

RESULTS AND DISCUSSION

It should be noted that the selected methods used in this study to recover aluminum and iron metals by dissolving their samples in hydrochloric acid and precipitation by sodium hydroxide and then the precipitate was treated with certain reagents to produce the metal salts. This is considered the simplified method in this field. However, *Shilimkar et al. (2005)* showed different methods for the extraction of aluminum from associated elements with n-octylaniline from succinate media in the pH range of 1–10 in the presence of sodium succinate (0.04 M). Also, *Murayama et al. (2012)* reported another different method as they showed that the aluminum dross was effectively leached with hydrochloric acid and sodium hydroxide. It should be noted that using hydrochloric acid was effectively in dissolving the dross (65%), however sodium hydroxide showed lower metal dissolution (36%). On the other hand, *Sarangi et al. (2007)* showed that the extraction of iron from the leach liquor was carried out with different concentrations (0.5–2.5 M) of tributyl phosphate (TBP). *Li et al. (2010)* confirmed that the extraction of iron by hydrochloric acid was a better choice than ammonium oxalate (Tamm's reagent).

Aluminum Recovery

It has been noted that dissolving aluminum in hydrochloric acid to yield aluminum chloride, its concentration in mg/L was in the range of 128.03 to 1783.00 and the percentage was between 77.52 % and 90.67%. Table (6) shows the weights, and concentration of aluminum in the different collected samples.

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Table (6): Concentration of aluminum in different metal wastes

Sample no	Source	Wt(g)	Concentration (mg/L)	percentage (%)
1	Sprite can	0.2300	1783.00	77.52
2	Bireil can	0.0251	227.60	90.67
3	Aluminum foil	0.0145	128.03	88.30
4	Schweppes can	0.0571	419.20	73.42
5	Cocacola can	0.0279	230.38	82.57
6	Fanta can	0.0796	662.84	83.27

Hu et al. (2011) found that controlled laboratory pot furnace tests using base household waste with different aluminum packaging types (thin foils, foil containers and beverage cans) produced metallic aluminum with recovery rates between 77 wt.% and 93 wt.%. This is nearly similar to the present result.

The step in which aluminum is recovered from the collected samples as aluminum hydroxide is performed to separate the insoluble metal hydroxides from other impurities.

Aluminum hydroxide was dissolved in hydrochloric acid for detection of any metals that may be found using atomic absorption. The weights and concentration of the metals detected were illustrated in Table (7). It was found that the concentration of aluminum is 2886.7 mg/L and its percentage is 18.27%. The highest percentage next to that of aluminum was for iron possessing 0.15%, while the lowest one was for zinc calculated as 4.49×10^{-3} .

Table (7) : Metal concentration in the prepared salt solution

Metal	Concentration (mg/L)	Percentage (%)
Al	2886.70	18.27
Fe	24.20	0.15
Mg	14.50	0.09
Si	14.33	0.09
Cu	4.33	0.03
Zn	0.71	4.49×10^{-3}

Iron

The concentration in mg/L of iron samples which were dissolved in hydrochloric acid are shown in Table (8) and it was between 379.50 and 2155.00. The percentage was 74.56 % - 95.99 %.

Table (8): Concentration of iron in different metal wastes

Sample No	Source	Weight (g)	Concentration (mg/L)	Percentage (%)
1	Tuna can	0.2245	2155.00	95.99
2	Cover of Tomato paste bottle	0.1478	1120.00	75.78
3	Cover of juice bottle	0.1806	1645.50	91.11
4	Cover of honey bottle	0.0561	494.50	88.15
5	Collie	0.0935	836.50	89.47
6	Ring	0.0693	572.00	82.54
7	Hot dog can	0.0923	778.00	84.29
8	Cover of Jam bottle	0.0509	379.50	74.56

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Sarangi et al. (2007) by using a complex technique represented by different concentration of TBP observed that the percentage of iron extraction increased from 42.68 to 98.41% with increase in TBP concentration from 0.5 to 1.0 M. With further increase in TBP concentration to 1.25 and 2.5 M, the percentage extraction increased to 99.66 and 100%, respectively. However, using organic solvent has bad effect on environment which was avoided in this study.

However, *Li et al. (2010)* showed that the percentage of iron extracted by using hydrochloric acid was about 60–83% which is lower than the present study.

Iron was recovered as iron (III) hydroxide to separate it from the soluble metal hydroxides. On dissolving 0.68 g of iron (III) hydroxide in hydrochloric acid giving iron(III) chloride contains 4485 mg/L of iron and percentage is 65.96%. The elements found in the sample are calcium, silicon, manganese, magnesium as shown in Table (9).

Table (9): Metal concentration in the prepared salt solution.

Metal	Concentration (mg/L)	Percentage (%)
Fe	4485	65.95
Ca	18.10	0.27
Si	12.08	0.18
Mn	10.00	0.15
Mg	9.10	0.13

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According to the results in Tables (7) and (9) it was found that the shared metals present with both aluminum and iron were magnesium and silicon. The percentage of magnesium was 0.13% in iron sample whereas it was 0.09% in aluminum sample indicating that magnesium is higher in iron sample. However, the percentage of silicon was 0.18% and 0.09% in iron and aluminum samples respectively.

Production of metal salts

Production of aluminum salts:

The salts are produced by the reaction of aluminum hydroxide with sulphuric acid, hydrochloric acid, nitric acid, potassium sulphate, phosphoric acid and sodium hydroxide respectively forming aluminum sulphate, aluminum chloride, aluminum nitrate, potassium aluminum sulphate (alum), aluminum phosphate and sodium aluminate respectively. The reaction was carried out at room temperature. The concentration and the percentage of aluminum in the previous salts are shown in Table (10)

Table (10): The concentration and the percentage of aluminum in different salts

Aluminum salt	Weight of sample (g)	Concentration (mg/L)	Percentage (%)
$\text{Al}_2(\text{SO}_4)_3$	1.36	597.08	4.39
AlCl_3	1.31	573.65	4.38
$\text{Al}(\text{NO}_3)_3$	0.684	243.73	3.56
$\text{KAl}(\text{SO}_4)_2$	0.145	241.48	17
AlPO_4	0.682	245.18	3.56
NaAlO_2	0.167	168.03	10.06

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The weight of Al(OH)_3 used to prepare the salts was 0.567 g - 1.360 g. The atomic absorption showed that weight of aluminum in mg/L was between 168.03 and 597.08. The percentage of aluminum is ranged from 3.56 % to 17 %.

Production of iron (III) salts:

Using iron (III) hydroxide to produce iron (III) chloride, iron (III) sulphate, iron (III) nitrate, iron (III) phosphate, ammonium iron sulphate and potassium ferricyanide, by the reaction at room temperature with hydrochloric acid, sulphuric acid, nitric acid, phosphoric acid, ammonium sulphate and potassium cyanide respectively. The concentration and the percentage of these salts are shown in Table (11).

Table (11): The concentration and the percentage of iron in different salts

Iron salt	Weight of sample (g)	Concentration (mg/L)	Percentage (%)
FeCl_3	3.123	10985	35.18
$\text{Fe}_2(\text{SO}_4)_3$	1.909	5955	31.19
$\text{Fe}(\text{NO}_3)_3$	0.112	684	61.07
FePO_4	0.145	591	40.76
$\text{NH}_4\text{Fe}(\text{SO}_4)_2$	0.156	822	52.69
$\text{K}_2[\text{Fe}(\text{CN})_6]$	0.135	683	50.59

The weight of iron (III) hydroxide is ranged between 0.112 g and 3.1228 g, the concentration of the salts is between 591 mg/L and 10985 mg/L. The percentage of iron is calculated and is found between 31.19 % and 61.07 % .

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In the present study, the production of the aluminum and iron salts, which are aluminum sulphate, aluminum chloride aluminum nitrate, aluminum phosphate, iron (III) chloride, iron (III) sulphate, iron (III) nitrate, iron (III) phosphate and potassium ferricyanide, respectively are produced by simplified chemical methods and the reagents used in the production are available and non expensive. As far as known *Shilimkar et al. (2005)*, *Saranghi et al. (2007)*, *Li et al. (2010)*, *Hu et al. (2011)* and *Murayama et al. (2012)* extracted only aluminum and iron without producing their salts.

The percentages of aluminum and iron in their salts were obtained by atomic absorption which is considered as a quantitative method for detection of metals in their salts. The qualitative analysis was showed by Vogel (1996) for detection of aluminum and iron in their salts using suitable reagents to give a characteristic result for each metal in its salt. He detected aluminum by several reagents such as ammonia solution in presence of ammonium chloride giving a white gelatinous precipitate, sodium hydroxide forming a white precipitate which is soluble in excess, aluminon reagent (triammonium aurine tricarboxylate) resulting a bright-red complex or lake and alizarin red S (sodium alizarin sulphonate) giving red precipitate or lake. On the other hand, Vogel detected iron (III) in its salts using the suitable reagents such as ammonia solution giving a reddish brown gelatinous precipitate insoluble in excess reagent but soluble in acids, sodium hydroxide solution forming a reddish brown precipitate insoluble in excess reagent, ammonium sulphide solution forming a black precipitate, potassium hexacyanoferrate (III) producing a brown colouration, disodium hydrogen phosphate solution forming a yellowish white precipitate, sodium acetate solution giving a reddish

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brown precipitate and ammonium thiocyanate solution forming a deep red colouration.

In respect to iron (II) salts, they should be prepared in a medium of hydrogen gas which was formed by adding zinc to hydrochloric acid to prevent formation of iron (III) salts.

In conclusion, the percentages obtained for aluminum and iron, and the salts produced by the simplified method performed in this study could be used for qualitative and quantitative analysis which is carried out by undergraduates and school students to identify the metal or using them to detect others. The school students mostly detect aluminum and iron using a qualitative analysis to identify them, while the both qualitative and quantitative analysis are applied in the scientific colleges and institutes. Moreover, the method performed in this study also help the students and undergraduates to produce the products in the faculty and school laboratories from MSW available in their places which contain aluminum and iron resources. This will save governmental financing supplies to buy these chemicals as well as the cost of production. On the other hand, the main purpose of this study to protect environment from MSW and save the resources of the metals.

The simple chemical methods used in this study will help the production of the salts as commercial products for school, scientific college and institute laboratories. This will support and develop the educational skills of students and the scientific applications. Also, the students will develop their scientific thinking by performing the practical work in the laboratory.

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From economic point of view, the price in Egyptian market for one ton of scrap aluminum is about L. E. 9000 while for the same amount of scrap iron is nearly L.E. 2500. Taking one chemical product as example of aluminum or iron, the price of hydrated aluminum chloride $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ is L.E/kg 110 . The percentage of aluminum (atomic weight is 27) according to the molecular formula is 11.18 % equivalent to L. E. 12.30, while the price of one kilogram of the scrap aluminum is L. E. 9. For hydrated iron III chloride $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ is L. E./kg 82 and the percentage of iron (atomic weight is 56) according to the molecular formula is 20.7 % equivalent to L. E. 17 (price of 1 kg of scrap iron is about L. E. 2.5P). From this economic point of view, it is found that there is a great difference in the cost of production of these compounds which supports the recovering of these two metals from the MSW and utilizing them in production of the chemical compounds.

MATERIALS AND METHODS

1. Chemicals used

1. Product of El-Nasr Pharmaceutical Chemical Co:
hydrochloric acid (30-40%).
2. Products of El-Salam for Chemical Industry:
sulphuric acid ((M.W. 98, 96-98%) - nitric acid (55%, M.W. 63.01).
3. Product of alpha aromatic chemicals :
phosphoric acid (85%, M.W. 98).
4. Product of united company for chemicals:
sodium hydroxide M.W. 40.
5. Product of Edwic:
hydrogen peroxide M.W 34.01, 30% W/V.
6. Products of bio chem. for lab. fine chemicals:
potassium sulphate, ammonium sulphate and ammonium chloride.
7. Products of gen lab:
potassium cyanide and ammonium hydroxide (M.W. 17.03, 25%).

2. Metal collection and washing:

Samples of MSW were collected and sorted from different places such as schools, houses, parks, containing iron and aluminum cans, covers, and others.

Samples were classified into two parts the first one contains aluminum waste and the second contains iron waste and carried to convert chemical laboratory at Faculty of Science, Ain Shams University.

3. The first stage: Determination of percentage of the metal in the sample:

3.1. Samples preparation:

1. All samples were prepared for dissolution in hydrochloric acid (HCl) by removing the painting material used for coating the metal samples using sandpaper, then washed by distilled water and dried in oven (WST 3010).
2. Solid aluminum and iron samples were cut into small pieces using scissor and weighed by analytical balance (Denver) to determine each sample before dissolution in HCl.
3. Each sample of aluminum or iron was placed in a beaker followed by adding of about 10 -20 ml concentrated HCl for each sample and left on hot plate (BEC) in the cupboard until reaching dissolution, then dryness.
4. After dissolution of aluminum sample a polymeric substance appeared then removed by filtration and discarded.
5. For three times each of aluminum or iron samples was washed and left to dry by using the hot plate to remove traces of HCl.
6. The samples were dissolved in distilled water and transferred to a measuring flask and completed to 100 ml distilled water.
7. These solutions were analyzed by atomic absorption (Savanta, GBC scientific equipment) to determine the percentage of aluminum or iron.

4. The second stage: Recovering of the metals

4.1. Preparation of aluminum hydroxide:

1. Concerning aluminum chloride AlCl_3 solution, a solution of ammonium hydroxide NH_4OH (25 %) in presence of ammonium

chloride is added till complete precipitation of aluminum hydroxide.

2. 1.58 g of $\text{Al}(\text{OH})_3$ was dissolved in 15 ml HCl and completed to 100 ml by distilled water to detect any metals found by atomic absorption.

4.2. Preparation of iron (III) hydroxide:

1. A concentrated solution of sodium hydroxide NaOH was added to iron (II) chloride FeCl_2 solution prepared in the first stage, till complete precipitation of iron (II) hydroxide which is oxidized to iron (III) hydroxide $\text{Fe}(\text{OH})_3 \cdot x\text{H}_2\text{O}$ using hydrogen peroxide H_2O_2 (30 % W/V).
2. 0.68 g of $\text{Fe}(\text{OH})_3$ was dissolved in HCl acid and completed to 100 ml by distilled water for detection which of meals may be found by atomic absorption.

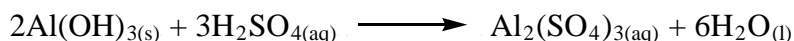
5. The third stage: preparation of aluminum and iron salts:

5.1. Preparation of aluminum salts:

Aluminum hydroxide was divided into five parts for preparation of the aluminum salts which are aluminum sulphate, aluminum chloride, aluminum phosphate and aluminum nitrate.

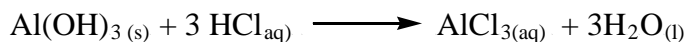
Aluminum sulphate $\text{Al}_2(\text{SO}_4)_3$:

By dissolving 1.36 g aluminum hydroxide in 10 ml sulphuric acid (96-98%) at room temperature according to the following equation



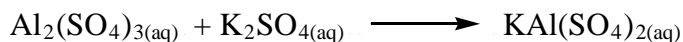
Aluminum chloride (AlCl₃):

By adding 10 ml of hydrochloric acid (30-40%) to 1.31g of aluminum hydroxide at room temperature according to the following equation:



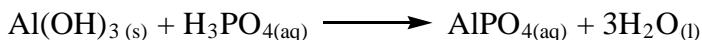
Potassium aluminum sulphate (alum) KAl(SO₄)₂:

On addition of 10 ml of sulphuric acid ((96-98%)) to 0.145 g of aluminum hydroxide. Then the produced aluminum sulphate Al₂(SO₄)₃ was reacted with potassium sulphate solution K₂SO₄ according to the following equation:



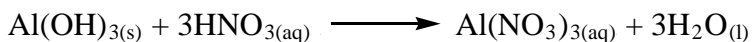
Aluminum phosphate AlPO₄:

It was prepared by addition of 10 ml of phosphoric acid (85%) to 0.682 g of aluminum hydroxide at room temperature.



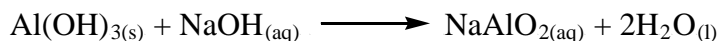
Aluminum nitrate Al(NO₃)₃:

It was prepared using 10 ml of nitric acid (55%) with 0.684 g aluminum hydroxide at room temperature



Sodium aluminate NaAlO₂:

By adding 10 ml of concentrated solution of sodium hydroxide to 0.167 g of aluminum hydroxide



5.2. Preparation of iron (III) salts:

Iron (III) hydroxide was divided into six parts for preparation of iron (III) salts which are iron (III) chloride, iron (III) sulphate, iron (III) nitrate, iron (III) phosphate, ammonium iron (III) sulphate and potassium ferricyanide.

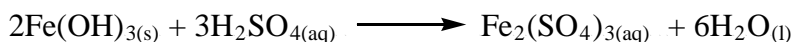
Iron (III) chloride (FeCl₃):

It was prepared by reacting of 3.123 g of iron (III) hydroxide Fe(OH)₃ with 10 ml of hydrochloric acid (30-40 %).



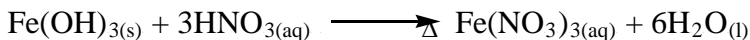
Iron (III) sulphate Fe₂(SO₄)₃:

It was prepared by adding of 1.909 g iron (III) hydroxide to 10 ml of sulfuric acid (69-98 %).



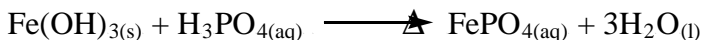
Iron (III) nitrate (Fe(NO₃)₃):

The salt was prepared by heating 10 ml of nitric acid (55 %) with 0.112 g iron (III) hydroxide



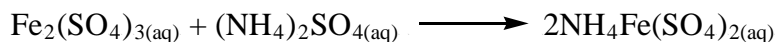
Iron (III) phosphate (FePO₄):

By heating 10 ml of phosphoric acid (85 %) with 0.145 g iron (III) hydroxide.



Ammonium iron (III) sulphate $\text{NH}_4\text{Fe}(\text{SO}_4)_2$:

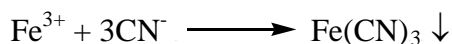
By reacting 0.156 g of Iron (III) hydroxide with 10 ml sulphuric (96–98 %) acid. Then by addition of 10 ml ammonium sulphate to iron (III) sulphate



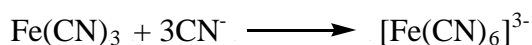
Potassium ferricyanide (potassium hexacyanoferrate (III))

$\text{K}_3[\text{Fe}(\text{CN})_6]$:

By reacting 0.135 g of iron (III) hydroxide with 10 ml hydrochloric acid followed by addition of Potassium cyanide slowly to iron (III) chloride forming reddish brown precipitate of iron (III) cyanide



Excess potassium cyanide was added the precipitate dissolves giving a yellow solution of hexacyanoferrate (III) ions:



The above mentioned reactions should be carried out in a fume cupboard as the free acid present in the iron (III) chloride solution forms hydrogen cyanide gas:

