

# High-Throughput Analysis of Materials for Chemical Looping Processes

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Chemical looping is a promising approach for improving the energy efficiency of many industrial chemical processes. However, a major limitation of modern chemical looping technologies is the lack of suitable active materials to mediate the involved subreactions. Identification of suitable materials has been historically limited by the scarcity of high-temperature ( $> 600$  °C) thermochemical data to evaluate candidate materials. An accurate thermodynamic approach is demonstrated here to rapidly identify active materials which is applicable to a wide variety of chemical looping chemistries. Application of this analysis to chemical looping combustion correctly classifies 17/17 experimentally studied redox materials by their viability and identifies over 1,300 promising yet previously unstudied active materials. This approach is further demonstrated by analyzing redox pairs for mediating a novel chemical looping process for producing pure SO<sub>2</sub> from raw sulfur and air which could provide a more efficient and lower emission route to sulfuric acid. 12 promising redox materials for this process are identified, two of which are supported by previous experimental studies of their individual oxidation and reduction reactions. This approach provides the necessary foundation for connecting process design with high-throughput materials discovery to accelerate the innovation and development of a wide-range of chemical looping technologies.

## File list (2)

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# High-Throughput Analysis of Materials for Chemical Looping Processes

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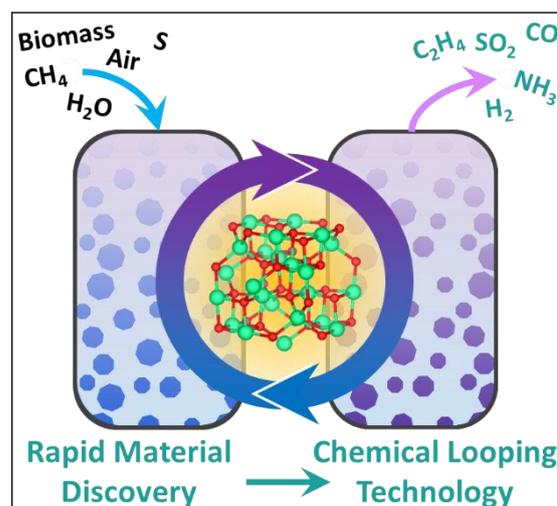
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## Abstract:

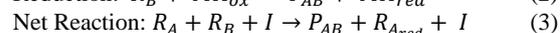
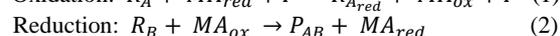
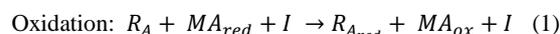
Chemical looping is a promising approach for improving the energy efficiency of many industrial chemical processes. However, a major limitation of modern chemical looping technologies is the lack of suitable active materials to mediate the involved subreactions. Identification of suitable materials has been historically limited by the scarcity of high-temperature (> 600 °C) thermochemical data to evaluate candidate materials. An accurate thermodynamic approach is demonstrated here to rapidly identify active materials which is applicable to a wide variety of chemical looping chemistries. Application of this analysis to chemical looping combustion correctly classifies 17/17 experimentally studied redox materials by their viability and identifies over 1,300 promising yet previously unstudied active materials. This approach is further demonstrated by analyzing redox pairs for mediating a novel chemical looping process for producing pure SO<sub>2</sub> from raw sulfur and air which could provide a more efficient and lower emission route to sulfuric acid. 12 promising redox materials for this process are identified, two of which are supported by previous experimental studies of their individual oxidation and reduction reactions. This approach provides the necessary foundation for connecting process design with high-throughput materials discovery to accelerate the innovation and development of a wide-range of chemical looping technologies.

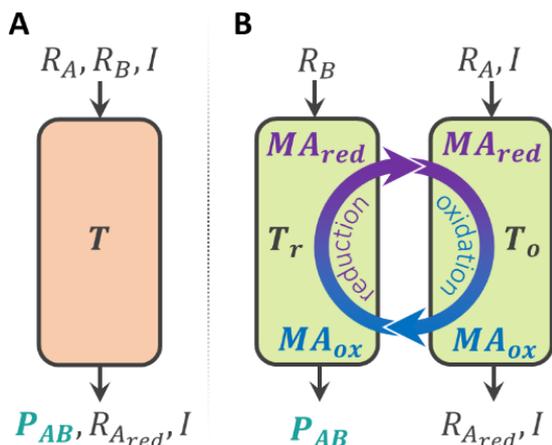


## Introduction

Chemical looping processes are a promising route for improving energy efficiency,<sup>[1–4]</sup> leveraging renewable energy sources,<sup>[5–11]</sup> facilitating chemical conversions,<sup>[12–20]</sup> and reducing undesirable emissions across many sectors of the chemical industry.<sup>[21–26]</sup> In a chemical looping (CL) process, the overall reaction is separated into multiple (typically two) subreactions, each mediated by the redox chemistry of a “looped” active material. In the first reaction (**Equation 1**), an anion (*A*) is transferred to an anion-deficient active material (*MA<sub>red</sub>*) from a reactant (*R<sub>A</sub>*) containing *A*. Reactant *R<sub>A</sub>* is commonly dilute (e.g., oxygen in air).<sup>[27–29]</sup> In the second reaction (**Equation 2**) the anion-rich active

material (*MA<sub>ox</sub>*) releases *A*, typically to undergo a chemical reaction with reactant(s) *R<sub>B</sub>* generating product(s) *P<sub>AB</sub>*. The division of a single reaction (**Figure 1a**) into multiple subreactions via a CL scheme (**Figure 1b**) can reduce or eliminate the need for downstream separations to isolate product(s) *P<sub>AB</sub>*,<sup>[23,29,30]</sup> improve the exergy efficiency of the process,<sup>[29,31,32]</sup> and overcome thermodynamic limitations imposed by operating at a single temperature.<sup>[15,27,33]</sup>





**Figure 1:** **A)** A general single-step reaction operating at temperature  $T$ . **B)** A two-step chemical looping cycle mediated by a looped active material  $MA_{ox}/MA_{red}$ .  $R_A$  is a reactant containing anion  $A$  that is initially dilute in the inert species  $I$ .  $R_A$  is reduced to  $R_{A_{red}}$  during the reaction with  $MA_{red}$ .  $R_B$  is a second reactant that reacts with  $A$  to produce the product(s)  $P_{AB}$ . **Equations 1-3** provide the detailed reactions. In certain processes,  $R_{A_{red}}$ ,  $R_B$  and/or  $I$  may be excluded, such as water splitting where  $R_A = H_2O$ ,  $R_{A_{red}} = H_2$ ,  $P_{AB} = O_2$ , and  $R_B$  and  $I$  are excluded.

Chemical looping combustion (CLC) and chemical looping reforming are two chemical looping processes that provide a potentially energy-efficient solution to  $CO_2$  capture and are therefore of considerable interest to the utilities sector.<sup>[23,29,31,34,35]</sup> Other applications that leverage CL have been examined for the production of high purity, value-added chemicals such as hydrogen,<sup>[33,36,37]</sup> oxygen from non-cryogenic separation of air,<sup>[38,39]</sup> hydrocarbons,<sup>[15,17,40,41]</sup> and ammonia.<sup>[5,12,42]</sup> Despite promising results from pilot-scale studies and techno-economic analyses for many of these CL processes,<sup>[43-47]</sup> the realization of industrial-scale units has encountered substantial challenges.<sup>[29,48-51]</sup> The primary barrier to commercialization of CL technologies is the lack of suitable active materials that lead to economically viable processes.<sup>[23,29]</sup> A superior active material should exhibit low material cost, high anion transport efficiency, high reaction conversion, high recyclability, high attrition resistance, and fast reaction kinetics.<sup>[23,29,52]</sup>

The identification of materials with superior figures of merit for CL has remained a long-standing challenge.<sup>[29,52]</sup> Although some of these properties can be readily determined or predicted, such as the cost of a material or its

theoretical anion transport efficiency, most require a detailed knowledge of the thermodynamic properties of the material system. To date, the few studies that have leveraged computational tools to identify active materials for CL processes have predominantly relied on experimental data, namely the temperature-dependent Gibbs formation energy of a material,  $\Delta G_f(T)$ .<sup>[12,52-55]</sup> Knowledge of  $\Delta G_f(T)$  of the candidate materials within a chemical system enables the determination of equilibrium products as a function of temperature and elemental composition, thus providing the reaction conversion and recyclability of an active material for a given CL process. Unfortunately, experimental values of  $\Delta G_f(T)$  are only tabulated for a limited set of materials,<sup>[56]</sup> and calculating  $\Delta G_f(T)$  from first principles is too computationally demanding for high-throughput materials screening.<sup>[57-59]</sup> The lack of free energy data for solid compounds limits the total number of materials that can be screened based on their thermodynamics and the extent to which they can be analyzed (e.g., the competition with side reactions). Consequently, previous studies aimed at identifying viable CL materials have evaluated only dozens of candidates.<sup>[12,52-55]</sup>

Recently, we reported a statistically learned descriptor,  $G^\delta(T)$ , for calculating the formation free energies,  $\Delta G_f(T)$ , of crystalline solid compounds at temperatures up to 1800 K with a resolution of  $\sim 50$  meV atom<sup>-1</sup>.<sup>[60]</sup> The descriptor  $G^\delta(T)$  requires only the composition, formation enthalpy and atomic density of a material at 0 K, which are widely tabulated in open databases of DFT-computed materials properties.<sup>[60]</sup> We exploit  $G^\delta(T)$  to provide the foundation for our high-throughput thermodynamic screening approach to rapidly identify active materials with high reaction conversion and high recyclability (i.e. low side product formation). Attrition resistance and reaction kinetics cannot be obtained with our high-throughput screening approach because they depend on properties beyond the free energies of the active materials, such as the support material, particle size, regeneration time, activation barriers, etc. However, these properties can nevertheless be tuned via the system parameters after viable active materials have been identified based on thermodynamic screening.<sup>[18,25,61-63]</sup>

We previously applied a thermodynamic screening approach based on the descriptor  $G^\delta(T)$  to rapidly identify active materials for solar-thermal ammonia synthesis in which  $\sim 1,100$  oxide

and nitride pairs were analyzed.<sup>[7]</sup> Here, we demonstrate that this approach can be applied to any CL process that operates at or near equilibrium conditions with temperatures up to at least 1800 K, irrespective of the active material class (e.g. oxide, halide, etc.), the number of subreactions,<sup>[7]</sup> or the number of reactant and/or product species. This includes well-studied CL processes (e.g. CLC,<sup>[23]</sup> CL reforming,<sup>[35]</sup> water splitting,<sup>[33]</sup> etc.) and emerging applications (e.g. air separation,<sup>[38]</sup> ammonia synthesis,<sup>[5,12]</sup> chemical looping with oxygen uncoupling,<sup>[64]</sup> three-way catalysis,<sup>[24]</sup> etc.). In this work we provide a detailed assessment of the accuracy of this method, including the expected errors in predicted reaction free energies and the classification accuracy for identifying thermodynamically viable (i.e. high conversion) active materials. Based on the success of this approach in correctly classifying thermodynamically viable active materials, we applied it to discover previously unstudied active materials for CLC with high reaction conversion, high recyclability, high transport efficiency, and low cost.

In addition to demonstrating our descriptor-based method for evaluating materials for CLC, we also applied it to evaluate materials for a novel process that we propose for sulfur dioxide (SO<sub>2</sub>) production. This is a compelling process to improve with CL because SO<sub>2</sub> is conventionally produced via the aerobic combustion of sulfur, which yields a dilute mixture of SO<sub>2</sub> in air and thus requires energy intensive separations to concentrate the SO<sub>2</sub> and limit SO<sub>2</sub> emissions.<sup>[65]</sup> We suggest a CL scheme for sulfur oxidation that yields pure SO<sub>2</sub> from sulfur and could provide a more energy-efficient and lower emission route to both concentrated SO<sub>2</sub> and sulfuric acid, the world’s most produced chemical by mass.<sup>[66]</sup> We identified 12 promising active materials for this process using our thermodynamic screening approach. Previous experimental studies of the individual oxidation and reduction reactions of a number of these materials corroborate our predictions. We expect that as the field of CL continues to grow, this robust and high-throughput screening approach based on machine-learned thermodynamic properties will provide an effective method for discovering active materials for a wide range of CL chemistries.

## Methods

We obtained formation enthalpies ( $\Delta H_f$ ) and atomic densities of materials from the Materials Project (MP) database, which currently contains properties for over 120,000 inorganic crystal structures.<sup>[67]</sup> We selected a subset of materials that are consistent with the known classes of active materials for CLC, specifically: binary oxides, ternary oxides, and sulfates. Sulfides were included as possible reduction products. The MP database contained 13,763 compounds from this subset and their respective 0 K properties. Similarly, for chemical looping sulfur oxidation we investigated sulfates and sulfides; MP contained 1,238 compounds in this subset. Compounds containing radioactive elements were not considered.  $\Delta G_f(T)$  for all entries in the MP database were calculated for the temperature range of 300 to 1800 K at intervals of 100 K using the statistically-learned physical descriptor  $G^\theta(T)$ .<sup>[60]</sup>  $\Delta G_f(T)$  for non-solids (e.g. CH<sub>4</sub>, H<sub>2</sub>O, CO<sub>2</sub>, SO<sub>2</sub>, etc.) at 1 atm were obtained from the NIST JANAF thermochemical database.<sup>[56]</sup> Decomposition energies,  $\Delta G_d(T)$ , were calculated over the temperature range of 300 to 1800 K using  $\Delta G_f(T)$  and the convex hull construction. Materials with  $\Delta G_d(T) < 0$  are stable relative to all competing phases at their corresponding compositions.<sup>[68]</sup> The convex hull method is described in the Supporting Information (**Section S1**), and reference [68].  $\Delta G_d(T)$  does not indicate whether a compound will melt or boil at a particular temperature.

Redox pairs were identified from the subset of stable materials. Each redox pair is comprised of a single oxidized compound ( $MA_{ox}$ ), and either one or two reduced materials ( $MA_{ox}$ ). Elemental phases were considered for the reduced material(s). Redox pairs were only investigated for thermodynamic viability at temperatures at which all constituent compounds are stable. 17,880 redox pairs meet this constraint for CLC. Stoichiometric coefficients for the subreactions (i.e., oxidation and reduction) of the redox pairs were normalized to maintain molar conservation with 1 mol of O<sub>2</sub> liberated from  $MA_{ox}$  during the reduction reaction (**Equation 2**), enabling the reaction energies of different redox pairs to be directly compared.

A thermodynamically viable redox pair is defined as one which undergoes both the oxidation and reduction reactions (**Equations 1 and 2**) spontaneously ( $\Delta G_r(T) < 0$ ). Temperature-dependent Gibbs energies of reaction,  $\Delta G_r(T)$ , are calculated as the differences in free energy

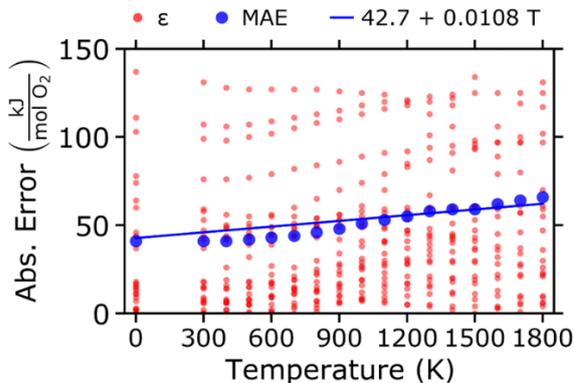
between the stoichiometrically-weighted  $\Delta G_f(T)$  of the products and reactants. For reactions involving gaseous species, an ideal gas correction term was included to account for the partial pressure of the gas:  $\Delta G_f(T) = \Delta G_f^\circ(T) + RT \ln(P_x)$ , where  $\Delta G_f^\circ(T)$  is the Gibbs formation energy at standard state pressure (1 atm) and  $x$  is the gaseous species of interest. Partial pressures are calculated at 90% conversion at a total pressure of 1 atm throughout this work.

The errors in  $\Delta G_r(T)$  relative to experiment were determined to arise predominantly from errors in the DFT-calculated reaction enthalpy,  $\Delta H_r$ , and to a lesser extent, the descriptor-calculated temperature-dependent contribution to  $\Delta G_f(T)$ . Additional errors in  $\Delta H_r$  arise for redox pairs that contain the magnetic elements Cr, Mn, Fe, Co, and Ni because antiferromagnetism is not systematically considered in Materials Project calculations.<sup>[67,69]</sup> To mitigate this additional error, we calculated  $\Delta H_f$  for binary oxides (listed in **Table S2**) containing these magnetic elements. We enumerated one ferromagnetic and ~8 antiferromagnetic supercells for each of the oxides containing these elements using MP calculation standards in order to determine magnetic ground states, and thus more accurate  $\Delta H_f$  values, while maintaining consistency with the MP database.

The equilibrium product distribution at any temperature was obtained by Gibbs energy minimization, which is described in detail in **Section S3**. Equilibrium conversions are calculated as the ratio between the moles of the desired product (i.e., the value-added product) at equilibrium and the theoretical maximum number of moles of the desired product. Thermodynamically viable redox pairs were ranked based on their calculated transport efficiencies,  $R_{OC}$ , which are quantified as  $R_{OC} = \frac{m_o - m_r}{m_o}$  where  $m_o$  is the mass of the oxidized material and  $m_r$  is the mass of the reduced material.<sup>[23,70]</sup> As  $R_{OC}$  decreases, the circulation rate of solids in the CL process must increase to maintain a constant conversion rate.<sup>[23]</sup> Thus, a higher  $R_{OC}$  is desirable. Prices of elements were obtained from the United States Geological Survey.<sup>[71]</sup> Prices of the OC materials were approximated from the price of the constituent metals (oxygen and sulfur are excluded) necessary to produce 1 kg of material.

## Results and Discussion

### Error Quantification for Gibbs Energy of Reaction



**Figure 1:** Absolute error ( $\epsilon$ ) of experimental versus predicted  $\Delta G_r(T)$  for 26 oxidation reactions as a function of temperature (red). The mean absolute error (MAE) at each temperature assessed is shown in blue.  $R^2 = 0.84$  for the linear regression model of MAE ( $\text{MAE} = 42.7 + 0.0108 T$ ).

We calculated  $\Delta G_r(T)$  for 26 oxidation reactions where experimental data was available to estimate the error of our  $\Delta G_r(T)$  calculations (**Figure 2**, **Table S4**). The mean absolute error (MAE) in  $\Delta G_r(T)$  in units of  $\text{kJ mol O}_2^{-1}$  is approximated by **Equation 4** where  $T$  is the temperature in Kelvin. The absolute error for the corresponding reduction reactions are, by definition, identical to the errors for the oxidation reactions. The error between experimental and predicted  $\Delta G_r(T)$  is comprised of both the 0 K error in the DFT-calculated  $\Delta H_f$ , and thus  $\Delta H_r$ , and the temperature-dependent error in the  $G^\delta(T)$  descriptor. Errors arise exclusively from the solid-state compounds because all data for gas-phase species are experimentally determined thermochemical properties. The reaction enthalpies contribute the 42.7  $\text{kJ mol O}_2^{-1}$  error present at 0 K, and  $G^\delta(T)$  contributes the temperature-dependent error, which increases approximately linearly according to  $0.0108T$  (where  $T$  is in K and the error is in  $\text{kJ/mol O}_2$ ). The 0 K error contribution of 42.7  $\text{kJ mol O}_2^{-1}$  agrees with our broader study of 415 decomposition reactions at 0 K which yielded an MAE of 88-100  $\text{meV atom}^{-1}$  (51.1  $\text{kJ mol O}_2^{-1}$  with respect to these 26 reactions).<sup>[68]</sup> This error was shown to vary only moderately across many material classes (e.g., oxides, halides, pnictides, etc.).<sup>[68]</sup> Furthermore, the temperature-dependent error contribution of  $0.0108 T$  (19.4  $\text{kJ mol O}_2^{-1}$  at 1800 K) agrees with the previously reported MAE

of 46 meV atom<sup>-1</sup> (25.0 kJ mol O<sub>2</sub><sup>-1</sup> with respect to these 26 reactions) for  $G^\delta(T)$  applied to 178 test compounds.<sup>[60]</sup> The root mean squared error of 61 meV atom<sup>-1</sup> for these 178 compounds differs only moderately from the MAE, which indicates that the error arising from  $G^\delta(T)$  varies only slightly across the many diverse material classes studied (e.g., alkalis, transition metals, halides, etc.).<sup>[60]</sup> Because neither of the two contributing factors to the error in  $\Delta G_r(T)$  assessed here vary substantially by material class, the error in  $\Delta G_r(T)$  will also not vary substantially by material class. Consequently, these results indicate that our thermodynamic screening approach can be applied with similar accuracy to any chemical looping process that operates near equilibrium for both the oxidation and reduction reactions, irrespective of the active material chemistry.

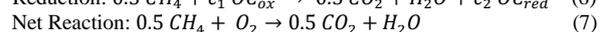
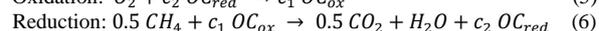
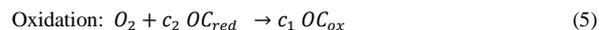
$$\Delta G_r(T): MAE(T) = 42.7 + 0.0108 T \quad (4)$$

### Benchmarking with Chemical Looping Combustion

Our descriptor-based thermodynamic screening approach involves 5 steps: 1) generate all possible redox pairs (i.e. pairs of anion-rich/ $MA_{ox}$  and anion-deficient/ $MA_{red}$  materials), 2) apply the  $G^\delta(T)$  descriptor to obtain  $\Delta G_f(T)$  for all materials, 3) calculate  $\Delta G_d(T)$  (decomposition free energy, **Section S1**) and remove redox pairs that include unstable materials, 4) calculate  $\Delta G_r(T)$  for all subreactions and remove redox pairs where any subreaction (**Equations 1 and 2**) is not spontaneous at the specified conversion within the temperature range of interest and 5) perform Gibbs energy minimization over all chemical species in the chemical system for each redox pair to determine conversion and side product formation (see Methods for additional details). Properties such as material price and transport efficiency were subsequently calculated for thermodynamically viable redox pairs. We used a reaction conversion of 90% as the threshold for thermodynamic viability in this study.

In order to assess the efficacy of our thermodynamic screening approach to identify thermodynamically viable redox pairs, we benchmarked it using experimentally studied oxygen carrying materials for CLC. We considered a diverse set of 10 materials with experimental reaction conversions of methane > 90% and 7 materials that demonstrate low or no conversion of methane, such as support materials (**Table S5**).<sup>[23,62,70,72–78]</sup> We used the aerobic combustion of methane as the net reaction for this benchmarking study, where the oxidation and reduction reactions for this process are shown in

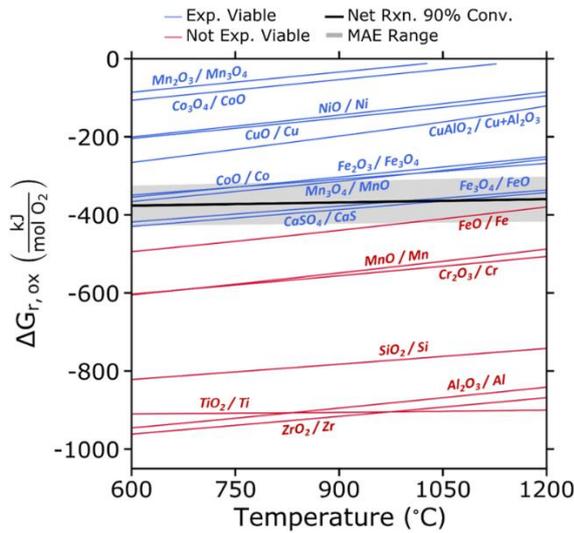
**Equations 5 and 6**, respectively, and the net reaction is shown in **Equation 7**. Oxygen carriers (OCs) are active materials for CLC, where  $OC_{ox}/OC_{red}$  is equivalent to  $MA_{ox}/MA_{red}$  and **Equations 5-7** are the CLC analogs of **Equations 1-3**. The stoichiometric coefficients for the oxidized and reduced phases of the OC are denoted by  $c_1$  and  $c_2$ , respectively. These coefficients were normalized so that 1 mole of O<sub>2</sub> is liberated from  $OC_{ox}$  to react with 0.5 moles of methane.



The oxidation reaction is always spontaneous because the redox pairs are only considered at temperatures where the constituent compounds are stable (i.e.  $OC_{ox}$  does not spontaneously decompose to  $OC_{red}$ ). Consequently, the spontaneity of the reduction reaction (**Equation 6**) determines the thermodynamic viability of candidate redox pairs for CLC. The reduction reaction is equivalent to the difference between the net reaction and the oxidation reaction (**Equation 8**). Thus, if the net reaction is more exergonic than the oxidation reaction at a given temperature ( $\Delta G_{r,net}(T) < \Delta G_{r,ox}(T)$ ), then the reduction reaction is spontaneous and the corresponding redox pair is thermodynamically viable.

$$\begin{aligned} \Delta G_{r,red} &= (0.5 \Delta G_{f,CO_2} + \Delta G_{f,H_2O} - 0.5 \Delta G_{f,CH_4}) \\ &\quad - (c_1 \Delta G_{f,OC_{ox}} - c_2 \Delta G_{f,OC_{red}}) \\ &= \Delta G_{r,net} - \Delta G_{r,ox} \end{aligned} \quad (8)$$

The Ellingham diagram for CLC is shown in **Figure 3** provides calculated  $\Delta G_{r,ox}$  as a function of temperature for the 17 experimentally studied materials. We consider the temperature range of 600-1200 °C because this is the conventional operating range for CLC.<sup>[23]</sup> In addition to  $\Delta G_{r,ox}(T)$ , the net combustion reaction for CLC ( $\Delta G_{r,net}$ ) is shown at 90% conversion of methane (black line). The 10 redox pairs that have been experimentally demonstrated to react with methane to form CO<sub>2</sub> and steam at > 90% conversion are shown in blue, and the 7 materials that have been experimentally observed to not react with methane or which are often used as inert support materials are shown in red. We note that although  $\Delta G_{r,net}$  is obtained from experiment, the MAE for  $\Delta G_r(T)$  (**Equation 4**) is included above and below the net reaction to indicate whether the calculated  $\Delta G_{r,ox}$  values lie within the MAE error range of being thermodynamically viable pairs.



**Figure 2:** Ellingham diagram showing the calculated oxidation energy,  $\Delta G_{r,ox}$ , for the 17 experimentally studied redox pairs as a function of temperature from 600-1200 °C. OCs with a high experimental conversion of methane (> 90%) are shown in blue, while OCs that experimentally do not react with methane or exhibit low methane conversion are shown in red. The bold line indicates the free energy of the net reaction,  $\Delta G_{r,net}$ , for methane oxidation at 90% conversion. Redox pairs are labeled as:  $OC_{ox}/OC_{red}$ .

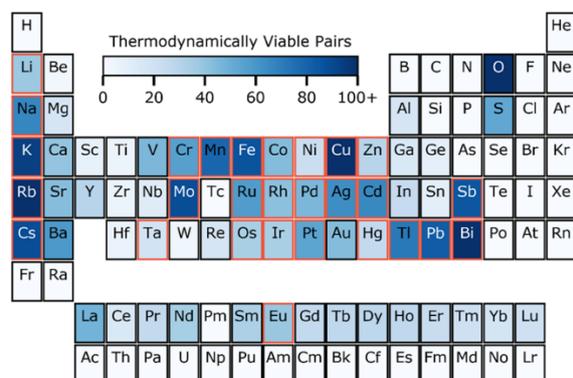
Our thermodynamic screening approach correctly classifies all 10 of the experimentally studied redox pairs with > 90% methane conversion for CLC (blue lines in **Figure 3**). These 10 pairs were predicted to be both stable and thermodynamically viable within the operating temperature range for CLC. Our method also correctly classifies all 7 redox pairs that were observed to exhibit low or no conversion of methane as not being thermodynamically viable for CLC (red lines in **Figure 3**). Furthermore, the prediction by our analysis that  $\text{CaSO}_4/\text{CaS}$  and  $\text{Fe}_3\text{O}_4/\text{FeO}$  transition to being thermodynamically viable pairs at higher temperatures agrees with experimental observations. The  $\text{CaSO}_4/\text{CaS}$  redox pair was observed to transition from 10% conversion of methane to  $\text{CO}_2$  at 850 °C to 90% conversion at 1000 °C, closely matching our results that this redox pair should demonstrate > 90% conversion above ~1050 °C.<sup>[75]</sup> Additionally, the reduction of  $\text{Fe}_3\text{O}_4$  to  $\text{FeO}$  was observed to be slow at 950 °C, matching our model's prediction that this redox pair has a low thermodynamic driving force (small  $|\Delta G_{r,red}|$ ) at 950 °C despite being thermodynamically viable.<sup>[62]</sup>

The prediction of equilibrium product yields of these 17 redox pairs using Gibbs energy minimization further corroborated the classification results. Of the 10 OCs that have been experimentally demonstrated to be viable, all exhibit conversions > 99% except  $\text{CaSO}_4/\text{CaS}$ ,  $\text{Fe}_3\text{O}_4/\text{FeO}$  and  $\text{CoO}/\text{Co}$  which are all predicted to yield a mixture of  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{H}_2\text{O}$  and  $\text{H}_2$  as combustion products. The  $\text{CaSO}_4/\text{CaS}$  redox pair suffers from the competing formation of  $\text{CaO}$ , as is observed experimentally.<sup>[76,79]</sup> Furthermore, all 7 of the redox pairs that are not experimentally viable are calculated to exhibit conversions below 1%. Overall, our high-throughput screening approach accurately classifies all 17 of the experimentally studied redox pairs by their thermodynamic viability and agrees with experimental observations for the two redox pairs that lie on the threshold of thermodynamic viability.

### New Active Materials for Chemical Looping Combustion

In order to identify new redox pairs for CLC, we obtained 13,763 oxygen-containing binary and ternary compounds from MP. Of these, 3,107 were predicted to be stable ( $\Delta G_d(T) \leq 0$ , see **Methods**) at some temperature between 300 and 1800 K using our  $G^\delta(T)$  descriptor. This subset of stable compounds was used to generate 17,880 redox pairs. Of these pairs, 1,320 meet the condition for thermodynamic viability ( $\Delta G_{r,net}(T) < \Delta G_{r,ox}(T)$ ) within the CLC operating range for a methane conversion of > 90%. This subset includes the 10 experimentally viable redox pairs analyzed in the previous section. **Figure 4** depicts the subset of elements that these 1,320 redox pairs are composed from, as well as the number of predicted thermodynamically viable redox pairs containing each element. The 28 highlighted elements (orange borders) comprise the 52 viable binary redox pairs. In the case of ternary redox pairs, 93% of the 1,268 ternary pairs that our scheme predicts are viable contain at least one of these 28 elements. The remaining 87 viable ternary compounds do not contain any of these 28 elements and thus would not have been identified by alloying a viable binary. Binary pairs of the alkali metals (Li, Na, K, Rb, Cs), some transition metals (Cr, Mo, Pd, Ag, Os, Pt), and some main group elements (Zn, Cd, Sb, Hg, Tl, Pb, and Bi) include materials with melting points below 600 °C,<sup>[80]</sup> and Ru, Rh and Ir are too expensive for industrial CLC applications.<sup>[71]</sup> Excluding binary pairs composed of these elements further reduces

the element set to Mn, Fe, Co, Ni and Cu, which have all been studied as CLC OCs and are included to benchmark our method, in addition to Ta and Eu, which have not been explored for CLC. The two unstudied binary pairs are TaO<sub>3</sub>/Ta<sub>2</sub>O<sub>5</sub> and Eu<sub>2</sub>O<sub>3</sub>/Eu<sub>3</sub>O<sub>4</sub>.



**Figure 4:** The number of thermodynamically viable redox pairs (1,320 total) for CLC that contain each respective element. The 28 elements highlighted by an orange border form viable binary oxide redox pairs. The majority of viable ternary redox pairs (93%) contain at least one of these highlighted elements.

TaO<sub>3</sub> forms in a layered structure that has been synthesized through delamination of RbTaO<sub>3</sub>,<sup>[81]</sup> but has not been studied for high-temperature applications. In contrast, our prediction that Eu<sub>2</sub>O<sub>3</sub>/Eu<sub>3</sub>O<sub>4</sub> is thermodynamically viable for CLC is corroborated by the synthesis of Eu<sub>3</sub>O<sub>4</sub> from Eu<sub>2</sub>O<sub>3</sub> and CO,<sup>[82]</sup> demonstrating that Eu<sub>2</sub>O<sub>3</sub> oxidizes CO to CO<sub>2</sub> and therefore likely also oxidizes methane. Moreover, the melting point of Eu<sub>2</sub>O<sub>3</sub> (2291 °C) is higher than any other material that comprises a viable binary OC for CLC,<sup>[80]</sup> suggesting that this material may have a higher attrition resistance than other currently studied OCs. The oxidation of Eu<sub>2</sub>O<sub>3</sub> to Eu<sub>3</sub>O<sub>4</sub> has a similar thermodynamic driving force ( $\Delta G_{r,ox}$ ) to that of the Fe<sub>2</sub>O<sub>3</sub>/Fe<sub>3</sub>O<sub>4</sub> redox pair which exhibits fast reaction kinetics and full methane conversion.<sup>[62]</sup> Although Eu<sub>2</sub>O<sub>3</sub>/Eu<sub>3</sub>O<sub>4</sub> has a low oxygen transport efficiency ( $R_{OC}$ ) of 0.02, it is similar to that of Fe<sub>2</sub>O<sub>3</sub>/Fe<sub>3</sub>O<sub>4</sub> (0.03).<sup>[72]</sup> While Gibbs energy minimization predicts that competing formation of EuCO<sub>3</sub> will lower methane conversion to CO<sub>2</sub>, this could be overcome at higher temperature (> 1200 °C). Furthermore, the cost of Eu<sub>2</sub>O<sub>3</sub> is greater than that of other currently studied OCs.<sup>[71]</sup> Nonetheless, Eu<sub>2</sub>O<sub>3</sub>/Eu<sub>3</sub>O<sub>4</sub> is an intriguing candidate for CLC at temperatures near or above 1200 °C.

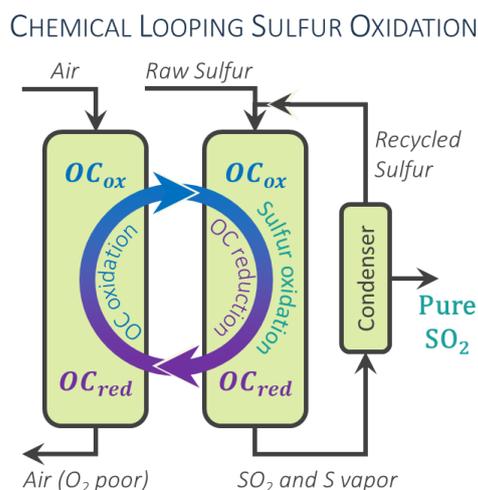
Gibbs energy minimization was performed on the 1,320 predicted thermodynamically viable redox pairs in order to determine the conversion of methane to CO<sub>2</sub> with the consideration of possible competing phases (i.e. side products). 342 redox pairs are predicted to convert methane to CO<sub>2</sub> with > 90% conversion. Of these, 124 yield the desired reduced phase(s) with a conversion > 90%, making them promising candidates for CLC due to their lack of side-product formation and high methane conversion. However, the Gibbs energy minimization scheme is more sensitive to  $\Delta G_f$  than the thermodynamic viability assessment, and consequently small errors in  $\Delta G_f$  can potentially produce substantial errors in predicted reaction conversions. This is because a small shift in  $\Delta G_f$  could stabilize or destabilize a material relative to competing phases, resulting in a substantial change in the equilibrium products. As such, some of the 978 redox pairs that the Gibbs energy minimization approach predicts yield a conversion approaching 90% may still be experimentally viable OCs for CLC. Likewise, a fraction of the 124 promising redox pairs may in fact yield conversions below 90%.

Our thermodynamic screening approach does not systematically consider melting points because experimental tabulation of this materials property is sparse for compounds and its calculation is computationally demanding.<sup>[56,83]</sup> As a result, some of the redox pairs predicted to be viable by our thermodynamic screening approach will not in fact be applicable for CLC because they include compounds that melt below CLC operating temperatures. **Table 1** reports a subset of the thermodynamically viable redox pairs with > 90% conversion; the full set of 1,320 thermodynamically viable redox pairs are reported in **Table S6**. Both tables include reaction conversions of methane to CO<sub>2</sub> and predicted side products obtained by Gibbs energy minimization. Where available, melting points are included. Transport efficiency and price are also listed (see **Methods** for details). Some of these materials may also be relevant for CL with oxygen uncoupling for solid fuel combustion or CL air separation, such as the perovskite SrNiO<sub>3</sub> which decomposes above 600 °C to yield SrNiO<sub>2.5</sub> ( $mp = 1350$  °C) and O<sub>2</sub>.<sup>[84]</sup> A large number of sulfate redox pairs are listed in **Table 1** due to their high theoretical  $R_{OC}$ , high methane conversion and few or no side products. The redox pairs reported in **Table 1** are predicted to be promising but unstudied OCs for CLC.

**Table 1:** Select redox pairs for CLC with methane conversion > 90%. Pairs are rank ordered by oxygen transport efficiency ( $R_{OC}$ , see **Methods**). The temperature range indicates the temperatures within the CLC operating range where conversion is > 90%, calculated at intervals of 50 °C, and where the reduced phase(s) are solid. All temperatures are in Celsius. Price is in \$/kg.  $mp_{ox}$  and  $mp_{red}$  are the melting points of the oxidized and reduced phases, respectively, and (d) indicates that the material decomposes at the indicated temperature.

Oxidized Phase	Reduced Phase(s)	CH <sub>4</sub> Conv.	$R_{OC}$	Side Prod.	Price	Temp. Range	$mp_{ox}$ <sup>[80]</sup>	$mp_{red}$ <sup>[80]</sup>
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	Al <sub>2</sub> S <sub>3</sub>	0.94	0.56	Al <sub>2</sub> O <sub>3</sub>	0.35	950 - 1100	1040 (d)	1100
Ga <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	Ga <sub>2</sub> S <sub>3</sub>	0.99	0.45	None	196	600 - 1090	--	1090
W(SO <sub>4</sub> ) <sub>2</sub>	WS <sub>2</sub>	0.99	0.34	None	0.1	600 - 750	--	1250 (d)
CdSO <sub>4</sub>	CdS	0.99	0.31	None	2.4	600 - 1200	1000	1750
Ag <sub>2</sub> SO <sub>4</sub>	Ag <sub>2</sub> S	0.99	0.21	None	444	600 - 825	652	825
PbSO <sub>4</sub>	PbS	0.99	0.21	None	1.65	600 - 1113	1087	1113
GdCu <sub>2</sub> O <sub>4</sub>	Gd <sub>2</sub> O <sub>3</sub> , Cu	0.99	0.11	Gd(OH) <sub>3</sub>	28	600 - 1084	--	2339, 1084
Al <sub>2</sub> (MoO <sub>4</sub> ) <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.99	0.09	None	19	600 - 1100	--	2053, 1100 (d)
YCrO <sub>4</sub>	YCrO <sub>3</sub>	0.99	0.08	None	36	800 - 1200	--	--
Ga <sub>2</sub> NiO <sub>4</sub>	Ga <sub>2</sub> O <sub>3</sub> , Ni	0.99	0.06	None	324	600 - 1200	--	1806, 1455
CrCuO <sub>2</sub>	Cr <sub>2</sub> O <sub>3</sub> , Cu	0.99	0.05	None	6.8	600 - 800	--	2329, 1084
SmCuO <sub>2</sub>	Sm <sub>2</sub> O <sub>3</sub> , Cu	0.99	0.03	None	39	600 - 1000	--	2269, 1084

### Novel Chemical Looping Process for SO<sub>2</sub> Production

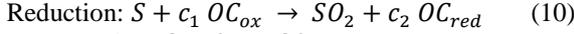
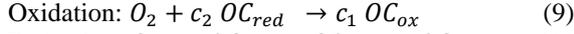


**Figure 5:** Proposed process for pure SO<sub>2</sub> production, envisioned in a circulating bed arrangement. An oxygen carrier,  $OC_{ox}$ , is used to oxidize sulfur to SO<sub>2</sub>, concomitantly reducing the oxygen carrier. The reduced oxygen carrier,  $OC_{red}$ , is regenerated in a second reactor via aerobic oxidation. Any unreacted sulfur vapor is readily separated from the effluent via condensation and recycled.

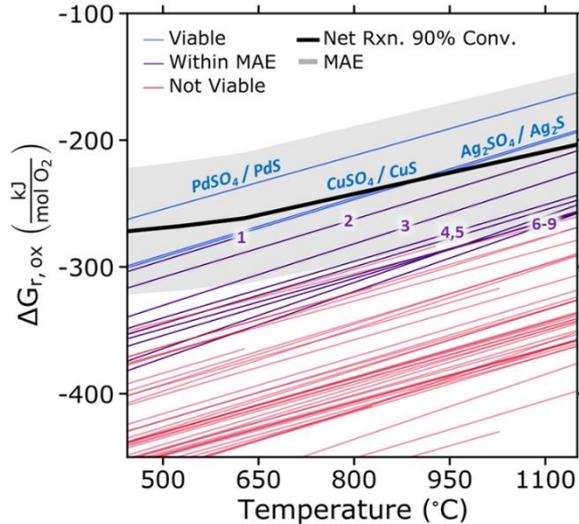
We also applied our thermodynamic screening approach to predict materials for a novel chemical looping process that we hypothesized can produce highly pure sulfur dioxide (SO<sub>2</sub>), as shown in **Figure 5**. SO<sub>2</sub> is an essential industrial chemical because it is a precursor for sulfuric acid,<sup>[85,86]</sup> a reducing agent for pulp and paper

production,<sup>[86]</sup> a de-chlorinating agent in wastewater treatment,<sup>[87]</sup> a food preservative (E220),<sup>[88]</sup> an antioxidant for wine,<sup>[89]</sup> a leachant for manganese ore,<sup>[90]</sup> and used in the production of other sulfur-containing chemicals.<sup>[65,91]</sup> The primary method for generating SO<sub>2</sub> for sulfuric acid production is via the aerobic combustion of sulfur (**Equation 11**), which produces a dilute SO<sub>2</sub> stream that is ~12 vol% SO<sub>2</sub>, 7% oxygen, and 79% nitrogen.<sup>[86]</sup> The substantial volume of inert N<sub>2</sub> dilutes this product stream, which dictates that gas flowrates and downstream process units must be proportionally larger and ultimately that energy intensive separations processes must be used to reduce the emission of unreacted SO<sub>2</sub> with the N<sub>2</sub>-rich effluent.<sup>[86]</sup> Some applications require concentrated (99.9%) liquid SO<sub>2</sub>, whose production begins with the aerobic combustion of sulfur, followed by absorption-desorption, drying, and finally cryogenic condensation to concentrate the SO<sub>2</sub>.<sup>[65]</sup> These additional process steps to concentrate SO<sub>2</sub> are expensive and energy intensive.<sup>[65]</sup> An efficient route to producing pure SO<sub>2</sub> using CL would therefore substantially decrease the capital cost, energy use, and SO<sub>2</sub> emissions of producing both concentrated liquid SO<sub>2</sub> and sulfuric acid, which would be significant considering that sulfuric acid is the world's most produced chemical by mass, with an annual production rate of 230 billion kg per year.<sup>[66,86]</sup> Pure SO<sub>2</sub> produced via a CL process can be condensed and provided as liquid SO<sub>2</sub> or subsequently converted to sulfuric acid via the contact process using recently-developed catalyst

bed designs capable of processing high SO<sub>2</sub> content streams.<sup>[92, 93]</sup>



Our descriptor-based screening approach enables a high-throughput screening strategy to discover thermodynamically viable redox pairs for the proposed chemical looping sulfur oxidation (CLSO) process. Sulfate/sulfide redox pairs were exclusively considered for this screening effort because metal oxides predominantly react with elemental sulfur at high temperatures to form sulfides and sulfates.<sup>[94–96]</sup> Similar to our analysis of methane oxidation for CLC,  $\Delta G_{r,ox}(T)$  (Equation 9) was compared directly to the reaction free energy of the net reaction (Equation 11), which is again normalized to the reaction of 1 mole of O<sub>2</sub> with a reaction conversion of 90%. The Ellingham diagram depicted in Figure 6 shows  $\Delta G_{r,ox}(T)$  relative to  $\Delta G_{r,net}(T)$  for 75 sulfate redox pairs and thus illustrates the thermodynamic viability of these pairs for CLSO. An operating range of 444 to 1150 °C was selected for this comparison because 444 °C is the boiling point of sulfur (at 1 atm),<sup>[80]</sup> and 1150 °C is the conventional reactor temperature of a sulfur burning furnace.<sup>[86]</sup>



**Figure 6:** An Ellingham diagram for CLSO showing  $\Delta G_{r,ox}(T)$  for 75 sulfate/sulfide redox pairs. All redox pairs are only shown in the temperature range where both the oxidized and reduced phases are stable. Thermodynamically viable redox pairs are those that meet the condition that  $\Delta G_{r,net}(T) < \Delta G_{r,ox}(T)$  within the operating range of 444 to 1150 °C. Redox pairs 1 to 9 which lie within the MAE are (in order): W(SO<sub>4</sub>)<sub>2</sub>/WS<sub>2</sub>,

NiSO<sub>4</sub>/NiS, Nb(SO<sub>4</sub>)<sub>2</sub>/NbS<sub>2</sub>, PbSO<sub>4</sub>/PbS, CoSO<sub>4</sub>/CoS, CdSO<sub>4</sub>/CdS, Ga<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>/Ga<sub>2</sub>S<sub>3</sub>, Tl<sub>2</sub>SO<sub>4</sub>/Tl<sub>2</sub>S, and Sb<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>/Sb<sub>2</sub>S<sub>3</sub>.

The screening of CLSO redox materials based on their thermodynamic viability identifies three sulfate/sulfide redox pairs as being thermodynamically viable OCs for CLSO within the defined operating range (444 - 1150 °C). All three of these pairs are within the MAE of  $\Delta G_r$  but meet the condition that  $\Delta G_{r,red}(T) < 0$ . Of these three, the redox pair CuSO<sub>4</sub>/CuS is highly promising due to its thermodynamic viability and low cost. An additional 9 redox pairs are identified within the MAE of  $\Delta G_r$  that meet the condition that  $\Delta G_{r,red}(T) < \text{MAE}(T)$ . Because  $\Delta G_{r,red}(T)$  of these pairs lies within the MAE of the threshold for thermodynamic viability, they could be experimentally viable for CLSO and are therefore included in the following screening. We next performed a Gibbs energy minimization for all 12 redox pairs to determine reaction conversions with consideration of the possible production of side products. The maximum sulfur conversion and predicted side products are tabulated alongside relevant material properties, where available, for each redox pair in Table 2.

Of the 12 candidates reported in Table 2, PdSO<sub>4</sub>, Tl<sub>2</sub>SO<sub>4</sub>, Ag<sub>2</sub>SO<sub>4</sub>, and Ga<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> are likely too expensive to be considered for industrial applications.<sup>[71]</sup> Furthermore, Sb<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> is experimentally observed to be thermodynamically unstable.<sup>[80]</sup> Of the remaining 7 candidates, the sulfates of W, Nb, and Ni demonstrate the highest conversions with minimal side-product formation, making them the most promising candidate OCs for CLSO. The formation of oxide side products (e.g. WO<sub>3</sub> and Nb<sub>2</sub>O<sub>5</sub>) during sulfate reduction does not hinder the recyclability of the OCs because these side products are also inherently oxygen carriers. Gibbs energy minimization predicts that both WO<sub>3</sub> and Nb<sub>2</sub>O<sub>5</sub> react with sulfur vapor to produce the corresponding sulfides and SO<sub>2</sub>. All of the candidates included in Table 2 exhibit high oxygen transport efficiencies.

Previous experimental studies on the reduction of sulfates and oxidation of sulfides corroborate several of our material predictions. The sulfates and oxides of Cu and Ni have been demonstrated to spontaneously react with sulfur vapor to form the corresponding metal sulfide under low-oxygen conditions,<sup>[97–99]</sup> even at lower temperatures (450 °C for Ni), agreeing with our predictions from  $\Delta G_{r,red}$  indicating that the reaction of CuSO<sub>4</sub> and NiSO<sub>4</sub> with sulfur is

**Table 2:** 12 viable and nearly viable sulfate redox pairs for CLSO listed in order of decreasing viability (i.e., increasing  $\Delta G_{r,red}$ ). The temperature range indicates where the tabulated corresponding sulfur conversion is achieved and the reduced phase(s) is stable and solid. All temperatures are in Celsius. Price is in \$/kg.  $mp_{ox}$  and  $mp_{red}$  are the melting points of the oxidized and reduced phases, respectively, and (d) indicates that the material decomposes at the indicated temperature.

Oxidized Phase	Reduced Phase(s)	Sulfur Conv.	$R_{oc}$	Side Prod.	Price	Temp. Range	$mp_{ox}^{[80]}$	$mp_{red}^{[80]}$
PdSO <sub>4</sub>	PdS	0.99	0.32	PdS <sub>2</sub>	9300	700 - 1150	--	--
Ag <sub>2</sub> SO <sub>4</sub>	Ag <sub>2</sub> S	0.97	0.21	None	440	600 - 825	652	825
CuSO <sub>4</sub>	CuS	0.66	0.40	CuS <sub>2</sub>	3.1	450 - 507	560 (d)	507 (d)
W(SO <sub>4</sub> ) <sub>2</sub>	WS <sub>2</sub>	0.97	0.34	WO <sub>3</sub>	0.1	550 - 750	--	1250 (d)
NiSO <sub>4</sub>	NiS	0.81	0.41	NiS <sub>2</sub> , Ni <sub>3</sub> S <sub>4</sub>	8.3	450 - 946	840 (d)	946
Nb(SO <sub>4</sub> ) <sub>2</sub>	NbS <sub>2</sub>	0.70	0.45	Nb <sub>2</sub> O <sub>5</sub> , NbS <sub>3</sub>	5.0	600 - 1150	--	--
PbSO <sub>4</sub>	PbS	0.59	0.21	PbS <sub>2</sub> O <sub>3</sub>	1.7	550 - 1113	1087	1113
CoSO <sub>4</sub>	CoS	0.58	0.41	CoS <sub>2</sub>	18	650 - 1150	> 700	1182
CdSO <sub>4</sub>	CdS	0.68	0.31	CdS <sub>2</sub>	2.4	850 - 1150	1000	1750
Ga <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	Ga <sub>2</sub> S <sub>3</sub>	0.49	0.45	None	200	950 - 1090	--	1090
Tl <sub>2</sub> SO <sub>4</sub>	Tl <sub>2</sub> S	--	0.13	--	4800	--	632	448
Sb <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub>	Sb <sub>2</sub> S <sub>3</sub>	0.00	0.36	None	4.0	450 - 550	(d)	550

spontaneous (or nearly so). Additionally, the sulfides of Ni,<sup>[100,101]</sup> Cu,<sup>[102]</sup> and Co<sup>[102,103]</sup> have been observed to spontaneously oxidize to a mixture of the sulfide, sulfate, and oxide phases with minimal or no SO<sub>2</sub> release when properly controlled. This agrees with our calculations that NiS, CuS, and CoS spontaneously react with air to form the corresponding sulfate without substantial side-product formation. The oxidation of nickel sulfide particles occurs in stages, with the initial stage of the reaction forming a dense nickel oxide layer as Ni atoms migrate to the surface of the particle.<sup>[100]</sup> This initial oxidation stage proceeds with little evolution of SO<sub>2</sub>. The sulfides of Cu and Co react in an analogous manner with optimal oxidation occurring near 450 °C.<sup>[102,103]</sup> Reactor conditions should be properly regulated to minimize the production of SO<sub>2</sub> during aerobic oxidation of the sulfide; however, experiments with fluidized bed reactors have demonstrated that this is achievable for sulfate roasting applications.<sup>[102,104]</sup> Although no study has previously investigated both the oxidation and reduction reactions considered for CLSO, experimental results exist supporting our contention that the constituent oxidation and reduction reactions of CLSO can be individually accomplished with a high degree of control for the sulfate/sulfide OCs based on Ni and Cu.<sup>[97–102]</sup>

## Conclusion

High-throughput materials screening is a promising route to accelerate the discovery of active materials for chemical looping processes.

Here, we demonstrated that a high-throughput thermodynamic screening approach based on our Gibbs energy descriptor  $G^\delta(T)$  can be broadly applied to chemical looping processes that operate at or near equilibrium with similar accuracy across a wide range of materials. This approach also provides an estimate for the mean absolute error in  $\Delta G_r(T)$ , which ranges from 43 kJ mol O<sub>2</sub><sup>-1</sup> at 0 K, due to errors in the DFT prediction of formation enthalpy, to 62 kJ mol O<sub>2</sub><sup>-1</sup> at 1800 K, due to the additional error contributed by the  $G^\delta(T)$  descriptor in predicting high-temperature contributions to the free energy. However, this contribution is likely significantly smaller because CL operating conditions involve temperatures considerably lower than 1800 K. Furthermore, these errors will decrease as *ab initio* databases increase in accuracy and the 0 K error decreases. Still, our screening method properly classified 100% (17/17) of the experimentally studied redox materials for CLC by their thermodynamic viability for this process. Moreover, we leveraged this approach to analyze unstudied redox materials for CLC and identified over 1,300 viable redox pairs, 124 of which are predicted to exhibit reaction conversions of methane > 90% with minimal side product formation, increasing the number of known materials that meet these constraints by an order of magnitude. Furthermore, a number of sulfate materials (e.g. Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>, W(SO<sub>4</sub>)<sub>2</sub>, CdSO<sub>4</sub>, etc.) are included in this set which not only exhibit high reaction conversion and minimal side-product formation, but which are also inexpensive and exhibit exemplary

oxygen transport efficiency, making them intriguing candidates for CLC.

Finally, we further demonstrated the ability of our thermodynamic screening approach by applying it to a novel chemical looping process to oxidize raw sulfur to pure SO<sub>2</sub>. This process could provide a considerably more energy efficient and lower emission route to sulfuric acid. Application of our screening approach revealed that 12 possible sulfate/sulfide redox pairs are thermodynamically viable for this process. 7 of these pairs involve low cost materials with calculated reaction conversions > 50% and high oxygen transport efficiencies. One of these materials, W(SO<sub>4</sub>)<sub>2</sub>, is calculated to yield 97% conversion of sulfur to SO<sub>2</sub>. Two others, NiSO<sub>4</sub> and CuSO<sub>4</sub>, are corroborated by experimental studies of their individual sulfide oxidation and sulfate reduction reactions constituting the CLSO process and are predicted to achieve sulfur oxidation conversions of 81% and 66%, respectively. As the field of chemical looping continues to grow, our screening approach provides a platform for rapid materials discovery to accelerate innovation across a wide range of chemical looping chemistries capable of increasing energy efficiency, leveraging renewable energy sources, facilitating chemical conversions, and decreasing undesirable emissions in many sectors of the chemical industry.

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## Supporting Information

Supporting Information is available on ChemRxiv or from the author.

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## Author Contributions

N.R.S. performed all calculations, analyzed the results, conceived of the CLSO process, and drafted the manuscript. C.J.B., C.B.M., and A.M.H. conceived of the project, designed the initial approach, provided essential guidance on the project and analysis and assisted in writing and revising the manuscript. All of the authors reviewed the manuscript.

## Conflicts of Interest

The authors report no conflicts of interest.

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## Supporting Information

**Title:** High-Throughput Analysis of Materials for Chemical Looping Processes

**Authors:** Nicholas R. Singstock, Christopher J. Bartel, Aaron M. Holder and Charles B. Musgrave

**S1:** Mathematical formulation of the convex hull. The convex hull is used to assess the stability of a material against competing phases. For any material,  $i$ , the decomposition energy ( $\Delta G_{d,i}(T)$ ), is assessed. The convex hull connects the minimum energy surface between stable compounds as composition/stoichiometry of the elements is varied. Decomposition energies are calculated using  $\Delta G_{d,i}(T) = \Delta G_{f,i}(T) - \sum_j^n x_j * \Delta G_{f,j}(T) \Big|_{j \neq i}$  where  $\vec{x}$  is the array that minimizes the function  $\sum_j^n x_j * \Delta G_{f,j}(T) \Big|_{j \neq i}$  with the constraints that  $\vec{els}_i = \sum_j^n x_j * \vec{els}_j \Big|_{j \neq i}$  and all  $x_j \geq 0$ .<sup>1</sup> In these equations,  $i$  is the compound for which  $\Delta G_d(T)$  is determined,  $j$  is any possible decomposition product from the space of all possible decomposition products,  $n$ , available from the Materials Project database, and  $\vec{els}$  is the array of element coefficients corresponding to each element in the compound (e.g.  $\vec{els}_{NiSO_4} = [1 \ 1 \ 4]$ ).

**S2:** Elements and compounds which were relaxed with DFT from a single ferromagnetic and multiple antiferromagnetic initial states in order to find the magnetic ground state. Numbers in parenthesis indicate the number of antiferromagnetic states sampled.

Cr (7)			CrO <sub>2</sub> (6)	Cr <sub>2</sub> O <sub>3</sub> (9)
Mn (9)	MnO (7)	Mn <sub>3</sub> O <sub>4</sub> (9)	MnO <sub>2</sub> (2)	Mn <sub>2</sub> O <sub>3</sub> (9)
Fe (7)	FeO (7)	Fe <sub>3</sub> O <sub>4</sub> (9)		Fe <sub>2</sub> O <sub>3</sub> (9)
Co (5)	CoO (7)	Co <sub>3</sub> O <sub>4</sub> (6)	CoO <sub>2</sub> (2)	
Ni (7)	NiO (7)	Ni <sub>3</sub> O <sub>4</sub> (19)		

**S3:** Reaction energies and equilibrium products are the primary tools for assessing the thermodynamic viability of redox pairs in this study. The Gibbs free energy of reaction is

calculated for all of the redox pairs using  $\Delta G_r(T) = \vec{c} \cdot \Delta \vec{G}_f$  where  $\Delta \vec{G}_f$  is the array of Gibbs formation energies for the products and reactants of the reaction, and  $\vec{c}$  is the array of molar coefficients corresponding to each specie. Coefficients are positive for products and negative for reactants. For gaseous reactions, the Gibbs free energy of reaction is  $\Delta G_r(T) = \vec{c} \cdot (\Delta \vec{G}_f + RT * \ln(\vec{P}/P_{tot}))$  where R is the gas constant,  $\vec{P}$  is the array of partial pressures of the gaseous species, and  $P_{tot}$  is the total system pressure. Spontaneous reactions have a negative Gibbs energy of reaction. Equilibrium products at any temperature, T, are defined by the array,  $\vec{x}$ , which minimizes the function  $\Delta G_{min}(T) = \vec{x} \cdot (\vec{G}_f + \vec{g} * RT * \ln(\vec{P}/P_{tot}))$  where  $\vec{G}_f(T)$  is the array of  $\Delta G_f(T)$  for all possible chemical species that could be formed by the system, and the array of molar coefficients for these species,  $\vec{x}$ , is subject to the constraints that  $\vec{e}l\vec{s}_{sys} = \sum_j^n x_j * \vec{e}l\vec{s}_j$  and all  $x_j \geq 0$ , where  $\vec{e}l\vec{s}_{sys}$  is the array of moles of elements that are present in the system, and  $x_j$  and  $\vec{e}l\vec{s}_j$  are previously defined.  $\vec{g}$  is an array containing zeros and ones which specifies whether a specie is gaseous (1) or solid (0).

**S4:** Redox pairs composed of materials with experimental Gibbs formation energies tabulated on NIST JANAF.<sup>2</sup>

Binary to Element		Binary to Binary	Ternary to Binary/Elements
Al <sub>2</sub> O <sub>3</sub> /Al	MgO/Mg	Co <sub>3</sub> O <sub>4</sub> /CoO	MgSiO <sub>3</sub> /Mg+Si
CaO/Ca	Na <sub>2</sub> O/Na	Fe <sub>2</sub> O <sub>3</sub> /Fe <sub>3</sub> O <sub>4</sub>	MgTiO <sub>3</sub> /Mg+Ti
BaO/Ba	PbO/Pb	MoO <sub>3</sub> /MoO <sub>2</sub>	Na <sub>2</sub> SiO <sub>3</sub> /Na+Si
CoO/Co	SrO/Sr	Nb <sub>2</sub> O <sub>5</sub> /NbO <sub>2</sub>	K <sub>2</sub> SiO <sub>3</sub> /K+Si
Cr <sub>2</sub> O <sub>3</sub> /Cr	TiO <sub>2</sub> /Ti		Al <sub>2</sub> MgO <sub>4</sub> /Al+Mg
CuO/Cu	V <sub>2</sub> O <sub>5</sub> /V		Al <sub>2</sub> SiO <sub>5</sub> /Al+Si
Fe <sub>3</sub> O <sub>4</sub> /Fe	SiO <sub>2</sub> /Si		FeSO <sub>4</sub> /FeS
			MgSO <sub>4</sub> /MgS

**S5:** Experimentally studied active materials (high and low conversion) and support materials (no conversion) for CLC.

Oxidized Phase	Reduced Phase	Temp (°C)	Conversion	Refs.
NiO	Ni	950	High	3-5
CuO	Cu	800-850	High	3-6
CuAl <sub>2</sub> O <sub>4</sub>	Cu + Al <sub>2</sub> O <sub>3</sub>	850	High	3
Fe <sub>2</sub> O <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub>	950	High	3,4
Fe <sub>3</sub> O <sub>4</sub>	FeO	950	Low	3,5
FeO	Fe	950	None	3,5
Mn <sub>2</sub> O <sub>3</sub>	MnO	450-550	High	4,7
Mn <sub>3</sub> O <sub>4</sub>	MnO	800-950	High	3,5,7
MnO	Mn	950-1300	None	5,7
CaSO <sub>4</sub>	CaS	950-1000	High	8,9
CaSO <sub>4</sub>	CaS	800-850	Low	8,9
Co <sub>3</sub> O <sub>4</sub>	CoO	500-700	High	10
CoO	Co	700	High	10
SiO <sub>2</sub>	Si	950-1300	None	4,5
TiO <sub>2</sub>	Ti	950-1300	None	5
ZrO <sub>2</sub>	Zr	950-1300	None	5
Al <sub>2</sub> O <sub>3</sub>	Al	950-1300	None	5
Cr <sub>2</sub> O <sub>3</sub>	Cr	730	None	11

**S6:** 1,320 thermodynamically viable redox pairs for CLC predicted by our screening. Price listed where data is available for constituent elements.<sup>12</sup>

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Ag <sub>2</sub> BiO <sub>3</sub>	Ag, Bi	0.91	0.102	Bi <sub>2</sub> CO <sub>5</sub>	300.56
Ag <sub>2</sub> HgO <sub>2</sub>	HgO, Ag	1.00	0.036	AgH <sub>9</sub> O <sub>5</sub> , Ag <sub>2</sub> O	320.36
Ag <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub>	Ag, Mo	0.34	0.216	MoO <sub>2</sub>	279.28
Ag <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub>	MoO <sub>2</sub> , AgO	1.00	0.031	MoH <sub>4</sub> O <sub>5</sub> , MoO <sub>3</sub>	279.28
Ag <sub>2</sub> MoO <sub>4</sub>	Ag, Mo	0.44	0.170	MoO <sub>2</sub>	377.34

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Ag <sub>2</sub> SO <sub>4</sub>	Ag <sub>2</sub> S	1.00	0.205	None	443.87
Ag <sub>3</sub> IrO <sub>4</sub>	Ag, Ir	1.00	0.110	None	7269.87
Ag <sub>3</sub> SbO <sub>4</sub>	Ag, Sb	0.73	0.126	Sb <sub>2</sub> O <sub>3</sub>	409.67
Ag <sub>5</sub> BiO <sub>4</sub>	Ag, Bi	0.93	0.079	Bi <sub>2</sub> CO <sub>5</sub>	430.47
Ag <sub>5</sub> Pb <sub>2</sub> O <sub>6</sub>	Ag, Pb	0.83	0.091	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	330.56
AgAuO <sub>2</sub>	AgO, Au	1.00	0.047	None	22713.53
AgBiO <sub>2</sub>	Ag, Bi	0.90	0.092	Bi <sub>2</sub> CO <sub>5</sub>	208.91
AgGeO <sub>3</sub>	GeO <sub>2</sub> , Ag	1.00	0.070	None	684.30
AgO	Ag	1.00	0.129	None	558.66
AgPdO <sub>2</sub>	AgO, Pd	1.00	0.065	Ag <sub>3</sub> Pd	7903.95
AgPtO <sub>2</sub>	AgO, Pt	1.00	0.048	None	30097.60
AgRhO <sub>2</sub>	Ag, Rh	1.00	0.132	None	34275.68
AgSbO <sub>3</sub>	Ag, Sb	0.53	0.173	Sb <sub>2</sub> O <sub>3</sub>	253.11
Al <sub>10</sub> ZnO <sub>16</sub>	Al <sub>2</sub> O <sub>3</sub> , Zn	0.02	0.027	Al <sub>2</sub> ZnO <sub>4</sub>	1.25
Al <sub>11</sub> AgO <sub>17</sub>	Al <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.012	AlHO <sub>2</sub>	103.23
Al <sub>12</sub> PbO <sub>19</sub>	Al <sub>2</sub> O <sub>3</sub> , Pb	0.06	0.019	Al <sub>2</sub> PbO <sub>4</sub>	1.45
Al <sub>2</sub> CoO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , Co	0.40	0.090	None	16.06
Al <sub>2</sub> CuO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.088	AlHO <sub>2</sub>	3.35
Al <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	Al <sub>2</sub> O <sub>3</sub> , Mo	0.20	0.270	AlHO <sub>2</sub> , MoO <sub>2</sub>	19.09
Al <sub>2</sub> NiO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , Ni	1.00	0.091	AlHO <sub>2</sub>	7.98
Al <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Al <sub>2</sub> S <sub>3</sub>	0.94	0.561	AlHO <sub>2</sub> , Al <sub>2</sub> O <sub>3</sub>	0.35
Al <sub>4</sub> Bi <sub>2</sub> O <sub>9</sub>	Al <sub>2</sub> O <sub>3</sub> , Bi	0.56	0.072	AlHO <sub>2</sub>	11.34
Al <sub>4</sub> CdO <sub>7</sub>	Al <sub>2</sub> O <sub>3</sub> , Cd	0.47	0.048	None	2.20
AlAgO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.048	AlHO <sub>2</sub>	415.10
AlCuO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.065	AlHO <sub>2</sub>	4.48
AlRhO <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.135	AlHO <sub>2</sub>	46389.75
AlSbO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , Sb	0.46	0.188	AlHO <sub>2</sub> , Sb <sub>2</sub> O <sub>3</sub>	5.32
AlSbO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , Sb <sub>3</sub> O <sub>7</sub>	1.00	0.013	AlHO <sub>2</sub> , Sb <sub>2</sub> O <sub>3</sub>	5.32
AlVO <sub>4</sub>	Al <sub>2</sub> O <sub>3</sub> , V <sub>2</sub> O <sub>3</sub>	0.39	0.113	VO <sub>2</sub> , AlHO <sub>2</sub>	5.95
Ba <sub>11</sub> Os <sub>4</sub> O <sub>24</sub>	BaO, Os	0.00	0.078	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
Ba <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub>	BaO, Bi	0.00	0.062	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaBiO <sub>3</sub> , BaCO <sub>3</sub>	
Ba <sub>2</sub> CoO <sub>4</sub>	BaO, Co	0.00	0.080	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
Ba <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub>	CuO, BaO	0.00	0.033	BaCuO <sub>2</sub> , BaCO <sub>3</sub> , Ba <sub>2</sub> Cu <sub>3</sub> O <sub>6</sub> , BaH <sub>2</sub> O <sub>2</sub> , BaCu <sub>2</sub> O <sub>2</sub>	
Ba <sub>2</sub> Cu <sub>3</sub> O <sub>6</sub>	CuO, BaO	0.00	0.029	BaCO <sub>3</sub> , BaCu <sub>3</sub> O <sub>4</sub> , BaH <sub>2</sub> O <sub>2</sub> , BaCu <sub>2</sub> O <sub>2</sub>	
Ba <sub>2</sub> Fe <sub>6</sub> O <sub>11</sub>	Fe <sub>3</sub> O <sub>4</sub> , BaO	0.00	0.020	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Ba <sub>2</sub> Fe <sub>6</sub> O <sub>11</sub>	FeO, BaO	0.00	0.061	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , Fe <sub>3</sub> O <sub>4</sub>	
Ba <sub>2</sub> FeO <sub>4</sub>	BaO, Fe	0.00	0.081	BaCO <sub>3</sub>	
Ba <sub>2</sub> Ir <sub>3</sub> O <sub>9</sub>	Ir, Ba	0.08	0.145	BaCO <sub>3</sub>	
Ba <sub>2</sub> PbO <sub>4</sub>	Pb <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.015	BaH <sub>2</sub> O <sub>2</sub> , BaPb <sub>3</sub> O <sub>4</sub> , BaCO <sub>3</sub>	
Ba <sub>2</sub> PdO <sub>3</sub>	BaO, Pd	0.00	0.037	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
Ba <sub>2</sub> Ru <sub>7</sub> O <sub>18</sub>	Ba, Ru	0.50	0.227	BaCO <sub>3</sub>	
Ba <sub>2</sub> Ti <sub>2</sub> O <sub>5</sub>	Ti <sub>4</sub> O <sub>3</sub> , BaO	0.00	0.031	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
Ba <sub>3</sub> Mn <sub>2</sub> O <sub>8</sub>	BaO, Mn	0.00	0.123	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , MnHO <sub>2</sub> , MnO	
Ba <sub>4</sub> Ir <sub>3</sub> O <sub>10</sub>	BaO, Ir	0.00	0.075	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCO <sub>3</sub>	
Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub>	Mn <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.027	BaCO <sub>3</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub> , MnO	
Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub>	MnO, BaO	0.00	0.055	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , MnHO <sub>2</sub>	
Ba <sub>4</sub> PdO <sub>6</sub>	PdO, BaO	0.00	0.021	BaH <sub>2</sub> O <sub>2</sub> , Ba <sub>2</sub> PdO <sub>3</sub> , BaCO <sub>3</sub>	
Ba <sub>4</sub> Pt <sub>3</sub> O <sub>9</sub>	BaO, Pt	0.00	0.063	BaH <sub>2</sub> O <sub>2</sub> , BaPt <sub>5</sub> , BaCO <sub>3</sub>	
Ba <sub>4</sub> PtO <sub>6</sub>	BaO, Pt	0.00	0.038	BaH <sub>2</sub> O <sub>2</sub> , BaPt <sub>5</sub> , BaCO <sub>3</sub>	
Ba <sub>4</sub> Ru <sub>3</sub> O <sub>10</sub>	BaO, Ru	0.00	0.095	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCO <sub>3</sub>	
Ba <sub>5</sub> Cr <sub>3</sub> O <sub>13</sub>	CrO <sub>2</sub> , BaO	0.00	0.030	BaH <sub>2</sub> O <sub>2</sub> , BaCr <sub>2</sub> O <sub>4</sub> , Ba <sub>2</sub> CrO <sub>4</sub> , BaCrO <sub>4</sub> , BaCO <sub>3</sub>	
Ba <sub>5</sub> Mn <sub>5</sub> O <sub>14</sub>	Ba <sub>8</sub> Mn <sub>8</sub> O <sub>21</sub>	0.00	0.012	Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub> , BaCO <sub>3</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub> , BaO, MnO	
Ba <sub>5</sub> Mn <sub>5</sub> O <sub>14</sub>	Mn <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.020	BaCO <sub>3</sub> , Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub> , MnO	
Ba <sub>5</sub> Pt <sub>2</sub> O <sub>9</sub>	BaO, Pt	0.00	0.052	BaH <sub>2</sub> O <sub>2</sub> , BaPt <sub>5</sub> , BaCO <sub>3</sub>	
Ba <sub>5</sub> Re <sub>3</sub> O <sub>16</sub>	ReO <sub>3</sub> , BaO	0.00	0.021	BaH <sub>2</sub> O <sub>2</sub> , Ba <sub>2</sub> ReO <sub>5</sub> , BaCO <sub>3</sub>	
Ba <sub>5</sub> Ru <sub>2</sub> O <sub>10</sub>	BaO, Ru	0.00	0.076	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Ba <sub>6</sub> Mn <sub>5</sub> O <sub>16</sub>	Mn <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.030	Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub> , BaCO <sub>3</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub> , MnO	
Ba <sub>6</sub> Mn <sub>5</sub> O <sub>16</sub>	MnO, BaO	0.00	0.059	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , MnHO <sub>2</sub>	
Ba <sub>8</sub> Mn <sub>8</sub> O <sub>21</sub>	Mn <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.009	Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub> , BaCO <sub>3</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub> , MnO	
Ba <sub>8</sub> Mn <sub>8</sub> O <sub>21</sub>	MnO, BaO	0.00	0.043	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , MnHO <sub>2</sub>	
Ba <sub>9</sub> Au <sub>2</sub> O <sub>12</sub>	BaO, Au	0.00	0.026	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
BaAg <sub>6</sub> O <sub>4</sub>	Ag, Ba	0.00	0.075	BaCO <sub>3</sub>	
BaAgO <sub>2</sub>	BaO, Ag	0.00	0.058	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
BaAu <sub>2</sub> O <sub>4</sub>	Au, Ba	0.00	0.108	BaCO <sub>3</sub>	
BaBiO <sub>3</sub>	BaO, Bi	0.00	0.081	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , Ba <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub> , BaCO <sub>3</sub>	
BaCdO <sub>2</sub>	BaO, Cd	0.00	0.057	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
BaCrO <sub>4</sub>	CrO <sub>2</sub> , BaO	0.00	0.063	BaH <sub>2</sub> O <sub>2</sub> , CrHO <sub>2</sub> , BaH <sub>8</sub> O <sub>5</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCr <sub>2</sub> O <sub>4</sub> , Ba <sub>2</sub> CrO <sub>4</sub> , BaCO <sub>3</sub>	
BaCu <sub>2</sub> O <sub>2</sub>	BaO, Cu	0.00	0.054	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , BaCu <sub>13</sub>	
BaCu <sub>3</sub> O <sub>4</sub>	Ba, Cu	0.00	0.163	BaCO <sub>3</sub>	
BaCuO <sub>2</sub>	BaO, Cu	0.00	0.069	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub>	
BaFe <sub>2</sub> O <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , BaO	0.00	0.017	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub>	
BaFe <sub>2</sub> O <sub>4</sub>	FeO, BaO	0.00	0.051	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub>	
BaHgO <sub>2</sub>	BaO, Hg	0.00	0.043	BaH <sub>2</sub> O <sub>2</sub> , BaCO <sub>3</sub>	
BaIr <sub>2</sub> O <sub>6</sub>	Ir, Ba	0.28	0.155	BaCO <sub>3</sub>	
BaMnO <sub>3</sub>	Mn <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.033	Ba <sub>4</sub> Mn <sub>3</sub> O <sub>10</sub> , BaCO <sub>3</sub> , MnHO <sub>2</sub> , MnO <sub>2</sub>	
BaMnO <sub>3</sub>	MnO, BaO	0.00	0.067	BaH <sub>2</sub> O <sub>2</sub> , MnHO <sub>2</sub> , BaCO <sub>3</sub>	
BaMo <sub>3</sub> O <sub>10</sub>	MoO <sub>2</sub> , Ba	0.00	0.109	BaCO <sub>3</sub>	
BaNiO <sub>3</sub>	BaO, Ni	0.00	0.131	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCO <sub>3</sub>	
BaPb <sub>3</sub> O <sub>4</sub>	BaO, Pb	0.00	0.058	BaH <sub>8</sub> O <sub>5</sub> , BaH <sub>4</sub> O <sub>3</sub> , Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , BaCO <sub>3</sub>	
BaPbO <sub>3</sub>	BaO, Pb	0.00	0.082	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaPb <sub>3</sub> O <sub>4</sub> , BaCO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
BaPbO <sub>3</sub>	Pb <sub>2</sub> O <sub>3</sub> , BaO	0.00	0.020	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , Ba <sub>2</sub> PbO <sub>4</sub> , BaPb <sub>3</sub> O <sub>4</sub> , BaCO <sub>3</sub>	
BaPd <sub>2</sub> O <sub>4</sub>	Ba, Pd	0.00	0.155	BaCO <sub>3</sub>	
BaRhO <sub>3</sub>	BaO, Rh	0.00	0.111	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCO <sub>3</sub>	
BaRu <sub>6</sub> O <sub>12</sub>	Ba, Ru	0.62	0.205	BaCO <sub>3</sub>	
BaRuO <sub>3</sub>	BaO, Ru	0.00	0.112	BaH <sub>2</sub> O <sub>2</sub> , BaH <sub>4</sub> O <sub>3</sub> , BaCO <sub>3</sub>	
BaRuO <sub>5</sub>	RuO <sub>2</sub> , Ba	0.00	0.151	BaH <sub>8</sub> O <sub>5</sub> , BaRuO <sub>3</sub> , BaCO <sub>3</sub>	
BaTbO <sub>3</sub>	BaO, Tb <sub>2</sub> O <sub>3</sub>	0.00	0.023	BaCO <sub>3</sub> , BaH <sub>2</sub> O <sub>2</sub> , BaTb <sub>2</sub> O <sub>4</sub>	
BaTi <sub>2</sub> O <sub>4</sub>	Ti, Ba	0.00	0.105	BaCO <sub>3</sub>	
BeSO <sub>4</sub>	BeS	0.77	0.609	BeSH <sub>8</sub> O <sub>8</sub> , BeO	18.87
Bi <sub>10</sub> Mo <sub>3</sub> O <sub>24</sub>	Bi <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.97	0.017	Bi <sub>2</sub> MoO <sub>6</sub> , Bi <sub>2</sub> CO <sub>5</sub>	16.97
Bi <sub>10</sub> Pb <sub>6</sub> O <sub>21</sub>	Pb <sub>2</sub> O <sub>3</sub> , Bi	0.87	0.052	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , Bi <sub>2</sub> O <sub>3</sub> , PbO	10.84
Bi <sub>12</sub> PbO <sub>19</sub>	Pb <sub>2</sub> O <sub>3</sub> , Bi	0.87	0.093	Bi <sub>2</sub> CO <sub>5</sub> , PbCO <sub>3</sub> , Bi <sub>2</sub> O <sub>3</sub>	14.79
Bi <sub>12</sub> PbO <sub>20</sub>	Pb <sub>2</sub> O <sub>3</sub> , Bi	0.88	0.098	Bi <sub>2</sub> CO <sub>5</sub> , PbCO <sub>3</sub>	14.71
Bi <sub>12</sub> SbO <sub>20</sub>	Sb <sub>2</sub> O <sub>5</sub> , Bi	0.74	0.095	Bi <sub>3</sub> SbO <sub>7</sub> , Bi <sub>2</sub> CO <sub>5</sub>	15.33
Bi <sub>14</sub> MoO <sub>24</sub>	Bi, Mo	0.87	0.113	Bi <sub>2</sub> CO <sub>5</sub>	16.11
Bi <sub>14</sub> MoO <sub>24</sub>	MoO <sub>3</sub> , Bi	0.89	0.099	Bi <sub>2</sub> CO <sub>5</sub>	16.11
Bi <sub>14</sub> WO <sub>24</sub>	Bi, W	0.83	0.110	Bi <sub>2</sub> CO <sub>5</sub>	14.75
Bi <sub>2</sub> Ir <sub>2</sub> O <sub>7</sub>	BiO <sub>2</sub> , Ir	0.99	0.052	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub>	8773.68
Bi <sub>2</sub> Mo <sub>2</sub> O <sub>9</sub>	Bi, Mo	0.52	0.191	MoO <sub>2</sub>	18.67
Bi <sub>2</sub> Mo <sub>2</sub> O <sub>9</sub>	MoO <sub>2</sub> , BiO <sub>2</sub>	1.00	0.021	Bi <sub>2</sub> MoO <sub>6</sub>	18.67
Bi <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	Bi <sub>2</sub> O <sub>3</sub> , Mo	0.69	0.160	MoO <sub>2</sub>	19.41
Bi <sub>2</sub> MoO <sub>6</sub>	MoO <sub>3</sub> , Bi	0.91	0.079	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	17.57
Bi <sub>2</sub> O <sub>3</sub>	Bi	0.88	0.103	Bi <sub>2</sub> CO <sub>5</sub>	15.79
Bi <sub>2</sub> Os <sub>2</sub> O <sub>7</sub>	BiO <sub>2</sub> , Os	0.98	0.053	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub>	6040.08
Bi <sub>2</sub> PdO <sub>4</sub>	PdO, Bi	0.96	0.082	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub> , BiPd	3203.37
Bi <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Bi <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	1.00	0.023	Bi <sub>2</sub> CO <sub>5</sub> , BiPt <sub>3</sub>	21770.31
Bi <sub>2</sub> Rh <sub>2</sub> O <sub>7</sub>	RhO <sub>2</sub> , Bi	1.00	0.065	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub>	22440.97
Bi <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	RuO <sub>2</sub> , Bi	0.98	0.066	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub>	1781.36
Bi <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Bi <sub>2</sub> S <sub>3</sub>	0.98	0.272	None	10.42
Bi <sub>3</sub> Pt <sub>3</sub> O <sub>11</sub>	PtO <sub>2</sub> , Bi	1.00	0.058	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub> , Bi <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub> , BiPt <sub>3</sub>	21644.86

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Bi <sub>3</sub> Ru <sub>3</sub> O <sub>11</sub>	RuO <sub>2</sub> , Bi	0.98	0.072	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub> , Bi <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	1768.47
Bi <sub>3</sub> SbO <sub>7</sub>	Sb <sub>2</sub> O <sub>5</sub> , Bi	0.71	0.084	Bi <sub>2</sub> CO <sub>5</sub> , Sb <sub>2</sub> O <sub>3</sub>	14.06
Bi <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	Bi, Au	0.91	0.105	Bi <sub>2</sub> CO <sub>5</sub> , BiAu <sub>2</sub>	11047.55
BiO <sub>2</sub>	Bi	0.90	0.133	Bi <sub>2</sub> CO <sub>5</sub>	15.26
BiPd <sub>2</sub> O <sub>4</sub>	Bi <sub>2</sub> O <sub>3</sub> , PdO	1.00	0.016	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> PdO <sub>4</sub>	7736.56
BiPd <sub>2</sub> O <sub>4</sub>	PdO, Bi	1.00	0.066	Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> PdO <sub>4</sub>	7736.56
BiSbO <sub>4</sub>	Sb <sub>3</sub> O <sub>7</sub> , Bi	0.77	0.068	Bi <sub>3</sub> SbO <sub>7</sub> , Bi <sub>2</sub> CO <sub>5</sub> , Sb <sub>2</sub> O <sub>3</sub>	12.03
Ca <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub>	CaO, Bi	0.00	0.083	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>2</sub> Mn <sub>3</sub> O <sub>8</sub>	MnO, CaO	0.00	0.129	MnHO <sub>2</sub> , CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>2</sub> Os <sub>2</sub> O <sub>7</sub>	CaO, Os	0.00	0.140	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>2</sub> PbO <sub>4</sub>	CaO, Pb	0.00	0.091	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>2</sub> Pt <sub>3</sub> O <sub>8</sub>	Pt, Ca	0.00	0.161	CaCO <sub>3</sub>	
Ca <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	CaO, Ru	0.00	0.203	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	CaO, RuO <sub>2</sub>	0.06	0.041	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub> , CaRuO <sub>3</sub>	
Ca <sub>2</sub> V <sub>2</sub> O <sub>7</sub>	VO <sub>2</sub> , CaO	0.00	0.054	CaCO <sub>3</sub> , CaV <sub>2</sub> O <sub>4</sub> , CaH <sub>2</sub> O <sub>2</sub> , Ca <sub>5</sub> V <sub>3</sub> O <sub>12</sub>	
Ca <sub>3</sub> CdO <sub>4</sub>	CaO, Cd	0.00	0.054	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>3</sub> Ru <sub>2</sub> O <sub>7</sub>	CaO, Ru	0.00	0.147	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>3</sub> Tl <sub>2</sub> O <sub>6</sub>	CaO, Tl	0.00	0.077	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>3</sub> Tl <sub>2</sub> O <sub>6</sub>	Tl <sub>4</sub> O <sub>3</sub> , CaO	0.00	0.038	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>4</sub> Cu <sub>5</sub> O <sub>10</sub>	CaO, Cu	0.00	0.150	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>4</sub> IrO <sub>6</sub>	CaO, Ir	0.00	0.071	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>4</sub> PdO <sub>6</sub>	PdO, CaO	0.00	0.044	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub> , CaPd <sub>3</sub> O <sub>4</sub>	
Ca <sub>4</sub> PtO <sub>6</sub>	Pt <sub>3</sub> O <sub>4</sub> , CaO	0.00	0.024	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>5</sub> Re <sub>2</sub> O <sub>12</sub>	ReO <sub>3</sub> , CaO	0.00	0.021	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
Ca <sub>5</sub> V <sub>3</sub> O <sub>12</sub>	VO <sub>2</sub> , CaO	0.00	0.029	CaCO <sub>3</sub> , CaV <sub>2</sub> O <sub>4</sub> , CaH <sub>2</sub> O <sub>2</sub>	
Ca <sub>5</sub> V <sub>3</sub> O <sub>13</sub>	VO <sub>2</sub> , CaO	0.00	0.057	CaCO <sub>3</sub> , CaV <sub>2</sub> O <sub>4</sub> , CaH <sub>2</sub> O <sub>2</sub> , Ca <sub>5</sub> V <sub>3</sub> O <sub>12</sub>	
CaAg <sub>2</sub> O <sub>4</sub>	Ag, Ca	0.00	0.200	CaCO <sub>3</sub>	
CaAgO <sub>2</sub>	CaO, Ag	0.00	0.089	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaAu <sub>2</sub> O <sub>4</sub>	Au, Ca	0.00	0.129	CaCO <sub>3</sub>	
CaBi <sub>2</sub> O <sub>4</sub>	CaO, Bi	0.00	0.092	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaBiO <sub>3</sub>	CaO, Bi	0.00	0.108	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaCd <sub>3</sub> O <sub>4</sub>	CaO, Cd	0.00	0.109	CaH <sub>2</sub> O <sub>2</sub> , CdH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
CaCdO <sub>2</sub>	CaO, Cd	0.00	0.087	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaCrO <sub>4</sub>	CaO, Cr	0.04	0.308	Cr <sub>2</sub> O <sub>3</sub> , CaCr <sub>2</sub> O <sub>4</sub> , CaCO <sub>3</sub>	
CaCu <sub>2</sub> O <sub>4</sub>	CaO, Cu	0.00	0.208	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaCu <sub>2</sub> O <sub>4</sub>	CuO, CaO	1.00	0.069	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub> , Ca <sub>4</sub> Cu <sub>5</sub> O <sub>10</sub>	
CaCu <sub>6</sub> O <sub>8</sub>	Cu, Ca	0.42	0.233	CaC <sub>2</sub> H <sub>6</sub> O <sub>7</sub> , CaCO <sub>3</sub>	
CaFe <sub>2</sub> O <sub>4</sub>	FeO, CaO	0.00	0.074	CaH <sub>2</sub> O <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub> , CaCO <sub>3</sub>	
CaHgO <sub>2</sub>	CaO, Hg	0.00	0.059	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaIrO <sub>3</sub>	CaO, Ir	0.00	0.114	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaMoO <sub>4</sub>	MoO <sub>2</sub> , CaO	0.00	0.080	CaH <sub>2</sub> O <sub>2</sub> , CaMoO <sub>3</sub> , Ca <sub>3</sub> Mo <sub>2</sub> O <sub>7</sub> , CaCO <sub>3</sub>	
CaPd <sub>3</sub> O <sub>4</sub>	Pd, Ca	0.00	0.151	CaCO <sub>3</sub>	
CaRh <sub>2</sub> O <sub>4</sub>	CaO, Rh	0.00	0.155	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaRhO <sub>3</sub>	CaO, Rh	0.00	0.168	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaRuO <sub>3</sub>	CaO, Ru	0.00	0.169	CaH <sub>2</sub> O <sub>2</sub> , CaCO <sub>3</sub>	
CaSO <sub>4</sub>	CaS	0.17	0.470	CaCO <sub>3</sub>	
CaSb <sub>2</sub> O <sub>6</sub>	Sb <sub>2</sub> O <sub>3</sub> , CaO	0.19	0.084	CaH <sub>2</sub> O <sub>2</sub> , Ca <sub>2</sub> Sb <sub>2</sub> O <sub>7</sub> , CaCO <sub>3</sub>	
Cd <sub>2</sub> GeO <sub>4</sub>	Cd, Ge	0.29	0.177	GeO <sub>2</sub> , CdGeO <sub>3</sub>	243.89
Cd <sub>2</sub> Os <sub>2</sub> O <sub>7</sub>	Cd, Os	0.99	0.156	CdCO <sub>3</sub>	7657.60
Cd <sub>2</sub> Os <sub>2</sub> O <sub>7</sub>	CdO, Os	0.99	0.112	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub>	7657.60
Cd <sub>2</sub> PbO <sub>4</sub>	CdO, Pb	1.00	0.065	CdH <sub>2</sub> O <sub>2</sub> , Pb <sub>2</sub> CO <sub>4</sub>	3.01
Cd <sub>2</sub> PbO <sub>4</sub>	Pb, Cd	0.87	0.129	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	3.01
Cd <sub>2</sub> PbO <sub>4</sub>	Pb <sub>2</sub> O <sub>3</sub> , Cd	1.00	0.081	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , CdO	3.01
Cd <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Cd, Ru	0.99	0.208	CdCO <sub>3</sub>	2407.90
Cd <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	CdO, Ru	0.99	0.148	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , RuO <sub>2</sub>	2407.90
Cd <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	RuO <sub>2</sub> , Cd	1.00	0.089	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdO	2407.90
Cd <sub>2</sub> Sb <sub>2</sub> O <sub>7</sub>	Sb <sub>2</sub> O <sub>5</sub> , Cd	0.92	0.055	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub> , CdSb <sub>2</sub> O <sub>6</sub>	5.40
Cd <sub>2</sub> SnO <sub>4</sub>	Sn, Cd	0.33	0.157	CdCO <sub>3</sub> , SnO <sub>2</sub>	10.12
CdAgO <sub>2</sub>	AgO, Cd	1.00	0.063	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdO	276.26
CdAuO <sub>2</sub>	Cd, Au	1.00	0.094	CdCO <sub>3</sub> , CdAu <sub>3</sub>	22210.01
CdBi <sub>2</sub> O <sub>4</sub>	Bi <sub>2</sub> O <sub>3</sub> , Cd	0.87	0.027	CdCO <sub>3</sub>	13.21
CdBi <sub>2</sub> O <sub>4</sub>	CdO, Bi	0.87	0.081	CdCO <sub>3</sub>	13.21

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
CdBiO <sub>3</sub>	BiO <sub>2</sub> , Cd	1.00	0.043	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdBi <sub>2</sub> O <sub>4</sub>	11.30
CdBiO <sub>3</sub>	CdO, Bi	0.89	0.087	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdBi <sub>2</sub> O <sub>4</sub>	11.30
CdCu <sub>2</sub> O <sub>4</sub>	CuO, Cd	1.00	0.105	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdO	4.85
CdCu <sub>6</sub> O <sub>8</sub>	CuO, Cd	1.00	0.051	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , CdO	5.52
CdCu <sub>6</sub> O <sub>8</sub>	CuO, CdO	1.00	0.026	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub>	5.52
CdFe <sub>2</sub> O <sub>4</sub>	Cd, Fe	0.33	0.222	CdCO <sub>3</sub> , FeO	1.76
CdGa <sub>2</sub> O <sub>4</sub>	Ga <sub>2</sub> O <sub>3</sub> , Cd	0.63	0.051	None	266.46
CdGeO <sub>3</sub>	GeO <sub>2</sub> , Cd	0.84	0.069	Cd <sub>2</sub> GeO <sub>4</sub>	376.15
CdHgO <sub>2</sub>	Cd, Hg	1.00	0.093	CdCO <sub>3</sub>	16.58
CdIn <sub>2</sub> O <sub>4</sub>	Cd, In	0.19	0.158	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	309.60
CdIn <sub>2</sub> O <sub>4</sub>	In <sub>2</sub> O <sub>3</sub> , Cd	0.35	0.039	InH <sub>3</sub> O <sub>3</sub>	309.60
CdMoO <sub>4</sub>	CdO, Mo	0.55	0.176	CdCO <sub>3</sub> , MoO <sub>2</sub>	14.15
CdMoO <sub>4</sub>	MoO <sub>3</sub> , Cd	1.00	0.059	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , MoO <sub>2</sub> , CdO	14.15
CdO	Cd	0.99	0.125	CdCO <sub>3</sub>	3.85
CdPbO <sub>3</sub>	CdO, Pb	1.00	0.087	CdH <sub>2</sub> O <sub>2</sub> , Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	2.71
CdPbO <sub>3</sub>	Pb, Cd	0.83	0.131	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	2.71
CdPd <sub>3</sub> O <sub>4</sub>	PdO, Cd	1.00	0.032	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub>	11364.08
CdPt <sub>3</sub> O <sub>6</sub>	Pt <sub>3</sub> O <sub>4</sub> , Cd	1.00	0.040	CdCO <sub>3</sub>	37845.66
CdPt <sub>9</sub> O <sub>12</sub>	Cd, Pt	1.00	0.093	CdPt <sub>3</sub>	43738.70
CdRh <sub>2</sub> O <sub>4</sub>	Cd, Rh	1.00	0.167	CdCO <sub>3</sub>	43180.62
CdRh <sub>2</sub> O <sub>4</sub>	CdO, Rh	1.00	0.126	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub>	43180.62
CdS <sub>2</sub> O <sub>7</sub>	CdS <sub>2</sub>	0.98	0.388	None	1.71
CdSO <sub>4</sub>	CdS	1.00	0.307	None	2.37
CdSb <sub>2</sub> O <sub>6</sub>	CdO, Sb	0.58	0.177	CdCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	5.84
CdSb <sub>2</sub> O <sub>6</sub>	SbO <sub>2</sub> , Cd	0.93	0.071	CdH <sub>2</sub> O <sub>2</sub> , CdCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub> , Cd <sub>2</sub> Sb <sub>2</sub> O <sub>7</sub>	5.84
Ce <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	Ce <sub>7</sub> O <sub>12</sub> , Mo	0.14	0.205	CeO <sub>2</sub> , MoO <sub>2</sub>	30.36
Ce <sub>2</sub> Ta <sub>2</sub> O <sub>9</sub>	CeTaO <sub>4</sub>	0.47	0.020	CeTa <sub>3</sub> O <sub>9</sub> , CeO <sub>2</sub>	68.46
Ce <sub>3</sub> PrO <sub>8</sub>	Pr <sub>2</sub> O <sub>3</sub> , Ce <sub>7</sub> O <sub>12</sub>	0.16	0.032	PrH <sub>3</sub> O <sub>3</sub> , CeO <sub>2</sub>	52.98
Ce <sub>9</sub> DyO <sub>20</sub>	Dy <sub>2</sub> O <sub>3</sub> , CeO <sub>2</sub>	1.00	0.005	Ce <sub>5</sub> Dy <sub>2</sub> O <sub>13</sub> , Dy <sub>2</sub> CO <sub>5</sub>	73.44
Ce <sub>9</sub> GdO <sub>20</sub>	Gd <sub>2</sub> O <sub>3</sub> , CeO <sub>2</sub>	1.00	0.005	Ce <sub>5</sub> Gd <sub>2</sub> O <sub>13</sub>	41.25
Ce <sub>9</sub> SmO <sub>20</sub>	Sm <sub>2</sub> O <sub>3</sub> , CeO <sub>2</sub>	1.00	0.005	Ce <sub>5</sub> Sm <sub>2</sub> O <sub>13</sub> , SmH <sub>3</sub> O <sub>3</sub>	41.63

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Ce9YO20	Y2O3, CeO2	1.00	0.005	YHO2, Ce5Y2O13, Ce2Y2O7, YC2H2O6	41.91
CeRh2O5	Ce2O3, Rh	0.89	0.131	CeO2	38765.11
CeS2O8	CeS2	0.94	0.385	CeO2	21.09
Co3O4	CoO	1.00	0.066	CoCO3	33.92
CoAgO2	Ag, Co	0.60	0.161	CoC2H4O6, CoO	361.78
CoMoO4	Co, Mo	0.39	0.292	MoO2	27.78
CoMoO4	CoO, Mo	0.60	0.219	MoO2, CoC2H4O6	27.78
CoO	Co	0.58	0.214	CoC2H4O6	36.34
CoO2	Co	0.60	0.352	CoC2H4O6	29.94
CoPdO2	Co, Pd	0.60	0.162	CoC2H4O6, CoO	9526.95
CoPt3O6	Pt3O4, Co	1.00	0.043	CoO2, CoPtO2	40583.00
CoPtO2	Pt, Co	0.99	0.112	None	35014.64
CoRh2O4	CoO2, Rh	1.00	0.097	None	50211.77
CoRh2O4	Rh, Co	0.72	0.195	CoC2H4O6, CoO	50211.77
CoSb2O4	Co, Sb	0.67	0.175	CoSb3, Sb2O3	13.28
CoSb2O4	CoO, Sb	0.74	0.131	Sb2O3	13.28
CoSb2O6	CoO2, Sb	0.73	0.161	CoC2H4O6, CoSb2O4, Sb2O3	12.21
Cr2Bi6O15	Bi2O3, Cr	0.92	0.060	CrHO2, CrBiO3, Bi2CO5	14.46
Cr2CdO4	Cr2O3, Cd	0.22	0.057	None	5.44
Cr2Mo3O12	Cr2O3, Mo	0.20	0.247	CrHO2, MoO2	19.02
Cr2Mo3O12	MoO2, Cr	0.30	0.164	CrHO2, Cr2O3, CrMoO4	19.02
CrAgO2	Cr2O3, Ag	1.00	0.042	CrHO2, CrO2	363.35
CrAuO2	Cr2O3, Au	1.00	0.028	CrHO2, CrO2	26985.89
CrBi14O24	Bi, Cr	0.83	0.114	Bi2CO5	15.47
CrBiO3	CrO2, Bi	0.83	0.052	Cr2O3, CrHO2, Bi2CO5	13.57
CrCdO4	Cd, Cr	0.39	0.280	Cr2CdO4, CdCO3, Cr2O3	4.42
CrCdO4	CdO, Cr	0.56	0.210	Cr2CdO4, CdCO3	4.42
CrCuO2	Cr2O3, Cu	0.98	0.054	CrHO2	6.81
CrIrO4	Ir, Cr	0.52	0.208	CrHO2, Cr2O3	13004.49
CrMoO4	MoO2, Cr2O3	0.46	0.038	CrHO2	18.27
CrO2	Cr2O3	1.00	0.095	CrHO2	6.13
CrPb2O5	Pb, Cr	0.51	0.146	CrHO2, Cr2O3, PbCO3	2.78
CrPb2O5	PbO, Cr	0.77	0.088	CrHO2, Cr2O3, Pb2CO4, PbCO3	2.78

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
CrPb5O8	Pb, Cr	0.63	0.105	CrHO2, Cr2O3, PbCO3	2.49
CrPb5O8	PbO, Cr	0.77	0.039	CrHO2, Cr2O3, Pb3H2O4, Pb2CO4	2.49
CrPbO4	Pb, Cr	0.44	0.198	CrHO2, Cr2O3, PbCO3	3.14
CrPbO4	PbO, Cr	0.68	0.149	CrHO2, Cr2O3, PbCO3	3.14
CrPdO2	Cr2O3, Pd	1.00	0.042	CrHO2, CrO2	9862.44
CrPtO2	Cr2O3, Pt	1.00	0.029	CrHO2, CrO2	35877.09
CrSbO4	CrO2, Sb	0.51	0.135	CrHO2, Cr2O3, Sb2O3	6.67
CrSbO4	CrO2, Sb2O3	0.99	0.034	CrHO2, Cr2O3	6.67
Cs2BeO2	BeO, Cs	0.00	0.052	CsHO, Cs2CO3	41937.13
Cs2Bi4O7	Cs2O, Bi	0.39	0.079	Cs2CH6O6, CsCHO3, Cs2CO3	10611.90
Cs2CeO3	CeO2, Cs	0.00	0.035	Cs2CO3, Ce5O9	28357.66
Cs2CoO3	CoO2, Cs	0.00	0.043	CsHO, Cs6Co2O7, Cs2CO3	34522.43
Cs2CrO4	Cr2O3, Cs	0.00	0.105	CsHO, Cs2CO3	33697.24
Cs2FeO4	Fe2O3, Cs2O2	0.00	0.021	CsHO, Fe3O4, CsFeO2, Cs2CO3, Cs4Fe2O5	33359.62
Cs2HgO2	Cs, Hg	0.00	0.064	CsHO, Cs2CO3	25823.60
Cs2HgO2	Cs3O, Hg	0.00	0.043	CsHO, Cs2CO3	25823.60
Cs2MnO4	Cs2O, Mn	0.00	0.125	MnHO2, CsH3O2, CsHO, Cs2CO3	33438.24
Cs2MnO4	MnO2, Cs2O	0.00	0.042	MnHO2, CsHO, Cs4Mn3O6, Cs2CO3	33438.24
Cs2Mo3O10	MoO2, Cs	0.25	0.090	Cs2CH6O6, CsCHO3, Cs2MoO4	18042.14
Cs2NiO2	Cs3O, Ni	0.00	0.060	CsHO, Cs2CO3	36090.96
Cs2NiO2	NiO, Cs	0.00	0.045	CsHO, Cs2CO3, Cs2O	36090.96
Cs2O	Cs	0.00	0.057	CsHO, Cs2CO3	45652.16
Cs2O	Cs3O	0.00	0.019	CsHO, Cs2CO3	45652.16
Cs2O2	Cs	0.00	0.107	CsHO, Cs2CO3	43199.56
Cs2O2	Cs3O	0.00	0.072	CsHO, Cs2CO3	43199.56
Cs2Pb2O3	Pb, Cs	0.00	0.066	CsH3O2, CsHO, Cs2CO3	17668.35
Cs2PbO2	Pb, Cs	0.00	0.063	CsHO, Cs2CO3	25476.24

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Cs <sub>2</sub> PbO <sub>3</sub>	Cs <sub>2</sub> O, Pb	0.00	0.061	CsH <sub>3</sub> O <sub>2</sub> , CsHO, Cs <sub>2</sub> CO <sub>3</sub>	24693.90
Cs <sub>2</sub> PbO <sub>3</sub>	Pb <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.046	CsH <sub>3</sub> O <sub>2</sub> , CsHO, Cs <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub> , Cs <sub>2</sub> CO <sub>3</sub>	24693.90
Cs <sub>2</sub> RuO <sub>4</sub>	Cs, Ru	0.07	0.149	Cs <sub>2</sub> CH <sub>6</sub> O <sub>6</sub> , Cs <sub>2</sub> CO <sub>3</sub>	31362.98
Cs <sub>2</sub> SnO <sub>3</sub>	SnO <sub>2</sub> , Cs	0.00	0.037	CsH <sub>3</sub> O <sub>2</sub> , CsHO, Cs <sub>2</sub> Sn <sub>2</sub> O <sub>3</sub> , Cs <sub>2</sub> CO <sub>3</sub>	29752.17
Cs <sub>2</sub> TbO <sub>3</sub>	Tb <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.051	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	27466.67
Cs <sub>2</sub> ZnO <sub>2</sub>	Zn, Cs	0.00	0.088	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	35420.51
Cs <sub>2</sub> ZnO <sub>2</sub>	ZnO, Cs	0.00	0.044	CsHO, Zn <sub>6</sub> HO <sub>6</sub> , Cs <sub>2</sub> CO <sub>3</sub>	35420.51
Cs <sub>3</sub> AuO <sub>2</sub>	Cs, Au	0.00	0.051	CsHO, Cs <sub>2</sub> CO <sub>3</sub> , CsAu	42823.22
Cs <sub>3</sub> BiO <sub>3</sub>	Bi, Cs	0.00	0.073	CsHO, Cs <sub>2</sub> CO <sub>3</sub> , CsBi	29436.78
Cs <sub>3</sub> Cu <sub>5</sub> O <sub>4</sub>	Cs, Cu	0.00	0.082	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	24729.92
Cs <sub>3</sub> DyO <sub>3</sub>	Dy <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.039	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	31783.34
Cs <sub>3</sub> ErO <sub>3</sub>	Er <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.039	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	
Cs <sub>3</sub> GaO <sub>3</sub>	Ga <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.046	CsGaO <sub>2</sub> , CsHO, Cs <sub>2</sub> CO <sub>3</sub>	37448.29
Cs <sub>3</sub> HoO <sub>3</sub>	Ho <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.039	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	
Cs <sub>3</sub> InO <sub>3</sub>	Cs, In	0.00	0.085	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	34477.93
Cs <sub>3</sub> InO <sub>3</sub>	In <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.043	CsIn <sub>3</sub> O <sub>5</sub> , CsHO, Cs <sub>2</sub> CO <sub>3</sub>	34477.93
Cs <sub>3</sub> LaO <sub>3</sub>	La <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.041	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	32967.12
Cs <sub>3</sub> O	Cs	0.00	0.039	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	46532.77
Cs <sub>3</sub> Sb <sub>5</sub> O <sub>14</sub>	Sb <sub>2</sub> O <sub>3</sub> , Cs	0.66	0.084	CsSbO <sub>2</sub> , Cs <sub>2</sub> CH <sub>6</sub> O <sub>6</sub> , CsCHO <sub>3</sub>	15674.47
Cs <sub>3</sub> SbO <sub>4</sub>	Cs <sub>3</sub> SbO <sub>3</sub>	0.00	0.027	CsH <sub>3</sub> O <sub>2</sub> , Cs <sub>4</sub> Sb <sub>2</sub> O <sub>5</sub> , CsSbO <sub>2</sub> , Cs <sub>2</sub> CO <sub>3</sub>	33019.34
Cs <sub>3</sub> TlO <sub>3</sub>	Cs <sub>2</sub> O, Tl	0.00	0.037	CsHO, CsTlO, Cs <sub>2</sub> CO <sub>3</sub>	31503.57
Cs <sub>3</sub> TlO <sub>3</sub>	Tl <sub>4</sub> O <sub>3</sub> , Cs	0.00	0.055	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	31503.57
Cs <sub>3</sub> TmO <sub>3</sub>	Tm <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.039	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	
Cs <sub>3</sub> YO <sub>3</sub>	Y <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.045	Cs <sub>2</sub> CO <sub>3</sub> , CsHO, CsY <sub>3</sub> O <sub>5</sub>	36041.95
Cs <sub>4</sub> Fe <sub>2</sub> O <sub>5</sub>	Fe <sub>3</sub> O <sub>4</sub> , Cs	0.00	0.052	FeO, CsHO, Cs <sub>2</sub> CO <sub>3</sub>	35573.34
Cs <sub>4</sub> Fe <sub>2</sub> O <sub>5</sub>	FeO, Cs	0.00	0.066	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	35573.34
Cs <sub>4</sub> FeO <sub>4</sub>	Fe, Cs	0.00	0.098	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	39496.41
Cs <sub>4</sub> IrO <sub>4</sub>	Ir, Cs	0.00	0.081	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	37746.55
Cs <sub>4</sub> Mn <sub>3</sub> O <sub>6</sub>	Mn <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.030	MnHO <sub>2</sub> , CsHO, MnO, Cs <sub>2</sub> CO <sub>3</sub>	32470.28

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Cs <sub>4</sub> PbO <sub>4</sub>	Cs <sub>4</sub> PbO <sub>3</sub>	0.00	0.020	CsHO, Cs <sub>2</sub> PbO <sub>2</sub> , Cs <sub>2</sub> CO <sub>3</sub>	32050.79
Cs <sub>4</sub> PbO <sub>4</sub>	Pb <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.050	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	32050.79
Cs <sub>4</sub> SnO <sub>4</sub>	SnO <sub>2</sub> , Cs	0.00	0.045	CsHO, Cs <sub>2</sub> Sn <sub>2</sub> O <sub>3</sub> , CsSn, Cs <sub>2</sub> CO <sub>3</sub>	36024.88
Cs <sub>4</sub> ZnO <sub>3</sub>	Zn, Cs	0.00	0.074	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	39890.67
Cs <sub>4</sub> ZrO <sub>4</sub>	ZrO <sub>2</sub> , Cs	0.00	0.047	Cs <sub>2</sub> ZrO <sub>3</sub> , CsHO, Cs <sub>2</sub> CO <sub>3</sub>	37475.23
Cs <sub>5</sub> FeO <sub>4</sub>	Fe, Cs	0.00	0.082	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	41005.05
Cs <sub>5</sub> FeO <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , Cs	0.00	0.054	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	41005.05
Cs <sub>5</sub> YO <sub>4</sub>	Y <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.049	Cs <sub>2</sub> CO <sub>3</sub> , CsHO, CsY <sub>3</sub> O <sub>5</sub>	39355.08
Cs <sub>6</sub> Co <sub>2</sub> O <sub>7</sub>	CoO <sub>2</sub> , Cs	0.00	0.047	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	37575.57
Cs <sub>6</sub> Ti <sub>2</sub> O <sub>7</sub>	TiO <sub>2</sub> , Cs	0.00	0.048	Cs <sub>2</sub> CO <sub>3</sub>	38398.56
Cs <sub>8</sub> In <sub>2</sub> O <sub>7</sub>	Cs, In	0.00	0.080	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	36719.42
Cs <sub>8</sub> In <sub>2</sub> O <sub>7</sub>	In <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.046	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	36719.42
CsAgO	Ag, Cs	0.00	0.062	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	25321.28
CsAgO	Cs <sub>2</sub> O, Ag	0.00	0.031	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	25321.28
CsAgO	Cs <sub>3</sub> O, Ag	0.00	0.042	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	25321.28
CsAgO <sub>2</sub>	Ag, Cs	0.07	0.117	Cs <sub>2</sub> CH <sub>6</sub> O <sub>6</sub> , Cs <sub>2</sub> CO <sub>3</sub>	23836.07
CsAgO <sub>2</sub>	Cs <sub>2</sub> O <sub>2</sub> , Ag	0.00	0.059	CsH <sub>3</sub> O <sub>2</sub> , CsH <sub>5</sub> O <sub>3</sub> , CsH <sub>7</sub> O <sub>4</sub> , Cs <sub>2</sub> CO <sub>3</sub>	23836.07
CsAuO	Cs, Au	0.00	0.046	CsH <sub>3</sub> O <sub>2</sub> , CsHO, Cs <sub>2</sub> CO <sub>3</sub>	40518.25
CsAuO <sub>2</sub>	Cs <sub>2</sub> O <sub>2</sub> , Au	0.04	0.044	CsH <sub>5</sub> O <sub>3</sub> , CsH <sub>7</sub> O <sub>4</sub> , Cs <sub>2</sub> CO <sub>3</sub>	38726.81
CsBiO <sub>2</sub>	Bi, Cs	0.07	0.086	Cs <sub>2</sub> CH <sub>6</sub> O <sub>6</sub> , Cs <sub>2</sub> CO <sub>3</sub>	17214.67
CsCu <sub>3</sub> O <sub>2</sub>	Cs, Cu	0.07	0.090	Cs <sub>2</sub> CH <sub>6</sub> O <sub>6</sub> , Cs <sub>2</sub> CO <sub>3</sub>	18096.56
CsCu <sub>3</sub> O <sub>2</sub>	Cs <sub>2</sub> O, Cu	0.06	0.067	CsH <sub>5</sub> O <sub>3</sub> , CsH <sub>7</sub> O <sub>4</sub> , Cs <sub>2</sub> CO <sub>3</sub>	18096.56
CsCuO	Cs, Cu	0.00	0.075	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	30280.48
CsCuO <sub>2</sub>	CuO, Cs	0.05	0.070	CsH <sub>5</sub> O <sub>3</sub> , CsH <sub>7</sub> O <sub>4</sub> , CsCu <sub>3</sub> O <sub>2</sub> , Cs <sub>2</sub> CO <sub>3</sub>	28159.80
CsErO <sub>2</sub>	Er <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.024	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	
CsFeO <sub>2</sub>	Fe <sub>3</sub> O <sub>4</sub> , Cs	0.00	0.048	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	29139.99
CsFeO <sub>2</sub>	FeO, Cs	0.00	0.072	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	29139.99
CsGdO <sub>2</sub>	Gd <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.025	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	19994.37
CsHoO <sub>2</sub>	Ho <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.024	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	
CsLa <sub>3</sub> O <sub>5</sub>	La <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.013	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	10256.41
CsLaO <sub>2</sub>	La <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.026	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	21200.63
CsNdO <sub>2</sub>	Nd <sub>2</sub> O <sub>3</sub> , Cs	0.00	0.026	CsHO, Cs <sub>2</sub> CO <sub>3</sub>	20861.36

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
CsOs2O6	Cs2O2, Os	0.72	0.131	CsH7O4, Cs2CH6O6, CsCHO3, Cs2CO3	19568.44
CsOs2O9	Cs2O, OsO4	0.00	0.012	CsH3O2, Cs2CO3, CsOs2O6	18139.62
CsOs2O9	OsO4, Cs	0.00	0.024	CsH3O2, Cs2CO3, CsOs2O6	18139.62
CsSO3	CsS	0.32	0.225	CsH7O4, CsS3, CsCHO3, Cs2SO4	30204.56
CsSO4	CsS	0.44	0.280	CsH7O4, CsS3, CsCHO3, Cs2SO4	28093.98
CsSmO2	Sm2O3, Cs	0.00	0.025	CsHO, Cs2CO3	20432.53
CsTlO	Tl, Cs	0.00	0.045	CsHO, Cs2CO3	21644.26
CsTmO2	Tm2O3, Cs	0.00	0.024	CsHO, Cs2CO3	
CsY3O5	Y2O3, Cs	0.00	0.017	Cs2CO3, CsHO	13455.29
Cu2PbO2	Pb2O3, Cu	0.87	0.022	Pb3H2O4, Pb2CO4, PbCO3	4.04
Cu2SO5	Cu2S	1.00	0.334	CuS	4.09
Cu3Mo2O9	CuO, Mo	0.87	0.182	MoO2	15.54
Cu4PtO5	CuO, Pt	1.00	0.030	Cu3Pt	18920.54
Cu4PtO5	PtO2, Cu	1.00	0.091	Cu3Pt, CuO	18920.54
Cu6PbO8	CuO, Pb	1.00	0.045	Cu2PbO2, PbCO3	4.80
Cu6PbO8	CuO, PbO	1.00	0.022	Cu2PbO2, PbCO3	4.80
Cu6SnO8	Sn, Cu	0.78	0.204	SnO2	9.67
CuAgO2	AgO, Cu	1.00	0.079	CuO	342.60
CuAuO2	Au, Cu	1.00	0.109	None	25920.25
CuBi2O4	CuO, Bi	0.91	0.088	Bi2O3, Bi2CO5	14.38
CuBiO2	Bi, Cu	0.90	0.105	Bi2CO5	13.68
CuMoO4	CuO, Mo	0.69	0.215	MoO2	17.21
CuO	Cu	1.00	0.201	None	6.15
CuPdO2	PdO, Cu	1.00	0.079	None	9298.30
CuPtO2	Pt3O4, Cu	1.00	0.037	Cu4PtO5, CuPt7	34451.20
CuRhO2	CuO, Rh	1.00	0.081	Cu3Rh	41584.63
CuSO4	CuS	1.00	0.401	None	3.07
CuSb2O6	CuO, Sb	0.60	0.198	Sb2O3	6.53
CuSb2O6	CuO, Sb3O7	1.00	0.013	Sb2O5, SbO2	6.53
Dy2Cu2O5	Dy2O3, Cu	1.00	0.060	DyHO2, Dy2CO5	246.16
Dy2Mn2O7	MnO, Dy2O3	0.00	0.059	MnHO2	237.72
Dy2Mo3O12	Dy2O3, MoO2	0.94	0.060	DyH3O3, Dy5Mo2O12, Dy2CO5	174.05

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Dy <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	Dy <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.94	0.067	Dy <sub>5</sub> Mo <sub>2</sub> O <sub>12</sub> , Dy <sub>2</sub> CO <sub>5</sub>	151.18
Dy <sub>2</sub> MoO <sub>6</sub>	Dy <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.94	0.031	DyHO <sub>2</sub> , Dy <sub>5</sub> Mo <sub>2</sub> O <sub>12</sub> , Dy <sub>2</sub> CO <sub>5</sub>	257.98
Dy <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	Dy <sub>2</sub> O <sub>3</sub> , Pb	0.77	0.075	DyHO <sub>2</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	153.87
Dy <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Dy <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.077	Dy <sub>2</sub> CO <sub>5</sub>	24365.24
Dy <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Dy <sub>2</sub> O <sub>3</sub> , Ru	0.99	0.100	Dy <sub>2</sub> CO <sub>5</sub>	2232.34
Dy <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Dy <sub>2</sub> S <sub>3</sub>	0.42	0.313	Dy <sub>2</sub> SO <sub>2</sub>	212.01
Dy <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	Dy <sub>2</sub> O <sub>3</sub> , FeO	0.55	0.042	DyHO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub> , Dy <sub>2</sub> CO <sub>5</sub>	203.43
Dy <sub>5</sub> Bi <sub>11</sub> O <sub>24</sub>	Dy <sub>2</sub> O <sub>3</sub> , Bi	0.73	0.076	Dy <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> CO <sub>5</sub>	104.56
Dy <sub>5</sub> Mo <sub>2</sub> O <sub>12</sub>	Dy <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.94	0.007	Dy <sub>2</sub> CO <sub>5</sub>	277.27
DyBi <sub>12</sub> O <sub>20</sub>	Bi, Dy	0.74	0.107	Bi <sub>2</sub> CO <sub>5</sub>	36.50
DyBi <sub>12</sub> O <sub>20</sub>	Bi <sub>2</sub> O <sub>3</sub> , Dy <sub>2</sub> O <sub>3</sub>	1.00	0.003	DyBi <sub>3</sub> O <sub>6</sub> , Bi <sub>2</sub> CO <sub>5</sub>	36.50
DyBi <sub>3</sub> O <sub>6</sub>	Dy <sub>2</sub> O <sub>3</sub> , Bi	0.73	0.081	Dy <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> CO <sub>5</sub>	85.87
DyCrO <sub>4</sub>	Dy <sub>2</sub> O <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub>	1.00	0.057	CrHO <sub>2</sub> , DyCrO <sub>3</sub> , Dy <sub>2</sub> CO <sub>5</sub>	235.25
DyCu <sub>2</sub> O <sub>4</sub>	CuO, Dy <sub>2</sub> O <sub>3</sub>	1.00	0.023	DyH <sub>3</sub> O <sub>3</sub> , Dy <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub> , Dy <sub>2</sub> CO <sub>5</sub>	186.60
DyFeO <sub>3</sub>	Dy <sub>2</sub> O <sub>3</sub> , FeO	0.55	0.030	DyHO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub> , Dy <sub>2</sub> CO <sub>5</sub>	244.07
DyMn <sub>2</sub> O <sub>5</sub>	MnO, Dy <sub>2</sub> O <sub>3</sub>	0.00	0.068	MnHO <sub>2</sub>	184.47
DyMnO <sub>3</sub>	MnO, Dy <sub>2</sub> O <sub>3</sub>	0.00	0.030	MnHO <sub>2</sub>	244.88
DyRhO <sub>3</sub>	Dy <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.077	DyHO <sub>2</sub> , DyH <sub>3</sub> O <sub>3</sub> , Dy <sub>2</sub> CO <sub>5</sub>	26537.63
DySbO <sub>4</sub>	Dy <sub>2</sub> O <sub>3</sub> , Sb	0.22	0.115	Dy <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub> , Dy <sub>3</sub> SbO <sub>7</sub>	189.72
DyTiO <sub>2</sub>	Dy <sub>2</sub> O <sub>3</sub> , Ti	0.57	0.020	DyHO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	3206.55
DyVO <sub>4</sub>	VO <sub>2</sub> , Dy <sub>2</sub> O <sub>3</sub>	0.99	0.029	Dy <sub>2</sub> CO <sub>5</sub> , DyHO <sub>2</sub>	237.11
Er <sub>2</sub> CuO <sub>4</sub>	Er <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.035	ErHO <sub>2</sub>	
Er <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	Er <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.99	0.067	ErHO <sub>2</sub>	
Er <sub>2</sub> MoO <sub>6</sub>	Er <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.99	0.030	ErHO <sub>2</sub>	
Er <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	Er <sub>2</sub> O <sub>3</sub> , Pb	0.77	0.074	ErHO <sub>2</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	
Er <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Er <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.076	ErHO <sub>2</sub>	
Er <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Er <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.099	ErHO <sub>2</sub>	
Er <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Er <sub>2</sub> S <sub>3</sub>	0.42	0.308	Er <sub>2</sub> O <sub>3</sub> , Er <sub>2</sub> SO <sub>2</sub>	
Er <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	Er <sub>2</sub> O <sub>3</sub> , FeO	0.55	0.041	ErHO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
ErBi12O20	Bi, Er	0.80	0.107	ErBiO3, ErHO2, Bi2CO5	
ErBi12O20	Bi2O3, Er2O3	1.00	0.003	ErBi3O6, Bi2CO5	
ErBi3O6	Er2O3, Bi	0.61	0.081	ErBiO3, ErHO2, Bi2CO5	
ErBiO3	Er2O3, Bi	0.62	0.057	ErHO2	
ErCu2O4	CuO, Er2O3	1.00	0.022	ErHO2, Er2CuO4	
ErFeO3	Er2O3, FeO	0.55	0.030	ErHO2, Fe3O4	
ErMn2O5	MnO, Er2O3	0.00	0.067	MnHO2	
ErMnO3	MnO, Er2O3	0.00	0.030	MnHO2	
ErRhO3	Er2O3, Rh	1.00	0.075	ErHO2	
ErSbO4	Er2O3, Sb	0.22	0.113	Er3Sb5O12, Er3SbO7	
ErTiO2	Er2O3, Ti	0.57	0.020	ErHO2, Ti2CO3	
ErVO4	ErVO3	0.39	0.057	VO2, ErHO2, Er2O3	
Eu2HgO4	EuO, Hg	0.06	0.056	EuCO3, Eu3O4	436.87
Eu2Ir2O7	EuO, Ir	0.11	0.100	EuCO3, Eu2O3	10318.34
Eu2Mo3O12	Eu3O4, Mo	0.02	0.191	Eu3MoO7, EuCO3, MoO2	323.09
Eu2MoO6	MoO2, Eu2O3	0.40	0.032	Eu3MoO7, EuMoO4, EuCO3	497.11
Eu2MoO6	MoO2, Eu3O4	0.20	0.043	Eu3MoO7, EuMoO4, Eu2Mo2O7, EuCO3	497.11
Eu2NiO4	EuO, Ni	0.06	0.075	EuCO3, Eu3O4	572.96
Eu2O3	Eu3O4	0.06	0.015	EuCO3	690.89
Eu2Pb2O7	EuO, Pb	0.11	0.096	Pb3H2O4, EuCO3, Eu2O3, Eu3O4	294.04
Eu2Pb2O7	Pb2O3, EuO	1.00	0.039	Pb3H2O4, Pb2CO4, PbCO3, PbO, Eu2O3	294.04
Eu2Pt2O7	EuO, Pt	0.11	0.099	EuCO3, Eu2O3	25142.53
Eu2Ru2O7	EuO, Ru	0.11	0.129	EuCO3, Eu2O3	2491.51
Eu2TiO5	TiO2, Eu3O4	0.07	0.012	EuCO3, EuTiO3, Eu2O3	564.32
Eu3AuO6	EuO, Au	0.06	0.064	EuCO3, Eu3O4	10611.12
Eu3Fe5O12	FeO, EuO	0.06	0.069	Fe3O4, Eu2O3, Eu3O4, EuCO3	393.42
Eu3FeO6	FeO, Eu3O4	0.08	0.026	Fe3O4, Eu2O3, EuCO3	600.13
Eu3IrO7	EuO, Ir	0.06	0.084	EuCO3, Eu2O3, Eu3O4	5752.26
Eu3OsO7	Eu2O3, Os	0.05	0.053	EuCO3, Eu3O4	4102.97

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Eu <sub>3</sub> RuO <sub>7</sub>	EuO, Ru	0.06	0.096	EuCO <sub>3</sub> , Eu <sub>2</sub> O <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub>	1514.44
Eu <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	EuO, Au	0.06	0.070	EuCO <sub>3</sub> , Eu <sub>2</sub> O <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub>	13658.11
Eu <sub>4</sub> PdO <sub>7</sub>	EuO, Pd	0.04	0.058	EuCO <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub>	2860.71
EuAgO <sub>2</sub>	EuO, Ag	0.06	0.055	EuCO <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub>	653.70
EuCrO <sub>4</sub>	Eu <sub>3</sub> O <sub>4</sub> , Cr	0.09	0.159	EuCrO <sub>3</sub> , EuCO <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub>	455.62
EuCu <sub>2</sub> O <sub>4</sub>	CuO, Eu <sub>3</sub> O <sub>4</sub>	1.00	0.031	EuCuO <sub>2</sub> , EuCO <sub>3</sub>	357.23
EuCuO <sub>2</sub>	Eu <sub>3</sub> O <sub>4</sub> , Cu	0.04	0.043	EuCO <sub>3</sub> , Eu <sub>2</sub> O <sub>3</sub>	493.16
EuMn <sub>2</sub> O <sub>5</sub>	Mn <sub>2</sub> O <sub>3</sub> , EuO	0.35	0.047	MnHO <sub>2</sub> , MnO, EuMnO <sub>3</sub> , EuCO <sub>3</sub> , MnO <sub>2</sub> , Eu <sub>2</sub> O <sub>3</sub>	355.64
EuMn <sub>2</sub> O <sub>5</sub>	MnO, EuO	0.00	0.094	Eu <sub>3</sub> O <sub>4</sub> , MnHO <sub>2</sub> , EuCO <sub>3</sub>	355.64
EuMnO <sub>3</sub>	Mn <sub>2</sub> O <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub>	0.36	0.010	MnHO <sub>2</sub> , EuCO <sub>3</sub> , MnO <sub>2</sub> , Eu <sub>2</sub> O <sub>3</sub>	476.94
EuMnO <sub>3</sub>	MnO, EuO	0.00	0.063	Eu <sub>3</sub> O <sub>4</sub> , MnHO <sub>2</sub> , EuCO <sub>3</sub>	476.94
EuMoO <sub>4</sub>	Eu <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub>	0.40	0.026	Eu <sub>3</sub> MoO <sub>7</sub> , EuCO <sub>3</sub> , MoO <sub>2</sub>	400.54
EuRe <sub>2</sub> O <sub>8</sub>	ReO <sub>3</sub> , EuO	0.21	0.025	EuCO <sub>3</sub> , Eu <sub>3</sub> ReO <sub>7</sub>	3037.23
EuRhO <sub>3</sub>	EuO, Rh	0.09	0.106	EuCO <sub>3</sub> , Eu <sub>2</sub> O <sub>3</sub>	27647.59
EuSO <sub>4</sub>	EuS	0.43	0.258	EuCO <sub>3</sub>	490.15
EuSbO <sub>4</sub>	EuO, Sb	0.12	0.142	Eu <sub>3</sub> SbO <sub>7</sub> , EuCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	363.15
EuTaO <sub>4</sub>	Eu <sub>2</sub> Ta <sub>2</sub> O <sub>7</sub>	0.98	0.020	EuTa <sub>2</sub> O <sub>6</sub> , EuCO <sub>3</sub>	356.44
EuVO <sub>4</sub>	Eu <sub>2</sub> V <sub>2</sub> O <sub>5</sub>	0.03	0.090	VO <sub>2</sub> , Eu <sub>3</sub> O <sub>4</sub> , EuVO <sub>3</sub> , EuCO <sub>3</sub>	458.43
EuVO <sub>4</sub>	VO <sub>2</sub> , EuO	0.05	0.060	Eu <sub>2</sub> O <sub>3</sub> , Eu <sub>3</sub> O <sub>4</sub> , EuVO <sub>3</sub> , EuCO <sub>3</sub>	458.43
Fe <sub>2</sub> CoO <sub>4</sub>	FeO, Co	0.60	0.136	Fe <sub>3</sub> O <sub>4</sub> , CoC <sub>2</sub> H <sub>4</sub> O <sub>6</sub>	11.66
Fe <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	Fe, Mo	0.20	0.325	MoO <sub>2</sub> , FeO, Fe <sub>3</sub> O <sub>4</sub>	17.05
Fe <sub>2</sub> NiO <sub>4</sub>	Ni, Fe	0.39	0.273	Fe <sub>3</sub> O <sub>4</sub> , FeO	5.57
Fe <sub>2</sub> O <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub>	1.00	0.033	None	0.08
Fe <sub>2</sub> O <sub>3</sub>	FeO	0.55	0.100	Fe <sub>3</sub> O <sub>4</sub>	0.08
Fe <sub>3</sub> O <sub>4</sub>	FeO	0.53	0.069	FeH <sub>2</sub> O <sub>2</sub>	0.09
Fe <sub>4</sub> Bi <sub>2</sub> O <sub>9</sub>	Bi <sub>2</sub> O <sub>3</sub> , FeO	0.91	0.041	Fe <sub>3</sub> O <sub>4</sub> , Bi <sub>2</sub> CO <sub>5</sub>	9.40
FeAgO <sub>2</sub>	Ag, Fe	0.39	0.163	Fe <sub>3</sub> O <sub>4</sub> , FeO	353.61
FeAuO <sub>2</sub>	Fe, Au	0.39	0.112	FeO, Fe <sub>3</sub> O <sub>4</sub>	26619.42
FeBiO <sub>3</sub>	Bi, Fe	0.50	0.153	FeO, Fe <sub>3</sub> O <sub>4</sub>	11.78

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
FeBiO <sub>3</sub>	Bi <sub>2</sub> O <sub>3</sub> , Fe <sub>3</sub> O <sub>4</sub>	1.00	0.009	Bi <sub>2</sub> CO <sub>5</sub>	11.78
FeCuO <sub>2</sub>	Fe, Cu	0.39	0.211	FeO, Fe <sub>3</sub> O <sub>4</sub>	3.28
FeS <sub>2</sub> O <sub>8</sub>	FeS <sub>2</sub>	0.96	0.516	None	0.03
FeSO <sub>4</sub>	FeS	0.82	0.421	FeS <sub>2</sub> , FeO	0.04
FeSb <sub>2</sub> O <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , Sb	0.31	0.117	Sb <sub>2</sub> O <sub>3</sub> , FeO	5.92
FeSb <sub>2</sub> O <sub>4</sub>	FeO, Sb	0.31	0.132	Sb <sub>2</sub> O <sub>3</sub>	5.92
FeSb <sub>2</sub> O <sub>6</sub>	FeO, Sb <sub>2</sub> O <sub>3</sub>	1.00	0.040	Sb <sub>2</sub> O <sub>3</sub> , Sb <sub>3</sub> O <sub>7</sub> , Fe <sub>3</sub> O <sub>4</sub>	5.44
FeSbO <sub>4</sub>	Fe, Sb	0.45	0.265	Sb <sub>2</sub> O <sub>3</sub> , FeSb <sub>2</sub> O <sub>4</sub> , FeO	4.46
FeSbO <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , Sb <sub>3</sub> O <sub>7</sub>	1.00	0.022	FeSb <sub>2</sub> O <sub>6</sub>	4.46
FeSbO <sub>4</sub>	FeO, Sb <sub>3</sub> O <sub>7</sub>	1.00	0.044	Sb <sub>2</sub> O <sub>3</sub> , FeSb <sub>2</sub> O <sub>6</sub> , Fe <sub>3</sub> O <sub>4</sub>	4.46
Ga <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	Ga <sub>2</sub> O <sub>3</sub> , Mo	0.22	0.233	MoO <sub>2</sub>	151.38
Ga <sub>2</sub> NiO <sub>4</sub>	Ga <sub>2</sub> O <sub>3</sub> , Ni	1.00	0.061	None	324.10
Ga <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Ga <sub>2</sub> S <sub>3</sub>	0.99	0.449	Ga <sub>2</sub> O <sub>3</sub>	195.65
Ga <sub>4</sub> Bi <sub>2</sub> O <sub>9</sub>	Ga <sub>2</sub> O <sub>3</sub> , Bi	0.19	0.057		207.76
GaAgO <sub>2</sub>	Ag, Ga	0.13	0.153	Ga <sub>2</sub> O <sub>3</sub>	529.76
GaAuO <sub>2</sub>	Ga <sub>2</sub> O <sub>3</sub> , Au	1.00	0.027	None	25522.63
GaBiO <sub>3</sub>	Ga <sub>2</sub> O <sub>3</sub> , Bi	0.44	0.073	Ga <sub>4</sub> Bi <sub>2</sub> O <sub>9</sub>	139.31
GaCuO <sub>2</sub>	Ga <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.048	None	256.09
GaFeO <sub>3</sub>	FeO, Ga <sub>2</sub> O <sub>3</sub>	0.55	0.046	Fe <sub>3</sub> O <sub>4</sub>	241.06
GaSbO <sub>4</sub>	Ga, Sb	0.38	0.250	Ga <sub>2</sub> O <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	167.94
Gd <sub>2</sub> CdO <sub>4</sub>	Gd <sub>2</sub> O <sub>3</sub> , Cd	0.99	0.033	GdHO <sub>2</sub> , CdCO <sub>3</sub>	36.24
Gd <sub>2</sub> HgO <sub>4</sub>	Gd <sub>2</sub> O <sub>3</sub> , Hg	1.00	0.028	GdHO <sub>2</sub>	38.89
Gd <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Gd <sub>2</sub> O <sub>3</sub>	0.94	0.060	GdHO <sub>2</sub> , Gd <sub>3</sub> MoO <sub>7</sub>	34.46
Gd <sub>2</sub> Mo <sub>5</sub> O <sub>18</sub>	MoO <sub>2</sub> , Gd <sub>2</sub> O <sub>3</sub>	0.95	0.074	GdH <sub>3</sub> O <sub>3</sub> , Gd <sub>3</sub> MoO <sub>7</sub>	31.50
Gd <sub>2</sub> MoO <sub>6</sub>	MoO <sub>2</sub> , Gd <sub>2</sub> O <sub>3</sub>	0.62	0.032	GdHO <sub>2</sub> , Gd <sub>3</sub> MoO <sub>7</sub>	40.79
Gd <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Gd <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.102	GdHO <sub>2</sub>	2090.35
Gd <sub>3</sub> AuO <sub>6</sub>	Gd <sub>2</sub> O <sub>3</sub> , Au	1.00	0.031	GdHO <sub>2</sub>	9948.08
Gd <sub>3</sub> Bi <sub>2</sub> O <sub>8</sub>	Bi <sub>2</sub> O <sub>3</sub> , Gd <sub>2</sub> O <sub>3</sub>	0.99	0.008	GdHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	32.72
Gd <sub>3</sub> Bi <sub>2</sub> O <sub>8</sub>	Gd <sub>2</sub> O <sub>3</sub> , Bi	0.89	0.055	GdHO <sub>2</sub>	32.72
Gd <sub>3</sub> FeO <sub>6</sub>	FeO, Gd <sub>2</sub> O <sub>3</sub>	0.55	0.013	Fe <sub>3</sub> O <sub>4</sub> , GdHO <sub>2</sub>	41.62
Gd <sub>3</sub> MoO <sub>7</sub>	MoO <sub>2</sub> , Gd <sub>2</sub> O <sub>3</sub>	0.46	0.012		43.11
Gd <sub>3</sub> OsO <sub>7</sub>	Gd <sub>2</sub> O <sub>3</sub> , Os	0.99	0.052	GdHO <sub>2</sub>	3581.20
Gd <sub>3</sub> ReO <sub>8</sub>	Gd <sub>2</sub> O <sub>3</sub> , ReO <sub>3</sub>	1.00	0.010	GdHO <sub>2</sub>	1216.19
Gd <sub>3</sub> RuO <sub>7</sub>	Gd <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.058	GdHO <sub>2</sub>	984.69
Gd <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	Gd <sub>2</sub> O <sub>3</sub> , Au	1.00	0.041	GdHO <sub>2</sub>	13023.56
Gd <sub>4</sub> PdO <sub>7</sub>	Gd <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.019	GdHO <sub>2</sub>	2256.31
GdBi <sub>4</sub> O <sub>8</sub>	Gd <sub>2</sub> O <sub>3</sub> , Bi	0.88	0.093	GdHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	20.84
GdCrO <sub>4</sub>	Gd <sub>2</sub> O <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub>	1.00	0.059	GdCrO <sub>3</sub>	33.54

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
GdCu2O4	CuO, Gd2O3	1.00	0.023	GdHO2	27.64
GdFeO3	FeO, Gd2O3	0.55	0.031	Fe3O4, GdHO2	33.15
GdMn2O5	MnO, Gd2O3	0.00	0.069	MnHO2	24.92
GdPd2O4	Gd2O3, PdO	1.00	0.018	GdH3O3, GdHO2, Gd4PdO7	8669.98
GdVO4	VO2, Gd2O3	0.97	0.029		34.66
Ge3Bi2O9	GeO2, Bi	0.20	0.062		344.75
Ge3Bi4O12	GeO2, Bi	0.29	0.077	Ge3Bi2O9	221.71
GeBi12O20	Bi, Ge	0.77	0.110	None	45.27
GePb5O7	Pb, Ge	0.34	0.092	PbCO3, GePbO3	73.47
Hf2Bi2O7	HfO2, Bi	0.19	0.054		229.66
HfCdO3	HfO2, Cd	0.88	0.047	CdCO3	291.13
HfMo2O8	HfO2, Mo	0.22	0.193	MoO2	210.46
HfSO6	HfS	0.80	0.313	HfO2	320.24
HfV2O7	HfO2, V2O3	0.44	0.082	VO2	254.20
Hg2Mo5O16	Mo, Hg	0.27	0.225	MoO2	23.96
Hg2Pt2O7	PtO2, HgO	1.00	0.018	None	22178.15
Hg2Sb2O7	HgO, Sb2O3	1.00	0.042	Sb2O5, SbO2, HgSb2O6	16.64
HgMoO4	Mo, Hg	0.44	0.178	MoO2	23.81
HgO	Hg	1.00	0.074	None	24.13
HgSb2O6	SbO2, HgO	1.00	0.030	Sb2O5	13.64
Ho2HgO4	Ho2O3, Hg	1.00	0.027	Ho2CH4O7	
Ho2Mn2O7	MnO, Ho2O3	0.00	0.058	MnHO2	
Ho2Mo3O12	Ho2O3, MoO2	0.96	0.059	Ho2CH4O7	
Ho2Mo4O15	Ho2O3, MoO2	0.96	0.067	Ho2CH4O7	
Ho2MoO6	Ho2O3, MoO2	0.96	0.031	Ho2CH4O7	
Ho2Pb2O7	Ho2O3, Pb	0.77	0.075	Ho2CH4O7, Pb2CO4, PbCO3, PbO	
Ho2Pt2O7	Ho2O3, Pt	1.00	0.077	Ho2CH4O7	
Ho2Ru2O7	Ho2O3, Ru	0.99	0.099	Ho2CH4O7	
Ho3Fe5O12	Ho2O3, FeO	0.55	0.041	Fe3O4, Ho2CH4O7	
Ho3ReO8	Ho2O3, ReO3	1.00	0.010	Ho6ReO12, Ho2CH4O7	
HoBi12O20	Bi, Ho	0.80	0.107	HoBiO3, Bi2CO5	
HoBi12O20	Bi2O3, Ho2O3	1.00	0.003	HoBiO3, Ho2CH4O7, Bi2CO5	
HoBiO3	Ho2O3, Bi	0.52	0.057	Ho2CH4O7	
HoCrO4	Ho2O3, Cr2O3	1.00	0.057	CrHO2, Ho2CH4O7, HoCrO3	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
HoCu <sub>2</sub> O <sub>4</sub>	CuO, Ho <sub>2</sub> O <sub>3</sub>	1.00	0.022	Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub> , HoCuO <sub>2</sub>	
HoCuO <sub>2</sub>	Ho <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.031	Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub>	
HoFeO <sub>3</sub>	Ho <sub>2</sub> O <sub>3</sub> , FeO	0.55	0.030	Fe <sub>3</sub> O <sub>4</sub> , Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub>	
HoMn <sub>2</sub> O <sub>5</sub>	MnO, Ho <sub>2</sub> O <sub>3</sub>	0.00	0.068	MnHO <sub>2</sub>	
HoMnO <sub>3</sub>	MnO, Ho <sub>2</sub> O <sub>3</sub>	0.00	0.030	MnHO <sub>2</sub>	
HoRhO <sub>3</sub>	Ho <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.076	Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub>	
HoSbO <sub>4</sub>	Ho <sub>2</sub> O <sub>3</sub> , Sb	0.14	0.114	Ho <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub> , Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub> , Ho <sub>3</sub> SbO <sub>7</sub>	
HoTiO <sub>2</sub>	Ho <sub>2</sub> O <sub>3</sub> , Ti	0.57	0.020	Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub> , Ti <sub>2</sub> CO <sub>3</sub>	
HoVO <sub>4</sub>	HoVO <sub>3</sub>	0.29	0.057	Ho <sub>2</sub> O <sub>3</sub> , VO <sub>2</sub> , Ho <sub>2</sub> CH <sub>4</sub> O <sub>7</sub>	
In <sub>11</sub> Sb <sub>3</sub> O <sub>24</sub>	Sb <sub>2</sub> O <sub>3</sub> , In	0.24	0.155	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	343.85
In <sub>2</sub> HgO <sub>4</sub>	In, Hg	0.19	0.129	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	263.94
In <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , In	0.35	0.135	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	190.70
In <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	In <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	1.00	0.029	InH <sub>3</sub> O <sub>3</sub> , InPt <sub>3</sub>	27533.85
In <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	In <sub>2</sub> S <sub>3</sub>	0.99	0.371	None	241.82
In <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	Sb, In	0.23	0.168	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	168.68
InAgO <sub>2</sub>	Ag, In	0.23	0.126	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub> , InAg <sub>3</sub>	517.54
InAuO <sub>2</sub>	Au, In	0.32	0.093	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	22235.19
InBiO <sub>3</sub>	Bi, In	0.35	0.129	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	178.29
InCu <sub>6</sub> O <sub>8</sub>	Cu, In	0.77	0.205	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	105.03
InCuO <sub>2</sub>	Cu, In	0.19	0.152	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	299.95
InRhO <sub>3</sub>	Rh, In	0.92	0.181	InH <sub>3</sub> O <sub>3</sub> , InRh <sub>3</sub>	31290.64
InSbO <sub>4</sub>	Sb, In	0.29	0.213	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	211.86
InSbO <sub>4</sub>	Sb <sub>2</sub> O <sub>3</sub> , In	0.35	0.133	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub> , In <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	211.86
Ir <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	IrO <sub>2</sub> , Pb	0.99	0.053	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	8801.01
IrO <sub>2</sub>	Ir	1.00	0.143	None	17873.89
K <sub>11</sub> Mn <sub>4</sub> O <sub>16</sub>	Mn <sub>2</sub> O <sub>3</sub> , K	0.00	0.177	K <sub>2</sub> CO <sub>3</sub> , KHO, MnO, KMn <sub>2</sub> O <sub>4</sub>	
K <sub>11</sub> Mn <sub>4</sub> O <sub>16</sub>	MnO, K <sub>2</sub> O	0.00	0.115	K <sub>2</sub> CO <sub>3</sub> , KHO, KMn <sub>2</sub> O <sub>4</sub>	
K <sub>2</sub> BeO <sub>2</sub>	BeO, K	0.00	0.134	K <sub>2</sub> Be <sub>2</sub> O <sub>3</sub> , K <sub>4</sub> Be <sub>3</sub> O <sub>5</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> Cd <sub>2</sub> O <sub>3</sub>	Cd, K	0.00	0.137	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> Cd <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O, Cd	0.00	0.091	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
K <sub>2</sub> CdO <sub>2</sub>	CdO, K	0.00	0.072	KHO, K <sub>6</sub> CdO <sub>4</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> CoO <sub>3</sub>	CoO, K	0.00	0.173	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> CoO <sub>3</sub>	K <sub>2</sub> O, Co	0.00	0.173	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	CrO <sub>2</sub> , K	0.05	0.163	KH <sub>9</sub> O <sub>5</sub> , KH <sub>3</sub> O <sub>2</sub> , Cr <sub>2</sub> O <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub> , K <sub>3</sub> CrO <sub>4</sub>	
K <sub>2</sub> HgO <sub>2</sub>	K, Hg	0.00	0.103	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> Mg <sub>2</sub> O <sub>3</sub>	MgO, K	0.00	0.092	K <sub>2</sub> CO <sub>3</sub> , KHO	
K <sub>2</sub> MgO <sub>2</sub>	MgO, K	0.00	0.119	K <sub>2</sub> CO <sub>3</sub> , KHO	
K <sub>2</sub> Mo <sub>3</sub> O <sub>10</sub>	K <sub>2</sub> O, MoO <sub>2</sub>	0.19	0.091	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , KMo <sub>4</sub> O <sub>8</sub> , K <sub>2</sub> CO <sub>3</sub> , K <sub>2</sub> MoO <sub>4</sub>	
K <sub>2</sub> Mo <sub>3</sub> O <sub>10</sub>	MoO <sub>2</sub> , K	0.06	0.122	KCHO <sub>3</sub> , KMo <sub>4</sub> O <sub>8</sub> , K <sub>2</sub> CO <sub>3</sub> , K <sub>2</sub> MoO <sub>4</sub>	
K <sub>2</sub> O	K	0.00	0.170	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> O <sub>2</sub>	K	0.00	0.290	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> OsO <sub>5</sub>	K <sub>2</sub> O, Os	0.02	0.184	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> OsO <sub>5</sub>	Os, K	0.11	0.230	KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> PbO <sub>2</sub>	Pb, K	0.00	0.101	KHO, KPb, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> PbO <sub>3</sub>	K <sub>2</sub> PbO <sub>2</sub>	0.00	0.048	KHO, KH <sub>3</sub> O <sub>2</sub> , KPbO <sub>2</sub> , K <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> PdO <sub>2</sub>	K <sub>2</sub> O, Pd	0.00	0.074	K <sub>3</sub> Pd <sub>2</sub> O <sub>4</sub> , KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> PdO <sub>2</sub>	Pd, K	0.00	0.148	KHO, K <sub>2</sub> PdH <sub>4</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> Rh <sub>2</sub> O <sub>5</sub>	RhO <sub>2</sub> , K	0.00	0.044	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> RuO <sub>4</sub>	K, Ru	0.00	0.263	K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> RuO <sub>4</sub>	K <sub>2</sub> O, Ru	0.00	0.197	KH <sub>9</sub> O <sub>5</sub> , KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> S <sub>2</sub> O <sub>7</sub>	KS	0.33	0.440	K <sub>2</sub> SO <sub>4</sub> , KCHO <sub>3</sub> , KS <sub>3</sub>	
K <sub>2</sub> S <sub>5</sub> O <sub>16</sub>	K <sub>2</sub> S <sub>5</sub>	0.89	0.518	K <sub>2</sub> SO <sub>4</sub> , KSO <sub>3</sub> , KS <sub>3</sub>	
K <sub>2</sub> Sb <sub>4</sub> O <sub>11</sub>	K <sub>2</sub> O, Sb	0.26	0.216	KCHO <sub>3</sub> , KSb <sub>3</sub> O <sub>5</sub> , K <sub>2</sub> CO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	
K <sub>2</sub> Sb <sub>4</sub> O <sub>11</sub>	Sb <sub>2</sub> O <sub>3</sub> , K	0.48	0.108	KCHO <sub>3</sub> , KSb <sub>3</sub> O <sub>5</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> TbO <sub>3</sub>	Tb <sub>2</sub> O <sub>3</sub> , K	0.00	0.084	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>2</sub> ZnO <sub>2</sub>	Zn, K	0.00	0.182	KHO, K <sub>2</sub> CO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
K <sub>2</sub> ZnO <sub>2</sub>	ZnO, K	0.00	0.091	KHO, K <sub>2</sub> Zn <sub>3</sub> O <sub>4</sub> , Zn <sub>6</sub> HO <sub>6</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> AgO <sub>2</sub>	Ag, K	0.00	0.124	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> AgO <sub>2</sub>	K <sub>2</sub> O, Ag	0.00	0.031	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> AuO	Au, K	0.00	0.048	KHO, K <sub>2</sub> CO <sub>3</sub> , K <sub>2</sub> Au <sub>3</sub>	
K <sub>3</sub> BiO <sub>4</sub>	Bi <sub>2</sub> O <sub>3</sub> , K	0.00	0.102	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> BiO <sub>4</sub>	K <sub>2</sub> O, Bi	0.00	0.102	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> Cu <sub>5</sub> O <sub>4</sub>	Cu, K	0.00	0.128	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> Cu <sub>5</sub> O <sub>4</sub>	K <sub>2</sub> O, Cu	0.00	0.080	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> CuO <sub>2</sub>	Cu, K	0.00	0.150	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> FeO <sub>4</sub>	K <sub>2</sub> O, Fe <sub>2</sub> O <sub>3</sub>	0.00	0.067	K <sub>2</sub> CO <sub>3</sub> , KHO, Fe <sub>3</sub> O <sub>4</sub> , KFeO <sub>2</sub> , K <sub>4</sub> Fe <sub>2</sub> O <sub>5</sub>	
K <sub>3</sub> Mn <sub>2</sub> O <sub>8</sub>	K <sub>2</sub> O, Mn	0.00	0.293	K <sub>2</sub> CO <sub>3</sub> , MnHO <sub>2</sub> , MnO	
K <sub>3</sub> Mn <sub>2</sub> O <sub>8</sub>	Mn, K	0.00	0.360	K <sub>2</sub> CO <sub>3</sub> , MnHO <sub>2</sub> , MnO	
K <sub>3</sub> MnO <sub>4</sub>	MnO <sub>2</sub> , K	0.00	0.135	K <sub>2</sub> CO <sub>3</sub> , KHO, KMn <sub>2</sub> O <sub>4</sub>	
K <sub>3</sub> Pd <sub>2</sub> O <sub>4</sub>	K <sub>2</sub> O, Pd	0.00	0.101	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> Pd <sub>2</sub> O <sub>4</sub>	Pd, K	0.00	0.162	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> Pt <sub>2</sub> O <sub>4</sub>	K <sub>2</sub> O, Pt	0.00	0.070	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> Pt <sub>2</sub> O <sub>4</sub>	Pt, K	0.00	0.112	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>3</sub> SbO <sub>4</sub>	K <sub>3</sub> SbO <sub>3</sub>	0.00	0.053	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>4</sub> Sb <sub>2</sub> O <sub>5</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>4</sub> Co <sub>2</sub> O <sub>5</sub>	CoO, K	0.00	0.135	KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>4</sub> IrO <sub>4</sub>	Ir, K	0.00	0.155	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>4</sub> MnO <sub>4</sub>	Mn <sub>2</sub> O <sub>3</sub> , K	0.00	0.145	K <sub>2</sub> CO <sub>3</sub> , KHO, KMn <sub>2</sub> O <sub>4</sub>	
K <sub>4</sub> PbO <sub>4</sub>	PbO, K	0.00	0.112	KHO, KPb, K <sub>2</sub> CO <sub>3</sub>	
K <sub>4</sub> ZnO <sub>3</sub>	Zn, K	0.00	0.178	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>4</sub> ZnO <sub>3</sub>	ZnO, K	0.00	0.119	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>5</sub> FeO <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , K	0.00	0.135	K <sub>2</sub> CO <sub>3</sub> , KHO	
K <sub>5</sub> FeO <sub>4</sub>	FeO, K	0.00	0.152	K <sub>2</sub> CO <sub>3</sub> , KHO	
K <sub>5</sub> TiO <sub>4</sub>	K <sub>2</sub> O, Ti	0.00	0.052	KHO, KTiO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>5</sub> TiO <sub>4</sub>	Ti <sub>4</sub> O <sub>3</sub> , K	0.00	0.112	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>5</sub> YO <sub>4</sub>	Y <sub>2</sub> O <sub>3</sub> , K	0.00	0.115	K <sub>2</sub> CO <sub>3</sub> , KHO, KYO <sub>2</sub>	
K <sub>6</sub> CdO <sub>4</sub>	K <sub>2</sub> O, Cd	0.00	0.039	KHO, K <sub>2</sub> CdO <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
K <sub>6</sub> Co <sub>2</sub> O <sub>7</sub>	Co, K	0.00	0.241	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>6</sub> Co <sub>2</sub> O <sub>7</sub>	CoO, K	0.00	0.172	KHO, K <sub>2</sub> CO <sub>3</sub>	
K <sub>6</sub> Pb <sub>2</sub> O <sub>5</sub>	Pb, K	0.00	0.110	KHO, KPb, K <sub>2</sub> CO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
KAgO	Ag, K	0.00	0.098	KHO, K <sub>2</sub> CO <sub>3</sub>	
KAgO	K <sub>2</sub> O, Ag	0.00	0.049	K <sub>3</sub> AgO <sub>2</sub> , KHO, K <sub>2</sub> CO <sub>3</sub>	
KAgO <sub>2</sub>	Ag, K	0.00	0.179	K <sub>2</sub> CO <sub>3</sub>	
KAuO <sub>2</sub>	Au, K	0.00	0.119	K <sub>2</sub> CO <sub>3</sub>	
KAuO <sub>2</sub>	K <sub>2</sub> O <sub>2</sub> , Au	0.00	0.060	KH <sub>9</sub> O <sub>5</sub> , KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
KBiO <sub>2</sub>	Bi, K	0.00	0.114	K <sub>2</sub> CO <sub>3</sub>	
KBiO <sub>3</sub>	Bi <sub>2</sub> O <sub>3</sub> , K <sub>2</sub> O <sub>2</sub>	0.00	0.027	KH <sub>3</sub> O <sub>2</sub> , KBiO <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub> , BiO <sub>2</sub>	
KBiO <sub>3</sub>	BiO <sub>2</sub> , K	0.00	0.054	KH <sub>3</sub> O <sub>2</sub> , KBiO <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub> , Bi <sub>2</sub> O <sub>3</sub>	
KCo <sub>2</sub> O <sub>4</sub>	K <sub>2</sub> O <sub>2</sub> , Co	0.16	0.217	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , CoO, K <sub>2</sub> CO <sub>3</sub>	
KCuO	Cu, K	0.00	0.135	KHO, K <sub>2</sub> CO <sub>3</sub>	
KCuO <sub>2</sub>	Cu, K	0.00	0.238	K <sub>2</sub> CO <sub>3</sub>	
KCuO <sub>2</sub>	K <sub>2</sub> O, Cu	0.00	0.178	KH <sub>9</sub> O <sub>5</sub> , KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
KIrO <sub>3</sub>	K <sub>2</sub> O <sub>2</sub> , Ir	0.08	0.115	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub> , IrO <sub>2</sub>	
KO <sub>2</sub>	K	0.00	0.450	K <sub>2</sub> CO <sub>3</sub>	
KOs <sub>2</sub> O <sub>6</sub>	K <sub>2</sub> O <sub>2</sub> , Os	0.64	0.155	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
KPbO <sub>2</sub>	Pb, K	0.00	0.115	K <sub>2</sub> CO <sub>3</sub>	
KPd <sub>2</sub> O <sub>3</sub>	K <sub>2</sub> O <sub>2</sub> , Pd	0.20	0.107	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub> , PdO	
KPd <sub>2</sub> O <sub>3</sub>	Pd, K	0.22	0.160	KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
KRu <sub>4</sub> O <sub>8</sub>	KO <sub>2</sub> , Ru	0.67	0.168	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub> , RuO <sub>2</sub>	
KRuO <sub>4</sub>	K <sub>2</sub> O, RuO <sub>2</sub>	0.08	0.118	KH <sub>9</sub> O <sub>5</sub> , KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub> , KRu <sub>4</sub> O <sub>8</sub> , K <sub>2</sub> RuO <sub>4</sub>	
KRuO <sub>4</sub>	RuO <sub>2</sub> , K	0.11	0.157	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> CO <sub>3</sub>	
KSO <sub>3</sub>	KS	0.23	0.403	K <sub>2</sub> SO <sub>4</sub> , KCHO <sub>3</sub> , KS <sub>3</sub>	
KSb <sub>5</sub> O <sub>13</sub>	K <sub>2</sub> O, SbO <sub>2</sub>	1.00	0.047	KH <sub>9</sub> O <sub>5</sub> , Sb <sub>3</sub> O <sub>7</sub> , KCHO <sub>3</sub> , K <sub>2</sub> Sb <sub>4</sub> O <sub>11</sub> , Sb <sub>2</sub> O <sub>3</sub>	
KSb <sub>5</sub> O <sub>13</sub>	K <sub>2</sub> O <sub>2</sub> , Sb	0.45	0.224	KCHO <sub>3</sub> , KSb <sub>3</sub> O <sub>5</sub> , Sb <sub>2</sub> O <sub>3</sub>	
KSb <sub>5</sub> O <sub>13</sub>	SbO <sub>2</sub> , K	1.00	0.056	KH <sub>9</sub> O <sub>5</sub> , KCHO <sub>3</sub> , K <sub>2</sub> Sb <sub>4</sub> O <sub>11</sub> , Sb <sub>2</sub> O <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
KSbO <sub>3</sub>	KSbO <sub>2</sub>	0.03	0.077	KH <sub>9</sub> O <sub>5</sub> , KSb <sub>3</sub> O <sub>5</sub> , K <sub>2</sub> CO <sub>3</sub>	
KTiO	K <sub>2</sub> O, Ti	0.00	0.031	KHO, K <sub>2</sub> CO <sub>3</sub>	
KTiO	Ti, K	0.00	0.062	KHO, K <sub>2</sub> CO <sub>3</sub>	
KTiO <sub>2</sub>	K <sub>2</sub> O, Ti <sub>4</sub> O <sub>3</sub>	0.00	0.044	Ti <sub>2</sub> O, KHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
KTiO <sub>2</sub>	Ti <sub>4</sub> O <sub>3</sub> , K	0.00	0.073	Ti <sub>2</sub> O, TiHO, KH <sub>3</sub> O <sub>2</sub> , K <sub>2</sub> CO <sub>3</sub>	
La <sub>2</sub> AuO <sub>4</sub>	La <sub>2</sub> O <sub>3</sub> , Au	0.03	0.030	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	14102.63
La <sub>2</sub> Bi <sub>2</sub> O <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Bi	0.10	0.079	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> CO <sub>5</sub>	29.74
La <sub>2</sub> Bi <sub>4</sub> O <sub>9</sub>	La <sub>2</sub> O <sub>3</sub> , Bi	0.32	0.076	La <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> CO <sub>5</sub>	24.95
La <sub>2</sub> CrO <sub>6</sub>	La <sub>2</sub> O <sub>3</sub> , Cr	0.05	0.113	CrHO <sub>2</sub> , LaCrO <sub>3</sub> , La <sub>2</sub> CO <sub>5</sub>	40.36
La <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub>	La <sub>2</sub> O <sub>3</sub> , Cu	0.03	0.066	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , LaCuO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	36.39
La <sub>2</sub> CuO <sub>4</sub>	La <sub>2</sub> O <sub>3</sub> , Cu	0.03	0.039	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , LaCuO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	42.33
La <sub>2</sub> HgO <sub>4</sub>	La <sub>2</sub> O <sub>3</sub> , Hg	0.03	0.029	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	40.37
La <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , La <sub>2</sub> O <sub>3</sub>	0.85	0.063	LaH <sub>3</sub> O <sub>3</sub> , La <sub>3</sub> MoO <sub>7</sub> , La <sub>2</sub> CO <sub>5</sub>	35.30
La <sub>2</sub> NiO <sub>4</sub>	La <sub>2</sub> O <sub>3</sub> , Ni	0.03	0.040	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	44.84
La <sub>2</sub> Pd <sub>2</sub> O <sub>5</sub>	La <sub>2</sub> O <sub>3</sub> , Pd	0.03	0.056	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	6609.24
La <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	0.25	0.027	La <sub>2</sub> CO <sub>5</sub>	25694.06
La <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	FeO, La <sub>2</sub> O <sub>3</sub>	0.03	0.045	LaH <sub>3</sub> O <sub>3</sub> , Fe <sub>3</sub> O <sub>4</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	28.20
La <sub>3</sub> Ir <sub>3</sub> O <sub>11</sub>	La <sub>2</sub> O <sub>3</sub> , Ir	0.11	0.089	La <sub>2</sub> CO <sub>5</sub>	10302.92
La <sub>3</sub> IrO <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Ir	0.03	0.055	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	5593.63
La <sub>3</sub> Os <sub>2</sub> O <sub>10</sub>	La <sub>2</sub> O <sub>3</sub> , Os	0.06	0.092	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> CO <sub>5</sub>	5763.49
La <sub>3</sub> OsO <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Os	0.03	0.056	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	3854.02
La <sub>3</sub> Pt <sub>3</sub> O <sub>11</sub>	La <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	0.25	0.034	La <sub>2</sub> CO <sub>5</sub> , La <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	25519.56
La <sub>3</sub> ReO <sub>8</sub>	ReO <sub>3</sub> , La <sub>2</sub> O <sub>3</sub>	0.03	0.011	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	1306.47
La <sub>3</sub> RuO <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Ru	0.03	0.064	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	1069.24
La <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	La <sub>2</sub> AuO <sub>4</sub>	0.85	0.015	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub> , LaAuO <sub>3</sub>	13896.30

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
La <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	La <sub>2</sub> O <sub>3</sub> , Au	0.03	0.044	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	13896.30
La <sub>4</sub> Bi <sub>2</sub> O <sub>9</sub>	La <sub>2</sub> O <sub>3</sub> , Bi	0.03	0.043	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	36.41
La <sub>4</sub> Mo <sub>7</sub> O <sub>27</sub>	MoO <sub>2</sub> , La <sub>2</sub> O <sub>3</sub>	0.87	0.068	LaH <sub>3</sub> O <sub>3</sub> , La <sub>3</sub> MoO <sub>7</sub> , La <sub>2</sub> CO <sub>5</sub>	34.26
La <sub>4</sub> Os <sub>6</sub> O <sub>19</sub>	La <sub>2</sub> O <sub>3</sub> , Os	0.42	0.104	La <sub>2</sub> CO <sub>5</sub>	8250.04
La <sub>4</sub> PdO <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Pd	0.03	0.021	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	2468.58
La <sub>4</sub> PtO <sub>7</sub>	La <sub>2</sub> O <sub>3</sub> , Pt	0.03	0.019	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	11644.07
La <sub>4</sub> Ru <sub>6</sub> O <sub>19</sub>	La <sub>2</sub> O <sub>3</sub> , Ru	0.39	0.142	La <sub>2</sub> CO <sub>5</sub>	2676.37
La <sub>7</sub> Ru <sub>3</sub> O <sub>18</sub>	La <sub>2</sub> O <sub>3</sub> , Ru	0.03	0.077	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	1281.38
La <sub>8</sub> Cu <sub>3</sub> O <sub>16</sub>	CuO, La <sub>2</sub> O <sub>3</sub>	0.03	0.010	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CuO <sub>4</sub> , La <sub>2</sub> CO <sub>5</sub>	43.74
La <sub>8</sub> Ni <sub>4</sub> O <sub>17</sub>	La <sub>2</sub> O <sub>3</sub> , Ni	0.03	0.049	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	44.40
La <sub>8</sub> Ni <sub>4</sub> O <sub>17</sub>	La <sub>2</sub> O <sub>3</sub> , NiO	0.99	0.010	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> NiO <sub>4</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	44.40
LaAgO <sub>2</sub>	La <sub>2</sub> O <sub>3</sub> , Ag	0.03	0.029	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	278.13
LaAuO <sub>2</sub>	La <sub>2</sub> O <sub>3</sub> , Au	0.03	0.022	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	20631.74
LaAuO <sub>3</sub>	La <sub>2</sub> O <sub>3</sub> , Au	0.03	0.063	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> CO <sub>5</sub>	19771.82
LaCoO <sub>3</sub>	La <sub>2</sub> O <sub>3</sub> , Co	0.22	0.098	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> CoO <sub>4</sub> , La <sub>2</sub> CO <sub>5</sub>	44.98
LaCu <sub>2</sub> O <sub>4</sub>	CuO, La <sub>2</sub> O <sub>3</sub>	1.00	0.024	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub> , La <sub>2</sub> CO <sub>5</sub>	28.22
LaCuO <sub>2</sub>	La <sub>2</sub> O <sub>3</sub> , Cu	0.03	0.034	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	37.64
LaFeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , La <sub>2</sub> O <sub>3</sub>	0.03	0.011	LaH <sub>3</sub> O <sub>3</sub> , LaHO <sub>2</sub> , La <sub>3</sub> FeO <sub>6</sub> , La <sub>2</sub> CO <sub>5</sub>	34.36
LaFeO <sub>3</sub>	FeO, La <sub>2</sub> O <sub>3</sub>	0.03	0.033	LaH <sub>3</sub> O <sub>3</sub> , Fe <sub>3</sub> O <sub>4</sub> , LaHO <sub>2</sub> , La <sub>2</sub> CO <sub>5</sub>	34.36
LaPd <sub>2</sub> O <sub>4</sub>	La <sub>2</sub> O <sub>3</sub> , Pd	0.20	0.096	La <sub>2</sub> CO <sub>5</sub>	9051.78
LaRhO <sub>3</sub>	La <sub>2</sub> O <sub>3</sub> , Rh	0.03	0.083	LaH <sub>3</sub> O <sub>3</sub> , La <sub>2</sub> CO <sub>5</sub>	28502.64
LaSO <sub>5</sub>	LaS	0.79	0.319	None	33.21
LaSb <sub>3</sub> O <sub>9</sub>	La <sub>2</sub> O <sub>3</sub> , Sb	0.46	0.185	Sb <sub>2</sub> O <sub>3</sub>	17.82
LaSb <sub>5</sub> O <sub>12</sub>	La <sub>2</sub> O <sub>3</sub> , Sb	0.39	0.179	Sb <sub>2</sub> O <sub>3</sub>	14.57
Li <sub>2</sub> CrO <sub>4</sub>	Li <sub>2</sub> O, Cr <sub>2</sub> O <sub>3</sub>	0.00	0.185	LiHO, LiCr <sub>2</sub> O <sub>4</sub> , Li <sub>2</sub> CO <sub>3</sub>	11.96

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Li <sub>2</sub> CrO <sub>4</sub>	Li <sub>2</sub> O, CrO <sub>2</sub>	0.00	0.123	LiHO, Li <sub>2</sub> O <sub>2</sub> , LiCr <sub>2</sub> O <sub>4</sub> , Li <sub>2</sub> CO <sub>3</sub>	11.96
Li <sub>2</sub> FeO <sub>3</sub>	Li <sub>2</sub> O, FeO	0.00	0.136	Fe <sub>3</sub> O <sub>4</sub> , Li <sub>2</sub> CO <sub>3</sub> , LiHO, Li <sub>2</sub> FeO <sub>2</sub>	8.88
Li <sub>2</sub> IrO <sub>3</sub>	Li <sub>2</sub> O <sub>2</sub> , Ir	0.00	0.063	LiHO, Li <sub>2</sub> CO <sub>3</sub> , LiIrO <sub>2</sub> , IrO <sub>2</sub>	15776.04
Li <sub>2</sub> O <sub>2</sub>	Li <sub>2</sub> O	0.00	0.349	LiHO, Li <sub>2</sub> CO <sub>3</sub>	22.63
Li <sub>2</sub> PdO <sub>2</sub>	Li <sub>2</sub> O, Pd	0.00	0.105	LiHO, Li <sub>2</sub> CO <sub>3</sub>	12334.00
Li <sub>2</sub> PdO <sub>3</sub>	Pd, Li	0.00	0.285	LiHO, Li <sub>2</sub> CO <sub>3</sub>	11161.48
Li <sub>2</sub> PtO <sub>3</sub>	Pt, Li	0.00	0.187	LiHO, Li <sub>2</sub> CO <sub>3</sub>	38966.76
Li <sub>2</sub> RhO <sub>3</sub>	Li <sub>2</sub> O <sub>2</sub> , Rh	0.00	0.097	LiHO, Li <sub>2</sub> CO <sub>3</sub> , RhO <sub>2</sub>	50083.41
Li <sub>2</sub> RuO <sub>3</sub>	Li <sub>2</sub> O, Ru	0.00	0.196	LiH <sub>3</sub> O <sub>2</sub> , LiHO, Li <sub>2</sub> CO <sub>3</sub>	3985.41
Li <sub>2</sub> SO <sub>4</sub>	Li <sub>2</sub> S	0.09	0.582	Li <sub>4</sub> S, Li <sub>2</sub> CO <sub>3</sub>	9.44
Li <sub>3</sub> AuO <sub>3</sub>	Li <sub>2</sub> O, Au	0.00	0.090	LiHO, Li <sub>2</sub> CO <sub>3</sub>	28530.42
Li <sub>3</sub> BiO <sub>3</sub>	Li <sub>2</sub> O, Bi	0.00	0.086	LiHO, Li <sub>2</sub> CO <sub>3</sub>	18.85
Li <sub>3</sub> BiO <sub>4</sub>	Li <sub>2</sub> O, Bi	0.00	0.136	LiH <sub>3</sub> O <sub>2</sub> , LiHO, Li <sub>3</sub> BiO <sub>3</sub> , Li <sub>2</sub> CO <sub>3</sub>	17.82
Li <sub>3</sub> BiO <sub>4</sub>	Li <sub>2</sub> O, BiO <sub>2</sub>	0.00	0.027	LiHO, LiBiO <sub>2</sub> , Li <sub>2</sub> O <sub>2</sub> , Li <sub>3</sub> BiO <sub>3</sub> , Li <sub>2</sub> CO <sub>3</sub> , Li <sub>5</sub> BiO <sub>5</sub>	17.82
Li <sub>3</sub> CrO <sub>4</sub>	Li <sub>2</sub> O, Cr <sub>2</sub> O <sub>3</sub>	0.00	0.117	LiHO, LiCrO <sub>2</sub> , LiCr <sub>2</sub> O <sub>4</sub> , Li <sub>2</sub> CO <sub>3</sub>	15.15
Li <sub>3</sub> CuO <sub>3</sub>	Li <sub>2</sub> O, CuO	0.00	0.060	Li <sub>2</sub> CO <sub>3</sub> , LiHO, LiCuO	15.46
Li <sub>3</sub> RuO <sub>4</sub>	Li <sub>2</sub> O, Ru	0.00	0.215	LiH <sub>3</sub> O <sub>2</sub> , LiHO, Li <sub>2</sub> CO <sub>3</sub> , Li <sub>2</sub> RuO <sub>3</sub>	3496.37
Li <sub>4</sub> PbO <sub>4</sub>	Li <sub>2</sub> O, Pb <sub>2</sub> O <sub>3</sub>	0.00	0.027	LiHO, Li <sub>2</sub> CO <sub>3</sub>	8.62
Li <sub>5</sub> AuO <sub>4</sub>	Li <sub>2</sub> O, Au	0.00	0.081	LiHO, Li <sub>2</sub> CO <sub>3</sub>	25650.55
Li <sub>5</sub> BiO <sub>5</sub>	Li <sub>2</sub> O, Bi	0.00	0.124	LiHO, Li <sub>3</sub> BiO <sub>3</sub> , Li <sub>2</sub> CO <sub>3</sub>	19.38
Li <sub>5</sub> OsO <sub>6</sub>	Li <sub>2</sub> O, Os	0.00	0.174	LiHO, Li <sub>2</sub> CO <sub>3</sub>	8563.87
Li <sub>5</sub> ReO <sub>6</sub>	Li <sub>2</sub> O, ReO <sub>3</sub>	0.00	0.025	LiHO, Li <sub>2</sub> CO <sub>3</sub>	2942.53
Li <sub>5</sub> TiO <sub>4</sub>	Li <sub>2</sub> O, Ti <sub>4</sub> O <sub>3</sub>	0.00	0.040	LiHO, Ti <sub>2</sub> O, Li <sub>2</sub> CO <sub>3</sub>	4014.15
LiAgO	Li <sub>2</sub> O, Ag	0.00	0.061	LiHO, Li <sub>2</sub> CO <sub>3</sub>	532.98
LiAuO <sub>2</sub>	Au, Li	0.00	0.136	Li <sub>2</sub> CO <sub>3</sub>	32139.86
LiBiO <sub>2</sub>	Li <sub>2</sub> O, Bi	0.00	0.097	LiH <sub>3</sub> O <sub>2</sub> , LiHO, Li <sub>3</sub> BiO <sub>3</sub> , Li <sub>2</sub> CO <sub>3</sub>	16.93
LiCo <sub>2</sub> O <sub>4</sub>	Li <sub>2</sub> O, Co	0.26	0.297	Li <sub>2</sub> CO <sub>3</sub> , CoO	31.59
LiCuO	Li <sub>2</sub> O, Cu	0.00	0.092	Li <sub>2</sub> CO <sub>3</sub> , LiHO	11.66
LiCuO <sub>2</sub>	Cu, Li	0.00	0.312	Li <sub>2</sub> CO <sub>3</sub>	9.84
LiIrO <sub>2</sub>	Ir, Li	0.00	0.138	Li <sub>2</sub> CO <sub>3</sub>	17339.43

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
LiMn <sub>4</sub> O <sub>8</sub>	Li <sub>2</sub> O, Mn <sub>2</sub> O <sub>3</sub>	1.00	0.068	MnHO <sub>2</sub> , LiMnO <sub>2</sub> , MnO, MnCO <sub>3</sub> , MnO <sub>2</sub>	1.47
LiMn <sub>4</sub> O <sub>8</sub>	Li <sub>2</sub> O <sub>2</sub> , MnO	0.00	0.135	MnHO <sub>2</sub> , LiMnO <sub>2</sub>	1.47
LiOsO <sub>3</sub>	Os, Li	0.28	0.196	Li <sub>2</sub> CO <sub>3</sub>	11201.80
LiReO <sub>4</sub>	Li <sub>2</sub> O, ReO <sub>3</sub>	0.00	0.031	LiHO, Li <sub>5</sub> ReO <sub>6</sub> , Li <sub>2</sub> CO <sub>3</sub>	3618.33
LiSb <sub>3</sub> O <sub>8</sub>	Li <sub>2</sub> O, Sb	0.32	0.240	Sb <sub>2</sub> O <sub>3</sub> , Li <sub>2</sub> CO <sub>3</sub>	7.46
LiSbO <sub>3</sub>	Li <sub>2</sub> O, Sb <sub>2</sub> O <sub>3</sub>	0.20	0.091	LiH <sub>3</sub> O <sub>2</sub> , Li <sub>2</sub> CO <sub>3</sub> , LiSbO <sub>2</sub>	9.00
LiVO <sub>3</sub>	Li <sub>2</sub> O, VO <sub>2</sub>	0.23	0.076	LiVO <sub>2</sub> , LiVC <sub>2</sub> O <sub>6</sub> , LiH <sub>3</sub> O <sub>2</sub> , Li <sub>2</sub> CO <sub>3</sub> , Li <sub>3</sub> VO <sub>4</sub>	12.31
Lu <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub>	Lu <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.057	LuH <sub>3</sub> O <sub>3</sub>	
Lu <sub>2</sub> Mn <sub>2</sub> O <sub>7</sub>	MnO, Lu <sub>2</sub> O <sub>3</sub>	0.00	0.056	MnHO <sub>2</sub>	
Lu <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Lu <sub>2</sub> O <sub>3</sub>	0.94	0.058	LuH <sub>3</sub> O <sub>3</sub>	
Lu <sub>2</sub> PdO <sub>4</sub>	Lu <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.031	LuH <sub>3</sub> O <sub>3</sub>	
Lu <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Lu <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.075	LuH <sub>3</sub> O <sub>3</sub>	
Lu <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Lu <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.096	LuH <sub>3</sub> O <sub>3</sub>	
LuAgO <sub>2</sub>	Lu <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.025	LuH <sub>3</sub> O <sub>3</sub>	
LuBi <sub>3</sub> O <sub>6</sub>	Lu <sub>2</sub> O <sub>3</sub> , Bi	0.75	0.080	LuH <sub>3</sub> O <sub>3</sub> , Bi <sub>2</sub> CO <sub>5</sub> , LuBiO <sub>3</sub>	
LuBiO <sub>3</sub>	Lu <sub>2</sub> O <sub>3</sub> , Bi	0.52	0.056	LuH <sub>3</sub> O <sub>3</sub>	
LuCu <sub>2</sub> O <sub>4</sub>	CuO, Lu <sub>2</sub> O <sub>3</sub>	1.00	0.022	LuH <sub>3</sub> O <sub>3</sub> , Lu <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub>	
LuCu <sub>2</sub> O <sub>4</sub>	Lu <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.109	LuH <sub>3</sub> O <sub>3</sub>	
LuFeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , Lu <sub>2</sub> O <sub>3</sub>	1.00	0.010	LuH <sub>3</sub> O <sub>3</sub> , LuFe <sub>2</sub> O <sub>4</sub>	
LuMnO <sub>3</sub>	MnO, Lu <sub>2</sub> O <sub>3</sub>	0.00	0.029	MnHO <sub>2</sub>	
LuRhO <sub>3</sub>	Lu <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.074	LuH <sub>3</sub> O <sub>3</sub>	
LuSbO <sub>4</sub>	Lu <sub>2</sub> O <sub>3</sub> , Sb	0.21	0.111	LuH <sub>3</sub> O <sub>3</sub> , Lu <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	
LuTiO <sub>2</sub>	Lu <sub>2</sub> O <sub>3</sub> , Ti	0.57	0.019	LuH <sub>3</sub> O <sub>3</sub> , Ti <sub>2</sub> CO <sub>3</sub>	
LuTiO <sub>3</sub>	Lu <sub>2</sub> O <sub>3</sub> , Ti	0.89	0.056	LuH <sub>3</sub> O <sub>3</sub> , Ti <sub>2</sub> CO <sub>3</sub>	
LuTiO <sub>3</sub>	Ti <sub>4</sub> O <sub>3</sub> , Lu <sub>2</sub> O <sub>3</sub>	0.17	0.028	LuH <sub>3</sub> O <sub>3</sub> , TiHO, Ti <sub>2</sub> CO <sub>3</sub> , Ti <sub>2</sub> O <sub>3</sub> , LuTiO <sub>2</sub>	
LuVO <sub>4</sub>	LuVO <sub>3</sub>	0.33	0.055	LuH <sub>3</sub> O <sub>3</sub> , VO <sub>2</sub> , Lu <sub>2</sub> O <sub>3</sub>	
Mg <sub>2</sub> PtO <sub>4</sub>	MgO, Pt <sub>3</sub> O <sub>4</sub>	1.00	0.035	MgCH <sub>10</sub> O <sub>8</sub> , MgCO <sub>3</sub> , Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub>	32539.98
Mg <sub>2</sub> V <sub>2</sub> O <sub>7</sub>	MgO, V <sub>2</sub> O <sub>3</sub>	0.25	0.122	MgCO <sub>3</sub> , VO <sub>2</sub>	6.96
Mg <sub>3</sub> V <sub>2</sub> O <sub>8</sub>	MgO, V <sub>2</sub> O <sub>3</sub>	0.25	0.106	MgCO <sub>3</sub> , VO <sub>2</sub>	6.45
Mg <sub>4</sub> Sb <sub>2</sub> O <sub>9</sub>	MgO, Sb	0.18	0.165	MgSb <sub>2</sub> O <sub>4</sub> , MgCO <sub>3</sub>	5.48

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Mg <sub>6</sub> MnO <sub>8</sub>	MnO, MgO	0.00	0.049	MnHO <sub>2</sub>	2.34
MgCrO <sub>4</sub>	MgO, Cr	0.26	0.342	MgCr <sub>2</sub> O <sub>4</sub> , MgCO <sub>3</sub>	4.58
MgFe <sub>2</sub> O <sub>4</sub>	FeO, MgO	0.55	0.080	Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub> , MgCH <sub>10</sub> O <sub>8</sub> , Fe <sub>3</sub> O <sub>4</sub> , MgCO <sub>3</sub>	0.71
MgMo <sub>2</sub> O <sub>7</sub>	MgO, Mo	0.10	0.293	MoO <sub>2</sub> , MgCO <sub>3</sub>	20.85
MgPt <sub>3</sub> O <sub>6</sub>	Pt, Mg	0.68	0.136	MgCH <sub>10</sub> O <sub>8</sub> , MgCO <sub>3</sub> , Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub>	42571.12
MgRe <sub>2</sub> O <sub>8</sub>	MgO, ReO <sub>3</sub>	1.00	0.030	MgCH <sub>10</sub> O <sub>8</sub> , MgCO <sub>3</sub> , Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub>	3544.72
MgRh <sub>2</sub> O <sub>4</sub>	Rh, Mg	0.55	0.218	MgCO <sub>3</sub> , Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub>	56114.75
MgS <sub>2</sub> O <sub>7</sub>	MgS <sub>2</sub>	0.60	0.559	MgSH <sub>2</sub> O <sub>5</sub> , MgCO <sub>3</sub> , MgSO <sub>4</sub>	0.64
MgSO <sub>4</sub>	MgS	0.51	0.532	MgCO <sub>3</sub> , Mg <sub>3</sub> C <sub>2</sub> O <sub>7</sub>	1.07
MgSb <sub>2</sub> O <sub>6</sub>	SbO <sub>2</sub> , MgO	1.00	0.044	MgSb <sub>2</sub> O <sub>4</sub> , MgCH <sub>10</sub> O <sub>8</sub> , MgCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	6.24
Mn <sub>2</sub> BiO <sub>5</sub>	MnO, Bi	0.31	0.120	MnHO <sub>2</sub>	9.22
Mn <sub>2</sub> BiO <sub>5</sub>	MnO, BiO <sub>2</sub>	0.99	0.040	MnHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub> , Bi <sub>2</sub> O <sub>3</sub> , MnO <sub>2</sub>	9.22
Mn <sub>2</sub> O <sub>3</sub>	Mn <sub>3</sub> O <sub>4</sub>	1.00	0.034	MnHO <sub>2</sub>	0.01
Mn <sub>3</sub> O <sub>4</sub>	MnO	1.00	0.070	MnHO <sub>2</sub>	0.01
MnCd <sub>6</sub> O <sub>8</sub>	Cd, Mn	0.69	0.149	MnHO <sub>2</sub> , CdCO <sub>3</sub>	3.46
MnCu <sub>6</sub> O <sub>8</sub>	Cu, Mn	0.77	0.227	MnHO <sub>2</sub>	5.20
MnCu <sub>6</sub> O <sub>8</sub>	MnO, CuO	1.00	0.028	MnHO <sub>2</sub>	5.20
MnHgO <sub>3</sub>	MnO, HgO	1.00	0.053	MnHO <sub>2</sub>	17.22
MnMoO <sub>4</sub>	MnO, MoO <sub>2</sub>	0.00	0.074	MnHO <sub>2</sub>	15.63
MnS <sub>2</sub> O <sub>8</sub>	MnS <sub>2</sub>	0.93	0.518	MnHO <sub>2</sub>	0.00
MnSO <sub>4</sub>	MnS	0.76	0.424	MnHO <sub>2</sub> , MnS <sub>2</sub>	0.00
MnSb <sub>2</sub> O <sub>4</sub>	MnO, Sb	0.26	0.132	Sb <sub>2</sub> O <sub>3</sub> , MnHO <sub>2</sub>	5.91
MnSb <sub>2</sub> O <sub>6</sub>	MnO <sub>2</sub> , Sb <sub>2</sub> O <sub>3</sub>	1.00	0.041	MnHO <sub>2</sub> , Sb <sub>3</sub> O <sub>7</sub> , SbO <sub>2</sub>	5.43
MnSb <sub>2</sub> O <sub>6</sub>	Sb <sub>2</sub> O <sub>3</sub> , Mn	0.46	0.122	MnHO <sub>2</sub>	5.43
MoO <sub>3</sub>	Mo	0.22	0.333	MoO <sub>2</sub>	23.33
MoPb <sub>2</sub> O <sub>5</sub>	MoO <sub>2</sub> , PbO	0.74	0.027	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , MoPb <sub>5</sub> O <sub>8</sub> , Pb <sub>2</sub> CO <sub>4</sub>	7.39
MoPb <sub>5</sub> O <sub>8</sub>	Pb, Mo	0.54	0.102	PbCO <sub>3</sub> , MoO <sub>2</sub>	4.66
MoPbO <sub>4</sub>	MoO <sub>2</sub> , Pb	0.66	0.087	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	10.51
MoRh <sub>2</sub> O <sub>6</sub>	Rh, Mo	0.91	0.241	MoRh <sub>3</sub> , MoO <sub>2</sub>	41502.07
Na <sub>2</sub> Bi <sub>4</sub> O <sub>7</sub>	Bi, Na	0.31	0.113	NaCHO <sub>3</sub> , Na <sub>2</sub> CO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Na <sub>2</sub> BiO <sub>3</sub>	Bi, Na	0.00	0.158	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> CdO <sub>2</sub>	Cd, Na	0.00	0.168	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> CoO <sub>3</sub>	Na <sub>2</sub> O, Co	0.00	0.209	Na <sub>2</sub> CO <sub>3</sub> , NaHO, NaH <sub>3</sub> O <sub>2</sub>	
Na <sub>2</sub> CrO <sub>4</sub>	Cr <sub>2</sub> O <sub>3</sub> , Na	0.04	0.247	NaCrO <sub>2</sub> , CrHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> CrO <sub>4</sub>	Na <sub>2</sub> O, Cr <sub>2</sub> O <sub>3</sub>	0.00	0.148	NaCrO <sub>2</sub> , NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaH <sub>3</sub> O <sub>2</sub>	
Na <sub>2</sub> HgO <sub>2</sub>	Na, Hg	0.00	0.115	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> IrO <sub>3</sub>	Ir, Na	0.00	0.168	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> Mn <sub>3</sub> O <sub>7</sub>	MnO, Na <sub>2</sub> O <sub>2</sub>	0.00	0.099	Na <sub>3</sub> MnO <sub>3</sub> , MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO, Na <sub>4</sub> Mn <sub>2</sub> O <sub>5</sub> , NaMnO <sub>2</sub>	
Na <sub>2</sub> MnO <sub>3</sub>	Mn <sub>2</sub> O <sub>3</sub> , Na	0.00	0.161	MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub>	MoO <sub>2</sub> , Na	0.00	0.137	Na <sub>2</sub> CO <sub>3</sub> , Na <sub>2</sub> MoO <sub>4</sub>	
Na <sub>2</sub> O	Na	0.00	0.258	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> O <sub>2</sub>	Na	0.00	0.410	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> OsO <sub>4</sub>	Os, Na	0.00	0.213	Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> PbO <sub>3</sub>	PbO, Na	0.00	0.106	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> PdO <sub>3</sub>	PdO, Na	0.00	0.160	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> PtO <sub>2</sub>	Pt, Na	0.00	0.117	NaHO, NaPt <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> PtO <sub>3</sub>	Pt, Na	0.00	0.166	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> RuO <sub>4</sub>	Na, Ru	0.00	0.303	Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>2</sub> SO <sub>4</sub>	Na <sub>2</sub> S	0.16	0.451	Na <sub>2</sub> CO <sub>3</sub> , NaCHO <sub>3</sub> , Na <sub>2</sub> S	
Na <sub>2</sub> TbO <sub>3</sub>	Na <sub>2</sub> O, Tb <sub>2</sub> O <sub>3</sub>	0.00	0.032	Na <sub>2</sub> CO <sub>3</sub> , NaHO, NaTbO <sub>2</sub>	
Na <sub>2</sub> TbO <sub>3</sub>	Tb <sub>2</sub> O <sub>3</sub> , Na	0.00	0.095	Na <sub>2</sub> CO <sub>3</sub> , NaTbO <sub>2</sub>	
Na <sub>3</sub> AgO <sub>2</sub>	Na <sub>2</sub> O, Ag	0.00	0.038	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> AuO <sub>3</sub>	Au, Na	0.00	0.153	NaHO, NaAu <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> BiO <sub>4</sub>	Bi, Na	0.00	0.187	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> Co <sub>4</sub> O <sub>8</sub>	CoO, Na	0.00	0.148	Na <sub>2</sub> CO <sub>3</sub> , NaHO, NaH <sub>3</sub> O <sub>2</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Na <sub>3</sub> Co <sub>4</sub> O <sub>8</sub>	Na <sub>2</sub> O, Co	0.04	0.240	Na <sub>2</sub> CO <sub>3</sub> , Na <sub>3</sub> C <sub>2</sub> H <sub>5</sub> O <sub>8</sub> , CoO	
Na <sub>3</sub> Cu <sub>2</sub> O <sub>4</sub>	Na, Cu	0.00	0.246	Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>3</sub> CuO <sub>3</sub>	Na, Cu	0.00	0.266	Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>3</sub> MnO <sub>4</sub>	Mn <sub>2</sub> O <sub>3</sub> , Na <sub>2</sub> O	0.00	0.085	Na <sub>3</sub> MnO <sub>3</sub> , MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO, Na <sub>4</sub> Mn <sub>2</sub> O <sub>5</sub> , NaMnO <sub>2</sub>	
Na <sub>3</sub> MnO <sub>4</sub>	MnO, Na <sub>2</sub> O	0.00	0.128	MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>3</sub> NiO <sub>3</sub>	NiO, Na	0.00	0.182	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> OsO <sub>5</sub>	Os, Na	0.00	0.236	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> Pt <sub>12</sub> O <sub>16</sub>	Pt, Na	0.52	0.096	NaH <sub>9</sub> O <sub>5</sub> , NaCHO <sub>3</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> RuO <sub>4</sub>	Na, Ru	0.00	0.273	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>3</sub> SbO <sub>4</sub>	Na <sub>3</sub> SbO <sub>3</sub>	0.00	0.063	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaSbO <sub>2</sub>	
Na <sub>4</sub> CoO <sub>4</sub>	CoO, Na	0.00	0.223	Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>4</sub> CoO <sub>4</sub>	Na, Co	0.00	0.298	Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>4</sub> IrO <sub>4</sub>	Ir, Na	0.00	0.184	NaHO, Na <sub>3</sub> IrH <sub>6</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>4</sub> MnO <sub>4</sub>	MnO, Na	0.00	0.228	MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO	
Na <sub>4</sub> PbO <sub>4</sub>	Na <sub>2</sub> O, Pb	0.00	0.088	NaHO, Na <sub>2</sub> PbO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>4</sub> PbO <sub>4</sub>	Pb, Na	0.00	0.176	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
Na <sub>5</sub> BiO <sub>5</sub>	Bi, Na	0.00	0.198	NaHO, Na <sub>2</sub> CO <sub>3</sub> , Na <sub>3</sub> Bi	
Na <sub>5</sub> BiO <sub>5</sub>	Na <sub>2</sub> O, Bi	0.00	0.099	NaHO, Na <sub>2</sub> CO <sub>3</sub> , Na <sub>3</sub> BiO <sub>3</sub> , Na <sub>3</sub> Bi	
Na <sub>5</sub> TlO <sub>4</sub>	Tl, Na	0.00	0.167	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
NaAg <sub>3</sub> O <sub>2</sub>	Ag, Na	0.00	0.085	Na <sub>2</sub> CO <sub>3</sub>	
NaAgO	Ag, Na	0.00	0.109	NaHO, Na <sub>2</sub> CO <sub>3</sub>	
NaAgO <sub>2</sub>	AgO, Na <sub>2</sub> O	0.00	0.049	NaH <sub>3</sub> O <sub>2</sub> , NaAg <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaAuO <sub>2</sub>	Au, Na	0.00	0.127	Na <sub>2</sub> CO <sub>3</sub>	
NaBiO <sub>3</sub>	Bi <sub>2</sub> O <sub>3</sub> , Na <sub>2</sub> O <sub>2</sub>	0.00	0.029	NaH <sub>9</sub> O <sub>5</sub> , BiO <sub>2</sub> , Na <sub>2</sub> Bi <sub>4</sub> O <sub>7</sub> , Na <sub>2</sub> CO <sub>3</sub> , Na <sub>3</sub> BiO <sub>4</sub>	
NaCoO <sub>2</sub>	Na <sub>2</sub> O, Co	0.00	0.211	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaH <sub>3</sub> O <sub>2</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
NaCuO	Na, Cu	0.00	0.156	Na <sub>2</sub> CO <sub>3</sub> , NaHO	
NaCuO <sub>2</sub>	CuO, Na	0.00	0.135	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaCuO <sub>2</sub>	CuO, Na <sub>2</sub> O	0.00	0.067	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaIrO <sub>3</sub>	IrO <sub>2</sub> , Na	0.00	0.061	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> IrO <sub>3</sub> , NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaIrO <sub>3</sub>	IrO <sub>2</sub> , Na <sub>2</sub> O	0.00	0.030	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>2</sub> IrO <sub>3</sub> , NaH <sub>3</sub> O <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaMn <sub>2</sub> O <sub>4</sub>	Mn <sub>2</sub> O <sub>3</sub> , Na	0.00	0.081	Na <sub>3</sub> MnO <sub>3</sub> , MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO, Na <sub>4</sub> Mn <sub>2</sub> O <sub>5</sub> , MnO, NaMnO <sub>2</sub>	
NaMnO <sub>2</sub>	MnO, Na	0.00	0.146	MnHO <sub>2</sub> , Na <sub>2</sub> CO <sub>3</sub> , NaHO	
NaPd <sub>3</sub> O <sub>4</sub>	Na, Pd	0.38	0.158	NaCHO <sub>3</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaPt <sub>3</sub> O <sub>4</sub>	Pt, Na	0.38	0.095	NaCHO <sub>3</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaReO <sub>4</sub>	ReO <sub>3</sub> , Na <sub>2</sub> O	0.00	0.029	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Na <sub>5</sub> ReO <sub>6</sub> , Na <sub>3</sub> ReO <sub>5</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaRh <sub>2</sub> O <sub>4</sub>	Na <sub>2</sub> O <sub>2</sub> , Rh	0.43	0.164	NaH <sub>9</sub> O <sub>5</sub> , RhO <sub>2</sub> , NaCHO <sub>3</sub> , Na <sub>2</sub> CO <sub>3</sub>	
NaRhO <sub>2</sub>	Rh, Na	0.00	0.203	Na <sub>2</sub> CO <sub>3</sub>	
NaSb <sub>5</sub> O <sub>13</sub>	Na <sub>2</sub> O <sub>2</sub> , Sb	0.45	0.229	Sb <sub>2</sub> O <sub>3</sub> , NaCHO <sub>3</sub>	
NaSbO <sub>3</sub>	NaSbO <sub>2</sub>	0.24	0.083	NaH <sub>9</sub> O <sub>5</sub> , Na <sub>3</sub> C <sub>2</sub> H <sub>5</sub> O <sub>8</sub> , Na <sub>2</sub> CO <sub>3</sub> , Na <sub>2</sub> Sb <sub>4</sub> O <sub>7</sub>	
NaTiO <sub>2</sub>	Na <sub>2</sub> O <sub>2</sub> , Ti	0.00	0.062	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Ti <sub>2</sub> O, Na <sub>2</sub> CO <sub>3</sub>	
NaTiO <sub>2</sub>	Ti <sub>4</sub> O <sub>3</sub> , Na	0.00	0.077	NaHO, NaH <sub>3</sub> O <sub>2</sub> , Ti <sub>2</sub> O, Na <sub>2</sub> CO <sub>3</sub>	
Nb <sub>2</sub> Cd <sub>2</sub> O <sub>7</sub>	Nb <sub>2</sub> O <sub>5</sub> , Cd	0.83	0.061	CdCO <sub>3</sub> , Nb <sub>2</sub> CdO <sub>6</sub>	7.37
Nb <sub>2</sub> CdO <sub>6</sub>	Nb <sub>2</sub> O <sub>5</sub> , Cd	0.83	0.041	None	8.51
Nb <sub>3</sub> Sb <sub>3</sub> O <sub>13</sub>	Nb <sub>2</sub> O <sub>5</sub> , Sb	0.22	0.103	NbSbO <sub>4</sub>	8.81
Nb <sub>3</sub> Ti <sub>3</sub> O <sub>10</sub>	Nb <sub>2</sub> O <sub>5</sub> , Ti <sub>2</sub> O	1.00	0.015	Ti <sub>2</sub> CO <sub>3</sub> , NbTiO <sub>3</sub>	3466.61
NbAgO <sub>3</sub>	Nb <sub>2</sub> O <sub>5</sub> , Ag	1.00	0.032	None	283.92
NbBiO <sub>4</sub>	Nb <sub>2</sub> O <sub>5</sub> , Bi	0.31	0.066		13.96
NbS <sub>2</sub> O <sub>8</sub>	NbS <sub>2</sub>	0.92	0.449	Nb <sub>2</sub> O <sub>5</sub>	5.02
NbSb <sub>3</sub> O <sub>8</sub>	Nb <sub>2</sub> O <sub>5</sub> , Sb	0.35	0.150	Sb <sub>2</sub> O <sub>3</sub> , NbSbO <sub>4</sub>	7.92
NbSbO <sub>4</sub>	Nb <sub>2</sub> O <sub>5</sub> , Sb	0.18	0.086		8.98
NbTiO <sub>3</sub>	Nb <sub>2</sub> O <sub>5</sub> , Ti	0.09	0.023		3520.16
NbVO <sub>5</sub>	Nb <sub>2</sub> O <sub>5</sub> , V <sub>2</sub> O <sub>3</sub>	0.87	0.071	VO <sub>2</sub> , NbVO <sub>4</sub>	9.90
Nd <sub>2</sub> Bi <sub>7</sub> O <sub>14</sub>	Bi <sub>2</sub> O <sub>3</sub> , Nd <sub>2</sub> O <sub>3</sub>	1.00	0.004	NdHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	29.83

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Nd <sub>2</sub> Bi <sub>7</sub> O <sub>14</sub>	Nd <sub>2</sub> O <sub>3</sub> , Bi	0.88	0.089	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	29.83
Nd <sub>2</sub> CuO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.038	NdHO <sub>2</sub> , NdCuO <sub>2</sub>	80.92
Nd <sub>2</sub> HgO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Hg	1.00	0.029	NdHO <sub>2</sub>	69.43
Nd <sub>2</sub> Ir <sub>2</sub> O <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.082	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	10253.86
Nd <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	MoO <sub>2</sub> , Nd <sub>2</sub> O <sub>3</sub>	1.00	0.070	NdH <sub>3</sub> O <sub>3</sub> , Nd <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub> , Nd <sub>2</sub> MoO <sub>6</sub>	51.09
Nd <sub>2</sub> MoO <sub>6</sub>	MoO <sub>2</sub> , Nd <sub>2</sub> O <sub>3</sub>	0.95	0.033	NdHO <sub>2</sub> , Nd <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub> , Nd <sub>3</sub> MoO <sub>7</sub>	76.04
Nd <sub>2</sub> Pd <sub>2</sub> O <sub>5</sub>	Nd <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.055	NdHO <sub>2</sub>	6516.29
Nd <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.081	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	25368.09
Nd <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.106	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	2206.94
Nd <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Nd <sub>2</sub> S <sub>3</sub>	0.78	0.333	NdSO	57.53
Nd <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	FeO, Nd <sub>2</sub> O <sub>3</sub>	0.55	0.044	Fe <sub>3</sub> O <sub>4</sub> , NdHO <sub>2</sub>	55.09
Nd <sub>3</sub> IrO <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.054	NdHO <sub>2</sub>	5505.71
Nd <sub>3</sub> MoO <sub>7</sub>	MoO <sub>2</sub> , Nd <sub>2</sub> O <sub>3</sub>	0.89	0.012	NdHO <sub>2</sub> , Nd <sub>2</sub> Mo <sub>2</sub> O <sub>7</sub> , Nd <sub>2</sub> MoO <sub>6</sub>	82.92
Nd <sub>3</sub> OsO <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Os	0.99	0.054	NdHO <sub>2</sub>	3803.76
Nd <sub>3</sub> RuO <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.062	NdHO <sub>2</sub>	1081.07
Nd <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	Nd <sub>2</sub> O <sub>3</sub> , Au	1.00	0.043	NdHO <sub>2</sub>	13659.85
Nd <sub>4</sub> Os <sub>6</sub> O <sub>19</sub>	Nd <sub>2</sub> O <sub>3</sub> , Os	1.00	0.103	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub> , Nd <sub>3</sub> OsO <sub>7</sub>	8179.28
Nd <sub>4</sub> PdO <sub>7</sub>	Nd <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.020	NdHO <sub>2</sub>	2443.84
NdBiO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Bi	0.91	0.096	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	48.57
NdCoO <sub>3</sub>	Nd <sub>2</sub> O <sub>3</sub> , Co	0.63	0.096	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	76.88
NdCrO <sub>4</sub>	CrO <sub>2</sub> , Nd <sub>2</sub> O <sub>3</sub>	1.00	0.031	NdH <sub>3</sub> O <sub>3</sub> , NdCrO <sub>3</sub>	65.72
NdCrO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub>	1.00	0.061	CrHO <sub>2</sub> , NdH <sub>3</sub> O <sub>3</sub> , NdCrO <sub>3</sub>	65.72
NdCu <sub>2</sub> O <sub>4</sub>	CuO, Nd <sub>2</sub> O <sub>3</sub>	1.00	0.024	NdH <sub>3</sub> O <sub>3</sub> , NdCuO <sub>2</sub>	52.39
NdCuO <sub>2</sub>	Nd <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.033	NdHO <sub>2</sub>	71.22
NdFeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , Nd <sub>2</sub> O <sub>3</sub>	1.00	0.011	NdHO <sub>2</sub> , Nd <sub>3</sub> FeO <sub>6</sub>	66.89
NdFeO <sub>3</sub>	FeO, Nd <sub>2</sub> O <sub>3</sub>	0.55	0.032	Fe <sub>3</sub> O <sub>4</sub> , NdHO <sub>2</sub>	66.89
NdMn <sub>2</sub> O <sub>5</sub>	MnO, Nd <sub>2</sub> O <sub>3</sub>	0.00	0.072	MnHO <sub>2</sub>	49.65
NdMnO <sub>3</sub>	MnO, Nd <sub>2</sub> O <sub>3</sub>	0.00	0.032	MnHO <sub>2</sub>	67.11
NdOsO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Os	1.00	0.100	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub> , Nd <sub>3</sub> OsO <sub>7</sub>	6932.54
NdPd <sub>2</sub> O <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.095	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	8956.66
NdRhO <sub>3</sub>	Nd <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.081	NdH <sub>3</sub> O <sub>3</sub> , NdHO <sub>2</sub>	28015.25

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
NdSbO <sub>4</sub>	Nd <sub>2</sub> O <sub>3</sub> , Sb	0.20	0.121	Nd <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub> , Nd <sub>3</sub> SbO <sub>7</sub> , NdH <sub>3</sub> O <sub>3</sub>	53.51
Ni <sub>2</sub> GeO <sub>4</sub>	Ni, Ge	0.86	0.252	GeO <sub>2</sub> , Ni <sub>3</sub> Ge	353.31
NiAuO <sub>2</sub>	Ni, Au	1.00	0.111	None	26360.30
NiMoO <sub>4</sub>	NiO, Mo	0.68	0.220	MoO <sub>2</sub>	21.26
NiO	Ni	1.00	0.214	None	17.29
NiPt <sub>3</sub> O <sub>6</sub>	Pt <sub>3</sub> O <sub>4</sub> , NiO	1.00	0.022	NiH <sub>2</sub> O <sub>2</sub>	40594.22
NiSb <sub>2</sub> O <sub>6</sub>	Sb <sub>2</sub> O <sub>5</sub> , Ni	1.00	0.040	Sb <sub>2</sub> O <sub>3</sub>	8.62
NiSb <sub>2</sub> O <sub>6</sub>	SbO <sub>2</sub> , NiO	1.00	0.040	Sb <sub>2</sub> O <sub>3</sub>	8.62
OsO <sub>4</sub>	Os	1.00	0.252	None	10800.63
OsPbO <sub>3</sub>	Pb <sub>2</sub> O <sub>3</sub> , Os	0.96	0.054	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	6165.57
Pb <sub>2</sub> O <sub>3</sub>	Pb	0.71	0.104	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	2.17
PbAuO <sub>2</sub>	Pb, Au	0.87	0.073	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO, PbAu <sub>2</sub>	17383.27
PbO	Pb	0.62	0.072	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	2.25
PbS <sub>2</sub> O <sub>3</sub>	PbS <sub>2</sub>	0.97	0.150	None	1.57
PbSO <sub>4</sub>	PbS	0.99	0.211	None	1.65
Pd <sub>2</sub> PbO <sub>4</sub>	PdO, Pb	1.00	0.066	PbCO <sub>3</sub> , PdPbO <sub>2</sub> , Pd <sub>3</sub> Pb	7758.45
Pd <sub>2</sub> PbO <sub>4</sub>	PdO, Pb <sub>2</sub> O <sub>3</sub>	1.00	0.017	PbCO <sub>3</sub> , PdPbO <sub>2</sub> , Pd <sub>3</sub> Pb	7758.45
PdAuO <sub>2</sub>	Au, Pd	1.00	0.095	PdAu <sub>3</sub> , Pd <sub>3</sub> Au	28203.14
PdO	Pd	1.00	0.131	None	15336.13
PdPbO <sub>2</sub>	Pb, Pd	0.83	0.093	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , Pd <sub>3</sub> Pb	5433.56
PdSO <sub>4</sub>	PdS	1.00	0.316	None	9272.11
Pr <sub>2</sub> CuO <sub>4</sub>	Pr <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.039	PrH <sub>3</sub> O <sub>3</sub> , PrCuO <sub>2</sub>	76.92
Pr <sub>2</sub> Ir <sub>2</sub> O <sub>7</sub>	Pr <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.082	PrH <sub>3</sub> O <sub>3</sub>	10338.93
Pr <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Pr <sub>2</sub> O <sub>3</sub>	0.55	0.063	PrH <sub>3</sub> O <sub>3</sub> , Pr <sub>2</sub> MoO <sub>6</sub> , Pr <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	53.93
Pr <sub>2</sub> MoO <sub>6</sub>	MoO <sub>2</sub> , Pr <sub>2</sub> O <sub>3</sub>	0.33	0.034	PrH <sub>3</sub> O <sub>3</sub> , Pr <sub>3</sub> MoO <sub>7</sub>	72.52
Pr <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Pr <sub>2</sub> S <sub>3</sub>	0.59	0.337	Pr <sub>3</sub> H <sub>6</sub> O <sub>9</sub> , PrSO	54.39
Pr <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	FeO, Pr <sub>2</sub> O <sub>3</sub>	0.55	0.045	Fe <sub>3</sub> O <sub>4</sub> , PrH <sub>3</sub> O <sub>3</sub> , Pr <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	52.05
Pr <sub>3</sub> IrO <sub>7</sub>	Pr <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.055	PrH <sub>3</sub> O <sub>3</sub>	5576.98
Pr <sub>3</sub> MoO <sub>7</sub>	MoO <sub>2</sub> , Pr <sub>2</sub> O <sub>3</sub>	0.33	0.013	Pr <sub>2</sub> MoO <sub>6</sub>	79.06
Pr <sub>3</sub> OsO <sub>7</sub>	Pr <sub>2</sub> O <sub>3</sub> , Os	0.96	0.055	PrH <sub>3</sub> O <sub>3</sub>	3851.74
Pr <sub>3</sub> ReO <sub>8</sub>	ReO <sub>3</sub> , Pr <sub>2</sub> O <sub>3</sub>	1.00	0.011	PrH <sub>3</sub> O <sub>3</sub> , Pr <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	1324.99
Pr <sub>5</sub> Ru <sub>2</sub> O <sub>12</sub>	Pr <sub>2</sub> O <sub>3</sub> , Ru	0.96	0.066	PrH <sub>3</sub> O <sub>3</sub>	1250.85

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
PrBiO <sub>4</sub>	Pr <sub>2</sub> O <sub>3</sub> , Bi	0.91	0.097	PrH <sub>3</sub> O <sub>3</sub> , PrC <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	46.34
PrCoO <sub>3</sub>	Pr <sub>2</sub> O <sub>3</sub> , Co	0.52	0.097	PrH <sub>3</sub> O <sub>3</sub> , PrC <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	73.53
PrCrO <sub>4</sub>	Cr <sub>2</sub> O <sub>3</sub> , Pr <sub>2</sub> O <sub>3</sub>	1.00	0.062	CrHO <sub>2</sub> , PrH <sub>3</sub> O <sub>3</sub> , PrCrO <sub>3</sub>	62.34
PrCrO <sub>4</sub>	CrO <sub>2</sub> , Pr <sub>2</sub> O <sub>3</sub>	1.00	0.031	PrH <sub>3</sub> O <sub>3</sub> , PrCrO <sub>3</sub>	62.34
PrCu <sub>2</sub> O <sub>4</sub>	CuO, Pr <sub>2</sub> O <sub>3</sub>	1.00	0.024	PrH <sub>3</sub> O <sub>3</sub> , PrCuO <sub>2</sub>	49.63
PrCuO <sub>2</sub>	Pr <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.034	PrH <sub>3</sub> O <sub>3</sub>	67.62
PrFeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , Pr <sub>2</sub> O <sub>3</sub>	1.00	0.011	PrH <sub>3</sub> O <sub>3</sub>	63.36
PrFeO <sub>3</sub>	FeO, Pr <sub>2</sub> O <sub>3</sub>	0.55	0.033	Fe <sub>3</sub> O <sub>4</sub> , PrH <sub>3</sub> O <sub>3</sub> , PrC <sub>3</sub> H <sub>6</sub> O <sub>9</sub>	63.36
PrHfO <sub>4</sub>	HfO <sub>2</sub> , Pr <sub>2</sub> O <sub>3</sub>	1.00	0.021	PrH <sub>3</sub> O <sub>3</sub>	296.48
PrMn <sub>2</sub> O <sub>5</sub>	MnO, Pr <sub>2</sub> O <sub>3</sub>	0.00	0.073	MnHO <sub>2</sub>	46.86
PrMnO <sub>3</sub>	MnO, Pr <sub>2</sub> O <sub>3</sub>	0.00	0.033	MnHO <sub>2</sub>	63.57
PrPd <sub>2</sub> O <sub>4</sub>	Pr <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.096	PrH <sub>3</sub> O <sub>3</sub>	9025.55
PrRhO <sub>3</sub>	Pr <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.082	PrH <sub>3</sub> O <sub>3</sub>	28331.63
Pt <sub>2</sub> PbO <sub>4</sub>	Pb, Pt	0.98	0.097	PbCO <sub>3</sub> , Pt <sub>3</sub> Pb, PtPb	30277.58
Pt <sub>3</sub> O <sub>4</sub>	Pt	1.00	0.099	None	46262.75
PtO <sub>2</sub>	Pt	1.00	0.141	None	44089.75
PtO <sub>2</sub>	Pt <sub>3</sub> O <sub>4</sub>	1.00	0.047	None	44089.75
PtPb <sub>2</sub> O <sub>4</sub>	PbO, Pt <sub>3</sub> O <sub>4</sub>	1.00	0.016	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , Pt <sub>2</sub> PbO <sub>4</sub> , Pt <sub>3</sub> Pb	14867.56
PtPb <sub>2</sub> O <sub>4</sub>	Pt <sub>3</sub> O <sub>4</sub> , Pb	0.98	0.063	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO, Pt <sub>3</sub> Pb	14867.56
Rb <sub>2</sub> Bi <sub>4</sub> O <sub>7</sub>	Rb <sub>2</sub> O, Bi	0.31	0.086	Rb <sub>2</sub> CO <sub>3</sub> , Bi <sub>2</sub> CO <sub>5</sub>	7948.05
Rb <sub>2</sub> Cd <sub>2</sub> O <sub>3</sub>	CdO, Rb	0.00	0.036	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	20008.69
Rb <sub>2</sub> CdO <sub>2</sub>	CdO, Rb	0.00	0.051	RbHO, Rb <sub>2</sub> Cd <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	28154.78
Rb <sub>2</sub> CdO <sub>2</sub>	Rb <sub>2</sub> O, Cd	0.00	0.051	RbHO, Rb <sub>2</sub> Cd <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	28154.78
Rb <sub>2</sub> CeO <sub>3</sub>	Ce <sub>5</sub> O <sub>9</sub> , Rb	0.00	0.053	CeO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	24745.84
Rb <sub>2</sub> CeO <sub>3</sub>	CeO <sub>2</sub> , Rb	0.00	0.045	Ce <sub>5</sub> O <sub>9</sub> , Rb <sub>2</sub> CO <sub>3</sub>	24745.84
Rb <sub>2</sub> Co <sub>2</sub> O <sub>3</sub>	Co, Rb	0.00	0.143	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	26375.97
Rb <sub>2</sub> Co <sub>2</sub> O <sub>3</sub>	CoO, Rb	0.00	0.048	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	26375.97
Rb <sub>2</sub> CoO <sub>3</sub>	Co, Rb	0.00	0.173	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	31960.28
Rb <sub>2</sub> CoO <sub>3</sub>	CoO, Rb	0.00	0.115	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	31960.28
Rb <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	Cr <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.165	CrHO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	22947.72
Rb <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub>	Rb <sub>2</sub> O, Cr <sub>2</sub> O <sub>3</sub>	0.00	0.124	CrHO <sub>2</sub> , RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> CrO <sub>4</sub> , Rb <sub>2</sub> CO <sub>3</sub>	22947.72

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Rb <sub>2</sub> CrO <sub>4</sub>	Cr <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.139	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	30943.16
Rb <sub>2</sub> Hf <sub>2</sub> O <sub>5</sub>	HfO <sub>2</sub> , Rb	0.00	0.026	Rb <sub>2</sub> CO <sub>3</sub>	14927.02
Rb <sub>2</sub> HgO <sub>2</sub>	Hg, Rb	0.00	0.079	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	22014.06
Rb <sub>2</sub> HgO <sub>2</sub>	Rb <sub>2</sub> O, Hg	0.00	0.040	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	22014.06
Rb <sub>2</sub> MgO <sub>2</sub>	MgO, Rb	0.00	0.070	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	39069.43
Rb <sub>2</sub> MnO <sub>4</sub>	MnO <sub>2</sub> , Rb <sub>2</sub> O	0.00	0.055	Rb <sub>2</sub> CO <sub>3</sub> , MnHO <sub>2</sub> , RbHO, RbMnO <sub>2</sub>	30627.34
Rb <sub>2</sub> MnO <sub>4</sub>	Rb <sub>2</sub> O, Mn	0.00	0.166	Rb <sub>2</sub> CO <sub>3</sub> , MnHO <sub>2</sub> , RbHO, RbH <sub>3</sub> O <sub>2</sub>	30627.34
Rb <sub>2</sub> Mo <sub>3</sub> O <sub>10</sub>	MoO <sub>2</sub> , Rb	0.20	0.103	Rb <sub>2</sub> CO <sub>3</sub> , Rb <sub>2</sub> MoO <sub>4</sub>	14364.55
Rb <sub>2</sub> NiO <sub>2</sub>	NiO, Rb	0.00	0.061	RbHO, Rb <sub>2</sub> CO <sub>3</sub> , Rb <sub>2</sub> O	33938.58
Rb <sub>2</sub> NiO <sub>2</sub>	Rb <sub>2</sub> O, Ni	0.00	0.061	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	33938.58
Rb <sub>2</sub> O	Rb	0.00	0.086	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	47492.36
Rb <sub>2</sub> O <sub>2</sub>	Rb	0.00	0.158	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	43748.05
Rb <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub>	Pb, Rb	0.00	0.076	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	14019.44
Rb <sub>2</sub> Pb <sub>4</sub> O <sub>7</sub>	Rb <sub>2</sub> O <sub>2</sub> , Pb	0.14	0.072	PbO, Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Rb <sub>2</sub> CO <sub>3</sub>	7987.53
Rb <sub>2</sub> PbO <sub>2</sub>	Pb, Rb	0.00	0.078	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	21647.75
Rb <sub>2</sub> PbO <sub>3</sub>	Pb <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.056	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	20834.97
Rb <sub>2</sub> PbO <sub>3</sub>	Rb <sub>2</sub> O, Pb	0.00	0.075	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	20834.97
Rb <sub>2</sub> RuO <sub>4</sub>	Ru, Rb	0.00	0.190	Rb <sub>2</sub> CO <sub>3</sub>	28352.02
Rb <sub>2</sub> S <sub>2</sub> O <sub>7</sub>	RbS	0.47	0.323	Rb <sub>2</sub> SO <sub>4</sub>	25580.44
Rb <sub>2</sub> Sb <sub>4</sub> O <sub>11</sub>	Sb <sub>2</sub> O <sub>3</sub> , Rb	0.70	0.096	RbSbO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	10650.60
Rb <sub>2</sub> SnO <sub>3</sub>	SnO <sub>2</sub> , Rb	0.00	0.047	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Rb <sub>2</sub> Sn <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	26303.22
Rb <sub>2</sub> TbO <sub>3</sub>	Tb <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.064	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	23810.93
Rb <sub>2</sub> Zn <sub>3</sub> O <sub>4</sub>	Zn, Rb	0.00	0.148	Rb <sub>2</sub> CO <sub>3</sub>	20591.92
Rb <sub>2</sub> Zn <sub>3</sub> O <sub>4</sub>	ZnO, Rb	0.00	0.037	RbHO, Zn <sub>6</sub> HO <sub>6</sub> , Rb <sub>2</sub> CO <sub>3</sub>	20591.92
Rb <sub>2</sub> ZnO <sub>2</sub>	Zn, Rb	0.00	0.119	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	33084.95
Rb <sub>2</sub> ZnO <sub>2</sub>	ZnO, Rb	0.00	0.060	RbHO, Zn <sub>6</sub> HO <sub>6</sub> , Rb <sub>2</sub> Zn <sub>3</sub> O <sub>4</sub> , Rb <sub>2</sub> CO <sub>3</sub>	33084.95
Rb <sub>3</sub> AgO <sub>2</sub>	Ag, Rb	0.00	0.081	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	33780.41
Rb <sub>3</sub> AlO <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.072	RbAlO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	40186.22
Rb <sub>3</sub> BiO <sub>3</sub>	Bi, Rb	0.00	0.093	RbHO, Rb <sub>2</sub> CO <sub>3</sub> , RbBi	25946.87
Rb <sub>3</sub> Cu <sub>5</sub> O <sub>4</sub>	Cu, Rb	0.00	0.100	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	20872.55

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Rb <sub>3</sub> CuO <sub>2</sub>	CuO, Rb	0.00	0.045	RbHO, RbCuO, Rb <sub>2</sub> CO <sub>3</sub>	37839.28
Rb <sub>3</sub> DyO <sub>3</sub>	Dy <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.051	RbHO, RbDyO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	28661.24
Rb <sub>3</sub> ErO <sub>3</sub>	Er <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.051	RbHO, RbErO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	
Rb <sub>3</sub> FeO <sub>3</sub>	Fe, Rb	0.00	0.133	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	36966.30
Rb <sub>3</sub> FeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , Rb	0.00	0.074	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	36966.30
Rb <sub>3</sub> HoO <sub>3</sub>	Ho <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.051	RbHO, RbHoO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	
Rb <sub>3</sub> InO <sub>3</sub>	In, Rb	0.00	0.114	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	31915.46
Rb <sub>3</sub> InO <sub>3</sub>	In <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.057	RbHO, Rb <sub>2</sub> In <sub>4</sub> O <sub>7</sub> , Rb <sub>2</sub> CO <sub>3</sub>	31915.46
Rb <sub>3</sub> LuO <sub>3</sub>	Lu <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.050	RbHO, RbLuO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	
Rb <sub>3</sub> MnO <sub>3</sub>	Mn, Rb	0.00	0.134	Rb <sub>2</sub> CO <sub>3</sub>	37059.58
Rb <sub>3</sub> MnO <sub>3</sub>	MnO <sub>2</sub> , Rb	0.00	0.045	Rb <sub>2</sub> CO <sub>3</sub> , MnHO <sub>2</sub> , RbHO, RbMnO <sub>2</sub>	37059.58
Rb <sub>3</sub> TlO <sub>3</sub>	Rb <sub>2</sub> O, Tl	0.00	0.047	RbHO, RbTlO, Rb <sub>2</sub> CO <sub>3</sub>	28560.23
Rb <sub>3</sub> TlO <sub>3</sub>	Tl <sub>4</sub> O <sub>3</sub> , Rb	0.00	0.071	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	28560.23
Rb <sub>3</sub> TmO <sub>3</sub>	Tm <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.051	RbHO, RbTmO <sub>2</sub> , Rb <sub>2</sub> CO <sub>3</sub>	
Rb <sub>3</sub> YO <sub>3</sub>	Y <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.061	Rb <sub>2</sub> CO <sub>3</sub> , RbHO, RbYO <sub>2</sub>	33876.58
Rb <sub>4</sub> Fe <sub>2</sub> O <sub>5</sub>	Fe <sub>3</sub> O <sub>4</sub> , Rb	0.00	0.070	Rb <sub>2</sub> CO <sub>3</sub> , RbHO, FeO	33278.44
Rb <sub>4</sub> Fe <sub>2</sub> O <sub>5</sub>	FeO, Rb	0.00	0.090	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	33278.44
Rb <sub>4</sub> FeO <sub>4</sub>	Fe, Rb	0.00	0.139	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	38456.67
Rb <sub>4</sub> PbO <sub>4</sub>	Pb <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.065	RbHO, Rb <sub>2</sub> Pb <sub>2</sub> O <sub>3</sub> , Rb <sub>2</sub> CO <sub>3</sub>	28963.26
Rb <sub>4</sub> SbO <sub>4</sub>	Sb <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.076	RbHO, Rb <sub>3</sub> SbO <sub>3</sub> , Rb <sub>4</sub> Sb <sub>2</sub> O <sub>5</sub> , RbSb, Rb <sub>2</sub> CO <sub>3</sub>	33654.42
Rb <sub>4</sub> SnO <sub>4</sub>	SnO <sub>2</sub> , Rb	0.00	0.061	RbHO, Rb <sub>2</sub> Sn <sub>2</sub> O <sub>3</sub> , RbSn, Rb <sub>2</sub> CO <sub>3</sub>	33854.02
Rb <sub>4</sub> WO <sub>5</sub>	WO <sub>3</sub> , Rb	0.00	0.053	Rb <sub>2</sub> CO <sub>3</sub>	29314.46
Rb <sub>5</sub> Au <sub>3</sub> O <sub>2</sub>	Au, Rb	0.00	0.030	RbHO, Rb <sub>2</sub> Au <sub>3</sub> , Rb <sub>3</sub> Au <sub>7</sub> , Rb <sub>2</sub> CO <sub>3</sub>	42789.75
Rb <sub>5</sub> Co <sub>2</sub> O <sub>4</sub>	Co, Rb	0.00	0.105	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	36441.72
Rb <sub>5</sub> Co <sub>2</sub> O <sub>4</sub>	CoO, Rb	0.00	0.053	RbHO, Rb <sub>2</sub> CO <sub>3</sub> , Rb <sub>2</sub> Co <sub>2</sub> O <sub>3</sub>	36441.72
Rb <sub>5</sub> FeO <sub>4</sub>	Fe, Rb	0.00	0.117	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	40562.34

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Rb5FeO4	Fe3O4, Rb	0.00	0.078	Rb2CO3, RbHO	40562.34
Rb5GaO4	Ga, Rb	0.00	0.114	RbGaO2, Rb3GaO3, Rb2CO3	39633.57
Rb5GaO4	Ga2O3, Rb	0.00	0.071	RbHO, RbGaO2, Rb3GaO3, Rb2CO3	39633.57
Rb6CdO4	Rb2O, Cd	0.00	0.023	Rb9O2, RbHO, Rb2CdO2, Rb2CO3	38644.59
Rb6Co2O7	Co, Rb	0.00	0.151	RbHO, Rb2CO3	35869.82
Rb6Co2O7	CoO, Rb	0.00	0.108	RbHO, Rb2CO3	35869.82
Rb7Fe2O8	Fe, Rb	0.00	0.153	Rb2CO3, RbHO, FeO	37081.68
Rb8Fe2O7	Fe, Rb	0.00	0.123	Rb2CO3, RbHO, FeO	39134.72
Rb8Fe2O7	Fe3O4, Rb	0.00	0.076	Rb2CO3, RbHO, FeO	39134.72
RbAgO	Ag, Rb	0.00	0.076	RbHO, Rb2CO3	21535.74
RbAgO	Rb2O, Ag	0.00	0.038	RbHO, Rb3AgO2, Rb2CO3	21535.74
RbAgO2	Ag, Rb	0.00	0.142	Rb2CO3	20006.64
RbAgO2	Rb2O2, Ag	0.00	0.071	RbH3O2, Rb2CO3	20006.64
RbAuO	Rb2O, Au	0.00	0.027	RbHO, RbAu5, Rb2CO3	40278.52
RbAuO2	Rb2O2, Au	0.00	0.051	RbH3O2, Rb2CO3	38229.02
RbBiO2	Bi, Rb	0.00	0.098	Rb2CO3	13609.16
RbCuO	Cu, Rb	0.00	0.097	RbHO, Rb2CO3	26903.80
RbCuO2	CuO, Rb	0.00	0.088	RbH3O2, Rb2CO3, Rb3Cu5O4	24525.82
RbDyO2	Dy2O3, Rb	0.00	0.029	RbHO, Rb2CO3	16087.61
RbErO2	Er2O3, Rb	0.00	0.028	RbHO, Rb2CO3	
RbEuO2	Eu2O3, Rb	0.00	0.030	RbHO, Eu3O4, Rb2CO3	16926.67
RbEuO2	Eu3O4, Rb	0.00	0.040	RbHO, Rb2CO3	16926.67
RbFeO2	Fe3O4, Rb	0.00	0.062	Rb2CO3, RbHO	25612.82
RbFeO2	FeO, Rb	0.00	0.092	Rb2CO3, RbHO	25612.82
RbGdO2	Gd2O3, Rb	0.00	0.029	RbHO, Rb2CO3	16189.93
RbHoO2	Ho2O3, Rb	0.00	0.028	RbHO, Rb2CO3	
RbIr6O12	Ir, Rb	0.80	0.134	None	19908.72
RbIr6O12	Rb2O2, Ir	0.83	0.123	None	19908.72
RbLaO2	La2O3, Rb	0.00	0.031	RbHO, Rb2CO3	17347.16
RbLuO2	Lu2O3, Rb	0.00	0.027	RbHO, Rb2CO3	
RbMnO2	Mn2O3, Rb	0.00	0.046	Rb2CO3, MnHO2, RbHO	25747.52
RbNdO2	Nd2O3, Rb	0.00	0.031	RbHO, Rb2CO3	17024.97
RbOs2O6	Rb2O2, Os	0.64	0.142	Rb2CO3	17672.54

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
RbOs <sub>2</sub> O <sub>9</sub>	OsO <sub>4</sub> , Rb	0.00	0.026	RbOs <sub>2</sub> O <sub>6</sub> , RbH <sub>3</sub> O <sub>2</sub> , RbHO, Rb <sub>2</sub> CO <sub>3</sub>	16281.79
RbOs <sub>2</sub> O <sub>9</sub>	Rb <sub>2</sub> O <sub>2</sub> , Os	0.77	0.210	Rb <sub>2</sub> CO <sub>3</sub>	16281.79
RbOsO <sub>3</sub>	Rb <sub>2</sub> O <sub>2</sub> , Os	0.09	0.099	Rb <sub>2</sub> CO <sub>3</sub>	22196.17
RbPrO <sub>2</sub>	Pr <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.031	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	17240.47
RbRu <sub>4</sub> O <sub>8</sub>	Rb <sub>2</sub> O <sub>2</sub> , Ru	0.73	0.181	Rb <sub>2</sub> CO <sub>3</sub>	11384.23
RbSO <sub>3</sub>	RbS	0.37	0.290	Rb <sub>2</sub> SO <sub>4</sub>	26816.68
RbScO <sub>2</sub>	Sc <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.049	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	71615.31
RbSmO <sub>2</sub>	Sm <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.030	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	16607.81
RbTiO	Ti, Rb	0.00	0.052	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	18482.98
RbTiO <sub>2</sub>	Rb <sub>2</sub> O, Ti <sub>4</sub> O <sub>3</sub>	0.00	0.037	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Ti <sub>2</sub> O, Rb <sub>2</sub> CO <sub>3</sub>	17564.18
RbTiO <sub>2</sub>	Ti <sub>4</sub> O <sub>3</sub> , Rb	0.00	0.062	RbHO, RbH <sub>3</sub> O <sub>2</sub> , Ti <sub>2</sub> O, Rb <sub>2</sub> CO <sub>3</sub>	17564.18
RbTmO <sub>2</sub>	Tm <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.028	RbHO, Rb <sub>2</sub> CO <sub>3</sub>	
RbYO <sub>2</sub>	Y <sub>2</sub> O <sub>3</sub> , Rb	0.00	0.039	Rb <sub>2</sub> CO <sub>3</sub> , RbHO	21543.22
Re <sub>2</sub> PbO <sub>8</sub>	ReO <sub>3</sub> , Pb	0.77	0.045	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	2629.05
ReBi <sub>3</sub> O <sub>8</sub>	Bi <sub>2</sub> O <sub>3</sub> , ReO <sub>3</sub>	0.92	0.008	Bi <sub>2</sub> CO <sub>5</sub>	999.80
ReBi <sub>3</sub> O <sub>8</sub>	Re, Bi	0.63	0.136	ReO <sub>3</sub>	999.80
ReBi <sub>9</sub> O <sub>17</sub>	Re, Bi	0.76	0.116	ReO <sub>3</sub>	411.72
Rh <sub>7</sub> Pb <sub>3</sub> O <sub>15</sub>	Pb, Rh	0.97	0.152	PbCO <sub>3</sub> , Rh <sub>3</sub> Pb	36515.82
RhO <sub>2</sub>	Rh	1.00	0.237	None	61169.23
Ru <sub>4</sub> Pb <sub>4</sub> O <sub>13</sub>	RuO <sub>2</sub> , Pb	0.99	0.056	Pb <sub>3</sub> H <sub>2</sub> O <sub>4</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	1801.12
RuO <sub>2</sub>	Ru	1.00	0.240	None	4872.55
RuO <sub>4</sub>	Ru	1.00	0.388	None	3927.99
Sb <sub>2</sub> O <sub>3</sub>	Sb	0.31	0.165		7.35
Sb <sub>2</sub> O <sub>5</sub>	Sb	0.46	0.247	Sb <sub>2</sub> O <sub>3</sub>	6.62
Sb <sub>2</sub> PbO <sub>6</sub>	PbO, Sb	0.44	0.146	PbCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	4.84
Sb <sub>2</sub> PbO <sub>6</sub>	PbO, Sb <sub>2</sub> O <sub>3</sub>	0.44	0.059	PbCO <sub>3</sub>	4.84
Sb <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Sb <sub>2</sub> S <sub>3</sub>	0.98	0.361	Sb <sub>2</sub> O <sub>3</sub>	4.03
Sb <sub>3</sub> O <sub>7</sub>	Sb	0.43	0.235	Sb <sub>2</sub> O <sub>3</sub>	6.74
SbO <sub>2</sub>	Sb	0.38	0.208	Sb <sub>2</sub> O <sub>3</sub>	6.97
SbRhO <sub>4</sub>	RhO <sub>2</sub> , Sb	1.00	0.111	SbO <sub>2</sub> , Sb <sub>2</sub> O <sub>3</sub> , Sb <sub>3</sub> O <sub>7</sub> , SbRh <sub>3</sub>	28590.64
Sc <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Sc <sub>2</sub> O <sub>3</sub>	1.00	0.084	ScHO <sub>2</sub>	25268.29
Sc <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Sc <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	1.00	0.036	ScHO <sub>2</sub> , ScH <sub>3</sub> O <sub>3</sub>	58117.47
Sc <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Sc <sub>2</sub> S <sub>3</sub>	0.71	0.508	ScHO <sub>2</sub> , Sc <sub>2</sub> O <sub>3</sub>	38047.89
ScAgO <sub>2</sub>	Sc <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.043	ScHO <sub>2</sub>	39292.45
ScBiO <sub>3</sub>	Sc <sub>2</sub> O <sub>3</sub> , Bi	0.86	0.079	ScHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	23835.05
ScCuO <sub>2</sub>	Sc <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.057	ScHO <sub>2</sub>	51198.57

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
ScVO <sub>4</sub>	Sc <sub>2</sub> O <sub>3</sub> , V <sub>2</sub> O <sub>3</sub>	0.39	0.100	ScHO <sub>2</sub> , VO <sub>2</sub>	44990.34
Sm <sub>2</sub> HgO <sub>4</sub>	Sm <sub>2</sub> O <sub>3</sub> , Hg	1.00	0.028	SmHO <sub>2</sub>	41.16
Sm <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Sm <sub>2</sub> O <sub>3</sub>	0.91	0.061	Sm <sub>3</sub> MoO <sub>7</sub>	36.02
Sm <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	MoO <sub>2</sub> , Sm <sub>2</sub> O <sub>3</sub>	0.94	0.069	Sm <sub>3</sub> MoO <sub>7</sub>	34.05
Sm <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.080	SmH <sub>3</sub> O <sub>3</sub> , SmHO <sub>2</sub>	24962.63
Sm <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.104	SmH <sub>3</sub> O <sub>3</sub> , SmHO <sub>2</sub>	2138.41
Sm <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Sm <sub>2</sub> S <sub>3</sub>	0.61	0.326	Sm <sub>2</sub> S <sub>2</sub> O <sub>2</sub>	30.64
Sm <sub>3</sub> AuO <sub>6</sub>	Sm <sub>2</sub> O <sub>3</sub> , Au	1.00	0.032	SmHO <sub>2</sub>	10225.95
Sm <sub>3</sub> Bi <sub>5</sub> O <sub>12</sub>	Sm <sub>2</sub> O <sub>3</sub> , Bi	0.69	0.071	SmH <sub>3</sub> O <sub>3</sub> , SmHO <sub>2</sub>	26.93
Sm <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	FeO, Sm <sub>2</sub> O <sub>3</sub>	0.55	0.043	Fe <sub>3</sub> O <sub>4</sub> , SmHO <sub>2</sub>	29.38
Sm <sub>3</sub> IrO <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.053	SmHO <sub>2</sub>	5341.87
Sm <sub>3</sub> OsO <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Os	0.99	0.053	SmHO <sub>2</sub>	3680.95
Sm <sub>3</sub> ReO <sub>8</sub>	ReO <sub>3</sub> , Sm <sub>2</sub> O <sub>3</sub>	1.00	0.010	SmHO <sub>2</sub>	1250.50
Sm <sub>3</sub> RuO <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.060	SmHO <sub>2</sub>	1017.02
Sm <sub>4</sub> Au <sub>2</sub> O <sub>9</sub>	Sm <sub>2</sub> O <sub>3</sub> , Au	1.00	0.042	SmHO <sub>2</sub>	13339.89
Sm <sub>4</sub> PdO <sub>7</sub>	Sm <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.020	SmHO <sub>2</sub>	2333.98
SmAgO <sub>2</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.028	SmHO <sub>2</sub>	269.52
SmBiO <sub>4</sub>	Sm <sub>2</sub> O <sub>3</sub> , Bi	0.77	0.094	SmH <sub>3</sub> O <sub>3</sub> , SmHO <sub>2</sub>	30.00
SmCrO <sub>4</sub>	Cr <sub>2</sub> O <sub>3</sub> , Sm <sub>2</sub> O <sub>3</sub>	1.00	0.060	CrHO <sub>2</sub> , SmH <sub>3</sub> O <sub>3</sub> , SmCrO <sub>3</sub>	35.80
SmCrO <sub>4</sub>	CrO <sub>2</sub> , Sm <sub>2</sub> O <sub>3</sub>	1.00	0.030	SmH <sub>3</sub> O <sub>3</sub> , SmCrO <sub>3</sub>	35.80
SmCu <sub>2</sub> O <sub>4</sub>	CuO, Sm <sub>2</sub> O <sub>3</sub>	1.00	0.023	SmH <sub>3</sub> O <sub>3</sub> , SmCuO <sub>2</sub>	29.29
SmCuO <sub>2</sub>	Sm <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.033	SmHO <sub>2</sub>	38.68
SmFeO <sub>3</sub>	Fe <sub>3</sub> O <sub>4</sub> , Sm <sub>2</sub> O <sub>3</sub>	1.00	0.010	SmHO <sub>2</sub>	35.52
SmMn <sub>2</sub> O <sub>5</sub>	MnO, Sm <sub>2</sub> O <sub>3</sub>	0.00	0.071	MnHO <sub>2</sub>	26.52
SmMnO <sub>3</sub>	MnO, Sm <sub>2</sub> O <sub>3</sub>	0.00	0.032	MnHO <sub>2</sub>	35.62
SmRhO <sub>3</sub>	Sm <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.080	SmH <sub>3</sub> O <sub>3</sub> , SmHO <sub>2</sub>	27421.20
SmSbO <sub>4</sub>	Sm <sub>2</sub> O <sub>3</sub> , Sb	0.20	0.119	Sm <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub> , Sm <sub>3</sub> SbO <sub>7</sub>	30.03
SmTiO <sub>2</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ti	0.57	0.021	SmHO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	3162.47
SmTiO <sub>3</sub>	Sm <sub>2</sub> O <sub>3</sub> , Ti	0.89	0.060	SmHO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	3036.83
SmTiO <sub>3</sub>	Ti <sub>4</sub> O <sub>3</sub> , Sm <sub>2</sub> O <sub>3</sub>	0.04	0.030	SmTiO <sub>2</sub> , SmHO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub> , Ti <sub>2</sub> O <sub>3</sub>	3036.83
SmVO <sub>4</sub>	VO <sub>2</sub> , Sm <sub>2</sub> O <sub>3</sub>	0.74	0.030	SmVO <sub>3</sub>	36.96
Sn <sub>2</sub> Bi <sub>2</sub> O <sub>7</sub>	SnO <sub>2</sub> , Bi	0.88	0.063	Bi <sub>2</sub> CO <sub>5</sub>	17.75
SnPb <sub>2</sub> O <sub>4</sub>	Pb, Sn	0.29	0.107	PbCO <sub>3</sub> , SnO <sub>2</sub>	6.93
SnS <sub>2</sub> O <sub>8</sub>	SnS <sub>2</sub>	1.00	0.412	SnO <sub>2</sub>	10.08
Sr <sub>11</sub> Os <sub>4</sub> O <sub>24</sub>	SrO, Os	0.00	0.099	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub>	SrO, Bi	0.00	0.071	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> CuO <sub>3</sub>	SrO, Cu	0.00	0.056	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> IrO <sub>4</sub>	SrO, Ir	0.00	0.074	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Sr <sub>2</sub> PbO <sub>4</sub>	SrO, Pb	0.00	0.072	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> PdO <sub>3</sub>	SrO, Pd	0.00	0.049	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> RhO <sub>4</sub>	SrO, Rh	0.00	0.094	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>2</sub> Tl <sub>2</sub> O <sub>5</sub>	Tl <sub>4</sub> O <sub>3</sub> , SrO	0.00	0.036	Sr <sub>3</sub> Tl <sub>2</sub> O <sub>6</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>3</sub> CdO <sub>4</sub>	SrO, Cd	0.00	0.036	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>3</sub> Tl <sub>2</sub> O <sub>6</sub>	Tl <sub>4</sub> O <sub>3</sub> , SrO	0.00	0.031	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> Cu <sub>2</sub> O <sub>7</sub>	CuO, SrO	0.00	0.027	SrH <sub>2</sub> O <sub>2</sub> , SrCu <sub>2</sub> O <sub>3</sub> , SrCO <sub>3</sub> , Sr <sub>2</sub> CuO <sub>3</sub>	
Sr <sub>4</sub> IrO <sub>6</sub>	SrO, Ir	0.00	0.050	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> PdO <sub>6</sub>	PdO, SrO	0.00	0.029	Sr <sub>2</sub> PdO <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> PtO <sub>6</sub>	SrO, Pt	0.00	0.050	SrPt <sub>5</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> RhO <sub>6</sub>	SrO, Rh	0.00	0.058	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> Ru <sub>2</sub> O <sub>9</sub>	SrO, Ru	0.00	0.115	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>4</sub> Ru <sub>3</sub> O <sub>10</sub>	SrO, Ru	0.00	0.118	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>5</sub> Au <sub>2</sub> O <sub>8</sub>	SrO, Au	0.00	0.050	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>5</sub> Bi <sub>3</sub> O <sub>12</sub>	SrO, Bi	0.00	0.089	SrH <sub>2</sub> O <sub>2</sub> , Sr <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub> , SrCO <sub>3</sub>	
Sr <sub>6</sub> Rh <sub>5</sub> O <sub>15</sub>	SrO, Rh	0.00	0.112	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
Sr <sub>8</sub> Fe <sub>8</sub> O <sub>23</sub>	Fe <sub>2</sub> O <sub>3</sub> , SrO	0.00	0.032	Sr <sub>2</sub> Fe <sub>2</sub> O <sub>5</sub> , SrH <sub>2</sub> O <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub> , SrCO <sub>3</sub>	
Sr <sub>8</sub> Fe <sub>8</sub> O <sub>23</sub>	FeO, SrO	0.00	0.074	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrAg <sub>6</sub> O <sub>4</sub>	Ag, Sr	0.00	0.080	SrCO <sub>3</sub>	
SrAgO <sub>2</sub>	SrO, Ag	0.00	0.070	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrAu <sub>2</sub> O <sub>4</sub>	Au, Sr	0.00	0.117	SrCO <sub>3</sub>	
SrBi <sub>2</sub> O <sub>4</sub>	SrO, Bi	0.00	0.084	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrBiO <sub>3</sub>	Bi <sub>2</sub> O <sub>3</sub> , SrO	0.00	0.023	SrH <sub>2</sub> O <sub>2</sub> , Sr <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub> , SrBi <sub>2</sub> O <sub>4</sub> , SrCO <sub>3</sub>	
SrBiO <sub>3</sub>	SrO, Bi	0.00	0.093	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , Sr <sub>2</sub> Bi <sub>2</sub> O <sub>5</sub> , SrCO <sub>3</sub>	
SrCrO <sub>4</sub>	SrO, Cr	0.03	0.236	Cr <sub>2</sub> O <sub>3</sub> , SrCr <sub>2</sub> O <sub>4</sub> , SrCO <sub>3</sub>	
SrCu <sub>2</sub> O <sub>3</sub>	SrO, Cu	0.00	0.122	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrFe <sub>2</sub> O <sub>4</sub>	FeO, SrO	0.00	0.061	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrHgO <sub>2</sub>	SrO, Hg	0.00	0.050	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrIrO <sub>3</sub>	SrO, Ir	0.00	0.098	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
SrNiO <sub>3</sub>	SrO, Ni	0.00	0.165	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrPbO <sub>3</sub>	SrO, Pb	0.00	0.093	SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrPd <sub>3</sub> O <sub>4</sub>	Sr, Pd	0.00	0.136	SrCO <sub>3</sub>	
SrPt <sub>3</sub> O <sub>4</sub>	Pt, Sr	0.00	0.087	SrCO <sub>3</sub>	
SrRh <sub>2</sub> O <sub>4</sub>	SrO, Rh	0.00	0.134	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrRu <sub>2</sub> O <sub>6</sub>	Sr, Ru	0.28	0.249	SrCO <sub>3</sub>	
SrRu <sub>2</sub> O <sub>6</sub>	SrO, RuO <sub>2</sub>	1.00	0.041	SrH <sub>4</sub> O <sub>3</sub> , SrCO <sub>3</sub> , SrRuO <sub>3</sub>	
SrRuO <sub>3</sub>	SrO, Ru	0.00	0.135	SrH <sub>4</sub> O <sub>3</sub> , SrH <sub>2</sub> O <sub>2</sub> , SrCO <sub>3</sub>	
SrSO <sub>4</sub>	SrS	0.15	0.348	SrCO <sub>3</sub>	
SrTi <sub>2</sub> O <sub>4</sub>	Ti, Sr	0.00	0.114	SrCO <sub>3</sub>	
Ta <sub>2</sub> Bi <sub>4</sub> O <sub>11</sub>	Ta <sub>2</sub> O <sub>5</sub> , Bi	0.39	0.070	TaBiO <sub>4</sub>	39.69
Ta <sub>2</sub> Cd <sub>2</sub> O <sub>7</sub>	Ta <sub>2</sub> O <sub>5</sub> , Cd	0.29	0.046	Ta <sub>2</sub> CdO <sub>6</sub>	58.39
Ta <sub>2</sub> CoO <sub>6</sub>	Ta <sub>2</sub> O <sub>5</sub> , Co	0.19	0.031	None	82.29
Ta <sub>2</sub> Mo <sub>2</sub> O <sub>11</sub>	MoO <sub>2</sub> , Ta <sub>2</sub> O <sub>5</sub>	1.00	0.044	TaO <sub>3</sub> , Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub>	63.75
Ta <sub>2</sub> Mo <sub>2</sub> O <sub>11</sub>	MoO <sub>2</sub> , TaO <sub>3</sub>	1.00	0.022	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , Ta <sub>2</sub> O <sub>5</sub>	63.75
Ta <sub>2</sub> NiO <sub>6</sub>	Ta <sub>2</sub> O <sub>5</sub> , Ni	1.00	0.031	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , TaO <sub>3</sub>	79.56
Ta <sub>3</sub> AgO <sub>8</sub>	Ta <sub>2</sub> O <sub>5</sub> , Ag	1.00	0.010	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , TaO <sub>3</sub>	165.55
Ta <sub>3</sub> Bi <sub>7</sub> O <sub>18</sub>	Ta <sub>2</sub> O <sub>5</sub> , Bi	0.49	0.073	TaBiO <sub>4</sub> , Ta <sub>2</sub> Bi <sub>4</sub> O <sub>11</sub>	37.26
Ta <sub>4</sub> Ag <sub>2</sub> O <sub>11</sub>	Ta <sub>2</sub> O <sub>5</sub> , Ag	1.00	0.014	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , TaO <sub>3</sub>	195.44
TaCuO <sub>3</sub>	Ta <sub>2</sub> O <sub>5</sub> , Cu	1.00	0.027	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub>	69.72
TaO <sub>3</sub>	Ta <sub>2</sub> O <sub>5</sub>	1.00	0.035	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub>	86.94
TaRhO <sub>4</sub>	Ta <sub>2</sub> O <sub>5</sub> , Rh	1.00	0.069	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , TaO <sub>3</sub>	23780.00
TaRhO <sub>4</sub>	TaO <sub>3</sub> , Rh	1.00	0.046	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , Ta <sub>2</sub> O <sub>5</sub>	23780.00
TaSb <sub>3</sub> O <sub>8</sub>	Ta <sub>2</sub> O <sub>5</sub> , Sb <sub>2</sub> O <sub>3</sub>	0.99	0.024	TaSbO <sub>4</sub>	34.29
TaSb <sub>3</sub> O <sub>8</sub>	TaO <sub>3</sub> , Sb	0.36	0.119	TaSbO <sub>4</sub> , Sb <sub>2</sub> O <sub>3</sub>	34.29
TaVO <sub>5</sub>	TaVO <sub>4</sub>	0.44	0.051	VO <sub>2</sub> , Ta <sub>2</sub> O <sub>5</sub>	66.33
Tb <sub>2</sub> Mn <sub>2</sub> O <sub>7</sub>	MnO, Tb <sub>2</sub> O <sub>3</sub>	0.00	0.059	MnHO <sub>2</sub>	441.69
Tb <sub>2</sub> Mo <sub>3</sub> O <sub>12</sub>	MoO <sub>2</sub> , Tb <sub>2</sub> O <sub>3</sub>	1.00	0.060	TbHO <sub>2</sub> , Tb <sub>5</sub> Mo <sub>2</sub> O <sub>12</sub>	311.49
Tb <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	MoO <sub>2</sub> , Tb <sub>2</sub> O <sub>3</sub>	1.00	0.068	TbHO <sub>2</sub> , Tb <sub>5</sub> Mo <sub>2</sub> O <sub>12</sub>	267.44
Tb <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	Tb <sub>2</sub> O <sub>3</sub> , Pb	0.77	0.076	TbHO <sub>2</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	283.56
Tb <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Tb <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.078	TbHO <sub>2</sub>	24709.85
Tb <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Tb <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.101	TbHO <sub>2</sub>	2429.10
Tb <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Tb <sub>2</sub> S <sub>3</sub>	0.41	0.317	Tb <sub>2</sub> SO <sub>2</sub>	393.35
Tb <sub>3</sub> Fe <sub>5</sub> O <sub>12</sub>	FeO, Tb <sub>2</sub> O <sub>3</sub>	0.55	0.042	TbHO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub>	377.23
Tb <sub>3</sub> OsO <sub>7</sub>	Tb <sub>2</sub> O <sub>3</sub> , Os	1.00	0.051	TbHO <sub>2</sub>	3983.82
Tb <sub>3</sub> RuO <sub>7</sub>	Tb <sub>2</sub> O <sub>3</sub> , RuO <sub>2</sub>	1.00	0.012	TbHO <sub>2</sub> , Tb <sub>5</sub> Ru <sub>2</sub> O <sub>12</sub>	1458.26

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
Tb5Mo2O12	MoO <sub>2</sub> , Tb <sub>2</sub> O <sub>3</sub>	0.98	0.007	TbHO <sub>2</sub>	511.40
Tb5Ru2O12	Tb <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.061	TbHO <sub>2</sub>	1592.20
TbBi3O6	Tb <sub>2</sub> O <sub>3</sub> , Bi	0.75	0.082	TbHO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	147.67
TbCeO <sub>4</sub>	Ce <sub>5</sub> O <sub>9</sub> , Tb <sub>2</sub> O <sub>3</sub>	0.54	0.031	CeO <sub>2</sub> , TbHO <sub>2</sub>	347.62
TbCeO <sub>4</sub>	Tb <sub>2</sub> O <sub>3</sub> , CeO <sub>2</sub>	1.00	0.022	TbHO <sub>2</sub>	347.62
TbCrO <sub>4</sub>	Cr <sub>2</sub> O <sub>3</sub> , Tb <sub>2</sub> O <sub>3</sub>	1.00	0.058	TbCrO <sub>3</sub>	435.43
TbFeO <sub>3</sub>	FeO, Tb <sub>2</sub> O <sub>3</sub>	0.55	0.030	TbHO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub>	453.63
TbMn <sub>2</sub> O <sub>5</sub>	MnO, Tb <sub>2</sub> O <sub>3</sub>	0.00	0.069	MnHO <sub>2</sub>	341.73
TbRhO <sub>3</sub>	Tb <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.077	TbHO <sub>2</sub>	27018.73
TbSbO <sub>4</sub>	Tb <sub>2</sub> O <sub>3</sub> , Sb	0.22	0.116	Tb <sub>3</sub> SbO <sub>7</sub> , Tb <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	348.92
TbVO <sub>4</sub>	VO <sub>2</sub> , Tb <sub>2</sub> O <sub>3</sub>	0.98	0.029	TbHO <sub>2</sub>	438.09
TiBi <sub>12</sub> O <sub>20</sub>	TiO <sub>2</sub> , Bi	0.87	0.100	Bi <sub>2</sub> CO <sub>5</sub>	15.53
TiBi <sub>2</sub> O <sub>5</sub>	TiO <sub>2</sub> , Bi	0.88	0.088	Bi <sub>2</sub> CO <sub>5</sub>	14.44
TiS <sub>2</sub> O <sub>8</sub>	TiS <sub>2</sub>	0.98	0.533	TiO <sub>2</sub>	2.19
TiTi <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub> , Ti	0.59	0.032	Ti <sub>2</sub> CO <sub>3</sub>	4812.62
Ti <sub>2</sub> CrO <sub>4</sub>	Ti <sub>2</sub> O, Cr	0.70	0.091	Cr <sub>2</sub> O <sub>3</sub> , CrHO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	4628.00
Ti <sub>2</sub> Ge <sub>2</sub> O <sub>7</sub>	Ti <sub>4</sub> O <sub>3</sub> , Ge	0.38	0.132	Ti <sub>2</sub> CO <sub>3</sub> , GeO <sub>2</sub>	3907.27
Ti <sub>2</sub> Mo <sub>4</sub> O <sub>13</sub>	Ti, Mo	0.25	0.208	MoO <sub>2</sub>	2440.24
Ti <sub>2</sub> Mo <sub>7</sub> O <sub>22</sub>	Ti <sub>4</sub> O <sub>3</sub> , Mo	0.26	0.229	MoO <sub>2</sub>	1711.60
Ti <sub>2</sub> MoO <sub>4</sub>	MoO <sub>2</sub> , Ti	0.81	0.056	Ti <sub>2</sub> CO <sub>3</sub>	4275.39
Ti <sub>2</sub> O	Ti	0.57	0.038	Ti <sub>2</sub> CO <sub>3</sub>	5716.26
Ti <sub>2</sub> O <sub>3</sub>	Ti	0.89	0.105	Ti <sub>2</sub> CO <sub>3</sub>	5315.81
Ti <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	PtO <sub>2</sub> , Ti <sub>2</sub> O	0.89	0.035	Ti <sub>2</sub> CO <sub>3</sub> , TiPt <sub>3</sub> O <sub>4</sub> , Ti <sub>2</sub> Pt <sub>3</sub>	24647.46
Ti <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Ti <sub>2</sub> O <sub>3</sub> , Ru	0.63	0.089	Ti <sub>2</sub> CO <sub>3</sub> , RuO <sub>2</sub>	5152.62
Ti <sub>2</sub> SO <sub>4</sub>	Ti <sub>2</sub> S	0.98	0.127	None	4809.69
Ti <sub>2</sub> SnO <sub>3</sub>	Sn, Ti	0.11	0.083	Ti <sub>2</sub> CO <sub>3</sub> , SnO <sub>2</sub>	4224.70
Ti <sub>3</sub> O <sub>3</sub> Os <sub>3</sub> O <sub>10</sub>	Ti <sub>2</sub> O <sub>3</sub> , Os	0.98	0.065	Ti <sub>2</sub> CO <sub>3</sub>	8840.05
Ti <sub>3</sub> V <sub>5</sub> O <sub>14</sub>	V <sub>2</sub> O <sub>3</sub> , Ti <sub>2</sub> O	0.66	0.073	VO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	3339.32
Ti <sub>3</sub> VO <sub>4</sub>	VO, Ti	0.47	0.066	VO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	5003.36
Ti <sub>4</sub> Mo <sub>5</sub> O <sub>17</sub>	Ti, Mo	0.23	0.173	Ti <sub>2</sub> CO <sub>3</sub> , MoO <sub>2</sub>	3105.32
Ti <sub>4</sub> O <sub>3</sub>	Ti	0.72	0.055	Ti <sub>2</sub> CO <sub>3</sub>	5610.60
Ti <sub>4</sub> O <sub>3</sub>	Ti <sub>2</sub> O	0.00	0.018	TiHO, Ti <sub>2</sub> CO <sub>3</sub>	5610.60
Ti <sub>4</sub> V <sub>2</sub> O <sub>7</sub>	VO, Ti	0.39	0.078	VO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	4709.77
Ti <sub>5</sub> SbO <sub>5</sub>	Sb <sub>2</sub> O <sub>5</sub> , Ti	0.62	0.033	Ti <sub>2</sub> CO <sub>3</sub> , TiSbO <sub>3</sub>	4961.50
Ti <sub>5</sub> V <sub>3</sub> O <sub>10</sub>	V <sub>2</sub> O <sub>3</sub> , Ti	0.55	0.066	VO <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	4549.62
TiAgO <sub>2</sub>	AgO, Ti	0.04	0.046	TiHO, Ti <sub>2</sub> CO <sub>3</sub>	3727.63
TiAuO <sub>2</sub>	Ti, Au	0.96	0.074	Ti <sub>2</sub> CO <sub>3</sub> , TiAu <sub>3</sub>	20296.63
TiCu <sub>2</sub> O <sub>2</sub>	Ti <sub>4</sub> O <sub>3</sub> , Cu	0.32	0.055	TiHO, Ti <sub>2</sub> CO <sub>3</sub>	3342.78

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
TiCuO <sub>2</sub>	CuO, Ti <sub>4</sub> O <sub>3</sub>	0.10	0.013	TiHO, TiCu <sub>2</sub> O <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	4049.39
TiCuO <sub>2</sub>	Ti <sub>2</sub> O <sub>3</sub> , Cu	0.10	0.027	TiHO, TiCu <sub>2</sub> O <sub>2</sub> , Ti <sub>2</sub> CO <sub>3</sub>	4049.39
TiInO <sub>2</sub>	Ti, In	0.19	0.091	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	3635.10
TiMo <sub>6</sub> O <sub>17</sub>	MoO <sub>2</sub> , Ti	0.96	0.076	Ti <sub>2</sub> CO <sub>3</sub>	1173.16
TiMo <sub>6</sub> O <sub>17</sub>	MoO <sub>2</sub> , Ti <sub>2</sub> O <sub>3</sub>	1.00	0.053	Ti <sub>2</sub> MoO <sub>4</sub>	1173.16
TiPd <sub>3</sub> O <sub>4</sub>	Ti <sub>2</sub> O <sub>3</sub> , Pd	1.00	0.068	None	11650.58
TiPt <sub>3</sub> O <sub>4</sub>	Ti <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.047	Ti <sub>2</sub> CO <sub>3</sub> , Ti <sub>2</sub> Pt <sub>3</sub>	36608.37
TiReO <sub>4</sub>	ReO <sub>3</sub> , Ti <sub>4</sub> O <sub>3</sub>	0.00	0.009	Ti <sub>2</sub> CO <sub>3</sub>	4716.26
TiSbO <sub>3</sub>	Ti, Sb	0.41	0.128	Ti <sub>2</sub> CO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	3247.72
Tm <sub>2</sub> Mn <sub>2</sub> O <sub>7</sub>	MnO, Tm <sub>2</sub> O <sub>3</sub>	0.00	0.057	MnHO <sub>2</sub>	
Tm <sub>2</sub> Mo <sub>4</sub> O <sub>15</sub>	MoO <sub>2</sub> , Tm <sub>2</sub> O <sub>3</sub>	1.00	0.067	TmH <sub>3</sub> O <sub>3</sub>	
Tm <sub>2</sub> MoO <sub>6</sub>	MoO <sub>2</sub> , Tm <sub>2</sub> O <sub>3</sub>	1.00	0.030	TmH <sub>3</sub> O <sub>3</sub>	
Tm <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	Tm <sub>2</sub> O <sub>3</sub> , Pb	0.77	0.074	TmH <sub>3</sub> O <sub>3</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub> , PbO	
Tm <sub>2</sub> Pt <sub>2</sub> O <sub>7</sub>	Tm <sub>2</sub> O <sub>3</sub> , Pt	1.00	0.076	TmH <sub>3</sub> O <sub>3</sub>	
Tm <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	Tm <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.098	TmH <sub>3</sub> O <sub>3</sub>	
Tm <sub>2</sub> S <sub>3</sub> O <sub>12</sub>	Tm <sub>2</sub> S <sub>3</sub>	0.39	0.307	TmH <sub>3</sub> O <sub>3</sub> , Tm <sub>2</sub> O <sub>3</sub> , Tm <sub>2</sub> SO <sub>2</sub>	
TmBiO <sub>3</sub>	Tm <sub>2</sub> O <sub>3</sub> , Bi	0.56	0.056	TmH <sub>3</sub> O <sub>3</sub>	
TmCu <sub>2</sub> O <sub>4</sub>	CuO, Tm <sub>2</sub> O <sub>3</sub>	1.00	0.022	TmH <sub>3</sub> O <sub>3</sub>	
TmFeO <sub>3</sub>	FeO, Tm <sub>2</sub> O <sub>3</sub>	0.55	0.029	TmH <sub>3</sub> O <sub>3</sub> , Fe <sub>3</sub> O <sub>4</sub>	
TmMnO <sub>3</sub>	MnO, Tm <sub>2</sub> O <sub>3</sub>	0.00	0.029	MnHO <sub>2</sub>	
TmRhO <sub>3</sub>	Tm <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.075	TmH <sub>3</sub> O <sub>3</sub>	
TmSbO <sub>4</sub>	Tm <sub>2</sub> O <sub>3</sub> , Sb	0.20	0.113	Tm <sub>3</sub> SbO <sub>7</sub> , TmH <sub>3</sub> O <sub>3</sub> , Tm <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	
TmTiO <sub>2</sub>	Tm <sub>2</sub> O <sub>3</sub> , Ti	0.57	0.020	TmH <sub>3</sub> O <sub>3</sub> , Ti <sub>2</sub> CO <sub>3</sub>	
TmTiO <sub>3</sub>	Ti <sub>4</sub> O <sub>3</sub> , Tm <sub>2</sub> O <sub>3</sub>	0.14	0.028	TmH <sub>3</sub> O <sub>3</sub> , Ti <sub>2</sub> CO <sub>3</sub> , Ti <sub>2</sub> O <sub>3</sub> , TmTiO <sub>2</sub>	
TmTiO <sub>3</sub>	Tm <sub>2</sub> O <sub>3</sub> , Ti	0.89	0.057	TmH <sub>3</sub> O <sub>3</sub> , Ti <sub>2</sub> CO <sub>3</sub>	
TmVO <sub>4</sub>	TmVO <sub>3</sub>	0.33	0.056	TmH <sub>3</sub> O <sub>3</sub> , VO <sub>2</sub> , Tm <sub>2</sub> O <sub>3</sub>	
V <sub>2</sub> Bi <sub>4</sub> O <sub>11</sub>	Bi <sub>2</sub> O <sub>3</sub> , V <sub>2</sub> O <sub>3</sub>	0.92	0.029	VO <sub>2</sub> , Bi <sub>2</sub> CO <sub>5</sub>	14.62
V <sub>2</sub> Bi <sub>4</sub> O <sub>11</sub>	VO, Bi	0.75	0.129	VO <sub>2</sub>	14.62
V <sub>2</sub> Cd <sub>2</sub> O <sub>7</sub>	VO, Cd	0.45	0.182	VO <sub>2</sub> , CdCO <sub>3</sub>	5.83
V <sub>2</sub> Ni <sub>3</sub> O <sub>8</sub>	VO, Ni	0.69	0.236	VO <sub>2</sub>	13.41
V <sub>2</sub> Pb <sub>2</sub> O <sub>7</sub>	VO <sub>2</sub> , Pb	0.71	0.076	PbO, Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	4.09
V <sub>2</sub> Pb <sub>3</sub> O <sub>8</sub>	VO <sub>2</sub> , Pb	0.69	0.075	PbO, Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	3.61

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
V2Pb4O9	VO, Pb	0.51	0.104	VO <sub>2</sub> , PbCO <sub>3</sub>	3.33
V2Zn2O7	VO <sub>2</sub> , Zn	0.17	0.139	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	5.39
V2Zn2O7	ZnO, V <sub>2</sub> O <sub>3</sub>	0.38	0.093	ZnH <sub>2</sub> O <sub>2</sub> , VO <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	5.39
V3Bi6O16	VO, Bi	0.74	0.125	VO <sub>2</sub>	14.69
V3Pb4O12	VO, Pb	0.47	0.123	VO <sub>2</sub> , PbCO <sub>3</sub>	3.71
V4Cr2O13	CrO <sub>2</sub> , V <sub>2</sub> O <sub>3</sub>	0.55	0.093	CrHO <sub>2</sub> , VO <sub>2</sub> , Cr <sub>2</sub> O <sub>3</sub>	8.08
V4Fe2O13	Fe <sub>3</sub> O <sub>4</sub> , VO	0.35	0.194	VO <sub>2</sub> , FeO	6.02
VAg3O4	Ag, V	0.44	0.146	VO <sub>2</sub>	475.17
VBiO4	VO, Bi	0.68	0.148	VO <sub>2</sub>	13.78
VInO4	V <sub>2</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	0.35	0.070	VO <sub>2</sub> , InH <sub>3</sub> O <sub>3</sub>	275.92
VInO4	VO <sub>2</sub> , In	0.19	0.139	InH <sub>3</sub> O <sub>3</sub> , In <sub>2</sub> O <sub>3</sub>	275.92
VS2O8	VS <sub>2</sub>	0.99	0.527	VO <sub>2</sub>	3.23
WS2O8	WS <sub>2</sub>	1.00	0.340	WO <sub>3</sub>	0.11
WS2O9	WS <sub>2</sub>	1.00	0.367	WO <sub>3</sub>	0.10
Y2HgO4	Y <sub>2</sub> O <sub>3</sub> , Hg	1.00	0.036	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	43.16
Y2Ir2O7	Y <sub>2</sub> O <sub>3</sub> , Ir	1.00	0.095	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	11908.33
Y2Mn2O7	MnO, Y <sub>2</sub> O <sub>3</sub>	0.00	0.080	MnHO <sub>2</sub>	34.70
Y2Mo3O12	Y <sub>2</sub> O <sub>3</sub> , MoO <sub>2</sub>	0.79	0.073	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	36.41
Y2Pb2O7	Y <sub>2</sub> O <sub>3</sub> , Pb	0.77	0.091	PbO, YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	21.12
Y2Pt2O7	Y <sub>2</sub> O <sub>3</sub> , Pt <sub>3</sub> O <sub>4</sub>	1.00	0.031	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	29468.58
Y2Ru2O7	Y <sub>2</sub> O <sub>3</sub> , Ru	1.00	0.130	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	2664.18
Y2S3O12	Y <sub>2</sub> S <sub>3</sub>	0.36	0.412	Y <sub>2</sub> SO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , Y <sub>2</sub> O <sub>3</sub>	29.76
Y3Fe5O12	Y <sub>2</sub> O <sub>3</sub> , FeO	0.55	0.054	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , Fe <sub>3</sub> O <sub>4</sub>	28.24
YAgO2	Y <sub>2</sub> O <sub>3</sub> , Ag	1.00	0.035	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	332.79
YAuO2	Y <sub>2</sub> O <sub>3</sub> , Au	1.00	0.025	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	23872.61
YBi15O24	Y, Bi	0.77	0.106	Bi <sub>2</sub> CO <sub>5</sub>	17.22
YBi3O6	Y <sub>2</sub> O <sub>3</sub> , Bi	0.75	0.089	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , YBiO <sub>3</sub>	22.13
YBiO3	Y <sub>2</sub> O <sub>3</sub> , Bi	0.75	0.069	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	30.68
YCrO4	Y <sub>2</sub> O <sub>3</sub> , Cr <sub>2</sub> O <sub>3</sub>	1.00	0.078	CrO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , YCrO <sub>3</sub>	36.36
YCu2O4	Y <sub>2</sub> O <sub>3</sub> , CuO	1.00	0.029	YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , YCuO <sub>2</sub>	28.26
YCuO2	Y <sub>2</sub> O <sub>3</sub> , Cu	1.00	0.043	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	40.25
YFeO3	Y <sub>2</sub> O <sub>3</sub> , FeO	0.57	0.042	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub> , Fe <sub>3</sub> O <sub>4</sub>	36.01
YMn2O5	MnO, Y <sub>2</sub> O <sub>3</sub>	0.00	0.086	MnHO <sub>2</sub>	24.88

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
YMnO <sub>3</sub>	MnO, Y <sub>2</sub> O <sub>3</sub>	0.00	0.042	MnHO <sub>2</sub>	36.15
YPd <sub>2</sub> O <sub>4</sub>	Y <sub>2</sub> O <sub>3</sub> , PdO	1.00	0.022	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	10285.39
YRhO <sub>3</sub>	Y <sub>2</sub> O <sub>3</sub> , Rh	1.00	0.100	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	34439.52
YVO <sub>4</sub>	Y <sub>2</sub> O <sub>3</sub> , VO <sub>2</sub>	1.00	0.039	YHO <sub>2</sub> , YC <sub>2</sub> H <sub>2</sub> O <sub>6</sub>	37.87
Yb <sub>2</sub> Cu <sub>2</sub> O <sub>5</sub>	CuO, YbO	0.02	0.029	YbCO <sub>3</sub>	
Yb <sub>2</sub> Ru <sub>2</sub> O <sub>7</sub>	YbO, Ru	0.02	0.121	YbCO <sub>3</sub>	
Yb <sub>2</sub> VO <sub>5</sub>	VO, YbO	0.02	0.067	YbVO <sub>3</sub> , YbCO <sub>3</sub> , VO <sub>2</sub>	
Yb <sub>3</sub> Ga <sub>5</sub> O <sub>12</sub>	Ga <sub>2</sub> O <sub>3</sub> , YbO	0.02	0.023	YbCO <sub>3</sub>	
Yb <sub>3</sub> Sb <sub>5</sub> O <sub>12</sub>	YbO, Sb	0.03	0.109	YbCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	
YbBi <sub>12</sub> O <sub>20</sub>	Bi, Yb	0.71	0.107	YbCO <sub>3</sub> , Bi <sub>2</sub> CO <sub>5</sub>	
YbBiO <sub>3</sub>	YbO, Bi	0.02	0.074	YbCO <sub>3</sub>	
YbCe <sub>9</sub> O <sub>20</sub>	Ce <sub>11</sub> O <sub>20</sub> , YbO	0.03	0.024	YbCeO <sub>3</sub> , YbCO <sub>3</sub> , CeO <sub>2</sub>	
YbCrO <sub>3</sub>	Cr <sub>2</sub> O <sub>3</sub> , YbO	0.02	0.029	CrHO <sub>2</sub> , YbCO <sub>3</sub>	
YbCrO <sub>4</sub>	YbO, Cr	0.02	0.166	Cr <sub>2</sub> O <sub>3</sub> , YbCO <sub>3</sub>	
YbEu <sub>3</sub> O <sub>6</sub>	Eu <sub>3</sub> O <sub>4</sub> , YbO	0.02	0.022	YbCO <sub>3</sub> , Eu <sub>2</sub> O <sub>3</sub>	
YbFe <sub>2</sub> O <sub>4</sub>	FeO, YbO	0.02	0.046	Fe <sub>3</sub> O <sub>4</sub> , YbCO <sub>3</sub>	
YbFeO <sub>3</sub>	YbO, Fe	0.02	0.116	YbCO <sub>3</sub>	
YbMnO <sub>3</sub>	MnO, YbO	0.00	0.058	MnHO <sub>2</sub> , YbCO <sub>3</sub>	
YbNbO <sub>4</sub>	YbNbO <sub>3</sub>	0.02	0.048	YbCO <sub>3</sub> , Nb <sub>2</sub> O <sub>5</sub> , YbO	
YbRhO <sub>3</sub>	YbO, Rh	0.02	0.099	YbCO <sub>3</sub>	
YbSbO <sub>4</sub>	YbO, Sb	0.02	0.134	YbCO <sub>3</sub> , Sb <sub>2</sub> O <sub>3</sub>	
YbTaO <sub>4</sub>	Ta <sub>2</sub> O <sub>5</sub> , YbO	0.02	0.019	Ta <sub>2</sub> H <sub>4</sub> O <sub>7</sub> , YbCO <sub>3</sub> , TaO <sub>3</sub>	
Zn <sub>2</sub> PtO <sub>4</sub>	Zn, Pt	0.68	0.164	ZnH <sub>2</sub> O <sub>2</sub> , ZnPt	25679.20
Zn <sub>3</sub> CdO <sub>4</sub>	Cd, Zn	0.11	0.172	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	2.49
Zn <sub>3</sub> Mo <sub>2</sub> O <sub>9</sub>	Zn, Mo	0.12	0.271	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>3</sub> Mo <sub>3</sub> O <sub>8</sub>	13.43
Zn <sub>4</sub> CoO <sub>5</sub>	Zn, Co	0.09	0.200	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	8.23
Zn <sub>7</sub> Sb <sub>2</sub> O <sub>12</sub>	Sb <sub>2</sub> O <sub>3</sub> , Zn	0.37	0.161	ZnH <sub>2</sub> O <sub>2</sub> , ZnSb <sub>2</sub> O <sub>4</sub> , Zn <sub>6</sub> HO <sub>6</sub>	3.53
ZnCu <sub>2</sub> O <sub>4</sub>	CuO, Zn	1.00	0.125	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	4.38
ZnFe <sub>2</sub> O <sub>4</sub>	Fe <sub>3</sub> O <sub>4</sub> , Zn	0.55	0.088	FeO, ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	0.65
ZnFe <sub>2</sub> O <sub>4</sub>	FeO, Zn	0.35	0.133	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>6</sub> HO <sub>6</sub>	0.65
ZnMo <sub>2</sub> O <sub>7</sub>	Zn, Mo	0.22	0.303	MoO <sub>2</sub>	18.58
ZnMoO <sub>4</sub>	Zn, Mo	0.22	0.284	Zn <sub>3</sub> Mo <sub>3</sub> O <sub>8</sub>	15.54
ZnO	Zn	0.05	0.197	Zn <sub>6</sub> HO <sub>6</sub>	1.77
ZnPt <sub>3</sub> O <sub>6</sub>	Pt <sub>3</sub> O <sub>4</sub> , Zn	1.00	0.043	ZnH <sub>2</sub> O <sub>2</sub> , Zn <sub>2</sub> PtO <sub>4</sub>	40227.57
ZnRh <sub>2</sub> O <sub>4</sub>	Zn, Rh	0.90	0.191	ZnH <sub>2</sub> O <sub>2</sub> , ZnRh <sub>3</sub>	49234.07
ZnSO <sub>4</sub>	ZnS	0.98	0.396	None	0.89
ZnSb <sub>2</sub> O <sub>4</sub>	Zn, Sb	0.31	0.172	ZnH <sub>2</sub> O <sub>2</sub> , Sb <sub>2</sub> O <sub>3</sub>	6.13

Oxidized Phase	Reduced Phase(s)	Max CH <sub>4</sub> Conv.	R <sub>oc</sub>	Side Products	Price (\$)
ZnSb <sub>2</sub> O <sub>6</sub>	SbO <sub>2</sub> , Zn	1.00	0.079	ZnH <sub>2</sub> O <sub>2</sub> , ZnSb <sub>2</sub> O <sub>4</sub> , Zn <sub>6</sub> H <sub>6</sub> O <sub>6</sub> , Sb <sub>2</sub> O <sub>3</sub>	5.65
Zr <sub>2</sub> Bi <sub>2</sub> O <sub>7</sub>	ZrO <sub>2</sub> , Bi	0.88	0.067	Bi <sub>2</sub> CO <sub>5</sub>	35.94
ZrMo <sub>2</sub> O <sub>8</sub>	ZrO <sub>2</sub> , Mo	0.22	0.234	MoO <sub>2</sub>	38.53
ZrPbO <sub>3</sub>	ZrO <sub>2</sub> , Pb	0.38	0.046	Pb <sub>2</sub> CO <sub>4</sub> , PbCO <sub>3</sub>	27.78
ZrS <sub>2</sub> O <sub>8</sub>	ZrS <sub>2</sub>	0.97	0.452	ZrO <sub>2</sub>	32.19
ZrV <sub>2</sub> O <sub>7</sub>	ZrO <sub>2</sub> , V <sub>2</sub> O <sub>3</sub>	0.43	0.105	VO <sub>2</sub>	35.04

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