Acid-base titrations Chemistry Questions with Solutions

Q1: If 83 mL of 0.45 M NaOH solution neutralizes a 235 mL HCl solution. Calculate the molarity of the HCl solution.

Answer: The balanced chemical reaction between HCl and NaOH is as follows:

$$HCl\ (aq) + NaOH\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l)$$

From the molarity equation: M_AV_A / n_A (acid) = M_BV_B / n_B (base)

Where: n_A and n_B are the number of moles from the balanced chemical equation.

M_A and V_A are the molarity and volume of the acid

M_B and V_B are the molarity and volume of the base.

Hence, $M_A = M_BV_Bn_A / n_BV_A$ = 0.45 M x 83 mL x 1 / 235 mL x 1 = 0.16 M

The molarity of the HCl solution is 0.16 M.

Q2. What is the self-ionization of water?

Answer: Pure water is considered to have some ions and thus, it possesses very low conductivity. The ions in the pure water are in equilibrium as:

$$H_2O\ (l) \Leftrightarrow H^+\ (aq) + OH^-\ (aq)$$

The H^+ ions are smaller and have high mobility and thus, they cannot exist independently in the solution. Hence, the H^+ ions attach with a H_2O molecule to form a hydronium ion, H_3O^+. This is called self-ionization of water.

$$H_2O\ (l) \Leftrightarrow H_3O^+\ (aq) + OH^-\ (aq)$$

Q3. What is the common-ion effect?

Answer: The ionization equilibrium of an acid or base gets disturbed when another acid base with 1 ion common to the initial acid/base is added to it. Hence, as a result, the ionization of the initial compound decreases. This is called the common-ion effect.

Q4. Give the reason for the following statement: The addition of CH_3COONa to CH_3COOH increases the pH whereas the addition of NH_4Cl to aqueous ammonia solution (NH_4OH) decreases the pH of the system.

Answer: The reason for the above mentioned changes is the common-ion effect. When CH_3COONa is added to the weak acid CH_3COOH, CH_3COONa dissociates completely. While CH_3COOH being a weak acid does not dissociate completely. The dissociation of CH_3COOH gets even more hindered due to the generation of common acetate ions. The suppressed ionization of the weak acid results in a lesser number of liberated H^+ ions than there would have been without the addition of CH_3COONa. As a result, the pH of the solution increases.

Similarly, the addition of NH_4Cl to NH_4OH suppresses the dissociation of NH_4OH and hence, decreases the pH of the solution.

Q5. Point out the situation when the pH change is carried out by the common-ion effect in salt analysis.

Answer: In case of weak acids and weak bases, the ionization is a reversible process.
HA (aq) ⇔ H^+ (aq) + A^- (aq); (weak acid)
BOH (aq) ⇔ B^+ (aq) + OH^- (aq); (weak base)
When the concentration of A^- ion from weak acid and that of the B^+ ion from weak base increases, then as the result of the common ion effect, the equilibrium reverses. This is because the concentration of H^+ and OH^- ions decreases in order to maintain the equilibrium constant value, i,e. K value. Hence, the pH value of the solutions change due to the effect of the common ion.

Q6. How do the buffer solutions resist the change in pH?

Answer: A buffer is a solution that contains either a large amount of weak acid and its conjugate base or a large amount of weak base and its conjugate acid.
Both of these buffers use the same principle such as: in a weak acid- conjugate base buffer solution, if an acid is added, the conjugate base neutralizes it. If a base is added to the buffer, then, the weak acid neutralizes it and vice-versa.
If at the end, the conjugate base/weak acid ratio does not change much, the value of the pH of the solution does not change much.

Q7. List the differences between strong and weak acids and give 2 examples of each.

Answer: The differences between the strong and weak acids are given below:

S. No.	Strong Acids	Weak Acids
1.	Dissociate 100% in aqueous solution.	Do not dissociate 100% in an aqueous solution.
2.	pH of strong acids lie in the range 1-2.5	pH of weak acid lie in the range 3-5
3.	K_a value is higher.	K_a value is lower.
4.	H^+ ions dissociate completely.	H^+ ions do not dissociate completely.
5.	Examples are: HCl and H_2SO_4	Examples are: CH_3COOH and HCOOH

Q8. In the titration of strong acid vs strong base, what trend of pH is observed?

Answer: The pH of the solution increases abruptly near the equivalence point.

Q9. How is an indicator selected for detecting the pH change in acid-base titrations?

Answer: The indicator is a compound that imparts colour on gaining or losing electrons in the solution. For example, Methyl orange imparts a red colour when the solution is strongly acidic (pH 1-3), an orange colour when the solution is weakly acidic (pH 3-5) and a yellow colour in basic solution (pH > 5). However, Phenolphthalein imparts a bright pink colour in basic solution (pH > 8) and gives no colour in acidic solutions.
Hence, the indicator is selected on the basis of the chemical reaction.

Q10. Why are the solutions of $FeCl_3$ and Na_2CO_3 not neutral?

Answer: $FeCl_3$ is a salt of a strong acid i,e. HCl and a weak base i,e. Ferric hydroxide. Therefore in solution, $FeCl_3$ undergoes hydrolysis and forms HCl which is a strong acid and dissociates completely into the solution to make it acidic in nature. This is why $FeCl_3$ solution is acidic in nature.

$$FeCl_3 + 3H_2O \rightarrow Fe(OH)_3 + 3HCl$$

Similarly, Na_2CO_3 being a salt of the strong base NaOH and weak acid H_2CO_3 gets hydrolysed to form NaOH which in turn, increases the pH of the solution.

$$Na_2CO_3 + H_2O \rightarrow NaOH + H_2CO_3$$

Hence, Na_2CO_3 solution is basic in nature.

Q11. Why do the salts of strong acid and strong base not hydrolyze in the solution?

Answer: This is because the salts of strong acid versus strong base reaction upon hydrolysis again forms a strong acid and a weak base. Hence, these hydrolysis products would convert into ions as soon as they were formed.
For example, NaCl is a salt of strong acid HCL and strong base NaOH. On hydrolysis:
$NaCl + H_2O \rightarrow NaOH + HCl$
This is why the salts of strong acid and strong base not hydrolyze in the solution.

Q12. What will be the pH of the solution when 25 mL of 0.1 M NaOH is added to 40 mL of 0.1 M HCl solution?

Answer: Given: volume of NaOH (V_1) = 25 mL, molarity of NaOH solution (M_1) = 0.1 M
Number of moles of NaOH = n_1
Volume of HCl (V_2) = 40 mL, molarity of HCl solution (M_2) = 0.1 M
Number of moles of HCl = n_2
Now, Number of moles of NaOH, $n_1 = M_1 \times V_1$ = 0.025 L x 0.1 mol/L = 0.0025 mol
Number of moles of HCl, $n_2 = M_2 \times V_2$ = 0.040 L x 0.1 mol/L = 0.004 mol
HCl and NaOH react in a 1:1 ratio. Hence, HCl moles are in excess and will turn the solution acidic.

Now, the remaining moles of HCl in the solution, $n = n_2 - n_1 = 0.004 - 0.0025 = 0.0015$ mol
Molarity = No. of moles / Volume of solution (L)
Total Volume of the solution = 0.025 L + 0.04 L = 0.065 L
Hence, molarity of the remaining solution= 0.0015 / 0.065 mol L^{-1} = 0.023 M
Now, pH = -log $[H^+]$ = -log[0.023] = 1.638
Hence, the pH of the solution after the reaction is 1.64.

Q13. Which of the following 0.1 M solutions will turn the phenolphthalein pink?

a. CO_2
b. HBr
c. CH_3OH
d. LiOH

Answer: (d.)

Explanation: Phenolphthalein turns pink in basic solutions.

Q14. What will be the pH at the equivalence point of the reaction when 50 mL of 0.257 M HBr is titrated with 0.450 M KOH solution?

Answer: Both HBr and KOH are strong acid and strong base respectively. Ths strong acid and Strong base neutralize completely at the equivalence point and the solution becomes neutral. Thus, the pH must be 7.

Q15. The solubility of ______ will increase with a decrease in the pH of the solution.

a. $PbCl_2$
b. AgI
c. $CaCO_3$
d. AgCl

Answer: (c)

Explanation: $CaCO_3$ precipitates out at higher pH.

Practise Questions on Acid-base titrations

Q1. Comment on the trend of pH change in the titration between a weak acid and weak base.

Answer: The pH in the titration between a weak acid and weak base changes slightly near the equivalence point.

Q2. Why do the salts of weak acid and weak base hydrolyze in the solution?

Answer: Salts of weak acids and weak bases upon hydrolysis form weak acid and weak base. The weak acid and weak base formed do not dissociate completely in the aqueous solution and hence, some amount of them remain in the solution. This is why it is said that the salts of weak acid and weak base can hydrolyze in the solution.
This can be explained from the following example: CH_3COONH_4 is a salt of the weak acid (CH_3COOH) and weak base (NH_4OH). Upon hydrolysis,
$CH_3COONH_4 + H_2O \Leftrightarrow CH_3COOH + NH_4OH$

Q3. Explain the significance of the phenomenon of hydrolysis in salt analysis.

Answer: The hydrolysis of a salt produces either an acid or a base which may take part in the reaction and disturb the analysis of salt.

Q4. Explain what difference does dilution bring in the pH of the salt solution?

Answer: The salts of strong acids and strong bases do not hydrolyze. Hence, upon dilution, no change comes in the pH of the solution and the solution remains neutral, pH = 7.
The salts of weak acids and weak bases undergo hydrolysis and thus, upon dilution, the salt may undergo hydrolysis leading to the formation of either an acid or a base depending upon the nature of salt. Hence, the pH of the solution can either decrease or increase.

Q5. During the titration of a base with an acid, if some amount of water was left in the burette before you filled it with the acid solution, will this bring about a change in the final result?

Answer: Some extra drops of water will add to the reading on the burette. This would mean that more acid is utilized to neutralize the base. In turn, the concentration of the base comes out to be higher than it actually is.