GOAL: Know how to prepare and when to utilize acid-base extraction.

1. TIPS:
   a. Always identify the acid/base and the neutral compound for extraction.
   b. Always identify the aqueous and organic layer.
   c. Before heading to the lab, think of steps that can affect your percent recovery + percent yield. This will save you a lot of time when writing error analysis discussions.
   d. Understand why each step of the experiment is completed. Knowing the theory behind each step and coming to lab prepared allows you to identify potential errors that may occur during your experiment.

2. KEY CONCEPTS:
   a. An acid is something that gives protons and can become neutral or negative. A base gains a proton and can become neutral or positive.
   b. Use a base to extract an acid and vice versa
   c. Understand the difference between percent yield and percent recovery.
   d. Understand how percent yield and percent recovery results determine what happened to your reaction. *This is important for the error analysis portion of your lab report.* Being able to move through the lab and understand the steps that can lead to higher percent yields/recoveries will save you a lot of time when you write this section of your lab report.
   e. Understand why each step of the acid-base extraction is completed.
      i. Doing so will help you identify potential errors that may have occurred, which can affect your percent recoveries and percent yields.
      ii. This can also save you time when writing the theory portion of your scaffold

1. Theory: Acid-Base Extraction Procedure
   a. In this experiment you are given a mixture of 2 types of compounds. What are they?
      i. Acid
      ii. Neutral compound
   b. How will you separate and recover the two from each other (HINT: there are two steps)? Explain the theory behind your procedure.
      i. Acid-base extraction is utilized to manipulate the preferential solubility of the acid. In its current state, the acid is a part of the organic layer. By adding a base to deprotonate the acid, this turns the acid into a salt. Salts are highly water soluble. Thus, deprotonating the acid allows for the acid to precipitate into solution.
      ii. Once you water solubilize the acid, you now have a mixture of water soluble acid and lipid soluble (i.e. in the organic layer of the extraction)
neutral compound. Separation of the two will be achieved by liquid-liquid extraction.

c. Using a separatory funnel will separate the compounds into two layers. What are these layers? Which compounds will be in which layer? Why?
   i. Organic layer: The neutral compound starts in the organic layer at the beginning of this experiment. Since the neutral compound's solubility is not manipulated during this experiment, it will be found in the organic layer at the end of the experiment as well.
   ii. Aqueous layer: Since the preferential solubility of the acid is manipulated during this experiment, the acid will move from the organic into the aqueous layer during the deprotonation step. Deprotonating the acid causes it to precipitate into solution (i.e. the aqueous layer), and it can be recovered experimentally from the aqueous layer.

2. You are given a mixture of H2CO3 and CCl4 and want to utilize an acid-base extraction technique to isolate carbonic acid. What reagent would you use and why?

   Because carbonic acid is an acid, you would want to use a base to extract it. Since H2CO3 is not a very strong acid, it would be better to use a strong base so that it becomes as deprotonated as possible. So, you can use OH- or an analogous strong base. By deprotonating the acid, it gains a positive charge. This allows it to be separated into the aqueous solvent, away from CCl4. Once the two have been separated, you can protonate the acid again to make it neutral, allowing it to come out of the aqueous solution.

3. Indicate which layer the following compounds would go into upon extraction.
   **Aqueous:** Water  **Organic:** diethyl ether

   Generally speaking, if a compound can easily gain a charge during extraction, it will move into the aqueous layer. For something that does not easily gain a charge, it will remain in the organic layer.

   a. NaOH- Since this is a base and can be protonated to gain a positive charge, it will go into the aqueous layer.
   b. CH3CH2CH2OH- Since this is relatively acidic, it will react with a base to become deprotonated, becoming negative. Thus, it will go into the aqueous layer.
WEEK 8 WORKSHEET

c. HCl- Since this is a strong acid, it will easily be deprotonated to become negatively charged, and move into the aqueous layer.
d. CH₃CH₂CH₂COOH- Since this is relatively acidic, it will react with a base to become deprotonated, becoming negative. Thus, it will go into the aqueous layer.
e. CH₃CH₂CH₂CH₂COH- Since this does not become easily protonated or deprotonated, it will not take a charge. It will remain neutral and, thus, will go into the organic layer.
f. CBr₄- Since this does not gain a charge, it will remain in the organic layer.

3. Extraction theory
   a. What does “wash” mean in the context of extraction?

When preparing a sep funnel, you often put the aqueous layer and organic layers in and then let them separate. Sometimes, the desired aqueous compounds can be left over in the funnel, specifically in the organic layer. In order to get rid of the aqueous compounds, you can wash it with water so that the desired compound stays in the water and comes out of the sep funnel. This ensures that all the necessary compounds are in their respective layers.

b. What is the purpose of using a drying agent?

Since washing takes place with water, there can be an excess of water left over in the solvent. Because of this, it can interfere with certain readings like mass and yield. Thus, you can add a drying agent to get rid of the excess water.

4. Calculation: Percent Yield and Percent Recovery
   a. What is the difference between percent yield and percent recovery?

Percent yield is a ratio of the actual and theoretical yield in an experiment; it indicates the total amount of product formed in the overall reaction. Percent recovery is a ratio of the crude (unpurified) and purified product in an experiment; it indicates the amount of pure product recovered from an overall reaction.

b. Perform the calculations for the following examples:
   i. When 16.0g of CaCO₃ are heated to thermal decomposition, 7.54 g of CaO is obtained. Calculate percent yield.

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\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
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WEEK 8 WORKSHEET

Steps:

- Determine what is given:
  - Actual yield = 7.54g CaO

- Determine theoretical yield by converting grams of limiting reagent to grams of product:
  - Limiting reagent = CaCO\(_3\) (molar mass: 100 g/mol)
  - Product = CaO (molar mass: 56 g/mol)
  - Molar ratio CaCO\(_3\):CaO = 1:1

- Determine percent yield using actual yield and theoretical yield

Theoretical yield = 16.0g CaCO\(_3\) x (1mol / 100g CaCO\(_3\)) x (1mol CaO / 1mol CaCO\(_3\)) x (56g CaO / 1mol)
= 8.96 g CaO

Percent yield = (actual yield/theoretical yield) x 100%
Percent yield = (7.54g CaO / 8.96 g CaO) x 100% = 84.16%

ii. If 14g of copper was used in a recrystallization process and the amount of copper recovered at the end of the process is 12g, calculate percent recovery.

Steps:

- Determine what is given:
  - Amount of crude product: 14g
  - Amount of purified product: 12g

- Determine percent recovery using amounts of crude product and purified product

Percent recovery = (Purified product/Crude product) x 100%
Percent recovery = (12g / 14g) x 100% = 85.71%

NOTE:
You divide actual yield over theoretical yield when calculating percent yield because you’re trying to determine the amount of product yielded in a specific reaction, out of the maximum amount that can be formed. If actual yield is the amount of product formed experimentally (portion of a whole) and theoretical yield is the maximum amount of product that can be formed (whole), dividing the portion by whole should give you the amount of product yielded in the experiment. This is the same thought process for percent recovery, except percent recovery determines the amount of purified product recovered from a specific reaction. In addition, the amount of purified product is the portion and the amount of crude product is the whole.
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