RLP-CHEMB · RLP Chemistry B — Energy, Equilibrium, Earth Systems and Nuclear Chemistry

Unit 3: Acids and Bases, Redox, Water and the Carbon Cycle

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 3.1 — Why Missouri Streams Must Stay Between pH 6.5 and 9.0

FLUENCY

1. What is the pH of 0.0100 M HCl, a strong acid?

2. Calculate $[H^+]$ for a stream sample with pH 8.30.

3. What is the pH of 0.0025 M NaOH, a strong base? ($K_w = 1.0 \times 10^{-14}$)

4. How many times greater is $[H^+]$ at pH 6.5 than at pH 9.0?

APPLICATION

5. A 0.250 M acetic acid solution ($K_a = 1.8 \times 10^{-5}$) is prepared. Find its $[H^+]$, its pH and the percent ionized.

6. A buffer contains 0.200 M acetic acid and 0.100 M acetate ($pK_a = 4.74$). Find its pH.

7. How many mL of 0.100 M NaOH neutralize 25.0 mL of vinegar with $[CH_3COOH] = 0.833$ M?

8. Missouri's lower pH limit is 6.5. A stream sample reads pH 5.8. How many times greater is its $[H^+]$ than at the limit?

CHALLENGE

9. Add 0.0050 mol NaOH to 1.00 L of a buffer that is 0.100 M in acetic acid and 0.100 M in acetate, and to 1.00 L of pure water. Compare the two final pH values.

10. 0.10 M HCl has pH 1.00, but 0.10 M acetic acid has pH 2.88. Explain the difference in terms of ionization.

REVIEW

11. How many moles are in 4.5 g of $CaCO_3$?

12. How much energy is needed to warm 250 g of water from 22.0 °C to 37.0 °C? ($c = 4.184\ J/g{\cdot}°C$)

13. For $N_2 + 3H_2 \rightleftharpoons 2NH_3$, $[N_2] = 0.50$ M, $[H_2] = 0.20$ M and $[NH_3] = 0.10$ M. Calculate Q.

Lesson 3.2 — Redox in a Lemon and in a Car Battery

FLUENCY

1. What is the oxidation number of manganese in $KMnO_4$?

2. In $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$, which species is oxidized and which is reduced?

3. Calculate E°_{cell} for Mg | Cu (E° $Mg^{2+}/Mg = -2.36$ V, $Cu^{2+}/Cu = +0.34$ V).

4. Calculate E°_{cell} for Zn | Fe ($Fe^{2+}/Fe = -0.44$ V, $Zn^{2+}/Zn = -0.76$ V) with iron as the cathode.

APPLICATION

5. Calculate ΔG° for the zinc-copper cell ($E^\circ = 1.10$ V, $n = 2$, $F = 96{,}485$ C/mol).

6. A lead-acid cell has $E^\circ = 1.69 - (-0.36)$ V. How many cells in series give a battery of about 12 V, and what is the exact voltage?

7. One lead-acid cell delivers 50 A·h, oxidizing Pb to $PbSO_4$ (two electrons per atom). What mass of lead is used? (Pb = 207.2 g/mol)

8. A lemon cell delivers 1.0 mA for 1.0 h. What mass of zinc ($Zn^{2+} + 2e^-$; 65.38 g/mol) dissolves?

CHALLENGE

9. Silver ($Ag^+/Ag = +0.80$ V) and copper ($Cu^{2+}/Cu = +0.34$ V). Will Ag^+ oxidize copper metal? Give E°_{cell} and your reasoning.

10. A lemon cell with two zinc nails reads about 0 V. Explain using the equation for E°_{cell}.

REVIEW

11. For the balanced reaction $CaCO_3 \rightarrow CaO + CO_2$, what mass of CO_2 forms from 50.0 g of $CaCO_3$, assuming $CaCO_3$ is the limiting reactant?

12. How much heat is needed to warm 125 g of water from 20.0 °C to 65.0 °C?

13. $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is at equilibrium. Which way does it shift when the pressure is increased, and why?

Lesson 3.3 — Big Spring: Water, Carbonate Rock and Hardness

FLUENCY

1. Calculate the molar mass of $CaCO_3$ (Ca 40.078, C 12.011, O 15.999).

2. Water with 40.0 mg/L Ca^{2+} and no magnesium has what hardness as mg/L $CaCO_3$, and what is its USGS class?

3. Convert 18.0 mg/L Mg^{2+} to mol/L.

4. Is a hardness of 195 mg/L as $CaCO_3$ soft, moderately hard, hard or very hard?

APPLICATION

5. USGS measured Ca 21.8 mg/L and Mg 12.7 mg/L at Big Spring on 03/20/2002 (1,020 ft^3/s). Calculate the hardness and classify it.

6. For the 03/20/2002 sample, estimate the bicarbonate concentration by charge balance, using HCO_3^- = 61.016 g/mol.

7. For the 07/10/2002 sample (Ca 34.5 mg/L, Mg 19.5 mg/L) calculate the Ca:Mg mole ratio and say what it suggests about the rock.

8. At 276 ft^3/s and 39.8 mg/L calcium, how many metric tons of dolomite (184.40 g/mol) dissolve per day? (1 ft^3 = 0.028317 m^3)

CHALLENGE

9. Hardness fell from 195 mg/L (276 ft^3/s) to 107 mg/L (1,020 ft^3/s). Calculate the ratio and explain it.

10. Write the balanced equation for dolomite dissolving in water containing CO_2, and find the mass of HCO_3^- formed from 1.00 mol of dolomite.

REVIEW

11. A balloon holds 5.0 L at 25 °C. At constant pressure, what is its volume at -20 °C?

12. What is $[H^+]$ of normal rain at pH 5.6?

13. Why is the zinc-copper lemon cell's voltage predicted to be 1.10 V?

Lesson 3.4 — Carbon in the Air, the Ocean and the Infrared

FLUENCY

1. Calculate the frequency of infrared radiation with a wavelength of 4.30 μm ($c = 2.998 \times 10^8$ m/s).

2. Find the energy of a photon with frequency 2.01×10^{13} Hz ($h = 6.626 \times 10^{-34}$ J·s).

3. Using the Mauna Loa annual means 316.91 ppm (1960) and 325.68 ppm (1970), find the average growth rate.

4. Ocean surface pH drops by 0.11. By what percent does $[H^+]$ increase?

APPLICATION

5. Find the energy per mole of photons for the 14.9 μm band of CO_2 ($N_A = 6.022 \times 10^{23}$ mol^{-1}).

6. The Mauna Loa annual mean rose 3.53 ppm from 2023 to 2024. With 1 ppm = 7.75 Gt of CO_2, how much CO_2 stayed in the air, and what is the airborne fraction against 37.4 Gt emitted?

7. Calculate the pH of rain in equilibrium with 280 ppm CO_2 ($K_H = 0.034$, $K_{a1} = 4.3 \times 10^{-7}$).

8. Wien's law: $\lambda_{max} = b \div T$, $b = 2.898 \times 10^{-3}$ m·K. Find the peak wavelength for a surface at 287.5 K.

CHALLENGE

9. Visible light at 0.55 µm carries 3.61×10^{-19} J per photon. Compare it with a 14.9 µm infrared photon and explain why CO_2 absorbs the infrared but not the visible.

10. In the 1960s, growth of 0.88 ppm/yr and emissions near 11 Gt/yr; in 2024, 3.53 ppm and 37.4 Gt. Calculate both airborne fractions and comment.

REVIEW

11. For the balanced reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, what mass of CO_2 forms from 4.0 g of CH_4, assuming CH_4 is the limiting reactant?

12. What is the pH of 0.0010 M HCl?

13. How many moles are in 22.0 g of CO_2 (44.009 g/mol)?

Unit 3 checkpoint

1. Missouri's rule allows stream pH from 6.5 to 9.0. A pH of 5.5 has how many times the [H⁺] of pH 6.5?
   A. 2 times
   B. 10 times
   C. 100 times
   D. 5.5 times

2. The pH of the vinegar with [CH₃COOH] = 0.833 M and K_a = 1.8 × 10^{−5} is _____ (two decimals).

3. A buffer resists a change in pH because it contains
   A. a strong acid and a strong base
   B. a weak acid and its conjugate base
   C. only water
   D. a metal and an acid

4. In a lemon cell with zinc and copper, oxidation occurs at the
   A. copper, the cathode
   B. zinc, the anode
   C. lemon peel
   D. wire

5. For Zn²⁺/Zn = −0.76 V and Cu²⁺/Cu = +0.34 V, E°_{cell} = _____ V (two decimals).

6. True or false: Cells connected in series add their voltages, so six 2.05 V lead-acid cells give about 12.3 V.

7. Big Spring water with Ca 39.8 mg/L and Mg 23.2 mg/L has a hardness of 195 mg/L as CaCO₃. The USGS class is
   A. soft
   B. moderately hard
   C. hard
   D. very hard

8. True or false: Normal rain has a pH near 5.6 because it carries dissolved carbon dioxide.

9. Rain in equilibrium with 427.35 ppm CO₂ has pH _____ (two decimals).

10. Which photon carries more energy?
    A. 14.9 µm infrared
    B. 4.30 µm infrared
    C. They are equal
    D. Cannot tell

11. A straight-line fit to Missouri's temperature for 1959-2025 gives a 2050 forecast of _____ °F (one decimal).

12. True or false: A correlation between two data sets proves one caused the other.