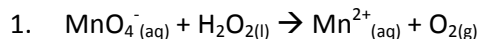


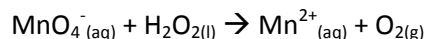
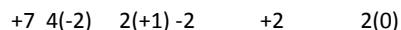
Redox Practice Problems Key

For each of following skeletal redox reactions:

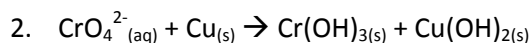
- Identify the oxidized species and state how many electrons are lost per atom
- Identify the reduced species and state how many electrons are gained per atom
- Identify the oxidizing agent
- Identify the reducing agent
- Write balanced half reactions (in acid)
- Write a balanced redox reaction (in acid)
- Write a balanced redox reaction (in base)



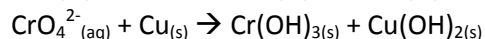
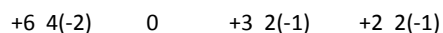
First write oxidation states for each element, per atom.



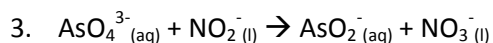
| | |
|----|---|
| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each O lost $1e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each Mn gained $5e^-$ |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> $\text{MnO}_4^- (\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> $\text{H}_2\text{O}_2 (\text{l})$ |
| e. | <p>Write balanced half reactions (in acid)</p> <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{H}_2\text{O}_2 (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 1e^-$ $5e^- + \text{MnO}_4^- (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq})$ Balance half reactions for same # of oxidized/reduced species $\text{H}_2\text{O}_2 (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 2(1e^-)$ $5e^- + \text{MnO}_4^- (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq})$ Balance half reactions for # of O, with H_2O, and # of H, with H^+ $\text{H}_2\text{O}_2 (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 2e^- + 2\text{H}^+ (\text{aq})$ $8\text{H}^+ (\text{aq}) + 5e^- + \text{MnO}_4^- (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq}) + 4\text{H}_2\text{O} (\text{l})$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $5(\text{H}_2\text{O}_2 (\text{l}) \rightarrow \text{O}_2 (\text{g}) + 2e^- + 2\text{H}^+ (\text{aq}))$ $2(8\text{H}^+ (\text{aq}) + 5e^- + \text{MnO}_4^- (\text{aq}) \rightarrow \text{Mn}^{2+} (\text{aq}) + 4\text{H}_2\text{O} (\text{l}))$ Rewriting the half reactions with the multiplication done $5\text{H}_2\text{O}_2 (\text{l}) \rightarrow 5\text{O}_2 (\text{g}) + 10e^- + 10\text{H}^+ (\text{aq})$ $16\text{H}^+ (\text{aq}) + 10e^- + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 8\text{H}_2\text{O} (\text{l})$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions $16\text{H}^+ (\text{aq}) + 10e^- + 5\text{H}_2\text{O}_2 (\text{l}) + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{O}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l}) + 10e^- + 10\text{H}^+ (\text{aq})$ Cross out spectators $6\text{H}^+ (\text{aq}) + 5\text{H}_2\text{O}_2 (\text{l}) + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{O}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l})$ |
| g. | <p>Write a balanced redox reaction (in base)</p> <ul style="list-style-type: none"> Count the # of $\text{H}^+ (\text{aq})$. Add the same # of $\text{OH}^- (\text{aq})$ to both sides of the equation $6\text{OH}^- (\text{aq}) + 6\text{H}^+ (\text{aq}) + 5\text{H}_2\text{O}_2 (\text{l}) + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{O}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l}) + 6\text{OH}^- (\text{aq})$ On the side with both $\text{H}^+ (\text{aq})$ & $\text{OH}^- (\text{aq})$, those become water $6\text{H}_2\text{O} (\text{l}) + 5\text{H}_2\text{O}_2 (\text{l}) + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{O}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l}) + 6\text{OH}^- (\text{aq})$ Cross out spectators $5\text{H}_2\text{O}_2 (\text{l}) + 2\text{MnO}_4^- (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 5\text{O}_2 (\text{g}) + 2\text{H}_2\text{O} (\text{l}) + 6\text{OH}^- (\text{aq})$ |



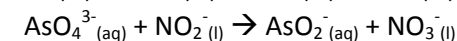
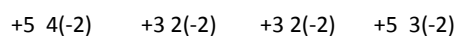
First write oxidation states for each element, per atom.



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| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each Cu lost $2e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each Cr gained $3e^-$ |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> $\text{CrO}_4^{2-}(\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> $\text{Cu}(\text{s})$ |
| e. | Write balanced half reactions (in acid) <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{Cu}(\text{s}) \rightarrow \text{Cu}(\text{OH})_2(\text{s}) + 2e^-$ $3e^- + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ Balance half reactions for same # of oxidized/reduced species $\text{Cu}(\text{s}) \rightarrow \text{Cu}(\text{OH})_2(\text{s}) + 2e^-$ $3e^- + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s})$ Balance half reactions for # of O, with H_2O, and # of H, with H^+ $2\text{H}_2\text{O}(\text{l}) + \text{Cu}(\text{s}) \rightarrow \text{Cu}(\text{OH})_2(\text{s}) + 2e^- + 2\text{H}^+(\text{aq})$ $5\text{H}^+(\text{aq}) + 3e^- + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + \text{H}_2\text{O}(\text{l})$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $3(2\text{H}_2\text{O}(\text{l}) + \text{Cu}(\text{s}) \rightarrow \text{Cu}(\text{OH})_2(\text{s}) + 2e^- + 2\text{H}^+(\text{aq}))$ $2(5\text{H}^+(\text{aq}) + 3e^- + \text{CrO}_4^{2-}(\text{aq}) \rightarrow \text{Cr}(\text{OH})_3(\text{s}) + \text{H}_2\text{O}(\text{l}))$ Rewriting the half reactions with the multiplication done $6\text{H}_2\text{O}(\text{l}) + 3\text{Cu}(\text{s}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 6e^- + 6\text{H}^+(\text{aq})$ $10\text{H}^+(\text{aq}) + 6e^- + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 2\text{Cr}(\text{OH})_3(\text{s}) + 2\text{H}_2\text{O}(\text{l})$ |
| f. | Write a balanced redox reaction (in acid) <ul style="list-style-type: none"> Combine half reactions $6\text{H}_2\text{O}(\text{l}) + 3\text{Cu}(\text{s}) + 10\text{H}^+(\text{aq}) + 6e^- + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 2\text{Cr}(\text{OH})_3(\text{s}) + 2\text{H}_2\text{O}(\text{l}) + 6e^- + 6\text{H}^+(\text{aq})$ Cross out spectators $4\text{H}_2\text{O}(\text{l}) + 4\text{H}^+(\text{aq}) + 3\text{Cu}(\text{s}) + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 2\text{Cr}(\text{OH})_3(\text{s})$ |
| g. | Write a balanced redox reaction (in base) <ul style="list-style-type: none"> Count the # of $\text{H}^+(\text{aq})$. Add the same # of $\text{OH}^-(\text{aq})$ to both sides of the equation $4\text{OH}^-(\text{aq}) + 4\text{H}_2\text{O}(\text{l}) + 4\text{H}^+(\text{aq}) + 3\text{Cu}(\text{s}) + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 2\text{Cr}(\text{OH})_3(\text{s}) + 4\text{OH}^-(\text{aq})$ On the side with both $\text{H}^+(\text{aq})$ & $\text{OH}^-(\text{aq})$, those become water $4\text{H}_2\text{O}(\text{l}) + 4\text{H}_2\text{O}(\text{l}) + 3\text{Cu}(\text{s}) + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 2\text{Cr}(\text{OH})_3(\text{s}) + 4\text{OH}^-(\text{aq})$ Cross out spectators $8\text{H}_2\text{O}(\text{l}) + 3\text{Cu}(\text{s}) + 2\text{CrO}_4^{2-}(\text{aq}) \rightarrow 3\text{Cu}(\text{OH})_2(\text{s}) + 2\text{Cr}(\text{OH})_3(\text{s}) + 4\text{OH}^-(\text{aq})$ |

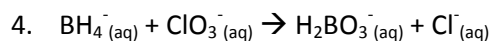


First write oxidation states for each element, per atom.

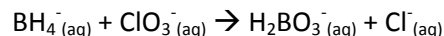
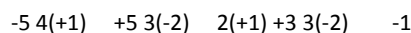


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| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each N lost $2e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each As gained $2e^-$ |
| c. | Identify the oxidizing agent |

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| | <ul style="list-style-type: none"> • $\text{AsO}_4^{3-}(\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> • $\text{NO}_2^-(\text{l})$ |
| e. | Write balanced half reactions (in acid) <ul style="list-style-type: none"> • Write Unbalanced half reactions including electron change per atom $\text{NO}_2^-(\text{l}) \rightarrow \text{NO}_3^-(\text{l}) + 2\text{e}^-$ $2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq})$ • Balance half reactions for same # of oxidized/reduced species $\text{NO}_2^-(\text{l}) \rightarrow \text{NO}_3^-(\text{l}) + 2\text{e}^-$ $2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq})$ • Balance half reactions for # of O, with H_2O, and # of H, with H^+ $\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) \rightarrow \text{NO}_3^-(\text{l}) + 2\text{e}^- + 2\text{H}^+(\text{aq})$ $4\text{H}^+(\text{aq}) + 2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> • Balance half reactions for # of electrons gained and lost $\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) \rightarrow \text{NO}_3^-(\text{l}) + 2\text{e}^- + 2\text{H}^+(\text{aq})$ $4\text{H}^+(\text{aq}) + 2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ • Rewriting the half reactions with the multiplication done $\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) \rightarrow \text{NO}_3^-(\text{l}) + 2\text{e}^- + 2\text{H}^+(\text{aq})$ $4\text{H}^+(\text{aq}) + 2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ |
| f. | Write a balanced redox reaction (in acid) <ul style="list-style-type: none"> • Combine half reactions $\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) + \text{NO}_3^-(\text{l}) + 2\text{e}^- + 2\text{H}^+(\text{aq})$ • Cross out spectators $\text{NO}_2^-(\text{l}) + 2\text{H}^+(\text{aq}) + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{NO}_3^-(\text{l})$ |
| g. | Write a balanced redox reaction (in base) <ul style="list-style-type: none"> • Count the # of $\text{H}^+(\text{aq})$. Add the same # of $\text{OH}^-(\text{aq})$ to both sides of the equation $2\text{OH}^-(\text{aq}) + \text{NO}_2^-(\text{l}) + 2\text{H}^+(\text{aq}) + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{NO}_3^-(\text{l}) + 2\text{OH}^-(\text{aq})$ • On the side with both $\text{H}^+(\text{aq})$ & $\text{OH}^-(\text{aq})$, those become water $2\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{NO}_3^-(\text{l}) + 2\text{OH}^-(\text{aq})$ • Cross out spectators $\text{H}_2\text{O}(\text{l}) + \text{NO}_2^-(\text{l}) + \text{AsO}_4^{3-}(\text{aq}) \rightarrow \text{AsO}_2^-(\text{aq}) + \text{NO}_3^-(\text{l}) + 2\text{OH}^-(\text{aq})$ |

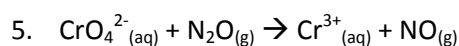


First write oxidation states for each element, per atom.

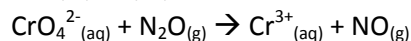
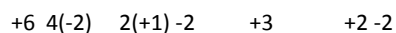


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| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> • Each B lost 8e^- |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> • Each Cl gained 6e^- |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> • $\text{ClO}_3^-(\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> • $\text{BH}_4^-(\text{aq})$ |
| e. | Write balanced half reactions (in acid) <ul style="list-style-type: none"> • Write Unbalanced half reactions including electron change per atom $\text{BH}_4^-(\text{aq}) \rightarrow \text{H}_2\text{BO}_3^-(\text{aq}) + 8\text{e}^-$ $6\text{e}^- + \text{ClO}_3^-(\text{aq}) \rightarrow \text{Cl}^-(\text{aq})$ • Balance half reactions for same # of oxidized or reduced species $\text{BH}_4^-(\text{aq}) \rightarrow \text{H}_2\text{BO}_3^-(\text{aq}) + 8\text{e}^-$ $6\text{e}^- + \text{ClO}_3^-(\text{aq}) \rightarrow \text{Cl}^-(\text{aq})$ |

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| | <ul style="list-style-type: none"> Balance half reactions for # of O, with H₂O, and # of H, with H⁺ $3\text{H}_2\text{O}_{(l)} + \text{BH}_4^{-}{}_{(aq)} \rightarrow \text{H}_2\text{BO}_3^{-}{}_{(aq)} + 8\text{e}^{-} + 8\text{H}^{+}{}_{(aq)}$ $6\text{H}^{+}{}_{(aq)} + 6\text{e}^{-} + \text{ClO}_3^{-}{}_{(aq)} \rightarrow \text{Cl}^{-}{}_{(aq)} + 3\text{H}_2\text{O}_{(l)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $3(3\text{H}_2\text{O}_{(l)} + \text{BH}_4^{-}{}_{(aq)} \rightarrow \text{H}_2\text{BO}_3^{-}{}_{(aq)} + 8\text{e}^{-} + 8\text{H}^{+}{}_{(aq)})$ $4(6\text{H}^{+}{}_{(aq)} + 6\text{e}^{-} + \text{ClO}_3^{-}{}_{(aq)} \rightarrow \text{Cl}^{-}{}_{(aq)} + 3\text{H}_2\text{O}_{(l)})$ Rewriting the half reactions with the multiplication done $9\text{H}_2\text{O}_{(l)} + 3\text{BH}_4^{-}{}_{(aq)} \rightarrow 3\text{H}_2\text{BO}_3^{-}{}_{(aq)} + 24\text{e}^{-} + 24\text{H}^{+}{}_{(aq)}$ $24\text{H}^{+}{}_{(aq)} + 24\text{e}^{-} + 4\text{ClO}_3^{-}{}_{(aq)} \rightarrow 4\text{Cl}^{-}{}_{(aq)} + 12\text{H}_2\text{O}_{(l)}$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions $9\text{H}_2\text{O}_{(l)} + 3\text{BH}_4^{-}{}_{(aq)} + 24\text{H}^{+}{}_{(aq)} + 24\text{e}^{-} + 4\text{ClO}_3^{-}{}_{(aq)} \rightarrow 4\text{Cl}^{-}{}_{(aq)} + 12\text{H}_2\text{O}_{(l)} + 3\text{H}_2\text{BO}_3^{-}{}_{(aq)} + 24\text{e}^{-} + 24\text{H}^{+}{}_{(aq)}$ Cross out spectators $3\text{BH}_4^{-}{}_{(aq)} + 4\text{ClO}_3^{-}{}_{(aq)} \rightarrow 4\text{Cl}^{-}{}_{(aq)} + 3\text{H}_2\text{O}_{(l)} + 3\text{H}_2\text{BO}_3^{-}{}_{(aq)}$ |
| g. | <p>Write a balanced redox reaction (in base)</p> <ul style="list-style-type: none"> Count the # of H⁺_(aq). Add the same # of OH⁻_(aq) to both sides of the equation $3\text{BH}_4^{-}{}_{(aq)} + 4\text{ClO}_3^{-}{}_{(aq)} \rightarrow 4\text{Cl}^{-}{}_{(aq)} + 3\text{H}_2\text{O}_{(l)} + 3\text{H}_2\text{BO}_3^{-}{}_{(aq)}$ No H⁺_(aq) so it's balanced in acid and in base $3\text{BH}_4^{-}{}_{(aq)} + 4\text{ClO}_3^{-}{}_{(aq)} \rightarrow 4\text{Cl}^{-}{}_{(aq)} + 3\text{H}_2\text{O}_{(l)} + 3\text{H}_2\text{BO}_3^{-}{}_{(aq)}$ |

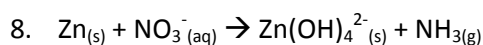


First write oxidation states for each element, per atom.

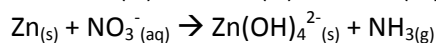
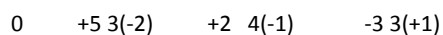


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|----|---|
| a. | <p>Identify the oxidized species and state how many electrons are lost per atom</p> <ul style="list-style-type: none"> Each N lost 1e⁻ |
| b. | <p>Identify the reduced species and state how many electrons are gained per atom</p> <ul style="list-style-type: none"> Each Cr gained 3e⁻ |
| c. | <p>Identify the oxidizing agent</p> <ul style="list-style-type: none"> CrO₄²⁻_(aq) |
| d. | <p>Identify the reducing agent</p> <ul style="list-style-type: none"> N₂O_(g) |
| e. | <p>Write balanced half reactions (in acid)</p> <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{N}_2\text{O}_{(g)} \rightarrow \text{NO}_{(g)} + 1\text{e}^{-}$ $3\text{e}^{-} + \text{CrO}_4^{2-}{}_{(aq)} \rightarrow \text{Cr}^{3+}{}_{(aq)}$ Balance half reactions for same # of oxidized/reduced species $\text{N}_2\text{O}_{(g)} \rightarrow 2\text{NO}_{(g)} + 2(1\text{e}^{-})$ $3\text{e}^{-} + \text{CrO}_4^{2-}{}_{(aq)} \rightarrow \text{Cr}^{3+}{}_{(aq)}$ Balance half reactions for # of O, with H₂O, and # of H, with H⁺ $\text{H}_2\text{O}_{(l)} + \text{N}_2\text{O}_{(g)} \rightarrow 2\text{NO}_{(g)} + 2\text{e}^{-} + 2\text{H}^{+}{}_{(aq)}$ $8\text{H}^{+}{}_{(aq)} + 3\text{e}^{-} + \text{CrO}_4^{2-}{}_{(aq)} \rightarrow \text{Cr}^{3+}{}_{(aq)} + 4\text{H}_2\text{O}_{(l)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $3(\text{H}_2\text{O}_{(l)} + \text{N}_2\text{O}_{(g)} \rightarrow 2\text{NO}_{(g)} + 2\text{e}^{-} + 2\text{H}^{+}{}_{(aq)})$ $2(8\text{H}^{+}{}_{(aq)} + 3\text{e}^{-} + \text{CrO}_4^{2-}{}_{(aq)} \rightarrow \text{Cr}^{3+}{}_{(aq)} + 4\text{H}_2\text{O}_{(l)})$ Rewriting the half reactions with the multiplication done $3\text{H}_2\text{O}_{(l)} + 3\text{N}_2\text{O}_{(g)} \rightarrow 6\text{NO}_{(g)} + 6\text{e}^{-} + 6\text{H}^{+}{}_{(aq)}$ $16\text{H}^{+}{}_{(aq)} + 6\text{e}^{-} + 2\text{CrO}_4^{2-}{}_{(aq)} \rightarrow 2\text{Cr}^{3+}{}_{(aq)} + 8\text{H}_2\text{O}_{(l)}$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions |

| | |
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| | $3\text{H}_2\text{O}_{(l)} + 3\text{N}_2\text{O}_{(g)} + 16\text{H}^+_{(aq)} + 6\text{e}^- + 2\text{CrO}_4^{2-}_{(aq)} \rightarrow 2\text{Cr}^{3+}_{(aq)} + 8\text{H}_2\text{O}_{(l)} + 6\text{NO}_{(g)} + 6\text{e}^- + 6\text{H}^+_{(aq)}$ <ul style="list-style-type: none"> Cross out spectators $3\text{N}_2\text{O}_{(g)} + 10\text{H}^+_{(aq)} + 2\text{CrO}_4^{2-}_{(aq)} \rightarrow 2\text{Cr}^{3+}_{(aq)} + 5\text{H}_2\text{O}_{(l)} + 6\text{NO}_{(g)}$ |
| g. | <p>Write a balanced redox reaction (in base)</p> <ul style="list-style-type: none"> Count the # of $\text{H}^+_{(aq)}$. Add the same # of $\text{OH}^-_{(aq)}$ to both sides of the equation $10\text{OH}^-_{(aq)} + 3\text{N}_2\text{O}_{(g)} + 10\text{H}^+_{(aq)} + 2\text{CrO}_4^{2-}_{(aq)} \rightarrow 2\text{Cr}^{3+}_{(aq)} + 5\text{H}_2\text{O}_{(l)} + 6\text{NO}_{(g)} + 10\text{OH}^-_{(aq)}$ <ul style="list-style-type: none"> On the side with both $\text{H}^+_{(aq)}$ & $\text{OH}^-_{(aq)}$, those become water $10\text{H}_2\text{O}_{(l)} + 3\text{N}_2\text{O}_{(g)} + 2\text{CrO}_4^{2-}_{(aq)} \rightarrow 2\text{Cr}^{3+}_{(aq)} + 5\text{H}_2\text{O}_{(l)} + 6\text{NO}_{(g)} + 10\text{OH}^-_{(aq)}$ <ul style="list-style-type: none"> Cross out spectators $5\text{H}_2\text{O}_{(l)} + 3\text{N}_2\text{O}_{(g)} + 2\text{CrO}_4^{2-}_{(aq)} \rightarrow 2\text{Cr}^{3+}_{(aq)} + 6\text{NO}_{(g)} + 10\text{OH}^-_{(aq)}$ |

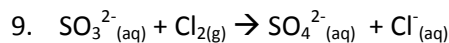


First write oxidation states for each element, per atom.



| | |
|----|--|
| a. | <p>Identify the oxidized species and state how many electrons are lost per atom</p> <ul style="list-style-type: none"> Each Zn lost 2e^- |
| b. | <p>Identify the reduced species and state how many electrons are gained per atom</p> <ul style="list-style-type: none"> Each N gained 8e^- |
| c. | <p>Identify the oxidizing agent</p> <ul style="list-style-type: none"> $\text{NO}_3^-_{(aq)}$ |
| d. | <p>Identify the reducing agent</p> <ul style="list-style-type: none"> $\text{Zn}_{(s)}$ |
| e. | <p>Write balanced half reactions (in acid)</p> <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{Zn}_{(s)} + \text{NO}_3^-_{(aq)} \rightarrow \text{Zn}(\text{OH})_4^{2-}_{(s)} + \text{NH}_3(g)$ $\text{Zn}_{(s)} \rightarrow \text{Zn}(\text{OH})_4^{2-}_{(s)} + 2\text{e}^-$ $8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g)$ <ul style="list-style-type: none"> Balance half reactions for same # of oxidized/reduced species $\text{Zn}_{(s)} \rightarrow \text{Zn}(\text{OH})_4^{2-}_{(s)} + 2\text{e}^-$ $8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g)$ <ul style="list-style-type: none"> Balance half reactions for # of O, with H_2O, and # of H, with H^+ $4\text{H}_2\text{O}_{(l)} + \text{Zn}_{(s)} \rightarrow \text{Zn}(\text{OH})_4^{2-}_{(s)} + 2\text{e}^- + 4\text{H}^+_{(aq)}$ $9\text{H}^+_{(aq)} + 8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g) + 3\text{H}_2\text{O}_{(l)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $4(4\text{H}_2\text{O}_{(l)} + \text{Zn}_{(s)} \rightarrow \text{Zn}(\text{OH})_4^{2-}_{(s)} + 2\text{e}^- + 4\text{H}^+_{(aq)})$ $9\text{H}^+_{(aq)} + 8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g) + 3\text{H}_2\text{O}_{(l)}$ <ul style="list-style-type: none"> Rewriting the half reactions with the multiplication done $16\text{H}_2\text{O}_{(l)} + 4\text{Zn}_{(s)} \rightarrow 4\text{Zn}(\text{OH})_4^{2-}_{(s)} + 8\text{e}^- + 16\text{H}^+_{(aq)}$ $9\text{H}^+_{(aq)} + 8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g) + 3\text{H}_2\text{O}_{(l)}$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions $16\text{H}_2\text{O}_{(l)} + 4\text{Zn}_{(s)} + 9\text{H}^+_{(aq)} + 8\text{e}^- + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g) + 3\text{H}_2\text{O}_{(l)} + 4\text{Zn}(\text{OH})_4^{2-}_{(s)} + 8\text{e}^- + 16\text{H}^+_{(aq)}$ <ul style="list-style-type: none"> Cross out spectators $13\text{H}_2\text{O}_{(l)} + 4\text{Zn}_{(s)} + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_3(g) + 4\text{Zn}(\text{OH})_4^{2-}_{(s)} + 7\text{H}^+_{(aq)}$ |
| g. | <p>Write a balanced redox reaction (in base)</p> |

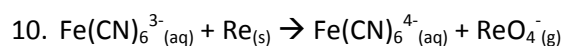
| |
|---|
| <ul style="list-style-type: none"> Count the # of H^+_(aq). Add the same # of OH^-_(aq) to both sides of the equation $7OH^-_{(aq)} + 13H_2O_{(l)} + 4Zn_{(s)} + NO_3^-_{(aq)} \rightarrow NH_{3(g)} + 4Zn(OH)_4^{2-}_{(s)} + 7H^+_{(aq)} + 7OH^-_{(aq)}$ On the side with both H^+_(aq) & OH^-_(aq), those become water $7OH^-_{(aq)} + 13H_2O_{(l)} + 4Zn_{(s)} + NO_3^-_{(aq)} \rightarrow NH_{3(g)} + 4Zn(OH)_4^{2-}_{(s)} + 7H_2O_{(l)}$ Cross out spectators $7OH^-_{(aq)} + 6H_2O_{(l)} + 4Zn_{(s)} + NO_3^-_{(aq)} \rightarrow NH_{3(g)} + 4Zn(OH)_4^{2-}_{(s)}$ |
|---|



First write oxidation states for each element, per atom.

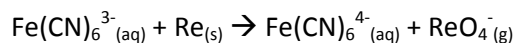


| | |
|----|--|
| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each S lost $2e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each Cl gained $1e^-$ |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> $Cl_{2(g)}$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> $SO_3^{2-}_{(aq)}$ |
| e. | Write balanced half reactions (in acid) <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $SO_3^{2-}_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2e^-$ $1e^- + Cl_{2(g)} \rightarrow Cl^-_{(aq)}$ Balance half reactions for same # of oxidized/reduced species $SO_3^{2-}_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2e^-$ $2(1e^-) + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)}$ Balance half reactions for # of O, with H_2O, and # of H, with H^+ $H_2O_{(l)} + SO_3^{2-}_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2e^- + 2H^+_{(aq)}$ $2e^- + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $H_2O_{(l)} + SO_3^{2-}_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2e^- + 2H^+_{(aq)}$ $2e^- + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)}$ Rewriting the half reactions with the multiplication done $H_2O_{(l)} + SO_3^{2-}_{(aq)} \rightarrow SO_4^{2-}_{(aq)} + 2e^- + 2H^+_{(aq)}$ $2e^- + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)}$ |
| f. | Write a balanced redox reaction (in acid) <ul style="list-style-type: none"> Combine half reactions $H_2O_{(l)} + SO_3^{2-}_{(aq)} + 2e^- + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)} + SO_4^{2-}_{(aq)} + 2e^- + 2H^+_{(aq)}$ Cross out spectators $H_2O_{(l)} + SO_3^{2-}_{(aq)} + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)} + SO_4^{2-}_{(aq)} + 2H^+_{(aq)}$ |
| g. | Write a balanced redox reaction (in base) <ul style="list-style-type: none"> Count the # of H^+_(aq). Add the same # of OH^-_(aq) to both sides of the equation $2OH^-_{(aq)} + H_2O_{(l)} + SO_3^{2-}_{(aq)} + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)} + SO_4^{2-}_{(aq)} + 2H^+_{(aq)} + 2OH^-_{(aq)}$ On the side with both H^+_(aq) & OH^-_(aq), those become water $2OH^-_{(aq)} + H_2O_{(l)} + SO_3^{2-}_{(aq)} + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)} + SO_4^{2-}_{(aq)} + 2H_2O_{(l)}$ Cross out spectators $2OH^-_{(aq)} + SO_3^{2-}_{(aq)} + Cl_{2(g)} \rightarrow 2Cl^-_{(aq)} + SO_4^{2-}_{(aq)} + H_2O_{(l)}$ |

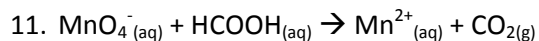


First write oxidation states for each element, per atom.

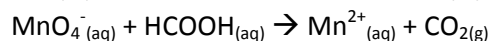
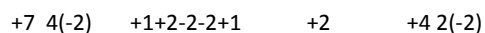




| | |
|----|---|
| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each Re lost $7e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each Fe gained $1e^-$ |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> $\text{Fe(CN)}_6^{3-}(\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> $\text{Re}(\text{s})$ |
| e. | Write balanced half reactions (in acid) <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{Re}(\text{s}) \rightarrow \text{ReO}_4^-(\text{g}) + 7e^-$ $1e^- + \text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow \text{Fe(CN)}_6^{4-}(\text{aq})$ Balance half reactions for same # of oxidized/reduced species $\text{Re}(\text{s}) \rightarrow \text{ReO}_4^-(\text{g}) + 7e^-$ $1e^- + \text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow \text{Fe(CN)}_6^{4-}(\text{aq})$ Balance half reactions for # of O, with H_2O, and # of H, with H^+ $4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) \rightarrow \text{ReO}_4^-(\text{g}) + 7e^- + 8\text{H}^+(\text{aq})$ $1e^- + \text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow \text{Fe(CN)}_6^{4-}(\text{aq})$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) \rightarrow \text{ReO}_4^-(\text{g}) + 7e^- + 8\text{H}^+(\text{aq})$ $7(1e^- + \text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow \text{Fe(CN)}_6^{4-}(\text{aq}))$ Rewriting the half reactions with the multiplication done $4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) \rightarrow \text{ReO}_4^-(\text{g}) + 7e^- + 8\text{H}^+(\text{aq})$ $7e^- + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq})$ |
| f. | Write a balanced redox reaction (in acid) <ul style="list-style-type: none"> Combine half reactions $4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) + 7e^- + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq}) + \text{ReO}_4^-(\text{g}) + 7e^- + 8\text{H}^+(\text{aq})$ Cross out spectators $4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq}) + \text{ReO}_4^-(\text{g}) + 8\text{H}^+(\text{aq})$ |
| g. | Write a balanced redox reaction (in base) <ul style="list-style-type: none"> Count the # of $\text{H}^+(\text{aq})$. Add the same # of $\text{OH}^-(\text{aq})$ to both sides of the equation $8\text{OH}^-(\text{aq}) + 4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq}) + \text{ReO}_4^-(\text{g}) + 8\text{H}^+(\text{aq}) + 8\text{OH}^-(\text{aq})$ On the side with both $\text{H}^+(\text{aq})$ & $\text{OH}^-(\text{aq})$, those become water $8\text{OH}^-(\text{aq}) + 4\text{H}_2\text{O}(\text{l}) + \text{Re}(\text{s}) + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq}) + \text{ReO}_4^-(\text{g}) + 8\text{H}_2\text{O}(\text{l})$ Cross out spectators $8\text{OH}^-(\text{aq}) + \text{Re}(\text{s}) + 7\text{Fe(CN)}_6^{3-}(\text{aq}) \rightarrow 7\text{Fe(CN)}_6^{4-}(\text{aq}) + \text{ReO}_4^-(\text{g}) + 4\text{H}_2\text{O}(\text{l})$ |

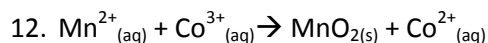


First write oxidation states for each element, per atom.

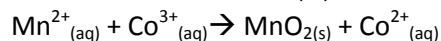


| | |
|----|--|
| a. | Identify the oxidized species and state how many electrons are lost per atom <ul style="list-style-type: none"> Each C lost $2e^-$ |
| b. | Identify the reduced species and state how many electrons are gained per atom <ul style="list-style-type: none"> Each Mn gained $5e^-$ |
| c. | Identify the oxidizing agent <ul style="list-style-type: none"> $\text{MnO}_4^-(\text{aq})$ |
| d. | Identify the reducing agent <ul style="list-style-type: none"> $\text{HCOOH}(\text{aq})$ |
| e. | Write balanced half reactions (in acid) |

| | |
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| | <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{HCOOH}_{(aq)} \rightarrow \text{CO}_{2(g)} + 2e^-$ $5e^- + \text{MnO}_4^-_{(aq)} \rightarrow \text{Mn}^{2+}_{(aq)}$ Balance half reactions for same # of oxidized/reduced species $\text{HCOOH}_{(aq)} \rightarrow \text{CO}_{2(g)} + 2e^-$ $5e^- + \text{MnO}_4^-_{(aq)} \rightarrow \text{Mn}^{2+}_{(aq)}$ Balance half reactions for # of O, with H₂O, and # of H, with H⁺ $\text{HCOOH}_{(aq)} \rightarrow \text{CO}_{2(g)} + 2e^- + 2\text{H}^+_{(aq)}$ $8\text{H}^+_{(aq)} + 5e^- + \text{MnO}_4^-_{(aq)} \rightarrow \text{Mn}^{2+}_{(aq)} + 4\text{H}_2\text{O}_{(l)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $5(\text{HCOOH}_{(aq)} \rightarrow \text{CO}_{2(g)} + 2e^- + 2\text{H}^+_{(aq)})$ $2(8\text{H}^+_{(aq)} + 5e^- + \text{MnO}_4^-_{(aq)} \rightarrow \text{Mn}^{2+}_{(aq)} + 4\text{H}_2\text{O}_{(l)})$ Rewriting the half reactions with the multiplication done $5\text{HCOOH}_{(aq)} \rightarrow 5\text{CO}_{2(g)} + 10e^- + 10\text{H}^+_{(aq)}$ $16\text{H}^+_{(aq)} + 10e^- + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 8\text{H}_2\text{O}_{(l)}$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions $5\text{HCOOH}_{(aq)} + 16\text{H}^+_{(aq)} + 10e^- + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 8\text{H}_2\text{O}_{(l)} + 5\text{CO}_{2(g)} + 10e^- + 10\text{H}^+_{(aq)}$ Cross out spectators $5\text{HCOOH}_{(aq)} + 6\text{H}^+_{(aq)} + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 8\text{H}_2\text{O}_{(l)} + 5\text{CO}_{2(g)}$ |
| g. | <p>Write a balanced redox reaction (in base)</p> <ul style="list-style-type: none"> Count the # of H⁺_(aq). Add the same # of OH⁻_(aq) to both sides of the equation $6\text{OH}^-_{(aq)} + 5\text{HCOOH}_{(aq)} + 6\text{H}^+_{(aq)} + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 8\text{H}_2\text{O}_{(l)} + 5\text{CO}_{2(g)} + 6\text{OH}^-_{(aq)}$ On the side with both H⁺_(aq) & OH⁻_(aq), those become water $6\text{H}_2\text{O}_{(l)} + 5\text{HCOOH}_{(aq)} + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 8\text{H}_2\text{O}_{(l)} + 5\text{CO}_{2(g)} + 6\text{OH}^-_{(aq)}$ Cross out spectators $5\text{HCOOH}_{(aq)} + 2\text{MnO}_4^-_{(aq)} \rightarrow 2\text{Mn}^{2+}_{(aq)} + 2\text{H}_2\text{O}_{(l)} + 5\text{CO}_{2(g)} + 6\text{OH}^-_{(aq)}$ |



First write oxidation states for each element, per atom.



| | |
|----|--|
| a. | <p>Identify the oxidized species and state how many electrons are lost per atom</p> <ul style="list-style-type: none"> Each Mn lost 2e⁻ |
| b. | <p>Identify the reduced species and state how many electrons are gained per atom</p> <ul style="list-style-type: none"> Each Co gained 1e⁻ |
| c. | <p>Identify the oxidizing agent</p> <ul style="list-style-type: none"> Co³⁺_(aq) |
| d. | <p>Identify the reducing agent</p> <ul style="list-style-type: none"> Mn²⁺_(aq) |
| e. | <p>Write balanced half reactions (in acid)</p> <ul style="list-style-type: none"> Write Unbalanced half reactions including electron change per atom $\text{Mn}^{2+}_{(aq)} \rightarrow \text{MnO}_{2(s)} + 2e^-$ $1e^- + \text{Co}^{3+}_{(aq)} \rightarrow \text{Co}^{2+}_{(aq)}$ Balance half reactions for same # of oxidized/reduced species $\text{Mn}^{2+}_{(aq)} \rightarrow \text{MnO}_{2(s)} + 2e^-$ $1e^- + \text{Co}^{3+}_{(aq)} \rightarrow \text{Co}^{2+}_{(aq)}$ Balance half reactions for # of O, with H₂O, and # of H, with H⁺ $2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} \rightarrow \text{MnO}_{2(s)} + 2e^- + 4\text{H}^+_{(aq)}$ $1e^- + \text{Co}^{3+}_{(aq)} \rightarrow \text{Co}^{2+}_{(aq)}$ <p>Now the half reactions are balanced within themselves, but not balanced for # of electrons gained and lost</p> |

| | |
|----|--|
| | <ul style="list-style-type: none"> Balance half reactions for # of electrons gained and lost $2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} \rightarrow \text{MnO}_{2(s)} + 2\text{e}^- + 4\text{H}^+_{(aq)}$ $2(1\text{e}^- + \text{Co}^{3+}_{(aq)} \rightarrow \text{Co}^{2+}_{(aq)})$ Rewriting the half reactions with the multiplication done $2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} \rightarrow \text{MnO}_{2(s)} + 2\text{e}^- + 4\text{H}^+_{(aq)}$ $2\text{e}^- + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)}$ |
| f. | <p>Write a balanced redox reaction (in acid)</p> <ul style="list-style-type: none"> Combine half reactions $2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} + 2\text{e}^- + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)} + \text{MnO}_{2(s)} + 2\text{e}^- + 4\text{H}^+_{(aq)}$ Cross out spectators $2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)} + \text{MnO}_{2(s)} + 4\text{H}^+_{(aq)}$ |
| g. | <p>Write a balanced redox reaction (in base)</p> <ul style="list-style-type: none"> Count the # of $\text{H}^+_{(aq)}$. Add the same # of $\text{OH}^-_{(aq)}$ to both sides of the equation $4\text{OH}^-_{(aq)} + 2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)} + \text{MnO}_{2(s)} + 4\text{H}^+_{(aq)} + 4\text{OH}^-_{(aq)}$ On the side with both $\text{H}^+_{(aq)}$ & $\text{OH}^-_{(aq)}$, those become water $4\text{OH}^-_{(aq)} + 2\text{H}_2\text{O}_{(l)} + \text{Mn}^{2+}_{(aq)} + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)} + \text{MnO}_{2(s)} + 4\text{H}_2\text{O}_{(l)}$ Cross out spectators $4\text{OH}^-_{(aq)} + \text{Mn}^{2+}_{(aq)} + 2\text{Co}^{3+}_{(aq)} \rightarrow 2\text{Co}^{2+}_{(aq)} + \text{MnO}_{2(s)} + 2\text{H}_2\text{O}_{(l)}$ |