Problem 8-01 pH – Strong bases

Calculate pH of aqueous solution of NaOH prepared at 17 °C

(a) by dilution of 1 cm^3 of NaOH solution with concentration of $1 \cdot 10^{-4}$ mol dm^{-3} to volume 10 dm^3

(b) by dilution of 1 cm^3 of NaOH solution with concentration of 0.1 mol dm^{-3} to volume 10 dm^3.

Is it possible to neglect the protolysis of water? Ionic product of water at the temperature of 17 °C is $5.83 \cdot 10^{-15}$ (standard state: infinite dilution, c^{st} = 1 mol dm^{-3}). Activity coefficients can be taken as equal to one.

[(a) pH = 7.146; (b) pH = 9.234;
Protolysis can be neglected in case (b): (a) pH = 6.234; (b) pH = 9.234]

Solution:

$c_1 = 0.0001$ mol dm^{-3} $\quad$ $c_2 = ?$
$V_1 = 1$ cm^3 $= 10^{-3}$ dm^3 $\quad$ $V_2 = 10$ dm^3 $\Big\}$ $c_2 = \dfrac{c_1 \cdot V_1}{V_2} = \dfrac{0.0001 \cdot 10^{-3}}{10} = 10^{-8}$ mol dm^{-3}

(1) $\quad NaOH = Na^+ + OH^-$
(2) $\quad H_2O = H^+ + OH^-$

$c_{H+} = x$
$c_{OH-} = x + c_2$

$K_w = c_{H+} \cdot c_{OH-} = x \cdot (x + c_2)$

$$x = -\frac{c_2}{2} \pm \sqrt{\left(\frac{c_2}{2}\right)^2 + K_v}$$

$$x = -\frac{10^{-8}}{2} \pm \sqrt{\frac{10^{-16}}{4} + 5.83 \cdot 10^{-15}} = -5 \cdot 10^{-9} \pm 7.6518 \cdot 10^{-8}$$

$x = c_{H+} = 7.1518 \cdot 10^{-8}$ mol dm^{-3}
pH = 7.1456

If we neglect water protolysis:

$c_{OH-} = c_2 = 1 \cdot 10^{-8}$ mol dm^{-3}

$$pH = -\log c_{H+} = -\log \frac{K_v}{c_{OH^-}} = -\log \frac{5.83 \cdot 10^{-15}}{1 \cdot 10^{-8}} = 6.2343$$

(b) $c_1 = 0.1$ mol dm^{-3} $\quad$ $c_2 = ?$
$V_1 = 1$ cm^3 $= 10^{-3}$ dm^3 $\quad$ $V_2 = 10$ dm^3 $\Big\}$ $c_2 = \dfrac{c_1 \cdot V_1}{V_2} = \dfrac{0.1 \cdot 10^{-3}}{10} = 10^{-5}$ mol dm^{-3}

$$x = -\frac{10^{-5}}{2} \pm \sqrt{\frac{10^{-10}}{4} + 5.83 \cdot 10^{-15}} = -5 \cdot 10^{-6} \pm 5.000582966 \cdot 10^{-6}$$

$x = c_{H+} = 5.82966 \cdot 10^{-10}$ mol dm^{-3}

pH = 9.23436

If we neglect water protolysis:

$c_{OH-} = c_2 = 1 \cdot 10^{-5}$ mol dm^{-3}

$$pH = -\log c_{H+} = -\log \frac{K_v}{c_{OH^-}} = -\log \frac{5.83 \cdot 10^{-15}}{1 \cdot 10^{-5}} = 9.23433$$ ... the protolysis can be neglected