

Strong and weak acids, bases and pH

AP Chemistry · Worksheet answers

Each answer shows the equation, the substitution and the result, with the final value in bold. Compare your method as well as your number, because AP markers award credit for correct setup even when an arithmetic slip occurs.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 8

Problem 1 pH of a strong acid

1. HCl is strong, so $[\text{H}_3\text{O}^+] = \mathbf{0.0100 \text{ mol/dm}^3}$.
2. $\text{pH} = -\log_{10}(0.0100) = \mathbf{2.000}$.

Problem 2 pH of a strong base

1. $\text{pOH} = -\log_{10}(0.0030) = \mathbf{2.52}$.
2. $\text{pH} = 14.00 - 2.52 = \mathbf{11.48}$.

Problem 3 Hydronium from pH

1. $[\text{H}_3\text{O}^+] = 10^{-3.40} = \mathbf{3.98 \times 10^{-4} \text{ mol/dm}^3}$.
2. Neutral water has $1.0 \times 10^{-7} \text{ mol/dm}^3$, so the ratio is $10^{3.6} = \mathbf{\text{about 3981 times}}$ larger.

Problem 4 Classify the species

HNO_3 : strong acid. HF : weak acid. NH_3 : weak base. KOH : strong base. CH_3COOH : weak acid. HBr : strong acid. **Strong: HNO_3 , KOH , HBr ; weak: HF , NH_3 , CH_3COOH .**

Problem 5 Calcium hydroxide

1. $\text{Ca}(\text{OH})_2$ gives two OH^- , so $[\text{OH}^-] = 2 \times 0.050 = \mathbf{0.100 \text{ mol/dm}^3}$.
2. $\text{pOH} = 1.000$, so $\text{pH} = \mathbf{13.000}$.

Problem 6 Conjugate pairs

HCO_3^- donates a proton, so it is the acid and CO_3^{2-} is its conjugate base. NH_3 accepts a proton, so it is the base and NH_4^+ is its conjugate acid. **Pairs: $\text{HCO}_3^-/\text{CO}_3^{2-}$ and $\text{NH}_4^+/\text{NH}_3$.**

Problem 7 Dilution of a strong acid

1. $c_2 = 0.50 \times 10.0 / 500 = \mathbf{0.010 \text{ mol/dm}^3}$.
2. $\text{pH} = -\log_{10}(0.010) = \mathbf{2.00}$.

Problem 8 Neutral water at 50 °C

1. $[\text{H}_3\text{O}^+] = \sqrt{K_w} = \sqrt{(5.5 \times 10^{-14})} = \mathbf{2.35 \times 10^{-7} \text{ mol/dm}^3}$.
2. $\text{pH} = \mathbf{6.63}$.
3. Neutral means $[\text{H}_3\text{O}^+] = [\text{OH}^-]$. This holds at every temperature, but the value of each shifts as K_w grows.

Problem 9 Hydrocyanic acid

$K_a = x^2/0.10$, so $x = \sqrt{(4.9 \times 10^{-11})} = 7.00 \times 10^{-6} \text{ mol/dm}^3$. The ionised fraction is far below 5 %, so the shortcut holds. $\text{pH} = \mathbf{5.15}$.

Problem 10 Fluoride as a base

1. $\text{p}K_a = -\log_{10}(6.8 \times 10^{-4}) = \mathbf{3.17}$.
2. $K_b = K_w/K_a = 1.0 \times 10^{-14} / 6.8 \times 10^{-4} = \mathbf{1.5 \times 10^{-11}}$.
3. $\text{p}K_b = 14.00 - 3.17 = \mathbf{10.83}$.

Problem 11 HCl against ethanoic acid

1. HCl: $\text{pH} = \mathbf{1.00}$. Ethanoic acid: $x = \sqrt{(1.8 \times 10^{-6})} = 1.342 \times 10^{-3} \text{ mol/dm}^3$, $\text{pH} = \mathbf{2.87}$.
2. Both contain $2.50 \times 10^{-3} \text{ mol}$ of acid. As OH^- removes H_3O^+ , the weak acid keeps ionising, so every molecule is eventually neutralised: **equal volumes**.

Problem 12 K_a from a pH reading

1. $[\text{H}_3\text{O}^+] = 10^{-3.00} = \mathbf{1.0 \times 10^{-3} \text{ mol/dm}^3}$.
2. $[\text{A}^-] = 1.0 \times 10^{-3}$ and $[\text{HA}] = 0.100 - 0.001 = 0.099 \text{ mol/dm}^3$. $K_a = (1.0 \times 10^{-3})^2 / 0.099 = \mathbf{1.0 \times 10^{-5}}$.

Problem 13 Percent ionisation of HF

1. $x = \sqrt{(6.8 \times 10^{-4} \times 0.500)} = \mathbf{0.0184 \text{ mol/dm}^3}$.
2. $\text{pH} = \mathbf{1.73}$.
3. Percent = $0.01844/0.500 \times 100 = \mathbf{3.7 \%}$, below 5 %, so valid.

Problem 14 Methylamine

$x = [\text{OH}^-] = \sqrt{(4.4 \times 10^{-4} \times 0.40)} = 0.0133 \text{ mol/dm}^3$ (3.3 % of 0.40, valid). $\text{pOH} = 1.88$, so $\text{pH} = \mathbf{12.12}$.

Problem 15 Ammonium chloride solution

1. $K_a = K_w/K_b = 1.0 \times 10^{-14} / 1.8 \times 10^{-5} = \mathbf{5.6 \times 10^{-10}}$.
2. $x = \sqrt{(5.56 \times 10^{-10} \times 0.10)} = 7.45 \times 10^{-6} \text{ mol/dm}^3$; $\text{pH} = \mathbf{5.13}$. The solution is acidic

because NH_4^+ donates protons.

Problem 16 Mixing acid and base

1. $n(\text{H}^+) = 0.0250 \times 0.100 = 2.50 \times 10^{-3} \text{ mol}$; $n(\text{OH}^-) = 0.0150 \times 0.200 = 3.00 \times 10^{-3} \text{ mol}$.
2. OH^- is in excess by **$5.0 \times 10^{-4} \text{ mol}$** .
3. Volume 40.0 cm^3 , so $[\text{OH}^-] = 0.0125 \text{ mol/dm}^3$, $\text{pOH} = 1.90$, $\text{pH} = \mathbf{12.10}$.

Problem 17 When the shortcut fails

1. $x = \sqrt{6.8 \times 10^{-6}} = 2.608 \times 10^{-3} \text{ mol/dm}^3$; that is 26 % of 0.0100, which fails the rule (pH would be 2.58).
2. $x^2 + 6.8 \times 10^{-4}x - 6.8 \times 10^{-6} = 0$ gives $x = 2.290 \times 10^{-3} \text{ mol/dm}^3$, so $\text{pH} = \mathbf{2.64}$. The shortcut underestimates the pH by about 0.06.

Problem 18 Very dilute acid

1. A pH above 7 would mean a basic solution, but adding an acid cannot make water basic. Water itself supplies $1.0 \times 10^{-7} \text{ mol/dm}^3$ of H_3O^+ , which the student ignored.
2. $[\text{H}_3\text{O}^+] = 1.0 \times 10^{-8} + [\text{OH}^-]$, and $[\text{OH}^-] = K_w/[\text{H}_3\text{O}^+]$. So $x^2 - 1.0 \times 10^{-8}x - 1.0 \times 10^{-14} = 0$, giving $x = 1.051 \times 10^{-7} \text{ mol/dm}^3$ and $\text{pH} = \mathbf{6.98}$.

Problem 19 Two weak acids

1. $K_a(\text{X}) = 10^{-4.20} = \mathbf{6.31 \times 10^{-5}}$; $K_a(\text{Y}) = 10^{-5.60} = \mathbf{2.51 \times 10^{-6}}$.
2. $x(\text{X}) = 3.552 \times 10^{-3} \text{ mol/dm}^3$, $\text{pH} = \mathbf{2.45}$; $x(\text{Y}) = 7.088 \times 10^{-4} \text{ mol/dm}^3$, $\text{pH} = \mathbf{3.15}$.
3. Ratio = 5.01, which is **about 5.0**. It equals $\sqrt{K_a \text{ ratio}} = \sqrt{(10^{1.4})} = 10^{0.7}$, because x depends on $\sqrt{K_a}$.

Problem 20 Dilution and ionisation

1. Before: $x = 1.342 \times 10^{-3} \text{ mol/dm}^3$, $\text{pH} = \mathbf{2.87}$. After: $x = 4.243 \times 10^{-4} \text{ mol/dm}^3$, $\text{pH} = \mathbf{3.37}$.
2. Before: 1.34 %. After: **4.24 %**.
3. Diluting lowers every concentration, so $Q = [\text{H}_3\text{O}^+][\text{A}^-]/[\text{HA}]$ falls below K_a . The system shifts right to restore equilibrium, so a larger fraction ionises. The pH rises by only 0.5, not 1.