CHAPTER 8 REVIEW

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Understanding Concepts

1. (a) An acid is a substance that dissolves to form a conducting solution that turns blue litmus red, neutralizes bases, reacts with active metals to form hydrogen gas, and reacts with carbonate compounds to form carbon dioxide gas.
   (b) A base is a substance that dissolves to form a conducting solution that turns red litmus blue, and neutralizes acids.
2 (a) sodium hydroxide base
   (b) acetic acid acid
   (c) magnesium hydroxide base
   (d) hydrochloric acid acid
   (e) calcium hydroxide base
   (f) (aqueous) ammonia base\
3 (a) basic: $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$
   (b) acidic: $HC_2H_3O_{2(aq)} \rightarrow H^+_{(aq)} + C_2H_3O^-_{2(aq)}$
   (c) basic: $Mg(OH)_{2(s)} \rightarrow Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)}$
   (d) acidic: $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$
   (e) basic: $Ca(OH)_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)}$
   (f) basic: $NH_{3(aq)} + H_2O_{(l)} \rightarrow NH^+_{4(aq)} + OH^-_{(aq)}$
4. (a) $[H^+_{(aq)}]$ is much greater in the hydrochloric acid solution.
   (b) In hydrochloric acid, essentially all of the HCl molecules are dissociated into ions. In acetic acid, only a very small percentage of $HC_2H_3O_2$ molecules are dissociated.
   (c) The same volume of $NaOH_{(aq)}$ would be required for each neutralization reaction.
5. In order of increasing pH, the solutions are:
   $HCl_{(aq)}$, $HC_2H_3O_{2(aq)}$, $NaCl_{(aq)}$, $NH_{3(aq)}$, $NaOH_{(aq)}$
6. (a) pH $= -\log [H^+_{(aq)}]$
   $= -\log [7.5 \times 10^{-3}\ mol/L]$
   pH $= 2.12$
   (b) pH $= -\log [H^+_{(aq)}]$
   $= -\log [2.5 \times 10^{-3}\ mol/L]$
   pH $= 2.60$
7. (a) $[H^+_{(aq)}] = 10^{-pH}$
   $= 10^{-11.56}$ mol/L
   $[H^+_{(aq)}] = 2.8\ 3\ 10^{-12}$ mol/L
   (b) $[H^+_{(aq)}] = 10^{-pH}$
   $= 10^{-3.50}$ mol/L
   $[H^+_{(aq)}] = 3.2 \times 10^{-4}$ mol/L
8. Electrical conductivity, pH, and rate of reaction with active metals can all be used to rank acids in terms of strength.
9. (a) $HNO_{2(aq)}$ has a higher pH (is less acidic, more basic).

   <50%
   (b) $HNO_{2(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + NO^-_{2(aq)}$
   >99%

$$HNO_{3(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + NO^-_{3(aq)}$$

As shown, nitric acid transfers protons to water completely, whereas in nitrous acid the transfer is much less than 50%, making the solution much less acidic.

10. $[H^+_{(aq)}]$ is ten times as concentrated in pH 5 as in pH 6.

11.

Concept	Main Idea	Limitations
oxygen	acids contain oxygen and react with limestone	doesn't explain solutions of $HCl_{(g)}$, or why some oxides make basic solutions
hydrogen	acids contain hydrogen and react with active metals to produce hydrogen gas	doesn't explain acidic solutions of $SO_{2(g)}$, or basic solutions from compounds containing hydrogen, e.g., $NH_{3(g)}$
Arrhenius	acids dissolve in water to produce $H^+_{(aq)}$	doesn't explain nonaqueous solutions, or hydrogen containing substances that can neutralize both acids and bases

12.

	acid	base	conjugate acid	conjugate base
(a)	$HSO^-_{4(aq)}$	$HCO^-_{3(aq)}$	$\rightarrow H_2CO_{3(aq)}$	$SO^{2-}_{4(aq)}$
(b)	$HSO^-_{4(aq)}$	$HPO^{2-}_{4(aq)}$	$\rightarrow H_2PO^-_{3(aq)}$	$SO^{2-}_{4(aq)}$
(c)	$H_2PO^-_{4(aq)}$	$H_2BO^-_{3(aq)}$	$\rightarrow H_3BO_{3(aq)}$	$HPO^{2-}_{4(aq)}$
(d)	$HCO^-_{3(aq)}$	$HS^-_{(aq)}$	$\rightarrow H_2S_{(aq)}$	$CO^{2-}_{3(aq)}$
(e)	$HSO^-_{3(aq)}$	$NH_{3(aq)}$	$\rightarrow NH^+_{4(aq)}$	$SO^{2-}_{3(aq)}$

13.

(a)	$NH_{3(aq)}$	ammonia	B-L acid or base
(b)	$NH^+_{4(aq)}$	ammonium ion	B-L acid
(c)	$NO^-_{2(aq)}$	nitrite ion	B-L base
(d)	$NO^-_{3(aq)}$	nitrate ion	B-L base

14. (a) conjugate acid–base pairs are: $PO^{3-}_{4(aq)}$ and $HPO^{2-}_{4(aq)}$

and: $H_2O_{(aq)}$ and $OH^-_{(aq)}$

(b) $PO^{3-}_{4(aq)}$ is a strong base that can only react as a base with water, so it must form a basic solution.

15. (a) $H_2SO_{3(aq)} + OH^-_{(aq)} \rightarrow HSO^-_{3(aq)} + H_2O_{(l)}$

(b) $HSO^-_{3(aq)} + OH^-_{(aq)} \rightarrow SO^{2-}_{3(aq)} + H_2O_{(l)}$

16. (a) $NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow H_2CO_{3(aq)} + NaCl_{(aq)}$

$HCO^-_{3(aq)} + H_3O^+_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)}$

(b) $NaHCO_{3(aq)} + NaOH_{(aq)} \rightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$

$HCO^-_{3(aq)} + OH^-_{(aq)} \rightarrow CO^{2-}_{3(aq)} + H_2O_{(l)}$

(c) $HCO^-_{3(aq)} + H_3O^+_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)}$

B A A B

$HCO^-_{3(aq)} + OH^-_{(aq)} \rightarrow CO^{2-}_{3(aq)} + H_2O_{(l)}$

A B B A

The conjugate acid–base pairs are:

$H_3O^+_{(aq)}$ and $H_2O_{(l)}$ and $H_2CO_{3(aq)}$ and $HCO^-_{3(aq)}$

$H_2O_{(l)}$ and $OH^-_{(aq)}$ and $HCO^-_{3(aq)}$ and $CO^{2-}_{3(aq)}$

(d) The hydrogen carbonate ion may act as either an acid or as a base; it is *amphiprotic*.

17. A chemical reaction suitable for titration must be spontaneous, fast, stoichiometric, and quantitative.

18. You must know the concentration of one reactant solution accurately to calculate precise results.

19. (a) titration: a laboratory procedure involving the carefully measured and controlled addition of a standard solution from a buret into a measured volume of a sample solution (or the sample solution could be in the buret ...)
(b) titrant: the solution in the buret during a titration
(c) endpoint: the point in a titration at which a sharp change in a property occurs (e.g., a colour change)

20. The acid reacts with an active metal to produce hydrogen gas.
$H_2SO_{4(aq)} + Zn_{(s)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$

The acid is partially neutralized by a basic solution.
$H_2SO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow Na_2SO_{4(aq)} + H_2CO_{3(aq)}$

The acid is completely neutralized by a strong basic solution.
$H_2SO_{4(aq)} + Zn_{(s)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$

Applying Inquiry Skills

21. The equipment required for the precision given would be:
(a) a volumetric flask
(b) a 10-mL graduated cylinder or a 10-mL graduated pipet
(c) a 10-mL volumetric pipet

22. **Experimental Design**
The pH is measured for samples of an acid and of a base. The samples are diluted tenfold, and the pH measured again.

Materials
- $HCl_{(aq)}$
- $NaOH_{(aq)}$
- two 150-mL beakers
- 100-mL graduated cylinder
- pH meter

23. (a) Analysis
Solution 1 is $NaHCO_{3(aq)}$, because it is basic, but not with the highest pH, and conducts well.
Solution 2 is $KNO_{3(aq)}$, because it is neutral, and conducts well.
Solution 3 is $H_2SO_{3(aq)}$, because it is acidic, but not with the lowest pH, and conducts poorly.
Solution 4 is $HCl_{(aq)}$, because it is acidic, with the lowest pH, and conducts well.
Solution 5 is $NaOH_{(aq)}$, because it is basic, with the highest pH, and conducts well.

(b) **Evaluation**
The experimental design is judged adequate because the experiment produces evidence needed to answer the question with a high degree of certainty.

24. (a) **Evidence**

Table 2: Titration of 10.00 mL of 0.120 mol/L $Na_2CO_{3(aq)}$ with $HCl_{(aq)}$

Trial	1	2	3	4
Final buret reading (mL)	17.9	35.0	22.9	40.1
Initial buret reading (mL)	0.3	17.9	5.9	22.9
Volume of $HCl_{(aq)}$ added	17.6	17.1	17.0	17.2
Colour at endpoint	red	orange	orange	orange

(b) **Analysis**
$Na_2CO_{3(aq)} + 2\ HCl_{(aq)} \rightarrow H_2CO_{3(aq)} + 2\ NaCl_{(aq)}$

10.00 mL 17.1 mL

0.120 mol/L C

$$n_{Na_2CO_3} = 10.00\ \text{m}\cancel{\text{L}} \times \frac{0.120\ \text{mol}}{1\ \cancel{\text{L}}} = 1.20\ \text{mmol}$$

$$n_{HCl} = 1.20\ \text{mmol} \times \frac{2}{1} = 2.40\ \text{mmol}$$

$$C_{HCl} = \frac{2.40\ \cancel{m}mol}{17.1\ \cancel{m}L}$$

$$C_{HCl} = 0.140\ mol/L$$

or $$C_{HCl} = 10.00\ \cancel{mL}\ \cancel{Na_2CO_3} \times \frac{0.120\ \cancel{mol\ Na_2CO_3}}{1\ L\ \cancel{Na_2CO_3}} \times \frac{2\ mol\ HCl}{1\ \cancel{mol\ Na_2CO_3}} \times \frac{1}{17.1\ \cancel{mL}}$$

$$C_{HCl} = 0.140\ mol/L$$

The concentration of the hydrochloric acid solution is 0.140 mol/L.

25. (a) **Evidence**

Table 3: Titration of 10.00 mL of $H_3PO_{4(aq)}$ with 1.25 mol/L $NaOH_{(aq)}$

Trial	1	2	3	4
Final buret reading (mL)	13.3	25.0	36.8	48.4
Initial buret reading (mL)	0.4	13.3	25.0	36.8
Volume of $NaOH_{(aq)}$ added	12.9	11.7	11.8	11.6
Colour at endpoint	deep red	pale pink	pale pink	pale pink

(b) **Analysis**

$$H_3PO_{4(aq)} + 2\ NaOH_{(aq)} \rightarrow H_2CO_{3(aq)} + 2\ NaCl_{(aq)}$$

10.00 mL　　11.7 mL

C　　1.25 mol/L

$$n_{NaOH} = 11.7\ m\cancel{L} \times \frac{1.25\ mol}{1\ \cancel{L}} = 14.6\ mmol$$

$$n_{H_3PO_4} = 14.6\ mmol \times \frac{1}{2}$$

$$n_{H_3PO_4} = 7.31\ mmol$$

$$C_{H_3PO_4} = \frac{7.31\ \cancel{m}mol}{10.00\ \cancel{m}L}$$

$$C_{H_3PO_4} = 0.731\ mol/L$$

or $$C_{H_3PO_4} = 11.7\ \cancel{mL}\ \cancel{NaOH} \times \frac{1.25\ \cancel{mol\ NaOH}}{1\ L\ \cancel{NaOH}} \times \frac{1\ mol\ H_3PO_4}{2\ \cancel{mol\ NaOH}} \times \frac{1}{10.00\ \cancel{mL}}$$

$$C_{H_3PO_4} = 0.731\ mol/L$$

The concentration of the original phosphoric acid solution in the rust remover is 7.31 mol/L — ten times the concentration of the diluted titrated solution.

(c) **Evaluation**

The prediction, based on the manufacturer's label, is verified by the results. The label seems to be quite accurate.

Making Connections

26. Personal experience indicates that acids "eat away" materials quite slowly — even the "instant" lime and scale cleaners advertised on television. The student response to this question will normally indicate that the movie industry generally greatly exaggerates (or even completely fabricates) the reactivity of acids for effect. Movies featuring entertaining misconceptions about acids include:

The Plastic Man Comedy/Adventure Show

Contaminazione

The Navy vs. the Night Monsters

Alien, Aliens

27. Boric acid is a very weak acid, so that almost none of its molecules in solution react with water to produce hydronium ions.

$$H_3BO_{3(aq)} + H_2O_{(l)} \xrightarrow{<50\%} H_3O^+_{(aq)} + H_2BO^-_{3(aq)}$$

For strong acids like $HCl_{(aq)}$, the dissolved molecules react with water almost totally, producing a high concentration of reactive hydronium ions.

$$HCl_{(aq)} + H_2O_{(l)} \xrightarrow{>99\%} H_3O^+_{(aq)} + Cl^-_{(aq)}$$

28. **Experimental Design**

The scale is removed by reaction with hydrochloric (shown here) or any other acid. A weaker acid reacts the same way, but more slowly — and would be much safer to work with. The reasoning behind this design is presented below. The hard-water scale ($CaCO_{3(s)}$ and/or $MgCO_{3(s)}$) reacts with the acid to form soluble compounds, as shown in the following reaction equations.

$$CaCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2CO_{3(aq)}$$

$$MgCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2CO_{3(aq)}$$

Materials

- eye protection
- rubber gloves
- hydrochloric acid (commercial scale remover or 0.10 mol/L)
- tap water
- plastic or glass bowls/containers
- plastic sponge

Procedure

1. Wear eye protection and rubber gloves.
2. Soak smaller scale-coated parts in the acid in a glass or plastic container.
3. Pour the acid solution into containers such as kettles that need to be descaled.
4. Wash larger scale-coated parts with the acid using a plastic sponge, being careful not to allow dripping onto other surfaces.
5. Rinse all solutions thoroughly down the sink with plenty of water.

29. Students will normally find that pH adjustment of municipal water is straightforward: any cheap non-toxic acid or base will do. Sodium hydroxide will increase pH while hydrochloric acid will decrease it, without adding any harmful ions in the process (providing only very low concentrations are achieved).

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30. Conifers have evolved to use nutrients that are most readily present in soils with lower pH values. Acid rain in general lowers the pH in plants more than the normal level, resulting in varying degrees of stress for the plants.

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Exploring

31. Lewis acid–base theory focuses on electron pairs in bond formation, with an acid being the electron pair acceptor, and a base the electron pair donor. This concept allows dealing with many reactions that do not involve Brønsted-Lowry acids or bases.

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