13A: The pH Scale

What does pH actually measure?

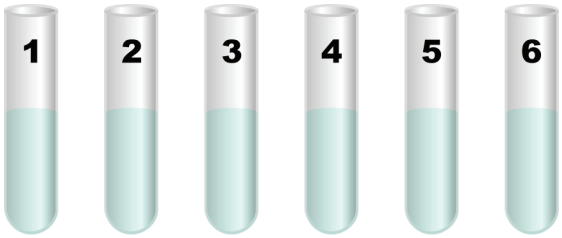
The pH scale is associated with acids and bases. It is a logarithmic scale, meaning a change of 1 pH unit means the concentration of H^+ ions in solution changes by a factor of 10. In this investigation, you will measure pH indirectly using indicators and absorption using the Lab-Master.

Materials

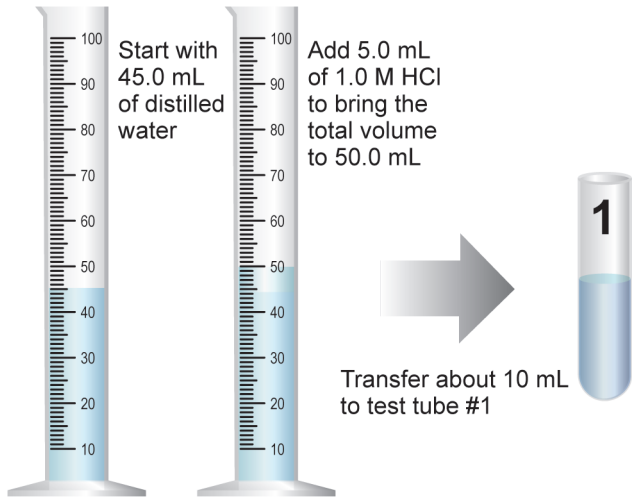
- Six cuvettes
- Two 100 mL graduated cylinders
- Six 12 mm test tubes
- Test tube rack
- Lab-Master
- Universal indicator solution
- Methyl orange
- 1 M HCl
- 1 M NaOH

Part 1: Setting up for acids

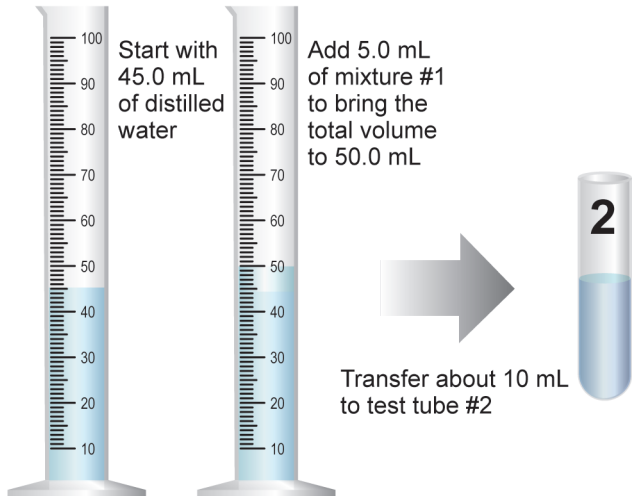
1. Label six small test tubes with numbers 1 through 6 and place them in your test tube rack.
2. Make mixture #1 by adding 5 mL of 1 M HCl to 45 mL of distilled water. *Mix* well by pouring back and forth.
3. Put about 10 mL of mixture #1 in test tube #1 and save it for later.
4. Make mixture #2 by adding 5 mL of mixture #1 to 45 mL of water. Mix well.
5. Put 10 mL of mixture #2 in test tube #2 and save it for later.
6. Clean out the first graduated cylinder. Make mixture #3 by adding 5 mL of mixture #2 to 45 mL of water. Mix well.
7. Save 10 mL of mixture #3 in test tube #3 and save it for later.
8. Repeat the process three more times, each time mixing 5 mL of each mixture with 45 mL of water to get the next mixture. Be sure each of your solutions are well mixed. You should finish with six test tubes like the diagram below.



Mixture #1



Mixture #2



Part 2: Doing the math for acids

Definition of pH

$$pH = -\log[H^+]$$

pH is –1 times the logarithm of the H^+ molarity

Each of the test tubes has a different concentration of acid. In this next step, you are going to calculate the concentration of each one.

a. First calculate the volume of acid in each mixture using the concentration of the previous mixture.

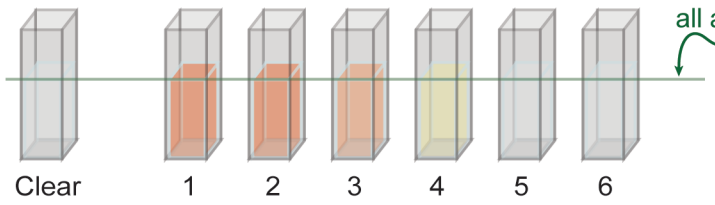
b. Use the result of (a) to calculate the concentration of the mixture itself. Record your calculations in a table similar to Table 1.

Table 1. Concentration data for acid measurement

Test tube #	Volume of 1 M HCl (mL)	Total Volume (mL)	Moles H^+	H^+ molarity	pH
1	5	50	0.005	0.1	1.0
2	0.5	50			
3		50			
4		50			
5		50			
6		50			

Part 3: Measuring the color for acids

Set up six cuvettes then add 1 drop of methyl orange to each



RGB on

Activates the spectrophotometer

Reference

Calibrates the instrument with clear water

Measure

Makes an RGB absorption measurement

For many scientific experiments, the human eye is not reliable enough to make an objective measurement. For the next part of the experiment you are going to use the spectrophotometer to measure the pH.

1. Calibrate the spectrophotometer using a cuvette with 2 mL of distilled water
2. Put about 2 mL of each solution into separate cuvettes. Add 1 drop of methyl orange to each cuvette. Be careful to add *only* 1 drop.
3. Take an RGB reading from each cuvette. Record the RGB measurements in a table similar to Table 2 shown on the next page, and transfer the pH values from Table 1 to this new table.

Table 2. Spectrophotometer data for acid concentrations

Test tube #	pH	R (AU)	G (AU)	B (AU)
1	1.0			
2				
3				
4				
5				
6				

Part 4: Observations

a. What can you say about the appearance of the cuvettes? How do they compare to each other? Which is the lightest? Which is the darkest? Do any appear the same? Give an answer in two or three sentences.

b. Do your observations agree with what you expected?

Part 5: Thinking about what you observed

a. Plot graphs of R, G, and B versus pH on the same graph axis. (Use graph paper similar to the one shown on page 105.)

b. Which of the colors was most sensitive to this range of pH?

c. Are there any pH ranges for which this technique would not work?

Part 6: Setting up for bases

Clean your acid cuvettes and test tubes well. You will need them to prepare a pH series of bases next.

1. Label six small test tubes with numbers 8 through 13.
2. Make mixture #13 by adding 5 mL of 1 M NaOH to 45 mL of distilled water. Put about 30 mL of this solution into test tube #13 and save it for later measurements.
3. Make mixture #12 by adding 5 mL of mixture #13 to 45 mL of water. Put about 30 mL into test tube #12 and save it for later measurements.
4. Clean out the first graduated cylinder. Make mixture #11 by adding 5 mL of mixture #12 to 45 mL of water. Save 30 mL of this solution in test tube #11.
5. Repeat the process three more times, each time mixing 5 mL of each mixture with 45 mL of water to get the next mixture. You should finish with six test tubes.

Part 7: Doing the math for bases

Definition of pH

$$pH = 14 + \log[OH^-]$$

pH is proportional to the logarithm of the OH^- molarity

Each of the test tubes has a different concentration of base. In this next step, you are going to calculate the concentration of base in each one.

a. First calculate the volume of base in each mixture using the concentration of the previous mixture.

b. Use the result of (a) to calculate the concentration of the mixture itself. Record your calculations in a table similar to Table 3.

Table 3. Concentration data for base measurement

Test tube #	Volume of 1 M NaOH (mL)	Total volume (mL)	Moles OH^-	OH^- molarity	pH
13	5	50	0.005	0.1	13.0
12	0.5	50			
11		50			
10		50			
9		50			
8		50			

Part 8: Measuring the color for bases

Here we follow the same procedure as in Part 3, but using a universal indicator. Record the data in Table 4.

Set up six cuvettes then add 1 drop of universal indicator to each

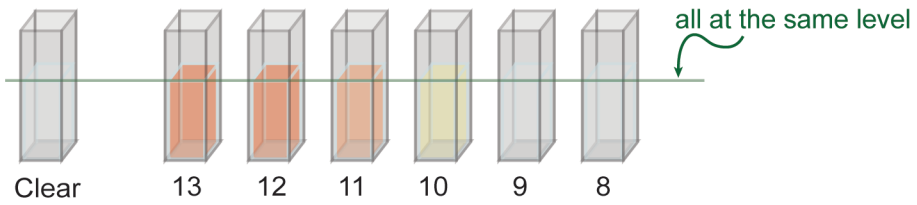


Table 4. Spectrophotometer data for base concentrations

Test tube #	pH	R (AU)	G (AU)	B (AU)
13	13.0			
12				
11				
10				
9				
8				

a. Now using the base paper, plot graphs of R, G, and B versus pH. (Use graph paper similar to the one shown on page 106.)

b. Which of the colors was most sensitive to this range of pH using the universal indicator solution?

RGB Calibration vs. pH for acids

Indicator _____

Amount per cuvette _____

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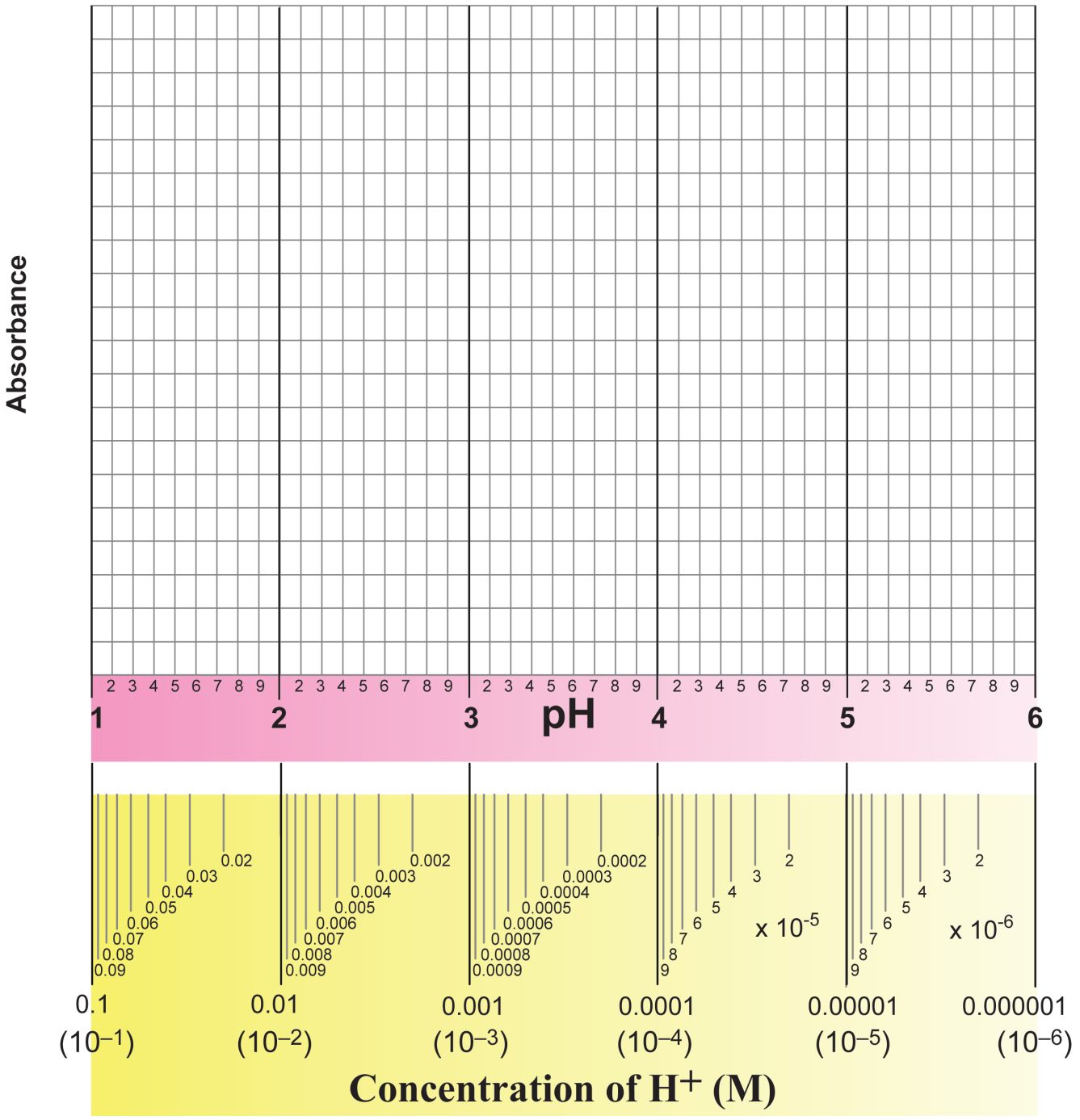

RGB Calibration vs. pH for bases

Indicator _____

Amount per cuvette _____

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