Answer on Question #63247 - Chemistry - Inorganic Chemistry

Question: We were estimating dissolved CO_2 in water by American Public Health Association method. It was a Titrimetric Method using phenolphthalein indicator. Titrant used was NaOH and analyte was sample water. Our instructor said that on adding phenolphthalein if the water sample turns pink then it can be concluded that no free CO_2 is present. But how's it so?

Answer: Phenolphthalein is a commonly used indicator in acid-base titrations. In extremely acidic conditions (pH < 0 or, in other words, concentration of hydronium ions is more than 1 mol/L) it exists in protonated form and has orange color. In the pH range 0 – 8.2 it is colorless (the lactone form), in the pH range 8.2 – 11 its color is pink (the singly deprotonated anion form of the indicator), and at pH > 11 (strongly basic conditions) it undergoes slow fading reaction and becomes completely colorless at pH > 13.

Free CO_2 is always dissolved in different amounts in water which contacts with air (as you know, air always contains some percent of CO_2). When you add carbon dioxide to the water, the pH decreases due to the following reactions:

$CO_2 + H_2O \leftrightarrow H_2CO_3$

$H_2CO_3 + H_2O \leftrightarrow H_3O^+ + HCO_3^-$

As you see, the second reaction generates the hydronium ion which makes pH more acidic.

If you see that phenolphthalein turns pink, you easily make a conclusion that pH of a solution is basic. In such conditions, the concentration of hydroxyl anions is higher than the concentration of the hydronium ions and if CO_2 gets into a solution with basic pH, it gets involved into the following reactions:

$CO_2 + OH^- \leftrightarrow HCO_3^-$

$HCO_3^- + OH^- \leftrightarrow CO_3^{2-} + H_2O$ (in strongly basic conditions)

So, the conclusion is that there really is no free CO_2 in water with basic pH, but it can be found in the form of ions of carbonic acid (HCO_3^- and CO_3^{2-}) by using some other analytic reactions. The most common reaction is adding a strong acid to a solution which is thought to contain carbonates or hydrocarbonates. The pH falls down, ions of carbonic acid turn into free CO_2 and if its concentration in solution appears to be higher than the solubility limit at this temperature, it is extruded from the solution in the form of bubbles which can be observed.