CURIOUS PH PROBLEM

CHEM 251 SDSU

CURIOUS PROBLEM

What is the pH of a solution of a solution with 7.93×10^{-8} M NaOH?

SIMPLE PH PROBLEM?

What is the pH of a solution of NaOH with a concentration of 7.93×10^{-8} M?

Standard approach:

$[\mathrm{NaOH}] = 7.93\times10^{-8}\,M$ pH=?

$14 = \mathrm{pH} + \mathrm{pOH}$

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

$\mathrm{pOH} = -\log\left[7.93\times10^{-8}\right] = 7.10$

$\mathrm{pH} = 14 - 7.10$

$\mathrm{pH} = 6.90$ ... so NaOH is an acid???

What went wrong with this calculation?
We neglected to account for the contribution of water (dissociation into H^+ and OH^-) and that contribution to the pH.
$K_w=[H^+][OH^-]=1.0\times10^{-14}$

NOT SO SIMPLE PH PROBLEM

What is the pH of a solution of NaOH with a concentration of 7.93×10^{-8} M?

$[\mathrm{NaOH}] = 7.93\times10^{-8} M$ pH=?

Equilibria:

$\mathrm{NaOH} \rightarrow \mathrm{Na^+} + \mathrm{OH^-}$

and $\mathrm{H_2O} \Leftrightarrow \mathrm{H^+} + \mathrm{OH^-} \quad K_w = [\mathrm{H^+}][\mathrm{OH^-}] = 1.0\times10^{-14}$

$[\mathrm{Na^+}] = 7.93\times10^{-8} M$

$[\mathrm{H^+}] = x$

$[\mathrm{OH^-}] = 7.93\times10^{-8} M + x$

$K_w = [\mathrm{H^+}][\mathrm{OH^-}] = (x)(7.93\times10^{-8} + x) = 1.0\times10^{-14}$

$1.0\times10^{-14} = x^2 + 7.93\times10^{-8}(x)$

$0 = x^2 + 7.93\times10^{-8}(x) - 1.0\times10^{-14}$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-7.93\times10^{-8} + \sqrt{(7.93\times10^{-8})^2 - 4(1)(-1.0\times10^{-14})}}{2(1)}$$

$x = [\mathrm{H^+}] = 6.79\times10^{-8} M \quad \mathrm{pH} = -\log(6.79\times10^{-8} M) = 7.17$

First identify the relevant equilibria and see how they are related, in this case OH^- is in common in both reactions.

Then solve for the common unknown value (x).

CONTRIBUTION OF WATER

- The autoprotolysis of water will contribute to the pH of a solution in select cases
- The concentration of the acid/base determines the influence:
  - $[H^+]$ or $[OH^-] \geq 10^{-6}$ water does not contribute
  - $[H^+]$ or $[OH^-] \leq 10^{-8}$ solution is pH 7
  - $10^{-6} \geq [H^+]$ or $[OH^-] \geq 10^{-8}$ autoprotolysis is important