2006 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.

2006 UNITED STATES NATIONAL CHEMISTRY OLYM
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

Turmeric, a natural compound, is added to mustard for flavor and color. It changes color from yellow to red at a pH of 7.4. Mustard also contains acetic acid. Given a sample of 0.50 M NaOH and the packets of mustard, create and perform an experiment to determine the mass percentage of acetic acid in mustard.

Lab Problem 2

Given a sample of 3.0 M hydrochloric acid, phenolphthalein, and some common laboratory equipment, devise an experiment using both *qualitative* and *quantitative* evidence to determine the provided unknown metal given these possible choices: Ag, Al, Ca, or Cr.

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.

This is a titration experiment. Yellow mustard must be between 2.6 – 3.5% acetic acid by law (See: Current CFR 21 for 2005 [http://www.gpoaccess.gov/cfr/index.html]http://www.gpoaccess.gov/cfr/index.html). Yellow mustard contains turmeric, here used as an indicator for this experiment.

Before beginning your experiment, you must get	Examiner’s Initials:

approval (for safety reasons) from the examiner.	

2. Record your data and other observations.

3. Calculations.

The calculations would be:

1. moles base used (V x M) = moles acid present

2. moles acid present x molar mass acetic acid = mass acetic acid

3. Percentage of acetic acid in mustard = mass acetic acid present / mass mustard used

Sample Calculation:

0.50 g mustard weighed, titrated with a volume of 0.5 mL NaOH

moles OH^- = 0.0005 L x 0.5M = 0.00025 mol OH^-

= 0.00025 mol H^+ from $HC_2H_3O_2$ in mustard

mass $HC_2H_3O_2$ = 0.00025 mol x 60 g/mol = 0.015 g $HC_2H_3O_2$

finally, % acetic acid in mustard = 0.015 g /.50 g x100 = approx. 3.0%

The percentage of acetic acid in your sample of mustard = ___3.0%__________________

Excellent work:
Student was able to complete two or more trials and average their results, using a minimum amount of both mustard and NaOH for each titration. Results were clearly shown and observations, i.e. color changes and endpoint were clearly noted.

Student thought to make dilute aqueous solutions with each of the samples of mustard in order to completely dissolve the mustard and be able to more clearly note a uniform and lasting color change

Average work:
Student only completed one trial. Evidence of a titration was performed. Measurements between trials were fairly consistent.

Below average work:
Student was not able to conclude that this was a titration experiment, or did so, but did not perform the titration correctly to obtain a mass/volume of NaOH added. Only one trial was performed. Measurements were inaccurate or inconsistent between trials.

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.

Students were to provide both qualitative and quantitative evidence to determine the unknown metal. The metal provided was calcium. The results to this experiment should have included both evidence form data obtained and exclusive information about what was not observed from students' previous chemical knowledge. Conclusions come from knowledge about each metals' reactivity to both water and HCl, with phenolphthalein, a possible titration, and gas generation. Students might also have explored reactivity of the metal with NaOH from Problem #1 (this is allowed, though not necessary to successfully complete this problem).

Excellent work:
Student combined HCl with the unknown metal (Ca) to obtain hydrogen gas in the well-plate, clearly showing evidence of gas production and exothermic reaction. A titration The student then performed this reaction with a measured amount of Ca and excess HCl using the Luer-Lok syringe to quantify the hydrogen gas produced (since room temperature and pressure were not given, student had to make some assumptions about the Kelvin temperature and room pressure, perhaps estimating 298K and 1 atm) to determine the expected volume of hydrogen and compare it to a theoretical volume produced from
$Ca + HCl \quad CaCl_2 + H_2$
Noting the color change when phenolphthalein is added to the metal reacted to either water or HCl. It is possible that a student might have thought to combine mustard (from Prob.#1) with the metal from this experiment. If so, mustard on the surface of Ca produces over time a crusty white solid, $Ca(C_2H_3O_2)_2$ (there is no evidence of reaction with mustard on the surface of Cr and with pure Ag, no visible reaction).

Concluding what DIDN'T occur:
If Cr + HCl   greenish color indicating $CrCl_3$ (or green color with many chromium salts
If Ag + HCl   no reaction
If Al + HCl   no visible reaction due to aluminum oxide layer (though student might have attempted to dissolve the metal with the NaOH from Exp. #1, if Al, would dissolve; Ca + NaOH   gives $Ca(OH)_2$, a noticeable milky white precipitate, with phenolphthalein produces a pink color.

a) Sample titration experiment conclusions:

Reacting a 0.10 g metal turning with water completely, adding phenolphthalein, then titrating with the 3M HCl to obtain a 2 : 1 ratio of OH^- : H^+ in solution, confirms that OH^- must be present in the metal hydroxide form, $M(OH)_2$.

b) Sample data for quantifying hydrogen gas generated using the Luer-Lok® syringe:

One metal turning, approx. 0.07 g Ca in excess 3M HCl

Begin at 12 mL mark on syringe
End at 40 mL mark on syringe
40 – 12 = 28 mL hydrogen gas generated, strongly exothermic reaction.

Assume room temp. 25oC (298K) and 1 atm: using the ideal gas law, $PV = nRT$

(1 atm)(0.028L) = n (0.0821atm L/mol K) (293K) ; n = 0.00116 mol $H_2(g)$

if given 0.07g of calcium, $Ca + 2HCl \quad CaCl_2(aq) + H_2(g)$, then 0.0035 g of hydrogen gas is produced, corresponds roughly to number of moles of $H_2(g)$ made with these assumed conditions.

Average work:

Student reacted metal with HCl and concluded hydrogen gas was present but didn’t quantify the gas produced, or did but incorrectly. Student wrote out possible reactions with the other possibilities but did not do so correctly.

Below average work:
Student was unable to conclude that hydrogen gas was produced, did not use either a titration or quantitative method of data collection, or unable to use the phenolphthalein to qualitatively justify the metal.

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

2. Record your data and other observations. (See comments above)

3. Conclusions and Evidence. **The unknown metal is = __Calcium__________**

PERIODIC TABLE OF THE ELEMENTS

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** 181.0	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** 226.0	89 **Ac** 227.0	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 (269)	111 (272)	112 (277)		112 (277)		116 (289)		118 (293)

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** 237.0	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** (260)