1. If 10.0 mL of 0.100 \( M \) HCl is titrated with 0.200 \( M \) NaOH, what volume of sodium hydroxide solution is required to neutralize the acid?

\[
\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}
\]

\[
M_1V_1 = M_2V_2 \quad (0.100M)(0.010L) = (0.200M)(V_2) \quad V_2 = 0.005 \text{ L} = 5 \text{ mL}
\]

2. If 20.0 mL of 0.500 \( M \) KOH is titrated with 0.250 \( M \) HNO\(_3\), what volume of nitric acid is required to neutralize the base?

\[
\text{HNO}_3(aq) + \text{KOH(aq)} \rightarrow \text{KNO}_3(aq) + \text{H}_2\text{O(l)}
\]

\[
M_1V_1 = M_2V_2 \quad (0.500M)(0.020L) = (0.250M)(V_2) \quad V_2 = 0.040 \text{ L} = 40 \text{ mL}
\]

3. If 25.0 mL of 0.100 \( M \) HCl is titrated with 0.150 \( M \) Ba(OH)\(_2\), what volume of barium hydroxide is required to neutralize the acid?

\[
2 \text{ HCl(aq)} + \text{Ba(OH)}_2(aq) \rightarrow \text{BaCl}_2(aq) + 2 \text{ H}_2\text{O(l)}
\]

\[
M_1V_1 = M_2V_2 \quad (0.100M)(0.025L) = (0.150M)(V_2) \quad V_2 = 0.0166 \text{ L} = 16.6 \text{ mL OH}^-
\]

But there are 2 OH’s per Ba(OH)\(_2\) so it takes half this volume = 8.33 mL of Ba(OH)\(_2\)

4. If 25.0 mL of 0.100 \( M \) Ca(OH)\(_2\) is titrated with 0.200 \( M \) HNO\(_3\), what volume of nitric acid is required to neutralize the base?

\[
2 \text{ HNO}_3(aq) + \text{Ca(OH)}_2(aq) \rightarrow 2 \text{ Ca(NO}_3)_2(aq) + 2 \text{ H}_2\text{O(l)}
\]

\[
M_1V_1 = M_2V_2 \quad (0.100M)(0.025L) = (0.200M)(V_2) \quad V_2 = 0.0125 \text{ L} = 12.5 \text{ mL H}^+
\]

But it takes 2 HNO\(_3\)’s per Ca(OH)\(_2\) so it takes twice this volume = 25 mL of HNO\(_3\)

5. If 20.0 mL of 0.200 \( M \) H\(_2\)SO\(_4\) is titrated with 0.100 \( M \) NaOH, what volume of sodium hydroxide is required to neutralize the acid?

\[
\text{H}_2\text{SO}_4(aq) + 2 \text{ NaOH(aq)} \rightarrow \text{Na}_2\text{SO}_4(aq) + 2 \text{ H}_2\text{O(l)}
\]

\[
0.200 \text{ M H}_2\text{SO}_4 = 0.400 \text{ M H}^+
\]

\[
M_1V_1 = M_2V_2 \quad (0.40M)(0.020L) = (0.100M)(V_2) \quad V_2 = 0.080 \text{ L} = 80 \text{ mL NaOH}
\]
6. If 30.0 mL of 0.100 \textit{M} \text{Ca(OH)}_2 is titrated with 0.150 \textit{M} \text{HC}_2\text{H}_3\text{O}_2, what volume of acetic acid is required to neutralize the base?

\[2 \text{HC}_2\text{H}_3\text{O}_2(aq) + \text{Ca(OH)}_2(aq) \rightarrow \text{Ca(C}_2\text{H}_3\text{O}_2)_2(aq) + 2 \text{H}_2\text{O}(l)\]

\[0.100 \text{ M Ca(OH)}_2 = 0.200 \text{ M OH}^-\]

M_1V_1 = M_2V_2 \hspace{1cm} (0.200M)(0.030L) = (0.150M)(V_2) \hspace{1cm} V_2 = 0.040 \text{ L} = 40 \text{ mL NaOH}

7. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 \textit{M} nitric acid to a methyl red endpoint, what is the molarity of the base?

\[\text{NH}_4\text{OH}(aq) + \text{HNO}_3(aq) \rightarrow \text{NH}_4\text{NO}_3(aq) + \text{H}_2\text{O}(l)\]

M_1V_1 = M_2V_2 \hspace{1cm} (0.200M)(0.025L) = (M_2)(0.050L) \hspace{1cm} M_2 = 0.100 \text{ M NH}_4\text{OH}

8. If a 50.0 mL sample of ammonium hydroxide is titrated with 25.0 mL of 0.200 \textit{M} sulfuric acid to a methyl red endpoint, what is the molarity of the base?

\[2 \text{NH}_4\text{OH}(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow (\text{NH}_4)_2\text{SO}_4(aq) + 2 \text{H}_2\text{O}(l)\]

\[0.200 \text{ M H}_2\text{SO}_4 = 0.400 \text{ M H}^+\]

M_1V_1 = M_2V_2 \hspace{1cm} (0.400M)(0.025L) = (M_2)(0.050L) \hspace{1cm} M_2 = 0.200 \text{ M NH}_4\text{OH}

9. If a 25.0 mL sample of sulfuric acid is titrated with 50.0 mL of 0.200 \textit{M} potassium hydroxide to a phenolphthalein endpoint, what is the molarity of the acid?

\[\text{H}_2\text{SO}_4(aq) + 2 \text{KOH}(aq) \rightarrow \text{K}_2\text{SO}_4(aq) + 2 \text{H}_2\text{O}(l)\]

M_1V_1 = M_2V_2 \hspace{1cm} (0.200M)(0.050L) = (M_2)(0.025L) \hspace{1cm} M_2 = 0.400 \text{ M H}^+

But, there are 2 H’s per H_2SO_4 so [H_2SO_4] = 0.200M

10. What is the molarity of a hydrochloric acid solution if 20.00 mL of HCl is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

\[2 \text{HCl}(aq) + \text{Na}_2\text{CO}_3(aq) \rightarrow 2 \text{NaCl}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)\]

\[0.424 \text{ g/105.99 g/mol} = 0.0040 \text{ mol \ Na}_2\text{CO}_3\]

Each Na_2CO_3 requires 2 HCl so we need 0.0080 mol HCl

MV = moles \hspace{1cm} (M)(0.020L) = 0.0080 \text{ mole HCl} \hspace{1cm} M = 0.40 \text{ M HCl}
11. What is the molarity of a nitric acid solution if 25.00 mL of HNO₃ is required to neutralize 0.424 g of sodium carbonate (105.99 g/mol)?

\[
\begin{align*}
2 \text{HNO}_3\text{(aq)} &+ \text{Na}_2\text{CO}_3\text{(aq)} \rightarrow 2 \text{NaNO}_3\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)} \\
0.424 \text{g/105.99 g/mol} &= 0.0040 \text{ mol Na}_2\text{CO}_3
\end{align*}
\]

Each Na₂CO₃ requires 2 HNO₃ so we need 0.0080 mol HNO₃

\[
\begin{align*}
\text{MV} &= \text{moles} \quad (M)(0.025L) = 0.0080 \text{ mole HNO}_3 \\
M &= 0.32 \text{ M HNO}_3
\end{align*}
\]

12. What is the molarity of a sulfuric acid solution if 30.00 mL of H₂SO₄ is required to neutralize 0.840 g of sodium hydrogen carbonate (84.01 g/mol)?

\[
\begin{align*}
\text{H}_2\text{SO}_4\text{(aq)} &+ 2 \text{NaHCO}_3\text{(aq)} \rightarrow \text{Na}_2\text{SO}_4\text{(aq)} + 2 \text{H}_2\text{O(l)} + 2 \text{CO}_2\text{(g)} \\
0.840 \text{ g / 84.01 g/mol} &= 0.010 \text{ mol NaHCO}_3
\end{align*}
\]

It takes 2 NaHCO₃ per H₂SO₄ so you need 0.005 mol H₂SO₄

\[
\begin{align*}
\text{MV} &= \text{moles} \quad M(0.030L) = 0.005 \text{ moles} \\
M &= 0.167 \text{ M H}_2\text{SO}_4
\end{align*}
\]

13. What is the molarity of a hydrochloric acid solution if 25.00 mL of HCl is required to neutralize 0.500 g of calcium carbonate (100.09 g/mol)?

\[
\begin{align*}
2 \text{HCl(aq)} &+ \text{CaCO}_3\text{(s)} \rightarrow \text{CaCl}_2\text{(aq)} + \text{H}_2\text{O(l)} + \text{CO}_2\text{(g)} \\
0.500 \text{ g/100.09 g/mol} &= 0.005 \text{ mol CaCO}_3
\end{align*}
\]

Each mole of CaCO₃ requires 2 mol HCl so you need 0.005 x 2 = 0.010 mol HCl

\[
\begin{align*}
\text{MV} &= \text{moles} \quad M(0.025L) = 0.010 \text{ mol} \\
M &= 0.40 \text{ M HCl}
\end{align*}
\]

14. What is the molarity of a sodium hydroxide solution if 40.00 mL of NaOH is required to neutralize 0.900 g of oxalic acid, H₂C₂O₄, (90.04 g/mol)?

\[
\begin{align*}
\text{H}_2\text{C}_2\text{O}_4\text{(aq)} &+ 2 \text{NaOH(aq)} \rightarrow \text{Na}_2\text{C}_2\text{O}_4\text{(aq)} + 2 \text{H}_2\text{O(l)} \\
0.900 \text{ g / 90.04 g/mol} &= 0.010 \text{ mol Oxalic acid}
\end{align*}
\]

It takes 2 mole NaOH for every mole of Oxalic acid

so you need 2 x 0.010 mol = 0.02 mol NaOH

\[
\begin{align*}
\text{MV} &= \text{moles} \quad M(0.040L) = 0.020 \text{ mole NaOH} \\
M &= 0.50 \text{ M NaOH}
\end{align*}
\]
15. What is the molarity of a sodium hydroxide solution if 35.00 mL of NaOH is required to neutralize 1.555 g of KHP, that is KHC₈H₄O₄ (204.23 g/mol)?

KHC₈H₄O₄(aq) + NaOH(aq) → KNaC₈H₄O₄(aq) + H₂O(l)

1.555 g / 204.23 g/mol = 0.00761 mol KHP

1 mole KHP needs 1 mole of NaOH so, 0.00761 mole KHP = 0.00761 mole NaOH

0.00761 mole NaOH / 0.0351 L = 0.2175 M NaOH

16. If a 0.200 g sample of sodium hydroxide (40.00 g/mol) is completely neutralized with 0.100 M H₂SO₄, what volume of sulfuric acid is required?

H₂SO₄(aq) + 2 NaOH(aq) → Na₂SO₄(aq) + 2 H₂O(l)

0.200 g NaOH / 40 g/mol = 0.005 mol NaOH

1 mole of H₂SO₄ needs 2 mole NaOH so 0.005 mole NaOH needs 0.0025 mole H₂SO₄

MV = moles (0.100 M H₂SO₄) (V) = 0.0025 mole V = 0.0250 L = 25 mL

17. If 0.900 g of oxalic acid, H₂C₂O₄, (90.04 g/mol) is completely neutralized with 0.300 M NaOH, what volume of sodium hydroxide is required?

H₂C₂O₄(aq) + 2 NaOH(aq) → Na₂C₂O₄(aq) + 2 H₂O(l)

0.900 g / 90.04 g/mol = 0.010 mol Oxalic acid

It takes 2 mole NaOH for every mole of Oxalic acid

so you need 2 x 0.010 mol = 0.02 mol NaOH

MV = moles (0.300M) (V) = 0.020 mole NaOH V = 0.0666 L = 66.6 mL

18. If 1.020 g of KHC₈H₄O₄ (204.23 g/mol) is completely neutralized with 0.200 M Ba(OH)₂, what volume of barium hydroxide is required?

2 KHC₈H₄O₄(aq) + Ba(OH)₂(aq) → BaK₂(C₈H₄O₄)₂(aq) + 2 H₂O(l)

1.020 g / 204.23 g/mol = 0.0050 mol KHP

2 mole KHP needs 1 mole of Ba(OH)₂ so, 0.0050 mole KHP needs 0.0025 mole Ba(OH)₂

MV = moles (0.200 M) (V) = 0.0025 mole Ba(OH)₂ V = 0.01250 L = 12.5 mL
19. Glycine is an amino acid that can be abbreviated HGly. If 27.50 mL of 0.120 \( M \) NaOH neutralizes 0.248 g of HGly, what is the molar mass of the amino acid?

\[
\text{HGly(aq)} + \text{NaOH(aq)} \rightarrow \text{NaGly(aq)} + \text{H}_2\text{O(l)}
\]

MV = moles \( (0.120 \text{ M})(0.02750\text{L}) = 0.033 \text{ mole NaOH} = 0.0033 \text{ mole HGly} \)

\[
0.248 \text{ g} / 0.0033 \text{ mole HGly} = 75.12 \text{ g/mol HGly}
\]

20. Proline is an amino acid that can be abbreviated HPro. If 33.55 mL of 0.150 \( M \) NaOH neutralizes 0.579 g of HPro, what is the molar mass of the amino acid?

\[
\text{HPro(aq)} + \text{NaOH(aq)} \rightarrow \text{NaPro(aq)} + \text{H}_2\text{O(l)}
\]

MV = moles \( (0.150 \text{ M})(0.03355\text{L}) = 0.005033 \text{ mole NaOH} = 0.005033 \text{ mole HPro} \)

\[
0.579 \text{ g} / 0.050033 \text{ mole HPro} = 115.05 \text{ g/mol HPro}
\]

21. Lactic acid is found in sour milk and can be abbreviated HLac. If 47.50 mL of 0.275 \( M \) NaOH neutralizes 1.180 g of HLac, what is the molar mass of the acid?

\[
\text{HLac(aq)} + \text{NaOH(aq)} \rightarrow \text{NaLac(aq)} + \text{H}_2\text{O(l)}
\]

MV = moles \( (0.275 \text{ M})(0.0475\text{L}) = 0.01306 \text{ mole NaOH} = 0.01306 \text{ mole HLac} \)

\[
1.180 \text{ g} / 0.01306 \text{ mole HLac} = 90.33 \text{ g/mol HLac}
\]

22. What is the pH of an aqueous solution if the \([\text{H}^+] = 5.5 \times 10^{-3} \text{ M}\)?

\[
\text{pH} = -\log[\text{H}^+] \quad \text{pH} = -\log[5.5 \times 10^{-3}] = 2.26
\]

23. What is the pH of an aqueous solution if the \([\text{H}^+] = 4.2 \times 10^{-5} \text{ M}\)?

\[
\text{pH} = -\log[\text{H}^+] \quad \text{pH} = -\log[4.2 \times 10^{-5}] = 4.38
\]

24. What is the pH of an aqueous solution if the \([\text{H}^+] = 7.5 \times 10^{-8} \text{ M}\)?

\[
\text{pH} = -\log[\text{H}^+] \quad \text{pH} = -\log[7.5 \times 10^{-8}] = 7.12
\]

25. What is the \([\text{H}^+]\) in an acid rain sample that has a pH = 3.22?

\[
[H^+] = 10^{-\text{pH}} \quad [H^+] = 10^{-3.22} \quad [H^+] = 6.03 \times 10^{-4} \text{ M}
\]

26. What is the \([\text{H}^+]\) in a blood sample that has a pH = 7.30?
[H+] = 10^{-7.30} \quad [H+] = 5.01 \times 10^{-8} \text{ M}

27. What is the [ H^+] in a bleach sample that has a pH = 9.55?

[H+] = 10^{0.55} \quad [H+] = 2.82 \times 10^{-10} \text{ M}

28. What is the [ OH^- ] in a seawater sample that has a pH = 8.65?

[H+] = 10^{-8.65} \quad [H+] = 2.24 \times 10^{-9} \text{ M}

29. What is the [ OH^- ] in an ammonia solution that has a pH = 10.20?

[H+] = 10^{-10.20} \quad [H+] = 6.31 \times 10^{-11} \text{ M}

30. What is the [ OH^- ] in an oven-cleaning solution that has a pH = 12.35?

[H+] = 10^{-12.35} \quad [H+] = 4.47 \times 10^{-13} \text{ M}

31. What substance is oxidized in the following redox reaction?

\textbf{Zn(s)} + \text{Cu}^{2+}(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{Cu(s)}

32. What substance is reduced in the following redox reaction?

\text{Co(s)} + 2\text{HCl}(aq) \rightarrow \text{CoCl}_2(aq) + \text{H}_2(g)

33. What substance is oxidized in the following redox reaction?

\text{F}_2(g) + 2\text{Br}^-(aq) \rightarrow 2\text{F}^-(aq) + \text{Br}_2(l)

34. What substance is oxidized in the following redox reaction?

\text{HgCl}_2(aq) + \text{Sn}^{2+}(aq) \rightarrow \text{Sn}^{4+}(aq) + \text{Hg}_2\text{Cl}_2(s) + \text{Cl}^-(aq)

35. What substance is reduced in the following redox reaction?

\text{H}^+(aq) + \text{Fe(s)} + \text{NO}_3^-(aq) \rightarrow \text{Fe}^{3+}(aq) + \text{NO(aq)} + \text{H}_2\text{O(l)}