

Answer on Question#38992-Chemistry-Organic Chemistry

Question

Arrange the following 0.1 M solutions in order of increasing pH and state why you placed each solution in that position: NaCH₃COO, HCl, HCN, NaOH, NH₃, NaCN, KNO₃, H₂SO₄, NH₄Cl, H₂SO₃, NaHCO₃, Na₃PO₄ and CH₃COOH.

Answer

pH of the solutions increases in the following range:

H₂SO₄ < HCl < H₂SO₃ < CH₃COOH < HCN < NH₄Cl < KNO₃ < NaCH₃COO < NaHCO₃ < NaCN < NH₃ < Na₃PO₄ < NaOH

There are three types of substances: acids, salts and bases.

Acids (pH < 7): H₂SO₄, HCl, CH₃COOH, H₂SO₃ and HCN

Salts: NaHCO₃, NaCN, NaCH₃COO, Na₃PO₄, KNO₃ and NH₄Cl

Bases (pH > 7): NaOH and NH₃ (note: NH₃ has no OH-groups but it is a base because in water solution it exists as NH₄OH (NH₃ + H₂O → NH₄OH)).

Acids and bases are divided into weak and strong. Strong acids dissociate easily and, thus, have lower pH, while weak acids dissociate hardly and have higher pH. Strong bases dissociate easily and, thus, have higher pH, while weak bases dissociate hardly and have lower pH. NaOH is a strong base, that is why it is last in the range. NH₄OH is a weak base.

The strength of the acids decrease in the range:

HCl > H₂SO₄ > H₂SO₃ > CH₃COOH > HCN

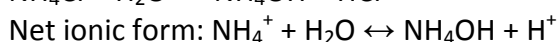
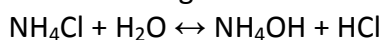
If one doesn't know which acid is stronger, one should find the pK_a values for the acid: the greater the pK_a the weaker the acid (note: HCl is stronger than H₂SO₄ but since the latter forms two hydrogen ions when dissociating it has lower pH).

pH of a salt solution depends on how the salt hydrolyze (if it does) in water solution. For such diluted solutions (0.1M) it may be assumed that salts hydrolyze completely. All salts are divided on:

- salts of strong acids and weak bases (so called acidic salts),
- salts of strong bases and weak acids (so called basic salts),
- salts of weak acids and weak bases,
- salts of strong acids and strong bases.

NH₄Cl is a salt of strong acid and weak base.

Salts of strong acids and weak bases hydrolyze producing strong acid. For NH₄Cl:



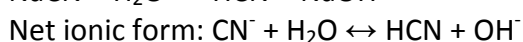
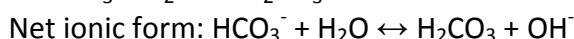
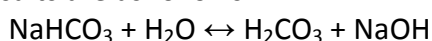
That is why this solution is acidic (pH < 7)

KNO₃ is a salt of strong acid and strong base. Such salts don't hydrolyze and their solution pH = 7. So, KNO₃ solution has pH = 7.

There are no salts of weak acids and weak bases in the given list of salts.

NaHCO₃, NaCN, NaCH₃COO, Na₃PO₄ are salts of a strong base (NaOH) and weak acids (actually H₃PO₄ is not weak but medium acid).

Salts of strong bases and weak acids hydrolyze producing strong base. Equations for four such salts are as follows:



Net ionic form: $\text{CH}_3\text{COO}^- + \text{H}_2\text{O} \leftrightarrow \text{CH}_3\text{COOH} + \text{OH}^-$

$\text{Na}_3\text{PO}_4 + 3 \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{PO}_4 + 3 \text{NaOH}$

Net ionic form: $\text{PO}_4^{3-} + 3 \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{PO}_4 + 3 \text{OH}^-$

Since Na_3PO_4 forms three hydroxyl ions when hydrolyzing, its solution is most basic (even more basic than ammonia solution). All other salts form only one hydroxyl ion. The weaker the acid formed when salt hydrolyzes the more basic the solution is. The strength of the acids decreases in the range: $\text{CH}_3\text{COOH} > \text{H}_2\text{CO}_3 > \text{HCN}$, so the pH of these three salts increases in the range: $\text{NaCH}_3\text{COO} < \text{NaHCO}_3 < \text{NaCN}$