0.0105 – 0.0116 moles	5 points
0.00784-0.00881 or 0.0117-0.0127 moles	3 point
any other answers (in moles)	0 points

    Answers in units other than moles of HCl were converted to moles and then graded using the scale above.

Lab Problem 2

Question*:* Design and carry out an experiment to determine the specific identity of the substance in each of six numbered vials. Each vial contains one of these substances.

- baking soda (sodium bicarbonate)
- borax (sodium tetraborate)
- cornstarch (polysaccharide of glucose)
- Epsom salts (magnesium sulfate)
- powdered sugar (sucrose and corn starch)
- washing soda (sodium carbonate)

Using the materials provided (including distilled water, 10% HCl, 10% NaOH, 2% iodine solution, bromothymol blue, and phenolphthalein), devise and carry out an experiment to correctly determine the contents of each vial.

Answer Sheet Questions

1. Give a brief description of your experimental plan (5 points)
    - use equal amounts of substances (i.e. end of a spatula, small amount in the bottom of test tube or well)
    - add a set volume of reagent (i.e. 0.25 mL) or add the reagents dropwise
    - stir samples and observe color changes, formation of gas, formation of precipitate

2. Record your data/observations (8 points)
    - Clear data table or flow chart indicating substances combined and the results of the tests performed

- observations (color changes, production of gas, solubility, formation of precipitate) – see table at end with sample results

3. Identify the substance in each unknown vial, giving a brief justification for that choice. (12 points)

Unknown #	Contains	Justification
1	Cornstarch	Insoluble in water, interacts with starch and turn blue-black
2	Baking Soda (sodium bicarbonate)	Produces a gas in the presence of an acid (HCl or vinegar),
3	Epsom salts (magnesium sulfate)	Forms a white precipitate in the presence of hydroxide
4	Powdered sugar	Soluble in water, interacts with starch and turns blue-black (smaller color change than cornstarch – indicating less starch present in the sample)
5	Washington soda (sodium carbonate)	Produces a gas in the presence of an acid, basic in the presence of phenolphalein (darker pink than sodium bicarbonate)
6	Borax (sodium tetraborate)	Soluble in water and aqueous acids but no gas produced in the presence of acid, basic in the presence of phenolphalein

Data from White Powder Trials – Data compiled from three students at the University of Mary Washington

	Cornstarch (unknown1)	Baking soda (unknown 2)	Epsom salts (unknown 3)	Powdered sugar (unknown 4)	Sodium carbonate (unknown 5)	Borax (unknown 6)
Water solubility	Insoluble	Soluble	Soluble	Soluble	Soluble	Sparingly soluble
10% HCl solubility	Insoluble	Soluble and gas produced	Soluble	Soluble (Note: one student listed as insoluble)	Soluble and gas produced	Soluble and no gas produced

10% NaOH reaction	No change	No change	White ppt formed	No change	No change	No change
Vinegar solubility	Insoluble	Soluble and gas produced	Soluble	Soluble (Note: one student listed as insoluble)	Soluble and gas produced	Soluble and no gas produced
Iodine	Dark blue/black	No change	No change	Faint blue/ black	No change	No change
Phenolphthalein	No change	Pale pink	No change	No change	Dark pink	pink
Bromothymol blue	Yellow-blue green	blue	Yellow	blue	blue	blue