The synthesis and characterization of rare-earth hydroxide as a processed result of monazite sand

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Abstract. The synthesis and characterization of rare-earth hydroxide as a processed result of monazite sand processing have been carried out. The synthesis and characterization of rare-earth hydroxide originating from monazite sand processing are necessary to support the pilot plant activity of rare earth hydroxide produced in the Center of Nuclear Mines Technology BATAN. Rare-earth hydroxide is produced through several stages of the process, namely decomposition of monazite sand with NaOH at 140 °C, partial dissolution with HCl at 80 °C, uranium and thorium deposition, and rare-earth hydroxide deposition with NH4OH. The rare-earth precipitate was dried in an oven at 110 °C. The rare-earth hydroxide produced is characterized and certified. The rare-earth hydroxide powder is homogenized, then a homogeneous test, stabilization test, and characterization test are conducted. In the evaluation of data obtained the rare earth hydroxide that has been homogeneous, stable, contains the minerals of perovskite (La0.18Si0.8CrO3), villiaumite (NaF), calcium aluminum silicate (CaAl2SiO7), breidigite (Ca3.5Mg0.8Mn0.6Si0.6O12), and cesium sodium uranium chloride (CsNaUCl6). Certificate of parametric test results in rare-earth hydroxide from 10 laboratories accredited with statistical methods obtained 8 rare earth elements, ie Ce: (27.670 ± 3.004) %, La: (13.846 ± 1.503) %, Nd: (8.447 ± 0.816) %, Y: (1.667 ± 0.140) %, Pr: (6.254 ± 0.286) %, Sm: (1.496 ± 0.330) %, Gd: (0.994 ± 0.211) % and Dy: (0.172 ± 0.005) %. Compared with the rare earth hydroxide product of Myanmar, in the rare earth hydroxide the result from Indonesian monazite sand, Pr content higher, but for Ce, La, Nd contents is lower.

1. Introduction
Rare earth elements have excellent chemical properties which are indispensable in high-tech fields, such as electronic and opt electric and in the production of high-intensity magnets and rare earth-nickel based alloys in high capacity nickel-metal hydride batteries used in electric-powered vehicles. The term rare earth refers to a group of fifteen elements, including those with atomic numbers 57(La) to 71(Lu), as well as yttrium (39) and scandium (21). These elements have varied applications in products of everyday use and also in advanced scientific research [1]. Rare earth compounds possess wide applications in high-performance luminescent devices, magnets, catalysts, and other functional materials because of their unique physical and chemical properties originating from the 4f shell of electrons. Most of these properties are highly sensitive to the composition and structure, especially to the complexation state and the crystal field of the matrix in which rare-earth ions are trapped [2]. Rare
Rare earth elements are often found together in nature at low concentrations in various minerals. About 95% of the rare-earth occur in only three minerals: bastnasite, monazite, and xenotime [3].

Rare earth elements have special properties, so they have a wide range of applications in several high technologies and industries. However, there are many domains for their uses at present which involve metallurgy, catalysts, ceramics and glass, magnets, electronics, optical and medical devices, space instrument and nuclear technologies [4]. Rare earth oxides in the composition of phosphors emitting wavelengths of red, blue and green, so they are mainly used in Cathode Ray Tubes as in color television screens and color monitors, X-Ray screens and fluorescent lamps [5]. Yttrium oxide has a high melting point, so it was used in advanced ceramic compounds for special temperature applications such as windows for furnaces, microscope lenses (for the study of molten material) and crucibles for vacuum melting of reactive materials like titanium. On the other hand, yttrium oxide is added as a sintering agent to SiAlON (silicon-nitride-based strongest ceramic material) [4].

Since the discovery of the carbon nanotubes (CNT), the one-dimensional (1D) nanostructures such as nanowires, nanorods, nanotubes, and nanobelt have been developed widely in mesoscopic physics and play an important role as an active component in the preparation of nanoscale electronic, optical, optoelectronic, electrochemical and electromechanical devices [5]. In particular, the use of one-dimensional nanostructures as a precursor for preparing the nanomaterial news for applications in many fields of solar energy converters, energy storage, fluorescent lighting and high-performance displays, chemical catalysis, biological labeling, bioimaging, and therapy are attracting the interest of many research groups [5].

Two of the important rare-earth minerals produced are monazite and xenotime. Monazite (Ce, La, Th)PO4 is a phosphate mineral comprises mainly of the light rare earth elements especially Ce, La, Nd, and Pr. The mineral also contains a considerable amount of heavy rare-earth elements notably yttrium and naturally occurring radioactive elements thorium and uranium. The composition of monazite, Mongmit Myitsone Myanmar is CeO2, La2O3, Nd2O3, Y2O3, ThO2, P2O5, Pr6O11, Sm2O3, Gd2O3, Dy2O3, SiO2, SiO2, etc. This research work involves digestion of monazite, removing the uranium, thorium and other impurities by using ammonium hydroxide, selective precipitation of rare earth hydroxide [1]. Rare-earth hydroxide (REOH) was a monazite process product containing rare earth elements namely Ce, La, Nd, Pr, Y, Sm, and Gd [6]. The characterization study determines the property values as part of the certification process. A homogeneity study is necessary for certification projects to demonstrate that the batch of bottles (units) is sufficiently homogeneous [7,2]. In the previous studies, for the certification of the rare earth hydroxide was carried out by statistic method. Whereas in this study to test the homogeneity and stability of the rare-earth hydroxide was made by ISO 13528-2008 [8,9]. The rare-earth hydroxide was characterized by XRF and XRD[9].

2. Experimental Section

2.1. Materials
Indonesian monazite sand from Bangka, rare earth hydroxide as the processed result of monazite sand, concentrated hydrochloric acid, ammonia, NaOH, and cerium oxide in-house CRM.

2.2. Instrumentation
A set of tools XRF spectrometer, XRD, scales, sample containers, ball mill, a sieve size of 200 mesh, beaker, magnetic stirrer, oven, mortar, and pestle.

2.3. The synthesis of rare-earth hydroxide
In this study, Indonesian monazite sand from Bangka was used as raw material. Rare earth hydroxide was made through several stages of the process namely monazite sand decomposition, partial dissolution, uranium and thorium deposition, and rare earth hydroxide deposition.
2.3.1. **Decomposition.** Sodium hydroxide (NaOH) dissolved in 750 ml of water in a 3 L beaker, monazite sand was added and heated at 140 °C for 2 hours. The decomposed sludge is washed with hot water at pH 8, then dried at 110 °C.

2.3.2. **Partial Dissolution.** The decomposed sludge and water are put into a 3 L beaker, stirred until homogeneous, HCl is added slowly to pH 3.7, at 80 °C for 1 hour. Added the water (pH 3.7), then do the separation of the solid sludge from the liquid with a vacuum pump. The precipitate of the partial dissolution is washed with water pH 3.7, dried at 110 °C.

2.3.3. **Partial precipitation (U and Th precipitation).** The partial dissolving filtrate was put into the 3L beaker, added NH\(_4\)OH slowly until the pH of the solution was 6.3, carried out the separation of liquid-solid with the vacuum pump, the precipitate was dried at 110 °C.

2.3.4. **Total Deposition (rare earth hydroxide deposition).** The partial filtrate deposited into the 3 L beaker, added NH\(_4\)OH slowly to a pH of 9.8 solution, separating solids from the liquid with a vacuum pump. The precipitate is dried at a temperature of 110 °C. These deposits are rare earth hydroxides.

2.4. **The homogenization test**

Randomly was taken 10 subsamples. Specified types of analytes that represent the macroelements and microelements for each type of analyte, to 10 subsamples were analyzed in the same laboratory, by the same analyst, using the same equipment and the same day. The analysis was performed in duplicate.

Data analysis results statistically calculated as follows:

- Calculated on average test results siplo and duplo (Xt) with the formula:
  \[
  X_t = \frac{(X_{t,1} + X_{t,2})}{2} \tag{1}
  \]

where \(X_{t,1}\) is the result of the first test and \(X_{t,2}\) is the second test result.

- Calculated absolute differences (Wt) of the proceeds from the results siplo and duplo by the formula:
  \[
  W_t = |X_{t,1} - X_{t,2}| \tag{2}
  \]

- Calculated on average general (average) or coded Xr by the formula:
  \[
  X_r = \frac{\sum X_t}{g} \tag{3}
  \]
where \(g\) is the number of subsamples that are used.

- Calculated standard deviation from the average subsample (Sx) by the formula:
  \[
  S_x = \sqrt{\frac{\sum (X_t - X_r)^2}{(g - 1)}} \tag{4}
  \]

- Calculated samples within the standard deviation (Sw) with the formula:
  \[
  S_w = \sqrt{\frac{\sum w_j^2}{2g}} \tag{5}
  \]

- Calculated standard deviation between samples (Ss) with formula
  \[
  S_s = \sqrt{S_x^2 - \left(\frac{S_w^2}{2}\right)} \tag{6}
  \]

The sample is said to be homogeneous, if \(S_s \leq 0.3 \sigma\), where \(\sigma\): standard deviation for proficiency assessment (SDPA), \(\sigma\) can be established through \(CV_{\text{Horwitz}}\).

\[
CV_{\text{Horwitz}} = 2^{(1-0.5\log C)} \tag{7}
\]

2.5. **The stability test**

After storage for a certain time (3-6 months) performed the analysis again in duplicate as follows: Test of stability carried out in the same laboratory with the implementation of the homogeneity test. The methods of stability testing were conducted using the same analysis with the same analyte compound according to assay analytes inhomogeneity test (concentrations of Ce and Y with XRF spectrometry analysis).
method). Selected a random subsample g packaging, where g ≥ 3. From the packaging g subsample is selected, each package subsamples divided by 2 for purposes of analysis duplo. Each subsample was weighed 0.5 g and it was analyzed by XRF and determined the concentrations of Ce and Y. Calculated on average concentrations of the first test of Ce (Yr,1) and the second testing (Yr,2) stabilization of test data. Calculated average difference test results obtained in homogeneity (Xr) by an average of the results obtained in the stability tests (Yr). The sample is said to be stable if |Xr - Yr| ≤ 0.3 σ.

2.6. Materials certification of rare earth element
For certification, rare earth hydroxide samples have used the statistical methods, for calculation of the average element concentration (X average) was used statistical method. Rare earth hydroxide samples were certified through a comparative test of 10 accredited laboratories by KAN (National Accreditation Committee). The distribution of the rare earth hydroxide to 10 accredited testing laboratory for the analysis of elements, namely: Laboratory of Geological Survey Center Bandung, Laboratory of tekMIRA Center Bandung, Laboratory of PSTNT-BATAN Bandung, Laboratory of PTBGN-BATAN Jakarta, Laboratory of Qualis, Laboratory of PSDG, Laboratory of SisLab, Laboratory of LIPI, Laboratory of AAN PSTA-BATAN, Yogyakarta and Laboratory of XRF, PSTA-BATAN, Yogyakarta

3. Result and Discussion
In this research, monazite sand from Bangka, Indonesia was used as raw material, while Myanmar monazite as the reference. The test composition of monazite sand is analyzed by XRF spectrometry methods and the result is presented in Table 1.

| No | Oxide    | Concentration, % | Indonesian Monazite, Bangka | Myanmar Monazite |
|----|----------|------------------|-------------------------------|------------------|
| 1  | CeO<sub>2</sub> | 31.506 ± 0.075   | 27.206                        |                 |
| 3  | La<sub>2</sub>O<sub>3</sub> | 13.165 ± 0.038 | 10.732                        |                 |
| 4  | Nd<sub>2</sub>O<sub>3</sub> | 11.025 ± 0.062 | 8.899                         |                 |
| 5  | ThO<sub>2</sub> | 6.283 ± 0.022   | 8.164                         |                 |
| 6  | Y<sub>2</sub>O<sub>3</sub> | 3.931 ± 0.024   | 0.887                         |                 |
| 7  | Pr<sub>6</sub>O<sub>11</sub> | 2.984 ± 0.022 | 1.773                         |                 |
| 9  | P<sub>2</sub>O<sub>5</sub> | 19.109 ± 0.102 | 19.338                        |                 |
| 11 | Sm<sub>2</sub>O<sub>3</sub> | 1.956 ± 0.005   | 1.024                         |                 |
| 12 | Gd<sub>2</sub>O<sub>3</sub> | 1.981 ± 0.003   | 0.657                         |                 |
| 13 | Dy<sub>2</sub>O<sub>3</sub> | 1.029 ± 0.011   | 0.196                         |                 |

In general, the rare earth composition of monazite sand from Indonesia and Myanmar contain CeO<sub>2</sub>, La<sub>2</sub>O<sub>3</sub>, Nd<sub>2</sub>O<sub>3</sub>, Y<sub>2</sub>O<sub>3</sub>, Pr<sub>6</sub>O<sub>11</sub>, Sm<sub>2</sub>O<sub>3</sub>, Gd<sub>2</sub>O<sub>3</sub>, Dy<sub>2</sub>O<sub>3</sub>. Compared with Myanmar monazite CeO<sub>2</sub>, La<sub>2</sub>O<sub>3</sub>, Nd<sub>2</sub>O<sub>3</sub>, Y<sub>2</sub>O<sub>3</sub>, Pr<sub>6</sub>O<sub>11</sub>, Sm<sub>2</sub>O<sub>3</sub>, Gd<sub>2</sub>O<sub>3</sub>, Dy<sub>2</sub>O<sub>3</sub> concentrations in the Indonesia monazite sand from Bangka are higher.

3.1. Synthesis of rare earth hydroxide from monazite sand

3.1.1. Decomposition.
The decomposition reaction of monazite sand and sodium hydroxide at 140 °C was shown in equation (8) [1,11].

\[2\text{RE(PO}_4\text{)} + 6\text{NaOH} = \text{RE}_2\text{O}_3 \cdot 3\text{H}_2\text{O} + 2\text{Na}_3\text{PO}_4\]
The mixture was heated to 140°C. After 2 hours, the mixture was diluted with distilled water at 110°C for one hour. In the resultant hot slurry, all the original phosphorus was present in solution as trisodium phosphate, rare earth and other associated minerals were present as a hydrous metal oxide.

3.1.2. Dissolution process
The reaction of hydrochloric acid and hydrous metal oxide was shown in equation (9). In this process, other associated mineral and rare-earth dissolved in acid solution and un-dissolved impurities were left as residue [1,11].

$$\text{RE (OH)}_3 + 3\text{HCl} = \text{RECl}_3 + 3\text{H}_2\text{O}$$

(9)

3.1.3. Selective precipitation
The acid solution (filtrate from hydrochloric acid dissolution) was precipitated with ammonium hydroxide. Uranium and thorium hydroxide was precipitated at pH 6.3, and rare earth hydroxide was precipitated at pH 9.8. The rare-earth hydroxide was dried in the drying oven at 110°C for one hour.

The precipitation is rare earth hydroxides.

$$\text{RECl}_3 + 3\text{NH}_4\text{OH} = \text{REOH} + 3\text{NH}_4\text{Cl}$$

(10)

3.2. Homogeneity test of the macroelement (cerium) and the microelement (yttrium) in the rare earth hydroxide
To test the homogeneity of the rare earth hydroxide samples can be seen the homogeneity of the macroelement in Table 2 and the homogeneity of the microelement in Table 3.

| Subsample code | The test result of Ce, % | Xt | Xr-Xr | (Xt-Xr)² | Wt | Wt² |
|----------------|--------------------------|----|-------|----------|----|-----|
| A              |                         |    |       |          |    |     |
| 1              | 28.4138                  | 28.0141 | 28.214 | 0.16449  | 0.0270553 | -0.3997 | 0.1597601 |
| 2              | 27.8163                  | 27.9083 | 27.8623 | -0.18717 | 0.0350307 | -0.092 | 0.008464 |
| 3              | 28.4252                  | 27.9107 | 28.168 | 0.11849  | 0.0140387 | 0.5145 | 0.2647103 |
| 4              | 28.0141                  | 28.1777 | 28.0959 | 0.04644  | 0.0021562 | 0.1636 | 0.026765 |
| 5              | 28.0678                  | 27.743 | 27.9054 | -0.14407 | 0.0207547 | 0.3248 | 0.105495 |
| 6              | 27.7511                  | 27.8781 | 27.8146 | -0.23487 | 0.0551616 | -0.127 | 0.016129 |
| 7              | 27.949                   | 27.7316 | 27.8403 | -0.20917 | 0.04375  | -0.2174 | 0.0472628 |
| 8              | 28.3804                  | 27.9319 | 28.1562 | 0.10669  | 0.0113817 | 0.4485 | 0.2011523 |
| 9              | 28.3495                  | 28.413 | 28.3813 | 0.33179  | 0.1100813 | 0.0635 | 0.0040323 |
| 10             | 28.194                   | 27.9197 | 28.0569 | 0.00739  | 5.45E-05  | 0.2743 | 0.0752404 |
| Xr             | 28.0495                  | Total | 0.319468 | 0.9000111 |
| Sx             | 0.017748                 | Sw   | 0.0227253 |
| Sx²            | 0.000315                 | Sw² | 0.0005164 |
| (Sw²/2)        | 0.0002582               |     |         |
| Sx² - (Sw²/2)  | 0.0036334               |     |         |
| Ss             | 2.84E-05                 |     |         |
As we know that the homogeneous sample can be found if the $S_s \leq 0.3\, \sigma$, where $\sigma$ for Ce test can be calculated through formula: $\sigma = CV_{\text{Horwitz}} = 2^{1.05} \log C$. C is Ce concentration measured = 28.049 \% or 0.28049, therefore $CV_{\text{Horwitz}} = 2^{1.05} \log 0.28049 = 2.422$. Then $0.3\, \sigma = 0.3 \times 2.422 = 0.727$. The results of the evaluation of the test data homogenization using measured concentration of Ce, $S_s = 0.000028$, Sample candidates already homogeneous, because $S_s < 0.3\, \sigma$ is $0.000028 < 0.727$ (see Table 2).

From Table 3, also $\sigma$ for Y test can be calculated through formula: $CV_{\text{Horwitz}} = 2^{1.05} \log C$. C is concentration measured Y = 1.72543 % or 0.017 in order to obtain the value of $CV_{\text{Horwitz}} = 2^{1.05} \log 0.017 = 3.685$. Then $0.3\, \sigma = 0.3 \times 3.685 = 1.105$. The results of the evaluation of the test data homogenization using measured concentration of Y, $S_s = 3.22 \times 10^{-8}$, the rare earth hydroxide already homogeneous, because $S_s < 0.3\, \sigma$ is $3.22 \times 10^{-8} < 1.105$ (see Table 3).

### Table 3. Homogeneity test data of the microelement (Y concentrations) in the rare earth hydroxide as a processed result of monazite sand

| Subsample code | The test result of Y, % | Xr | Total | Sx | Sx² | Sw | Sw² | Sw²/2 | Sx² - (Sw²/2) | Ss |
|----------------|------------------------|----|-------|----|-----|----|-----|-------|----------------|----|
| 1              | 1.714                  | 1.665 | 1.6895 | -0.0359 | 0.001291 | -0.049 | 0.002401 |
| 2              | 1.7968                 | 1.7597 | 1.7782 | 0.0528 | 0.00279 | 0.0371 | 0.001376 |
| 3              | 1.6974                 | 1.7092 | 1.7033 | -0.0221 | 0.00049 | -0.0118 | 0.000139 |
| 4              | 1.6974                 | 1.7944 | 1.7459 | 0.0204 | 0.000419 | 0.097 | 0.000949 |
| 5              | 1.6974                 | 1.7029 | 1.7002 | -0.0253 | 0.000639 | -0.0055 | 3.02E-05 |
| 6              | 1.6982                 | 1.7424 | 1.7203 | -0.0051 | 2.63E-05 | -0.0442 | 0.001954 |
| 7              | 1.6895                 | 1.7108 | 1.7001 | -0.0253 | 0.000639 | 0.0213 | 0.000454 |
| 8              | 1.7297                 | 1.7747 | 1.7522 | 0.0268 | 0.000717 | -0.045 | 0.002025 |
| 9              | 1.725                  | 1.7155 | 1.7203 | -0.0052 | 2.68E-05 | -0.0095 | 9.03E-05 |
| 10             | 1.7542                 | 1.7344 | 1.7443 | 0.0189 | 0.000356 | 0.0198 | 0.000392 |

$X_r = 1.7254\, \text{Total} = 0.007394, S_x = 0.000411, S_{x^2} = 1.69E-07, S_{w^2} = 2.09E-07, S_{w^2/2} = 1.04E-07$

$S_x^2 - (S_{w^2/2}) = 6.80E-09, S_s = 3.22E-08$

### 3.3. Stability test of the macroelement (cerium) and the microelement (yttrium) in the rare earth hydroxide

Data acquisition for the stability test of the rare earth hydroxide is presented in Table 4 and Table 5. The sample acceptance criteria declared stable, if $|X_r - Y_r| \leq 0.3\, \sigma$. Based on homogeneity test data concentrations of Ce (in Table 2) was obtained $X_r = 28.049\, \%$ and stability test data (Table 4) is obtained $Y_r = 27.941\%$ and then $|X_r - Y_r| = 0.108$ the value of $0.3\, \sigma = 0.727$, so that the sample declared stable because it fulfills the criteria $|X_r - Y_r| \leq 0.3\, \sigma$, ie $0.108 < 0.727$. 


Table 4. Stability test data of the macroelement (Ce concentration) in the rare earth hydroxide as processed result of monazite sand according to ISO 13528: 2008

| No. | Subsample Code | Test Results of Ce after 3 months | Yt (%) | On average Y_A and Y_B |
|-----|----------------|-----------------------------------|--------|------------------------|
|     |                | Y_A                              | Y_B    |                        |
| 1   | 1              | 28.214                           | 28.014 | 28.114                 |
| 2   | 2              | 27.862                           | 27.905 | 27.884                 |
| 3   | 6              | 27.815                           | 27.840 | 27.828                 |

Table 5. Stability test data of the microelement (Y concentrations) in the rare earth hydroxide as processed result of monazite sand according to ISO 13528: 2008

| No. | Subsample Code | Test Results of Y after 3 months | Yt (%) | On average Y_A and Y_B |
|-----|----------------|----------------------------------|--------|------------------------|
|     |                | Y_A                              | Y_B    |                        |
| 1   | 2              | 1.778                            | 1.761  | 1.770                  |
| 2   | 5              | 1.700                            | 1.794  | 1.747                  |
| 3   | 9              | 1.720                            | 1.735  | 1.728                  |

While from the homogeneity test data of Y concentrations (table 3) obtained Xr = 1.725 % and stability test data (Table 5) was obtained Yr = 1.748 % so that |Xr - Yr| = 0.023, and the value of 0.3 σ = 1.105, so the sample is declared stable because it adequate the criteria |Xr - Yr| ≤ 0.3 σ, ie 0.023 < 1.105. So based on the stabilization test of the data in Tables 4 and 5, the condition of rare-earth hydroxide samples is stable.

3.4. Characterization of the rare earth hydroxide as a processed result of monazite sand
In Figure 1, the minerals and chemical compounds the rare earth hydroxide as a processed result from monazite sand i.e. perovskite (La0.9Sr0.1CrO3), villiaumite sodium fluoride (NaF), calcium aluminum silicate (CaAl2Si2O8), bredigite (Ca13.5B0.3Mg1.8Mn0.4Si9O32) and cesium sodium uranium chloride (CsNaUCl6).
3.5. Certification
For certification, rare earth hydroxide samples have used the statistical method, for calculation of the average element concentration (X average) was used statistical method. Rare earth hydroxide samples were certified through a comparative test of 10 accredited laboratories by KAN (National Accreditation Committee). Obtained data of the comparative test results from 10 laboratories as listed in table 6 to table 7. The composition in the rare earth hydroxide there are 8 elements, i.e. Ce: (27.670 ± 3.004) %, La: (13.846 ± 1.503) %, Nd: (8.447 ± 0.816) %, Y: (1.667 ± 0.140) %, Pr: (6.254 ± 0.286) %, Sm: (1.496 ± 0.330) %, Gd: (0.994 ± 0.211) %, and Dy: (0.172 ± 0.005) %.

Table 6. Rare-earth elements content in the rare-earth hydroxide as a processed result of monazite sand from 10 laboratory

| Laboratory    | Ce  | La  | Nd  | Y   | Pr  | Sm  | Gd  | Dy  |
|---------------|-----|-----|-----|-----|-----|-----|-----|-----|
| PSTA          | 29.874 | 16.098 | -   | 1.814 | -   | -   | -   | -   |
| PTBGN         | 24.643 | 13.248 | 7.540 | -   | 6.20 | 1.708 | 0.807 | -   |
| Qualis        | 27.427 | 13.632 | 9.873 | 1.823 | 6.54 | 1.881 | 0.954 | -   |
| PSDG          | -   | 10.955 | 8.681 | -   | 6.524 | -   | 0.754 | -   |
| SisLab        | 23.813 | 12.498 | 7.857 | 1.57 | 5.753 | 1.657 | 0.937 | -   |
| LIPI          | -   | -   | 9.204 | -   | -   | 1.717 | 1.110 | -   |
| Pustekmira    | 29.00 | 16.249 | -   | 1.46 | -   | -   | 1.431 | 0.175 |
| PSTNT-AAN     | -   | 14.698 | 7.686 | -   | -   | -   | -   | -   |
| PSTNT-XRF     | 31.555 | 13.393 | 8.286 | -   | -   | 2.028 | -   | -   |
| PSG           | -   | -   | -   | -   | -   | -   | 0.963 | 0.168 |

27.670 ± 3.004 13.846 ± 1.503 8.447 ± 0.816 1.667 ± 0.140 6.254 ± 0.286 1.496 ± 0.330 0.994 ± 0.211 0.172 ± 0.005
Table 7. Certificate of elements in the rare earth hydroxide from the product of monazite sand

| No | Oxides | Concentration, % | Deviation Standard, % |
|----|--------|------------------|-----------------------|
| 1  | Ce     | 27.670 ± 3.004   | 3.004                 |
| 2  | La     | 13.846 ± 1.503   | 1.503                 |
| 3  | Nd     | 8.447 ± 0.816    | 0.816                 |
| 4  | Y      | 1.667 ± 0.140    | 0.140                 |
| 5  | Pr     | 6.254 ± 0.286    | 0.286                 |
| 6  | Sm     | 1.496 ± 0.005    | 0.330                 |
| 7  | Gd     | 0.994 ± 0.005    | 0.211                 |
| 8  | Dy     | 0.172 ± 0.005    | 0.005                 |

Table 8. Rare-earth element concentration in the rare-earth hydroxide from monazite sand with the precipitation by using NH₄OH, extraction by using H₂SO₄ and precipitation by using NaOH methods

| No | Rare-earth element | Precipitation of RE by using NH₄OH | Extraction of RE by using H₂SO₄ method [10] | Precipitation of RE by using NaOH [1] |
|----|-------------------|-----------------------------------|---------------------------------------------|---------------------------------------|
| 1  | Ce                | 27.670 ± 3.004                   | 12.220                                       | 33.435                                |
| 2  | La                | 13.846 ± 1.503                   | 6.040                                        | 20.009                                |
| 3  | Nd                | 8.447 ± 0.816                    | 4.930                                        | 14.625                                |
| 4  | Pr                | 6.254 ± 0.286                    | 1.170                                        | 3.042                                 |
| 5  | Y                 | 1.667 ± 0.140                    | 0.559                                        | 1.092                                 |
| 6  | Sm                | 1.496 ± 0.033                    | 0.771                                        | 2.122                                 |
| 7  | Gd                | 0.994 ± 0.211                    | 0.570                                        | 1.145                                 |
| 8  | Dy                | 0.172 ± 0.005                    | 0.201                                        | n.d                                   |

According to Table 8, in general, the comparison of the rare-earth hydroxide product from Indonesia, and Myanmar contains Ce, La, Nd, Pr, Y, Sm, and Gd, while Dy in the rare-earth hydroxide is not detected. Compared with the rare-earth hydroxide product from Myanmar monazite sand, Pr concentration in the Indonesian rare-earth hydroxide by precipitation method is higher, but for Ce, La, Nd, Sm content are lower, whereas the rare earth oxide content in Myanmar monazite sand is lower than rare-earth oxide content in Indonesian monazite sand (Table 1). If compared to extraction processes, the concentrations of Ce, La, Nd, Pr, Y, Sm, and Gd resulting from the processing of Indonesian monazite with the precipitation process by using NH₄OH are obtained higher.

4. Conclusion

Form the research were obtained the synthesis and characterization methods of the rare-earth hydroxide as the processed result of monazite sand. The content of minerals and chemical compounds in the rare earth hydroxide as processed result of monazite sand were perovskites (La₁₀Sr₆CrO₁₉), villiaumite sodium fluoride (NaF), calcium aluminum silicate (CaAl₂Si₂O₈), breddigite (Ca₁₃₃Bo₃Mg₁₃Mn₁₃Si₁₀O₃₂) and cesium sodium uranium chloride (CsNaUCl₆). The composition in the rare earth hydroxide there are 8 rare earth elements, ie Ce: (27.670 ± 3.004) %, La: (13.846 ± 1.503) %, Nd: (8.447 ± 0.816) %, Y: (1.667 ± 0.140) %, Pr: (6.254 ± 0.286) %, Sm: (1.496 ± 0.330) %, Gd: (0.994 ± 0.211) %, Dy: (0.172 ± 0.005) %. Compared with the rare earth hydroxide product from Myanmar, in the rare-earth hydroxide the result from Indonesian monazite sand, Pr content is higher, but for Ce, La, Nd contents are lower.
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