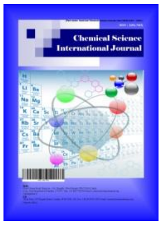

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The Concept of Coredox Reaction

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Eleven sets of organic and inorganic coloured reduction-oxidation (coredox) reactions (organic and inorganic chemical reactions that can show change in colour brightness after undergo redox reaction) were used during these research findings. All were carried out under suitable condition in order to see if the compounds that exist as coloured compounds before reaction, after reaction or both will become brighter or darker when undergo reduction or oxidation respectively. Six sets of this reaction type which include both organic and inorganic species showed special results. In which, all the targeted species gained electrons, their oxidation number decreased in positive direction and colour of species became brighter after reaction by increased in colour brightness. While in last five sets, which also include both organic and inorganic species showed their own results in which all the targeted species donated electrons, their oxidation number increased in positive direction, colour of species became darker after reaction by decreased in colour brightness. Series and repeated number of observations (more than 20 times) were made before recording any changed in colour brightness. Therefore, for all pure form of chemical species that can undergo any one of the coloured reduction-oxidation (coredox) reaction, brightness formation of the product after reaction implies reduction while darkness, oxidation.

Keywords: Coredox; brighter, darker; brightness; darkness.

1. INTRODUCTION

Our great scientists already solved the problems of frequency and wavelength of coloured compounds, their atomic oxidation states, determination of their reducing and oxidizing participated ionic species, and so on. This manuscript will helps in recognising a redox

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process for coloured compounds even if a reducing or oxidizing agent remains unknown. And hypothesized that in chemical reduction-oxidation (redox) reaction, brighter product formation is reduction while darker one is oxidation. Hence, the study was aimed to test and provide scientific evidence on hypothesis.

Vision is obviously involved in the perception of colour. A typical human eye will respond to wavelengths from about 380 to 740nm [1]. Colourfulness is the attribute of a visual perception according to which the perceived colour of an area appears to be more or less chromatic [2]. Chroma is the colourfulness of an area judged as a proportion of the brightness of a similarly illuminated area that appears white or highly transmitting [3]. As a result, chroma is mostly only dependent on the spectral properties, and as such is seen to describe the object colour [4]. It is how different from a grey of the same lightness such an object colour appears to be [5]. Colour brightness is an attribute of visual perception in which a source appears to be radiating or reflecting light [6]. Saturation is the colourfulness of an area judge in proportion to its brightness [7]. An object with a given spectral reflectance exhibits approximately constant saturation for all levels of illumination, unless the brightness is very high [5]. Hue is the degree to which a stimulus can be described as similar to or different from stimuli that are described as red, green, blue, and yellow [8]. Redox reactions are characterized by the transfer of electrons between chemical species, most often with one species (the reducing agent) undergoing oxidation (losing electrons) while another species (the oxidizing agent) undergoes reduction (gain electrons) [9]. Four redox models according to the Ringnes (1995) are Oxygen model, Hydrogen model, Electron model and Oxidation number model.

2. METHODOLOGY

2.1 Preparation of Solutions

All preparation of solutions used throughout in this work were in molar solution without any further chemical purification. Company name, CAS number and purity of some chemicals used are shown below in the following table.

2.2 Instruments and Apparatus Used

All experiments were carried out in laboratory at room temperature of 298-300 K. Instrument and apparatus used during the work include the following, but not limited to Beaker of different sizes, Conical flaks, boiling flask, test tubes, test tube rack, test tube holder, watch glass, crucible, funnel, graduated cylinders, gas jars, volumetric flasks of different sizes, Dropper, Pipettes, Burettes, Ring Stand, Rings, Clamps, wire gauze, Tong, Forceps, Spatulas, Mettler Balance, Thermometer, Bunsen Burner, Kipps Apparatus, Still, vertical High pressure stream sterilizer autoclave.

2.3 Obtaining of Distilled Water and Chemicals Used

Distillation apparatus (Still) was used throughout in obtaining distilled water from portable water for preparation of chemical solutions. This water has specific conductivity of 1.5 uS/cm at 298 K and was used for the calibration and measurements. Weighing of chemicals was achieved by using mettler balance with precision of 10 mg. Chemical substances used include: dyes, dried wood, egg-white, *potassium iodide* (KI), *iodine* crystals, acidified *potassium tetraoxomanganet*(VII) ($KMnO_4$), acidified *potassium heptaoxodichromate*(VI) ($K_2Cr_2O_7$),

Table 1. Chemical identification

Name of Chemicals	Company Name	CAS Number	Purity (%)
Potassium tetraoxomanganate(VII)	CDH	7722-64-7	99.0
Potassium heptaoxodichromate(VI)	Alfa Aesar	7778-50-9	99.5
Potassium iodide	TiangiKermel	7681-11-0	99.0
Iodide crystals	Hebei Guanlang Biotech	7553-56-2	99.99
Tetraoxosulphate(vi) acid	CDH	7664-93-9	98.0
Trioxonitrate(v) acid	CDH	7697-37-2	69.0-72.0
Hydrochloric acid	CDH	7647-01-0	35-38
Iron(ii) tetraoxosulphate(vi)	MOLBASE	7720-78-7	99.0
Iron(ii) Sulphide	Alfa Aesar	1317-37-9	99.98
Brilliant blue FCF	IndiaMART	3844-45-9	85.0

Iron(II) *tetraoxosulphate*(VI) ($FeSO_4$), *tetraoxosulphate*(VI) acid (H_2SO_4*),* *trioxosulphate*(IV) acid (H_2SO_3), *hydrochloric acid* (HCl), *Iron*(II) *sulphide* (FeS), *trioxonitrate* (V) acid (HNO_3), *chlorine* gas (Cl_2), *hydrogen sulphide* (H_2S), redish-brown hydrated *iron*(III) *oxide* (rust/FeO_3xH_2O).

The right method supposed to be used for supporting this phenomenon is by allowing such chemical species to suitably react with one another under suitable condition.

2.3.1 To check for reduction of MnO_4^- to Mn^{2+}

a. Two drops of purple acidified *potassium tetraoxomanganate*(VII) solution were added to 5cm^3 of water in test tube. This is to dilute the purple colour of the solution and to get result easily. Into this solution, drops of *potassium iodide* solution were added one by one till all purple colour of MnO_4^- change to colourless Mn^{2+}.

$$\underset{\text{purple}}{MnO^-_{4(aq)} + 8H^+_{(aq)} + 2I^-_{(aq)}} \rightarrow \underset{\text{colourless}}{Mn^{2+}_{(aq)} + 4H_2O_{(l)} + I_{2(g)}}$$

b. Two drops of purple acidified *potassium tetraoxomanganate*(VII) were added to 5cm^3 of water in test tube. Into this solution, drops of pale green *iron*(II) *tetraoxosulphate*(VI) solution were added one by one till all purple colour of MnO_4^- changed to colourless Mn^{2+}.

$$\underset{\text{purple}}{MnO^-_{4(aq)} + 5Fe^{2+}_{(aq)} + 8H^+_{(aq)}} \rightarrow \underset{\text{colourless}}{Mn^{2+}_{(aq)} + 5Fe^{3+}_{(aq)} + 4H_2O_{(l)}}$$

2.3.2 To check for reduction of $Cr_2O_7^{2-}$ to Cr^{3+}

A colourless *hydrogen sulphide* gas is allowed to bubble through a solution of 10cm^3 of orange acidified *potassium heptaoxodichromate* (VI) in 250cm^3 of water inside 500cm^3 gas jar capacity. The gas was continues supplied till all orange colour of $Cr_2O_7^{2-}$ changed to green Cr^{3+}.

$$\underset{\text{orange}}{Cr_2O^{2-}_{7(aq)}} + 14H^+_{(aq)} + 3S^{2-}_{(aq)} \rightarrow \underset{\text{green}}{2Cr^{3+}_{(aq)}} + 7H_2O_{(l)} + 3S_{(s)}$$

2.3.3 To check for oxidation of Fe^{2+} to Fe^{3+}

Two drops of pale green *iron*(II) *tetraoxosulphate* (VI) solution were added to 5cm^3 of water in test tube. Into this solution, drops of purple acidified *potassium tetraoxomanganate*(VII) were added one by one till all pale green colour of Fe^{2+} changed to redish-brown Fe^{3+}.

$$\underset{\text{pale green}}{5Fe^{2+}_{(aq)} + MnO^-_{4(aq)} + 8H^+_{(aq)}} \rightarrow \underset{\text{redish - brown}}{5Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)} + 4H_2O_{(l)}}$$

2.3.4 To check for oxidation of S^{2-} to S

a. A colourless *hydrogen sulphide* gas is allowed to bubble through a solution of 10cm^3 purple acidified *potassium tetraoxomanganate*(VII) in 250cm^3 of water inside 500cm^3 gas jar capacity. The gas was continues supplied till all purple colour disappears to colourless. At the same time, all colourless S^{2-} changed to yellow S which is seen as yellow solid mass deposited.

$$2MnO^-_{4(aq)} + 6H^+_{(aq)} + \underset{\text{colourless}}{5S^{2-}_{(aq)}} \rightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)} + \underset{\text{yellow}}{5S_{(s)}}$$

b. A Colourless *hydrogen sulphide* gas reacted with greenish-yellow *chlorine* gas inside 250cm^3 moisten gas jar. All colourless S^{2-} changed to yellow S deposited mass.

$$Cl_{2(g)} + \underset{\text{colourless}}{S^{2-}_{(aq)}} \xrightarrow{\text{moisture}} \underset{\text{yellow}}{S_{(s)}}$$

2.3.5 To check for reduction of Cl_2 to Cl^-

A greenish-yellow *Chlorine* gas was reacted with colourless *hydrogen sulphide* gas inside 250cm^3 moisten gas jar. All greenish-yellow colour of Cl_2 changed to colourless Cl^-.

$$\underset{\text{greenish - yellow}}{Cl_{2(g)}} + S^{2-}_{(aq)} \xrightarrow{\text{moisture}} \underset{\text{colourless}}{2Cl^-_{(aq)}}$$

2.3.6 To check for reduction of Fe^{3+} to Fe^{2+}

Some silvery coins made from *iron* were placed inside a 250cm^3 beaker, in which 2.5cm^3 of water was added. The beaker was then closed completely except a very small hole for air entering not for water escaping. After 72 hours later, silvery *iron* metals coins (Fe^0) started oxidizing to redish brown droplets substance. This redish brown is “Rust”. The redish brown colour of rust is due to Fe^{3+}. Two drops of rust were added to 5cm^3 of water in test tube. Into this solution, drop by drop of *iodine* solution were added till all redish brown colour of Fe^{3+} changed to pale green Fe^{2+}. And this can be called “Reverse iron”.

$$\underset{\text{Redish Brown}}{Fe^{3+}} + 2I^- \rightarrow \underset{\text{Pale Green}}{Fe^{2+}} + I_{2(g)}$$

2.3.7 To check for the reduction of both natural and artificial dyes

Fully developed red *Hibiscus sabdariffa* flower, orange and blue bird of paradise flowers were collected, dried and powdered separately each. About 5g of each powdered material was added separately into three separated 250ml beakers contained 25ml of boiled water each. These were left in beaker for good one hour till good infusion method of extraction achieved. Filtration was also achieved pharmaceutically in three separated beakers using filter papers. 1ml of each infusion was transferred into 5ml of water in one separated test tube each. That is, three separated infusions were in three separated test tube containing 5ml of water each. At the same time, 1g of Brilliant blue FCF is transferred into $1000cm^3$ beaker containing $500cm^3$ of water and stirred. Then, $0.5cm^3$ of this mixture was added to $5cm^3$ of water inside test tube. Into all four test tubes drop by drop of *trioxosulphate*(IV) acid were added till all colours of red *Hibiscus sabdariffa* flower red-extract, orange Bird of paradise flower orange-extract, blue bird of paradise flower blue-extract and Brilliant Blue FCF changed to colourless.

$$\underset{\text{Coloured}}{\text{Dye}} + SO^{-}_{3(aq)} \rightarrow \text{Colourless dye} + H_2SO_{4(aq)}$$

2.3.8 To check for oxidation of aromatic ring containing amino acids

In a crucible, $3cm^3$ of egg-white was transferred and beaten until turns to white by application of pressure followed by $1cm^3$ of water and a pinch of salt. Salt help in making egg-white dissolved after gentle mixing. $1cm^3$ of concentrated *trioxonitrate*(V) acid was then added and heated gently. A white colour egg-white solution changes to yellow non-crystallizable substance (*Xanthoproteic* acid*). Xanthoproteic* acid formed due to nitrated aromatic rings in the protein*. Nitrogen*(IV) *oxide* radical abstracts *hydrogen* atom from an aromatic ring containing *amino* acid. Hence oxidation of the ring occurred which caused the change of white colour to yellow. Therefore, this oxidation is by both electron model and *hydrogen* model acted on *benzene* ring.

$$\underset{\text{white}}{C_{11}H_{12}N_2O_{2(aq)}} + NO^{-}_{3(aq)} \rightarrow \underset{\text{yellow}}{C_{11}H_{11}N_3O_{4(s)}} + H_2O_{(l)}$$

2.3.9 To check for the oxidation of carbon in wood

Dried redish brown wood of *Azadirachta indica* was burned in plentiful supply of air in order to allowed combustion process from occurring. During this combustion, electrons of redish brown carbon transferred to molecular *oxygen.* This helps *carbon* to oxidize and became black by acting as a reducing agent.

$$\underset{\text{redish − brown}}{C_{(s)}} \rightarrow \underset{\text{black}}{C^{4+}_{(s)}}$$

With respect to the above reactions (from 1 to 9), two colours of each targeted chemical species before and after reaction were compared by repeated observations in order to find out which colour between them is more brighter than the other (in terms of high or low). In addition, the percentage of colour brightness for each exact colour of targeted species before and after reaction was carefully recorded using prepared colour brightness table. Which shows both the Decimal equivalents for each component (Red, Green and Blue) and the Hex Code for each colour [10]. This was carefully recorded. Provided that white is full brightness and black is full darkness [10].

3. RESULTS

The purpose of this research is to see if that compound which exist as coloured compound before reaction, after reaction or both will becomes brighter or darker when undergoes reduction or oxidation respectively.

4. DISCUSSION

Some of the limitations of this research work are: black and white are not considered as colours in science view because they do not have specific wavelengths, and the percentage of colour brightness value for colourless remains unavailable. However, the concept remains the same. No doubt black is darker than any colour including white. Likewise, white is brighter than all colours including black. Since bright is also means clear, and colourless is clear in nature. We can’t neglect black, white and colourless in world of science of colours, and this is because, there are many chemical compounds that exist as black, white or colourless and hence there is

Table 2. Result of species that gained electrons during redox reaction

S/N	Parameters	Change of MnO_4^- to Mn^{2+}	Change of $Cr_2O_7^{2-}$ to Cr^{3+}	change of Cl_2 to Cl^-	Change of Fe^{3+} to Fe^{2+}	Change of natural and artificial dyes to colourless
1.	Reaction test	$KMnO_4 + H_2SO_4 + KI$ or $KMnO_4 + H_2SO_4 + FeSO_4$	$K_2Cr_2O_7 + H_2SO_4 + H_2S$	$Cl_{2+}H_2S + H_2O$	$FeO_3.H_2O + 2I$	$Dyes + H_2SO_3$
2.	Ionic colour before reaction	Purple	Orange	Greenish-yellow	Redish-brown	Red, orange, blue
3.	Ionic colour after reaction	Colourless	Green	Colourless	Pale green	Each became colourless in different test tubes
4.	colour brightness before reaction	Low	Low	Low	Low	Low
5.	Colour brightness after reaction	High	High	High	High	High
6.	Percentage of colour brightness before reaction (%)	55.5	60.8	75.7	32.5	33.3, 60.8, 16.7
7.	Percentage of colour brightness after reaction (%)		79.0		79.0	
8.	Electron transfer	Gain	Gain	Gain	Gain	Gain
9.	Oxidation number before reaction	+7	+6	0	+3	0
10.	Oxidation number after reaction	+2	+3	-1	+2	-2

If the colour brightness before reaction is low and high after reaction it shows the increase in degree of brightness

Table 3. Result of species that donated electrons during redox reaction

S/N	Parameters	Change of Fe^{2+} to Fe^{3+}	Change of S^{2-} to S	Change of egg-white solution to Xanthoproteic acid	Change of C to C^{4+}
1.	Reaction test	$FeSO_4 + H_2SO_4 + KMnO_4$	$H_2S + KMnO_4 + H_2SO_4$ or $H_2S + Cl_2 + H_2O$	Egg-white solution + concentrated HNO_3	$C + O_2 +$ burning
2.	Ionic colour before reaction	Pale green	Colourless	White	Redish-brown
3.	Ionic colour after reaction	Redish-brown	Yellow	Yellow	Black
4.	colour brightness before reaction	High	High	High	High
5.	colour brightness after reaction	Low	Low	Low	Low
6.	Percentage of colour brightness before reaction (%)	79.0		100	32.5
7.	Percentage of colour brightness after reaction (%)	32.5	83.3	83.3	0
8.	Electron transfer	Donate	Donate	Donate	Donate
9.	Oxidation number before reaction	+2	-2	+1	0
10.	Oxidation number after reaction	+3	0	+4	+4

If the colour brightness before reaction is high and low after reaction it shows the decreased in degree of brightness an interchanging between them and other colours. In addition, black and white are considered as colours in philosophy of arts.

4.1 Species That Gained Electrons during Redox Reaction

All members of this table shared same properties in the sense that, they all gained electrons, oxidation number decreased in positive direction, colour of species became brighter after reaction by increased in percentage of colour brightness. Hence reduction process occurred.

4.2 Species That Donated Electrons during Redox Reaction

All members in this table shared common properties in the sense that, they all donated electrons, oxidation number increased in positive direction, colour of species became darker after reaction by decreased in percentage of colour brightness. Thereby, oxidation process occurred.

Since redox reaction is all about transfer of electrons. Decreased or increased in oxidation number implies reduction or oxidation respectively. Therefore, reduction is gaining of electrons while oxidation is losing of electrons [9].

This manuscript comes with a new proposed theory which will support the hypothesis furthermore. The proposed theory will also contribute to the science in understanding many aspects in chemistry and physics. And conclusion of this manuscript itself will significantly help in understanding and treatment of many ailments associated with colour change.

The proposed theory claims that, during reduction process ion gains additional electrons from its participant which makes it to increases in size by providing more spaces among electrons themselves and between cloud of electrons and nucleus. And thereby, allowing entering of light through the ion in relative ease, which later make ion to appear brighter than before. But during oxidation process, ion donates its electrons to its participant which make it to decreases in size. Decreasing in ionic size will increase more nuclear attraction which later causes more decreasing in ionic size. Now, electrons will manage to arrange themselves in their orbits to maintain their electronic configuration but in relative squeezed. Therefore, each electron becomes so contact with its neighbouring electrons at all angles and the nucleus itself. As a result, the shadow of each electron will fall on its neighbouring electrons and nucleus and vice versa. This may lead the ionic environment to be darker than before.

5. CONCLUSION

For all pure form of chemical species that can undergo any one of the coloured reduction-oxidation (coredox) reaction, brightness formation of the product after reaction implies reduction while darkness, oxidation.

Some of the applications of coredox reaction can be seen in fluid mechanics, chemistry of earth and space, understanding and management of many ailments associated with colour change e.g. cancer.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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