

Balancing Half Reactions

Video Workbook with Dr. B

 Once we've written the half-rxns we need to balance the atoms & electrons for each half-rxn.

 Balancing Half-Reactions
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 Full Redox Playlist

 Watch the video on Balancing Half-Reactions and then work through the examples and practice problems below.

 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.

 Balancing Half-Reactions

After you have written the half-reactions, the rest of the process is more straightforward (with a few exceptions). The steps are:

Balance each half-reactions for:

- atoms of interest.
- Oxygen (O) atoms by adding H₂O.
- Hydrogen (H) atoms by adding $\mathrm{H^{+}}$ ions.
- electrons (charge) by adding electrons.

balance both the atoms and the electrons (charge)!

Remember. with Redox we must

Example

Given the following equation, write the balanced half rxns.

 $Al \hspace{0.1in} + \hspace{0.1in} Cu^{2+} \hspace{0.1in} \rightarrow \hspace{0.1in} Al^{3+} \hspace{0.1in} + \hspace{0.1in} Cu$

Answer: For simple redox rxns we don't have any O or H atoms to balance. So we just add e- to balance the charge.

$$Al^0 \rightarrow Al^{3+} + 3e^{-1}$$

 $2e^- + Cu^{2+} \rightarrow Cu^0$

Note, we we still need to make the e- in each half rxn match (they don't right now). We'll balance the **overall** charge for the entire reaction in the next guide.

Balance each half-reactions for:

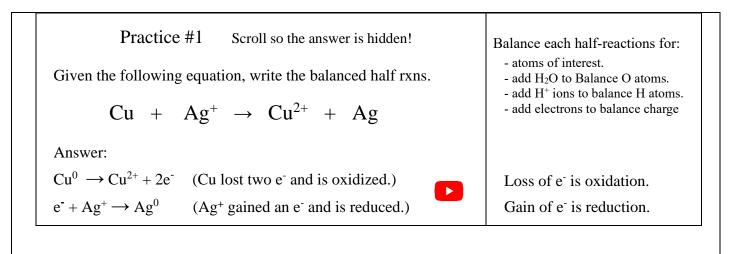
- atoms of interest.
- add $\mathrm{H}_{2}\mathrm{O}$ to Balance O atoms.
- add $\mathrm{H}^{\scriptscriptstyle +}$ ions to balance H atoms.
- add electrons to balance charge

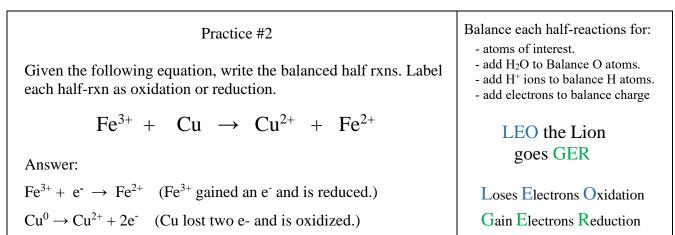
Key Idea

Half-reactions don't happen separately. The are two parts of the same chemical reaction.



Watch <u>the video</u> for balancing the entire redox reaction.





More Practice

Write the half rxns showing the e⁻ lost or gained, then label each half rxn as oxidation or reduction.

$1. Zn + Al^{3+} \rightarrow Zn^{2+} + Al$ $2. Ag^{+} + Ni \rightarrow Ag + Ni^{2+}$ $3. Pb + Mg^{2+} \rightarrow Pb^{2+} + Mg$	4. $Au^{3+} + Pb \rightarrow Au + Pb^{3+}$ 5. $Ag + Al^{3+} \rightarrow Ag^{2+} + Al$
Answers (below)	

1. $Zn \rightarrow Zn^{2+} + 2e^{-}$ 3e- $+Al^{3+} \rightarrow Al$	(oxidation) (reduction)	4. $3e^{-} + Au^{3+} \rightarrow Au$ $Pb \rightarrow Pb^{2+} + 2e^{-}$		
$\begin{array}{ccc} 2 & 1e^{-} + Ag^{+} \rightarrow Ag \\ Ni \rightarrow Ni^{2+} + 2e^{-} \end{array}$	(reduction) (oxidation)	5. $3e^{-+} Al^{3+} \rightarrow Al$ Ag $\rightarrow Ag^{+} + le^{-}$	(reduction) (oxidation)	
3. $Mg^{2+} + 2e^{-} \rightarrow Mg$ $Pb \rightarrow Pb^{2+} + 2e^{-}$				

Half-Reactions Involving the H and O

This is complicated at first but quickly becomes easier. It's almost always the same set of steps. But be careful, small mistakes can cause big problems later. Check your work at the end of this step!

Example #1: Balance the half-rxns.	Steps
$MnO_4^- \rightarrow Mn^{2+}$	Balance each half-reaction for:1. atoms of interest.2. add H₂O to Balance O atoms.
$I^- \rightarrow I_2$	 add H⁺ ions to balance H atoms. add electrons to balance charge
Answer:	
1. Balance the Iodine (I) atoms. The Mn atoms are already balanced. $MnO_4^- \rightarrow Mn^{2+}$ $\rightarrow 2 I^- \rightarrow I_2$	Don't worry about charge when balancing atoms.
2. Add H ₂ O to balance the O atoms. $MnO_4^- \rightarrow Mn^{2+} + H_2O$ $2 I^- \rightarrow I_2$	We can add H ₂ O because the rxn is taking place in water.
3. Balance the H atoms $8H^+ MnO_4 \rightarrow Mn^{2+} + 4H_2 O$ by adding H ⁺ . $\uparrow \qquad 2I^- \rightarrow I_2$	We can add H ⁺ because the rxn is in acidic medium.
4. Add e ⁻ to balance charge. Note the total charge on each side must match. $5e + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$ $1 \rightarrow I_2 + 2e^-$	On the first half rxn we add $5e^{-}$ so the charge equals $2+$ on each side ($5e^{-}$ and $8H+$ and $1-=2+$).
Check your work . The number of atoms and overall charge for each half-rxn should be the same on both sides.	We add 2e ⁻ on to the second half-rxn so the charge on each side is 2
Watch the video solution.	each side is 2

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Practice #1: Balance each half re	
$M_{n}O = M_{n}O_{n}$	Balance each half-reaction for: 1. atoms of interest.
$MnO_4 \rightarrow MnO_2$	2. add H ₂ O to Balance O atoms
$\mathrm{SO}_3^{2-} \rightarrow \mathrm{SO}_4^{2-}$	 add H⁺ ions to balance H ator add electrons to balance char
Answer (below)	For each half-rxn ask
1. Mn and S atoms are already MnO_4^-	\rightarrow MnO ₂ Do the main atoms balance
Dalanceu.	
5032	\rightarrow SO ₄ ²⁻
2. Add H ₂ O to $MnO_4^- \rightarrow$	$MnO_2 + 2 H_2$ Do the O atoms balance?
balance the O $\square \square $	-
atoms. $\Pi_2 \bigcirc + S \bigcirc_3^2 \rightarrow$	504
	• $MnO_2 + 2 H_2 \bigcirc$ Do the H atoms balance?
by adding H ⁺ . $H_1 \bigcirc + SO_3^{2-} \rightarrow$	\rightarrow SO ₄ ²⁻ + ZH ⁺
4. Add e^{-} to balance abarge $3e^{-} + 4H^{+} + MnO_{4}^{-} \rightarrow$	M $_{n}$ O Does the charge balance?
Dalance charge.	_
Dalance charge.	$SO_4^{2-} + ZH^+ + Ze^-$
Dalance charge.	_
balance charge. $\exists H_2 \bigcirc + SO_3^{2-} \rightarrow \exists$	_
balance charge. $H_2 \bigcirc + \mathrm{SO}_3^{2-} \rightarrow$	$SO_4^{2-} + ZH^+ + Ze^-$
Watch the video solution. Practice #2: Balance each half reference	$SO_4^{2-} + ZH^+ + Ze^-$
► Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$	$SO_4^{2-} + ZH^+ + Ze^-$ eaction. $Steps$ Balance each half-reaction for: 1. atoms of interest.
Watch the video solution. Practice #2: Balance each half reference	$SO_4^{2-} + ZH^+ + Ze^-$ eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom
► Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$	SO ₄ ²⁻ + ZH^+ + Ze^- eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms
Balance charge: H ₂ O + SO ₃ ²⁻ → 1 Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer	SO ₄ ²⁻ + ZH^+ + Ze^- eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char
Balance charge: H ₂ O + SO ₃ ²⁻ → 1 Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer	$SO_4^{2-} + ZH^+ + Ze^-$ eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom
Balance charge. H ₂ O + SO ₃ ²⁻ → F Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer 1. Balance the Cr atoms. The Fe atoms are already balanced. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$	SO ₄ ²⁻ + ZH^+ + Ze^- eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char
Balance charge. H ₂ O + SO ₃ ²⁻ → F Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer 1. Balance the Cr atoms. The Fe atoms are already balanced. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Cr_2O_7 Fe^{2+}	SO ₄ ²⁻ + ZH ⁺ + Ze ⁻ eaction. Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char $h^{2-} \rightarrow Fe^{3+}$
Watch the video solution.Practice #2: Balance each half received and the video solution.Practice #2: Balance each half received an	eaction. Steps Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char
Balance charge. H ₂ O + SO ₃ ²⁻ → F Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer 1. Balance the Cr atoms. The Fe atoms are already balanced. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Cr_2O_7 Fe^{2+}	$SO_{4}^{2-} + ZH^{+} + Ze^{-}$ eaction. Steps Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char $P^{2-} \rightarrow ZCr^{3+}$ $- \rightarrow Fe^{3+}$ $ZCr^{3+} + 7H_{2}O$
Balance charge: H ₂ O + SO ₃ ²⁻ → F Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer 1. Balance the Cr atoms. The Fe atoms are already balanced. Fe^{2+} 2. Add H ₂ O to balance the O atoms. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Cr_2O_7 $Fe^{2+} \rightarrow Fe^{3+}$	SO ₄ ²⁻ + ZH ⁺ + Ze ⁻ eaction. steps Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char $h^{2-} \rightarrow Fe^{3+}$ $2Cr^{3+} + 7H_2O$ Fe ³⁺
Balance charge. H ₂ O + SO ₃ ²⁻ → M Watch the video solution. Practice #2: Balance each half re $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Answer 1. Balance the Cr atoms. The Fe atoms are already balanced. Fe^{2+} 2. Add H ₂ O to balance the O atoms. $Cr_2O_7^{2-} \rightarrow Cr^{3+}$ $Fe^{2+} \rightarrow Fe^{3+}$ Cr_2O_7 $Fe^{2+} \rightarrow Fe^{3+}$	SO ₄ ²⁻ + 2H ⁺ + 2e ⁻ eaction. eaction. Steps Balance each half-reaction for: 1. atoms of interest. 2. add H ₂ O to Balance O atoms 3. add H ⁺ ions to balance H atom 4. add electrons to balance char $A^{2-} \rightarrow ZCr^{3+}$ $\rightarrow Fe^{3+}$ $2Cr^{3+} + 7H_2O$ Fe ³⁺ $\rightarrow 2Cr^{3+} + 7H_2O$

4. Add e⁻ to balance charge.	$ \begin{array}{c} \left\langle e^{-} + \mathcal{H} \right\rangle^{+} + Cr_{2}O_{7}^{2-} \rightarrow 2Cr^{3+} + \mathcal{H}_{2} \\ Fe^{2+} \rightarrow Fe^{3+} + e^{-} \end{array} $	$6e^{+} + 14H^{+} + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 7H_2O$ On the right we have $2Cr^{3+}$. That gives us a total charge of 6 +.
Check to make sure atoms and charge are balanced.		On the left we have $14H^+$ and 2- on the $Cr_2O_7^{2-}$ ion. We need to
Watch the full video solution.		make that equal $6+$. Therefore we add $6e^-$ ($6e^-$ and $14H^+$ and $2-$ is equal to $6+$)

More Practice: Balance the Half-Reactions and Check Your Work (answers below) Remember, we'll make the electrons match and add the half-rxns together in the next guide.

1. $MnO_2 \rightarrow Mn$	7. $Fe_2O_3 \rightarrow Fe$
Al $\rightarrow Al_2O_3$	CO \rightarrow CO ₂
2. $H_2O_2 \rightarrow H_2O$	8. $\operatorname{Cr}_2 \operatorname{O}_7^{2-} \to \operatorname{Cr}^{3+}$
$Fe^{2+} \rightarrow Fe^{3+}$	$\operatorname{C}_2 \operatorname{O}_4^{2-} \to \operatorname{CO}_2$
3. $MnO_4^- \rightarrow Mn^{2+}$	9. $CH_3OH \rightarrow CH_2O$
$H_2SO_3 \rightarrow HSO_4^-$	$Cr_2O_7^{2-} \rightarrow Cr^{3+}$
4. $MnO_4^- \rightarrow Mn^{2+}$ SO ₂ \rightarrow HSO4 ⁻	$10. C_{2}H_{5}OH \rightarrow CO_{2}$ $Cr_{2}O_{7}^{2-} \rightarrow Cr^{3+}$
5. $\operatorname{Cr}_2 \operatorname{O}_7^{2-} \to \operatorname{Cr}^{3+}$	11. $\operatorname{Cr}_2 \operatorname{O}_7^{2-} \to \operatorname{Cr}^{3+}$
SO ₂ \to SO ₄ ²⁻	$\operatorname{SO}_2 \to \operatorname{SO}_4^{2-}$
6. $BrO_3^- \rightarrow Br^-$	12. $MnO_4 \rightarrow Mn^{2+}$
$N_2H_4 \rightarrow N_2$	$C_2H_5OH \rightarrow CH_3COOH$
	1

Answers (below)



1. $4e^{-} + 4H^{+} + MnO_2 \rightarrow Mn + 2H_2O$ 7. Fe₂O₃ + 6H⁺ + 6e⁻ \rightarrow 2Fe + 3H₂O $3H_2O + Al \rightarrow Al_2O_3 + 6H^+ + 6e^ CO + H_2O \rightarrow CO_2 + 2H^+ + 2e^-$ Video Solution Video Solution 2. $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ 8. $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $Fe^{2+} \rightarrow Fe^{3+} + e^{-}$ $C_2O_4^{2-} \rightarrow 2CO_2 + 2e^{-}$ Video Solution Video Solution 3. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ 9. CH₃OH \rightarrow CH₂O + 2H⁺ + 2e⁻ $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $H_2SO_3 + H_2O \rightarrow HSO_4^- + 3H^+ + 2e^-$ Video Solution Video Solution 4. $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O_1$ $10. C_2H_5OH + 3H_2O \rightarrow 2CO_2 + 12H^+ + 12e^ SO_2 + 2H_2O \rightarrow HSO_4 + 3H^+ + 2e^ Cr_{2}O_{7}^{2-} + 14H^{+} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_{2}O$ Video Solution Video Solution 11. $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ 5. $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^ SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ Video Solution Video Solution 6. $N_2H_4 \rightarrow N_2 + 4H^+ + 4e$ 12. $C_2H_5OH + H_2O \rightarrow C_2H_4O_2 + 4H^+ + 4e^ BrO_3^- + 6H^+ + 6e^- \rightarrow Br^- + 3H_2O$ $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ Video Solution Video Solution

In the next section we'll get the electrons to be the same on each side and then add the half-rxns together. From there we cancel out like terms, and we're done. But we should check our work to make sure atoms and charge balances.

Redox Guides

Introduction to Redox <u>Finding Oxidation Numbers</u> <u>Writing Half Reactions</u> <u>Key Terms: Oxidized, Reduced, Oxidizing Agent, Reducing Agent</u> Balancing Half Reactions (this guide) <u>Matching Electrons, Combining Half Reactions</u> <u>Balancing Redox in Basic Medium</u> <u>Practice, Practice</u>



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