

PRACTICE PAPERS CHEMISTRY OLYMPIADS

STAGE – 2

Paper – 15 Part – C

TIME: 1HR 30MIN

MAX MARKS: 180

- Attempt all the Questions.
- All questions carry +3 for right answer and -1 for wrong answer.
- Use of Calculator is allowed.

PERIODIC TABLE OF THE ELEMENTS

1 1A																		18 8A					
1 H 1.008												13 B 10.81	14 C 12.01	15 N 14.01	16 O 16.00	17 F 19.00	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 B 10.81	4 C 12.01	5 N 14.01	6 O 16.00	7 F 19.00	8 Ne 20.18	9 Na 22.99	10 Mg 24.31	11 Al 26.98	12 Si 28.09	13 P 30.97	14 S 32.07	15 Cl 35.45	16 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)										

Name:

Correct Questions =

Wrong Questions =

Unattempt Questions =

Marks =

Lab Problem 1

Devise and carry out an experimental procedure to determine the concentration (in mass %) of the hydrogen peroxide solution with which you have been provided.

Lab Problem 2

Consider the reaction:



Prepare an initial $[\text{Cu}(\text{H}_2\text{O})_4]^{2+} / [\text{CuCl}_4]^{2-}$ equilibrium mixture by dissolving sodium chloride in 0.3 M copper(II) nitrate solution until you observe a color change.

Devise and carry out experimental procedures to

- 1) determine the sign of ΔH for this reaction, and*
- 2) identify Solution A and Solution B as containing either KCl or AgNO₃ based on their effect on this equilibrium system.*

Directions to the Examiner:

Thank you for administering the 2015 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.

It is your responsibility to ensure that all students wear safety goggles and non-latex rubber gloves 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* 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 and non-latex rubber gloves at all times.** Please wash off any chemicals spilled on your skin or clothing with large amounts of tap water.*

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 there 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 there any additional questions?

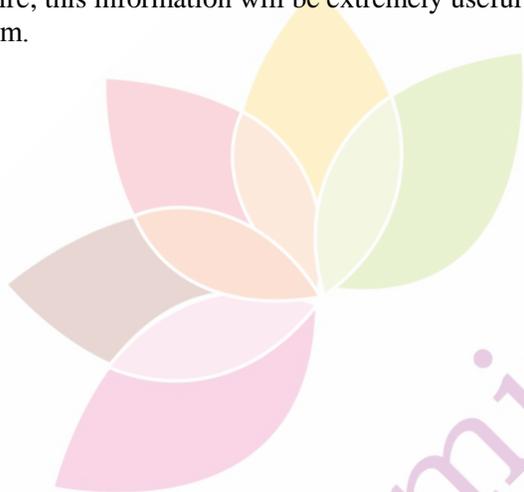
If there are no further questions, the students should be ready to start **Part III**.

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.



The Chemistry Guru

Lab Problem #1: Materials and Equipment

Each student should have available the following equipment and materials:

Materials:

- ❖ 3 – 250 mL Erlenmeyer flasks (Pyrex, Kimax or equivalent)
- ❖ 3 – watch glasses, large enough in diameter to cover the mouths of the Erlenmeyer flasks
- ❖ 1 – spatula (a Scoopula® is fine)
- ❖ 2 – Beral pipets
- ❖ disposable, non-latex rubber gloves
- ❖ access to electronic balance, capable of determining mass to at least two decimal places, and with a capacity of at least 250 g
- ❖ access to paper towels and a sink with running water

Chemicals:

- ❖ 100 mL – Hydrogen Peroxide Solution - 6 mass % (see Note 1), in a bottle labeled only as “Hydrogen Peroxide Solution” (DO NOT provide the concentration on the label)
- ❖ 1 g – Manganese(IV) Oxide (see Note 2), in a small vial labeled “Manganese(IV) Oxide”

Notes:

- 1) This solution is best prepared within a few days of the administration of the lab practical. Prepare the 6% by mass hydrogen peroxide solution by appropriate dilution of 30% hydrogen peroxide (e.g., Fisher brand H325-500 Hydrogen Peroxide, 30%, or 27% hydrogen peroxide available at swimming pool stores have been found to be suitable). From the Certificate of Analysis of the lot of hydrogen peroxide used, obtain the actual concentration of the hydrogen peroxide solution, as determined by assay. Use distilled or deionized water (do not use tap water). Store the solution in amber bottles (4 ounce or 125 mL narrow mouth bottles are fine).
- 2) It was brought to the attention of the USNCO Subcommittee that the MnO_2 should be checked to ensure that it hasn't somehow become deactivated. A small amount of MnO_2 should facilitate a fairly rapid and exothermic decomposition of 25 mL of 6% hydrogen peroxide.
- 3) Avery Label Template (Template 5160) provided for your convenience.

These materials are in addition to and separate from lab problem #1.

Lab Problem #2: Materials and Equipment

Each student should have available the following equipment and materials:

Materials:

- ❖ 3 – 50 mL beakers (Pyrex, Kimax or equivalent)
- ❖ 1 – stirring rod
- ❖ 1 pair – beaker tongs
- ❖ 1 – 10 mL graduated cylinder
- ❖ 1 – Spatula (a Scoopula® is fine)
- ❖ disposable, non-latex rubber gloves
- ❖ access to a hotplate (can be shared with up to 3 other students)
- ❖ access to an ice bath (shallow, but large enough to accommodate up to four 50 mL beakers; can be shared with up to 3 other students)
- ❖ access to paper towels and a sink with running water

Chemicals:

- ❖ 5 g – Sodium Chloride, in a small vial labeled “Sodium Chloride”
- ❖ 50 mL – 0.3 M copper(II) nitrate solution, in a bottle labeled “Copper(II) Nitrate Solution, 0.3 M”
- ❖ **Solution A:** 3 mL of 0.1M silver nitrate solution in a Beral pipet labeled only as “Solution A”
- ❖ **Solution B:** 3 mL of 2M potassium chloride solution in a Beral pipet labeled only as “Solution B”

Notes:

- 1) The type of Beral pipets for Solution A and Solution B (5 mL capacity is sufficient):



- 2) Cut off the excess stem to yield about a 2 cm tip:



- 3) Avery Label Template (Template 5160) provided for your convenience.

Safety Instructions for Lab Problem #1 and #2:

It is your responsibility to ensure that all students wear safety goggles and non-latex rubber gloves 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.

Lab Problem #1:

Devise and carry out an experimental procedure to determine the concentration (in mass %) of the hydrogen peroxide solution with which you have been provided.

Answer sheet questions:

1. Give a brief description of your experimental plan.
2. Record your data/observations.
 - a) Data (example; student may tare flask and/or watch glass rather than determine and report their masses, determine the mass of the flask, watch glass and MnO₂, or other:
 - i) Mass of flask + watch glass = 120.432
 - ii) Mass of flask + watch glass + MnO₂ = 120.638 g
 - iii) Mass of flask + watch glass + MnO₂ + H₂O₂ = 140.693 g
 - iv) Mass of iii above, after reaction = 140.118 g

NOTES: Students should at least have iii and iv above, (or the necessary data to determine them).

Students should have data from at least TWO trials.

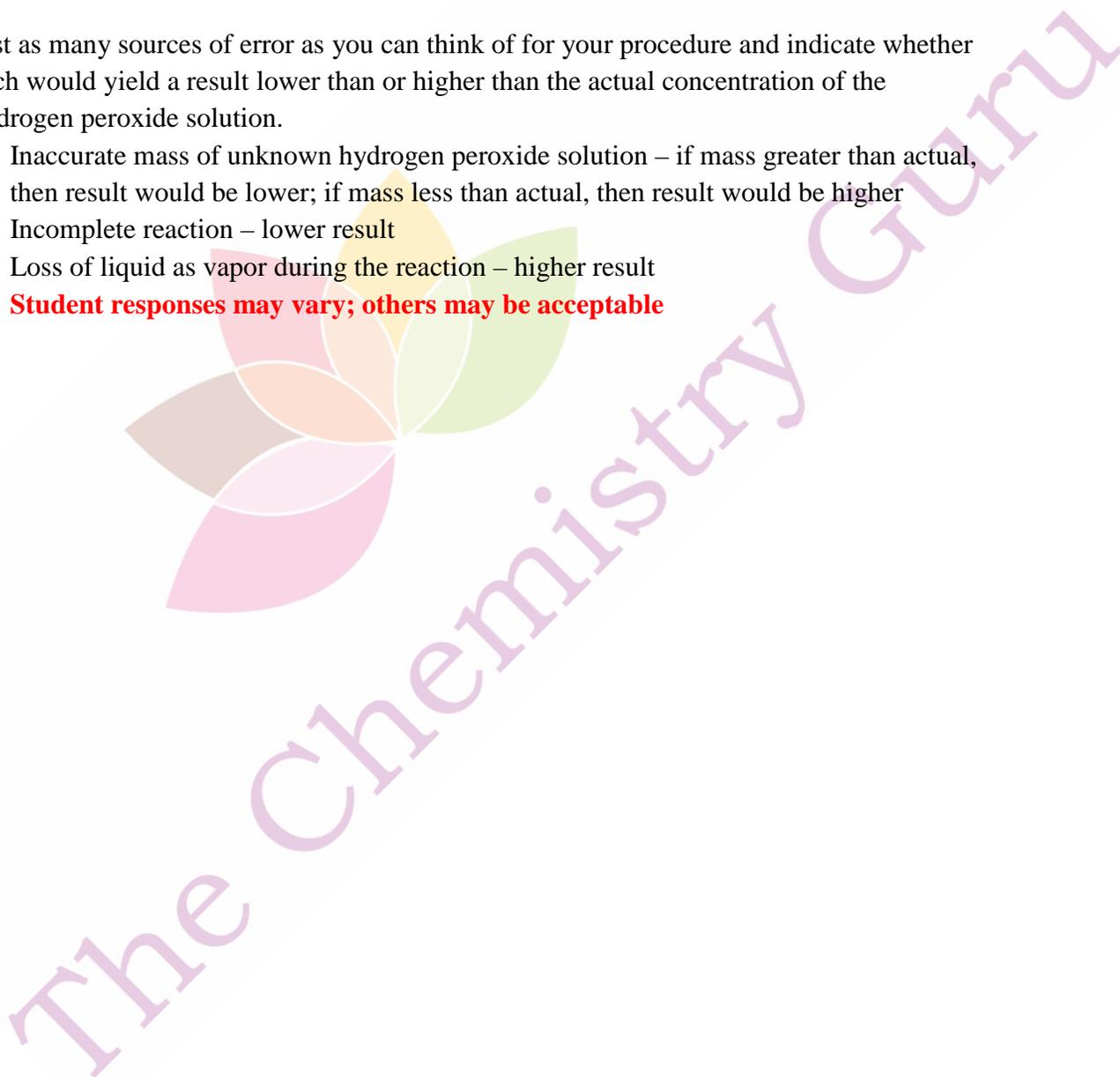
- b) Observations – **(Student responses may vary; best response would include at least 3 observations)**

Upon addition of the MnO₂ to the H₂O₂:

- i) the resulting mixture is black (gray-black) and opaque (“murky”)
 - ii) evolution of a colorless gas is evident
 - iii) heat is produced
 - iv) condensation forms on the upper walls of the flask and the bottom of the watch glass
 - v) gas evolution eventually subsides
3. Show all calculations - Example **(set up and solution may vary)**
 - a) Balanced equation: $2\text{H}_2\text{O}_{2(\text{aq})} \rightarrow 2\text{H}_2\text{O}_{(\text{l})} + \text{O}_{2(\text{g})}$
 - b) Mass of H₂O₂ solution used = 140.693 g – 120.638 g = 20.055 g
 - c) Mass of oxygen gas evolved = mass of system before reaction – mass of system after
= 140.693 g – 140.118 g
= 0.575 g
 - d) $0.575 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{32.0 \text{ g O}_2} \times \frac{2 \text{ mol H}_2\text{O}_2}{1 \text{ mol O}_2} \times \frac{34.01 \text{ g H}_2\text{O}_2}{1 \text{ mol H}_2\text{O}_2} = 1.22 \text{ g H}_2\text{O}_2$

e) $\text{Mass \% H}_2\text{O}_2 = \frac{1.22 \text{ g H}_2\text{O}_2}{20.055 \text{ g soln}} \times 100 = 6.08 \% \text{ (m/m)}$

4. The concentration of the hydrogen peroxide solution provided = 6.08 mass %. **1 of which is for correct sf]**
5. List as many sources of error as you can think of for your procedure and indicate whether each would yield a result lower than or higher than the actual concentration of the hydrogen peroxide solution.
- a) Inaccurate mass of unknown hydrogen peroxide solution – if mass greater than actual, then result would be lower; if mass less than actual, then result would be higher
 - b) Incomplete reaction – lower result
 - c) Loss of liquid as vapor during the reaction – higher result
 - d) **Student responses may vary; others may be acceptable**



Lab Problem #2:

Consider the reaction:



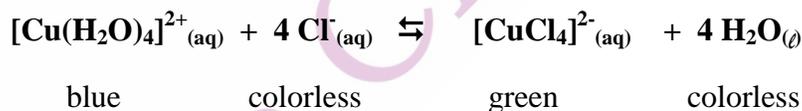
Prepare an initial $[\text{Cu}(\text{H}_2\text{O})_4]^{2+} / [\text{CuCl}_4]^{2-}$ equilibrium mixture by dissolving sodium chloride in 0.3M copper(II) nitrate solution until you observe a color change.

Devise and carry out experimental procedures to

- 1) determine the sign of ΔH for this reaction, and
- 2) identify Solution A and Solution B as containing either KCl or AgNO_3 based on their effect on this equilibrium system.

Answer sheet questions:

1. Give a brief description of your experimental plan.
2. Record your data and other observations. Explain each change in color that you observed, in terms of a shift in the equilibrium position of this system.
 - a) When heated, the solution becomes greener in color, indicating a shift in the equilibrium position of the system toward the right.
 - b) When Solution A is added, the system becomes bluer in color, indicating a shift in equilibrium position toward the left.
 - c) When Solution B is added, the system becomes greener in color, indicating a shift in equilibrium position toward the right.
3. What is the color of each species in this equilibrium system?



4. The sign of ΔH for this reaction is + (positive).
5. a) Solution A contains AgNO_3 .
b) Solution B contains KCl.