ALCHEMY : JOURNAL OF CHEMISTRY

Research Article

Identification of the Redox Reaction between $CuSO_4$ and Zn through Basic Visual Observation in Basic Chemistry

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Article Info

Article History
Received 21 November 2025
Revised 6 January 2026
Accepted 12 January 2026
Available online 16 July 2026

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ABSTRACT

Oxidation–reduction (redox) reactions are fundamental chemical processes that involve electron transfer and changes in oxidation states; yet, they are often difficult for students to conceptualize due to their abstract nature. This study aims to identify the occurrence of a redox reaction between copper (II) sulfate ($CuSO_4$) and zinc (Zn) metal through visual observation, while also examining the effect of varying Zn mass on observable reaction behavior. The experiment was conducted descriptively using three different Zn masses (0.1, 0.2, and 0.3 g) and a negative control employing $ZnSO_4$ to confirm the absence of redox activity. Observable indicators included changes in solution color, formation of copper deposits, and physical alterations of the Zn metal. The results showed that pure Zn reacted spontaneously with Cu^{2+} ions, as indicated by the fading blue color of the $CuSO_4$ solution and the formation of reddish-brown copper deposits on the Zn surface. Smaller Zn masses exhibited faster visible reaction onset, while larger masses showed a delayed initial response but still produced copper deposits at the end of the observation period. The negative control showed no copper formation, confirming that the observed changes were due to redox processes. This study demonstrates that visual observation provides clear and effective evidence of redox reactions and can support students' conceptual understanding in basic chemistry learning.

Keywords: Redox reaction, Visual observation, Basic chemistry, Oxidation-reduction.

1. Introduction

Understanding oxidation–reduction (redox) reactions is essential in chemistry, as these reactions play a fundamental role in numerous chemical processes occurring both in nature and in everyday life [1], [2], [3]. Redox reactions involve the transfer of electrons between substances, leading to changes in oxidation numbers. Oxidation refers to the loss of electrons by a substance, while reduction refers to electron gain by another substance [1], [4]. These two processes occur simultaneously, with the oxidized species acting as the reducing agent and the reduced species serving as the oxidizing agent [5], [6]. A strong conceptual understanding of redox principles is crucial for explaining phenomena such as metal corrosion, cellular respiration, photosynthesis, and electrochemical reactions in batteries and voltaic cells [7], [8], [9], [10]. Redox processes can be identified both theoretically, through oxidation number analysis, and empirically, through observable changes such as color shifts or precipitate formation [11], [12], [13].

Despite its importance, many students struggle to grasp redox concepts due to their abstract and complex nature [14], [15] Chemistry topics that involve symbolic representations, microscopic interactions, and electron transfer often lead students to memorize rather than understand the underlying principles [16], [17]. Research indicates that appropriate instructional models can effectively reduce misconceptions and improve conceptual comprehension [18]. These misconceptions may also stem from the way learning materials are designed, including insufficient attention to visual elements such as color.

The issue is further exacerbated in online or digital learning environments, where color is often used merely for aesthetics instead of purposeful cognitive support [19], [20], [21]. In reality, color is one of the first sensory stimuli perceived by learners, shaping emotional responses and influencing cognitive processing [22], [23], [24]. Color is closely tied to cognitive psychology, affecting memory, attention, and interpretation. As an essential component of a learning tool, color contributes to how students perceive and process chemical information [25], [26], [27], [28].

Based on these considerations, this study integrates a simple redox experiment with a visual observation approach to support conceptual understanding. The reaction between $CuSO_4$ solution and Zn metal was selected because it produces clear macroscopic changes that students can directly observe. The objectives of this study are: (1) to identify the occurrence of a redox reaction between $CuSO_4$ and Zn through visual indicators, (2) to determine the roles of oxidizing and reducing agents in the system, and (3) to analyze the effect of Zn mass variation on the observable characteristics of the reaction. The findings are expected to contribute to more effective learning strategies for teaching redox reactions in basic chemistry.

2. Materials and Methods

2.1. Preparation of Reaction Solutions

The glassware and reagents follow prior research [29], [30], [31]. Standard laboratory glassware was used throughout the experiment, including a volumetric pipette for precise volume measurement, a 100 mL beaker as the reaction vessel, and a glass spoon for transferring solid reagents. A stopwatch for recording observation time intervals. A volume of 25 mL of 0.1 M $CuSO_4$ solution was transferred into a 100 mL beaker and used as the reaction medium for all experiments. The solution was maintained at room temperature throughout the observation period.

2.2. Negative Control Procedure

For the negative control, $ZnSO_4$ powder with masses of 0.1, 0.2, and 0.3 g was separately added to the $CuSO_4$ solution. These samples were prepared to observe physical dissolution behavior in the absence of a redox reaction. No metallic zinc was introduced in the control experiments, ensuring that no electron transfer could occur.

2.3. Experimental Reaction with Zn Metal

For the experimental samples, zinc metal pieces with masses of 0.1, 0.2, and 0.3 g were prepared. Before immersion, the surfaces of the Zn metal were polished using fine sandpaper until a shiny appearance was

achieved in order to remove surface oxide layers that could inhibit electron transfer [32], [33]. Each Zn sample was then immersed in the $CuSO_4$ solution using tweezers, with most of the metal surface submerged in the solution.

2.4. Observation and Data Collection

This study assessed color changes during the redox reaction solely through direct visual observation without the use of instrumental color measurement devices such as a color reader or spectrophotometer. Consequently, the evaluation of color variation was qualitative and may be influenced by subjective perception and environmental factors such as lighting conditions. While this approach is adequate for demonstrating redox phenomena in an educational context, it limits the precision and reproducibility of color analysis.

All reaction systems were left undisturbed at room temperature for 90 minutes without stirring. Observations were recorded at regular time intervals (60, 70, 75, 80, 85, and 90 minutes). The recorded parameters included changes in solution color, the formation of copper deposits, and physical changes in the Zn metal. A descriptive qualitative approach was employed based on the students' agreement to analyze the visual indicators associated with redox reactions.

3. Result and Discussion

The negative control involving $ZnSO_4$ demonstrated that a redox reaction does not take place in the absence of a metallic electron source. Throughout the observation period, the $CuSO_4$ solution retained its blue coloration, and no copper-colored deposits were detected. The only observable change was the slow dissolution of $ZnSO_4$ crystals, indicating that the process was purely physical rather than chemical in nature. These findings confirm that the formation of copper deposits requires electron donation from a metallic reducing agent [34], [35], [36], [37]. Conversely, experiments conducted with metallic Zn provided clear evidence of a spontaneous redox process. Upon immersion of Zn into the $CuSO_4$ solution, a gradual decrease in the intensity of the blue color was observed, reflecting the reduction in Cu^{2+} ion concentration. At the same time, reddish-brown copper layers formed on the Zn surface. These results indicate that Zn was oxidized to Zn^{2+} ions, while Cu^{2+} ions were reduced to elemental copper, in agreement with established redox principles.

The mass of Zn influenced the observable progression of the reaction. The sample containing 0.1 g of Zn exhibited the earliest appearance of copper deposits and the most rapid color fading, suggesting a more efficient initial electron transfer. In contrast, samples with 0.2 and 0.3 g of Zn showed a slower onset of visible changes during the early stages of the reaction. This behavior may be associated with surface passivation effects or limited effective interaction between the Zn surface and Cu^{2+} ions. Despite these differences, copper deposition was ultimately observed in all samples, indicating that the redox reaction occurs spontaneously regardless of Zn mass.

The appearance of reddish-brown copper deposits serves as a clear visual marker of reduction, whereas the reduction in size and deformation of the Zn metal reflect oxidation. These macroscopic changes provide direct evidence of electron transfer, linking theoretical redox concepts with observable chemical phenomena. From an instructional standpoint, such visual indicators can facilitate students' understanding of oxidizing and reducing agents and help minimize misconceptions commonly associated with redox reactions.

The experimental data for the reaction between $CuSO_4$ solution and $ZnSO_4$ as a negative control are presented in **Table 1.** At the 60-minute mark, the solution remained bright blue, and the $ZnSO_4$ was still in solid crystalline form. After 5 minutes, a reduction in crystal size was observed, indicating the initial dissociation of $ZnSO_4$ salt into Zn^{2+} and SO_4^{2-} ions. As time progressed up to 90 minutes, the solution gradually changed to a pale blue and eventually became very faint, indicating a decrease in the concentration of complex ions or the complete dissolution of the salt.

Table 1. Profile of Changes in the Negative Control Solution ($ZnSO_4$ Powder)

No.	Time (minutes)	Weight of $ZnSO_4$ (g)	Solution Color After Reaction	Changes on $ZnSO_4$ Surface
1	0	0.1	Bright Blue	Shape unchanged (crystal)
2	60	0.1	Bright Blue	Crystal size decreases
3	70	0.1	Bright Blue	Crystal size decreases
4	75	0.1	Slightly Pale Blue	Fully dissolved
5	80	0.1	Slightly Pale Blue	Fully dissolved
6	85	0.1	Pale Blue	Fully dissolved
7	90	0.1	Pale Blue	Fully dissolved
8	0	0.2	Bright Blue	Shape unchanged (crystal)
9	60	0.2	Bright Blue	No changes observed
10	70	0.2	Bright Blue	Crystals decrease in size
11	75	0.2	Slightly Fading Blue	Crystals begin to dissolve
12	80	0.2	Slightly Fading Blue	Crystals dissolve
13	85	0.2	Pale Blue	Crystals dissolve
14	90	0.2	Pale Blue	Crystals fully dissolved
15	0	0.3	Bright Blue	Shape unchanged (crystal)
16	60	0.3	Bright Blue	No changes observed
17	70	0.3	Bright Blue	Slightly dissolving
18	75	0.3	Pale Blue	Dissolving further
19	80	0.3	Pale Blue	Dissolving significantly
20	85	0.3	Very Pale Blue	Very little remains, dissolving
21	90	0.3	Very Pale Blue	Very little remains, dissolving

Note: The Cu product may appear as a coating or as a precipitate in the solution.

The fastest dissolution occurred at the lowest concentration (0.1 g), in which all crystals were completely dissolved by the 60-minute mark. At higher concentrations (0.2 g and 0.3 g), the dissolution process occurred more slowly but still reached complete dissolution after 90 minutes. No copper layer or precipitate was found on the surface or at the bottom of the solution, confirming that no reduction of Cu^{2+} ions took place and that the only process occurring was the physical dissolution of $ZnSO_4$. The negative control experiment using $ZnSO_4$ confirmed that no redox reaction occurred in the absence of a pure metal electron donor. The $CuSO_4$ solution remained blue throughout the observation period, and no reddish copper deposits were observed. The only change detected was the gradual dissolution of $ZnSO_4$ crystals, indicating a purely physical process rather than a chemical redox reaction. This control experiment verifies that the formation of copper deposits requires electron transfer from a metallic reducing agent.

Figure 1a-f shows that the $CuSO_4$ solution in the negative control samples containing $ZnSO_4$ remained predominantly blue from 0 to 90 minutes across all tested masses. The absence of significant changes in color intensity and the lack of reddish copper deposits indicate that no reduction of Cu^{2+} ions occurred. The slight visual variations observed are attributed to the physical dissolution of $ZnSO_4$ rather than to a chemical redox reaction. These results confirm that, without a metallic electron donor, the system does not undergo a redox process.

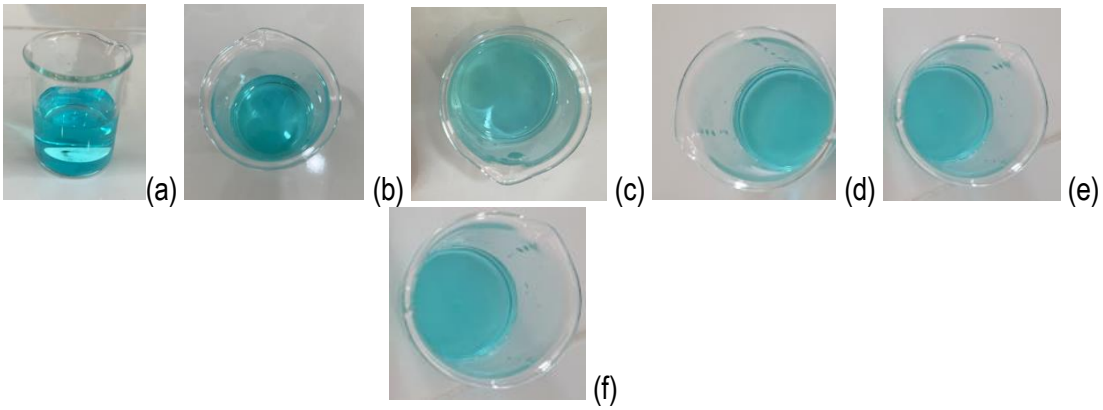

Figure 1. Visual observation of the negative control samples ($ZnSO_4$ in $CuSO_4$ solution) at different masses and reaction times: (a) 0.1 g $ZnSO_4$ at 0 minutes, (b) 0.1 g $ZnSO_4$ at 90 minutes, (c) 0.2 g $ZnSO_4$ at 0 minutes, (d) 0.2 g $ZnSO_4$ at 90 minutes, (e) 0.3 g $ZnSO_4$ at 0 minutes, (f) 0.3 g $ZnSO_4$ at 90 minutes. No copper deposition was observed, indicating the absence of a redox reaction.

The experimental data did not produce a reddish copper-colored precipitate from the $ZnSO_4$ and $CuSO_4$ samples because no redox reaction occurred. The principle of a redox reaction involves the exchange of electrons between a pure metal and the solution [38]. A dark reddish-brown precipitate will only appear when the $CuSO_4$ solution reacts with pure Zn.

3.1. The First Zinc Sample

The experimental data for the reaction between $CuSO_4$ solution and Zn are presented in **Table 2**. Observations show that during the first 60 minutes of the reaction, the $CuSO_4$ solution remained bright blue to slightly faded, and the Zn metal retained its silver color without any significant physical changes. This indicates that no substantial redox reaction had occurred during the early stage, as the activation energy required for ion exchange had not yet been reached. Between minutes 70 and 85, the blue color of the solution began to fade, accompanied by changes in the Zn surface, including a reduction in size and the appearance of a reddish-brown tint. This phenomenon indicates the onset of the redox reaction, in which Zn undergoes oxidation to form Zn^{2+}, while Cu^{2+} ions in the solution are reduced to solid copper metal.

By minute 90, the reaction became more evident with the formation of dark reddish copper flakes or layers on the surface of the Zn. The increasingly faded blue color of the solution indicates a decrease in Cu^{2+} concentration as most ions had been reduced to copper metal. Meanwhile, the Zn metal, initially solid, began to bend due to partial dissolution of its mass. Experiments using pure Zn metal showed clear evidence of a spontaneous redox reaction. When Zn was immersed in the $CuSO_4$ solution, the blue color of the solution gradually faded, indicating a decrease in Cu^{2+} ion concentration. Simultaneously, reddish-brown copper deposits formed on the surface of the Zn metal. These observations confirm that Zn underwent oxidation to Zn^{2+} ions, while Cu^{2+} ions were reduced to solid copper, consistent with redox theory.

The initial visualization of the $CuSO_4$ solution is shown in **Figure 2a**. The $CuSO_4$ solution was mixed with pure Zn powder, and an aluminum foil was placed over the beaker, sealed, and allowed to dilute for 60 minutes as shown in **Figure 2b**. Based on the experimental results, the $CuSO_4$ solution remained bright in color after 70 minutes of reaction, as shown in **Figure 2c**. The $CuSO_4$ solution also remained bright at minutes 70 and 75, as seen in **Figure 2d** and **2e** at minute 80. The color of the $CuSO_4$ solution became more faded at minute 85 and very pale at minute 90, as shown in **Figure 2f** and **2g**, with the Zn powder in the solution decreasing as it continued to dissolve.

Table 2. Redox Reaction Profile of Pure Zn Metal (0.1 g)

No.	Time (minutes)	Weight of Zn (g)	Changes on Zn Surface	Presence of Copper Product
1	60	0.1	Shape unchanged and silver-colored	None
2	70	0.1	Shape unchanged and silver-colored	None
3	75	0.1	Shape unchanged and silver-colored	None
4	80	0.1	Shape unchanged and silver-colored	None
5	85	0.1	Begins to shrink and shows reddish color	Initial formation of Cu powder flakes
6	90	0.1	Curved shape, reduced size, reddish color	Formation of dark Cu powder flakes

Note: The Cu product may appear as a coating or as a precipitate in the solution.

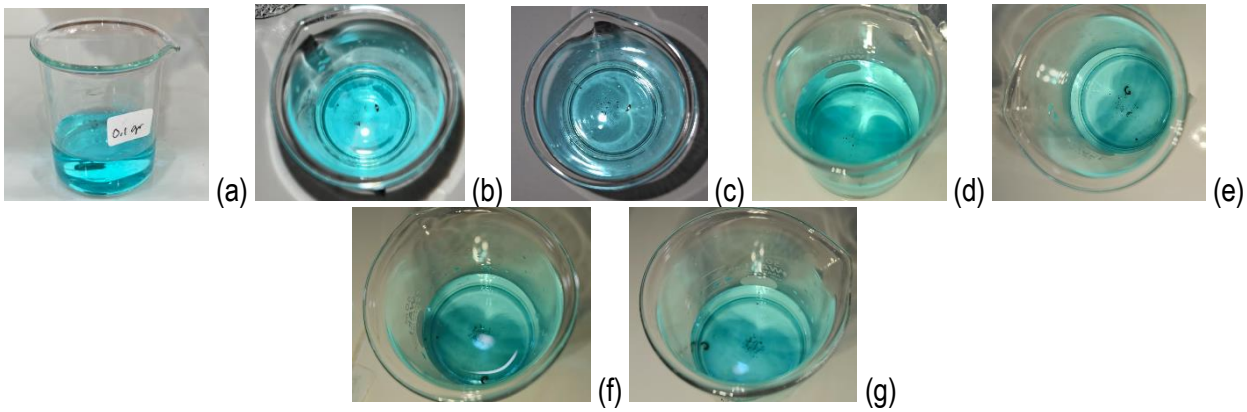

Figure 2. Visualization of the redox reaction solution from the 0.1 g Zn sample.

3.2 The Second Zn Sample

The experimental data for the reaction between $CuSO_4$ solution and Zn are presented in **Table 3**. The experiment using solid zinc (Zn) immersed in the $CuSO_4$ solution provides clear evidence of a redox reaction occurring between Zn(s) and Cu^{2+}(aq). At the beginning (0 minutes), the solution appeared bright blue, characteristic of Cu^{2+} ions, and the surface of the Zn remained silver, indicating no observable macroscopic chemical changes. After 5 minutes, the solution began to fade in color, indicating a decrease in dissolved Cu^{2+} concentration due to partial reduction to Cu^0. Between 60 and 80 minutes, a reddish tint started to appear on the Zn surface along with the formation of copper deposits, signifying the progression of copper reduction and the release of zinc ions into the solution. By minutes 85 to 90, the changes became increasingly evident: the solution became very pale (reflecting reduced Cu^{2+} levels), and the Zn surface shrank and curved while being coated with noticeable red copper deposits. The change in shape and reduction of Zn mass further confirms that Zn undergoes dissolution (oxidation), while copper precipitates on or near its surface.

The initial visualization of the $CuSO_4$ solution is shown in **Figure 3a**. After the $CuSO_4$ solution was combined with pure Zn powder as the negative control sample, aluminum foil was placed over the beaker, sealed, and left for 60 minutes, as shown in **Figure 3b**. Based on the experimental results, the $CuSO_4$ solution became increasingly pale after 70 minutes of reaction, as seen in **Figure 3c**. The $CuSO_4$ solution continued to fade in color at minutes 75 and 80, as shown in **Figure 3d** and **3e**. The solution became very pale at minutes 85 and 90, as presented in **Figure 3f** and **3g**.

Table 3. Redox Reaction Profile of Pure Zn Metal (0.2 g)

No.	Time (minutes)	Weight of Zn (g)	Changes on Zn Surface	Presence of Copper Product
1	60	0.2	Shape unchanged and silver-colored	None
2	70	0.2	Shape unchanged and silver-colored	None
3	75	0.2	Shape unchanged and slightly reddish silver	Initial appearance of precipitate
4	80	0.2	Shape unchanged and slightly reddish silver	Significant Cu precipitate
5	85	0.2	Curved shape, reduced size, reddish color	Clear Cu precipitate
6	90	0.2	Curved shape, reduced size, reddish color	Clear Cu precipitate

Note: The Cu product may appear as a coating or as a precipitate in the solution.

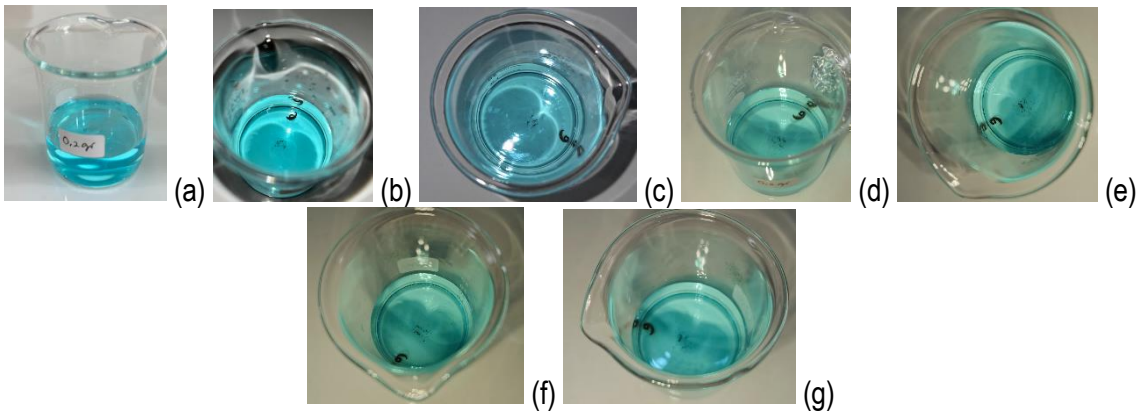

Figure 3. Visualization of the Redox Reaction Solution from the 0.2 g Zn Sample

3.3 The Third Zn Sample

The experimental data for the reaction between $CuSO_4$ solution and Zn as the positive control are presented in **Table 4**. The redox reaction between zinc (Zn) metal and copper (II) sulfate ($CuSO_4$) solution using 0.3 g of Zn showed that the reaction progressed more slowly compared to samples with smaller Zn masses. During the initial observation period up to minute 10, the solution remained bright blue to slightly faded, and the surface of the Zn metal stayed silver in color without significant changes. A substantial redox reaction had not yet occurred because the larger surface area of the Zn metal may form a temporary passive layer that inhibits direct contact between Zn and Cu^{2+} ions in the solution. Between minutes 75 and 85, a faint reddish tint began to appear on the metal surface along with thin copper deposits, indicating the onset of Cu^{2+} ion reduction to solid copper, accompanied by the oxidation of Zn-to-Zn^{2+} ions.

At minute 90, the changes became more evident with the formation of a reddish copper layer on the Zn surface, along with a reduction in size and the formation of curvature due to partial dissolution of the zinc metal. The consistently faded color of the solution indicates a continued decrease in Cu^{2+} ion concentration as reduction proceeds, although not yet completely depleted. These results show that the redox reaction between Zn and $CuSO_4$ still occurs spontaneously, but the reaction rate is slower at the beginning due to the larger mass and surface area of the metal.

The initial visualization of the $CuSO_4$ solution is shown in **Figure 4a**. After the $CuSO_4$ solution was combined with pure Zn powder as the negative control sample, aluminum foil was placed over the beaker, sealed, and left until minute 60, as shown in **Figure 4b**. Based on the experimental results, the $CuSO_4$ solution remained bright after 70 minutes of reaction, as shown in **Figure 4c**. The $CuSO_4$ solution then became slightly faded at minutes 75 and 80, as shown in **Figure 4d** and **4e**, along with the formation of pure Zn deposits. The color of the $CuSO_4$

solution turned very pale at minutes 85 and 90, as seen in **Figure 4f** and **4g**, with the remaining Zn powder in the solution gradually dissolving.

Table 4. Redox Reaction Profile of Pure Zn Metal (0.3 g)

No.	Time (minutes)	Weight of Zn (g)	Changes on Zn Surface	Presence of Copper Product
1	60	0.3	Shape unchanged and silver-colored	None
2	70	0.3	Shape unchanged and silver-colored	None
3	75	0.3	Shape unchanged and silver-colored	None
4	80	0.3	Shape unchanged and slightly reddish silver	Initial appearance of precipitate
5	85	0.3	Shape unchanged and slightly reddish silver	Initial appearance of precipitate
6	90	0.3	Curved shape, reduced size, reddish color	Clear Cu precipitate

Note: The Cu product may appear as a coating or as a precipitate in the solution.

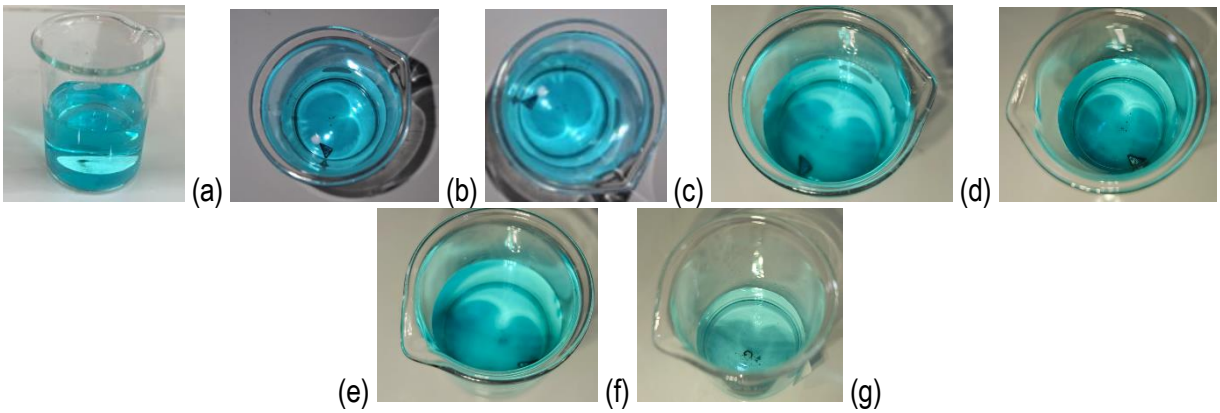

Figure 4. Visualization of the Redox Reaction Solution from the 0.3 g Zn Sample

The reduction reaction that produces a reddish-brown precipitate occurs when copper ions (Cu^{2+}) in the solution gain electrons and are converted into solid copper (Cu). The result of this reaction is the formation of pure copper deposits with a reddish-brown color, which is a distinctive characteristic of copper metal formed from the reduction of Cu^{2+} ions in the solution [39]. Increasing the concentration of Zn can reduce the intensity of the blue color in the $CuSO_4$ solution. The duration of immersion also affects the decrease in the color intensity of the $CuSO_4$ solution. When the Zn concentration increases and is combined with a longer immersion time, the $CuSO_4$ solution becomes increasingly faint, and a reddish copper precipitate forms as an indicator of copper deposition.

A redox reaction that produces copper powder or colored precipitates occurs when copper ions (Cu^{2+}) in the solution are reduced to solid copper (Cu). In this process, Cu^{2+} ions accept two electrons and form a brown-colored precipitate. The redox reaction illustrates the electron transfer between copper metal and its ions in the solution, producing a characteristic copper precipitate that signifies the formation of solid copper resulting from the reduction process [40].

Variations in Zn mass influenced the observable reaction behavior. The 0.1 g Zn sample showed the fastest visible onset of copper deposition and solution color fading, suggesting more efficient initial electron transfer. In the 0.2 g and 0.3 g samples, the reaction appeared to proceed more slowly during the early stages. This delay may be attributed to surface passivation or reduced effective contact between the Zn surface and Cu^{2+} ions. Nevertheless, all Zn mass variations eventually produced copper deposits, demonstrating that the reaction proceeds spontaneously regardless of mass. The formation of reddish-brown copper precipitates serves as a strong visual indicator of reduction processes, while the physical shrinkage and curvature of Zn metal indicate oxidation. These macroscopic observations provide direct, tangible evidence of electron transfer, bridging the

gap between symbolic redox equations and real chemical behavior. From an educational perspective, such visual cues can help students identify oxidizing and reducing agents more intuitively and reduce common misconceptions associated with redox reactions.

4. Conclusion

This study demonstrates that visual observation is an effective and accessible approach for identifying redox reactions, determining oxidizing and reducing agents, and analyzing reaction behavior in basic chemistry. The results support the use of visually guided experiments to enhance students' conceptual understanding of oxidation–reduction processes, although future studies should incorporate color measurement instruments to enable more accurate and quantitative analysis of observed color changes. Using the $CuSO_4$–Zn reaction system, the study successfully met its research objectives through clear visual evidence of redox activity, including the fading of the blue $CuSO_4$ solution and the formation of reddish-brown copper deposits. Zinc functioned as the reducing agent and Cu^{2+} ions as the oxidizing agent, a conclusion reinforced by the absence of copper formation in the $ZnSO_4$ control. Variations in zinc mass affected the rate and visibility of the reaction but did not alter its spontaneous nature, as all treatments ultimately produced copper deposits.

Acknowledgement

Thank you to the Food Security Faculty members and the rest of the TPHP students for supporting this journal. We also appreciate Annisa Roudhotul Jannah for giving insights into organic chemistry.

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