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# AN INNOVATIVE APPROACH FOR BALANCING CHEMICAL EQUATION BY ION-ELECTRON METHOD

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## ABSTRACT

Balancing chemical equations by the ion-electron method is very important for chemistry students at the undergraduate, graduate, and postgraduate levels. With this in mind, an innovative method for rapid balancing of an ionic equation by ion electron method was introduced. I can strongly suggest that this innovative method will be very helpful for balancing the ionic equation, which will save time for students in various competitive exams.

Keywords: Ionic equation, Ion-electron method, Undergraduate, Postgraduate and Competitive exams.

## INTRODUCTION

For balancing the ionic equation, clear knowledge is essential for chemistry students at the undergraduate, graduate, and postgraduate levels to solve a wide variety of problems related to it. The method that is adopted in this article to balance an ionic equation by the ion-electron method involves a few steps, which are as follows:

Step-I: Firstly, we balance other elements by the hit-and-trial method without balancing oxygen and hydrogen.

Step II: Secondly, we will balance oxygen by adding water molecules to the side where the deficiency of oxygen is taking place.

Step-III: Thirdly, for balancing hydrogen, we have to check the medium (i.e., acidic or basic) of the equation in which it is present.

a) If the equation is in an acidic medium, then hydrogen is balanced by adding hydrogen ions (H+) on the side where the deficiency of hydrogen is taking place.
b) If the equation is in a basic medium, then hydrogen is balanced by adding water molecules on the side where the deficiency of hydrogen is taking place, and at the same time, an equal number of hydroxyl ions ($OH^-$) must be added on the opposite side.

Step IV: Finally, we balance the charge by adding suitable number of electrons on either side of the equation.

## RESULTS AND DISCUSSION

Let us discuss some examples in which the above-reported methods are used to balance chemical equations by the ion-electron method for oxidation, reduction half-reactions or redox reactions in both acidic and basic mediums.

**Ex. 1 Consider an ionic equation in acidic medium; $MnO_4^- \rightarrow Mn^{+2}$**

Step-I: $MnO_4^- \rightarrow Mn^{+2}$ (Manganese is already balanced)

Step-II: $MnO_4^- \rightarrow Mn^{+2} + 4H_2O$

Step-III: $MnO_4^- + 8H^+ \rightarrow Mn^{+2} + 4H_2O$

Step-IV: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{+2} + 4H_2O$

**Ex. 2 Consider an ionic equation in acidic medium; $Cr_2O_7^{2-} \rightarrow Cr^{+3}$**

Step-I: $Cr_2O_7^{2-} \rightarrow 2Cr^{+3}$

Step-II: $Cr_2O_7^{2-} \rightarrow 2Cr^{+3} + 7H_2O$

Step-III: $Cr_2O_7^{2-} + 14H^+ \rightarrow 2Cr^{+3} + 7H_2O$

Step-IV: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{+3} + 7H_2O$

**Ex. 3 Consider an ionic equation in basic medium; $MnO_4^- \rightarrow MnO_2$**

Step-I: $MnO_4^- \rightarrow MnO_2$ (Manganese is already balanced)

Step-II: $MnO_4^- \rightarrow MnO_2 + 2H_2O$

Step-III: $MnO_4^- + 4H_2O \rightarrow MnO_2 + 2H_2O + 4OH^-$

Or, $MnO_4^- + 2H_2O \rightarrow MnO_2 + 4OH^-$

Step-IV: $MnO_4^- + 2H_2O + 3e^- \rightarrow MnO_2 + 4OH^-$

**Ex. 4 Consider an ionic equation in basic medium; $Cr_2O_7^{2-} \rightarrow Cr_2O_3$**

Step-I: $Cr_2O_7^{2-} \rightarrow Cr_2O_3$ (Chromium is already balanced)

Step-II: $Cr_2O_7^{2-} + H_2O \rightarrow Cr_2O_3 + 4H_2O$

Step-III: $Cr_2O_7^{2-} + 8H_2O \rightarrow Cr_2O_3 + 4H_2O + 8OH^-$

or $Cr_2O_7^{2-} + 4H_2O \rightarrow Cr_2O_3 + 8OH^-$

Step-IV: $Cr_2O_7^{2-} + 4H_2O + 6e^- \rightarrow Cr_2O_3 + 8OH^-$

**Ex. 5 Consider an ionic equation in basic medium; $S_2O_3^{2-} \rightarrow SO_4^{2-}$**

Step-I: $S_2O_3^{2-} \rightarrow 2SO_4^{2-}$

Step-II: $S_2O_3^{2-} + 5H_2O \rightarrow 2SO_4^{2-}$

Step-III: $S_2O_3^{2-} + 5H_2O + 10OH^- \rightarrow 2SO_4^{2-} + 10H_2O$

Or, $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O$

Step-IV: $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-$

**Ex. 6 Consider an ionic redox equation in basic medium;**

**$CrO_4^{2-} + S_2O_3^{2-} \rightarrow SO_4^{2-} + Cr(OH)_4^-$**

First of all, we will separate the redox reaction into two half reactions, i.e., the oxidation half (increase in oxidation number) and the reduction half (decrease in oxidation number), by considering the oxidation number of the central atoms in the ionic species.

In the given equation, the oxidation number of Cr is +6 in $CrO_4^{2-}$ and +3 in $Cr(OH)_4^-$. That means the oxidation number of Cr decreases from +6 to +3 and will be regarded as a reduction-half reaction. Similarly, the oxidation number of S is +2 in $S_2O_3^{2-}$ and +6 in $SO_4^{2-}$. That means the oxidation number of S increases from +2 to +6 and will be regarded as an oxidation-half reaction. Thus, for balancing this equation, we will follow the same rules as adopted above.

Step-I: Balancing Cr and S by the hit and trial method.

Reduction half reaction; $CrO_4^{2-} \rightarrow Cr(OH)_4^-$

Oxidation half reaction; $S_2O_3^{2-} \rightarrow 2SO_4^{2-}$

Step-II: Balancing oxygen.

Reduction half reaction; $CrO_4^{2-} \rightarrow Cr(OH)_4^-$

Oxidation half reaction; $S_2O_3^{2-} + 5H_2O \rightarrow 2SO_4^{2-}$

Step-III: Balancing hydrogen.

Reduction half reaction; $CrO_4^{2-} + 4H_2O \rightarrow Cr(OH)_4^- + 4OH^-$

Oxidation half reaction; $S_2O_3^{2-} + 5H_2O + 10OH^- \rightarrow 2SO_4^{2-} + 10H_2O$

Or, $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O$

Step-IV: Balancing charge by adding electron.

Reduction half reaction; $CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr(OH)_4^- + 4OH^-$

Oxidation half reaction; $S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-$

Finally we will add the oxidation and reduction half reactions to get the balanced equation.

Reduction half reaction; $[CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr(OH)_4^- + 4OH^-] \times 8$

Oxidation half reaction; $[S_2O_3^{2-} + 10OH^- \rightarrow 2SO_4^{2-} + 5H_2O + 8e^-] \times 3$

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$$8\,CrO_4^{2-} + 17H_2O + 3S_2O_3^{2-} \rightarrow 8Cr\,(OH)_4^- + 6SO_4^{2-} + 2OH^-$$

**Ex. 7 Consider an ionic equation in acidic medium;**

**$MnO_4^- + NO_2^- \rightarrow Mn^{+2} + NO_3^-$**

Like the above example, we will separate the redox reaction into two half reactions, i.e., the oxidation half (increase in oxidation number) and the reduction half (decrease in oxidation number), by considering the oxidation number of the central atoms in the ionic species.
In the given equation, the oxidation number of Mn is +7 in $MnO_4^-$ and +2 in $Mn^{+2}$. That means the oxidation number of Mn decreases from +7 to +2 and will be regarded as a reduction-half reaction. Similarly, the oxidation number of N is +3 in $NO_2^-$ and +5 in $NO_3^-$.That means the oxidation number of N increases from +3 to +5 and will be regarded as an oxidation-half reaction. Thus, for balancing this equation, we will follow the same rules as adopted above.

Step-I: Balancing Mn and N by the hit and trial method.

Reduction half reaction; $MnO_4^- \rightarrow Mn^{+2}$

Oxidation half reaction; $NO_2^- \rightarrow NO_3^-$

Step-II: Balancing oxygen.

Reduction half reaction; $MnO_4^- \rightarrow Mn^{+2} + 4H_2O$

Oxidation half reaction; $NO_2^- + H_2O \rightarrow NO_3^-$

Step-III: Balancing hydrogen.

Reduction half reaction; $MnO_4^- + 8H^+ \rightarrow Mn^{+2} + 4H_2O$

Oxidation half reaction; $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+$

Step-IV: Balancing charge.

Reduction half reaction; $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{+2} + 4H_2O$

Oxidation half reaction; $NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-$

Finally we will add the oxidation and reduction half reactions to get the balanced equation.

Reduction half reaction; $[MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{+2} + 4H_2O] \times 2$

Oxidation half reaction; $[NO_2^- + H_2O \rightarrow NO_3^- + 2H^+ + 2e^-] \times 5$

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$$2MnO_4^- + 5\,NO_2^- + 6\,H^+ \rightarrow 2\,Mn^{+2} + 5\,NO_3^- + 3H_2O$$

## CONCLUSIONS

In this article, we propose a simplified method of balancing chemical equations by the ion-electron method, which is an important trick in terms of applicability and high accuracy. It will be very helpful for students to face the competitive exams. We strongly recommend that, using this method, any ionic equation can be easily balanced using the ion-electron method.

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