

Problem 8-01 pH – Strong bases

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

(a) by dilution of 1 cm³ of NaOH solution with concentration of 1·10⁻⁴ mol dm⁻³ to volume 10 dm³

(b) by dilution of 1 cm³ of NaOH solution with concentration of 0.1 mol dm⁻³ to volume 10 dm³.

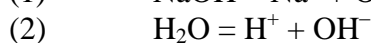
Is it possible to neglect the protolysis of water? Ionic product of water at the temperature of 17°C is 5.83·10⁻¹⁵ (standard state: infinite dilution, $c^{\text{st}} = 1 \text{ mol dm}^{-3}$). Activity coefficients can be taken as equal to one.

[(a) pH = 7.146; (b) pH = 9.234;

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

Solution:

$$\left. \begin{array}{l} c_1 = 0.0001 \text{ mol dm}^{-3} \\ V_1 = 1 \text{ cm}^3 = 10^{-3} \text{ dm}^3 \end{array} \right\} \begin{array}{l} c_2 = ? \\ V_2 = 10 \text{ dm}^3 \end{array} \quad c_2 = \frac{c_1 \cdot V_1}{V_2} = \frac{0.0001 \cdot 10^{-3}}{10} = 10^{-8} \text{ mol dm}^{-3}$$



$$c_{\text{H}^+} = x$$

$$c_{\text{OH}^-} = x + c_2$$

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

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

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

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

pH = 7.1456

If we neglect water protolysis:

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

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

$$\left. \begin{array}{l} \text{(b)} \quad c_1 = 0.1 \text{ mol dm}^{-3} \\ V_1 = 1 \text{ cm}^3 = 10^{-3} \text{ dm}^3 \end{array} \right\} \begin{array}{l} c_2 = ? \\ V_2 = 10 \text{ dm}^3 \end{array} \quad c_2 = \frac{c_1 \cdot V_1}{V_2} = \frac{0.1 \cdot 10^{-3}}{10} = 10^{-5} \text{ mol dm}^{-3}$$

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

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

pH = 9.23436

If we neglect water protolysis:

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

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