

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 we get started there are a few things 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 to 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 25°C 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 have 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:

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, N₂H₄, 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?

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

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) Dihydridoxygen

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?

11. (1.00 pts) Given that K_{sp} of compound A is twice as large as the K_{sp} 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?

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

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?

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?

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

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

(Mark **ALL** correct answers)

- ☐ A) Basic but not acidic
- ☐ 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
- ☐ 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?

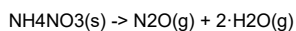
(Mark **ALL** correct answers)

- ☐ A) Deliberately weighing one half the recommended amount of KHP
- ☐ B) Dissolving the KHP in more water than is recommended
- ☐ 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 attached seperatly) and the reaction for following reaction, answer the questions.



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

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.

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

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?

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 O_2 in the air change as a result of the explosion?

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.

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

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)

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 $[\text{Ca}^{2+}]$ to $[\text{F}^-]$ and $[\text{HF}]$)

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?

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

32. (10.00 pts)

7) [10] Now we have all of the information we need to calculate the solubility of CaF_2 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 $[\text{Ca}^{2+}]$, $[\text{F}^-]$, $[\text{HF}]$, and the solubility of CaF_2 in this solution. The K_{sp} of CaF_2 is 4.0×10^{-11} and the K_{a} of HF is 6.6×10^{-4}

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.

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?

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.

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 through 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.

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)

38. (5.00 pts)

6) [5] Ethyl acetate, $\text{CH}_3\text{CO}_2\text{C}_2\text{H}_5$, 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 °C and 1 atm? Assume ideal behavior.

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 $K_w = 1.0 \times 10^{-14}$, $K_2 = 1.2 \times 10^{-2}$ at 25 ° calculate the following concentrations: H^+ , OH^- , HSO_4^- , and SO_4^{2-} .

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

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: (H_3PO_4 (aq), purity = 85 mass %, density = 1.69 g/cm^3 ($\text{pK}_1 = 2.15$, $\text{pK}_2 = 7.20$, $\text{pK}_3 = 12.44$).

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



Calculate the ratio of the total concentration($\text{HA} + \text{A}^-$) of the drug Aspirin ($\text{pK}_a = 3.52$) in the blood in the stomach.

🎉👏 Congrats on Finishing! You're amazing! 🍀🍀🍀

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