

pH DETERMINATION

ALL THE DATA YOU WOULD COLLECT IN THE LABORATORY TO COMPLETE THIS LABORATORY REPORT IS IN THIS DOCUMENT HIGHLIGHTED IN YELLOW

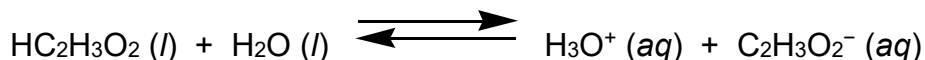
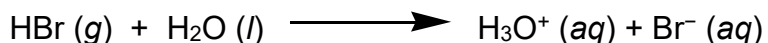
ENTER YOUR ANSWERS AND INFORMATION IN THE LIGHT BLUE FIELDS

Purpose

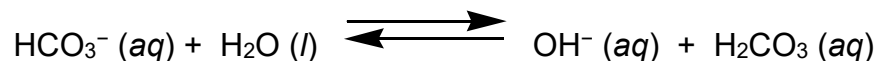
The purpose of this experiment is to use universal pH paper to measure the acidity of different solutions, and to use these values to determine the relative acidity of the solutions.

Theory

An acid is a substance that increases the hydronium ion concentration of a solution when dissolved in water. The equations below describe the acid behavior of hydrogen bromide and acetic acid, respectively.



A base is a substance that increases the concentration of hydroxide ion of a solution when dissolved in water. The following equations describe the base behavior of potassium hydroxide and the bicarbonate ion, respectively.



The pH value of a solution is a measure of its acidity and hydronium ion (or hydrogen ion) concentration. The pH of an aqueous solution can be calculated if the hydrogen ion concentration of the solution is known using the following equation.

$$\text{pH} = -\log[\text{H}^+]$$

Alternatively the hydrogen ion concentration of a solution can be calculated if the pH of the solution is known using the equation shown here.

$$[\text{H}^+] = 10^{-\text{pH}}$$

In addition, the hydroxide concentration of a solution can be determined using the equation shown below if the hydrogen ion concentration of the solution is known.

$$[\text{H}^+] \times [\text{OH}^-] = 1 \times 10^{-14} \text{ M}^2$$

$[\text{H}^+]$ corresponds to the molar concentration of the hydrogen ion and $[\text{OH}^-]$ corresponds to the molar concentration of the hydroxide ion in these equations.

In this experiment you will determine the pH values of several solutions using universal pH paper. From these values you will be able to calculate the hydrogen ion and hydroxide ion concentrations. You will also determine whether the solutions are acidic, basic or neutral. In addition, using the pH values you will be able to rank the relative acidities of the solutions. Solutions that have hydrogen ion concentrations greater than $1 \times 10^{-7} \text{ M}$ will have pH values below 7 and are acidic. Solutions that have hydroxide ion concentrations greater than $1 \times 10^{-7} \text{ M}$ will have pH values above 7 and are basic. The lower the pH value the more acidic the solution and the higher the pH value the more basic the solution.

Before you start this experiment you will need to prepare 0.1 M solutions of sodium carbonate (Na_2CO_3), sodium bicarbonate (NaHCO_3), sodium chloride (NaCl), and ammonium chloride (NH_4Cl). You will need 100 mL of each solution. In order to prepare these solutions you will need to calculate the mass of each solid that you will need for each solution. Recall that molarity (M) refers to the moles of solute per liter of solution. The calculation for the 0.1 M sodium chloride solution is shown below.

$$\text{Molar mass of NaCl} = (1 \times \text{molar mass of Na}) + (1 \times \text{molar mass of Cl})$$

$$\text{Molar mass of NaCl} = (1 \times \frac{22.98977 \text{ g}}{\text{mol}}) + (1 \times \frac{35.453 \text{ g}}{\text{mol}}) = \frac{58.443 \text{ g}}{\text{mol}}$$

$$100. \text{ mL of solution} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.100 \text{ mol NaCl}}{1 \text{ L}} \times \frac{58.443 \text{ g NaCl}}{1 \text{ mol NaCl}} = 0.583 \text{ g NaCl}$$

Notice that all of the units cancel except for the “g NaCl” unit. This calculation shows that you would need 0.584 grams of sodium chloride to make 100 mL of a 0.100 M solution. You will need to perform calculations like this for the other solutions. (See the **Prelaboratory Assignment**.)

Materials Needed

- Universal pH paper
- 0.1 M HCl solution (25 mL per student)
- 0.1 M NH₃ solution (25 mL per student)
- 0.1 M H₃BO₃ solution (25 mL per student)
- 0.1 M NaOH solution (25 mL per student)
- Na₂CO₃
- NaHCO₃
- NaCl
- NH₄Cl

Procedure

A. Preparation of salt solutions

1. Put on your chemical-splash safety goggles. Your goggles must be worn at all times while in the laboratory. Don't take off your goggles until you leave the laboratory.

2. Before you start the experiment you will need to prepare 100 mL of 0.1 M solutions of sodium carbonate (Na₂CO₃), sodium bicarbonate (NaHCO₃), sodium chloride (NaCl), and ammonium chloride (NH₄Cl) in clean 250-mL beakers. Do this as described in steps below.

- Calculate the amount of solid that you will need to prepare each solution. The amount of NaCl that you will need to prepare the sodium chloride solution is calculated in the **Theory** section. Use this calculation method to determine the amounts of the other solids you will need to prepare the other solutions. (See the **Prelaboratory Assignment**.)
- Put a clean 250-mL beaker on a balance and zero (tare) the balance. Then weigh the appropriate amount of solid into the beaker and record the solid on your data sheet. Pour 50 mL of distilled water into the beaker and stir to dissolve the solid. Measure the volume of water with a clean graduated cylinder.
- Pour this solution into a clean 100-mL graduated cylinder and dilute the solution with distilled water to the 100-mL mark. Stir the solution in the graduated cylinder with a clean stirring rod to completely mix the solution. The solution is now ready to use.
- Use this procedure to prepare all four solutions. Be sure to use clean glassware for each solution.

B. Measuring pH values of common acids and bases

1. Measure about 25 mL each of 0.1 M HCl (aq), 0.1 M NH₃ (aq), 0.1 M H₃BO₃ (aq), and 0.1 NaOH (aq) into four clean 100-mL beakers. **These solutions can cause skin irritation. Wash with soap and water if you spill any of these solutions on your skin.**

2. Determine the pH of these solutions using universal pH paper. This can be done by dipping the end of a short strip of paper into the solution and observing the color that appears on the paper. Compare this color with the color scale on the pH paper container to determine the pH. Record the pH values of each solution on your data sheet. Use a dry piece of pH paper for each solution.

C. Measuring the pH values of salt solutions

1. Measure the pH values of the salt solutions that you prepared in **Part A** using universal pH paper. Record the values on your data sheet.

2. **Clean all glassware and equipment that you used during this experiment and return it to its proper location. Clean your workstation and wash your hands with soap and water before you leave the laboratory.**

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pH DETERMINATION

Prelaboratory Assignment

1. What should you do if you accidentally spill 0.1 M HCl solution on your skin?

The acid can be flushed off immediately using a lot of water for about fifteen minutes. Clothes should be removed where the acid has spilled on. Disinfectant soap and antibacterial cream can be used in severe cases.

2. In **Part A** of this experiment you will prepare 0.1 M solutions of sodium carbonate (Na_2CO_3), sodium bicarbonate (NaHCO_3), sodium chloride (NaCl), and ammonium chloride (NH_4Cl). You will need 100 mL of each solution. Calculate the mass of each solute that you will need for each solution.

Mass of Na_2CO_3 needed to make the Na_2CO_3 solution:

$$\begin{aligned}\text{molar mass} &= (2 \times 22.98977) + (3 \times 15.999) + (1 \times 12.011) \\ &= 105.98754 \\ \text{mass} &= 0.1 \times 100 \times 105.98754 / 1000\end{aligned}$$

Mass of NaHCO_3 needed to make the NaHCO_3 solution:

$$\begin{aligned}\text{molar mass} &= (22.98977) + (1.008) + (12.011) + (3 \times 15.999) \\ &= 84.00577 \\ \text{mass} &= 0.1 \times 100 \times 84.00577 / 1000\end{aligned}$$

Mass of NaCl needed to make the NaCl solution:

$$\begin{aligned}\text{Molar mass of NaCl} &= (1 \times \text{molar mass of Na}) + (1 \times \text{molar mass of Cl}) \\ &= 22.98977 + 35.453 \\ &= 58.443 \text{ g NaCl}\end{aligned}$$

Mass of NH_4Cl needed to make the NH_4Cl solution:

$$\begin{aligned}\text{molar mass} &= (14.007) + (4 \times 1.008) + (35.453) \\ &= 53.492 \\ \text{mass} &= 0.1 \times 100 \times 53.492 / 1000\end{aligned}$$

3. Complete the table below for solutions A, B, C and D. Indicate whether these solutions are acidic, basic or neutral.

Solution	[H ⁺]	[OH ⁻]	pH	Acidic, Basic or Neutral
A	3.87×10^{-4}	2.58×10^{-11}	3.4	acidic
B	1.43×10^{-13}	6.98×10^{-2}	12.8	basic
C	3.16×10^{-9}	3.16×10^{-6}	8.5	basic
D	6.3×10^{-2}	1.59×10^{-13}	1.2	acidic

Rank solutions A, B, C and D in order of increasing acidity.

(least acidic $\longrightarrow$ most acidic)

A,D

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pH DETERMINATION

Data Sheet

A. Preparation of salt solutions

Note: Indicate the volumes of the four solutions and the masses of the four solids below. **See Question #2 of the Prelaboratory Assignment.**

0.1 M sodium carbonate solution (Na_2CO_3) solution

Mass of Na_2CO_3	<u>1.05989754g</u>
Volume of solution	<u>100ml</u>

0.1 M sodium bicarbonate (NaHCO_3) solution

Mass of NaHCO_3	<u>0.8400577g</u>
Volume of solution	<u>100ml</u>

0.1 M sodium chloride (NaCl) solution

Mass of NaCl	<u>0.58443g</u>
Volume of solution	<u>100ml</u>

0.1 M ammonium chloride (NH₄Cl) solution

Mass of NH ₄ Cl	0.53492g
Volume of solution	100ml

B. Measuring pH values of common acids and bases

Complete the table below.

Solution	pH
HCl (<i>aq</i>)	1.0
H ₃ BO ₃ (<i>aq</i>)	4.8
NH ₃ (<i>aq</i>)	10.2
NaOH (<i>aq</i>)	14.0

C. Measuring pH values of salt solutions

Complete the table below.

Solution	pH
$\text{Na}_2\text{CO}_3 (aq)$	9.1
$\text{NaHCO}_3 (aq)$	8.5
$\text{NaCl} (aq)$	7.3
$\text{NH}_4\text{Cl} (aq)$	6.4

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Questions

1. Indicate the pH values that you determined for the solutions in **Part B** of this experiment on the table below. Calculate the H^+ and OH^- concentrations of these solutions and indicate whether the solutions are acidic, basic or neutral.

Solution	pH	$[H^+]$	$[OH^-]$	Acidic, Basic or Neutral
HCl (aq)	1.0	0.1	1×10^{-13}	acidic
H_3BO_3 (aq)	4.8	1.58×10^{-5}	6.33×10^{-10}	acidic
NH_3 (aq)	10.2	6.31×10^{-11}	1.58×10^{-4}	basic
NaOH (aq)	14.0	1×10^{-14}	1	basic

2. Indicate the pH values that you determined for the solutions in **Part C** of this experiment on the table below. Calculate the H^+ and OH^- concentrations of these solutions, and indicate whether the solutions are acidic, basic, or neutral.

Solution	pH	$[H^+]$	$[OH^-]$	Acidic, Basic or Neutral
Na_2CO_3 (aq)	9.1	7.94×10^{-10}	1.26×10^{-5}	basic
$NaHCO_3$ (aq)	8.5	3.16×10^{-9}	3.16×10^{-6}	basic
NaCl (aq)	7.3	5.01×10^{-8}	1.995×10^{-7}	neutral
NH_4Cl (aq)	6.4	3.98×10^{-7}	2.51×10^{-8}	acidic

3. You determined the pH values of the following solutions during this experiment.

- HCl (aq)
- $\text{H}_3\text{BO}_3 \text{ (aq)}$
- $\text{NH}_3 \text{ (aq)}$
- NaOH (aq)
- $\text{Na}_2\text{CO}_3 \text{ (aq)}$
- $\text{NaHCO}_3 \text{ (aq)}$
- NaCl (aq)
- $\text{NH}_4\text{Cl (aq)}$

Rank the acidity of **ALL** these solutions based on the pH values.

(least acidic $\longrightarrow$ most acidic)

$\text{NH}_4\text{Cl (aq)}$, $\text{H}_3\text{BO}_3 \text{ (aq)}$, HCl (aq)