Partial Oxidation of Methane to Synthesize Gas Over \( \text{La}_{1-x}\text{Sr}_x\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3\pm\delta} \) Perovskite

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Abstract. Catalytic partial oxidation of methane into syngas has been investigated over a series of \( \text{La}_{1-x}\text{Sr}_x\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3\pm\delta} \) perovskite powder (\( x = 0.0; 0.1; 0.2; 0.3; 0.4 \)) in a continuous flow reactor. Characterization studies of this powder by XRD showed that the incorporation of more Sr (\( x \)) increased the lattice parameter and transformed broad to single, sharp peak of \( \text{La}_{1-x}\text{Sr}_x\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3\pm\delta} \). The performance of syngas formation from methane without the presence of molecular oxygen was determined by the ratio of \( \text{H}_2/\text{CO} \) in the range of 750–950 °C. The performance correlated with thermogravimetric analysis. At a low temperature (750 °C), the CH\(_4\) conversions over \( \text{La}_{1-x}\text{Sr}_x\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3\pm\delta} \) were affected by the crystallite size, whereas at a high temperature (950 °C), it was influenced by the mobility of oxygen ions coming from bulk. The weight loss in the range of 455–1100 °C due to the reduction of Fe\(^{3+}\) to Fe\(^0\) had a reverse effect on \( \text{H}_2/\text{CO} \) ratio. Among all of the powder catalysts tested at 950 °C, \( \text{LaCo}_{0.8}\text{Fe}_{0.2}\text{O}_{3\pm\delta} \) had the largest Fe\(^{3+}\) reduction to Fe\(^0\) and the lowest ratio of \( \text{H}_2/\text{CO} \).

Keywords: \( \text{H}_2/\text{CO} \); La\(^{3+}\); Sr substitution; Fe\(^{3+}\) reduction; solid-state reaction

1. Introduction
Natural gases, with methane as the main content, are the abundant fossil fuels. Compared to other fossil fuels such as coals and petroleum, natural gases with the high H:C ratio produce the lowest CO\(_2\) emission. However, natural gas has more potential to produce global warming than CO\(_2\). Therefore, it is necessary to utilize natural gases by converting them into syngas (a mixture of H\(_2\) and CO). The role of syngas is to increase the efficiency of electrical power through Solid Oxide Fuel Cell (SOFC). In addition, syngas is also used as a raw material in the Fischer-Tropsch synthesis and acetic acid production [1].

The method for obtaining syngas is by using a catalyst, one of which is through the partial oxidation process of methane. The conversion of methane into H\(_2\) and CO in this process results in an exothermic reaction so that a large furnace is not required for the reaction. The development of the use of the catalyst is using perovskite oxide instead of metal oxide. The suitable perovskite used to provide oxygen in the process of methane oxidation into syngas is a cobalt-based perovskite with the composition of Ln\(_{1-x}\text{A}_x\text{Co}_{1-y}\text{B}_y\text{O}_{3\pm\delta} \) (Ln = La, Pr, Nd, Sm; A = Sr, Ca, Ba; B = Mn, Cr, Fe, Co, Ni, Cu). In lanthanide
group, samarium has a higher value than lanthanum. As both do not give a different effect on the perovskite characteristics, lanthanum is often used as an element in A-site [2].

Substitution cations on A-site commonly used in the partial oxidation reaction of methane are the cations from the alkali earth such as calcium, strontium, and barium. The highest ion radius from barium causes barium to have the highest ionic conductivity compared to calcium and strontium. Because barium and calcium react more easily with CO₂ than strontium, strontium is preferred to be used as a substitution cation for A-site on perovskite [3]. In addition to the lack of interaction between strontium ion with CO₂, perovskite of which La³⁺ is substituted by Sr²⁺ has the highest ion and electron conductivity among other perovskites which La³⁺ is substituted by Ca²⁺ and Ba²⁺ [4].

The high Sr concentration in the La₁₋ₓSrₓCoO₃₋δ catalyst leads the formation of oxygen ion vacancies. This results in a lowering of catalyst phase stability when the La₁₋ₓSrₓCoO₃₋δ catalyst is in a reducing environment or as a catalyst for syngas production [5]. Schulze-Küppers et al. stated that when the Sr concentration in La₁₋ₓSrₓCoO₃₋δ is more than 50% (x > 0.5), it can cause decomposition of La₁₋ₓSrₓCoO₃₋δ [6]. The high strontium content needs to be stabilized by increasing the Fe substitution towards Co to obtain La₁₋ₓSrₓCo₁₋yFeₓO₃₋δ catalyst [7].

When identified from the iron substitution for cobalt of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ it was found that the optimum substitution of iron increasing oxygen ion transfer was at a concentration of 20% Fe (y = 0.2) in comparison with 50%, 25%, 15%, and 0% of Fe (y = 0.5; 0.25; 0.15; 0) [8]. A perovskite with 20% iron substitution for cobalt (La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ) has been selected in this work because of its high oxygen flux [9]. Nonetheless, this oxygen release can be excessive, which results in a reduction in ionic conductivity of oxygen [10]. For these reasons, perovskite oxides in the form of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ have been gaining attention as a highly promising material for many applications, such as catalysts for syngas production and the fabrication of anodes and cathodes for solid oxide fuel cells (SOFCs). Therefore, whenever perovskite-type materials are intended to be used as catalytic agents for partial oxidation reactions, such as the reaction of methane into syngas, particular care should be taken to find the optimum value for the composition of its substituent ions.

The only study on La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ catalysts for syngas production is limited to the composition of La₀.₈Sr₀.₂Co₀.₈Fe₀.₂O₃₋δ [11]. Therefore, this study was aimed to investigate the process of syngas production through a partial oxidation reaction of methane (in the absence of oxygen gas) by using La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ compound series at the range of x from 0.0 to 0.4 (x = 0.0, 0.1, 0.2, 0.3, and 0.4).

2. Methods
Perovskite materials of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ (x = 0.0 - 0.4) were synthesized using a solid-state reaction method then characterized using XRD and TGA. The method for synthesis and characterization has been written in the previous publication [12]. The catalytic test of the partial oxidation reaction of methane via oxygen lattice from La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ (x = 0.0 - 0.4) was conducted in a continuous reactor at 750, 850, and 950 °C. In each experiment, 0.5 g of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ catalyst powder (0.5-0.6 mm) with a weight ratio of 1:2. Then, the mixture in the form of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃₋δ and quartz powder was put in a quartz reactor (0.4 cm inner diameter) equipped with quartz wool on the bottom of the catalyst bed. The reactor was positioned vertically in a heater of which temperature was kept constant through a thermocouple system. The gas flow rate was regulated by MFC. Methane gas in the form of 5% CH₄ and N₂ was used as a feed gas in the partial oxidation reaction of methane. The products from the partial oxidation reaction of methane (i.e. H₂, CO, and CH₄) were analyzed quantitatively by gas chromatography equipped with a TCD detector, molecular sieve 13X column, porapak q column, and Helium as a carrier gas.
3. Results and Discussion

3.1. XRD measurement
The crystalline structure of the La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3+\delta}$ ($x=0.0-0.4$) perovskite calcined at 1000 °C was determined by XRD. The perovskite structure was successfully refined in the model described for LaCoO$_3$ (PDF No. 84-0847), considering the rhombohedral ($R-3cR$ space group), with unit-cell parameters of $a = 5.3489$ Å, $b = 5.3489$ Å, and $c = 5.3489$ Å. The quality of the fit of the XRD profiles for La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3+\delta}$ ($x=0.0-0.4$) samples is illustrated in Figure 1.

![XRD spectra](image1.png)

*Figure 1.* Observed (plus in black color), calculated (red solid line), and reflection markers (vertical bars) for rhombohedral La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3+\delta}$ at room temperature.
Based on Bragg’s Law, an increase in lattice parameters by Sr$^{2+}$ ion substitutions of 20, 30 and 40% for La$^{3+}$ resulted in the shift of a peak (approximately 47.4° (2θ)) of x = 0.2, 0.3, and 0.4 towards a lower 2θ position as shown in Figure 2. Table 1 shows that the particle sizes decreased when Sr substitutions of La in the A-sites of the La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ lattice increased. The smaller the crystallite size, the broader the FWHM value. FWHM is the full width at half maximum. In this case, the peak chosen as reference was located at approximately 47.4° (2θ). Correlations between Sr substitutions (x) and crystallite sizes are in line with results reported by Irusta et al. (1998) for La$_{0.8}$Sr$_{0.2}$CoO$_3$ [13].

### Table 1. Particle sizes and crystallinity of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$

| Sample | Size (nm) | FWHM (~47.4° (2θ)) (rad) |
|--------|-----------|---------------------------|
| LaCo$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ | x = 0.0 | 37 | 0.244 |
| La$_{0.8}$Sr$_{0.1}$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ | x = 0.1 | 29 | 0.309 |
| La$_{0.8}$Sr$_{0.2}$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ | x = 0.2 | 25 | 0.365 |
| La$_{0.7}$Sr$_{0.3}$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ | x = 0.3 | 34 | 0.266 |
| La$_{0.6}$Sr$_{0.4}$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ | x = 0.4 | 23 | 0.390 |

#### 3.2. TGA measurement
The thermogravimetric analysis of the La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ (x = 0.0-0.4) oxide series is divided into four-reduction zones which are then categorized into a low temperature and high temperature reduction zone [14]. TGA thermograms of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ (x = 0.0-0.4) with its zone divisions are presented in Figure 3. The percentage of weight loss in La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$ series for each reduction zone was obtained through calculation using thermograms of which results are written in Table 2 and its detailed reduction zone for each sample is presented in Table 3.

### Table 2. Reduction Zone of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-δ}$

| Low temperature reduction zone | Zone I | Co$^{3+}$ → Co$^{2+}$ | T = 440-537 °C |
| Zone II | Fe$^{4+}$ → Fe$^{3+}$ | T = 538-588 °C |
| High temperature reduction zone | Zone III | Co$^{2+}$ → Co$^0$ | La$_2$CoO$_4$ → La$_2$O$_3$ | T = 646-743 °C |
| Zone IV | Fe$^{3+}$ → Fe$^0$ | T = 744-1100 °C |

At T = 589-645 °C, SrCO$_3$ was decomposed to SrO which did not include a reduction zone.

On the low-temperature reduction zones (zone I & zone II), the samples undergoing considerable weight loss were x = 0.1 and x = 0.2. The formation of Co$^{3+}$ and Fe$^{4+}$ on x = 0.1 and x = 0.2 was more dominant than the formation of Co$^{3+}$ and Fe$^{4+}$ on x = 0.3 and x = 0.4. The concentrations of 10 and 20% Sr$^{2+}$ ions to lanthanum, each on x = 0.1 and x = 0.2 resulted in Co$^{3+}$ undergoing oxidation to Co$^{4+}$ as iron ions to be Fe$^{3+}$ as a result of a charge neutralization. The tetravalent Fe ion is more likely to form than Co$^{4+}$ because of the lower electronegativity of Fe with respect to Co [15]. The concentration of Sr$^{2+}$ ions that was bigger than 20% for lanthanum’s ion substitution on x = 0.3 and x = 0.4 resulted in oxygen losses rather than the formation of Fe$^{4+}$ ions. In their report, Petrov et al. wrote that for charge neutralization to Sr ion with bigger concentration substitution than 40% on solid phase La$_{1-x}$Sr$_x$CoO$_{3-δ}$, the oxygen losses were more dominant than the formation of Co$^{3+}$ ions [16]. Moreover, the Fe$^{4+}$ to Fe$^{3+}$ reduction step weakened along with the increasing Sr substitution levels because of the low concentration of Fe$^{4+}$ resulted from the Fe ions’ stability against oxidation [17]. In the sample without Sr$^{2+}$ ion substitution for La$^{3+}$ (x = 0.0), the percentage of weight loss in zone II (Fe$^{4+}$ to Fe$^{3+}$) was nearly 0%. Without the substitution of strontium ion, the increase in iron oxidation number from 3+ to 4+ did not occur. On a high-temperature reduction zone (zone III and zone IV), the samples undergoing considerable weight loss were x = 0.3 and x = 0.4. The oxygen losses for charge neutralization on 30
and 40 % substitution of Sr$^{2+}$ ion for La$^{3+}$ resulted in ions with small positive oxidation numbers namely Co$^{2+}$ and Fe$^{3+}$ on $x = 0.3$ and $x = 0.4$ that were not much oxidized to be considerable positive oxidation numbers, namely Co$^{3+}$ and Fe$^{4+}$ on $x = 0.3$ and $x = 0.4$. When seen in the total reduction zone (zone I up to zone IV), the samples which had considerable percentage of weight loss consecutively were as follow, for $x: 0.4 > 0.3 > 0.0 > 0.1 > 0.2$, which is consistent with a previous report [12]. The sample with considerable weight loss, such as $x = 0.4$, showed that it was easy for it to have a reduction.

![Figure 2](image1.png)  
**Figure 2.** Peak position (2θ) as a function of the strontium content ($x$)

![Figure 3](image2.png)  
**Figure 3.** Reducibility of the La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$ series ($x = 0.0-0.4$) and LaCoO$_3$

| Reduction Zone | Percentage of weight loss of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$ (%) |
|---------------|---------------------------------------------------------------------------------|
|               | $x = 0.0$ | $x = 0.1$ | $x = 0.2$ | $x = 0.3$ | $x = 0.4$ |
| I             | Co$^{3+}$ → Co$^{2+}$ | 2.13 | 1.25 | 1.41 | 0.17 | 0.48 |
| II            | Fe$^{4+}$ → Fe$^{3+}$ | 0.23 | 1.51 | 1.47 | 0.12 | 0.69 |
| III           | Co$^{2+}$ → Co$^0$ | 0.77 | 2.36 | 2.93 | 3.60 | 5.59 |
| IV            | Fe$^{3+}$ → Fe$^0$ | 5.39 | 3.39 | 2.56 | 4.83 | 5.30 |

The results of the measurement of thermal stability against La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$ using Differential Scanning Calorimetry (DSC) are shown in Figure 4. The curve of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$ ($x = 0.0-0.4$) compound has an endothermic peak at 240 °C caused by H$_2$O desorption process from hygroscopic La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$. The exothermic peak at 920 °C (curve a) was the result of the release of oxygen lattice from the LaCoO$_3$ oxide compound by reducing from Co$^{2+}$ to Co$^0$. The exothermic peak has two zones, the low-temperature zone which ranged from 290 to 633 °C and the high-temperature zone which ranged from 634 to 1115 °C. The exothermic peak caused by the release of lattice oxygen ion of both LaCoO$_3$ and La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3±δ}$ compounds occurred in the low-temperature reduction zones and high-temperature reduction zones.

LaCoO$_3$ compounds, $x = 0.0$, and $x = 0.4$, have a similarity of curve profiles, namely narrow peaks in the low-temperature reduction zones (290 to 633 °C) and broad peaks in the high-temperature reduction zones. The absence of Sr substitution $x = 0.0$ failed to form Fe$^{4+}$ ions. The release of lattice oxygen ions at $x = 0.0$ occurred only through the reduction of Co$^{3+}$ to Co$^{2+}$. The result of $x = 0.4$ corresponds to the report from Petrov *et al.* that the neutralization of the charge on Sr substitution of which the concentration was large of La$_{1-x}$Sr$_x$CoO$_{3±δ}$ was less affected by the formation of Co$^{4+}$ ions [16]. In this study, the similarity of curve profiles is also found at $x = 0.1$ and $x = 0.2$. In the low-temperature reduction zone, the exothermic peaks of $x = 0.1$ and $x = 0.2$, which were at 526 and 473 °C, were wider
than the exothermic peaks of LaCoO$_3$, $x = 0.0$, and $x = 0.4$. At $x = 0.1$ and $x = 0.2$ the charge neutralization caused by the Sr substitution by 10 % and 20 % of La was influenced by the formation of Fe$^{4+}$ ions. At $x = 0.3$ and $x = 0.4$, the small endothermic peak at 607 °C was formed due to the decomposition of strontium carbonate.

Figure 4. DSC curve for La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_3$$^{\pm\delta}$ samples series (a) LaCoO$_3$ (b) $x = 0.0$ (c) $x = 0.1$ (d) $x = 0.2$ (e) $x = 0.3$ and (f) $x = 0.4$ in 5 %H$_2$

3.3. Catalytic Activity of La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-\delta}$ series for partial methane oxidation

The compound series La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-\delta}$ ($x = 0.0-0.4$) has been used as a catalyst to produce syngas through a partial oxidation reaction of methane. The results showed that the conversion of methane produced from this series catalyst was achieved at around 90% as shown in Figure 5. The higher the temperature the greater the conversion produced by the La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-\delta}$ ($x = 0.0 - 0.4$) catalyst. According to Cheng et al. the high reaction temperature resulted in the ease of transport of lattice oxygen ion from the body to the catalyst surface so that the lattice oxygen ion more easily oxidizes methane to produce syngas through a partial oxidation reaction [18].

In this experiment, at 950 °C, La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-\delta}$ ($x = 0.0 - 0.4$) catalysts series produced a conversion of methane with a reverse sequence compared to nonstoichiometric oxygen content ($\delta$). Methane conversion resulted from La$_{1-x}$Sr$_x$Co$_{0.8}$Fe$_{0.2}$O$_{3-\delta}$ perovskite oxide catalyst was 83.72 % ($x = 0.4$), 95.71 % ($x = 0.3$), and 99.74 % ($x = 0.1$) while nonstoichiometric oxygen ($\delta$) from the appointed catalyst was -0.33 ($x = 0.1$), +0.07 ($x = 0.3$) and +0.15 ($x = 0.4$). The lowest methane conversion was produced by a catalyst that had oxygen ion excess, $x = 0.4$. Conversely, large methane conversions were produced by catalysts that had oxygen ion vacancies, $x = 0.1$. The excess of oxygen ions possessed by $x = 0.4$ and $x = 0.3$ resulted in the decrease of mobility of oxygen ions so that the reactants, in this case of methane, were less able to react with oxygen ions of which concentration decreased. At 950 °C, this caused a methane conversion of $x = 0.4$ and $x = 0.3$ was lower compared than the methane conversion of $x = 0.1$. Conversely, the conversion of methane produced by $x = 0.1$ is large because the vacancy of oxygen ions is the pathway for diffusion of lattice oxygen ions from the bulk to surface. According to Anderson et al. catalysts with oxygen ions vacancies have greater mobility of oxygen ions than catalysts with excess of oxygen ions [19]. Different things occur at $x = 0.0$ which is caused $x = 0.0$ does not have the content of Sr ions.

Syngas products as a result of methane conversion are shown by the ratio between H$_2$ and CO (H$_2$/CO). The ratio which starts from the lowest to the highest is successively resulted by the $x = 0.0$, $x$
= 0.4, x = 0.3, and x = 0.1. The H₂/CO ratio decreased according to the sequence percentage reduction of Fe³⁺ to Fe⁰ which is written in Table 4. The more the Fe³⁺ reduced to Fe⁰, the smaller the H₂/CO ratio and vice versa. A selective oxidation of methane to syngas (H₂/CO ≈ 2) is enhanced by Fe species reduced [20]. The increasing intensities of reduced Fe³⁺ to Fe⁰ accompanied by the decrease of the H₂/CO molar ratio for the increasing Sr substitution indicate that those reductions can be used to predict the ability to form syngas from the partial oxidation reaction of methane over La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃±δ.

Table 4. Results of catalytic activity test on the partial oxidation of methane over La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃±δ catalysts at 950 °C

| Catalyst | CH₄ reactiona | Reduction in TGA² | CH₄ conversion | H₂/CO molar ratio | % Fe³⁺ reduced to Fe⁰ |
|----------|--------------|-------------------|----------------|-------------------|---------------------|
| x = 0.0  | 99.89        | 4.4               | 5.39           |                   |                     |
| x = 0.1  | 99.74        | 26.2              | 3.40           |                   |                     |
| x = 0.3  | 95.71        | 15.3              | 4.84           |                   |                     |
| x = 0.4  | 83.72        | 7.7               | 5.30           |                   |                     |

a CH₄ reaction conditions: 950 °C in 5% CH₄/N₂; 6 mL min⁻¹ flow rate; 0.5 g catalyst weight; 1.6 s contact time
b TGA conditions: 780-1050 °C in 5% H₂ attribute/N₂ with a flow rate of 20 mL min⁻¹

The low H₂/CO ratios accompanied the decrease of methane conversions as seen in Figure 6. At x = 0.4, both the conversions of methane and the H₂/CO ratio were low. These to oxygen species of x = 0.4 have selectively oxidized CH₄ to CO. Also, the cracking of the methane over x = 0.4 did not occur much [21]. For the low Sr substitution, i.e. x = 0.1, both the conversions of methane and H₂/CO ratio were high. The low content of oxygen ion of x = 0.1 caused the cracking of methane.

4. Conclusion
The series of La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃±δ perovskite powders with x ranging from 0.0 to 0.4 were successfully investigated to determine the best Sr substitution for syngas formation. Lanthanum that was not substituted by Sr (x = 0.0) yielded the smallest ratio of H₂/CO in the partial oxidation reaction of methane, and the TGA results showed the highest weight loss due to the reduction of Fe³⁺ to Fe⁰ for this sample. The detection of the Fe³⁺ to Fe⁰ reductions at temperatures ranged from 780 to 1050 °C using TGA can be done to predict their ability to form syngas from the partial oxidation reaction of methane using La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃±δ at 950 °C. Syngas with a low ratio of H₂/CO is appropriate for the advanced processing, for the methanol production. This work concluded that La₁₋ₓSrₓCo₀.₈Fe₀.₂O₃±δ perovskites without Sr substitution are suitable catalyst powders for syngas production.
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