# Balancing REDOX Reactions - Supplemental Worksheet KEY

The tutorials have been removed to save space. Refer to the original worksheet for clarification on how to balance REDOX reactions.

Are these reactions are REDOX reactions? If yes, then balance the reaction using the half-reaction method.

1. 
$$\underline{2}$$
Au<sup>3+</sup> (aq) +  $\underline{6}$ I<sup>-</sup> (aq)  $\rightarrow \underline{2}$ Au (s) +  $\underline{3}$ I<sub>2</sub> (s)

To balance elements: Insert coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $2\Gamma \rightarrow I_2$ 

Reduction  $\frac{1}{2}$  reaction: Au<sup>3+</sup>  $\rightarrow$  Au

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $2I^{-} \rightarrow I_2 + 2e^{-}$ 

Reduction  $\frac{1}{2}$  reaction: Au<sup>3+</sup> + 3e<sup>-</sup>  $\rightarrow$  Au

To balance electrons: Multiply by coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $3x(2I^{-} \rightarrow I_2 + 2e^{-})$ 

New Oxidation  $\frac{1}{2}$  reaction:  $6I^{-} \rightarrow 3I_2 + 6e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $2x(Au^{3+} + 3e^{-} \rightarrow Au)$ 

New Reduction  $\frac{1}{2}$  reaction:  $2Au^{3+} + 6e^{-} \rightarrow 2Au$ 

Combine:

Oxidation  $\frac{1}{2}$  reaction:  $6I^{-} \rightarrow 3I_2 + 6e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $+2Au^{3+}+6e^{-} \rightarrow 2Au$ 

Combined Balanced Equation:  $6I^- + 2Au^{3+} \rightarrow 3I_2 + 2Au$ 

2. Cu (s) + 
$$\underline{2}$$
Ag<sup>+</sup> (aq)  $\rightarrow$  Cu<sup>2+</sup> (aq) +  $\underline{2}$ Ag (s)

To balance elements: Insert coefficients.

Oxidation ½ reaction: Cu → Cu<sup>2+</sup>

Reduction  $\frac{1}{2}$  reaction: Ag<sup>+</sup>  $\rightarrow$  Ag

To balance charge: Add electrons.

Oxidation ½ reaction: Cu → Cu<sup>2+</sup> + 2e<sup>-</sup>

Reduction  $\frac{1}{2}$  reaction: Ag<sup>+</sup> + 1e<sup>-</sup>  $\rightarrow$  Ag

To balance electrons: Multiply by coefficients.

Oxidation ½ reaction: Cu → Cu<sup>2+</sup> + 2e<sup>-</sup>

Reduction  $\frac{1}{2}$  reaction:  $2x(Ag^+ + 1e^- \rightarrow Ag)$ 

New Reduction  $\frac{1}{2}$  reaction:  $2Ag^+ + 2e^- \rightarrow 2Ag$ 

Combine:

Oxidation  $\frac{1}{2}$  reaction: Cu  $\rightarrow$  Cu<sup>2+</sup> + 2e<sup>-</sup>

Reduction  $\frac{1}{2}$  reaction:  $+2Ag^{+} + 2e^{-} \rightarrow 2Ag$ 

Combined Balanced Equation: Cu + 2Ag<sup>+</sup> → Cu<sup>2+</sup> + 2Ag

3. 
$$BaSO_3(s) \rightarrow BaO(s) + SO_2(g)$$

NOT A REDOX REACTION. Also, it is already balanced:)

Balance the following reactions using the half-reaction method in an *acidic* solution.

1. 
$$3\text{NbO}_2 + 2\text{W} + 2\text{H}_2\text{O} \rightarrow 3\text{Nb} + 2\text{WO}_4^{2-} + 4\text{H}_4^+$$

To balance elements (other than 0 and H): Insert coefficients.

Oxidation ½ reaction: W  $\rightarrow$  WO<sub>4</sub><sup>2</sup>-

Reduction  $\frac{1}{2}$  reaction: NbO<sub>2</sub>  $\rightarrow$  Nb

To balance oxygens: Add water.

Oxidation  $\frac{1}{2}$  reaction:  $4H_2O + W \rightarrow WO_4^{2-}$ 

Reduction  $\frac{1}{2}$  reaction: NbO<sub>2</sub>  $\rightarrow$  Nb + 2H<sub>2</sub>O

To balance hydrogens: Add H<sup>+</sup> (since we're in acidic solutions).

Oxidation ½ reaction:  $4H_2O + W \rightarrow WO_4^{2-} + 8H^+$ 

Reduction  $\frac{1}{2}$  reaction:  $4H^+ + NbO_2 \rightarrow Nb + 2H_2O$ 

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $4H_2O + W \rightarrow WO_4^{2-} + 8H^+ + 6e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $4e^{-} + 4H^{+} + NbO_{2} \rightarrow Nb + 2H_{2}O$ 

To balance electrons: Multiply by coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $2x(4H_2O + W \rightarrow WO_4^{2-} + 8H^+ + 6e^-)$ 

New Oxidation  $\frac{1}{2}$  reaction:  $8H_2O + 2W \rightarrow 2WO_4^{2-} + 16H^+ 12e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $3x(4e^+ + 4H^+ + NbO_2 \rightarrow Nb + 2H_2O)$ 

New Reduction  $\frac{1}{2}$  reaction:  $12e^{-} + 12H^{+} + 3NbO_{2} + 12e^{-} \rightarrow 3Nb + 6H_{2}O$ 

Combine:

Oxidation  $\frac{1}{2}$  reaction:  $8H_2O + 2W \rightarrow 2WO_4^{2-} + 16H^+ 12e^-$ 

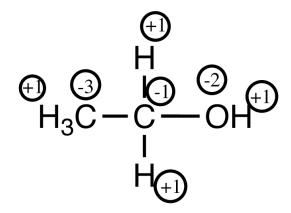
Reduction  $\frac{12 e^{-} + 12 H^{+} + 3 NbO_{2} + 12 e^{-} \rightarrow 3 Nb + 6 H_{2}O$ 

Combined Balanced Equation:  $3NbO_2 + 2W + 2H_2O \rightarrow 2WO_4^{2-} + 3Nb + 4H^+$ 

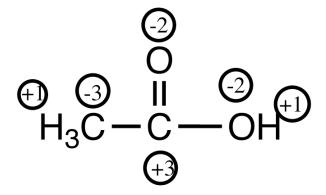
# 2. $\underline{5}C_2H_5OH$ (aq) + $\underline{4}MnO_4$ (aq) + $\underline{12H^+} \rightarrow \underline{4}Mn^{2+}$ (aq) + $\underline{5}CH_3COOH$ (aq) + $\underline{11H_2O}$

Here the assignment of oxidation numbers can be challenging. Refer to the following diagrams for the assignment of oxidation numbers on the hydrocarbons!

### **Ethanol**:



## Acetic Acid:



To balance elements (other than O and H): Insert coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $C_2H_5OH \rightarrow CH_3COOH$ 

Reduction  $\frac{1}{2}$  reaction:  $MnO_4^- \rightarrow Mn^{2+}$ 

To balance oxygens: Add water.

Oxidation  $\frac{1}{2}$  reaction:  $H_2O + C_2H_5OH \rightarrow CH_3COOH$ 

Reduction  $\frac{1}{2}$  reaction: MnO<sub>4</sub><sup>-</sup>  $\rightarrow$  Mn<sup>2+</sup> + 4H<sub>2</sub>O

To balance hydrogens: Add H<sup>+</sup> (since we're in acidic solutions).

Oxidation  $\frac{1}{2}$  reaction:  $H_2O + C_2H_5OH \rightarrow CH_3COOH + 4H^+$ 

Reduction  $\frac{1}{2}$  reaction:  $8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$ 

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $H_2O + C_2H_5OH \rightarrow CH_3COOH + 4H^+ + 4e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4H_2O$ 

To balance electrons: Multiply by coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $5x(H_2O + C_2H_5OH \rightarrow CH_3COOH + 4H^+ + 4e^-)$ 

New Oxidation  $\frac{1}{2}$  reaction:  $5H_2O + 5C_2H_5OH \rightarrow 5CH_3COOH + 20H^+ + 20e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $4x(8H^+ + MnO_4^- + 5e^- \rightarrow Mn^{2+} + 4H_2O)$ 

New Reduction  $\frac{1}{2}$  reaction:  $32H^+ + 4MnO_4^- + 20e^- \rightarrow 4Mn^{2+} + 16H_2O$ 

Combine:

Oxidation  $\frac{1}{2}$  reaction:  $5H_2O + 5C_2H_5OH \rightarrow 5CH_3COOH + 20H^+ + 20e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $+32H^{+} + 4MnO_{4}^{-} + 20e^{-} \rightarrow 4Mn^{2+} + 16H_{2}O_{4}$ 

Combined Balanced Equation:  $12H^+ + 5C_2H_5OH + 4MnO_4^- \rightarrow 5CH_3COOH + 4Mn^{2+} + 11H_2O$ 

# 3. $ClO^- + 2ZnO + 6H^+ \rightarrow Cl^- + 2Zn^{3+} + 3H_2O$

To balance elements (other than 0 and H): Insert coefficients.

Oxidation ½ reaction: ZnO → Zn<sup>3+</sup>

Reduction ½ reaction: ClO<sup>-</sup> → Cl<sup>-</sup>

To balance oxygens: Add water.

Oxidation  $\frac{1}{2}$  reaction: ZnO  $\rightarrow$  Zn<sup>3+</sup> + H<sub>2</sub>O

Reduction  $\frac{1}{2}$  reaction:  $ClO^{-} \rightarrow Cl^{-} + H_2O$ 

To balance hydrogens: Add H<sup>+</sup> (since we're in acidic solutions).

Oxidation  $\frac{1}{2}$  reaction:  $2H^+ + ZnO \rightarrow Zn^{3+} + H_2O$ 

Reduction  $\frac{1}{2}$  reaction:  $2H^+ + ClO^- \rightarrow Cl^- + H_2O$ 

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $2H^+ + ZnO \rightarrow Zn^{3+} + H_2O + 1e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $2H^+ + Cl0^- + 2e^- \rightarrow Cl^- + H_2O$ 

To balance electrons: Multiply by coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $2x(2H^+ + ZnO \rightarrow Zn^{3+} + H_2O + 1e^-)$ 

New Oxidation  $\frac{1}{2}$  reaction:  $4H^+ + 2ZnO \rightarrow 2Zn^{3+} + 2H_2O + 2e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $2H^+ + ClO^- + 2e^- \rightarrow Cl^- + H_2O$ 

Combine:

Oxidation  $\frac{1}{2}$  reaction:  $4H^+ + 2ZnO \rightarrow 2Zn^{3+} + 2H_2O + 2e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $+2H^+ + ClO^- + 2e^- \rightarrow Cl^- + H_2O$ 

Combined Balanced Equation:  $6H^+ + 2ZnO + ClO^- \rightarrow 2Zn^{3+} + Cl^- + 3H_2O$ 

Balance the following reactions using the half-reaction method in a *basic* solution.

$$1.4H_2O + 1AlH_4 + 4H_2CO \rightarrow 1Al^{3+} + 4CH_3COH + 4OH^{-}$$

To balance elements (other than O and H): Insert coefficients (nothing needed to be done here though!)

Oxidation  $\frac{1}{2}$  reaction: AlH<sub>4</sub><sup>-</sup>  $\rightarrow$  Al<sup>3+</sup>

Reduction ½ reaction: H<sub>2</sub>CO → CH<sub>3</sub>COH

To balance oxygens: Add water (also nothing needed to be added in this example)

Oxidation  $\frac{1}{2}$  reaction: AlH<sub>4</sub><sup>-</sup>  $\rightarrow$  Al<sup>3+</sup>

Reduction  $\frac{1}{2}$  reaction:  $H_2CO \rightarrow CH_3COH$ 

To balance hydrogens: Add H<sup>+</sup>.

Oxidation ½ reaction: AlH<sub>4</sub><sup>-</sup> → Al<sup>3+</sup> + 4H<sup>+</sup>

Reduction ½ reaction: 2H+ + H<sub>2</sub>CO → CH<sub>3</sub>COH

BUT it is a BASIC solution. Add OH- to BOTH sides (enough to combine with all H+)

Oxidation  $\frac{1}{2}$  reaction:  $40H^{-} + AlH_{4}^{-} \rightarrow Al^{3+} + 4H^{+} + 40H^{-}$ 

Combine to make water:  $40H^{-} + AlH_{4}^{-} \rightarrow Al^{3} + 4H_{2}O$ 

Reduction  $\frac{1}{2}$  reaction:  $20H^{-} + 2H^{+} + H_{2}CO \rightarrow CH_{3}COH + 2OH^{-}$ 

Combine to make water:  $2H_2O + H_2CO \rightarrow CH_3COH + 2OH^-$ 

Cancel any waters on both sides: Not needed in this example

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $40H^{-} + AlH_{4}^{-} \rightarrow Al^{3+} + 4H_{2}O + 8e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $2e^- + 2H_2O + H_2CO \rightarrow CH_3COH + 2OH^-$ 

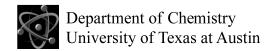
To balance electrons: Multiply by coefficients.

Oxidation  $\frac{1}{2}$  reaction:  $40H^{-} + AlH_{4}^{-} \rightarrow Al^{3+} + 4H_{2}O + 8e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $4x(2e^- + 2H_2O + H_2CO \rightarrow CH_3COH + 2OH^-)$ 

**NEW Reduction**  $\frac{1}{2}$  reaction:  $8e^- + 8H_2O + 4H_2CO \rightarrow 4CH_3COH + 8OH^-$ 

Combine:



Name:	_

Oxidation  $\frac{1}{2}$  reaction:  $40H^- + AlH_4^- \rightarrow Al^{3+} + 4H_2O + 8e^-$ 

Reduction  $\frac{1}{2}$  reaction:  $8e^- + 8H_2O + 4H_2CO \rightarrow 4CH_3COH + 8OH^- +$ 

**Combined Balanced Equation:** 

 $4H_2O + AlH_4^- + 4H_2CO \rightarrow Al^{3+} + 4CH_3COH + 4OH^-$ 

# 2. Fe + NiO<sub>2</sub> + $\frac{2H_2O}{}$ $\rightarrow$ Fe(OH)<sub>2</sub> + Ni(OH)<sub>2</sub>

To balance elements (other than 0 and H): Insert coefficients.

Oxidation  $\frac{1}{2}$  reaction: Fe  $\rightarrow$  Fe(OH)<sub>2</sub>

Reduction  $\frac{1}{2}$  reaction: NiO<sub>2</sub>  $\rightarrow$  Ni(OH)<sub>2</sub>

To balance oxygens: Add water.

Oxidation  $\frac{1}{2}$  reaction: Fe +  $2H_2O \rightarrow Fe(OH)_2$ 

Reduction  $\frac{1}{2}$  reaction: NiO<sub>2</sub>  $\rightarrow$  Ni(OH)<sub>2</sub>

To balance hydrogens: Add H<sup>+</sup>.

Oxidation  $\frac{1}{2}$  reaction: Fe +  $2H_2O \rightarrow Fe(OH)_2 + 2H^+$ 

Reduction  $\frac{1}{2}$  reaction: NiO<sub>2</sub> + 2H<sup>+</sup>  $\rightarrow$  Ni(OH)<sub>2</sub>

BUT it is a BASIC solution. Add OH- to BOTH sides (enough to combine with all H+)

Oxidation ½ reaction: Fe +  $2H_2O + 2OH \rightarrow Fe(OH)_2 + 2H + 2OH$ 

Combine H<sup>+</sup> and OH<sup>-</sup>: Fe +  $2H_2O$  + 2OH  $\rightarrow$  Fe(OH)<sub>2</sub> +  $2H_2O$ 

Cancel Extra  $H_2O: \mathbf{Fe} + \mathbf{2OH} \rightarrow \mathbf{Fe}(\mathbf{OH})_2$ 

Reduction  $\frac{1}{2}$  reaction: NiO<sub>2</sub> + 2H<sup>+</sup>+ 2OH<sup>-</sup>  $\rightarrow$  Ni(OH)<sub>2</sub> + 2OH<sup>-</sup>

Combine H<sup>+</sup> and OH<sup>-</sup>: NiO<sub>2</sub> + 2H<sub>2</sub>O $\rightarrow$  Ni(OH)<sub>2</sub> + 2OH<sup>-</sup>

Cancel Extra  $H_2O$ :  $NiO_2 + 2H_2O \rightarrow Ni(OH)_2 + 2OH^-$ 

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction: Fe + 20H- $\rightarrow$  Fe(OH)<sub>2</sub> + 2e<sup>-</sup>

Reduction  $\frac{1}{2}$  reaction: NiO<sub>2</sub> + 2H<sub>2</sub>O + 2e<sup>-</sup>  $\rightarrow$  Ni(OH)<sub>2</sub> + 2OH<sup>-</sup>

To balance electrons: Multiply by coefficients.

Not necessary! 2e are already on either side!

Combine:

Oxidation  $\frac{1}{2}$  reaction: Fe + 20H<sup>-</sup>  $\rightarrow$  Fe(OH)<sub>2</sub> + 2e<sup>-</sup>

Reduction  $\frac{1}{2}$  reaction:  $\frac{1}{2} + \frac{100}{2} + \frac{2}{100} + \frac{2}{2} + \frac{2}{100} + \frac{$ 

Combined Balanced Equation: Fe +  $2H_2O + NiO_2 \rightarrow Ni(OH)_2 + Fe(OH)_2$ 

 $3.2MnO_4 + 3CN + H_2O$ 

 $\rightarrow$  2MnO<sub>2</sub> + 3CNO<sup>-</sup> + 2OH<sup>-</sup>

To balance elements (other than 0 and H): Insert coefficients.

Oxidation ½ reaction: CN- → CNO-

Reduction  $\frac{1}{2}$  reaction: MnO<sub>4</sub>  $\rightarrow$  MnO<sub>2</sub>

To balance oxygens: Add water.

Oxidation  $\frac{1}{2}$  reaction:  $CN^- + H_2O \rightarrow CNO^-$ 

Reduction  $\frac{1}{2}$  reaction: MnO<sub>4</sub>-  $\rightarrow$  MnO<sub>2</sub> + 2H<sub>2</sub>O

To balance hydrogens: Add H<sup>+</sup>.

Oxidation  $\frac{1}{2}$  reaction: CN<sup>-</sup> + H<sub>2</sub>O  $\rightarrow$  CNO<sup>-</sup> + 2H<sup>+</sup>

Reduction  $\frac{1}{2}$  reaction: MnO<sub>4</sub>- + 4H+  $\rightarrow$  MnO<sub>2</sub> + 2H<sub>2</sub>O

BUT it is a BASIC solution. Add OH- to BOTH sides (enough to combine with all H+)

Oxidation  $\frac{1}{2}$  reaction:  $CN^{-} + H_{2}O + 2OH^{-} \rightarrow CNO^{-} + 2H^{+} + 2OH^{-}$ 

Combine H<sup>+</sup> and OH<sup>-</sup>:  $CN^- + H_2O + 2OH^- \rightarrow CNO^- + 2H_2O$ 

Cancel Extra  $H_2O: CN^- + 2OH^- \rightarrow CNO^- + H_2O$ 

Reduction  $\frac{1}{2}$  reaction: MnO<sub>4</sub> + 4H<sup>+</sup> + 4OH<sup>-</sup>  $\rightarrow$  MnO<sub>2</sub> + 2H<sub>2</sub>O + 4OH<sup>-</sup>

Combine H<sup>+</sup> and OH<sup>-</sup>:  $MnO_4$  +  $4H_2O \rightarrow MnO_2 + 2H_2O + 4OH^-$ 

Cancel Extra  $H_2O: MnO_4$  +  $2H_2O \rightarrow MnO_2 + 4OH$ 

To balance charge: Add electrons.

Oxidation  $\frac{1}{2}$  reaction:  $CN^{-} + 20H^{-} \rightarrow CN0^{-} + H_{2}O + 2e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$ 

To balance electrons: Multiply by coefficients.

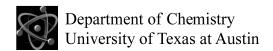
Oxidation  $\frac{1}{2}$  reaction:  $3x(CN^2 + 20H^2 \rightarrow CNO^2 + H_2O + 2e^2)$ 

New Oxidation  $\frac{1}{2}$  reaction:  $3CN^{-} + 6OH^{-} \rightarrow 3CNO^{-} + 3H_{2}O + 6e^{-}$ 

Reduction  $\frac{1}{2}$  reaction:  $2x(MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-)$ 

New Reduction  $\frac{1}{2}$  reaction:  $2MnO_4$  +  $4H_2O$  +  $6e^-\rightarrow 2MnO_2$  +  $8OH^-$ 

Combine:  $3CN^{-} + 6OH^{-} \rightarrow 3CNO^{-} + 3H_{2}O + 6e^{-}$ 



 $+ 2MnO_4^- + 4H_2O + 6e^- \rightarrow 2MnO_2 + 8OH^-$ 

Combined Balanced Equation:  $3CN^- + 2MnO_{4^-} + H_2O \rightarrow 3CNO^- + 2MnO_2 + 2OH^-$