# BEARSO Chem Lab

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**Instructions (PLEASE READ, IMPORTANT INFO):**

- There are two ways to do this test depending on your situation. PLEASE READ THE DIRECTIONS CAREFULLY
- Method 1 (if you have a phone or camera to take pictures or a scanner): Please do this test on a separate sheet of paper, and make sure to write your name and team number down on the first page. Please make sure you make it clear which problem you're doing in which space (eg writing 4.1) and then solving it) and this way you and your partner can turn in different files with your separate work without complications. If you can download a scanner on your phone to convert your photo files to pdfs or if you have a printer to scan it with that would be nice. Although I will take image files (png, jpeg, heic, etc), pdf is preferable.
- Method 2 (if you do not have access to a phone, scanner, or camera, **please only use this method if you do not have access to any of those devices**): Do the test in the short answer boxes in the Scilympiad platform. Type in your work, just make sure to write down the important intermediate steps. Don't worry about subscripts or super scrips as long as it isn't ambiguous, this should make inputting answers faster. For example 10^-5 is fine, pka is fine, CO3 2- is fine, etc. There are also 5 questions that would require you to draw, for these questions provide a detailed description of the key features of the drawing in as much detail and accuracy as possible.
- The test is 45 minutes long, and I will give you an extra 10-15 minutes (until the top of the hour) for you to send me an email (or if you are doing Method 2, since typing your work is in general slower you can use this time to type in the rest of your answers). I will give you the benefit of the doubt if you turn it in slightly late, but please do not take advantage of this and use the extra time to do more of the test.
- Remember that "brevity is the soul of wit." The longer answer isn't always the better answer.
- This is not a multiple choice test SO REMEMBER TO SHOW YOUR WORK; partial credit will be given and there are very little points attached to the answer itself for many questions. And remember units!
- Use an appropriate number of significant figures, just don't be unreasonable
- Unless otherwise stated assume conditions are 25C˚ and 1 atm
- Good luck and have fun. uwu ♥YOU CAN DO IT!

## 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) |

**“Lab” (30 pts) (Tiebreaker, total lab points)**

Unfortunately, or maybe fortunately, you will not have to do some boring acid-base titration that they make you do at every tournament. Have fun!

Being the snoopy chemist you are, you sneak into your teachers chemistry’s closet and discover that there is an unlabeled dry waste container. What an irresponsible teacher indeed. But now you are obligated to determine what it was in order to protect the environment and other humans from irresponsible toxic waste disposal. Luckily, you checked the bottom of the bottle to find its manufacturing date, which eliminates many possibilities as you knew the lab schedule.

The waste can contain any combination of the following compounds (in appreciable amounts): Methyl Red (an indicator $pK_a$ = 4.95 goes from yellow to red), Potassium Chromate, Silver Nitrate, Zinc Sulfate, and Lead Acetate.

**1. (4.00 pts)**

Qual 1. The first thing you do is dissolve everything in distilled water. The solution remains colorless and no insolubles are observed. Based on this information what, if any, compound(s) can you conclude is not in the waste mixture and why? (4 pts)

**2. (2.00 pts)**

Qual 2. Next you add some dilute NaOH and a white precipitate forms, this eliminates silver nitrate as a possibility. Why are you not yet certain about the contents of the waste? (2 pts)

**3. (4.00 pts)**
Qual 3. Next you add concentrated NaOH and some of the cloudiness disappears, but a precipitate still remains. What can you conclude about the contents of the waste and why does this step make certain what you could not determine in the previous step? (4 pts)

Wanting to know what other idiotic things your teacher has been doing, you go snooping around more and find that they made a solution of silver nitrate for no reason. They didn't even bother to label the concentration. So you must determine it yourself.

**4. (3.00 pts)**
Tech 1. You decide to determine the concentration through a back titration using an excess of either NaOH and $NH_3$ and titrating the excess with HCl. Your options of titrants are NaOH or $NH_3$, which one should you pick and why? (3 pts)

**5. (4.00 pts)** Tech 2. Write the net ionic reactions that occur in the first step and second step. (4 pts)

**6. (5.00 pts)**
Tech 3. You want to prepare a 0.1 M solution of NaOH (MM = 40) but you only have solid crystals of it. Describe how to prepare 50 mL of this 0.1M solution using common general chemistry lab equipment. (5 pts)

**7. (2.00 pts)**
Tech 4. Now you have to standardize your NaOH (MM = 40) solution against some KHP. Why do you have to standardize your NaOH solution? (2 pts)

**8. (2.00 pts)**

Quant 1. You titrated 3.01 g of KHP (Monoprotic, MM = 204) with 15.0 mL of your NaOH solution to a phenolphthalein endpoint. Determine the concentration of your NaOH solution. (2 pts)

**9. (4.00 pts)**

Quant 2. Now you are ready to do the titration. You add 5.00 mL of your NaOH solution to a 25 mL aliquot of the mystery $AgNO_3$ solution and titrate the mixture with 20.4 mL of your 0.1 M HCl solution to a methyl red endpoint. Determine the concentration of the silver nitrate. (4 pts)

**Question 1 (15 pts)**

You embark on this chemistry adventure we call a scioly test. But first thing you note is that you really need to go to the bathroom. Huh, someone must have slipped some $Mg(OH)_2$ into your water, or maybe your careless self did on accident.

As you sit on the toilet seat you begin to ponder some of the properties of $Mg(OH)_2$.

**10. (2.00 pts)** 1.1 Is $Mg(OH)_2$ an acid or a base? Why? (2 pts)

**11. (2.00 pts)**

1.2 $Mg(OH)_2$ is strong, but if you stick your hand into a saturated solution of $Mg(OH)_2$ it should not burn your hand. Why is this the case? (2 pts)

**12. (2.00 pts)** 1.3 The solubility of $Mg(OH)_2$ in neutral water is $1.71 \times 10^{-4}$ mol/L. Calculate the $K_{sp}$ of $Mg(OH)_2$. (2 pts)

**13. (4.00 pts)**

1.4 What you just calculated in the previous problem is only an approximation. For $Mg(OH)_2$ and other sparingly soluble/insoluble salts, the method you used is a rather good method, but still an approximation nonetheless. Why is it an approximation? (4 pts)

**14. (3.00 pts)**

1.5 Since the approximation is rather good, use the $K_{sp}$ value you determined in 1.3 to determine the solubility of $Mg(OH)_2$ (MM = 58.3) in g/L in a buffer solution whose pH is maintained at 10. (3 pts)

**15. (2.00 pts)**

1.6 If you tried to dissolve the $Mg(OH)_2$ in a solution of $MgCl_2$ would you expect the solubility of $Mg(OH)_2$ to be higher, the same, or lower? Why? (2 pts)

**Question 2 (15 pts)**

So now that you are relieved, it is time to tackle some more problems. If you did not start on the lab question, your adventure so far has been rather basic. Well it is about to get a whole lot more basic.

**16. (2.00 pts)** 2.1 What makes a compound more strongly basic? What does that say about the corresponding conjugate acid? (2 pts)

**17. (4.00 pts)**

2.2 Your interest in bases has gotten your friends calling you basic. What they don't know is that you're a proton ripping SciOlyer. You aspire to deprotonate ethanol ($pK_a$ = 16). But since you're extra, you pick one of the strongest bases you can easily find, sodium amide ($NaNH_2$ , $pK_a$ of ammonia = 38). You make a 6M aqueous solution of the sodium amide and add some ethanol to the solution. Using spectroscopy you find that very little of your ethanol is actually deprotonated! You realize the reason is that water is not a suitable solvent; explain why that is the case. (4 pts)

**18. (3.00 pts)**

2.3 Now you have to pick a different solvent so you can actually deprotonate ethanol. You decide on DMSO (Dimethylsulfoxide, $pK_a$ = 35, assuming everything you're working with dissolves in DMSO). Why is this a better choice of solvent for this purpose? (3 pts)

**19. (2.00 pts)**

2.4 Estimate the percentage of amide molecules (assume they all dissolve) that are protonated in DMSO to 1 decimal place (assume no EtOH is present). (2 pts)

**20. (4.00 pts)**

2.5 Why would the procedure you used in 2.2 work if instead of ethanol you used 2,2,2-trifluoroethanol ($CF_3CH_3OH$)? Explain using concepts of acidity. (4 pts)

**Question 3 (24 pts)**

Mixing things can sometimes be oddly satisfying. Whether it looks like a colorful vortex, or stirring around beautiful crystals in suspension, there are things about the process of mixing that never gets old. However, as you probably know, the science mixing isn't always as pretty as it looks, so I won't bother asking you about the ugly stuff :) .

**21. (3.00 pts)** 3.1 What drives ideal mixing? In other words, why is ideal mixing spontaneous? (3 pts)

**22. (4.00 pts)**

3.2 Of these two mixtures, which one would be a more ideal solution: Toluene($CH_3C_6H_5$)-Benzene($C_6H_6$) or water-isopropanol($CH_3CH_2OHCH_3$) and why? (4 pts)

**23. (5.00 pts)**

3.3 On the same graph, draw a pressure-composition diagram (Hint: the name gives away what the axes are) for both mixtures. No need to know exact vapor pressures, but you should know the relative vapor pressures. (5 pts)

**24. (5.00 pts)**

3.4 On another graph, draw a rough temperature composition (include both liquid and vapor phase, look at hint in 3.3) diagram of the toluene-benzene mixture. Assuming the mixture begins at around 10% (in mole fraction) of benzene and is in liquid phase, label the starting point on the graph and draw how the mixture will change after at least 2 consecutive boiling and condensing cycles with the goal being toward purer benzene. (5 pts)

**25. (7.00 pts)**

3.5 The vapor pressure of water at 25C is 22.8 mmHg and the vapor pressure at the same temperature of ethanol is 60.8 mmHg. Use Raoult's law to determine the vapor pressure of a 5 percent by mass aqueous solution of ethanol (MM = 46). Then explain why Raoult's law is a limiting law, or a law that works at the limit. (7 points) (Tiebreaker)

**Question 4 (27 pts)**

Buffer solutions are like the safety net of chemistry. Unlike US oligarchs who care nothing about you and would allow minor downturns ruin your life, buffer solutions help maintain your body pH despite changes in your environment. Yes, buffers are very progressive :) .

**26. (2.00 pts)** 4.1 Can you make a buffer solution from $HNO_3$ and $NaNO_3$? Why or why not? (2 pts)

**27. (2.00 pts)** 4.2 Explain why buffer solutions help maintain pH despite additions of small amounts of strong acid or base. (2 pts)

**28. (4.00 pts)**

4.3 Let's say you have 100 mL of a 0.1M solution of sodium oxalate, $Na_2C_2O_4$. How many milliliters of a 10M HCl solution do you need to add to the solution to create a pH 4 buffer? ($pK_{a1}$ = 1.25, $pK_{a2}$ = 3.81) (4 pts)

**29. (6.00 pts)**

4.4 With the same starting materials as in 4.3, how many milliliters of the HCl solution would you need to add to create a pH 1 buffer? (6 pts) (Tiebreaker)

**30. (13.00 pts)**

4.5 Draw the titration curve for adding HCl to sodium oxalate. Be sure to label and calculate the pH for the important points: initial, 1st half equivalence, 1st equivalence, 2nd half equivalence, 2nd equivalence. (You do not need to calculate the pH at the first equivalence point)(13 points)

**Question 5 (21 pts)**

Learning through diffusion really do be a thing. If your friends are legends a little will rub off onto you. If you are a legend then a little will rub off onto your friends. Well let's examine some diffusion (osmosis) in chemistry.

**31. (2.00 pts)**

5.1 In a very theoretical U-tube with water and in the middle there is a semipermeable membrane that only allows water to pass through, we dissolve 50 milligrams of an unknown monoprotic carboxylic acid. Each side is filled with about 100 ml of water/solution and the system is allowed to equilibrate. Draw a diagram of the setup. Be sure to label which side has the dissolved acid, and be sure to identify which side is the water level higher. (2 pts)

**32. (4.00 pts)**

5.2 One side of the **theoretical** tube is a whopping 625 mm higher than the other side. Assuming the density of the water and solution is 1 g/mL, calculate the molar mass of the carboxylic acid. (4 pts)

**33. (3.00 pts)**

5.3 To corroborate your observations, you decide to perform a titration. You dissolve enough of the acid into water to have a total of 5 grams, and titrate it with 32.6 mL of 1.5M NaOH to a phenolphthalein endpoint. Determine the molar mass of the carboxylic acid. (3 pts)

**34. (3.00 pts)**
5.4 If you did it correctly, you should get two different answers for 5.2 and 5.3, can you explain why this is the case, and explain which one is the correct value if any? (3 pts) (Tiebreaker)

**35. (3.00 pts)**
5.5 If you tried using boiling point elevation to calculate the molar mass would your answer be closer to that of 5.2 or 5.3, explain why. (3 pts)

**36. (6.00 pts)**
5.6 To determine the identity, you finally perform a combustion analysis. You burn 5 grams of the sample and collect 13.4 g of $CO_2$ and 2.43 g of $H_2O$. The molecule contains only C, H, and O. Determine the molecular formula using the information from this problem and previous problems. Then draw a plausible structure for the compound. (6 pts) (Tiebreaker)

**Question 6 (13 pts)**
Each human has their own complex personalities, and that is usually seen as a good thing. It is interesting to know each human's complexities. Complex ions and molecules in chemistry also have very complex properties and personalities. Careful manipulation of ligands often drastically changes the properties of the molecule. Although we will not be looking at properties of complex ions, we will be answering some questions about their formation.

**37. (3.00 pts)**
6.1 The $K_{sp}$ of FeS (MM = 87.92) is $4 \times 10^{-19}$. Calculate in ppm (use µg/L) the solubility of FeS in neutral distilled water. (3 pts)

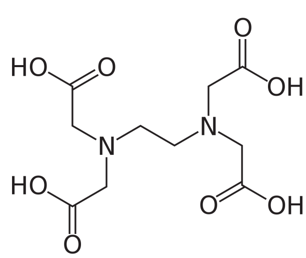
**38. (3.00 pts)**
As you can see the solubility of FeS in water is very low, we can increase the solubility of FeS by adding a chelating agent, in this case we will use EDTA, which is a hexadentate ion usually with a charge of 4-. A simplified reaction is given below

$$Fe^{2+} + EDTA^{4-} \leftrightarrow [Fe(EDTA)]^{2-} \quad K_f = 2.1 \times 10^{14}$$

6.2 $[Fe(EDTA)]^{2-}$ is soluble in water and, as you can see from the formation constant, is very stable. Using your knowledge of free energy and solubility (think about hydration complexes), explain why a chelating agent like EDTA creates very stable complexes. (3 pts)

**39. (4.00 pts)**
6.3 Ignoring effects of pH (assume neutral solution), determine the $[EDTA^{4-}]$ needed to completely dissolve 0.1g of FeS in 1 L of water. (4 pts)

**40. (3.00 pts)**
6.4



Here's EDTA in its acid form. Often, complex formation is regarded as a Lewis acid-Lewis base reaction. Draw $Fe(EDTA)^{2-}$. Do not worry about orientation or how it looks, I just want to see that you identified correctly which atoms bond to the iron. Also be sure to label which is the Lewis acid and which is the Lewis base. (3 pts)

**Question 7 (13 pts)**
Welcome to the last question! In the previous question, we worked with metal ions. We will end our little chemistry excursion with a problem regarding metal.

**41. (3.00 pts)**

7.1 You have a 5.5 g sample of mixed metal shavings containing silver, gold, and aluminum. You prepare a concentrated solution of sodium hydroxide and pour it into the mixture of metal and collect the gas released. Please write the significant reaction(s) that occured, and why the (or none of) the other metals didn't react. (3 pts)

**42. (3.00 pts)**

7.2 Assuming this gas is pure, you combust this gas and collected 1.483 g of a liquid. Assuming the combustion process is 80% efficient and gas collection is 100% efficient, how many moles of gas was collected in the process performed in the previous question. (3 pts)

**43. (4.00 pts)**

7.3 You now treat this solution with hot, concentrated nitric acid. (You performed this in a fume hood of course) You stir and filter away the liquid. Write the significant reaction(s) that occurred and why the (or none of) the other metals didn't react? (4 pts)

**44. (3.00 pts)**

7.4 You dry and weigh whatever is left, and find that you are left with 0.99 g of stuff. What compound remains, and calculate the percent composition of aluminum, silver, and gold in the original mixture. (3 pts)

Congrats, you've done it!