

Balancing chemical equations

Teacher instructions and answers

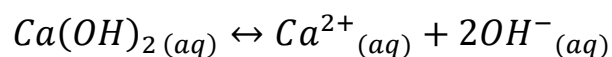
Chemical processes in water treatment

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

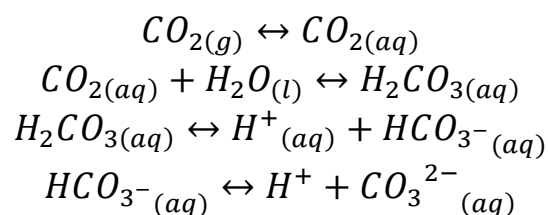
1. **Write the relevant chemical equations of the dissolution of calcium hydroxide (lime). Then, identify the reasons why calcium hydroxide was added to the water after screening.**



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.

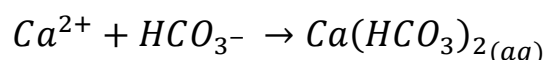
When pH is:

- < 6.3 , H_2CO_3 dominates

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

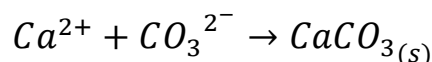
When HCO_3^- dominates, there's enough buffering capacity for the acidic coagulation reaction compared to lower pH range. HCO_3^- is a proton donor and proton acceptor. This means that when chemicals are added to the system that may produce acidic (or alkaline) conditions, it can resist changes in pH.

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



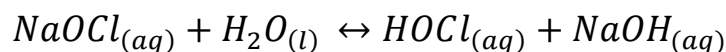
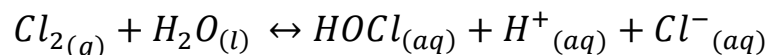
This ensures the calcium remains in solution and decreases the amount of solid to be filtered.

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



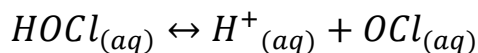
This solid is not harmful but will require a great deal more work to remove it and cause aesthetic and functional issues (scaling). It is not efficient and costly.

- 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.