Section 14.2
pH and pOH

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Learning Objectives

- Explain the characterization of aqueous solutions as acidic, basic, or neutral
- Express hydronium and hydroxide ion concentrations on the pH and pOH scales
- Perform calculations relating pH and pOH

$[H^+][HO^-]$

- The ion product of water shows that $[H^+]$ and $[HO^-]$ are inversely proportional.

$$[H^+] = \frac{K_W}{[HO^-]} \qquad [HO^-] = \frac{K_W}{[H^+]}$$

- A solution is
  - **Neutral** if it contains equal concentrations of hydronium and hydroxide ions
  - **Acidic** if it contains a greater concentration of hydronium ions than hydroxide ions;
  - **Basic** if it contains a lesser concentration of hydronium ions than hydroxide ions.

pH

- A common means of expressing quantities that may span many orders of magnitude is to use a logarithmic scale.

$$\mathrm{pX} = -\log \mathrm{X}$$

- The pH of a solution is defined as

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

- Where $[H_3O^+]$ is the molar concentration of hydronium ion in the solution

pOH

- The hydroxide ion molarity may be expressed as a p-function, called pOH

$$\mathrm{pOH} = -\log[\mathrm{OH^-}]$$

- pOH is not as common a quantity as it is more difficult to measure and can be calculated from pH.

pH and pOH to $[H_3O^+]$ and $[HO^-]$

- We can rearrange the pH and pOH definitions to solve for $[H_3O^+]$ and $[HO^-]$

$$[H_3O^+] = 10^{-pH}$$

$$[OH^-] = 10^{-pOH}$$

Converting between pH and pOH

- The relationship between pH and pOH can be derived from the K_w expression:

$$K_\mathrm{w} = [\mathrm{H_3O^+}][\mathrm{OH^-}]$$

$$-\log K_\mathrm{w} = -\log\left([\mathrm{H_3O^+}][\mathrm{OH^-}]\right) = -\log[\mathrm{H_3O^+}] + -\log[\mathrm{OH^-}]$$

$$\mathrm{p}K_\mathrm{w} = \mathrm{pH} + \mathrm{pOH}$$

- At 25 °C, the value of K_w is 1.0×10^{-14} so:

$$14.00 = \mathrm{pH} + \mathrm{pOH}$$

Neutral Solutions

- Neutral solutions have $[H^+] = [HO^-]$
  - At 25 °C

$$K_W = 1.00 \times 10^{-14} = (1.00 \times 10^{-7})(1.00 \times 10^{-7}) = [H^+][HO^-]$$

$$pH = -\log[H_3O^+] = -\log(1.0 \times 10^{-7}) = 7.00$$

$$pOH = -\log[OH^-] = -\log(1.0 \times 10^{-7}) = 7.00$$

Neutral Solutions

- Because K_W is dependent on temperature the pH and pOH of neutral solutions will also vary.

  For example, at 80 °C

$$\mathrm{pH} = -\log\left[\mathrm{H_3O^+}\right] = -\log\left(4.9 \times 10^{-7}\right) = 6.31$$

$$\mathrm{pOH} = -\log\left[\mathrm{OH^-}\right] = -\log\left(4.9 \times 10^{-7}\right) = 6.31$$

- This distinction can be important when studying certain processes, such as enzyme reactions in warm-blooded organisms at a temperature around 36–40 °C.

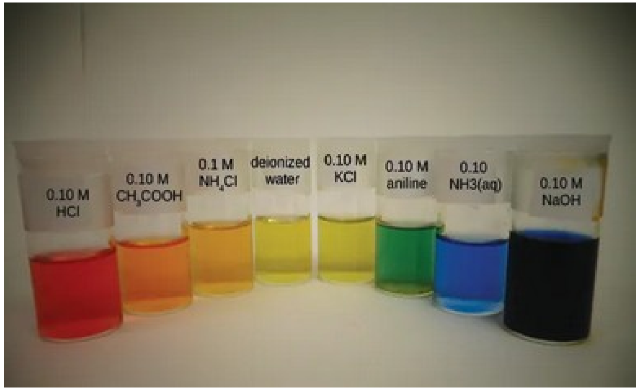
Common Examples

- Relationships between $[H_3O^+]$, $[OH^-]$, pH, and pOH for solutions classified as acidic, basic, and neutral

$[H_3O^+]$ (M)	$[OH^-]$ (M)	pH	pOH	Sample Solution
10^{1}	10^{-15}	–1	15	
10^{0} or 1	10^{-14}	0	14	1 M HCl (acidic)
10^{-1}	10^{-13}	1	13	gastric juice
10^{-2}	10^{-12}	2	12	lime juice; 1 M CH_3CO_2H (vinegar)
10^{-3}	10^{-11}	3	11	stomach acid; wine
10^{-4}	10^{-10}	4	10	orange juice
10^{-5}	10^{-9}	5	9	coffee
10^{-6}	10^{-8}	6	8	rain water
10^{-7}	10^{-7}	7	7	pure water (neutral)
10^{-8}	10^{-6}	8	6	blood; ocean water; baking soda
10^{-9}	10^{-5}	9	5	
10^{-10}	10^{-4}	10	4	Milk of Magnesia
10^{-11}	10^{-3}	11	3	
10^{-12}	10^{-2}	12	2	household ammonia, NH_3
10^{-13}	10^{-1}	13	1	bleach
10^{-14}	10^{0} or 1	14	0	1 M NaOH (basic)
10^{-15}	10^{1}	15	–1	

Measuring pH

- The acidity of a solution is typically assessed experimentally by measurement of its pH.
- The pOH of a solution is not usually measured, as it is easily calculated from an experimentally determined pH value.



Summary

Classification	Relative Ion Concentrations	pH at 25 °C
acidic	$[H_3O^+] > [OH^-]$	pH < 7
neutral	$[H_3O^+] = [OH^-]$	pH = 7
basic	$[H_3O^+] < [OH^-]$	pH > 7