

Self-Ionization of Water and pH

Read from **Lesson 2: Acids and Bases in Aqueous Solutions** in the **Chemistry Tutorial Section, Chapter 15** of **The Physics Classroom**:

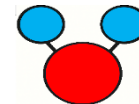
Part a: [Water and its Ionization](#)

Part b: [The pH Scale](#)

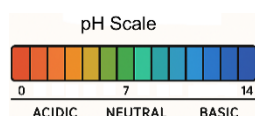
Part c: [pH Indicators](#)

Water, pH, and pH Indicators

Water is a unique substance because even in its pure form, a small number of water molecules naturally break apart in a process called **self-ionization**. In this process, two H_2O molecules interact to form a hydronium ion (H_3O^+) and a hydroxide ion (OH^-), or more simply, we often write it as H^+ and OH^- .



This reaction establishes a balance described by the **ionization constant of water, K_w** , which at 25°C equals 1.0×10^{-14} . The concentrations of H^+ and OH^- are equal in pure water, each at $1.0 \times 10^{-7} \text{ M}$, which gives water a **neutral pH of 7**.



The **pH scale** is a way to express the concentration of hydrogen ions using the formula **$\text{pH} = -\log[\text{H}^+]$** , and similarly, **$\text{pOH} = -\log[\text{OH}^-]$** . Since **$\text{pH} + \text{pOH} = 14$** at 25°C , this scale helps us quickly determine whether a solution is acidic, basic, or neutral.

pH indicators are substances that visibly change color depending on the **acidity** or **basicity** of a solution, making them valuable tools for measuring pH. Most indicators are **weak acids or bases** whose color shifts result from chemical interactions with hydrogen ions (H^+). These ions attach to or detach from the indicator molecule, altering its shape and structure. This structural change affects how the molecule absorbs and reflects light, producing a noticeable **color change**. Each indicator responds within a specific pH range, allowing precise detection of pH levels. Chemistry students use pH indicators like litmus, phenolphthalein, and bromothymol blue.

Part 1: pH and Concentration Calculations (PSAW – please show all work!)

Use the following formula to calculate complete the table below.

$$\text{pH} = -\log [\text{H}^+] \quad \text{pOH} = -\log [\text{OH}^-] \quad [\text{H}^+] = 10^{-\text{pH}} \quad [\text{OH}^-] = 10^{-\text{pOH}} \quad \text{pH} + \text{pOH} = 14$$

(Assume a temperature of 25°C . for all problems.)

1. Bo Rheum is cheering on his favorite baseball team. At the seventh inning stretch, he prepares a hot dog with lots of ketchup. If the **pH of ketchup is 3.59**, calculate the

$$\text{pOH} =$$

$$[\text{H}^+] =$$

$$[\text{OH}^-] =$$

2. Ima Jazzin purchased a morning latte that had a **pOH of 10.72**. Determine the

$$\text{pH} =$$

$$[\text{H}^+] =$$

$$[\text{OH}^-] =$$



Acids and Bases

3. At the local pet store, Guppy Garden, lava rock is placed in an aquarium to change the pH of the water. Before the lava rock is added, the aquarium **pH was 6.18**. Find the

$$\text{pOH} =$$

$$\text{pH} =$$

$$[\text{H}^+] =$$

Is this acidic, basic, or neutral?

4. The venom of a poison dart frog contains an alkaloid solution that has a **pOH of 2.45**. Calculate the

$$\text{pOH} =$$

$$\text{pH} =$$

$$[\text{H}^+] =$$

Is this acidic, basic, or neutral?



5. Freshly made guacamole from avocado pulp typically has a **hydrogen ion concentration of 2.5×10^{-6} M**. Find the

$$\text{pOH} =$$

$$\text{pH} =$$

$$[\text{H}^+] =$$

Is this acidic, basic, or neutral?

6. Bella Baker is whisking egg whites to make her chemistry teacher's favorite macarons. Egg whites have a **hydroxide concentration of 4.1×10^{-7} M**. Calculate the

$$\text{pOH} =$$

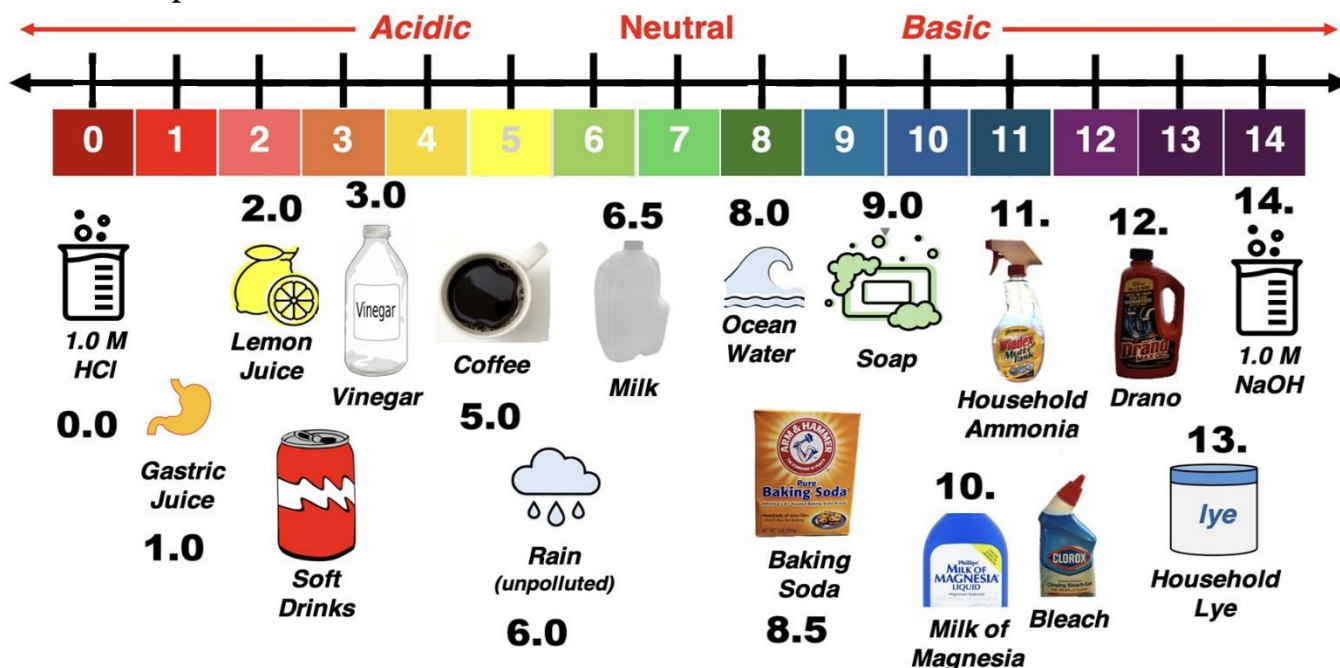
$$\text{pH} =$$

$$[\text{H}^+] =$$

Is this acidic, basic, or neutral?

Acids and Bases

Part 2: The pH Scale



Answer the following questions about the following image of common household items and their pH.

1. Which food on the pH scale is the most acidic? Explain your reasoning.
2. Which food on the pH scale is the most basic? Explain your reasoning.
3. Which item is closest to neutral pH? What does this suggest about its chemical behavior in aqueous solution?
4. Rank the following items from most acidic to most basic: baking soda, coffee, gastric acid, and soap. Justify your ranking.
The ranking is based on pH – the lowest to highest pH is the most acidic to most basic.
5. Compare the pH of lemon juice and vinegar. How much more acidic is lemon juice than vinegar? Explain your reasoning.
6. What would happen to the pH of milk if gastric acid were added to it?
7. Aaron Agin claims that lemon juice and soda are equally acidic because they taste sour. Is he correct? Use pH values and chemical reasoning to support or refute Aaron's claim.

Acids and Bases

Part 3: pH Indicators

Color Changes for Litmus

Litmus turns red in acidic solutions and blue in basic solutions.



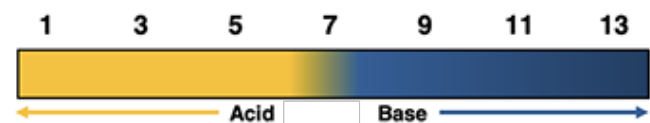
Color Changes for Phenolphthalein

Phenolphthalein is colorless in acidic and neutral solutions and is bright pink in basic solutions.



Color Changes for Bromothymol Blue

Bromothymol blue is yellow in acidic solutions and is blue in basic solutions.



Color Changes for Universal Indicator

Universal indicator is a blend of several indicators and displays a range of colors depending on the pH of the solution.



Questions

1. What is a pH indicator?
2. Why do pH indicators change color in different solutions?
3. Use the pH Scale on page 3 and the above color change charts for each pH indicator to answer the following questions:
 - a. Which indicator(s) would appear **yellow** when added to a sample of **unpolluted rain**?
 - b. Which indicator(s) would appear **red** when added to a **vinegar solution**?
 - c. Which substance(s) would show the **same color** when tested with **litmus**, **bromothymol blue**, and **universal indicator** (separately)?
4. Why might pH indicators give inaccurate readings in strongly colored or opaque solutions?