STUDENT USNCO ID:

2019 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.

<u>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.</u>

DIRECTIONS TO THE EXAMINEE

DO NOT TURN THE PAGE UNTIL DIRECTED TO DO SO. WHEN DIRECTED, TURN TO PAGE THREE 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. Be sure to use the same ID number you were given in **Part I**.

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

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

$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

$R = 0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1}$

$F = 96{,}500 \text{ C mol}^{-1}$

$F = 96{,}500 \text{ J V}^{-1} \text{ mol}^{-1}$

$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

$h = 6.626 \times 10^{-34} \text{ J s}$

$c = 2.998 \times 10^{8} \text{ m s}^{-1}$

0 °C = 273.15 K

1 atm = 1.013 bar = 760 mm Hg

Specific heat capacity of H_2O = $4.184 \text{ J g}^{-1} \text{ K}^{-1}$

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	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** 78.97	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

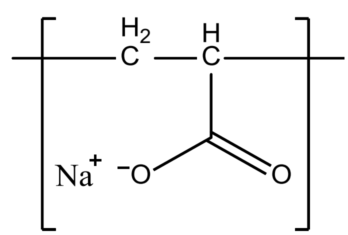
Hydrogen peroxide slowly decomposes in aqueous solution:

$$\mathbf{H_2O_2\,(\mathit{aq}) \rightarrow H_2O\,(\mathit{l}) + \tfrac{1}{2}\,O_2(\mathit{g})}$$

In the presence of a catalyst, the rate of decomposition increases. Using the provided supplies, determine the enthalpy of decomposition of hydrogen peroxide.

Lab Problem 2

Sodium polyacrylate is a superabsorbent polymer utilized in household items such as diapers, artificial snow, and water absorbing spheres.



Using the provided materials, Rank the aqueous solutions provided in order of their ability to be absorbed by sodium polyacrylate.

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. The enthalpy of decomposition of hydrogen peroxide is: ______________________________

5. What is the role of the $Fe(NO_3)_3$ in the reaction? Provide experimental evidence to support your answer.

<u>Examiner please indicate the item replaced or refill provided:</u>

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. The order of absorption of the aqueous solutions by the polymer is:

Least absorbed	**Most absorbed**

4. Explain the observed trend in the data using chemical principles.

Examiner please indicate the item replaced or refill provided:

ACS

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2019 U. S. NATIONAL CHEMISTRY OLYMPIAD

NATIONAL EXAM - PART III

EXAMINER'S INSTRUCTIONS

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

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DIRECTIONS TO THE EXAMINER:

Thank you for administering the 2019 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.

Wednesday, May 1, 2019, 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 29, 2019** 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:

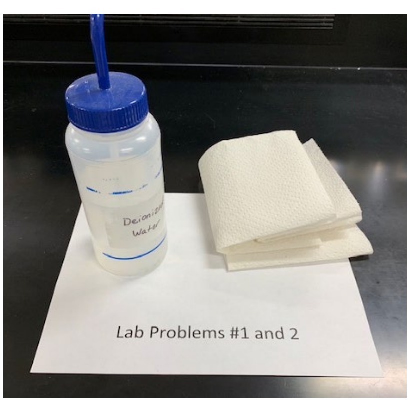
Materials for both Problem #1 and 2:

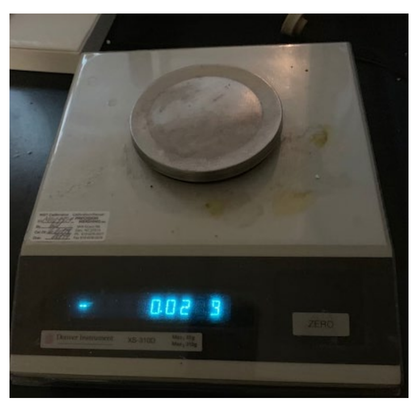
- Distilled or deionized water, at least 500 mL, in a wash bottle labelled appropriately as "Distilled water" or "Deionized water"
- Access to paper towels and a sink with running water
- One (1) balance that can measure to the nearest 0.01 g or better. If one balance per student is not available, two to three students could share a balance

Notes

- Distilled or deionized water is appropriate to provide for the students.
- Example balances that could be provided to the students

Suggested Set-up for both Problems





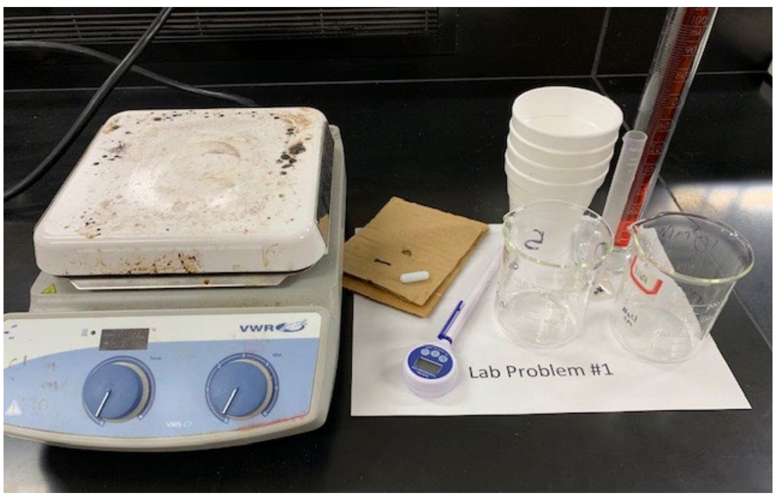
Materials needed for Problem #1:

- Two (2) graduated cylinders, 10 mL and 50 mL (or 100 mL)
- Four (4) Styrofoam cups, 8 or 12 ounce size
- Two (2) squares of cardboard with a hole in the center
- One (1) thermometer
- One (1) magnetic stirrer/hot plate
- One (1) magnetic stir bar
- Two (2) beakers, 150 or 250 mL
- One (1) balance that can measure to the nearest 0.01 g or better. If one balance per student is not available two to three students could share a balance
- Distilled or deionized water, at least 500 mL, in a wash bottle labelled appropriately as "Distilled water" or "Deionized water"
- Access to paper towels and a sink with running water

Chemicals for Problem #1: (see attached suggested labels for chemicals)

- Hydrogen peroxide, 3% by mass, 150 mL per student
- $Fe(NO_3)_3$, 0.5 M, 30 mL per student
  Weigh 60.47 g of iron (III) nitrate and dissolve it in enough distilled water to make 500 mL of solution. If using iron (III) nitrate nonahydrate, weigh 101 g and dissolve in enough distilled water to make 500 mL of solution.

Suggested Laboratory Set-up for Problem 1



Notes:

- Graduated cylinders can be plastic or glass and 10 mL and 50 or 100 mL in size.
- Beakers can be either 150 or 250 mL and should be pyrex as the students may heat then on the hot plate.
- Styrofoam cups may be 8 ounces as shown or 12 ounce size.
- Thermometer can vary depending upon what is available at the institution.

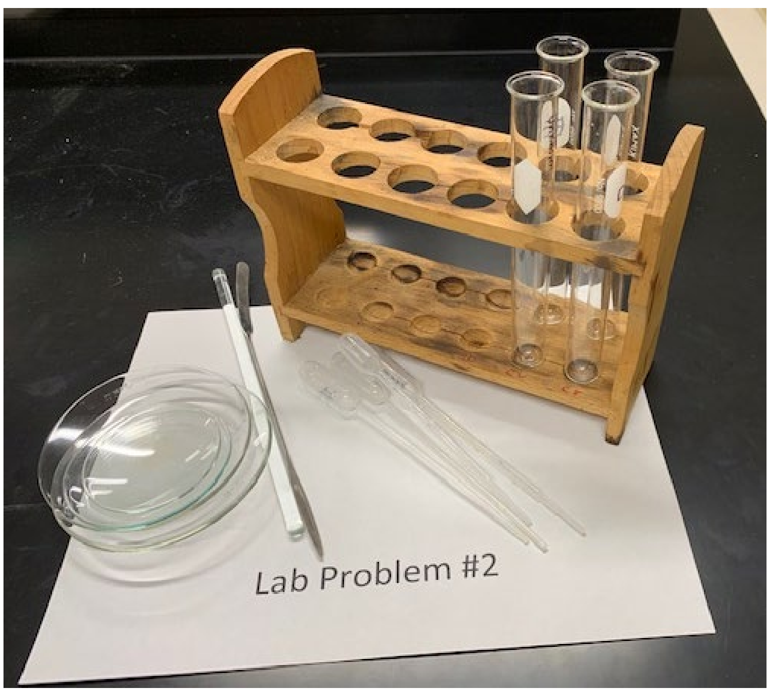
Materials needed for Problem #2:

- Four (4) watch glasses
- Four (4) test tubes
- Four (4) Beral pipets
- One (1) balance that can measure to the nearest 0.01 g. If one balance per student is not available two to three students could share a balance
- One (1) spatula
- One (1) glass stirring rod
- Distilled or deionized water, at least 500 mL, in a wash bottle labelled appropriately as "Distilled water" or "Deionized water"
- Access to paper towels and a sink with running water
- Waste container for polymer samples – the gel can go in the trash can but do not put it down the drain as it may clog the sink

Chemicals for Problem #2:

- Sodium polyacrylate powder, 1 g
- Sodium chloride solution, 0.05 M, 25 mL
- Ammonium chloride solution, 0.05 M, 25 mL
- Magnesium chloride solution, 0.05 M, 25 mL
- Glucose solution, 0.05 M, 25 mL

Suggested Laboratory Set-up for Problem 2



Notes:

- Solutions are not shown in the figures. Can be supplied in any appropriate container (vial, bottle) that is well labeled. Sample labels are provided for your use.
- Balances are also not shown in this set-up. Example balances are shown in the problems #1 and 2 materials. Balances can be provided in stations for up to 3 students per balance.
- Waste container is also not shown in the figure. Individual waste containers can be provided at each station or a communal waste container in an easily accessible area could also be supplied.
- Watch glasses and beral pipets do not have to be of a specific size. Various examples of acceptable ones are shown in this figure.

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2019 UNITED STATES NATIONAL CHEMISTRY OLYMPIAD
National Exam Part III

Lab Problem 1

Hydrogen peroxide slowly decomposes in aqueous solution:

$$H_2O_2\ (aq) \rightarrow H_2O\ (l) + O_2(g)$$

In the presence of a catalyst, the rate of decomposition increases. Using the provided supplies, determine the enthalpy of decomposition of hydrogen peroxide.

Answer Sheet:

1. Give a brief description of your experimental plan

   - Indication that calorimetry will be used to solve the problem
   - Excellent plan indicates a strategy to determine the heat capacity for the coffee cup
     - Measure temperature change of known quantity of warm/hot water is added to a quantity of room or cold water temperature – plot temperature versus time – extrapolate to determine the initial and final temperatures of each water
     - Determine the mass of warm and cold water used
     - Calculate the heat capacity for the coffee cup
   - Experimental details on calorimetry
     - Measure temperature change of known quantity of hydrogen peroxide when iron (III) nitrate is added – plot temperature versus time – extrapolate to determine the initial and final temperatures
     - Determine the mass of solutions used
     - Calculate the heat of decomposition and enthalpy of decomposition
     - Note: the rate of reaction is dependent on the concentration of iron(III) nitrate added. Excellent results are obtained with about 0.08 M iron (III) nitrate added. The enthalpy of decomposition should be independent of the concentration of catalyst used.
   - Replicate measurements

2. Record your data/observations.

   Calorimetry Constant – one sample set of data

   Room temperature water (50.0 mL): T_1 = 22.4°C and T_2 = 30.5°C
   Warm water (50.0 mL): T_1 = 39.6°C and T_2 = 30.5°C

   Decomposition of H_2O_2 - sample data

   50 mL hydrogen peroxide: $T_{initial}$ = 20.0°C

Added 10 mL of 0.5 M iron (III) nitrate
T_{final} = 34.8°C
Student should observe the evolution of bubbles from the mixture and the change of color from pale yellow to darker amber color and back to pale yellow.

3. Show all calculations.

Calorimetry Constant –sample set of data

Room temperature water (50.0 mL): T_1 = 22.4°C and T_2 = 30.5°C
Warm water (50.0 mL): T_1 = 39.6°C and T_2 = 30.5°C

$$q_{gained\ cold\ water} = m\ c\ \Delta T = 50.0\ g\ x\ 4.184\ \frac{J}{g\ °C}\ x\ (8.1°C) = \mathbf{16}94.5\ J$$

$$q_{lost\ warm\ water} = m\ c\ \Delta T = 50.0\ g\ x\ 4.184\ \frac{J}{g\ °C}\ x\ (9.1°C) = \mathbf{19}03.7\ J$$

$$q_{gained\ calorimeter} = 1903.7 - 1694.5 = \mathbf{2}09.2\ J$$

$$C_{cal} = \frac{q_{cal}}{\Delta T} = \frac{209.2\ J}{8.1\ °C} = \mathbf{2}5.8\ J/°C$$

Significant figures are indicated in black.

Acceptable ranges would include 0-60 J/°C

Decomposition of H_2O_2 - sample data

50.0 mL hydrogen peroxide: $T_{initial}$ = 20.0°C
Added 10.0 mL of 0.5 M iron (III) nitrate
T_{final} = 34.8°C

$$q_{calorimeter} = C(T_f - T_i) = \mathbf{2}5.8\frac{J}{°C}(34.8°C - 20.0°C) = \mathbf{3}81.8\ J$$

$$q_{solution} = c(T_f - T_i) = 4.184\frac{J}{g\ °C}(60.0\ g)\ (14.8°C) = \mathbf{371}5\ J$$

$$q_{total} = q_{cal} + q_{sol} = \mathbf{3}81.8 + 3715\ J = \mathbf{40}97\ J$$

3% Hydrogen peroxide, assume density = 1 g/mL - Students will need to calculate the moles of hydrogen peroxide added:

$$molarity = \frac{3\ g\ H2O2}{100\ g\ soln}\ x\ \frac{1\ g\ soln}{1\ mL}\ x\ \frac{1000\ mL}{L}\ x\ \frac{1\ mol}{34.04\ g} = \mathbf{0.8813}2M$$

$$mole = 0.88132\ \frac{mol}{L}\ x\ 0.0500L = \mathbf{0.0440}7\ mol$$

Enthalpy of decomposition

q_{rxn}= -q_{total}

$$\Delta H = \frac{qrxn}{n} = \frac{-\mathbf{40}97\ J}{\mathbf{0.0440}7\ mole} = -\mathbf{93},100\ J/mol$$ **(-92,975 KJ/mol)**

Literature value is -94.6 kJ/mol.
Acceptable ranges: -92.7 and 96.5 kJ/mol

4. The enthalpy of decomposition of hydrogen peroxide is: ______

   Literature value is -94.6 kJ/mol.
   Acceptable ranges: -92.7 and 96.5 kJ/mol

5. What is the role of the $Fe(NO_3)_3$ in the reaction? Provide experimental evidence to support your answer.

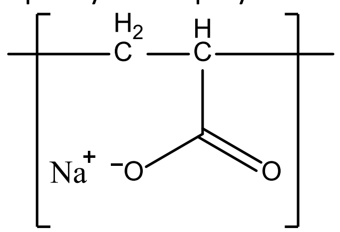
   A careful student would likely not open the coffee cup calorimeter during the experiment. Provided the prompt in the question, a strong student could perform a small scale reaction in a beaker to observe the reaction occurring.

   The iron (III) nitrate catalyzes the decomposition of the hydrogen peroxide. A good experimental finding that supports this answer is that the rate of bubble formation increases in the presence of the iron(III)nitrate. An excellent answer indicates the color change from pale yellow to darker color back to the pale yellow demonstrating that the catalyst is not consumed in the reaction. Another excellent answer could include providing the mechanism of decomposition (Haber-Weiss Cycle):

   $Fe^{3+} + H_2O_2 \rightleftharpoons [Fe^{III}OOH]^{2+} + H^+$
   $[Fe^{III}OOH]^{2+} \rightleftharpoons [Fe^{V}O]^{3+} + H_2O$
   $[Fe^{V}O]^{3+} + H_2O_2 \rightleftharpoons Fe^{3+} + H_2O + O_2$

Lab Problem 2

Sodium polyacrylate is a superabsorbent polymer utilized in household items such as diapers, artificial snow, and water absorbing spheres. Using the provided materials, characterize the capacity of the polymer to absorb the provided aqueous substances.



Answer Sheet:

1. Give a brief description of your experimental plan

   - Excellent plan indicates a strategy to determine the absorption properties of the polymer

    - use a standard amount of polymer (either spatula full or some mass amount) for each trial
    - add small quantities of each solution and observe the addition of solution to the polymer
    - determine in terms of drops or volume the amount of solution absorbed
- Alternative excellent plan includes
    - use a standard volume of solution for each trial
    - add small quantities of polymer to the solution until the mixture solidifies
    - quantify the amount of polymer added
- Replicate measurements

2. Record your data/observations.

Starting with approximately the same amount of polymer (spatula full) and counting the amount of drops added to the sample before the polymer no longer absorbs the solution

Solution	**Number of Drops**
Ammonium chloride	6-7 drops
Magnesium chloride	3-4 drops
Sodium chloride	8 drops
water	26-27 drops
Glucose	30-32 drops

Alternative trial

Solution	Mass of polymer before adding solution	Mass of polymer plus solution (added until saturation)	Mass of solution absorbed per gram of polymer
Ammonium chloride	0.068 g	7.427 g	110
Magnesium chloride	0.068 g	3.467 g	50
Sodium chloride	0.067 g	7.275 g	110
Water	0.066 g	27.84 g	410
Glucose	0.067 g	21.09 g – ran out of 25 mL solution	>310

3. The order of absorption of the aqueous solutions by the polymer is:

Least absorbed most absorbed

Mg^{2+} (aq) < NH_4^+ (aq) ≤ Na^+ (aq) < glucose ≤ water

4. Explain the observed trend in the data using chemical principles.

   Water is absorbed by the polymer through osmotic swelling of the gel. When water is added to the polymer network, the sodium ions distribute equally between the network and the solution. To maintain the osmotic pressure inside and outside the network, the water molecules enter and swell the polymer network to keep the sodium concentration balanced between the water and polymer.

   The cations are attracted to the negative carboxylates in the backbone and the structure collapses or absorbs less water. The degree of swelling is proportional to the ionic charge, radius and the degree of hydration.

   An alternative explanation about the lower swelling with the divalent cation is that the divalent cation increases the cross-linking density of the polymer and reduces the equilibrium swelling.