TEAM EXAM

WUCT 2018

60 minutes are allotted for the team round. Team members are permitted and encouraged to work together on these questions. The team round will require answers that involve written explanations of students' thought processes in addition to numerical answers. Only responses written in the provided spaces on the exam will be graded. Clearly labelled answers on the back of each page will also be accepted. Students are not permitted to communicate with their coach in any way during this time, but they are encouraged to collaborate among themselves to work through the problems. As a general strategy, we recommended that the entire team do every question together as time would become an issue. At the end, the team must submit a single copy of each page of the exam to the proctor for grading. Please be certain that you are submitting every page on the team exam, otherwise the team will lose all points for the page(s) that were not submitted. Submitting multiple copies of a page will also lead to a loss of points.
Cheating will NOT be tolerated.

Team ID			
0	0	0	0
1	1	1	1
2	2	2	2
3	3	3	3
4	4	4	4
5	5	5	5
6	6	6	6
7	7	7	7
8	8	8	8
9	9	9	9

Team: ______________________________

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TEAM

Question 1

The question-writers at WUCT have been so busy struggling to write chemistry questions that they have begun to neglect their appearance, wearing dirty clothes repeatedly. Luckily for everyone involved, WUCT team round found a solution to both of their problems: laundry.

A key ingredient in laundry detergent, added to dirty clothes before washing, is a chemical called a surfactant. These surfactants are comprised of two parts: a nonpolar hydrocarbon end and a polar benzosulfate end. In the washing machine, the surfactant molecules surround nonpolar fat/oil stains and remove them from the clothes in the process.

a. (2 points) Sketch an oil stain surrounded by surfactant molecules in the water. The surfactant molecules need only include a labeled distinction between ends. Clearly label all important elements of your sketch.

Sketch should show oil stain with shapes representing surfactant molecules around it. The ends closest to the oil stain should be labeled as "hydrocarbon/nonpolar" and the ends pointing out towards the water should be labeled as "polar/benzosulfate."

b. (2 points) Explain the process of stain removal by the surfactant molecules in terms of intermolecular interactions.

In order to maximize favorable intermolecular interactions, the surfactant molecules align their nonpolar ends towards the stain to avoid interacting with the polar molecules of water. This tendency to avoid unfavorable interactions causes the surfactant molecules to surround the stain and detach from the clothes to be washed down the drain.

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After washing clothes, a machine dryer is used to finish the laundry process. In order to soften clothes, prevent static cling, and provide a fresh scent, a dryer sheet is placed into the dryer along with the wet clothes. Dryer sheets are coated with softening agents that contain fragrance molecules and positively-charged atoms with long hydrophobic chains. This coating melts in the heat of the dryer and releases the agent's molecules to bind to the clothes.

c. (2 points) Suppose the melting point of the dryer sheet coating is similar to that of solid molecular iodine at standard conditions. Would you expect this point to be higher or lower than solid NaI? Explain.

It will be lower because molecular solids have weak intermolecular forces holding them together while NaI is held together by ionic bonds, which require a lot of energy to break.

d. (2 points) Given that static cling is due to a buildup of electrons through close contact, propose how dryer sheets reduce static cling, paying close attention to what happens at the atomic level. Remember that the surfactant molecules are positively charged.

The positively-charged atoms can prevent buildup by accepting electrons.

Alternative Answer: The surfactant molecules provide a barrier between clothes, reducing friction and thus reducing buildup of electrons.

e. (2 points) Dryer sheets must contain fragrance molecules that don't evaporate at typical dryer heat. Consider a dryer that starts at 25℃ and supplies a total of 42 kJ of energy. If the boiling point of fragrance molecule A is 135℃, will 3.7 mol of fragrance molecule A reach the boiling point in this dryer? ($\Delta H_{vap} = 15\ \frac{kJ}{mol}$, $\Delta H_{fus} = 6\ \frac{kJ}{mol}$, $specific\ heat\ capacity = 50\ \frac{J}{mol\ x\ K}$, $Melting\ point\ =\ 90$℃)

Equations needed: $q=mc\Delta T$, $q = m\Delta H$

q_{liquid} = (3.7 mol) * (50 J/(mol*K)) * (65 K) = 12025 J = 12.025 kJ
q_{fusion} = (3.7 mol) * (6 kJ/mol) = 22.2 kJ
q = 42 kJ - 12.025 kJ - 22.2 kJ = 7.775 kJ = 7775 J
t_{final} = q/ (mc) + $t_{initial}$ = 7775 J / (50 J/(mol*K) * 3.7) + 363 K = 405 K - 273 = 132℃

No, it doesn't reach boiling point.

DO NOT WRITE BELOW THIS LINE

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Question 2

Scientists recently discovered a new chemically covalent compound and are having trouble determining its makeup and structure. Help the scientists determine the chemical structure by using the information they have already collected.

a. (3 points) Determine the central atom of the compound by using the data listed below:

- Oxygen has a higher electronegativity than the central atom
- The central atom has been found in both covalent and ionic compounds
- Phosphorus has a smaller ionization energy than the central atom
- The central atom has a larger atomic radius than Argon
- The central atoms valence electrons are located in the 3p orbital
- The central atom has an even number of protons

Sulfur

b. The molecular mass for the compound is determined to be 162.51 g/mol and the compound displays an octahedral molecular geometry.

i. (2 points) Using this information, determine which and how many of the following elements surrounds the central atom. (Note: The compound contains no more than two different outer elements)

Element	Molecular Weight (g/mol)
Chlorine	35.453
Hydrogen	1.0079
Sulfur	32.066
Fluorine	18.998

Total - Sulfur = Surrounding Atom

162.51 - 32.06 = 130.45 g/mol

$1x + 5y = 130.45$

Or

$2x + 4y = 130.45$

Or

$3x + 3y = 130.45$

Correct answer: Chlorine, 5 Fluorine

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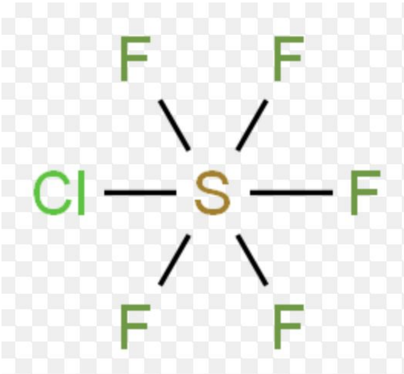
ii. (1 point) Draw the lewis dot diagram for this molecule.



iii. (1 point) What is the name of this compound? Use IUPAC convention when naming.

Sulfur chloride pentafluoride

iv. (1 point) What are the bond angles for this compound?

90 Degrees

c. (2 points) Suppose scientists are successfully able to ionize the molecule by removing one of the atoms surrounding the central atom, leaving the central atom with a positive charge. Sketch the resulting ion, illustrating and clearly indicating its geometry.

Sketch should be square pyramidal

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Question 3

The wave-particle duality of light describes that light exhibits properties of both waves (electromagnetic wave) and particles (photon). Generally speaking, the energy of a photon can be related to the wavelength of an electromagnetic wave using the equation $E = \frac{hc}{\lambda}$; E is the energy carried by the photon with unit Joule, h is Planck's constant 6.626×10^{-34} J·s, c is the speed of light 3×10^{8} m·s^{-1}, λ is the wavelength in units of meters. The duality concept is applied in microscopes used in research labs.

Scientists use fluorescence microscopy to excite fluorophores so that they can observe micro scale organelles by looking at the fluorescence. Normally fluorescence microscope (for example, confocal microscopy) uses one photon excitation meaning that photons are emitted and absorbed one at a time. After the concept of two photon excitation was introduced, two photon excitation microscopy was invented and put into use. Two photon excitation microscopy emits two photons one after another within a very short time difference as if the two photons are absorbed at the same time. In the following questions, we assume that both of the photons emitted have the same wavelength of infrared light which is 700 nm.

a. (3 points) It is shown that in two photon microscopy, the wavelength of each photon emitted is greater than that of an equivalent photon absorbed. If the total energy absorbed by the fluorophore is the total energy of the two photons, what is the wavelength of the one equivalent photon emitted?

   The energy of each photon:

   E = hc / lambda = (6.626*(10^(−34)) J*s)*(3*10^8 m/s) / (700*10^(−9) m) = 2.83*10^(-19) J

   The energy of two photons:

   E' = 2E = 5.68*10^(-19) J

   Wavelength of the light:

   Lambda' = hc / E' = (6.626*(10^(−34)) J*s)*(3*10^8 m/s) / (5.68*10^(-19) J) = 3.5*10^(-7)m = 350nm

   (Basically just 700nm/2 = 350nm)

b. (3 points) Suppose you are using the two photon excitation microscopy to excite a fluorophore whose excitation wavelength is 665nm and emission wavelength is 716nm. Will you be able to see fluorescence under the microscope? If you are able to see fluorescence, explain why and tell what color will you see? Refer to the chart on the following page. If you are not able to see fluorescence, explain why and calculate how much extra energy is needed for the fluorophore to be excited?

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Color	Wavelength	Frequency	Photon energy
Violet	380–450 nm	668–789 THz	2.75–3.26 eV
Blue	450–495 nm	606–668 THz	2.50–2.75 eV
Green	495–570 nm	526–606 THz	2.17–2.50 eV
Yellow	570–590 nm	508–526 THz	2.10–2.17 eV
Orange	590–620 nm	484–508 THz	2.00–2.10 eV
Red	620–750 nm	400–484 THz	1.65–2.00 eV

Yes, because 665nm > 350nm, enough energy to excite the fluorophore. 716nm: red

c. (4 points) FRET, or Forster Resonance Energy Transfer, is a mechanism describing the energy transfer between 2 light sensitive molecules called chromophores. The energy transfer usually occurs in a pair of chromophores, with the donor chromophore transferring its energy to a nearby acceptor chromophore. The efficiency of the energy transfer (FRET efficiency) can be described by the equation $E = \frac{1}{1+(r/R0)^6}$. R_0 is the Forster distance between the donor and acceptor, which is also the distance at which the energy transfer efficiency is 50% and r is the actual distance between donor and acceptor chromophores. FRET efficiency represents the fraction of energy transfer event occurring per donor excitation event, which can be described by the equation:

$$E = \frac{energy\ transferred}{energy\ emitted\ by\ the\ microscope}\ x\ 100\%$$

Suppose there are two proteins whose R_0 value is 5nm. When the two proteins are bound together and the donor protein is excited by the 415nm UV light, the acceptor protein releases a 526nm yellow light. When the two proteins are cleaved by a protease and the donor protein is excited by a 415nm UV light, the donor protein releases a 477nm cyan light. What is the distance between the two proteins when they are bound together?

Efficiency = [(hc/415-hc/526)] - [(hc/415-hc/477)] / (hc/415) = E = 1/ [1+(r/5)^6]

r = 7.43nm

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Question 4

The bicarbonate buffer system, combined with the respiratory system, is essential for maintaining blood pH of the human body. Red blood cells convert carbon dioxide that is dissolved in the blood into carbonic acid, which may then dissociate to bicarbonate and hydrogen ions, depicted by the following equation:

$$H^+ (aq) + HCO_3^- (aq) \rightleftharpoons H_2CO_3 (aq) \rightleftharpoons H_2O (l) + CO_2 (g)$$

Furthermore, the primary function of the respiratory system is to exchange two gases: the body inhales oxygen for its metabolic needs and exhales carbon dioxide as a waste product.

a. Using Le Châtelier's Principle, answer the following questions:

  i. (1 point) What happens to the pH of the blood as a person holds his or her breath? Explain in 1-2 sentences.

Since no CO_2 is being exhaled, the reaction is pushed "to the left," and $[H^+]$ increases. Thus, the pH decreases.

  ii. (1 point) What happens to the pH of the blood as a person hyperventilates, or breathes at an abnormally rapid rate? Explain in 1-2 sentences.

As more CO_2 is exhaled, the reaction is pushed "to the right," and $[H^+]$ decreases. Thus, the pH increases.

  iii. (1 point) One method for countering the effects of hyperventilation is breathing into a closed paper bag. Explain why this technique is effective in 1-2 sentences. Recall that CO2 is expelled from the body during exhalation.

When you breathe into a closed paper bag, you are rebreathing your exhaled CO_2. Increasing the amount of CO_2 in you body then acts to counteract the pH increase due to hyperventilation.

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iv. (1 point) Hyperventilating before diving underwater is a risky practice that can lead to freediving blackout, a loss of consciousness caused by lack of oxygen. Usually, the diver does not experience an urgent need to breathe. Explain this seemingly paradoxical phenomenon. (Hint: the need to breathe is triggered by low pH levels in the blood).

Hyperventilating drives your blood pH to a level higher than normal. As you hold your breath under water, the blood pH decreases. Since the starting point for blood pH is higher than normal, it takes longer for the pH to reach a level that triggers the need to breathe. Thus, your body can run out of oxygen before you experience a need to breathe.

b. During cellular respiration in the human body, the cell converts energy from nutrients into ATP and byproducts. There are two modes of cellular respiration: aerobic, in which the cell uses oxygen, and anaerobic, in which the cell does not use oxygen. The (unbalanced) chemical formulas for each type are given below:

Aerobic: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + ATP$

Anaerobic: $C_6H_{12}O_6 \rightarrow Lactic\ Acid + ATP$

i. (1 point) What happens to the pH of the blood during aerobic respiration? Explain in 1-2 sentences.

The CO_2 byproduct increases the concentration of CO_2 in the blood, driving the reaction "to the left." Thus, the pH of the blood decreases.

ii. (1 point) What happens to the pH of the blood during anaerobic respiration? Explain in 1-2 sentences.

The pH of the blood also decreases. The lactic acid product releases more $[H^+]$ into the blood, further lowering the pH.

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c. The acid dissociation constants of H_2CO_3 are $K_{a1} = 4.45 \times 10^{-7}$ and $K_{a2} = 4.69 \times 10^{-11}$. Calculate the pH of the following solutions:

i. (1 point) 1.00 M solution of H_2CO_3 in water. (Assume the formation of CO_3^{2-} is negligible)

The pH is determined by the first acid dissociation constant, because the contribution to pH of the second dissociation is negligible.

	H_2CO_3	H^+	HCO_3^-
I	1.00 M	0 M	0 M
C	- x	+ x	+ x
E	1 - x	x	x

$$\frac{x^2}{1-x} = 4.45 * 10^{-7}$$

Since x is small compared to 1, approximate (1 – x) as 1.

$$x^2 \approx 4.45 * 10^{-7}$$

$$x = [H^+] \approx 6.67 * 10^{-4}$$

$$pH = -\log [H^+] \approx 3.156$$

ii. (1 point) 1.00 M solution of $NaHCO_3$ in water

$$pK_{a1} = -\log (4.45 * 10^{-7}) \approx 6.35$$

$$pK_{a2} = -\log (4.69 * 10^{-11}) \approx 10.33$$

$$pH \approx \tfrac{1}{2}(pK_{a1} + pK_{a2}) \approx 8.34$$

ICE Chart works too, but takes longer.

iii. (2 points) 1.00 M solution of Na_2CO_3 in water. (Assume the formation of H_2CO_3 is negligible)

$$CO_3^{2-} + H_2O \leftrightarrow HCO_3^- + OH^-$$

$$K_{b2} = \frac{10^{-14}}{K_{a2}} = 2.13 * 10^{-4}$$

	CO_3^{2-}	HCO_3^-	OH^-
I	1.00 M	0 M	0 M
C	- x	+ x	+ x
E	1 - x	x	x

$$\frac{x^2}{1-x} = 2.13 * 10^{-4}$$

Since x is small compared to 1, approximate (1 – x) as 1.

$$x^2 \approx 2.13 * 10^{-4}$$

$$x = [OH^-] \approx 1.46 * 10^{-2}$$

$$pOH = -\log [OH^-] \approx 1.84$$

$$pH = 14 - pOH \approx 12.16$$

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d. In controlled conditions, a beaker contains 1 L of solution that is similar to the bicarbonate-buffer system in the blood, with the concentration of dissolved CO_2 being 2mM and the concentration of dissolved HCO_3^- being 30mM. Assume that the value of K for this system is also $8.0x10^{-7}$.

   i. (1 point) Calculate the pH of this solution.

$$pH = pK - log\left(\frac{[CO_2]}{[HCO_3^-]}\right)$$

$$pH = 6.1 - log\left(\frac{2\ mM}{30\ mM}\right) = 7.28$$

   ii. (1 point) Calculate the pH of the solution after 2 mmol of HCl is added to the original solution.

$$pH = 6.1 - log\left(\frac{4\ mM}{28\ mM}\right) = 6.95$$

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iii. (2 points) Calculate the pH of the solution after 2 mmol of NaOH is added to the original solution.

All of the CO_2 is used to neutralize the added NaOH. Thus, the pH is dictated solely by HCO_3^-.

$$pK_{a1} = -\log(4.45 * 10^{-7}) \approx 6.35$$
$$pK_{a2} = -\log(4.69 * 10^{-11}) \approx 10.33$$

$$pH \approx \frac{1}{2}(pK_{a1} + pK_{a2}) \approx 8.34$$

iv. (1 point) Based on your answers in parts (a)-(c), is the bicarbonate-buffer system better suited to countering the effects of acidosis (excessively acidic body fluids) or alkalosis (excessively basic body fluids)? Explain in 1-2 sentences.

The bicarbonate-buffer system is better suited to countering acidosis, because the pH change upon the addition of strong acid is smaller than the pH change upon the addition of an equal amount of strong base.

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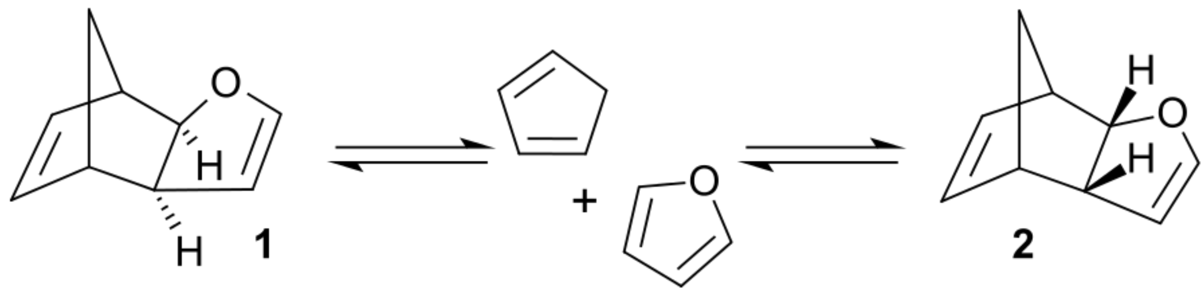
Question 5
In the organic reaction below, two products can form. Product 1 forms spontaneously at 25°C and after a short reaction time. Product 2 forms spontaneously at 81°C and after a long reaction time.



a. (2 points) At 50°C, which product will have a larger amount formed? Why?

Product 1 will have a larger amount formed because it forms spontaneously at 25°C while Product 2 requires a temperature of 81°C to form.

b. (2 points) Given that entropy decreases in the formation of Product 1, predict the sign of the enthalpy change in the formation of Product 1 at 25°C. Justify your answer with respect to thermodynamic principles.

Using the Gibbs free energy equation, the sign of the entropy term will be positive since the change in entropy is negative. Since the reaction happens spontaneously, the sign of the change in Gibbs free energy must be negative so that means the change in enthalpy must be negative.

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c. (3 points) With all other conditions being constant, suppose the temperature in part (b) is raised to 81°C and the reaction is allowed to continue for a long time**.** Compare the activation energy of the resulting reaction to the reaction at 25°C.

The activation energy of the formation of Product 2 will be higher than the activation energy of the formation of Product 1 since more thermal energy is needed for the reaction to occur.

Alternate Justification: Since Product 1 is favored kinetically, it must have a lower activation energy that Product 2.

d. (3 points) A back-reaction occurs when the reactants backform from Product 2 to establish equilibrium. Assuming that the enthalpy change in the formation of Product 2 is the same sign as in Product 1, how will increasing the temperature from 81°C affect the equilibrium constant of the back-reaction?

Since the formation of Product 2 is exothermic, the retro-Diels-Alder reaction must be endothermic. Increasing the temperature will shift equilibrium to the right, favoring the formation of cyclopentadiene and furan.

(If the sign in part b was said to be positive, points will be awarded for correct reasoning to conclude that the equilibrium will shift left, favoring the formation of Product 2)

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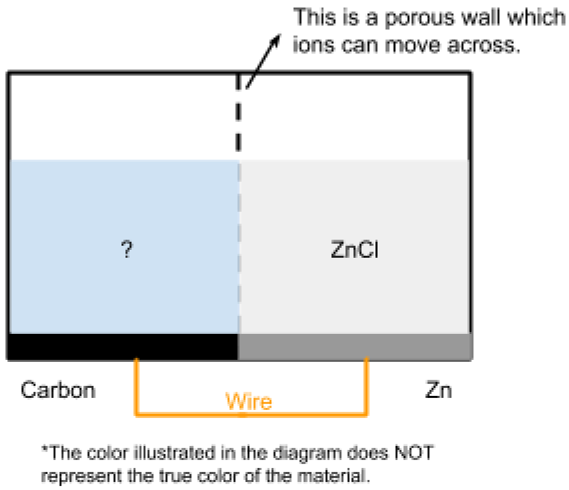
Question 6



(To solve this problem, you only need basic knowledge of oxidation-reduction reaction!)

The container has two chambers. The two chambers are connected with a porous wall which ions can move across. In the left chamber, a piece of graphite is placed on the bottom; in the right chamber, a piece of zinc is placed on the bottom. They both have an initial weight of 5 grams. They are connected with a wire.

The right chamber is filled with zinc chloride solution. The left chamber is filled with an unknown solution which contains samples of two chloride compounds of equal mass (actual mass, not molar mass). The two chloride compounds can be denoted as XCl_a and YCl_b, where X and Y are common metal elements. The solutions in both chambers are stirred.

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At each time point throughout the experiment, let's imagine all reactions are suspended, and the graphite and zinc are taken out as whole individual pieces to measure their weight. The weight of the graphite and zinc over time is recorded in the table below.

Time points	Total mass of the piece of graphite and the precipitate on it (g)	Total mass of the piece of Zn (g)
Before experiment	5.00	5.00
Time point 1	5.00	4.78
Time point 2	5.00	4.6
Time point 3	5.50	4.44
Time point 4	5.74	4.36
Time point 5	6.49	4.12

Your final goal in this problem is to work out the following questions

- What are the two chemical reactions in this experiment?
- What are the two unknown metal ions initially in the left chamber, including their oxidation state?
- What is the initial weight for the two unknown chloride compounds in the left chamber?

It may look a bit intimidating at first, but we'll guide you to the final answer through the following problems. Let's begin!

a. (2 points) As shown in the table, you know that a redox reaction took place between the beginning of the experiment and time point 3, but while the total mass of the piece of zinc is decreasing, the total mass of the piece of graphite and the precipitate on it remains the same. Please briefly explain this observation.

The redox reaction products are soluble in water.

b. (2 points) Two redox reactions total happened during the experiment: the first one went from before experiment to time point 2; the second one went from time point 3 to time point 5. Let's take a look at the second redox reaction. As shown in the table above, the mass of the graphite increased, which is caused by redox product precipitating on the graphite. Can you deduct from the table above whether the precipitate is pure metal solid or a metal compound? Show calculation to explain why. (For example, Zn is pure metal; $ZnCl_2$ is a metal compound)

Calculate how many moles of electrons transferred out of Zn ($Zn \rightarrow Zn^{2+}$)

2-3: 2* (4.6g - 4.44g) / 65.4g/mol = 0.0049mol

3-4: 2* (4.44g - 4.36g) / 65.4g/mol = 0.0024mol

4-5: 2* (4.36g - 4.12g) / 65.4g/mol = 0.0073mol

The following calculation is to determine whether the precipitate from this reaction was in the pure metal form or in the form of an insoluble metal chloride compound. If you divide the mass difference by the moles of electrons transferred calculated above, there could be two situations: 1) the precipitate is pure metal if the answers are the same as or are all multiples of a metal element's molar mass 2) otherwise it's a metal chloride compound.

2-3: (5.5g - 5g) / 0.0049mol = 102.04g/mol

3-4: (5.74g - 5.5g) / 0.0024mol = 100g/mol

4-5: (6.49g - 5.74g) / 0.0073mol = 102.74g/mol

You will find out that there should be no metal element that has a molar mass of 100g/mol. Then it must be the molar mass of a metal chloride compound.

c. (2 points) What is the precipitate? What is the second reaction? What is the reactant metal ion that is initially in the left chamber?

Try subtracting Cl's molar mass or multiples of that and find what the metal ion is. You will find out that there is only one Cl in the compound.

2-3: 102.04 - 35.5 = 66.54

3-4: 100 - 35.5 = 64.5

4-5: 102.74 - 35.5 = 67.24

The molar mass of Cu is around 64, 65 g/mol and the precipitate is CuCl, which means the original compound in the left chamber is $CuCl_2$. Reaction 2 is $Zn + 2Cu^{2+} \rightarrow Zn^{2+} + 2Cu^{+}$

d. (2 points) Assume time point 5 is the end of the experiment and the second reaction has stopped by then. The metals ions in part c have all precipitated out. Then what is the initial mass of the two unknown chloride compounds?

How much CuCl precipitated out: (6.49g-5g)/99.5g/mol = 0.015mol

Molar mass of CuCl2: 135g/mol

Weight of the two unknown chloride compounds: (0.015mol) * 135g/mol = 2g

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e. (2 points) Remember, we still haven't figured the other metal ion. We know in the redox reaction that this metal ion is involved in, the metal ion decreased one oxidation state. Then what is the other metal ion initially in the left chamber? What is the first reaction?

Moles of electrons transferred when Zn reacted with the other chloride compound:
2* (5g - 4.6g) / 65.4 g/mol = 0.0122 mol
Suppose there were n moles of the other compound, then there should have been n moles of electrons transferred. Its molar mass is 2g / 0.0122mol = 163.93 g/mol. This is about the molar mass of FeCl3. So the other compound is $FeCl_3$
Reaction 1 is $Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$

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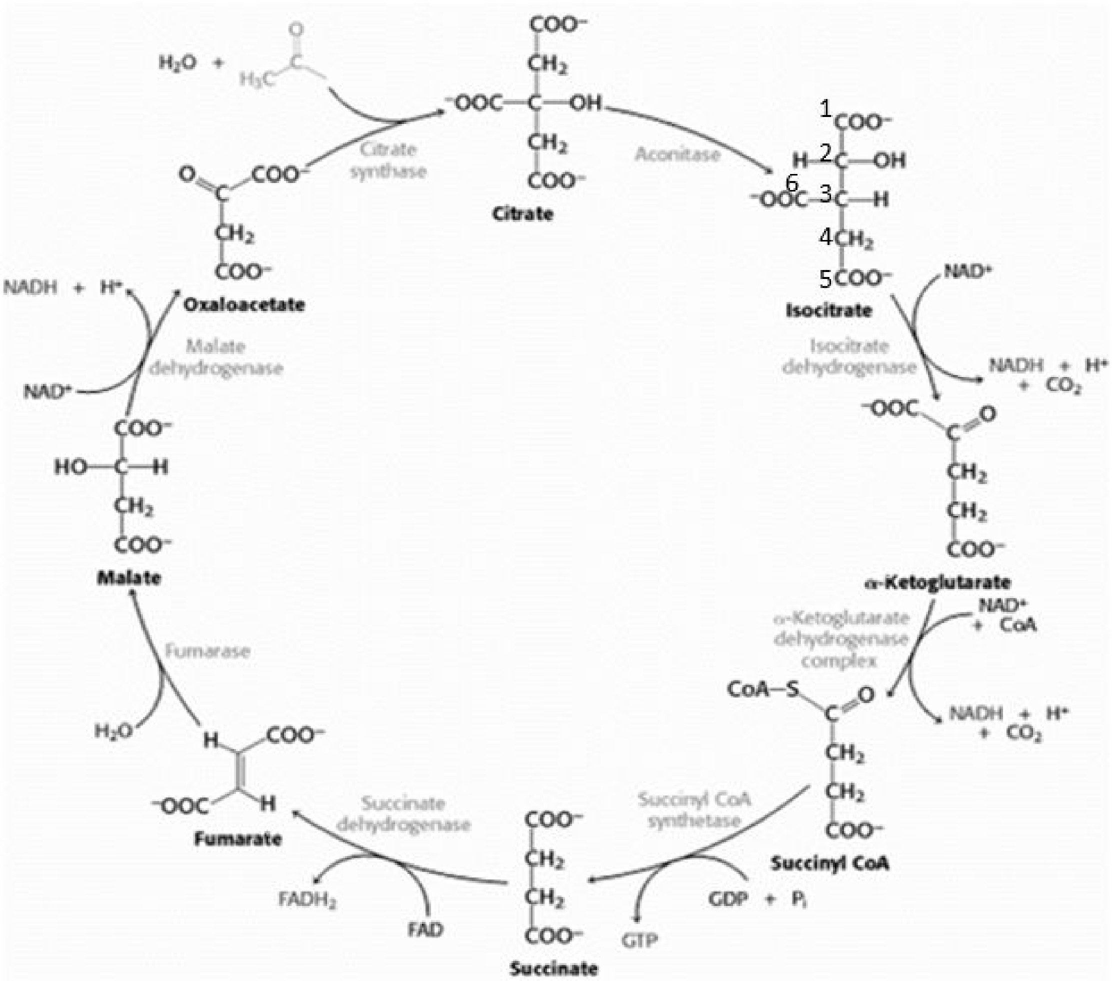
Question 7

The tricarboxylic acid (TCA) cycle, also known as the citric acid cycle, is an essential step of cellular respiration. The cycle takes as input carbon from glucose metabolism and converts it into energy used to generate ATP. Below is a schematic showing the set of reactions that comprise the TCA cycle.



Suppose you are able to track the molar masses of all TCA cycle intermediates. You perform a series of reactions in which you label isocitrate, a TCA cycle intermediate with ^{13}C. The carbons in **isocitrate** are referred to by number and are shown in the diagram above, **to the left of each carbon atom**. The results of 2 such reactions are shown below:

Experiment 1: Carbon 1, Carbon 5 labeled with ^{13}C. Result: succinate has molar mass 119.09 g/mol

Experiment 2: Carbon 5, Carbon 6 labeled with ^{13}C. Results: succinate has molar mass 119.09g/mol

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a. (3 points) Suppose you label Carbon 1 and Carbon 6 with ^{13}C (Experiment 3). Predict all possible results for succinate's molar mass.

All possibilities: no 13C removed (120.09 g/mol), 1 13C removed (119.09 g/mol), both 13C removed (118.09 g/mol)

b. (2 points) Circle the two results consistent with Experiment 1 and Experiment 2.

From experiment 1 and 2, either both C1 and C6 removed (118.09 g/mol), or neither removed (120.09 g/mol)

c. (1 point) Before you can run Experiment 3, your labeling machine malfunctions; due to this, you may only label one carbon instead of two. Design an experiment (Experiment 4) in which you label a single carbon atom in isocitrate and measure the resulting molar mass of succinate produced to rest which of the two results from (b) actually occur. Experiments should say something like "Carbon X labeled with ^{13}C."

Student may label either C1, C5, or C6

d. (4 points) Explain how your experiment helps distinguish between the two results from part (2) by giving the expected result (succinate's molar mass) of Experiment 4 in each case.

C5: if molar mass is 119.09, then C5 is not removed -> result of experiment 3 should be 118.09
If molar mass is 118.09, then result of experiment 3 should be 120.09.
C1 or C6: if molar mass is 119.09, then result of experiment 3 should be 120.09
If molar mass is 118.09, then result of experiment 3 should be 118.09.