

# Regeneration of Metallic Aluminum from Discarded Polycarbonate Compact Disc with Chemical Stripping, Precipitation and Titrimetric Quantification.

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**Abstract:** There was successful retrieval of metallic aluminum from discarded compact discs in the presence of an active alkaline stripping solution (sodium hydroxide, sodium phosphate, and sodium carbonate) with sodium lauryl sulphate as a viscosity modifier at 80°C and 20KHz ultrasonic frequency. At standard conditions and precautions, the qualitative and quantitative isolation of metallic aluminum with sodium hydroxide/ammonia solutions and 0.5M sulphuric acid yields 0.012Molar, 0.0953g/mol, and 21.99% aluminum salt from 10g of compact disc materials.

**Keywords:** Aluminum, compact disc, chemical stripping, Sodium hydroxide and sulphuric acid.

## 1.0 INTRODUCTION

The compact audio disc was first presented to the world in the early 1980s by the Dutch (Philips) and Japanese industries (Sony) [1]. Since then, the applications with discs have expanded into the fields of text, motion pictures, and computer data storage and programming. Compact discs have grown in popularity among consumers due to their ability to store large amounts of data in smaller sizes than other types of magnetic storage media. The use of specific polycarbonate resins with features like remarkable clarity and light transmittance, fast melt flow rates, low moisture absorption, and significant impact strength is critical to the disc functionality [2].

Worldwide production has increased significantly in the last few years as the advances in compact disc technology have created a higher demand for superior-quality products, which has placed a more challenging role on the plastics industry [3].

Due to the complex manufacturing process, it has been estimated that approximately 10% of all CDs manufactured

are rejected, as more than two billion polycarbonate compact discs are manufactured each year, and around 150–200 million CDs are scrapped annually due to rejects [4].

They are also destroyed because of the artist's rights issues, as unsold copies are destroyed, with possible injuries on the surface. Consequently, CDs are currently being reclaimed to produce grades of recycled poly carbonate (PC) and are typically landfilled or granulated and sold back to the resin supplier at a nominal price [5]. However, their nature does not allow them to be easily recycled [5].

As depicted in Figure 1, a compact disc is a multi-layer product consisting of a thermoplastic substrate and three coatings. These coatings, aluminum, lacquer, and printing, make up only a small portion of the entire disc. The aluminum coating is only 55–70 nm thick, and the lacquer and printing account for approximately 20 microns of the overall thickness [6]. Meanwhile, in order to recover the full properties of the polycarbonate, these coatings must be removed prior to recycling [7].

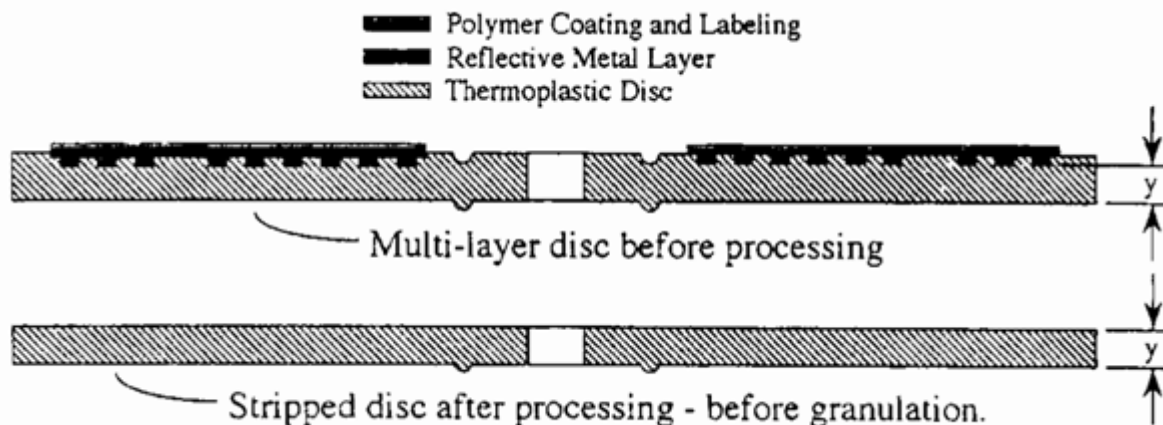


Figure 1. A model of thermoplastic compact disc before and after stripping.



Figure 2. Compact and DVD discs

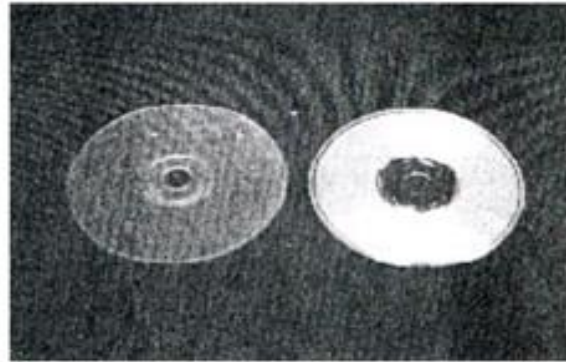


Figure 2. Stripped and unstripped discs

A compact disc is comparable to a digital video disc, except that compact disc has an advanced data capacity of almost seven times that of a CD. They both employ the same technology, but for different applications, as DVDs are used for memory-intensive visual movies and CDs are used for music [8]. DVDs have the same thickness and dimensions as compact discs, with similar materials and production techniques [8].

The inner layers are protected by aluminum, but the outer layers are protected by a thin layer of gold that allows the laser to concentrate on the external and internal layers. Each layer that is individually coated with lacquer was homogenized and preserved under infrared radiation to make a single disc [4].

Polycarbonate, the main plastic of CDs, is quite valuable and the gold used in gold CD-R is real gold. However, it is a fraction of 80 nm thickness which can give only a few grams from a slew of discs [4]. With a large number of CDs, it is worth getting in touch with a local recycling plant as the scrap may have some value with significant global pollution management and control.

There are established methods for the removal of paint or plating from engineering plastics. Such techniques include chemical stripping or chemical recovery (high-temperature alkaline treatment) [9], mechanical abrasion [10], melt filtration [11], hydrolysis [12], compressed vibration [13], liquid cyclone [14], dry crushing [15], cryogenic grinding [16] and roller pressing [17].

Similarly, Fennhoff *et al.* (1993) introduced a process for the purification of waste thermoplastics, especially compact disc waste. This process was developed and patented by Bayer Corporation in Dormagen, Germany. In this process, the compact discs are reduced to fragments with a mean diameter of 0.1 cm to 5 cm, preferably 0.5 cm to 1.5 cm. Then the fragments are immersed in a tank containing a 5% sodium hydroxide solution for 90 minutes at temperatures ranging from 70 °C to 95 °C. This alkaline bath breaks down the lacquer and dissolves and separates the aluminum from the polycarbonate.

After draining the NaOH solution, the polycarbonate is washed with 10% acetic acid, then softened water until the pH

is neutral and any lacquer residues are rinsed out [6]. Coatings are most often stripped from engineering plastics using proprietary solutions based on alkaline cleaners and inorganic salts, and this is generally performed at elevated temperatures, such as chemical stripping to remove coatings from a polymer [4].

Martins *et al.* 2020 presented a comparison between two mechanical techniques for recycling aluminum/copper alloy from coaxial cables using comminution, centrifuging, and electrostatic separation with respect to roll speed, electrostatic electrode distance, voltage electrodes, and splitter angle.

In the interest of economy and concept, the process was concluded to be more sustainable with coaxial cable recycling and the regeneration of aluminum from cables, with an optimum purity of 99.51 %, process efficiency of 94.53%, purity of 96.79% with copper-steel alloy and a recovery rate of 99.68% [18].

Mahmoud and Farghaly, 2021, recovered aluminum from the standard alloy of aluminum, copper, zinc, and magnesium through turning scrap using the hydrometallurgy method. The technique uses H<sub>2</sub>O<sub>2</sub> with ammonia/ammonium carbonate to selectively leach copper through reduction with hydrazine hydrate solution to recover free metallic radicals from the leached solution [19].

Gioia *et al.* (2016) also discovered some unique procedures for the recycling process of bisphenol A polycarbonate (PC) directly from post-consumer compact discs. According to them, the preliminary reprocessing method is a function of renewable molecules such as succinic acid, isosorbide, and ethylene carbonate. And as the final procedure with a direct reaction of post-consumer polycarbonate as treated with ethylene carbonate, does not completely break down to light molecular mass components, the resulting polymers have characteristics that make them acceptable for powder coating applications [20].

Additionally, according to Barrios *et al.* (2015), conventional polycarbonate DVD/CD surface coatings can induce remarkable adhesion with aluminum films that is both active enough to allow aluminum film nanopatterning and weak enough to allow Scotch tape dissociation of

nanopatterned aluminum films. Distributed aluminum on nanohole networks on Scotch tape provides excellent plasmonic and optical characteristics [21].

In this context, we regenerated metallic aluminum from discarded polycarbonate compact discs with a relatively concentrated alkaline solution and subsequent precipitation with sodium carbonate under specified analytical conditions, with the final quantitative yield under specified conditions.

## 2.0 MATERIALS AND METHOD

Wasted compact discs have a protective lacquer coating over an aluminum coating and are locally sourced. 0.8M NaOH, improvised steel reactor, magnetic heating mantle, sonicator, 0.5M solution H<sub>2</sub>SO<sub>4</sub>, sodium phosphate, acetic acid, sodium lauryl sulfate, distilled water, and drying cabinet

### 2.1 Alkaline stripping of Metallic Aluminum

Shredded compact discs (10g) were placed in a 2-liter glass beaker containing an aqueous mixture of sodium hydroxide (50g/l), sodium phosphate (50g/l), and sodium carbonate (100g/l) with sodium lauryl sulfate (1g/l) as a viscosity modifier between 40 and 50 dynes/cm. The solution was raised to a temperature of 80°C and subjected to one kilowatt of ultrasonic energy at a frequency of 20 kHz. The lacquer coating was stripped, and the aluminum coating dissolved, in about one hour [22].

### 2.2 Confirmatory test for aluminum in solution

The existence of Al<sup>3+</sup> in solution can be detected using either the sodium hydroxide (NaOH) or the ammonia (NH<sub>3</sub>) test. [23].

## 3.0 RESULTS AND DISCUSSION

Table 1. Qualitative (confirmatory) analysis of aluminum ions in a stripped solution.

Test	Observation	Inference
(a) Few drops of 0.5M NaOH solution were added to some quantity of the stripped solution in a test tube.	There was a development of white precipitate.	Al ions was suspected.
(b) Few drops of ammonia solution were added to another test tube with some quantity of the stripped solution.	There was also a formation of white precipitate.	Al ions was again suspected.
(c) Excess 0.5M NaOH solution was added to the solution (a) above.	The white precipitate disappeared.	Al ions was confirmed.

Table 2. Titrimetric analysis of aluminum salt with a standard sodium carbonate

Burette reading (ml)	0.4M sodium carbonate				
	1 <sup>st</sup> Titre	2 <sup>nd</sup> Titre	3 <sup>rd</sup> Titre	4 <sup>th</sup> Titre	5 <sup>th</sup> Titre

### 2.2 Extraction and precipitation of metallic Aluminum from stripped solution

The dissolved salt is transformed to a carbonate in the excess of sodium carbonate in order to neutralize any acidic fraction and precipitate as aluminum carbonate. The gelatinous white insoluble carbonate is filtered and washed multiple times with hot water to separate it from the soluble reagents. After that, the filter paper and carbonate are transferred to a beaker with 20 mL of water. With an acid indicator, the beaker is warmed with diluted hydrochloric acid, dropping wisely till all the white precipitate is dissolved. Finally, a diluted and standard solution of NaCO<sub>3</sub> is introduced to the clear solution while constantly mixing until traces of white aluminum carbonate remain undissolved even after boiling. [24]

### 2.3 Quantitative determination of Aluminum salt with a standard (0.4M) sodium carbonate

A 0.4M solution of NaCO<sub>3</sub> is titrated with an aluminum salt solution made in a 100ml volumetric flask and diluted with water to the desired concentration. The amount of NaCO<sub>3</sub> that hasn't been reacted with is calculated. The amount of aluminum present is shown in the difference between the two sodium carbonate values. [25].

### 2.4 Titration of Unreacted Sodium Carbonate Solution

In the burette, 0.5M sulphuric acid is transferred, and 25ml of the freshly filtered excess Sodium Carbonate solution is transferred to two or three tiny flasks, depending on the amount gathered. It is indicated how much carbonate was used in the titration. The 0.5 Sulphuric Acid is used to titrate the NaCO<sub>3</sub> in the flasks with 4 drops of Bromocresol Purple indicator [26].

Final	33.80	33.95	33.93	29.43	37.03
Initial	0.00	0.00	0.00	21.82	29.43
Actual	33.94	33.95	33.93	33.94	33.94

Table 3. Titrimetric analysis Unreacted Sodium Carbonate Solution

Burette reading (ml)	0.5M sulphuric acid				
	1 <sup>st</sup> Titre	2 <sup>nd</sup> Titre	3 <sup>rd</sup> Titre	4 <sup>th</sup> Titre	5 <sup>th</sup> Titre
Final	10.78	21.59	32.37	43.18	11.00
Initial	0.00	10.78	21.59	32.37	0.00
Actual	10.80	10.81	10.78	10.81	11.00



According to dilution theory;

$$C_a V_a = C_b V_b$$

$$0.5 \times 10.84 = C_b \times 25$$

$$C_b = \frac{0.5 \times 10.84}{25}$$

$$25$$

$$C_b = 0.2168 \approx 0.2\text{M}$$

Table 4. Descriptive statistics of the titrations

Parameter	Titrimetric analysis of Aluminum salt with a standard sodium carbonate	Titrimetric analysis Unreacted Sodium Carbonate Solution
Mean titre volume	33.94	10.84
Standard Error	0.003	0.040
Median	33.94	10.81
Mode	33.94	10.81
Standard Deviation	0.001	0.09
Sample Variance	5E-05	0.01
Kurtosis	2.00	4.66
Skewness	2.51243E-12	2.13
Range	0.02	0.22
Minimum	33.93	10.78
Maximum	33.95	11.00
Sum	169.70	54.20
Count	5.00	5.00
Confidence Level at 95.0%	0.01	0.11

Table 3. Quantitative estimations of Aluminum from its solution

	Relationship	Value
Aluminum salt [Molarity] (M)	$\text{Molarity} = \frac{M_{\text{NaCO}_3} \times V_{\text{NaCO}_3} - [V_1/V_2 (A_{\text{Mol}} \times \text{Vol}_{\text{titre}})]}{R_f \times \text{Vol}_{\text{Al}}}$	0.012
Aluminum salt [Weight] (gram)	$\text{Weight} = \frac{\text{Vol}_{\text{Al}} \times M_{\text{Al}} \times \text{RMM}_{\text{Al}}}{1000}$	0.0953
Aluminum salt (%)	$\% \text{ Al} = \frac{\text{Vol}_{\text{Al}} \times M_{\text{Al}} \times 27 \times \text{Al}_{\text{factor}}}{10 \times M_{\text{sample}}}$	21.99

Where;

$$M_{\text{Al}} \text{ (Molarity of aluminum sample salt)} = 0.012 \text{ M}$$

$$M_{\text{NaCO}_3} \text{ (Molarity of sodium carbonate solution)} = 0.4\text{M}$$

$$V_{\text{NaCO}_3} \text{ (Volume of sodium carbonate reacted with aluminum salt)} = 25\text{ml}$$

$V_1$  (Volume of excess sodium carbonate gathered in volumetric flask) = 98ml

$V_2$  (Volume of excess sodium carbonate used for titration) = 53.8ml

$A_{Mol}$  (Molarity of acid) = 0.5M

$Vol_{titre}$  (Volume of titre) = 10.84ml

$R_f$  (Ratio factor) = 1.5

$Vol_{Al}$  (Volume of aluminum salt reacted with sodium carbonate) = 33.94ml

$RMM_{Al}$  (Relative molecular mass of aluminum salt used) = 233.99g/mol

$Al_{factor}$  (Number of aluminum atoms found in its compound salt) = 2

$M_{sample}$  (Original mass of the sample) = 10g

Theoretically, sodium carbonate will neutralize all excess acidic activity with simultaneous precipitation of aluminum carbonate, as it is critical that all aluminum be converted to solid carbonate, and to ensure that no aluminum salt remains, more carbonate solution is reacted with the filtered solution; if otherwise, no aluminum is present. [24].

The established qualitative and quantitative tests were declared on table 1,2 and 3 accordingly with the statistical backup information on table 4. The qualitative analysis with the 0.5M NaOH and  $NH_3$  solutions against the isolated stripped aluminum solution confirmed the activity of aluminum ions. Similarly, the quantification of the same metallic ion against the standard 0.4M  $Na_2CO_3$  with the average actual titre volume of 33.94ml yields 0.012Molar concentration, 0.0953g/mol and 21.99% per 10g of Aluminum salt as  $Al_2CO_3$  from shredded compact discs. However, the unreacted  $Na_2CO_3$  solution from its excessive portion was calculated from the reaction with 10.84ml of 0.5M  $H_2SO_4$  to be approximately 0.2M.

#### 4.0 CONCLUSION

The outcome in this project shows that chemical treatment of compact disc would require a pre-separation process that will allow for the effective recovery of aluminum, and deactivation of the organic component of the polycarbonate fraction of the CD material. However, the percentage recovery with this approach is obviously insignificant and this makes the recovery from scrapped CDs economically unattractive and energy consuming [27].

Therefore, research methods that will enhance the process optimization with the substantiate yield of the metallic aluminum should be encouraged as recycling of compact disc in the nearest future could be considered as the production and waste generation of these resources are rapidly increasing.

**Conflict of interest:** None

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