

Review Questions

1. Write the balanced half-reaction involving O_2 that occurs in acidic waters when it oxidizes organic matter.
2. How does temperature affect the solubility of O_2 in water? Explain what is meant by *thermal pollution*.
3. Define *BOD* and *COD*, and explain why their values for the same water sample can differ slightly. Explain why natural waters can have a high *BOD*.
4. What do the acronyms *TOC* and *DOC* stand for, and how do they differ in terms of what they measure?
5. Write the half-reaction, used in the *COD* titration, which converts dichromate ion to Cr^{3+} ion, and balance it.
6. Write the balanced chemical reaction by which organic carbon, represented as CH_2O , is disproportionated by bacteria under anaerobic conditions.
7. Draw a labeled diagram classifying the top and bottom layers of a lake in summer as either oxidizing or reducing in character, and showing the stable forms of carbon, sulfur, nitrogen, and iron in the two layers.
8. What are some examples of highly reduced and of highly oxidized sulfur in environmentally important compounds? Write the balanced reaction by which sulfate can oxidize organic matter.
9. Explain the phenomenon of *acid mine drainage*, writing balanced chemical equations as appropriate.
10. What is meant by the *pE* of an aqueous solution? What does a low (negative) *pE* value imply about the solution? What species determines the *pE* value in aerated water?
11. What is the acid and what is the base that dominate the chemistry of most natural water systems, and whose interaction produces bicarbonate ion?
12. What is the source of most of the carbonate ion in natural waters? What name is given to waters that are exposed to this source?
13. Write the approximate net reaction between carbonate ion and water in a system that is *not* also exposed to atmospheric carbon dioxide. Is the resulting water acidic, alkaline, or neutral?
14. Write the approximate net reaction between carbonate ion and water in a system that *is* exposed to atmospheric carbon dioxide. Is the resulting water mildly acidic or mildly alkaline? Explain why the production of bicarbonate ion from carbonate ion does not inhibit its production from carbon dioxide, and vice-versa.
15. If two equilibrium reactions are added together, what is the relationship between the equilibrium constants for the individual reactions and that for the overall reaction?
16. Which are the most abundant ions in clean, fresh, calcareous water?
17. What is the natural source of fluoride ion in water? How and why is the fluoride level in drinking water artificially increased to about 1 ppm in many municipalities? How can fluoride be removed from natural water in which its concentration is too high?
18. Define the *total alkalinity index* and the *phenolphthalein alkalinity index* for water.
19. Define the *hardness index* for water.
20. Explain why aluminum ion concentrations in acidified waters are much greater than those in neutral water. How does the increased aluminum ion level affect fish and trees?



Green Chemistry Questions

1. What takes place during the scouring of cotton, and why is this process necessary for the production of finished cotton fibers?
2. Biopreparation (an enzymatic process) replaced the use of large amounts of sodium hydroxide in the scouring of cotton.
 - (a) Describe any environmental problems or worker hazards that would be associated with the use of sodium hydroxide solutions in the scouring of cotton.
 - (b) Would these same environmental problems or worker hazards be eliminated by the use of Biopreparation?

Additional Problems

1. Over a period of several days, estimate your approximate daily water usages in the categories of showering/bathing, clothes washing, toilets, dishwashing, and cooking. (Many flush toilets display volume-per-flush data. Washing machine water volume capacity can be estimated from the dimensions of the washer cavity: $1 \text{ L} = 10 \text{ cm} \times 10 \text{ cm} \times 10 \text{ cm}$. Using a measuring cup, discover how long it takes your shower to deliver one liter of water, and adjust the data accordingly for the length of your average shower.)
2. The TOC parameter for water samples is measured by oxidizing the organic material to carbon dioxide and then measuring the amount of this gas evolved from the solution. If a 5.0-L sample of wastewater produced 0.25 mL of carbon dioxide gas, measured at a pressure of 0.96 atm and a temperature of 22°C , calculate the TOC value for the sample. Assuming the average composition of the organic matter to be CH_2O , calculate what the Chemical Oxygen Demand value for the water sample would be due to its organic content. (The gas constant $R = 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$.)
3. The development of Biopreparation by Novozymes won a Presidential Green Chemistry Challenge Award.
 - (a) Which of the three focus areas (see page xxviii) for these awards does this award best fit into?
 - (b) List at least three of the twelve principles of green chemistry (see pages xxiii–xxiv) that are addressed by the green chemistry developed by Novozymes.
3. (a) Balance the reduction half-reaction that converts SO_4^{2-} to H_2S under acidic conditions.
 - (b) Deduce the expressions relating pE to pH, the concentration of sulfate ion and the partial pressure of hydrogen sulfide gas, given that for the half-reaction, $\text{pE}^0 = -3.50 \text{ V}$ when the pH is 7.0.
 - (c) Deduce the partial pressure of hydrogen sulfide when the sulfate ion concentration is 10^{-5} M and the pH is 6.0 for water that is in equilibrium with atmospheric oxygen.
4. Calculate the solubility of lead(II) carbonate, PbCO_3 ($K_{\text{sp}} = 1.5 \times 10^{-13}$) in water, given that most of the carbonate ion it produces subsequently reacts with water to form bicarbonate ion. Recalculate the solubility assuming that none of the carbonate ion reacts to form bicarbonate; is your result significantly different from that calculated assuming complete reaction of carbonate with water?
5. The bicarbonate ion, HCO_3^- , can potentially act as an acid or as a base in water. Write the chemical equations for these two processes, and

from the information given in this chapter, determine the corresponding acid and base dissociation constants. Given the relative magnitudes of the dissociation constants, decide whether the dominant reaction of bicarbonate in water will be as an acid or as a base. Calculate the pH of an aqueous 0.010 M solution of sodium bicarbonate in water using the dominant reaction alone, and assuming that the amounts of carbonate ion and carbonic acid from other sources are negligible in this case.

6. A sample of lake water at 25°C is analyzed and the following parameters are found for it:

$$\text{total alkalinity} = 6.2 \times 10^{-4} \text{ M}$$

$$\text{phenolphthalein alkalinity} = 1.0 \times 10^{-5} \text{ M}$$

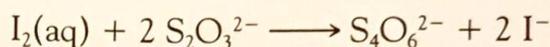
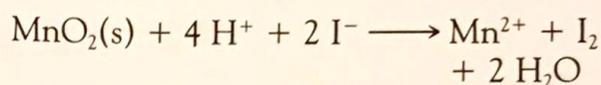
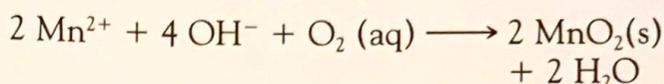
$$\text{pH} = 7.6$$

$$\text{hardness} = 30.0 \text{ mg L}^{-1}$$

$$[\text{Mg}^{2+}] = 1.0 \times 10^{-4} \text{ M}$$

Extract all possible single ion concentrations that you can by combining one or more of these data. Also determine whether or not the water is at equilibrium with respect to the carbonate–bicarbonate system and whether or not it is saturated with calcium carbonate.

7. The O_2 concentration of a water sample can be determined using the so-called Winkler titration method. In it, the oxygen in a small sample of the water is reacted with MnSO_4 in a basic solution. The reaction precipitates the manganese as MnO_2 , which converts added I^- to I_2 . Molecular iodine is then quantitatively determined by titrating it in acidic solution with a standardized solution of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$. The set of equations for the reactions is:



In determining the BOD of a sample of water, a chemist used two 10.00-mL samples of the water, one before and one after the five-day incubation period. They required 10.15 and 2.40 mL of a 0.00100 M standard solution of $\text{K}_2\text{S}_2\text{O}_3$. Calculate the BOD, in units of milligrams per liter, of this water sample. On the basis of these results, would you consider this water to be polluted?