1. In alkaline dry-cell batteries, the half-reactions involve Zn and manganese compounds. Complete and balance the following reaction in basic solution:

\[
\text{Zn} (s) + \text{MnO}_2 (s) \rightarrow \text{ZnO} (s) + \text{Mn}_2\text{O}_3 (s)
\]

steps i-iv. 

\[
\begin{align*}
2 \text{OH}^- &+ H_2O + \text{Zn} \rightarrow \text{ZnO} + 2 e^- + 2 H^+ + 2 \text{OH}^- \\
2 OH^- &+ 2 H^+ + 2 e^- + 2 \text{MnO}_2 \rightarrow \text{Mn}_2\text{O}_3 + H_2O + 2 \text{OH}^- \\
\end{align*}
\]

step v: 

\[
2 \text{OH}^- + \text{Zn} + H_2O + 2 \text{MnO}_2 \rightarrow \text{ZnO} + H_2O + \text{Mn}_2\text{O}_3 + 2 \text{OH}^-
\]

overall reaction: 

\[
\text{Zn} (s) + 2 \text{MnO}_2 (s) \rightarrow \text{ZnO} (s) + \text{Mn}_2\text{O}_3 (s)
\]

2. Although copper is less active than hydrogen, copper reacts with nitric acid because nitrate ion can act as a strong oxidizing agent in acidic solution. Complete and balance the following reaction (in acidic solution):

\[
\text{Cu} (s) + \text{HNO}_3 (aq) \rightarrow \text{Cu}^{2+} (aq) + \text{NO}_2 (g)
\]

steps i-iii. 

\[
\begin{align*}
\text{Cu} &\rightarrow \text{Cu}^{2+} + 2 e^- \\
2 (H^+ &+ 1 e^- + \text{HNO}_3 \rightarrow \text{NO}_2 + H_2O ) \quad x2 \text{ to balance } e^- \\
\end{align*}
\]

step v: 

\[
\text{Cu} + 2 H^+ + 2 \text{HNO}_3 \rightarrow \text{Cu}^{2+} + 2 \text{NO}_2 + 2 H_2O
\]

overall: 

\[
\text{Cu} (l) + 2 H^+ (aq) + 2 \text{HNO}_3 (aq) \rightarrow \text{Cu}^{2+} (aq) + 2 \text{NO}_2 (g) + 2 H_2O (l)
\]
3. Calculate the concentration of the ions that remain in solution after 50.0 mL of a 1.25M sodium phosphate solution is mixed with 75.0 mL of a 2.00M calcium nitrate solution.

\[
2 \text{Na}_3\text{PO}_4(aq) + 3 \text{Ca(NO}_3)_2(aq) \rightarrow \text{Ca}_3(\text{PO}_4)_2(s) + 6 \text{NaNO}_3(aq)
\]

\[
0.0500 \text{ L} \times \frac{1.25 \text{ mol Na}_3\text{PO}_4}{\text{L}} \times \frac{3 \text{ mol Ca(NO}_3)_2}{2 \text{ mol Na}_3\text{PO}_4} = 0.09375 \text{ mol Ca(NO}_3)_2
\]

\[
0.0750 \text{ L} \times \frac{2.00 \text{ mol Ca(NO}_3)_2}{\text{L}} = 0.150 \text{ mol Ca(NO}_3)_2 \rightarrow \text{Na}_3\text{PO}_4(aq) \text{ is L.R.}
\]

\[
0.150 \text{ mol Ca}^{2+} \text{ at start} - 0.09375 \text{ mol Ca}^{2+} \text{ react} = \frac{0.05625 \text{ mol}}{0.1250 \text{ L}} = 0.45 \text{M Ca}^{2+} \rightarrow [\text{PO}_4^{3-}] = 0 \text{M}
\]

\[
\text{NO}_3^- \text{ is a spectator ion} \rightarrow \text{All NO}_3^- \text{ ions still in solution: } [\text{NO}_3^-] = \frac{2 \times (0.150 \text{ mol})}{0.1250 \text{ L}} = 2.40 \text{M NO}_3^-
\]

\[
0.0500 \text{ L} \times \frac{1.25 \text{ mol Na}_3\text{PO}_4}{\text{L}} = 0.0625 \text{ mol Na}_3\text{PO}_4
\]

\[
\text{Na}^+ \text{ is a spectator ion} \rightarrow \text{All Na}^+ \text{ ions still in solution: } [\text{Na}^+] = \frac{3 \times (0.0625 \text{ mol})}{0.1250 \text{ L}} = 1.50 \text{M Na}^+
\]

4. A student pipetted 25.00 mL of phosphoric acid to a 125 mL Erlenmeyer flask and titrated the solution with potassium hydroxide.

a. If 26.09 mL of potassium hydroxide solution was required for complete neutralization to a phenolphthalein endpoint, calculate the molarity of the potassium hydroxide solution. The concentration of phosphoric acid was 0.3816M.

\[
\text{H}_3\text{PO}_4(aq) + 3 \text{KOH}(aq) \rightarrow \text{K}_3\text{PO}_4(aq) + 6 \text{H}_2\text{O(l)}
\]

\[
0.02500 \text{ L} \times \frac{0.3816 \text{ mol H}_3\text{PO}_4}{\text{L}} \times \frac{3 \text{ mol KOH}}{1 \text{ mol H}_3\text{PO}_4} = 0.02862 \text{ mol KOH}
\]

\[
[KOH] = \frac{0.02862 \text{ mol KOH}}{0.02609 \text{ L}} = 1.097 \text{M KOH}
\]

b. If the student added 50.0 mL of deionized water to the flask described in part a after the acid was transferred but before the titration began, calculate the molarity of the ions remaining in solution in the flask at the endpoint.

At the endpoint (corresponding to the equivalence point), # mol of H$_3$PO$_4$ = # mol KOH, so all the OH$^-$ ions react with the H's in the H$_3$PO$_4$ and the only ions remaining in solution are the K$^+$ and PO$_4^{3-}$ ions. $V_{total}=25.00+26.06+50.00 \text{ mL}=101.09 \text{ mL}$

\[
0.02500 \text{ L} \times \frac{0.3816 \text{ mol H}_3\text{PO}_4}{\text{L}} = 0.009540 \text{ mol H}_3\text{PO}_4
\]

\[
[K^+] = \frac{0.02862 \text{ mol K}^+}{0.10109 \text{ L}} = 0.2831 \text{M K}^+ \quad [\text{PO}_4^{3-}] = \frac{0.009540 \text{ mol PO}_4^{3-}}{0.10109 \text{ L}} = 0.09437 \text{M PO}_4^{3-}
\]
5. Mixing household ammonia with chlorine bleach can be dangerous because ammonia can react with hypochlorite ion, ClO\(^{-}\), the active ingredient in bleach, to form hydrazine, N\(_2\)H\(_4\), a toxic gas. Complete and balance the following reaction in basic solution:

\[
\text{ClO}^{-}(aq) + \text{NH}_3(g) \rightarrow \text{N}_2\text{H}_4(g) + \text{Cl}^{-}(aq)
\]

\[
\text{steps i-iv.} \quad 2 \text{OH}^- + 2 \text{H}^+ + 2 \text{e}^- + \text{ClO}^{-} \rightarrow \text{Cl}^- + \text{H}_2\text{O} + 2 \text{OH}^- \\
\]

\[
\text{step v:} \quad 2 \text{OH}^- + 2 \text{NH}_3 \rightarrow \text{N}_2\text{H}_4 + 2 \text{e}^- + 2 \text{H}^+ + 2 \text{OH}^- \\
\]

overall reaction: \(\text{ClO}^{-}(aq) + 2 \text{NH}_3(g) \rightarrow \text{Cl}^{-}(aq) + \text{N}_2\text{H}_4(g) + \text{H}_2\text{O}(l)\)

6. Complete and balance the following reaction (in basic solution) that occurs in nickel-cadmium (NiCad) batteries:

\[
\text{Cd}(s) + \text{NiO}_2(s) \rightarrow \text{Cd(OH)}_2(s) + \text{Ni(OH)}_2(s)
\]

\[
\text{steps i-iv.} \quad 2 \text{OH}^- + 2 \text{H}_2\text{O} + \text{Cd} \rightarrow \text{Cd(OH)}_2 + 2 \text{e}^- + 2 \text{H}^+ + 2 \text{OH}^- \\
\]

\[
\text{step v:} \quad 2 \text{OH}^- + \text{Cd} + 2 \text{H}_2\text{O} + \text{NiO}_2 \rightarrow \text{Cd(OH)}_2 + \text{Ni(OH)}_2 + 2 \text{OH}^- \\
\]

overall reaction: \(\text{Cd}(s) + 2 \text{H}_2\text{O}(l) + \text{NiO}_2(s) \rightarrow \text{Cd(OH)}_2(s) + \text{Ni(OH)}_2(s)\)

7. Limestone is a mixture of calcium carbonate and other substances. A 1.356 g sample of limestone rock is pulverized then analyzed with a standard solution of hydrobromic acid. The sample required 25.87 mL of a 0.750M hydrobromic acid solution for complete neutralization to a phenolphthalein endpoint. Calculate the mass percent concentration of calcium carbonate in the limestone.

\[
\text{CaCO}_3(s) + 2 \text{HBr}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) + \text{CaBr}_2(aq)
\]

\[
0.02587 \text{ L} \times \frac{0.750 \text{ mol HBr}}{\text{L}} \times \frac{1 \text{ mol CaCO}_3}{2 \text{ mol HBr}} \times \frac{100.09 \text{ g CaCO}_3}{1 \text{ mol CaCO}_3} = 0.970998 \text{ g CaCO}_3
\]

\[
\% \text{ CaCO}_3 = \frac{0.970998 \text{ g CaCO}_3}{1.356 \text{ g limestone}} \times 100\% = 71.6\% \text{ CaCO}_3
\]