

Balancing chemical equations

Teacher instructions and answers

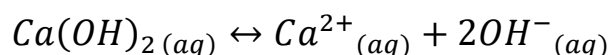
Chemical processes in water treatment

Instructions

1. Print student worksheets and equation cards (single-sided makes it easier to arrange).
2. Hand worksheets and the three sets of equation cards to each group of students.
3. Ask the students to work as a group to balance equations. Students will need to draw on their understanding of chemical principles to answer the reasons why they were added.

Answers

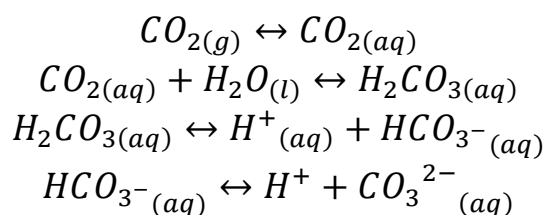
1. Write the relevant chemical equations of the dissolution of calcium hydroxide (lime). Then, identify the reasons why calcium hydroxide was added to the water after screening.



OH^{-} increases pH to reach the targeted pH range ($6.3 < pH < 10.3$) for a water filtration plant. At Orchard Hills this is $pH \sim 9$ to:

- boost pH to buffer the acidic reactions that occur from subsequent additions of chemicals eg, coagulants like ferric chloride.
 - create an optimal environment for stable floc formation. Floc occurs better in a mildly alkaline environment. Ferric hydroxide floc is insoluble in the pH range.
 - add calcium ions to harden the water, reducing calcium being leached from pipes, increasing the life of the pipes.
2. In all surface waters, carbon dioxide dissolves into water, forming the carbon dioxide/carbonic acid buffer system.

Write the relevant chemical equations to explain how the water is naturally buffered. How does calcium hydroxide from above manipulate this buffer? When would an unwanted by-product be produced?



This is an equilibrium buffer system; different species will dominate at different pH ranges.

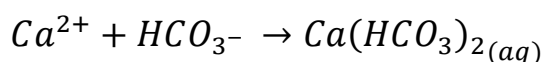
When pH is:

- < 6.3 , H_2CO_3 dominates

- $6.3 < \text{pH} < 10.3$, HCO_3^- dominates
- > 10.3 , CO_3^{2-} dominates.

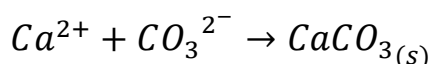
When HCO_3^- dominates, there's enough buffering capacity for the acidic coagulation reaction compared to lower pH range. HCO_3^- is a proton donor and proton acceptor. This means that when chemicals are added to the system that may produce acidic (or alkaline) conditions, it can resist changes in pH.

When $\text{Ca}(\text{OH})_2$ is added to the water at $6.3 < \text{pH} < 10.3$, the following will occur:



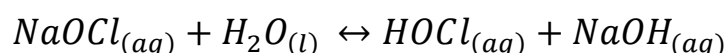
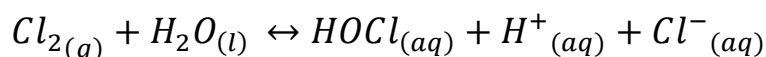
This ensures the calcium remains in solution and decreases the amount of solid to be filtered.

When $\text{Ca}(\text{OH})_2$ is added to the water at this $\text{pH} > 10.3$, the following will occur:



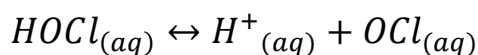
This solid is not harmful but will require a great deal more work to remove it and cause aesthetic and functional issues (scaling). It is not efficient and costly.

- 3. Balance and write the chemical equations to identify the difference between chlorination using chlorine gas compared to sodium hypochlorite. Hint: HOCl (hypochlorous acid) is the disinfectant. List some pros and cons of each chlorination technique.**



Chlorine gas is a better oxidising agent (more effective) than sodium hypochlorite. Only part of the chlorine in the hypochlorite solution is freely available to react with water. Sodium hypochlorite is a liquid which easier and safer to use than gas.

Being a weak acid, HOCl partially dissociated to hypchlorite ion (OCl^-).



The degree of dissociation varies with temperature and pH. An increase in pH will shift the equilibrium to the right. Sodium hypochlorite does this very slightly.