Solutions & Answers to Questions 4 to 12

4. Three Characteristic reactions of acids:

1. (HA) acid + active metal → $H_2(g)$ + (XA) salt (single replacement)
2. (HA) acid + metal carbonate → $CO_2(g) + H_2O(l)$ + (XA) salt (double replacement + decomposition)
3. (HA) acid + (XOH) base → (XA) salt + $H_2O(l)$ (neutralization)

5. The four requirements to use a chemical rxn in a titration are that they must be: spontaneous, fast, quantitative and stoichiometric

6. Acid (goes into the Erlenmeyer flask)
   Base (goes into the Buret)

7. A standard solution is the solution for which you know the precise and accurate concentration

8. Several titrations are typically peformed to improve the reliability of your answer

Practice

Understanding Concepts

4. Briefly describe three types of characteristic reactions of acids.
5. What are the four reaction requirements in order to use a reaction in a titration in a chemical analysis?
6. What are the two reactants in a titration, and what equipment is used to contain them?
7. What is a standard solution?
8. Why are several trials usually done in a titration?

Applying Inquiry Skills

9. Analysis shows that 9.44 mL of 0.0506 mol/L $KOH_{(aq)}$ is needed for the titration of 10.00 mL of a water sample taken from an acidic lake. Determine the molar concentration of acid in the lake water, assuming that the acid is sulfuric acid.

9.

$$2KOH(aq) + H_2SO_4(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$$

$$9.44\,\text{mK}\left(\frac{1\cdot10^{-3}\,K}{1\,\text{mK}}\right)\left(\frac{0.0506\,\text{mol KOH}}{1\,K}\right)\left(\frac{1\,\text{mol}\,H_2SO_4}{2\,\text{mol KOH}}\right)\left(\frac{1}{10.00\,\text{mL}}\right)\left(\frac{1\,\text{mL}}{1\cdot10^{-3}\,L}\right)$$

$$= 0.0239\ \text{M}\ H_2SO_4$$

10. $H_2C_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(\ell)$

$13.4\ mL \left(\frac{1 \cdot 10^{-3}\ L}{1\ mL}\right)\left(\frac{0.0161\ mol\ NaOH}{1\ L}\right)\left(\frac{1\ mol\ H_2C_2O_4}{2\ mol\ NaOH}\right)\left(\frac{1}{10.00\ mL}\right)\left(\frac{1\ mL}{1 \cdot 10^{-3}\ L}\right) = 0.0108\ M\ H_2C_2O_4$

b. (diluted value)

$0.0108\ M \cdot 100 =$

$1.08\ M\ H_2C_2O_4$

c. $1.08\ M\ H_2C_2O_4 \cong 1.11\ M$ $H_2C_2O_4$ predicted value

10. Solutions of oxalic acid, $H_2C_2O_{4(aq)}$, have many applications. Like $H_2SO_{4(aq)}$, oxalic acid reacts in a 2:1 mole ratio with sodium hydroxide. Complete the **Evidence**, **Analysis**, and **Evaluation** sections of the following investigation report.

Question

What is the concentration of oxalic acid in a rust-removing solution?

Prediction

The oxalic acid solution is labelled as 10% W/V, or 1.11 mol/L.

Experimental Design

The original oxalic acid solution (rust remover) is diluted by a factor of 100 that is, 10.00 mL to 1000 mL. The concentration of dilute oxalic acid solution is determined by titration with a sodium hydroxide solution.

Evidence

(a) Copy and complete **Table 4**.

Table 4: Volume of 0.0161 mol/L Sodium Hydroxide Required to Neutralize 10.00 mL of Diluted Oxalic Acid

Trial	1	2	3	4
Final buret reading (mL)	14.3	27.8	41.1	13.8
Initial buret reading (mL)	0.2	14.3	27.8	0.4
Volume of $NaOH_{(aq)}$ used (mL)	14.1	13.5	13.3	13.4

outlier ∴ discard

average = 40.2 ÷ 3 = 13.4 mL NaOH

Analysis

(b) Using the Evidence in **Table 5**, calculate the concentration of oxalic acid in the rust remover.

Evaluation

(c) Evaluate the Prediction: Is the manufacturer's label accurate?

11. Complete the **Evidence** and **Analysis** for the following titration.

Question

What is the molar concentration of the hydrochloric acid in a solution of kettle-scale remover?

Experimental Design

The hydrochloric acid in a solution of kettle-scale remover is titrated with a standardized solution of barium hydroxide. The colour change of bromothymol blue indicator (from blue to green) is the endpoint.

Evidence

(a) Copy and complete **Table 5**.

Table 5: Titration of 10.00-mL Samples of $HCl_{(aq)}$ with 0.974 mol/L $Ba(OH)_{2(aq)}$

Trial	1	2	3	4
final buret reading (mL)	15.6	29.3	43.0	14.8
initial buret reading (mL)	0.6	15.6	29.3	1.2
volume of $Ba(OH)_{2(aq)}$ added (mL)	15.0	13.7	13.7	13.6
colour at endpoint	blue	green	green	green

outlier ∴ discard

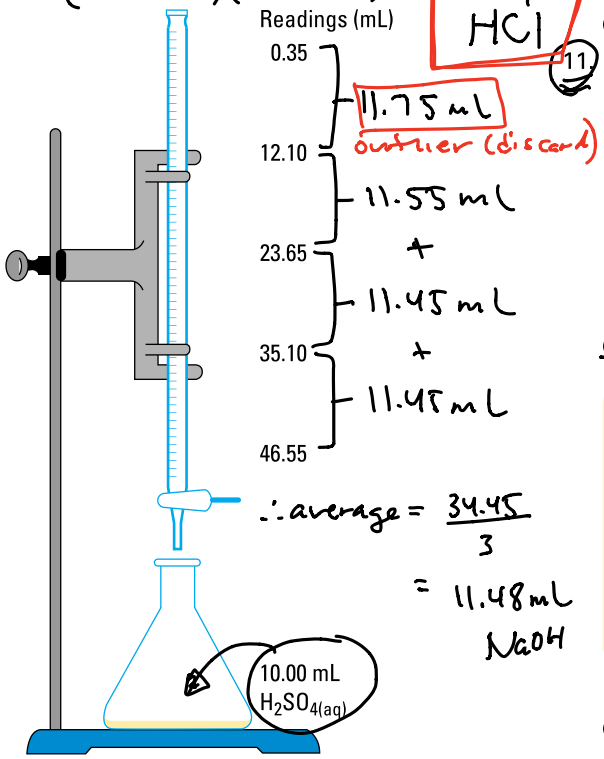
average: 41.0 ÷ 3 = 13.7 mL $Ba(OH)_2$

Analysis

(b) Using the Evidence in **Table 5**, calculate the concentration of the hydrochloric acid in the kettle-scale remover.

11. $2HCl(aq) + Ba(OH)_2 \rightarrow BaCl_2 + 2H_2O(\ell)$

$13.7\ mL \left(\frac{1 \cdot 10^{-3}\ L}{1\ mL}\right)\left(\frac{0.974\ mol\ Ba(OH)_2}{1\ L}\right)\left(\frac{2\ mol\ HCl}{1\ mol\ Ba(OH)_2}\right)\left(\frac{1}{10.00\ mL}\right)\left(\frac{1\ mL}{1 \cdot 10^{-3}\ L}\right) = 2.67\ M\ HCl$



∴ average = 34.45 / 3 = 11.48 mL NaOH

Figure 3

Sodium hydroxide titrant is added to samples of sulfuric acid in successive trials.

12. Samples of sulfuric acid were titrated with 0.484 mol/L sodium hydroxide. The evidence is shown in **Figure 3**. Calculate the concentration of the sulfuric acid solution.

12. $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$

$11.48\ mL \left(\frac{1 \cdot 10^{-3}\ L}{1\ mL}\right)\left(\frac{0.484\ mol\ NaOH}{1\ L}\right)\left(\frac{1\ mol\ H_2SO_4}{2\ mol\ NaOH}\right)\left(\frac{1}{10.00\ mL}\right)\left(\frac{1\ mL}{1 \cdot 10^{-3}\ L}\right) = 0.278\ M\ H_2SO_4$