Key

pH and pOH Calculations

1. Find the pH of the following solutions. Make sure you express your answer in the correct number of significant digits. (12 marks)

a) 0.0010 M $HClO_4$ ..... 3.00 b) 2.35 x 10^{-3} M KOH ... 11.371

c) 4.678 x 10^{-5} M HNO_3.. 4.3299 d) 12.0 M HCl ..... −1.079

e) 0.20 M $Ba(OH)_2$ ..... 13.60 f) 4.30 M H_3O^+ ..... −0.633

2. Find the $[H_3O^+]$ in 0.00256 M HBr. (1 mark)

$[H_3O^+] = [HBr] = 0.00256M$

Answer 0.00256M

3. Find the $[H_3O^+]$ in 0.80 M LiOH. (2 marks)

$[OH^-] = 0.80M$

$[H_3O^+] = \frac{1.00 \times 10^{-14}}{0.80} = 1.3 \times 10^{-14} M$

Answer $1.3 \times 10^{-14} M$

4. Find the $[H_3O^+]$ in a solution with a pH = 3.216 (1 mark)

$[H_3O^+] = 10^{-3.216}$

Answer $6.08 \times 10^{-4} M$

5. Find the $[H_3O^+]$ in 0.45 M BaO (2 marks)

$O^{2-} + H_2O \rightarrow 2OH^-$

$[O^{2-}] = 0.45M$

$[OH^-] = 0.90M$

$[H_3O^+] = \frac{1.00 \times 10^{-14}}{0.90}$

Answer $1.1 \times 10^{-14} M$

6. Find the $[OH^-]$ in 0.150 M $HClO_4$ (2 marks)

$[H_3O^+] = 0.150M$

$[OH^-] = \frac{1.00 \times 10^{-14}}{0.150}$

Answer $6.67 \times 10^{-14} M$

7. Find the $[OH^-]$ in a solution with a pH = 8.940 (2 marks)

$pOH = 5.060$

$[OH^-] = 10^{-5.060}$

Answer $8.71 \times 10^{-6} M$

8. Find the $[OH^-]$ in a solution with a pOH = 2.156 (1 mark)

$[OH^-] = 10^{-2.156}$

Answer 6.98×10^{-3} M

9. Find the $[OH^-]$ in 0.87 M HNO_3. (2 marks)

$[OH^-] = \frac{1.00 \times 10^{-14}}{0.87}$

Answer 1.1×10^{-14} M

10. Find the $[H_3O^+]$ in a solution in which the pOH = 4.50. (2 marks)

pH = 9.50

$[H_3O^+] = 10^{-9.50}$

Answer 3.2×10^{-10} M

11. Solution A has a pH of 3.0 while solution B has a pH of 7.0.

a) Which solution is more acidic? (1 mark) A

b) The $[H_3O^+]$ in solution A is 10^4 times as high as it is in solution B (1 mark).

12. How much water should be added to 500.0 mL of a solution of HCl with a pH of 2.00 to bring the pH to 2.50. Show all your work. (3 marks)

$V_1C_1 = V_2C_2$

$C_1 = 10^{-2.00} = 0.010\ M$

$C_2 = 10^{-2.50} = 0.00316\ M$

$V_2 = \frac{V_1 \times C_1}{C_2} = \frac{0.5000 \times 0.010}{0.00316}$

$= 1.581$ L

Vol of water added

$= 1.581 - 0.5000$ L

Answer 1.1 L

13. What mass of NaOH should be added to 300.0 mL of water in order to prepare a solution with a pH = 11.50. Show all your work. (4 marks)

pH = 11.50

pOH = 2.50 $[OH^-] = 3.16228 \times 10^{-3}$ M = [NaOH]

mol NaOH = $3.16228 \frac{mol}{L} \times 0.3000\ L = 9.4868 \times 10^{-4}$ mol

Mass NaOH = 9.4868×10^{-4} mol $\times$ 40.0 g/mol

Answer 3.8×10^{-2} g

$= 0.038$ g

Key

Bronsted Acid-Bases and Equilibria

1. What is the $[OH^-]$ in a solution made by adding 0.060 moles of calcium oxide to 500.0 mL water? Be careful! (2 marks)

$[CaO] = \frac{0.060\ mol}{0.5000\ L} = 0.12\ M$ $[OH^-] = 2 \times [CaO]$

$CaO \rightarrow Ca^{2+} + O^{2-}$

$O^{2-} + H_2O \rightarrow 2OH^-$

Answer 0.24 M.

2. What is the $[H_3O^+]$ in a solution made by adding 0.020 moles of nitric acid to 500.0 mL of water? (2 marks)

$[HNO_3] = \frac{0.020\ mol}{0.500\ L} = 0.040\ M.$

Answer 0.040 M.

3. If 0.10 M HSO_3^- is mixed with 0.10 M $HC_2O_4^-$, which species will ***donate*** a proton? (1 mark)

Answer $H_2C_2O_4^-$

4. If 0.10 M HSO_4^- is mixed with 0.10 M $HC_6H_5O_7^{2-}$, which species will ***donate*** a proton? (1 mark)

Answer HSO_4^-

5. If 0.10 M HSO_3^- is mixed with 0.10 M $HC_6H_5O_7^{2-}$, which species will ***donate*** a proton? (1 mark)

Answer $HC_6H_5O_7^{2-}$

6. If 0.10 M HCO_3^- is mixed with 0.10 M $HC_2O_4^-$, which species will ***accept*** a proton? (1 mark)

Answer HCO_3^-

7. If 0.10 M HS^- is mixed with 0.10 M NO_2^-, which species will ***accept*** a proton? (1 mark)

Answer NO_2^-

8. If 0.10 M H_2SO_4 is mixed with 0.10 M HPO_4^{2-}, which species will ***accept*** a proton? (1 mark)

Answer HPO_4^{2-}

9. a) Write the balanced equation which describes the equilibrium present when 0.1 M H_2SO_3 is mixed with 0.1 M NO_2^-. (1 mark)

$H_2SO_3 + NO_2^- \rightleftharpoons HNO_2 + HSO_3^-$

Stronger A — Weaker A

b) For this reaction, equilibrium tends to favour the (*reactants/products*) (1 mark)

Answer products

c) For this reaction the value of Keq is (*<1, >1 or about =1*) (1 mark) >1

10. a) Write the balanced equation which describes the equilibrium present when 0.1 M HSO_3^- is mixed with 0.1 M $HC_2O_4^-$. (1 mark)

$HSO_3^- + HC_2O_4^- \rightleftharpoons H_2SO_3 + C_2O_4^{2-}$

weaker A SA

b) For this reaction, equilibrium tends to favour the (*reactants/products*) (1 mark)

Answer Reactants

c) For this reaction the value of Keq is (*<1, >1 or about =1*) (1 mark) <1

11. a) Write the balanced equation which describes the equilibrium present when 0.1 M HPO_4^{2-} is mixed with 0.1 M $H_2C_6H_5O_7^-$. (1 mark)

$H_2C_6H_5O_7^- + HPO_4^{2-} \rightleftharpoons H_2PO_4^- + HC_6H_5O_7^{2-}$

SA B WA B

b) For this reaction, equilibrium tends to favour the (*reactants/products*) (1 mark)

Answer products

c) For this reaction the value of Keq is (*<1, >1 or about =1*) (1 mark) >1

12. The Keq for the reaction: $HA_2B + CD^- \rightleftharpoons HCD + A_2B^-$ is **0.0020** (small)

WA WB SA SB

a) Which is the stronger conjugate acid in the above equilibrium?(1 mark) HCD

b) Which is the stronger conjugate base in the above equilibrium?(1 mark) A_2B^-

13. The Keq for the reaction: $H_2X + YZ^- \rightleftharpoons HYZ + HX^-$ is **3.4×10^5** (large)

SA SB WA WB

a) Which is the stronger conjugate acid in the above equilibrium?(1 mark) H_2X

b) Which is the stronger conjugate base in the above equilibrium?(1 mark) YZ^-

14. Equilibrium always favours the (*stronger/weaker*) weaker acid (1 mark)

15. Equilibrium always favours the (*stronger/weaker*) weaker base (1 mark)

Chem 12 **ABS part 1 - REVIEW QUESTIONS (Units 4 pt 1)** Key

1. Rank the following substances in the order of decreasing electrical conductivity (i.e. brightest light bulb to dimmest light bulb). Justify your answers!

1.0 M CCl_4 molecular	1.0 M H^+/Cl^-	1.0 M CH_3COOH molecular
1.0 M CCl_4	1.0 M HCl	1.0 M CH_3COOH
1.5 M NaCl	2.0 M NaOH	0.5 M HCN
1.5 M Na^+/Cl^-	2.0 M Na^+/OH^-	0.5 M H^+/CN^-

Greatest conductivity → 2.0 M NaOH — why? highest [ ] of Na^+/OH^-

1.5 M NaCl — why? higher [ ] of Na^+/Cl^-

1.0 M HCl — why? higher [ ] of H^+/Cl^-

} 100% dissociation

0.5 M HCN — why? low [ ] <100% dissociation, WA

1.0 M CH_3COOH — why? hardly dissociates but WA

Lowest conductivity → 1.0 M CCl_4 — why? molecular. no dissociation

2. Define the terms *strong acid* and *weak acid*. Using hydrobromic and hydrofluoric acid as examples, write equations to show the dissociation of each acid in aqueous solution.

Strong acid 100% dissociation into ions. Fwd rxn only. no eq'm

Ex: $HBr \rightarrow H^+ + Br^-$ / $HBr + H_2O \rightarrow H_3O^+ + Br^-$

Weak acid <100% dissociation. Equilibrium in water

Ex: $HF \rightleftharpoons H^+ + F^-$ / $HF + H_2O \rightleftharpoons H_3O^+ + F^-$

3. Identify **one** example of a strong base and **one** example of a weak base. Outline **three** different methods to distinguish between equimolar solutions of these bases in the laboratory. State how the results would differ for each base.

Strong base NaOH Weak base NH_3

i) pH meter

ii) conductivity

iii) neutralization/titration?

4. Vinegar has a pH of approximately 3 and some detergents have a pH of approximately 8. State and explain which of these has the higher concentration of H^+ and by what factor.

Vinegar. 10^5 more H^+. / lower pH = higher $[H^+]$. / pH = 3 acidic, pH = 8 basic

5. Calculate the pH of 0.125 M $HClO_4$.

$pH = -\log(0.125) = 0.903$ (1)

6. The value of the ionic product constant of water, K_w, at 60°C is 5.60×10^{-14}.

(a) State the expression for K_w. $= [H_3O^+][OH^-]$ (1)

(b) Calculate the values of $[H^+]$ and pH in water at 60°C. (2)

$[H^+] = [OH^-] = x$. $\quad x^2 = 5.6\times10^{-14}$

$[H^+] = \sqrt{5.6\times10^{-14}} = 2.366\times10^{-7}$ → pH = 6.626

(c) The value of $[OH^-]$ in water at 60°C is greater than the value at room temperature. Explain why water is not alkaline at 60°C.

$[H^+] = [OH^-]$ ⇒ makes water neutral. (2)

7. Calculate the resulting pH and pOH of a mixture between 60.0 mL of 0.150 M HI and 40.0 mL of 0.250 M $Sr(OH)_2$.

$2HI + Sr(OH)_2 \rightarrow SrI_2 + 2H_2O$

moles H^+: $0.150\ \frac{mol}{L} \times 0.0600\ L = 0.00900\ mol$ (1)

moles OH^-: $2 \times 0.250\ \frac{mol}{L} \times 0.0400\ L = 0.0200\ mol$ ← excess. (1)

excess $[OH]^-$: $\left(\frac{0.0200\ mol - 0.00900\ mol}{0.0600\ L + 0.0400\ L}\right) = \frac{0.011\ mol}{0.1\ L} = 0.11\ M.$ (1)

$\therefore pOH = -\log 0.11 = \boxed{0.959}$ (1)

$\therefore pH = 14 - 0.959 = \boxed{13.041}$ (1)