Chem Lab C - Chem Lab - Camas C-Invite - 12-12-2020

Hello competitors! My name is Roland Hu (University of Washington Biochem 2024, formerly Palo Alto HS 2020) and I'll be your Camas SO Chemistry Lab Event Supervisors. Before w get started there are a few thing we need to go over.

1. Please provide the necessary information requested on the previous page! It will make everything go a lot more smoothly.

2. Please show your work and write your answers on the provided answer sheet! We will not be grading the test document. Make sure to box your answers on the answer sheet so we know what to look for.

3. For each multiple choice question, we will only be grading the letter you write down on the answer sheet/Scilympiad. You do not need to show work, although you probably will need t write equations down for a couple of questions. (You can either type your work directly into Scilympiad or do it on a piece of paper and upload that)

4. For each free response question, we will be grading your work! Make sure you carefully show each step so that if you make a mistake, we can still give points for work.

5. Make it clear which problem you are working on at any point. For example, if you are working on problem 2.c., please write down 2.c. at the start of the problem.

6. There is a periodic table on the following page, as required by the rules. Any necessary constants/values/whatever will be provided in/before the question if necessary.

7. We won't grade significant figures, but try to be reasonable.

8. Unless the question says differently, assume physical conditions are 25C° and 1 atm.

9. If you believe there is a mistake in the exam, please ask right away so we can clarify for you and the rest of the test-takers as soon as possible.

10. Good luck and have fun!

Tables and Stuff (https://scilympiad.com/Data/turs/10H6/tests/00015X/Camas_Chem_Lab_Supp.pdf)

If you have any questions about the exam after it has concluded whether you are a Camas SO competitor, taking this test for practice, reviewing the solutions and notice a mistake, or h any related chemistry question to this exam, please email us at rolandhu123@gmail.com.

1. (3.00 pts)
Chemistry is the study of matter and how it interacts with other forms of matter (typically bridging the macroscopic and microscopic). List 3 branches/fields of chemistry:

Expected Answer: Many answers can work some examples include: inorganic, organic. physical, computational, biological, etc. 1 pt for each correct response

2. (1.00 pts) The Michaelis-Menten assumptions are integral to understanding the kinetics of enzyme-based reactions. Which of the following is NOT one of these assumptions?

- (●) A) Substrate is present in slightly greater quantities than the enzyme
- ( ) B) In a steady state, the concentration of the intermediate is always constant
- ( ) C) Rate is highest when enzyme catalytic sites are saturated with substrate
- ( ) D) The reaction between the substrate and the enzyme is reversible

3. (2.00 pts)
Hydrazine, N_2H_4, is manufactured at extremely high pressures and temperatures using ammonia gas and producing hydrogen gas. If 22.4 liters of ammonia gas are used to make hydrazine, how many liters of hydrazine gas are produced?

Expected Answer: 11.2 L 1 pt for number 1 pt for units

4. (2.00 pts) Being a foolish chemists, you accidently drop a graduated cylinder full of concentrated sulfuric acid. What is the first thing you should do?

Expected Answer: 2 pts for an answer that says to neutralize the acid with a base 1 pt for saying to wash it with water.

5. (1.00 pts) NaCl is well known as table salt (along with anticaking agents such as starch). What is the IUPAC name for this compound?

- (●) A) Sodium Chloride
- ( ) B) Natrium Carbon iodide
- ( ) C) Nacl (pronounced NAH-kul)
- ( ) D) Sodium chlorine

6. (1.00 pts) What is the IUPAC name for water?

- ( ) A) Dihyrdogen oxgenide
- ( ) B) Mickey mouse molecule
- ( ) C) Hydroxic acid
- (●) D) Dihydridooxygen

7. (1.00 pts) How many millimeters are there in 2.45 meters?

- ( ) A) 245
- (●) B) 2450
- ( ) C) 24500
- ( ) D) 245000

8. (1.00 pts) Which ion is most likely to form a precipitate

- ( ) A) NO3-
- ( ) B) NH4+
- ( ) C) Na+
- (●) D) CO3-

9. (1.00 pts) Which acid/base indicator has a pH range of 6-7?

- ( ) A) Phenolphthalein
- (●) B) Bromothymol blue
- ( ) C) Methyl red
- ( ) D) Potassium dichromate

10. (1.00 pts) What is the name for a compound that can act as both an acid or a base?

Expected Answer: Amphoteric no credit for amphiprotic

11. (1.00 pts) Given that Ksp of compound A is twice as large as the Ksp of compound B, which of the following is true?

- A) Compound A is twice as soluble as compound B
- B) Compound B is twice as soluble as compound A
- C) Compound A will deposit more mass of precipitate than compound B
- D) None of the above

12. (2.00 pts)
Bismuth has a negative slope between the solid and liquid boundary on a phase diagram. Based on the given information what does this tell you about bismuth when it freezes?

Expected Answer: Bismuth expands

13. (1.00 pts) Tartaric acid is an important food additive. Write out the molecular formula for it.

Expected Answer: HO2C-CH(OH)-CH(OH)-CO2H or (CH(OH)COOH)2

14. (1.00 pts) Which of the following compounds can be used as a buffer?

- A) Sodium hydroxide and water
- B) Dichromate and chromic acid
- C) Bromic acid and Bromide
- D) Oxalic acid and oxalate

15. (1.00 pts) HCl and HBr are both strong acids, but their relative strengths can be determined by what principle?

Expected Answer: Leveling effect

16. (1.00 pts) After burning a mixture of hydrocarbons, you notice some black stuff on the surface. What is the chemical formula of this black stuff?

Expected Answer: C no credit for carbon, coal, or soot

17. (1.00 pts) What is the pKa of water?

Expected Answer: 15.7 so credit for 14

18. (1.00 pts) A drink has a pH of 4. This drink is?

(Mark **ALL** correct answers)

- [ ] A) Basic but not acidic
- [x] B) Acidic but not basic
- [ ] C) Both acidic and basic
- [ ] D) Neither acidic nor basic

19. (1.00 pts) Based on HSAB theory, which compound is predicted to have the lowest solubility?

(Mark **ALL** correct answers)

- [ ] A) AgF
- [x] B) CaF2
- [ ] C) LaCl3
- [ ] D) Li2CO3

20. (1.00 pts)
A NaOH solution is to be standardized by titrating it against a known mass of potassium hydrogen phthalate, KHP. Which procedure will give a molarity of NaOH that is too low?

(Mark **ALL** correct answers)

- [ ] A) Deliberately weighing one half the recommended amount of KHP
- [ ] B) Dissolving the KHP in more water than is recommended
- [x] C) Neglecting to fill the tip of the burette with NaOH before titrating
- [ ] D) Losing some of the KHP solution from the flask before titrating

The next few questions are all long response! The background information will be given before hand in a text block and the questions will be split into multiple parts.

Explosive Fertilizer!

Back in April, in the city of Beirut in Lebanon, there was an explosion involving the West Fertilizer Company. The primary explosive was the agricultural fertilizer ammonium nitrate, specifically 2,750 metric tonnes of it. Given the values in table (which is attacked seperatly) and the reaction for following reaction, answer the questions.

$NH_4NO_3(s) \rightarrow N_2O(g) + 2 \cdot H_2O(g)$

21. (3.00 pts) 1) [3] How much heat is released per mole of ammonium nitrate?

Expected Answer: 1. From the given data, we see the enthalpies of formation of the relevant species (in kJ/mol) $H_2O(g)$: -241.8 $N_2O(g)$: 82.1 $NH_4NO_3(s)$: -365.6 By Hess' law we can find the enthalpy of the given reaction (where mol_rxn is equal to mol_NH_4NO_3): ΔH = [2(-241.8 kJ/mol) + 82.1 kJ/mol] - [-365.6 kJ/mol] = -35.9 kJ/mol [2 for work 1 for right answer]

22. (3.00 pts) 2) [3] In ideal conditions, calculate the total amount of energy released in the form of heat as a result of the explosion.

Expected Answer: 2. Ammonium nitrate is 80.0 g/mol: (2750 metric tons) / (80.0 g/mol) = 34.4 Mmol (34.4 Mmol) (-35.9 kJ/mol) = -1.23 TJ So 1.23 TJ of energy released assuming constant pressure [2 for work 1 for right answer]

23. (3.00 pts) 3) [3] How much water (in Litres) could you boil with energy given off by the explosion?

Expected Answer: 3. Heat of vaporization of liquid water is +40.7 kJ/mol, its specific heat is 75.3 J/(mol K), its molar mass is 18.0 g/mol and its density is 1.00 g/mL. If we start with water at room temperature (25 °C), then the heat required for heating and vaporization is (75 K)(75.3 J/(K mol)) + (40.7 kJ/mol) = 46.3 kJ/mol (1.23 PJ) / (46.3 kJ/mol) = 26.6 Mmol water (26.6 Mmol) (18 g/mol) = 479 Mg water (479 Mg) / (1 g/mL) = 479 kL water So 479,000 L of room temperature water could be vaporized. [2 for work 1 for right answer]

24. (2.00 pts)
4) [2] Ammonium nitrate has a standard molar entropy of 151.08 J/K·mol at standard conditions. What does this say about its Gibbs free energy with regards to increase in temperature?

Expected Answer: 4. $\Delta G = \Delta H - T\Delta S$, so if ΔS is positive, then ΔG will decrease as T increases. [anything along these lines is okay]

25. (4.00 pts)
5) [4] Assume the city of Beirut (19.8 km^2) to be a closed system with a height of 1 km. By how much does the composition of O2 in the air change as a result of the explosion?

Expected Answer: 5. Prior to the reaction, we can use ideal gas law to calculate moles of atmospheric gases at 25 °C: n = PV/RT = (1 atm)(19.8 km^3)/(R)(298 K) = 810 Gmol From the balanced equation, we see that 3 mol of gas is produced for every 1 mol of NH4NO3 that decomposes, so (34.4 Mmol)(3) = 103 Mmol of gas is produced. Therefore, as no new oxygen is produced, the percentage of oxygen in the atmosphere changes by a factor of (810 Gmol)/(810 Gmol + 103 Mmol) = 0.9999; the composition of atmospheric gases is essentially unchanged. [2 for work 2 for right answer with numerical backing otherwise max pts is 2]

MCB a Problem Oriented Guide

Mass-charge balance (MCB) is a technique for analyzing aqueous solutions containing multiple, simultaneously occurring equilibria (usually in the form of a system of equations). In this problem you'll use it to analyze the solubility of calcium fluoride in an acidic solution.

26. (2.00 pts) 1) [2] Write the dissolution of calcium fluoride and the formation of hydrofluoric acid.

Expected Answer: 1) CaF2 (s) -> Ca2- (aq) + 2 F-(aq) H+ (aq) + F- (aq) -> HF (aq) [Both equations for 1 pt, states for another pt]

27. (2.00 pts) 2) [2] Would adding more acid increase or decrease the solubility of calcium fluoride? Justify your answer.

Expected Answer: 2) Increase, because H+ reacts with F- , thus shifting the equilibrium for the dissolution of calcium fluoride to the right [any explanation with some form Le Chatelier's principle receives full credit]

MCB a Problem Oriented Guide cont.

You have obtained a solution of calcium fluoride buffered at a pH of 4.00. Each of the questions will walk you through how to determine the concentration of all ions. (note there are multiple ways to do this but for this problem use MCB techniques)

28. (3.00 pts)
3) [3] The first step of MCB (or any equilibria problem) is to write down all equilibrium expressions for all of the reactions occurring in the solution. (hint there are 3 of them)

Expected Answer: Ksp = [Ca2+][F-]^2 Ka = [H+][F-]/[HF] Kw = [H+][OH-] [each one is worth 1 pt]

29. (3.00 pts)

4) [2] Matter cannot be created nor destroyed (easily). With this in mind write down a mass- balance equation for the ions in this solution. (hint: how can we relate [Ca2+] to [F-] and [HF])

Expected Answer: 4) [F-] + [HF] = 2[Ca2+] [Has to be exact for full credit]

30. (1.00 pts)

5) [1] A way MCB problem can get difficult is by constricting one of the ions. In this problem pH of the solution is buffered at a pH of 4.00. By constricting the pH one of our equations no longer becomes consistent. Which equation is it?

Expected Answer: 5) The Charge Balance one. [The reason is that you can't account for the amount of positive charges because you can't make an assumption about the initial amount of positive charge.]

31. (1.00 pts) 6) [1] Calculate the concentration of protons in this solution.

Expected Answer: 6) [H+] = 10-pH M = 10-4.00 M = 1.0 × 10-4 M a. [No partial credit]

32. (10.00 pts)

7) [10] Now we have all of the information we need to calculate the solubility of CaF2 in a solution with a pH of 4.00. Solve the system of equations that you wrote down in previous parts of the problem (excluding the one that was deemed unnecessary in part 5) and determine [Ca2+], [F-], [HF], and the solubility of CaF2 in this solution. The Ksp of CaF2 is 4.0 × 10-11 and the Ka of HF is 6.6 × 10-4

Expected Answer: This one is super long and will be linked on a separate document. (along with all other frq answers)
https://docs.google.com/document/d/1ut49aUI9GWxJfv3jdFfJNMHHLVXzv_gYVMx83bF7j9s/edit?usp=sharing

Crooked Coffee

Note drinking coffee late in the day has been known to screw with your sleep schedule. Fortunately, this doesn't apply to coffee themed chemistry problems! :)

It has been said that there is a time and a place for decaffeinated coffee-- never and in the trash.

33. (4.00 pts)

1) [4] One method of decaffeinating coffee beans is called the Swiss Water Process. It involves soaking a batch of fresh coffee beans in very hot water to extract all the caffeine, oils, and flavorful molecules. The caffeine is selectively removed, and this mixture is heated with a fresh batch of coffee beans. Use solubility principles to explain why this will result in decaffeination of the second batch of beans without a huge loss of oils and flavor molecules.

Expected Answer: This process works because there is some equilibrium between the amounts of caffeine and oils/flavors present in the beans and in the solution. In the second round of heating, there is a lot of caffeine in the beans but none in the water, so the caffeine will be extracted and dissolve in the water until this equilibrium is reached. However, the water already contains a significant amount of oils/flavor molecules so the solution is nearly saturated with respect to these molecules, and there will not be a huge loss of oils/flavors

34. (2.00 pts)

2) [2] It would be unacceptable to just throw all of that caffeine away, so let's further investigate how we might be able to isolate/purify the caffeine into a useful form. The first step to separating the caffeine from the rest of the solution is to convert it from its protonated form to its neutral form. Should we use an acid or a base to accomplish this?

Expected Answer: 2) The Bronsted-Lowry definition of acids and bases tells us that acids are proton donors and bases are proton acceptors, therefore we should add a base

35. (4.00 pts)

3) [4] Now, we want to choose a solvent that will selectively dissolve the caffeine and allow us to separate it from the aqueous solution by forming 2 distinct layers. Choose between: H2O (water), CH3CH2OH (ethanol), and CH2Cl2 (dichloromethane) and justify your answer.

Expected Answer: 3) H2O can be eliminated because we've already established that water will dissolve all of the components of the solution. CH3CH2OH could potentially be usefu in dissolving caffeine since it's a polar molecule, however ethanol is miscible with water and we would not be able to separate the two solutions. That leaves CH2Cl2 which is a polar solvent that is not miscible with water and is therefore perfect for dissolving caffeine. (Nile red did a video on this! https://www.bing.com/videos/search?q=nile+red+caffeine&&view=detail&mid=7BF6D8027C744FCE7E8F7BF6D8027C744FCE7E8F&&FORM=VRDGAR)

36. (4.00 pts)

4) [4] Once we separate the two solvents from one another, we still need to figure out a way to remove the solvent and obtain our caffeine crystals. One method to do this is throug distillation. Suppose, however, that you want to speed up the process or avoid exposing the caffeine to heat. How could you accomplish this? Hint: think about the definition of boiling or how we can manipulate the boiling point of a substance.

Expected Answer: 4) The boiling point of a substance is defined as the temperature at which its vapor pressure becomes equal to the external pressure. Therefore, in order to lower the boiling point of a substance we can either find a way to change the vapor pressure of the substance or the external pressure. The best option is to change the external pressure, which we can accomplish by putting the solution under vacuum. This lowers the external pressure and therefore the boiling point.

37. (2.00 pts)

5) [2] In part 3 we mentioned that CH2Cl2 might be useful in the decaffeination process. Say that you have a supply of methane and chlorine gas, and want to synthesize dichloromethane. Write a balanced overall reaction for this synthesis. (hint: might involve a certain strong acid)

Expected Answer: 5) CH4 (g)+2 Cl2 (g) -> CH2Cl2 (l) +2HCl (aq) [Need states for full credit]

38. (5.00 pts)

6) [5] Ethyl acetate, CH3CO2C2H5, is another compound commonly used in decaffeination. If 30 grams of ethyl acetate are combusted in excess oxygen and the reaction goes to completion, how many liters of gas are present when the product mixture is at 120 ºC and 1 atm? Assume ideal behavior.

Expected Answer: 6) First write the balanced equation for the combustion of ethyl acetate: CH3CO2C2H5 (l) +5O2 (g) ->4CO2 (g) +4H2O (l) Need states Then calculate how many moles of products will be formed 30 g CH3CO2C2H5 x (1 mol CH3CO2C2H5/88.11g) = 0.34 mol CH3CO2C2H5 0.34 mol CH3CO2C2H5 x (4 mol CO2/1 mol CH3CO2C2H5) = 1.36 mol CO2 produced 0.34 mol CH3CO2C2H5 x (4 mol H2O /1 mol CH3CO2C2H5) = 1.36 mol H2O produced At 120 C, both products will be in the gas phase, so we have 2.72 mol of gas Then just ideal gas law PV=nRT (1 atm)V=(2.72 mol)(0.08206 L*atm/mol*K)(393 K) V = 87.7 L of gas The steps are worth 3 pts the final answer is worth 2

Classic Acid Base Problem

Typically in these sort of academic competitions you see the standard acid base titration problem. These problems involve some sort of neutralization reaction, ice tables, and MCB [which you should be a master at ;)]. Use the culmination of the skills you practiced in previous problems to tackle this classical problem!

39. (7.00 pts)

1) [7] You have a 1.0 * 10^-7 M solution of sulfuric acid. Knowing that Kw = 1.0×10-14 , K2 = 1.2×10-2 at 25 ° calculate the following concentrations: H+, OH-, HSO4-, and SO42-.

Hint: MCB is a good way to solve this problem but is not the only way

Expected Answer: Answer is long and is on the linked FRQ answer key https://docs.google.com/document/d/1ut49aUI9GWxJfv3jdFfJNMHHLVXzv_gYVMx83bF7j9s/edit?usp=sharing

40. (6.00 pts)

2) [6] You have a 250 cm^3 aqueous solution containing 3.48 cm^3 of concentrated phosphoric acid. You wish to create a 7.4 pH buffer using a .80 M NaOH stock solution. The following values have been given to you: (H3PO4 (aq), purity = 85 mass %, density = 1.69 g/cm3 (pK1 = 2.15, pK2 = 7.20, pK3 = 12.44).

Expected Answer: https://docs.google.com/document/d/1ut49aUI9GWxJfv3jdFfJNMHHLVXzv_gYVMx83bF7j9s/edit?usp=sharing

41. (5.00 pts)

3) [5] Drugs typically are absorbed into the blood stream typically via osmosis and some form of acid base chemistry. However a problem exists is that the pH of the stomach (pH = 2 and blood (pH = 7.4) means that weakly acidic drugs don't make it past the stomach membrane whereas neutral drugs do. Given the following diagram:

Stomach | Blood

H+ + A- <-> HA <-> H+ + A-

Calculate the ratio of the total concentration(HA + A-) of the drug Aspirin (pka = 3.52) in the blood in the stomach.

Expected Answer: Answer is 7400 More work on the doc https://docs.google.com/document/d/1ut49aUI9GWxJfv3jdFfJNMHHLVXzv_gYVMx83bF7j9s/edit?usp=sharing

(づ￣ ³￣)づ Congrats on Finishing! You're amazing! ⊂(・▽・⊂)

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