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CRITICAL REVIEWS ON STABILITY AND PHOTOSENSITIZER POTENTIAL OF METAL FERROCYANIDES: A POSSIBLE PREBIOTIC MINERAL PART-III

REVISIONES CRÍTICAS DE ESTABILIDAD Y DE POTENCIAL DE FOTOSENSIBILIZADOR DE FERROCIANUROS METÁLICOS: UN POSIBLE MINERAL PREBIÓTICO PARTE III

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Palabras clave: *Ferrocianuros metálicos, Estabilidad, Oxidante, Fotosensibilizador, Prebiótico mineral.*

ABSTRACT

Copper, lanthanum, mercury, molybdenum, silver, titanium, and zinc ferrocyanides were synthesized and characterized by elemental analysis and spectral studies. The stability of synthesized metal ferrocyanides were recorded in heat (various temperature), various concentrations of acids (HCl, H_2SO_4, HNO_3, CH_3 COOH) various concentrations of bases (NaOH, KOH, NH_4OH), and in sea and tap water. All stabilities were recorded at room and boiling temperature. Stability of synthesized metal ferrocyanides were also recorded in presence of visible and ultraviolet radiation. Oxidizing and photosensitizing potential of synthesized metal ferrocyanides were tested using potassium iodide and freshly prepared starch solution indicated copper ferrocyanide as possible strong oxidizer and photosensitizer. Molybdenum, mercury and tungsten ferrocyanides were found to act as weak oxidizer and photosensitizer. Lanthanum and zinc ferrocyanide did not show any oxidizing and photosensitizing potential.

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RESUMEN

Los ferrocianuros de cobre, lantano, mercurio, molibdeno, plata, titanio y zinc se sintetizaron y caracterizaron mediante análisis elemental y estudios espectrales. La estabilidad de los ferrocianuros metálicos sintetizados se registró en calor (varias temperaturas), varias concentraciones de ácidos (HCl, H_2SO_4, HNO_3, CH_3 COOH) varias concentraciones de bases (NaOH, KOH, NH4OH), y en agua de mar y de grifo. Todas las estabilidades se registraron a temperatura ambiente y de ebullición. La estabilidad de los ferrocianuros metálicos sintetizados también se registró en presencia de radiación visible y ultravioleta. El potencial oxidante y fotosensibilizante de los ferrocianuros metálicos sintetizados se probó con yoduro de potasio y la solución de almidón recién preparada indicó que el ferrocianuro de cobre es un posible oxidante fuerte y fotosensibilizador. Se descubrió que los ferrocianuros de molibdeno, mercurio y tungsteno actúan como oxidante débil y fotosensibilizador. El lantano y el ferrocianuro de zinc no mostraron ningún potencial oxidante y fotosensibilizante.

INTRODUCTION

Environment conditions on early Earth were important for both, the origin and the early evolution of life. Two variables are of particular significance (i) the atmospheric redox state, and (ii) the mean surface temperature. Most recent models of Earth prebiotic atmosphere [1, 2] suggested that this was weakly reduced, with N_2 and CO_2, predominating over NH_3 and CH_4. Nucleic acid bases are part of important compounds in biological systems. Most of the bases are readily formed in prebiotic conditions. Their synthesis and stability in environmental conditions is of paramount importance in chemical evolution [3]. Clay minerals considered the most likely inorganic material to promote organic reactions at the interface of the hydrosphere and lithosphere [4]. The relevancy of clay minerals to the origin of life is due to their ancient origin, wide distribution and especially for their physico-chemical properties [5]. Clays are important because of their strong affinity for organic compounds [6]. Certain montmorillonites catalyze the formation of RNA oligomers that contain up to fifty (50) monomers units determined by MALDI mass spectrometry and gel electrophoresis [7, 8]. Montmorillonite is a catalyst that favours sequence selectivity and phosphodiester bond selectivity [9].

Primitive atmosphere was anoxygenic and reaction potential of atmosphere was not high enough, hence metals like iron, copper, mercury, molybdenum, zinc etc. were in the form of their lower oxidation states. During the course of chemical evolution, cyanide ions were abundant in nature. Cyanide ion is smaller in size and is considered as a strong ligand due to the presence of triple bond. It shows basic ambidentate characteristics and form a variety of complexes with transition metal ions [10, 11]. Consequently, several insoluble metal ferrocyanides of general formula M_2 [Fe $(CN)_6$].X H_2 O where M= Fe, Cu, Hg, Mo, Zn, etc., could have been formed. It is well established that metal ferrocyanides act as adsorbents [12-14], ion exchangers [15-17] and photosensitizers [18,19]. It is also suggested that the interaction of organic molecules with metal ferrocyanides take place through the coordination between the exchangeable outer metal ion and the available adsorption site of organic molecules.

A search of literature indicated some reports available on synthesis of metal-cyano complexes and very few reports available on stability and photosensitizing activity of these complexes. In view of this, attempt was made to study stability and photosensitizing activity of copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc ferrocyanides. In addition, the present work describes a critical reviews on stability and photosensitizer potential of copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc ferrocyanides.

RESULTS AND DISCUSSION

Elemental analysis of metal ferrocyanides

The percentage compositions of metals in metal ferrocyanides are given in Table 1. The percentage of metals (copper, - lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc) are found higher in comparison to iron in all metal ferrocyanides studied. The found percentage of carbon was maximum and minimum in zinc and lanthanum ferrocyanides, respectively. The found percentage of hydrogen was maximum and minimum in titanium and mercury ferrocyanides, respectively. It is also clear from Table 1 that percentage of nitrogen was maximum and

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minimum in zinc and molybdenum ferrocyanides, respectively. The greater the percentage of hydrogen the more water molecules are expected to be attached to metal ferrocyanides.

Spectral studies of metal ferrocyanides

The infrared special data of metal ferrocyanides are given in Table 2. It is observed from Table 2 that water molecules/OH groups and metal-nitrogen band showed highest and lowest absorption frequencies, respectively. The HOH bending, cyanide and Fe-C stretching frequencies were observed around 1600 cm-1, 2000 cm-1 and 600 cm-1, respectively. It is also clear from Table 2 that the found frequencies for metal-nitrogen bands were maximum and minimum in titanium and copper ferrocyanides, respectively.

Effect of heat on the stability of metal ferrocyanides

It is clear from Table 3 that copper, lanthanum, mercury, molybdenum, silver, titanium, and zinc ferrocyanides are found to be stable at 100º C, while those of tungsten and titanium ferrocyanides are found to be unstable at 100º C.

Stability of metal ferrocyanides in various concentrations of acids at room temperature and at boilling temperature

It is observed from Table 4 that molybdenum, titanium, silver, and zinc ferrocyanides are insoluble in various concentrations of hydrochloric acid at room temperature with no colour change of particles in silver, titanium and zinc ferrocyanides and with colour change of particles in molybdenum ferrocyanide. Lanthanum and mercury ferrocyanides are slightly soluble in various concentrations of hydrochloric acid at room temperature with colour change of particles. Copper and tungsten ferrocyanides are slightly soluble at high concentration of hydrochloric acid at room temperature with colour change of particles, while insoluble at lower concentration of hydrochloric acid at room temperature with no colour change of particles.

It is clear from Table 5 that copper and zinc ferrocyanides are insoluble in various concentrations of boilling hydrochloric acid with colour change of particles. Silver and titanium ferrocyanides are insoluble in various concentrations of boilling hydrochloric acid with no colour change of particles. Mercury ferrocyanides is soluble at all concentrations of boilling hydrochloric acid. Lanthanum, molybdenum and tungsten ferrocyanides are slightly soluble at high concentrations of boilling hydrochloric acid and insoluble at low concentrations of boilling hydrochloric acid with no colour change of particles.

Table 6 shows that copper, zinc, silver, titanium, molybdenum, tungsten ferrocyanides are insoluble in various concentrations of sulfuric acid at room temperature with no colour change of particles. Lanthanum ferrocyanide is soluble in various concentrations of sulfuric acid at room temperature with colour of solution blue and clear at high and low concentrations, respectively.

It is observed from Table 7 that silver, titanium, molybdenum, tungsten ferrocyanides are insoluble in various concentrations of sulphuric acid at boilling temperature with no change in colour of particles. Copper and zinc ferrocyanides are insoluble in various concentrations of sulphuric acid at boilling temperature with colour change of the particles. Mercury ferrocyanide is soluble at all concentrations of sulphuric acid at boilling temperature with colour of solution change blue. Lanthanum ferrocyanide is soluble at high concentration of sulphuric acid at boilling temperature with colour of solution change to blue, while slightly soluble to low concentration of sulphuric acid at boilling temperature with colour change of solution light blue.

It is clear from Table 8 that copper, zinc, silver, titanium, molybdenum and tungsten ferrocyanides are insoluble in various concentrations of nitric acid at room temperature with no change in colour of the particles. Lanthanum and mercury ferrocyanides are soluble and slightly soluble in various concentrations of nitric acid at room temperature with colour change of solution to green in both cases.

Table 9 shows that copper, zinc, molybdenum and tungsten ferrocyanides are insoluble in various concentrations of nitric acid at boilling temperature with colour change of particles in case of copper and zinc ferrocyanides, while colour of particles did not change in case of molybdenum and tungsten ferrocyanides. Lanthanum and mercury ferrocyanide are soluble in various concentrations of nitric acid at boilling temperature.

It is observed from Table 10 that mercury, tungsten, copper and zinc ferrocyanides are insoluble in various concentrations of acetic acid at room temperature with no change in colour of particles. Silver, titanium, lanthanum

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and molybdenum ferrocyanides are insoluble in various concentrations of acetic acid at room temperature with colour change of the particles.

It is clear from Table 11 that lanthanum, copper and zinc, molybdenum ferrocyanides are insoluble in various concentrations of boilling acetic acid with no change in colour of particles. Titanium ferrocyanide is slightly soluble in various concentrations of boilling acetic acid with colour change in particles. Mercury, silver and tungsten ferrocyanides are insoluble in various concentrations of boilling acetic acid with no change in colour of particles. The colour change of metal ferrocyanides in various acids at room and boilling temperature is probable due to electronic transition within molecules of metal ferrocyanides.

Stability of metal ferrocyanides in various concentrations of bases at room and boilling temperature.

Table 12 show that copper, tungsten, silver, molybdenum, mercury ferrocyanides are insoluble in various concentrations of sodium hydroxide at room temperature with no change in the original particles. Titanium ferrocyanide is insoluble in various concentrations of sodium hydroxide with no colour change in the original particles. Zinc ferrocyanide is soluble in high concentration and insoluble at low concentration of sodium hydroxide at room temperature. The lanthanum ferrocyanide is slightly soluble at all concentrations of sodium hydroxide at room temperature with colour change in the particles.

It is observed from Table 13 that copper and silver ferrocyanides are insoluble in various concentrations of boilling sodium hydroxide with colour change in the original particles. Titanium, tungsten and lanthanum ferrocyanides is insoluble in various concentrations of sodium hydroxide with no colour change in the original particles. Zinc and molybdenum ferrocyanides are soluble in various concentrations of sodium hydroxide at boilling temperature. Mercury ferrocyanideis soluble in high concentration and insoluble at low concentration of boilling sodium hydroxide.

It is clear from Table 14 that copper, mercury, molybdenum and tungsten ferrocyanides are insoluble in various concentrations of potassium hydroxide at room temperature with change in colour of original particles. Zinc ferrocyanide is soluble in all concentrations of potassium hydroxide at room temperature. Silver, titanium and lanthanum ferrocyanides are insoluble in various concentrations of potassium hydroxide at room temperature with no colour change in original particles.

Table 15 showed that copper, tungsten, mercury, molybdenum and tungsten ferrocyanides are insoluble in boilling potassium hydroxide with change in colour of the original particles. Zinc ferrocyanide is soluble in various concentrations of boilling potassium hydroxide. Titanium and lanthanum ferrocyanides are insoluble in various concentrations of boilling potassium hydroxide with no change in colour of original particles.

It is observed from Table 16 that copper and titanium ferrocyanides are insoluble in various concentrations of ammonium hydroxide at room temperature with no colour change in particles. Molybdenum and zinc ferrocyanides are soluble in various concentrations of ammonium hydroxide at room temperature. Silver, tungsten and lanthanum ferrocyanides are insoluble in various concentrations of ammonium hydroxide at room temperature with no change in colour. Mercury ferrocyanide is soluble in high concentrations of ammonium hydroxide and insoluble at low concentration of ammonium hydroxide at room temperature.

It is observed from Table 17 that copper and titanium ferrocyanides are insoluble in various concentrations of boilling ammonium hydroxide with colour change in original particles. Molybdenum and zinc ferrocyanides are soluble in various concentrations of ammonium hydroxide at boilling temperature. Lanthanum and tungsten ferrocyanides are insoluble in various concentrations of boilling ammonium hydroxide with colour change in original particles. Silver and mercury ferrocyanide are partially soluble in high concentration of boilling ammonium hydroxide and insoluble at low concentrations of boilling ammonium hydroxide. The colour change of metal ferrocyanides in various bases at room and boilling temperature is probably due to electronic transition within molecules of metal ferrocyanides.

Stability of metal ferrocyanides in tap water and sea water at room and boilling temperature

Table 18 showed that all eight copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc ferrocyanides are found to be insoluble and stable in tap water and sea water at room and boiling temperature.

Effects of visible light on the stability of metal ferrocyanides

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It is observed from Table 19 that tungsten, lanthanum, molybdenum and mercury ferrocyanides are stable to visible light until the 48 hours of radiations. Copper and silver ferrocyanides are unstable to visible light until the 12 hours of irradiation, it is also clear from Table 19 that zinc and titanium ferrocyanides are found stable to visible light 24 hours of irradiation.

Effects of ultraviolet light on the stability of metal ferrocyanides

It is clear from Table 20 that lanthanum, mercury and molybdenum ferrocyanides are stable to ultraviolet light until the 48 hours of irradiations. Copper ferrocyanide is stable to ultraviolet light until the 24 hours of irradiation. Zinc, tungsten and titanium ferrocyanides are found to be stable to ultraviolet light 12 hours of irradiation. It is also clear from Table 20 that silver ferrocyanide unstable to ultraviolet light at 12 hours of irradiations.

Test of oxidizing and photosensitizing activity of metal ferrocyanides

Test on oxidizing and photosensitizing potential of copper, zinc, molybdenum, mercury, tungsten lanthanum ferrocyanides in potassium iodide and freshly prepared starch solution indicated copper ferrocyanide as a strong oxidizer and photosensitizer. Lanthanum and zinc ferrocyanides did not show any oxidizing and photosensitizing potential. Molybdenum, mercury and tungsten ferrocyanides found to act as weak oxidizer and photosensitizer during the course of chemical evolution on primitive Earth.

CONCLUDING REMARKS

1. The copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc ferrocyanides are found to be stable to heat at 100ºC of temperature.
2. The molybdenum, titanium, silver and zinc ferrocyanides are insoluble in various concentrations of hydrochloric acid at room temperature with no change in colour of original particles.
3. The copper, zinc, silver, titanium, molybdenum, tungsten, ferrocyanides are insoluble in various concentrations of sulphuric and nitric acids at room temperature with no change in colour particles.
4. Lanthanum ferrocyanide found to be more unstable in various concentrations of acids at room and boilling temperature in comparison to other metal ferrocyanides studied.
5. Most of the metal ferrocyanides are more stable to room temperature at various concentrations of acids and bases.
6. Zinc ferrocyanide is found to be soluble in various concentrations of bases (NaOH, KOH, NH_4OH) at room and boilling temperature.
7. Titanium ferrocyanide is found to be more stable in various concentrations of bases (NaOH, KOH, NH_4OH) at room and boilling temperature with no change in colour of original particles.
8. Copper, mercury, molybdenum tungsten ferrocyanide is found to be insoluble in various concentrations of bases (NaOH, KOH, NH_4OH) at room temperature with change in colour of original particles.
9. Metal ferrocyanides seems to be more stable in various concentrations of acids at room and boilling temperature in comparison to bases.
10. All eight metal ferrocyanides (copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc) are found to be insoluble and stable in tap water and sea water at room and boilling temperature.
11. Lanthanum, mercury and molybdenum ferrocyanides are stable until the 48 hours of visible and ultraviolet light radiations.
12. Zinc and titanium ferrocyanides are found to be stable until the 24 hours of visible light radiation while they’re stable until the 12 hours in ultraviolet light radiations.
13. Silver ferrocyanide is found to be unstable in both visible and ultraviolet light on 12 hours of radiations.
14. Copper ferrocyanide is found to have high oxidizing and photosensitizing potential whereas molybdenum, mercury and tungsten ferrocyanides found to have weak oxidizer and photosensitizing potential during the course of chemical evolution on primitive Earth.
15. It is also concluded from present study that double metal ferrocyanides are insoluble and stable during the course of chemical evolution on primitive Earth and played a significant role in condensation of precursors of early life in primeval seas.

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EXPERIMENTAL

Chemicals

Potassium ferrocyanide, copper (II) chloride, lanthanum chloride, mercury (II) chloride, sodium molylidate, silver nitrate, titanium tetrachloride, sodium tungsten, zinc chloride were obtained from British Drug House (BDH), Poole, England. All chemical used were of AnalaR grade and used as such without any further purification. Solutions were prepared in doubly distilled water.

Synthesis of metal ferrocyanides

Copper, zinc, silver, mercury, lanthanum ferrocyanides were prepared by Kourim's method [20] by adding potassium ferrocyanide (167 m L, 0.1 M) slowly to metal chloride (500 m L; 0.1 M) with constant stirring. The reaction mixture was heated on a water bath for 2-3 h and then cured for 24 h. The precipitate was washed and dried at 60° C. The dried product was ground and sieved at 125 µM BSS mesh size. In case of silver ferrocyanide all procedure were carried out in the dark.

The best condition for the preparation of titanium ferrocyanide involves variation in the mole ratio of titanium to hexacyanoferrate (II), which vary between10 to 1 and 1 to 10, respectively. For this experiment we used a 0.5 M solution of titanium tetrachloride in 2.0 M aqueous hydrochloric acid and 0.34 M solution of hexacyanoiron (II) acid [21]. The solution of hexacyanoiron (II) acid is won by pouring a solution of potassium hexacyanoferrate (II) over a Dower-50-exchanger and then poured into the 2.0 M HCl / $TiCl_4$ solution. The filling material from the exchanger is centrifused out after 24 h and dried over phosphorus pentaoxide and potassium hydroxide in a vacuum desiccators. The dried product was washed with water free from chloride ion and then dried again in the vacuum desiccators. The dried product was ground and sieved at 125 µM BSS mesh size.

Molybdenum hexacyanoferrate was isolated [22, 23] by adding ethyl alcohol to a mixture containing 14 m L of 0.1 M molybdic acid and 20 m L of 0.1 M potassium hexacyanoferrate solution. The precipitate was filtered and washed with alcoholic water and dried for 48 h. The dried compound was ground and sieved to 125 µM BSS mesh size.

Tungsten ferrocyanide was prepared by adding potassium ferrocyanide (0.1 M, 200 m L) sodium tungstate (0.1 M, 400 m L) and HCl (1.0 M, 10 m L) with constant stirring [24]. The reaction mixture was then heated in a boiling water bath for 3 h. the product was left at room temperature for 24 h. The precipitate was then filtered under vacuum, washed with distilled water and dried in an oven at 60° C. The dried product was ground and sieved to 125 µM, BSS mesh size.

Characterization of metal ferrocyanides

Copper, lanthanum, mercury, molybdenum, silver, titanium, tungsten and zinc ferrocyanides are dark rust brown, white, blue, green, light blue, forest green, dark green and white, respectively. The double metal ferrocyanides are amorphous insoluble solid and showed no X-ray pattern. The metal ferrocyanides are characterized on the basis of elemental and spectral studies. The percentage composition of metals was determined by IL-751 atomic absorption spectrophotometer [25]. Carbon, hydrogen and nitrogen analysis were carried out by CEST-118, CHN analyzer. Percentage composition of elements in the metal ferrocyanides are given in Table 1.

Infrared spectra of metal hexacyanoferrate (II) complexes were recorded in KBr disc on Beckman IR-20 spectrophotometer (Table 2). All eight metal ferrocyanides show a broad peak at 3600 - 3800 cm^{-1} is characteristic of water molecule and OH groups. A peak at around 1590-1625 cm^{-1} is due to HOH bending [25], two sharp peaks, one at around 2020 cm^{-1} and the other at around 600 cm^{-1} in all eight spectra of complexes are characteristic frequencies of cyanide and Fe-C stretching, respectively [26]. Another sharp band at 450-500 cm^{-1} in all eight metal ferrocyanides probably shows the presence of metal-nitrogen bond thus indicating a certain degree of polymerization in the products [27,28].

Stability study on metal ferrocyanides

Effect of heat on the stability of metal ferrocyanides

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A 20 mg of each metal ferrocyanides was placed in a petri dish. The petri dishes were then placed in the air oven for 6 hours at 100º C. This process was repeated at 150º C, 200º C, and 250º C to demonstrate the effect of heat on the various metal ferrocyanides. The colour of metal ferrocyanides at various was carried temperatures was observed (Table 3). All procedure for silver ferrocyanide was carried out in the dark.

Stability of metal ferrocyanides in various concentrations of acids at room temperature and at boilling temperature

The metal ferrocyanides (20 mg) were placed in the test tubes containing 10 mL of each 2.0 M, 1.0 M, 0.5 M, 0.2 M and 0.1 M acids (hydrochloric acid, sulphuric acid, nitric acid and acetic acid).The mixture was agitated for 20 minutes at room temperature and observation for any change in colour of metal ferrocyanides were recorded (Tables 4, 6, 8. 10). The same reaction mixture boilling on a Bunsen flame for 20 minutes and any change in colour of metal ferrocyanides were recorded (Tables 5, 7, 9, 11). This process was repeated for each metal ferrocyanides. The colour change for ferrocyanides metallic was recorded. All procedures for silver ferrocyanide were carried out in the dark.

Stability of metal ferrocyanides in various concentrations of bases at room temperature and at boilling temperature

The metal ferrocyanides (20 mg) were placed in test tubes containing 10 mL of each 2.0 M, 1.0 M, 0.5 M, 0.2 M and 0.1 M bases (sodium hydroxide, potassium hydroxide, ammonium hydroxide). The mixture was agitated for 20 minutes at room temperature and observation for any change in color of metal ferrocyanides was recorded (Tables 12, 14, 16). The same reaction mixture boiled on a Bunsen flame for 20 minutes and any change in color of metal ferrocyanides was recorded (Tables 13, 15, 17). This process was repeated for each ferrocyanide metallic. The color change for metal ferrocyanides was recorded. All procedures for silver ferrocyanide were carried out in the dark.

Stability of metal ferrocyanides in tap water and sea water at room temperature and at boilling temperature

The metal ferrocyanides (20 mg) were placed in the test tubes containing 10 mL tap water and sea water. The mixture was agitated for 1h and observation for any change in colour of metal ferrocyanide were recorded (Table 18). The same reaction mixture boilling on Bunsen flame for 20 minutes and any change in colour of ferrocyanides were recorded (Table 18). All procedures for silver ferrocyanide was carried out in the dark.

Effect of light (UV/Vis) on the stability of metal ferrocyanides

A 20 mg of each metal ferrocyanides were placed in a dry petri dish and the original colour was recorded. A 250 W visible lamp was kept vertically above the sample at a distance of 28 cm. The observations for any change in colour of metal ferrocyanides were recorded at 12, 24, 36 and 48 hours (Table 19). The same experiment was repeated using a long wave (300 – 380 nm) ultraviolet lamp. The observations of any change in colour of metal ferrocyanides were recorded (Table 20).

Test on oxidizing and photosensitizing potential of metal ferrocyanides

The oxidizing and photosensitizing activity of copper, lanthanum, mercury molybdenum, tungsten and zinc ferrocyanides were compared by potassium iodide and freshly prepared starch solution. Oxidation of iodide to iodine in presence of starch gives blue colour. One drop of freshly prepared 2.0 % starch solution was added into test tubes (length =10 cm; internal diameter = 1.30 cm) containing 10 mL of 0.1 M potassium iodide solution. A 25 mg of potassium ferrocyanide were added into each test tube and agitated, observation for any decolourization of blue color and potassium iodide and starch solution were recorded. The same experiment was repeated using a 250 W visible lamp and a long wave UV lamp, which was kept vertically above the test tubes at a distance of 15.0 cm. Photosensitizer will decolorize the blue color of potassium iodide and starch solution in the presence of visible and ultraviolet light. The oxidizers will decolorize the blue color of potassium iodide and starch solution in the absence of light.

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***Table 1**: Elemental analysis of metal ferrocyanides*

Metal Ferrocyanides*	Percentage (%) found Metal	Iron	Carbon	Hydrogen	Nitrogen
CuFc	28.30	12.90	16.03	2.56	18.32
LaFc	35.20	7.10	9.40	3.90	11.90
HgFc	54.90	10.50	14.00	0.60	14.35
MoFc	39.80	16.60	10.73	1.86	11.72
AgFc	40.22	8.75	11.47	2.75	13.77
TiFc	25.35	11.95	15.62	3.17	18.25
WFc	52.71	7.27	9.31	1.67	12.07
ZnFc	29.80	15.50	18.80	1.55	19.89

*CuFu = Copper ferrocyanide
HgFc = Mercury ferrocyanide
AgFc = Silver ferrocyanide
WFc = Tungsten ferrocyanide
LaFc = Lanthanum ferrocyanide
MoFc = Molybdenum ferrocyanide
TiFc = Titanium ferrocyanide
ZnFc = Zinc ferrocyanide

***Table 2:** Infrared spectra data of metal ferrocyanides*

Metal ferrocyanides	Absorption frequency (cm^{-1}) H_2O molecule /OH group	HOH bending	C=N Streching	Fe-C	Metal-N*
CuFc	3600	1590	2090	6 00	450
LaFc	3600	1590	2000	600	500
HgFc	3600	1620	2000	600	490
MoFc	3600	1600	1990	620	500
AgFc	3800	1600	2010	600	490
TiFc	3800	1615	2020	600	510
WFc	3510	1600	2000	620	490
ZnFc	3650	1620	2080	600	475

*Metal-nitrogen band show degree of polymerization

***Table 3**:Effect of heat on the stability of metal ferrocyanides*

MFcs	Original colour	100° C	150° C	200° C	250° C
CuFc	Dark Rust Brown	No change	Black	Black	Black
LaFc	White	No change	Light brown	Brown	Brown
HgFc	Blue	No change	No change	Brown	Deep brown
MoFc	Green	No change	Greenish Brown	Brown	Brown black
AgFc	Light blue	Light blue	Light blue	Dark blue	Blackish blue
TiFc	Forest green	Change forest green to light black	Change forest green to light black	Change forest green to black	Change forest green to black
WFc	Dark green	Change dark green to black	Change dark green to black	Change dark green to black	Change dark green to black
ZnFc	White	No change	Light brown	Light brown	Dark brown

MFcs = metal ferrocyanides
Amount of metal ferrocyanides = 20 mg Time: 6 hours

***Table 4**: Stability of metal ferrocyanides in hydrochloric acid at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M

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CuFc (Dark rust brown)	Slightly red brown Particles changed to light green	Insoluble no change	Insoluble no change	Insoluble no change	Insoluble no change
LaFc (White)	Slightly soluble white particles turn blue	Slightly soluble white particles turn blue	Slightly soluble white particles turn blue	Slightly soluble white particles turn blue	Slightly soluble white particles turn blue
HgFc (Blue)	Slightly soluble blue particles turned deep blue	Slightly soluble blue particles turned deep blue	Slightly soluble blue particles turned deep blue	Slightly soluble blue particles turned deep blue	Slightly soluble white particles turned deep blue
MoFc (Green)	Insoluble green particles turned to deeper green	Insoluble green particles turned to deeper green	soluble green particles turned to deeper green	soluble green particles turned to deeper green	soluble green particles turned to deep green
AgFc (Light blue)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)
TiFc (Forest green)	Insoluble bottle green (no change)	Insoluble bottle green (no change)	Insoluble bottle green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)
WFc (Dark green)	Slightly Soluble dark green to black	Insoluble dark green	Insoluble dark green	Insoluble dark green	Insoluble dark green
ZnFc (White)	Insoluble	Insoluble	Insoluble	Insoluble	Insoluble

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of hydrochloric acids = 10 mL

***Table 5**: Stability of metal ferrocyanides in hydrochloric acid at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown particles turn black	Insoluble dark rust brown particles turn black	Insoluble dark rust brown particles turn black	Insoluble dark rust brown particles turn black	Insoluble dark rust brown particles turn black
LaFc (White)	Slightly soluble solution turn blue white powder became blue	Slightly soluble solution faint blues white powder because blue	Insoluble supernatant clear white powder became blue	Insoluble supernatant clear white powder became blue	Insoluble supernatant clear white powder became blue
HgFc (Blue)	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue

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MoFc (Green)	Slightly soluble	Slightly soluble	Insoluble green particles did not change	Insoluble green particles did not change	Insoluble green particles did not change
AgFc (Light blue)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble I blue (no change)	nsoluble blue (no change)
TiFc (Forest green)	Insoluble bottle green (no change)	Insoluble bottle green (no change)	Insoluble bottle green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)
WFc (Dark green)	Slightly Soluble dark green particles change to black	Slightly Soluble dark green particles change to black	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green
ZnFc (White)	Insoluble white Particles turn light green	Insoluble white particles turn light green	Insoluble white particles turn light green	Insoluble white particles turn light green	Insoluble white particles turn light green

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0° C
Amount of metal ferrocyanides = 20 mg
Volume of hydrochloric acids = 10 mL

***Table 6**: Stability of metal ferrocyanides in sulphuric acid at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles did not change black	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change
LaFc (White)	Soluble solution turned blue	Soluble solution faintly blues	Soluble solution clear	Soluble solution clear	Soluble solution clear
HgFc (Blue)	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue
MoFc (Green)	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear
AgFc (Light blue)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)
TiFc (Forest green)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)
WFc (Dark green)	Insoluble particles remains dark greendark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green

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ZnFc (White)	Insoluble white Particles did not change	Insoluble white particles did not change	Insoluble white particles did not change	Insoluble white particles did not change	Insoluble white particles did not change

OC = Original colour of metal ferrocyanides
Volume of sulphuric acid = 10 mL
Room temperature = 31.0° C
Amount of metal ferrocyanides = 20 mg
Time: 20 minutes

***Table 7**: Stability of metal ferrocyanides in sulphuric acid at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown particles turned black	Insoluble dark rust brown particles turned black	Insoluble dark rust brown particles turned black	Insoluble dark rust brown particles turned black	Insoluble dark rust brown particles turned black
LaFc (White)	Soluble solution turned blue	Soluble solution blues	Slighty soluble solution light blue	Slighty soluble solution light blue	Slightly soluble solution turn blue
HgFc (Blue)	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue	Soluble solution turned blue
MoFc (Green)	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear
AgFc (Light blue)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)	Insoluble blue (no change)
TiFc (Forest green)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)	Insoluble forest green (no change)
WFc (Dark green)	Insoluble particles remains dark greendark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green
ZnFc (White)	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0° C
Amount of metal ferrocyanides = 20 mg
Volume of sulphuric acids = 10 mL

***Table 8**: Stability of metal ferrocyanides in nitric acid at room temperature*

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MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown particles did not change	Insoluble dark rust brown particles did not change	Insoluble dark rust brown particles did not change	Insoluble dark rust brown particles did not change	Insoluble dark rust brown particles did not change
LaFc (White)	Soluble solution turned green	Soluble solution faintly greens	soluble solution green	soluble solution green	soluble solution green
HgFc (Blue)	Slightly soluble solution turned green	Slightly soluble solution turned green	Slightly soluble solution turned green	Slightly soluble solution turned green	Slightly soluble solution turned green
MoFc (Green)	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear	Insoluble green powder did not change supernatant clear
AgFc (Light blue)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)
TiFc (Forest green)	Insoluble night green dark green	Insoluble dark green (no change)	Insoluble dark green (no change)	Insoluble dark green (no change)	Insoluble dark green (no change)
WFc (Dark green)	Insoluble particles remains dark greendark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains
ZnFc (White)	Insoluble white Particles Did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of nitric acids = 10 mL

***Table 9**: Stability of metal ferrocyanides in nitric acid at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turned Black	Insoluble dark rust brown Particles turned black	Insoluble dark rust brown Particles turned black	Insoluble dark rust brown Particles turned black	Insoluble dark rust brown Particles turned black
LaFc (White)	Soluble solution turned Brown	Soluble solution faintly greens	soluble solution green	soluble solution green	soluble solution green
HgFc (Blue)	Soluble solution turned green	Soluble solution turned green	Soluble solution turned green	Soluble solution turned green	Soluble solution turned green
MoFc (Green)	Insoluble green powder	Insoluble green powder	Insoluble green powder	Insoluble green powder	Insoluble green powder

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	did not change supernatant clear	did not change supernatant clear	did not change supernatant clear	did not change supernatant clear	did not change supernatant clear
AgFc (Light blue)	Insoluble light blue particles did not change	Insoluble light blue particles did not change	Insoluble light blue particles did not change	Insoluble light blue particles did not change	Insoluble light blue particles did not change
TiFc (Forest green)	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change
WFc (Dark green)	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green	Insoluble particles remains dark green
ZnFc (White)	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of nitric acids = 10 mL

***Table 10**: Stability of metal ferrocyanides in acetic acid at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change	Insoluble dark rust brown Particles did not change
LaFc (White)	Soluble white powder turned blue	Soluble white powder turned blue	soluble white powder turned blue	soluble white powder turned blue	soluble white powder turned blue
HgFc (Blue)	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change
MoFc (Green)	Insoluble green powder turned deep blue	Insoluble green powder turned deep blue	Insoluble green powder turned deep blue	Insoluble green powder turned deep blue	Insoluble green powder turned deep blue
AgFc (Light blue)	Insoluble light blue-blue green	Insoluble light green - (no change)	Insoluble light blue -light blue - (no change)	Insoluble -light blue - (no change)	Insoluble (no change)
TiFc (Forest green)	Insoluble forest green Particles change to dark green	Insoluble forest green Particles change to dark green	Insoluble forest green Particles change to dark green	Insoluble forest green Particles change to dark green	Insoluble forest green Particles change to dark green
WFc (Dark green)	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged

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ZnFc (White)	Insoluble white Particles Did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of acetic acids = 10 mL

***Table 11**: Stability of metal ferrocyanides in acetic acid at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turn black	Insoluble dark rust brown Particles turn black	Insoluble dark rust brown Particles turn black	Insoluble dark rust brown Particles turn black	Insoluble dark rust brown Particles turn black
LaFc (White)	Insoluble white powder turned blue	Insoluble white powder turned blue	Insoluble white powder turned blue	Insoluble white powder turned blue	Insoluble white powder turned blue
HgFc (Blue)	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change	Insoluble blue powder did not change
MoFc (Green)	Insoluble green powder turned deep blue	Insoluble green powder turned blue	Insoluble green powder turned blue	Insoluble green powder turned blue	Insoluble green powder turned blue
AgFc (Light blue)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)	Insoluble light blue (no change)
TiFc (Forest green)	Slightly insoluble forest green Particles change to dark green	Slightly insoluble forest green Particles change to dark green	Slightly insoluble forest green Particles change to dark green	Slightly insoluble forest green Particles change to dark green	Slightly insoluble forest green Particles change to dark green
WFc (Dark green)	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged	Insoluble dark green particles remain unchanged
ZnFc (White)	Insoluble white Particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green	Insoluble white particles turned light green

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of acetic acids = 10 mL

***Table 12**: Stability of metal ferrocyanides in sodium hydroxide at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M

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CuFc (Dark rust brown)	Insoluble dark brown Particles change to green	Insoluble dark brown Particles change to green	Insoluble dark brown Particles change to green	Insoluble dark brown Particles change to green	Insoluble dark brown Particles change to green
LaFc (White)	Slightly soluble white particles turned blue	Slightly soluble white particles turned blue	Slightly soluble white particles turned blue	Slightly soluble white particles turned blue	Slightly soluble white particles turned blue
HgFc (Blue)	Insoluble blue particles change to rust brown	Insoluble blue particles change to rust brown	Insoluble blue particles change to rust brown	Insoluble blue particles change to rust brown	Insoluble blue particles change to rust brown
MoFc (Green)	Insoluble green particles turned deep green	Insoluble green particles turned deep green	Insoluble green particles turned deep green	Insoluble green particles turned deep green	Insoluble green particles turned deep green
AgFc (Light blue)	Insoluble light blue Particles change to gray	Insoluble no change in colour	Insoluble light blue Particles change to black	Insoluble light blue Particles change to black	Insoluble light blue Particles change to black
TiFc (Forest green)	Insoluble forest green particles did not change	Insoluble forest green particles did not change	Insoluble forest green particles did not change	Insoluble forest green particles did not change	Insoluble forest green particles did not change
WFc (Dark green)	Insoluble dark green to black particles	Insoluble black particles	Insoluble black particles	Insoluble black particles	Insoluble black particles
ZnFc (White)	Soluble white particles	Slightly soluble white particles	Insoluble white particles	Insoluble white particles	Insoluble white particles

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of sodium hydroxide = 10 mL

***Table 13**: Stability of metal ferrocyanides in sodium hydroxide at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green
LaFc (White)	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change
HgFc (Blue)	Soluble blue powder turned brown	Soluble blue powder turned brown	Soluble blue powder turned green	Soluble blue powder turned green	Soluble blue powder turned green
MoFc (Green)	Soluble green powder turned brown	Soluble green powder turned brown	Soluble green powder turned brown	Soluble green powder turned brown	Soluble green powder turned blue
AgFc	Insoluble	Soluble	Soluble	Soluble	Soluble

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(Light blue)	light grayish peach-slate grey	Peach- black	Peach- black	Peach- black	Peach- black
TiFc (Forest green)	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change
WFc (Dark green)	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change
ZnFc (White)	Soluble white Particles Dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of sodium hydroxides = 10 mL

***Table 14**: Stability of metal ferrocyanides in potassium hydroxide at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green
LaFc (White)	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change
HgFc (Blue)	Insoluble blue powder turned brown	Insoluble blue powder turned brown	Insoluble blue powder turned green	Insoluble blue powder turned green	Insoluble blue powder turned green
MoFc (Green)	Insoluble green powder Turned brown	Insoluble green powder turned brown	Insoluble green powder turned brown	Insoluble green powder turned brown	Insoluble green powder turned blue
AgFc (Light blue)	Insoluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change
TiFc (Forest green)	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change	Insoluble forest green Particles did not change
WFc (Dark green)	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black
ZnFc					

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(White)	Soluble white Particles Dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of potassium hydroxides = 10 mL

***Table 15**: Stability of metal ferrocyanides in potassium hydroxide at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green
LaFc (White)	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change
HgFc (Blue)	Insoluble blue powder turned brown	Insoluble blue powder turned brown	Insoluble blue powder turned green	Insoluble blue powder turned green	Insoluble blue powder turned green
MoFc (Green)	Insoluble green powder turned brown	Insoluble green powder turned brown	Insoluble green powder turned brown	Insoluble green powder turned brown	Insoluble green powder turned blue
AgFc (Light blue)	Insoluble light blue Change to light grey	Soluble light blue change to light grey	Soluble light blue change to light grey	Soluble light blue change to light grey	Soluble light blue change to light grey
TiFc (Forest green)	Insoluble forest green colour did not change	Insoluble forest green colour did not change	Insoluble forest green colour did not change	Insoluble forest green colour did not change	Insoluble forest green colour did not change
WFc (Dark green)	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black	Insoluble dark green particles changed to dark greenish black
ZnFc (White)	Soluble white Particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved

OC = Original colour of metal ferrocyanides
Amount of metal ferrocyanides = 20 mg
Time: 20 minutes
Volume of potassium hydroxides = 10 mL
Room temperature = 31.0º C

***Table 16**: Stability of metal ferrocyanides in ammonium hydroxide at room temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust	Insoluble dark rust brown	Insoluble dark rust brown	Insoluble dark rust brown	Insoluble dark rust brown	Insoluble dark rust brown

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brown)	Particles turned green	Particles turned green	Particles turned green	Particles turned green	Particles turned green
LaFc (White)	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change
HgFc (Blue)	Soluble blue powder turned brown, supernatant brown	Soluble blue powder turned green, supernatant brown	Soluble blue powder turned green, supernatant slightly green	Soluble blue powder turned green, supernatant slightly green	Soluble blue powder turned green supernatant green
MoFc (Green)	Soluble green powder turned brown, supernatant brown	Soluble green powder turned brown supernatant brown	Soluble green powder turned brown supernatant light brown	Soluble green powder turned brown supernatant clear	Soluble green powder turned blue supernatant clear
AgFc (Light blue)	Insoluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change	Soluble light blue Particles did not change
TiFc (Forest green)	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow
WFc (Dark green)	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change
ZnFc (White)	Soluble white Particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of ammonium hydroxides = 10 mL

***Table 17**: Stability of metal ferrocyanides in ammonium hydroxide at boiling temperature*

MFcs (OC)	2.0 M	1.0 M	0.5 M	0.2 M	0.1 M
CuFc (Dark rust brown)	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green	Insoluble dark rust brown Particles turned green
LaFc (White)	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change	Insoluble white powder did not change
HgFc (Blue)	Slightly soluble blue powder Turned gold brown	Slightly soluble blue powder turned green,	Slightly soluble blue powder turned green,	Soluble blue powder turned green,	Soluble blue powder turnedgreen
MoFc (Green)	Soluble green powder	Soluble green powder	Soluble green powder	Soluble green powder	Soluble green powder

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	turned brown	turned brown	turned brown	turned brown	turned blue
AgFc (Light blue)	Partially soluble light blue to brown Particles change to light grey	Partially soluble light blue Particles change to light grey	Insoluble light blue Particles change to light grey	Insoluble light blue Particles change to light grey	Insoluble light blue
TiFc (Forest green)	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow	Insoluble forest green particles changed to light yellow
WFc (Dark green)	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change	Insoluble dark green particles did not change
ZnFc (White)	Soluble white Particles Dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved	Soluble white particles dissolved

OC = Original colour of metal ferrocyanides
Time: 20 minutes
Room temperature = 31.0º C
Amount of metal ferrocyanides = 20 mg
Volume of ammonium hydroxides = 10 mL

***Table 18**: Stability of metal ferrocyanides in sea water and tap water (at boilling and room temperature)*

MFcs (OC)	Tap water		Sea water	
	Room temperature	Boiling temperature	Room temperature	Boiling temperature
CuFc (dark rust brown)	Insoluble dark rust brown particles did not changed	Insoluble dark rust brown particles did not changed	Insoluble dark rust brown particles did not changed	Insoluble dark rust brown blue particles did not changed
LaFc (White)	Insoluble white powder did not changed	Insoluble white powder did not changed	Insoluble white powder did not changed	Insoluble white powder did not changed
HgFc (Blue)	Insoluble blue powder did not changed	Insoluble blue powder did not changed	Insoluble blue powder did not changed	Insoluble blue powder did not changed
MoFc (Green)	Insoluble green powder did not changed	Insoluble green powder did not changed	Insoluble green powder did not changed	Insoluble green powder did not changed
AgFc (Light blue)	Insoluble light blue particles did not changed	Insoluble light blue particles did not changed	Insoluble light blue particles did not changed	Insoluble light blue particles did not changed
TiFc (Forest green)	Insoluble forest green particles did not change	Insoluble forest green particles did not changed	Insoluble forest green particles did not changed	Insoluble forest green particles did not changed
WFc (Dark green)	Insoluble dark green Particles did not changed	Insoluble dark green particles did not changed	Insoluble dark green particles did not changed	Insoluble dark green particles did not changed

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ZnFc (White)	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not changed	Insoluble white particles did not change

***Table 19**: Effects of light (Visible) on the stability of metal ferrocyanides*

MFcs	Original colour	12 hrs	24 hrs	36 hrs	48 hrs
CuFc	Dark rust brown	Reddish brown	brown	brown	brown
LaFc	White	White	No change	No change	No change
HgFc	Blue	Green	No change	No change	No change
MoFc	Green	Green	No change	No change	No change
AgFc	Light blue	Dark blue	Dark blue	Blackish blue	Blackish blue
TiFc	Forest green	Forest green	Forest green	Light forest green	Light forest green
WFc	Dark green	Dark green	Dark green	Dark green	Dark green
ZnFc	White	White	White	Dark white	Dark white

Amount of metal ferrocynides = 20 mg
Distance of lamp from metal ferrocynides = 28 cm
Lamp = 250 Watts, Visible

***Table 20**: Effects of light (Ultra violet) on the stability of metal ferrocyanides*

MFcs	Original colour	12 hrs	24 hrs	36 hrs	48 hrs
CuFc	Dark rust brown	No change	No change	No change	No change
LaFc	White	No change	No change	No change	No change
MoFc	Green	Green	No change	No change	No change
HgFc	Blue	Green	No change	No change	No change
AgFc	Light blue	Dark blue	Blackish blue	Blackish blue	Blackish blue
TiFc	Forest green	Forest green	Light forest green	Light forest green	Light forest green
WFc	Dark green	Dark green	Dark blue	Dark blue	Dark blue
ZnFc	White	No change	Dark white	Dark white	Darker white

Amount of metal ferrocynides = 20 mg
Lamp = 220 Watts, UV, Longwave (380 nm)
Distance of lamp from metal ferrocynides = 28 cm

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