The pH Scale

For most solutions, the concentration of H_3O^+ ions is a very small number. Even in strongly acidic solutions, the concentration of H_3O^+ ions is only about $0.01\ mol/L$. In strong basic solutions, the concentration of H_3O^+ ions may be as low as $10^{-13}\ mol/L$.

In 1909, Søren Sørenson proposed a more compact way of expressing the concentration of H_3O^+ ions. His scale is based on logarithms and is known as the **pH scale** (pH stands for potency of hydrogen). According to this scale, the pH of a substance is given by

$$pH = -\log\left[H_3O^+\right]$$

Example 1
Calculate the pH of a solution with an H_3O^+ ion concentration of $4.7\times10^{-11}\ mol/L$.

Example 2
Calculate the pH of pure water.

The pH of a solution can be used to determine whether the solution is acidic, basic, or neutral.

- If $pH < 7.00$ the solution is acidic.
- If $pH = 7.00$ the solution is neutral.
- If $pH > 7.00$ the solution is basic.

If pH is measured in an experiment, it is possible to determine the H_3O^+ ion concentration. The following example illustrates this procedure.

Example 3
Convert a pH of 10.33 to a hydrogen ion concentration.

The concentration of OH^- ions is also very small in basic solutions. It is, therefore, useful to express OH^- ion concentrations is a similar way as is done for H_3O^+ ion concentrations, by calculating **pOH**.

$$pOH = -\log\left[OH^-\right]$$

Example 4
Calculate the pOH of a solution with a hydroxide ion concentration of $3.0 \times 10^{-6}\ mol/L$.

It is worth noting that there is a relationship between the pH and the pOH of a given solution at $25°C$.

$$pH + pOH = 14.00$$

Example 5
What is the pOH of a solution whose pH was measured to be 6.4?

The table below illustrates the relationship between pH, pOH, $\left[H_3O^+\right]$, $\left[OH^-\right]$. It also indicates the acidic or basic nature of solutions based on their pH.

	pH	$\left[H_3O^+\right]$	$\left[OH^-\right]$	pOH	
hydrochloric acid	0	1	10^{-14}	14	strongly acidic
stomach acid	1	10^{-1}	10^{-13}	13	
lemon juice	2	10^{-2}	10^{-12}	12	
vinegar, coke, beer	3	10^{-3}	10^{-11}	11	
tomatoes	4	10^{-4}	10^{-10}	10	weakly acidic
rain, black coffee	5	10^{-5}	10^{-9}	9	
urine	6	10^{-6}	10^{-8}	8	barely acidic
pure water	7	10^{-7}	10^{-7}	7	neutral
seawater	8	10^{-8}	10^{-6}	6	barely basic
baking soda	9	10^{-9}	10^{-5}	5	
milk of magnesia	10	10^{-10}	10^{-4}	4	weakly basic
household ammonia	11	10^{-11}	10^{-3}	3	
bicarbonate soda	12	10^{-12}	10^{-2}	2	
oven cleaner	13	10^{-13}	10^{-1}	1	
sodium hydroxide	14	10^{-14}	1	0	strongly basic

Worksheet

1. Normal rainwater has a pH near 6. In rainwater that falls close to a coal-burning power plant, the concentration of H_3O^+ ions is $6.23\times10^{-4}\ mol/L$. What is the pH? Is this more or less acidic than normal rainwater?

2. In household bleach, the concentration of OH^- ions is $5.0\times10^{-2}\ mol/L$. What is the pH?

3. In one brand of vegetable juice, the concentration of H_3O^+ ions is $7.3\times10^{-5}\ mol/L$. What is the pH of the juice?

4. Analysis of a sample of maple syrup reveals that the concentration of OH^- ions is $5.0\times10^{-8}\ mol/L$. What is the pH of this syrup? Is it acidic, basic, or neutral?

5. In a sample of bananas and water, it is found that $\left[H_3O^+\right]=2.51\times10^{-5}\ mol/L$. What is the corresponding pH value? Is the bananas and water solution acidic, basic, or neutral?

Answers

1. $pH = 3.206$. The rainwater is more acidic than normal.

2. $pH = 12.70$

3. $pH = 4.13$

4. $pH = 6.70$. The solution is acidic.

5. $pH = 4.60$. The solution is acidic.