Calculating pH of Salt Solutions

Ck12 Science

To access the online version of this FlexBook
click the link below:

https://www.ck12.org/c/chemistry/calculating-ph-of-salt-solutions/lesson/Calculating-pH-of-Salt-Solutions-CHEM/?referrer=concept_details

AUTHORS
Ck12 Science

To access a customizable version of this book, as well as other interactive content, visit www.ck12.org

CK-12 Foundation is a non-profit organization with a mission to reduce the cost of textbook materials for the K-12 market both in the U.S. and worldwide. Using an open-source, collaborative, and web-based compilation model, CK-12 pioneers and promotes the creation and distribution of high-quality, adaptive online textbooks that can be mixed, modified and printed (i.e., the FlexBook® textbooks).

Printed: August 3, 2023 (PST)

Calculating pH of Salt Solutions

Describes the ICE method and gives examples.

Calculating pH of Salt Solutions

[Figure1]

How do we keeping pools safe and healthy?

We all enjoy a cool dip in a swimming pool on a hot day, but we may not realize the work needed to keep that water safe and healthy. The ideal pH for a swimming pool is around 7.2. The pH will change as a result of many factors. Adjustment can be accomplished with different chemicals depending on the tested pH. High pH can be lowered with liquid HCl (unsafe material) or sodium bisulfate. The bisulfate anion is a weak acid and can dissociate partially in solution. To increase pH, use sodium carbonate. The carbonate anion forms an equilibrium with protons that results in some formation of carbon dioxide.

Calculating pH of Salt Solutions

It is often helpful to be able to predict the effect a salt solution will have on the pH of a certain solution. Knowledge of the relevant acidity or basicity constants allows us to carry out the necessary calculations.

Sample 1 Problem: Salt Hydrolysis

If we dissolve NaF in water, we get the following equilibrium:

$$\mathrm{F^-}(aq) + \mathrm{H_2O}(l) \rightleftarrows \mathrm{HF}(aq) + \mathrm{OH^-}(aq)$$

The pH of the resulting solution can be determined if the K_b of the fluoride ion is known.

20.0 g of sodium fluoride is dissolve in enough water to make 500.0 mL of solution. Calculate the pH of the solution. The K_b of the fluoride ion is 1.4×10^{-11}.

Step 1: List the known values and plan the problem.

Known

- mass NaF = 20.0 g
- molar mass NaF = 41.99 g/mol
- volume solution = 0.500 L
- K_b of F^- = 1.4×10^{-11}

Unknown

- pH of solution = ?

The molarity of the F^- solution can be calculated from the mass, molar mass, and solution volume. Since NaF completely dissociates, the molarity of the NaF is equal to the molarity of the F^- ion. An ICE **Table** (below) can be used to calculate the concentration of OH^- produced and then the pH of the solution.

Step 2: Solve.

$$20.0\ \cancel{\mathrm{g\ NaF}} \times \frac{1\ \cancel{\mathrm{mol\ NaF}}}{41.99\ \cancel{\mathrm{g\ NaF}}} \times \frac{1\ \mathrm{mol\ F^-}}{1\ \cancel{\mathrm{mol\ NaF}}} = 0.476\ \mathrm{mol\ F^-}$$

$$\frac{0.476\ \mathrm{mol\ F^-}}{0.5000\ \mathrm{L}} = 0.953\ \mathrm{M\ F^-}$$

$$\text{Hydrolysis equation:} \qquad F^-(aq) + H_2O(l) \rightleftarrows HF(aq) + OH^-(aq)$$

Concentrations	$[F^-]$	[HF]	$[OH^-]$
Initial	0.953	0	0
Change	$-x$	$+x$	$+x$
Equilibrium	$0.953 - x$	x	x

$$K_b = 1.4 \times 10^{-11} = \frac{(x)(x)}{0.953 - x} = \frac{x^2}{0.953 - x} \approx \frac{x^2}{0.953}$$
$$x = [OH^-] = \sqrt{1.4 \times 10^{-11}(0.953)} = 3.65 \times 10^{-6}\ M$$
$$pOH = -\log(3.65 \times 10^{-6}) = 5.44$$
$$pH = 14 - 5.44 = 8.56$$

Step 3: Think about your result.

The solution is slightly basic due to the hydrolysis of the fluoride ion.

Salts That Form Acidic Solutions

When the ammonium ion dissolves in water, the following equilibrium exists:

$$NH_4^+(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + NH_3(aq)$$

The production of hydronium ions causes the resulting solution to be acidic. The pH of a solution of ammonium chloride can be found in a very similar way to the sodium fluoride solution in Sample Problem above. However, since the ammonium chloride is acting as an acid, it is necessary to know the K_a of NH_4^+, which is 5.6×10^{-10}.

Sample Problem 2: Salt that form Acidic Solutions

Find the pH of a 2.00 M solution of NH_4Cl.

Step 1: List the known values and plan the problem.

Known

- molarity of NH_4Cl = 2.00 M
- molarity of NH_4^+ = 2.00 M
- K_a of NH_4^+ = 5.6 × 10^{-10}

Unknown

- pH of solution = ?

Because the NH_4Cl completely ionizes, the concentration of the ammonium ion is 2.00 M.

$$\mathrm{NH_4Cl}(s) \rightarrow \mathrm{NH_4^+}(aq) + \mathrm{Cl^-}(aq)$$

Again, an ICE **Table** (below) is set up in order to solve for the concentration of the hydronium (or H^+) ion produced.

Step 2: Solve.

Concentrations	**[NH_4^+]**	**[H^+]**	**[NH_3]**
Initial	2.00	0	0
Change	$-x$	$+x$	$+x$
Equilibrium	$2.00 - x$	x	x

Now substituting into the K_a expression gives:

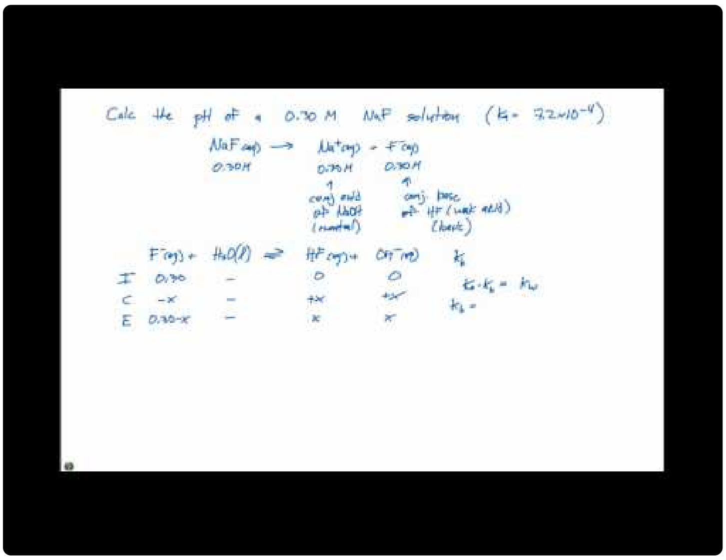
$$K_a = 5.6 \times 10^{-10} = \frac{x^2}{2.00 - x} \approx \frac{x^2}{2.00}$$
$$x = [\mathrm{H^+}] = \sqrt{5.6 \times 10^{-10}(2.00)} = 3.3 \times 10^{-5}\ \mathrm{M}$$
$$\mathrm{pH} = -\log(3.3 \times 10^{-5}) = 4.48$$

Step 3: Think about your results.

A salt produced from a strong acid and a weak base yields a solution that is acidic.

Video: Finding the pH of a Salt Solution Sample Problem

Watch Dr. Matthew W. Stoltzfus solve a sample problem!



https://www.ck12.org/flx/render/embeddedobject/185671

Review

1. In the first sample problem (*Sample Problem 1: Salt Hydrolysis*), how do we know that we can ignore x when determining $[F^-]$?
2. In the second sample problem (*Sample Problem 2: Salt that form Acidic Solutions*), how do we know the ammonium ion concentration?
3. Could we write the equilibrium in example two as $\mathrm{NH_4^+ \rightleftarrows H^+ + NH_3}$?

Science Friday: The Medical Wonders of Worm Spit

How useful is worm spit? It turns out that worm spit, also known as silk, is a very useful material in medicine. In this video by Science Friday, Dr. David Kaplan describes how silk is used in a variety of medical applications.

Sample Problem 2: Salt

1.0 REFERENCES

Image	Attributions
	**Credit:** User:Daderot/Wikimedia Commons **Source:** http://commons.wikimedia.org/wiki/File:Pool_2,_Fessenden_School_-_IMG_0262.JPG **License:** Public Domain