

# **Combining Half Reactions**

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Video Workbook with Dr. B

At this point we need to make the number of electrons in each half reaction match. Then we can combine the half-reactions.

For example, we have 5e in the first half-rxn and 2e in the second. They don't match!

$$5e + 8H^{+} + MnO_{4} \rightarrow Mn^{2+} + H_{2}O$$
  
 $2I \rightarrow I_{2} + Ze^{-}$ 

They must match because they are the same electrons!

- Balancing Half-Reactions
- Full Redox Playlist

We'll work in *acidic medium* when balancing all half rxns. This works for basic medium as well – we just need an extra step at the end of the entire process.

### **Simple Half-Rxns**

**Important**: Electrons are neither created nor destroyed in a redox process. They are simply transferred from one species (substance) to another to maintain charge neutrality.

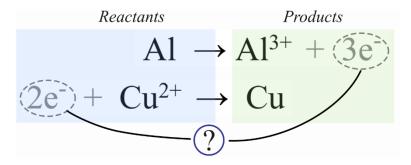
$$5\bar{e} + 8H^{+} + MnO_{4}^{-} \rightarrow Mn^{2+} + H_{2}O$$

$$\uparrow \qquad \qquad 2I^{-} \rightarrow I_{2} + 2\bar{e}^{-} = 1$$

The arrows above show the electrons lost by Manganese (Mn) and gained by Iodine (I). But the numbers don't match! That is why they need to be balanced.

*No matter how hard I try I cannot remove this whitespace here without destroying the rest of the document.* 

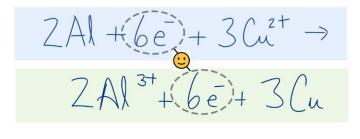
Example #1: Match the electrons in each half-rxn and combine the half-rxns.



**Answer** 

$$\begin{bmatrix} A1 \rightarrow A1^{3+} + (3e) \end{bmatrix} 2$$

$$2e + Cu^{2+} \rightarrow Cu \end{bmatrix} 3$$



$$2Al + be + 3Cu^{2+} \rightarrow$$

$$2Al^{3+} + be + 3Cu$$

Be sure to check to make sure the atoms are balanced and the charge is balanced for the entire equation.



Watch <u>the video</u> after doing the problem.

Everything is balanced except the number of electrons. *We're almost there*.

We multiply the top by half-rxn by 2 and the bottom by 3.

The ratios stay the same for each half-rxn.

This gives 6e<sup>-</sup> in each half reaction. They now match and we can add them together.

When adding the half-rxns together, make sure you keep the reactants together and the products together.

Cancel like terms and you're done.

Practice #1: Match the electrons in each half-rxn and combine the half-rxns.

$$\begin{array}{c}
\text{Reactants} & \text{Products} \\
\text{Cu} \rightarrow \text{Cu}^{2+} + 2e^{2} \\
\text{Fe}^{3+} + e^{2} \rightarrow \text{Fe}^{2+}
\end{array}$$

Everything is balanced except the number of electrons. *We're almost there*.

### Answer

$$\begin{bmatrix} Cu \rightarrow Cu^{2+} + (2e^{-}) \\ Fe^{3+} + (e^{-}) \rightarrow Fe^{2+} \end{bmatrix}$$

We multiply the top by half rxn by 1 and the bottom by 1.

$$Cu + 2Fe^{3+} + (Ze^{3}) \rightarrow$$
  
 $Cu^{2+} + (Ze^{3+} + ZFe^{2+})$ 

This gives 2e<sup>-</sup> in each half reaction. They now match and we can add them together.

$$Cu + 2Fe^{3+} + 2e \rightarrow$$

$$Cu^{2+} + 2e + 2Fe^{2+}$$

When adding the half-rxns together, make sure you keep the reactants together and the products together.

Cancel like terms and you're done.

It is a bit tricky to check that ther charge balances in this problem.

- In the reactants we have 2Fe<sup>3+</sup> so the total charge is 6+
- In the products we have Cu<sup>2+</sup> and 2Fe2<sup>+</sup>. So the charge is 2+ and 4+ for a total of 6+.

Always check to be sure the **number of atoms** and the **charge** balance.

The number of Cu and Fe atoms are the same on both sides (don't worry about charge when counting atoms).

### Half-Reactions involving H and O

Example #1: Match the electrons in each half-rxn and combine the half-rxns.

$$5e + 8H^{+} + MnO_{4} \rightarrow Mn^{2+} + H_{2} \bigcirc$$
  
 $2I \rightarrow I_{2} + 2e^{-}$ 

Watch <u>the video</u> after doing the problem.

**Answer** 

Reactants

Products  $\begin{array}{c}
(5e + 8H^{+} + MnO_{4}^{-} \rightarrow Mn^{2+} + HH_{2}O) \\
2 I^{-} \rightarrow I_{2} + (2e^{-})
\end{array}$ 

Everything is balanced except the number of electrons. *We're almost there*.

$$\begin{bmatrix}
5e + 8H^{+} + MnO_{4} \rightarrow Mn^{2+} + H_{2}O \end{bmatrix} Z$$

$$\begin{bmatrix}
2I^{-} \rightarrow I_{2} + 2e^{-}\end{bmatrix} 5$$

We multiply the top by half-rxn by 2 and the bottom by 5.

This gives 10e<sup>-</sup> in each half reaction. They now match and we can add them together.

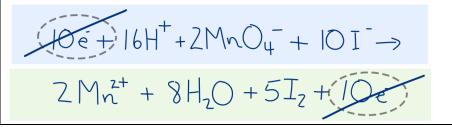
When adding the half-rxns together, make sure you keep the reactants together and the products together.

$$(10e + 16H^{+} + 2MnO_{4}^{-} + 10I^{-})$$

$$(2Mn^{2+} + 8H_{2}O + 5I_{2} + 10e^{-})$$

Cancel like terms.

Finally, check to make sure the atoms are balance and the charge is balanced for the entire equation.



Practice #1 Match electrons and combine the half-rxns.

$$3e^{-} + 4H^{+} + MnO_{4}^{-} \rightarrow MnO_{2} + 2H_{2}^{0}$$
  
 $H_{1}^{0} + SO_{3}^{2-} \rightarrow SO_{4}^{2-} + 2H^{+} + 2e^{-}$ 

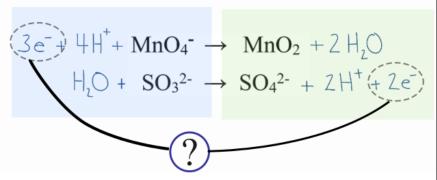


Watch <u>the video</u> for this reaction.

Answer

Reactants

**Products** 



Everything is balanced except the number of electrons.

$$\begin{bmatrix}
 3e^{-} + 4H^{+} + MnO_{4}^{-} \rightarrow MnO_{2} + 2H_{2}O \end{bmatrix} 2
 \begin{bmatrix}
 H_{2}O + SO_{3}^{2-} \rightarrow SO_{4}^{2-} + 2H^{+} + 2e^{-}\end{bmatrix} 3$$

We multiply the top by half-rxn by 2 and the bottom by 3.

$$(6e^{+}) 8H^{+} + 2MnO_{4}^{-} + 3H_{2}O + 3SO_{3}^{2-} \rightarrow 2MnO_{2} + 4H_{2}O + 3SO_{4}^{2-} + 6H^{+} + 6e^{-})$$

This gives 6e<sup>-</sup> in each half reaction. They now match and we can add them together.

$$6e + 8H^{+} + 2MnO_{4}^{-} + 3H_{2}O + 3SO_{3}^{2-} \rightarrow$$
  
 $2MnO_{2} + 4H_{2}O + 3SO_{4}^{2-} + 6H^{*} + 6e^{-}$ 

When adding the half-rxns together, make sure you keep the reactants together and the products together.

Note: for this reaction we have  $3H_2O$  in the reactions and  $4H_2O$  in the products. We cancel out three on each side and are left with  $1H_2O$  in the products.

Cancel like terms and you're done.

Practice #2: Match the electrons in each half-rxn and combine the half-rxns.

$$(6e^{-} + 14H^{+} + Cr_{2}O_{7}^{2-} \rightarrow 2Cr^{3+} + 7H_{2}O_{2})$$
 $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ 



Watch <u>the video</u> for this reaction.

**Answer:** 

Reactants

**Products** 

$$(6e) + 14H^{+} + Cr_{2}O_{7}^{2-} \rightarrow 2Cr^{3+} + 7H_{2}O_{7}^{2-} \rightarrow Fe^{3+} + (e^{-})$$

Everything is balanced except the number of electrons.

$$\begin{bmatrix}
6 e + 14H^{+} + Cr_{2}O_{7}^{2-} \rightarrow 2Cr^{3+} + 7H_{2}O\end{bmatrix} 1$$

$$\begin{bmatrix}
Fe^{2+} \rightarrow Fe^{3+} + e^{-}\end{bmatrix} 6$$

We multiply the top by half-rxn by 1 and the bottom by 6.

$$(6e)+14H^{+}+C_{2}O_{7}^{2-}+6F_{e}^{2+}-)$$
  
 $2C_{7}^{3+}+7H_{2}O+6F_{e}^{3+}+(6e)$ 

This gives 6e<sup>-</sup> in each half reaction. They now match and we can add them together.

$$6e^{-} + 14H^{+} + C_{2}O_{7}^{2-} + 6F_{e}^{2+} \rightarrow 2C_{7}^{3+} + 7H_{2}O + 6F_{e}^{3+} + 6F_{e}^{3+}$$

When adding the half-rxns together, make sure you keep the reactants together and the products together.

Cancel like terms and you're done.

Check that atoms and charge balance. If not, go back and check each step to find the problem.

## More Practice



Balance the electrons, combine the half-rxns, and cancel out like terms.

1.  $4e^{-} + 4H^{+} + MnO_{2} \rightarrow Mn + 2H_{2}O$  $3H_2O + Al \rightarrow Al_2O_3 + 6H^+ + 6e^-$ 

7. 
$$Fe_2O_3 + 6H^+ + 6e^- \rightarrow 2Fe + 3H_2O$$
  
 $CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$ 

2.  $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$  $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ 

8. 
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$
  
 $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-$ 

3.  $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$  $H_2SO_3 + H_2O \rightarrow HSO_4^- + 3H^+ + 2e^-$ 

9. 
$$CH_3OH \rightarrow CH_2O + 2H^+ + 2e^-$$
  
 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ 

4.  $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$  $SO_2 + 2H_2O \rightarrow HSO_4^- + 3H^+ + 2e^-$ 

10. 
$$C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^-$$
  
 $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ 

5.  $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$  $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ 

11. 
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$
  
 $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ 

6.  $N_2H_4 \rightarrow N_2 + 4H^+ + 4e$  $BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$ 

12. 
$$C_2H_5OH + H_2O \rightarrow C_2H_4O_2 + 4H^+ + 4e^-$$
  
 $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ 

Answers (below)

1. 
$$2MnO_4^- + 5H_2SO_3 + H^+ \longrightarrow$$
  
 $2Mn^{2+} + 5HSO_4^- + 3H_2O$   
Video Solution

2. 
$$H_2O_2 + 2Fe^{2+} + 2H^+ \longrightarrow 2Fe^{3+} + 2H_2O$$
  
Video Solution

3. 
$$2MnO_4^- + 5H_2SO_3 + H^+ \rightarrow$$
  
 $2Mn^{2+} + 5HSO_4^- + 3H_2O$   
Video Solution

4. 
$$2MnO_4^- + 5SO_2 + 2H_2O + H^+ \rightarrow$$
  
 $2Mn^{2+} + 5HSO_4^-$   
Video Solution

5. 
$$Cr_2O_7^{2-} + 3SO_2 + 2H^+ \rightarrow$$
  
 $2Cr^{3+} + 3SO_4^{2-} + H_2O$   
Video Solution

6. 
$$2BrO_3^- + 3N_2H_4 \rightarrow 2Br^- + 3N_2 + 6H_2O$$
  
Video Solution

7. 
$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$
  
Video Solution

8. 
$$Cr_2O_7^{2-} + 3C_2O_4^{2-} + 14H^+ \rightarrow 2Cr^{3+} + 6CO_2 + 7H_2O$$
  
Video Solution

9. 
$$3CH_3OH + Cr_2O_7^{2-} + 8H^+ \rightarrow$$
  
 $3CH_2O + 2Cr^{3+} + 7H_2O$   
Video Solution

10. 
$$C_2H_5OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 4Cr^{3+} + 2CO_2 + 11H_2O$$
Video Solution

11. 
$$Cr_2O_7^{2-} + 3SO_2 + 2H^+ \rightarrow 2Cr^{3+} + 3SO_4^{2-} + H_2O$$
  
Video Solution

12. 
$$4\text{MnO}_4^- + 5\text{C}_2\text{H}_5\text{OH} + 12\text{H}^+ \rightarrow 4\text{Mn}^{2+} + 5\text{CH}_3\text{COOH} + 11\text{H}_2\text{O}$$
  
Video Solution

## Redox Guides

Introduction to Redox
Finding Oxidation Numbers
Writing Half Reactions

<u>Key Terms: Oxidized, Reduced, Oxidizing Agent, Reducing Agent</u>
<u>Balancing Half Reactions</u>

Matching Electrons, Combining Half Reactions (this guide)

<u>Balancing Redox in Basic Medium</u>

<u>Practice, Practice</u>

Report errors and suggestions to DrB@breslyn.org



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