Year 13 Science: Weak acids, bases, pH and buffers

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the Ka expression for HCOOH.

2. Calculate the pH of 0.050 mol L^{-1} HCOOH. Ka = 1.78×10^{-4}.

3. Calculate the pH of 0.20 mol L^{-1} NH_4Cl. Ka(NH_4^+) = 5.75×10^{-10}.

4. Which solution conducts better, 0.10 mol L^{-1} CH_3COOH or 0.10 mol L^{-1} CH_3COONa?

5. A buffer has [NH_3] = [NH_4^+] = 0.10 mol L^{-1}. What is its pH? pKa(NH_4^+) = 9.24.

Exam-style question: pool chlorine

Pools are disinfected with sodium hypochlorite, NaOCl. Hypochlorous acid, HOCl, is the better disinfectant. Ka(HOCl) = 2.95×10^{-8}, pKa = 7.53.

6. Write the Ka expression for HOCl.

7. Calculate the pH of 0.050 mol L^{-1} NaOCl.

8. List the species in 0.050 mol L^{-1} NaOCl, except water, in order of decreasing concentration.

9. A pool is kept at pH 7.50. Calculate the ratio [OCl^-] ÷ [HOCl], and say which is present in the greater amount.

10. Compare the conductivity of 0.050 mol L^{-1} NaOCl and 0.050 mol L^{-1} HOCl.

Fix the mistake

11. Correct this statement: "For 0.10 mol L^{-1} CH_3COOH, [H_3O^+] = 0.10 mol L^{-1}, so the pH is 1.00."

12. Correct this statement: "NH_4Cl is a salt, so its solution has pH 7."

13. Correct this statement: "A buffer keeps the pH exactly constant whatever is added."

14. Correct this statement: "A weak acid conducts poorly because it is dilute."

Answer key (for parents and tutors)

1. Write the Ka expression for HCOOH.
   $K_a = [HCOO^-][H_3O^+] \div [HCOOH]$.

2. Calculate the pH of 0.050 mol L^{-1} HCOOH. Ka = 1.78×10^{-4}.
   $[H_3O^+] = \sqrt{(1.78 \times 10^{-4} \times 0.050)} = 2.98 \times 10^{-3}$ mol L^{-1}, so pH = 2.53.

3. Calculate the pH of 0.20 mol L^{-1} NH_4Cl. Ka(NH_4^+) = 5.75×10^{-10}.
   $[H_3O^+] = \sqrt{(5.75 \times 10^{-10} \times 0.20)} = 1.07 \times 10^{-5}$ mol L^{-1}, so pH = 4.97.

4. Which solution conducts better, 0.10 mol L^{-1} CH_3COOH or 0.10 mol L^{-1} CH_3COONa?
   CH_3COONa: it is fully dissociated into Na^+ and CH_3COO^- ions, while the acid is mostly molecules.

5. A buffer has $[NH_3] = [NH_4^+]$ = 0.10 mol L^{-1}. What is its pH? pKa(NH_4^+) = 9.24.
   $[NH_3] = [NH_4^+]$, so $[H_3O^+]$ = Ka and pH = pKa = 9.24.

6. Write the Ka expression for HOCl.
   $K_a = [OCl^-][H_3O^+] \div [HOCl]$ (Achieved).

7. Calculate the pH of 0.050 mol L^{-1} NaOCl.
   OCl^- is a weak base: $[H_3O^+] = \sqrt{(K_a \times K_w \div c)} = \sqrt{(2.95 \times 10^{-8} \times 1.0 \times 10^{-14} \div 0.050)} = 7.68 \times 10^{-11}$ mol L^{-1}, so pH = 10.11 (Merit).

8. List the species in 0.050 mol L^{-1} NaOCl, except water, in order of decreasing concentration.
   $Na^+ > OCl^- > HOCl = OH^- > H_3O^+$: NaOCl dissociates fully, a small fraction of OCl^- reacts, $OCl^- + H_2O \rightleftharpoons HOCl + OH^-$, giving equal small amounts of HOCl and OH^-, and $[H_3O^+]$ is tiny in a basic solution (Merit; Excellence with the reasons).

9. A pool is kept at pH 7.50. Calculate the ratio $[OCl^-] \div [HOCl]$, and say which is present in the greater amount.
   $[H_3O^+]$ = 10^−7.50 = 3.16×10^{-8} mol L^{-1}; $[OCl^-] \div [HOCl] = K_a \div [H_3O^+] = 2.95 \times 10^{-8} \div 3.16 \times 10^{-8} = 0.93$, so there is slightly more HOCl. The pH is just below the pKa, which is why pools are not allowed to drift much higher (Excellence).

10. Compare the conductivity of 0.050 mol L^{-1} NaOCl and 0.050 mol L^{-1} HOCl.
    NaOCl is a soluble salt, fully dissociated into Na^+ and OCl^-, so it conducts well. HOCl is a weak acid: very few molecules form H_3O^+ and OCl^-, so it conducts poorly (Merit; Excellence with equations for both).

11. Correct this statement: "For 0.10 mol L^{-1} CH_3COOH, $[H_3O^+]$ = 0.10 mol L^{-1}, so the pH is 1.00."
    A weak acid reacts only partly: $[H_3O^+] = \sqrt{(K_a \times c)} = 1.32 \times 10^{-3}$ mol L^{-1}, so the pH is 2.88.

12. Correct this statement: "NH_4Cl is a salt, so its solution has pH 7."
    NH_4^+ is a weak acid, so NH_4Cl solution is acidic; only salts whose ions do not react with water are neutral.

13. Correct this statement: "A buffer keeps the pH exactly constant whatever is added."
    A buffer only resists small additions; enough acid or base uses up one partner and the pH then changes sharply.

14. Correct this statement: "A weak acid conducts poorly because it is dilute."
    It conducts poorly because few of its molecules form ions; concentration and strength are separate ideas.