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THE PHYSICAL PROPERTIES OF RED MUD AS ABSORBANCE

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Abstract

Red mud is a waste material generated during alumina refining that has traditionally been viewed as an environmental and disposal challenge. The history of red mud, its traditional uses, and potential applications in the future, particularly in carbon capture were explored. However, recent research has revealed that red mud has potential for a range of applications, includeing environmental remediation, energy conversion, and materials science. In particular, nano red mud has emerged as a promising material due to its high surface area, enhanced adsorption and catalytic properties, and potential for functionalization. Despite these advantages, there are also potential health and safety concerns associated with the use of nano red mud, and the synthesis of this material can be expensive and difficult. Nonetheless, further research is needed to optimize the synthesis and application of red mud and nano red mud, and to address the challenges and limitations associated with their use. The potential applications

Keywords

Red mud, characterization, adsorbance, nano, properties

of red mud and nano red mud are promising, and they have the potential to contribute to a more sustainable and resource-efficient future

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Introduction. Red mud, also known as bauxite residue, is a byproduct of the Bayer process, which is used to extract aluminum oxide from bauxite ore. Bauxite is a reddish-brown rock that is primarily composed of aluminum hydroxide minerals, along with various impurities such as iron oxides, silica, and titania. During the Bayer process, bauxite ore is digested with a solution of sodium hydroxide at high temperature and pressure, which dissolves the aluminum oxide and leaves behind the impurities as a solid residue. This solid residue, known as red mud, is highly alkaline and can have a pH value as high as 13. Red mud is typically stored in large ponds or impoundments, which can pose a risk of environmental contamination if not properly managed. The high pH of red mud can cause it to leach heavy metals and other contaminants into the surrounding soil and water, which can have negative impacts on local ecosystems and human health. However, red mud also contains valuable metals such as iron, titanium, and rare earth elements, which can be extracted and used for various applications. Researchers are exploring ways to develop more sustainable and environmentally friendly methods for processing red mud, such as using it as a source of raw materials for construction or using it to remove pollutants from wastewater [1–3].

The usage and application of red mud have evolved over time and continue to evolve as new technologies and applications are developed. In the past, red mud was primarily disposed of in large impoundments or ponds, where it could pose a risk of environmental contamination. Red mud has been used as a source of raw material for manufacturing building materials such as bricks and tiles, due to its high content of iron and aluminum oxides. In present, red mud can be used as a substitute for clay in cement production, reducing the need for virgin raw materials and lowering carbon emissions. Red mud can be used as a soil amendment to improve soil structure and fertility, and to remediate contaminated soils. Red mud can be used to remove pollutants such as heavy metals, organic compounds, and nutrients from wastewater. In future, red mud contains high concentrations of rare earth elements, which are critical for many high-tech applications. Researchers are developing new methods for extracting these elements from red mud. It has high levels of iron, which can be used to produce iron-based batteries for energy storage. Red mud can be used as a sorbent for capturing carbon dioxide from industrial emissions. The future of red mud usage and application is likely to focus on finding innovative ways to extract valuable metals and minerals, while also reducing the environmental impact of red mud disposal. The potential usage of red mud in future has several potential futures uses that could help to reduce waste, create new products, and support sustainable development. Red mud contains high concentrations of rare earth elements (REEs), which are critical for many high-tech applications, including smartphones, electric vehicles, and renewable energy systems. Researchers are exploring new methods for extracting these REEs from red mud, which could help to reduce our reliance on rare earth mining and improve the sustainability of these industries. It can be used as a raw material for manufacturing building materials such as bricks and tiles, due to its high content of iron and aluminum oxides. Researchers are exploring ways to use red mud in more advanced construction materials, such as concrete and asphalt, which could help to reduce the environmental impact of these industries. It can be used as a sorbent for capturing carbon dioxide from industrial emissions. Researchers are exploring ways to optimize this process, which could help to reduce greenhouse gas emissions and mitigate climate change. The potential uses of red mud in the future are wide-ranging and diverse, reflecting the material's high value and versatility. Continued research and development in this area could help to create new industries, reduce waste, carbon capture, and support sustainable development [3–6]. The concept of carbon capture in Fig. 1.

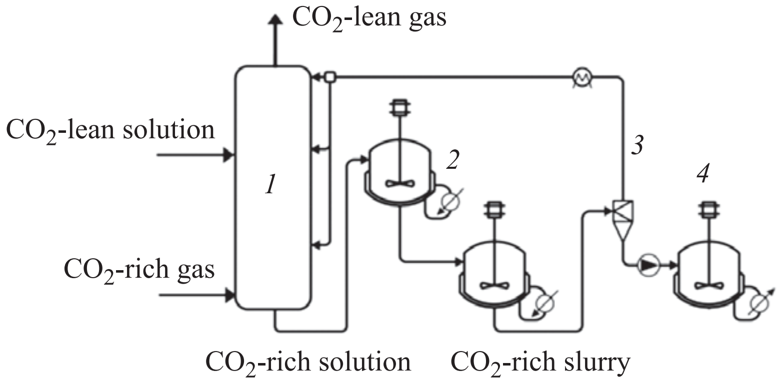

Fig. 1. The carbon capture process:
1 — CO_2 absorber; *2* — crystallization; *3* — separation; *4* — dissolution

Overview of red mud and its synthesis for adsorbent. Following new issue, the global agreement to reduce carbon emissions has increased the demand for sustainable and environmentally friendly products and processes, which has created new opportunities for red mud utilization. It can be used as a sorbent for capturing carbon dioxide from industrial emissions. By using red mud as a carbon capture material, industries can reduce their carbon footprint and contribute to the global effort to mitigate climate change [7]. Also, it can be used as a substitute for clay in cement production, reducing the need for virgin raw materials and lowering carbon emissions. As the construction industry seeks to reduce its carbon footprint, the use of red mud in cement production could become more widespread. It contains high levels of iron, which can be used to produce iron-based batteries for energy storage. As renewable energy systems become more common, the demand for sustainable and cost-effective energy storage solutions is increasing. Red mud-based batteries could help to meet this demand while reducing the environmental impact of energy storage systems. It has high concentrations of REEs, which are critical for many high-tech applications. By recovering these REEs from red mud, industries can reduce their reliance on environmentally damaging rare earth mining and support the development of more sustainable technologies. Another function, it can be used to remove pollutants such as heavy metals, organic compounds, and nutrients from wastewater. By using red mud in wastewater treatment, industries can reduce their environmental impact and support sustainable water management practices. The red mud has significant potential for use in a carbon-less future, with applications ranging from carbon capture to rare earth element recovery to battery production. Continued research and development in this area could help to create new industries, reduce waste, and support sustainable develop-ment [8].

The conceptualization of carbon capture using red mud involves using the material as a sorbent to capture carbon dioxide CO_2 from industrial emissions. The process involves exposing the red mud to a stream of flue gas, which contains CO_2 as well as other pollutants such as sulfur dioxide and nitrogen oxides. The red mud sorbent reacts with the CO_2, absorbing it and trapping it within the material. The resulting “captured” CO_2 can then be sequestered or used in other applications. There are several advantages to using red mud as a carbon capture material. First, it is readily available and inexpensive, as it is a byproduct of the aluminum refining process. Second, it has a high surface area and high alkalinity, which make it an effective sorbent for CO_2. Third, using red mud for carbon capture can help to reduce the environmental impact of industrial emissions and contribute to global efforts to mitigate climate change. There are several challenges associated with using red mud for carbon capture as well. One challenge is the potential for the red mud to leach out heavy metals and other pollutants when exposed to water or acidic conditions. Another challenge is the need to optimize the sorbent material to maximize CO_2 capture while minimizing other undesirable reactions. Despite these challenges, researchers and companies are actively exploring the use of red mud for carbon capture, with promising results. Continued research and development in this area could help to improve the efficiency and effectiveness of red mud-based carbon capture technologies and support the transition to a more sustainable and low-carbon future.

The mechanisms of carbon capture in red mud involve the adsorption and chemical reactions between CO_2 and the components of the red mud. CO_2 molecules are physically adsorbed onto the surface of the red mud particles. This occurs due to the high surface area of the red mud, which provides ample sites for CO_2 adsorption. CO_2 molecules react chemically with the metal oxides in the red mud, forming stable carbonates. The alkaline nature of red mud, due to the presence of metal hydroxides and carbonates, enhances the chemisorption process. The carbonates formed in the chemisorption step react with water to form bicarbonates, which can be converted back to CO_2 by heating. This allows the captured CO_2 to be sequestered or used in other applications. The specific mechanisms of carbon capture in red mud can vary depending on factors such as the composition of the red mud and the conditions under which the capture process takes place. However, the overall process generally involves a combina-tion of physical adsorption and chemical reactions between CO_2 and the components of the red mud [9].

Activating the carbon capture property in red mud involves modifying the material to increase its surface area and alkalinity, which enhances its ability to adsorb and chemically react with CO_2. Treating red mud with an acid, such as hydrochloric acid or sulfuric acid, can increase its surface area and porosity, making it more effective at adsorbing CO_2 [10]. This process is known as acid activation and involves leaching out the metal oxides and other impurities that can block adsorption sites. Red mud is naturally alkaline due to the presence of metal hydroxides and carbonates, but treating it with an alkali, such as sodium hydroxide or potassium hydroxide, can increase its alkalinity and enhance its carbon capture properties. Impregnation involves soaking red mud in a solution of chemicals that can enhance its carbon capture properties, such as potassium carbonate or sodium carbonate. This process can increase the amount of chemically reactive sites on the red mud surface, improving its ability to capture CO_2. Heating red mud can increase its porosity and surface area, making it more effective at adsorbing CO_2. This process is known as thermal activation and involves heating the red mud at temperatures between 200 °C and 800 °C. Overall, activating the carbon capture property in red mud involves modifying its properties to enhance its adsorption and chemical reaction capabilities. Each activation method has its own advantages and limitations, and the optimal method will depend on factors such as the composition of the red mud and the specific carbon capture application [11–17]. The carbon yield in carbon capture process of red mud in Fig. 2.

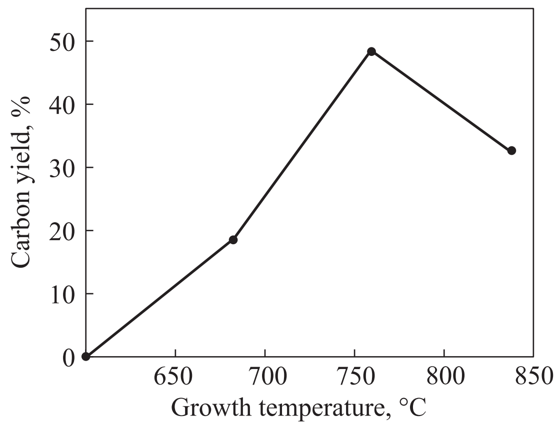

Fig. 2. The carbon yield of red mud [10]

Nano red mud and recent development. Particle size also can have a significant effect on the carbon capture property of red mud. Smaller particle size results in a higher surface area per unit mass of red mud, which can increase the number of adsorption sites available for CO_2 capture [18–22]. This can enhance the physical adsorption of CO_2 onto the surface of the red mud particles. This process can enhance diffusion of CO_2 into the internal pores of the red mud particles, allowing for greater penetration of CO_2 into the material and increasing the amount of chemisorption that occurs. And it can enhance the chemical reactivity of red mud due to the increased accessibility of metal oxide sites. This can lead to a greater extent of carbonation and bicarbonate formation, which can increase the overall CO_2 capture capacity of the red mud [17–24]. However, there are also some potential drawbacks to using smaller particle sizes of red mud for carbon capture. These include increased pressure drop in the capture system due to the smaller pore size, increased tendency for particle agglomeration, and increased difficulty in separating the red mud particles from the gas stream after capture [25].

Nano red mud can be produced using a variety of methods, including chemical, physical, and biological methods. Here are some common mechanisms for making nano red mud, sol-gel method, this involves the hydrolysis and condensation of metal alkoxides or metal salts in a solution containing red mud particles. This results in the formation of a gel, which can be dried and calcined to produce nano red mud particles. This method allows for precise control over the particle size and morphology of the resulting material. Ultrasonication, the use of high-frequency sound waves to break down red mud particles into smaller sizes. This can be done in a liquid medium to produce a stable suspension of nano red mud particles. This method is relatively simple and low-cost but can be time-consuming and may require the use of surfactants to stabilize the suspension. Ball milling, the use of mechanical force to break down red mud particles into smaller sizes. This can be done using a ball mill, which uses balls of different sizes and materials to grind the red mud particles into a fine powder. This method is relatively simple and low-cost but can lead to particle agglomeration and contamination from the milling media. Biogenic method, the use of microorganisms, such as bacteria or fungi, to biologically synthesize nano red mud particles. This method is environmentally friendly and can produce highly crystalline particles with well-defined shapes and sizes. However, it can be time-consuming and may require the use of specialized equipment and culture media. The mechanisms for making nano red mud depend on the specific application and desired properties of the resulting material. Careful consideration of the advantages and disadvantages of each method is necessary to choose the optimal approach for a given application. There has been significant recent research focused on the synthesis and application of nano red mud. Nano red mud has been found to be an effective adsorbent for heavy metals such as lead, cadmium, and chromium. Recent studies have focused on optimizing the synthesis of nano red mud particles to enhance their adsorption properties and to develop novel functionalization strategies to improve their selectivity and reusability. It has also been investigated as a potential adsorbent for carbon capture. Recent studies have focused on optimizing the synthesis of nano red mud particles to enhance their CO_2 adsorption capacity and stability under various operating conditions. It has been found to exhibit catalytic activity for a variety of chemical reactions, including the conversion of CO_2 to value-added chemicals and the degradation of organic pollutants. Recent studies have focused on understanding the underlying mechanisms of these catalytic processes and developing new catalyst formulations based on nano red mud particles [26–33]. CO_2 neutralization is using reaction equations [25]:

$$NaAl(OH)_4 + CO_2 \leftrightarrow NaAlCO_3(OH)_2 + H_2O \tag{1}$$

$$NaOH + CO_2 \leftrightarrow NaHCO_3 \tag{2}$$

$$Na_2CO_3 + CO_2 + H_2O \leftrightarrow 2NaHCO_3 \qquad (3)$$

$$3Ca(OH)_2 + 2Al(OH)_3 + 3CO_2 \leftrightarrow 3CaCO_3 + Al_2O_3 + 3H_2O \qquad (4)$$

$$Na_6[AlSiO_4]_6 + 2NaOH + 2CO_2 \leftrightarrow Na_6[AlSiO_4]_6 + NaHCO_3 \qquad (5)$$

Equations (1)–(5) demonstrate that the use of red mud as CO_2 absorbance can be adjusted, as can the use of novel media to reduce the glass house effect.

Nano red mud has several advantages and disadvantages compared to conventional red mud. Nano red mud has a significantly higher surface area than conventional red mud, which makes it more reactive and increases its adsorption and catalytic properties. It can be functionalized with various surface groups to enhance its selectivity for specific target compounds or ions. It has less prone to agglomeration and sedimentation than conventional red mud particles, which makes them more stable and easier to handle. It can potentially be synthesized using greener and more sustainable methods, such as biogenic synthesis, which reduces the environmental impact of the material [28–30].

Nano red mud particles also have disadvantages, it may pose health and safety risks due to their small size and high surface area. Proper safety measures must be taken when handling and synthesizing nano red mud. The synthesis of nano red mud can be more expensive and time-consuming than conventional red mud due to the need for specialized equipment and processing methods. Nano red mud may not be widely available, and the quality and consistency of the material may vary depending on the synthesis method and source. It has prone to aggregation and may lose their properties if not properly stabilized or dispersed. Overall, the advantages and disadvantages of nano red mud depend on the specific application and synthesis method. Careful consideration of these factors is necessary to determine whether nano red mud is a suitable material for a given application [31–33].

Conclusion. Red mud is a by-product of alumina refining and has traditionally been viewed as a waste material. However, recent research has shown that red mud has potential applications in a variety of fields, including environmental remediation, energy conversion, and materials science. In particular, nano red mud has emerged as a promising material due to its high surface area, enhanced adsorption and catalytic properties, and potential for functionalization. However, the use of nano red mud also presents potential health and safety concerns and may be more expensive and difficult to synthesize than conventional red mud. As the field continues to develop, further research will be needed to optimize the synthesis and application of red mud and to address the challenges associated with its use. Nevertheless, the potential applications of red mud and nano red mud are promising, and they have the potential to contribute to a more sustainable and resource-efficient future.

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REFERENCES

[1] Li L.Y. A study of iron mineral transformation to reduce red mud tailings. *Waste Manage*., 2001, vol. 21, iss. 6, pp. 525–534.
DOI: https://doi.org/10.1016/S0956-053X(00)00107-0

[2] Genc-Fuhrman H., Tjell J.C., McConchie D. Adsorption of arsenic from water using activated neutralized red mud. *Environ. Sci. Technol*., 2004, vol. 38, iss. 8, pp. 2428–2434. DOI: https://doi.org/10.1021/es035207h

[3] Burchell T.D., Judkins R.R. Passive CO_2 removal using a carbon fiber composite molecular sieve. *Energy Conserv. Manag*., 1996, vol. 37, iss. 6-8, pp. 947–954.
DOI: https://doi.org/10.1016/0196-8904(95)00282-0

[4] White C.M., Strazisar B.R., Granite E.J., et al. Separation and capture of CO_2 from large stationary sources and sequestration in geological formation-coalbeds and deep saline aquifers. *J. Air Waste Manag. Assoc*., 2003, vol. 53, iss. 6, pp. 645–715.
DOI: https://doi.org/10.1080/10473289.2003.10466206

[5] Enick R.M., Beckman E.J., Shi C., et al. Remediation of metal-bearing aqueous waste streams via direct carbonation. *Energy Fuels*, 2001, vol. 15, iss. 2, pp. 256–262.
DOI: https://doi.org/10.1021/ef000245x

[6] Richard S., Rajadurai J.S., Manikandan V., et al. Study of tribological properties of nano-sized red mud particle-reinforced polyester composites. *Trans. Indian Inst. Met*., 2019, vol. 72, no. 9, pp. 2417–2431. DOI: https://doi.org/10.1007/s12666-019-01694-0

[7] Goldberg D.C., Gray A.G., Hamaker J.C., et al. Processes for extracting Alumina from nonbauxite ores. Washington, National Academies Press, 1970.

[8] Gupta K.K. Extraction of non-ferrous metals. In: *Principles of Engineering Metallurgy*. New Age International, 2007, pp. 3–35.

[9] Paramguru R.K., Rath P.C., Misra V.N. Trends in red mud utilization — a review. *Miner. Process. Extr. Metall. Rev*., 2005, vol. 26, iss. 1, pp. 1–29.
DOI: https://doi.org/10.1080/08827500490477603

[10] Rao P.P. The characteristics and genesis discussion of fracture in dry red mud disposal yard. *Ind. Const*., 2010, vol. 40, pp. 73–77.

[11] Zhang Y., Li L. Recent advances in the synthesis and applications of nano red mud: a review. *Chemical Engineering Journal*, 2020, vol. 398, art. 125577.

[12] Bhattacharyya K.G., Gupta S.S. Adsorption of heavy metals from aqueous solutions using nano-particles of red mud. *Journal of Hazardous Materials*, 2019, vol. 371, pp. 709–724.

[13] Hanahan C., McConchie D., Pohl J., et al. Chemistry of seawater neutralization of bauxite refinery residues (red mud). *Environ. Eng. Sci.*, 2004, vol. 21, no. 2, pp. 125–138. DOI: https://doi.org/10.1089/109287504773087309

[14] Glenister D.J., Thornber M.R. Alkalinity of red mud and its applications for management of acid wastes. *Chemica*, 1995, vol. 85, pp. 100–113.

[15] Piga L., Pochette F., Stoppa L. Recovering metals from red mud generated during alumina production. *JOM*, 1993, vol. 45, no. 11, pp. 54–59.
DOI: https://doi.org/10.1007/BF03222490

[16] Khaitan S., Dzomback D.A., Gregory V.L. Mechanisms of neutralization of bauxite residue by carbon dioxide. *J. Environ. Eng.*, 2009, vol. 135, no. 6, pp. 433–438.
DOI: http://dx.doi.org/10.1061/(ASCE)EE.1943-7870.0000010

[17] Hoang M. Catalysts and processes for treatment of industrial process and waste streams. Patent WO 2000000285. Appl. 25.06.1999, publ. 06.01.2000.

[18] Sushil S., Batra V.S. Catalytic applications of red mud, an aluminium industry waste: a review. *Appl. Catal. B*, 2008, vol. 81, iss. 1-2, pp. 64–77.
DOI: https://doi.org/10.1016/j.apcatb.2007.12.002

[19] Shing J.S. Method of activation of red mud. Patent US 4017425. Appl. 10.11.1972, publ. 12.04.1994.

[20] Cakici A.I., Yanik J., Karayildirim T., et al. Utilization of red mud as catalyst in conversion of waste oil and waste plastics to fuel. *J. Mater. Cycles Waste Manag.*, 2004, vol. 6, no. 1, pp. 20–26. DOI: https://doi.org/10.1007/s10163-003-0101-y

[21] Garg D., Givens E.N. Coal liquefaction catalysis by industrial metallic wastes. *Ind. Eng. Chem. Process Des. Dev.*, 1985, vol. 24, iss. 1, pp. 66–72.
DOI: https://doi.org/10.1021/i200028a012

[22] Shaobin W., Aug H.M., Tade M.O. Novel applications of red mud as coagulant, adsorbent and catalyst for environmentally benign processes. *Chemosphere*, 2008, vol. 72, iss. 11, pp. 1621–1635. DOI: https://doi.org/10.1016/j.chemosphere.2008.05.013

[23] Yadav V.S., Prasad M., Khan J., et al. Sequestration of carbon dioxide (CO_2) using red mud. *J. Hazard. Mater.*, 2010, vol. 176, no. 1-3, pp. 1044–1050.
DOI: https://doi.org/10.1016/j.jhazmat.2009.11.146

[24] Marabini A.M., Plescia P., Maccari D., et al. New materials from industrial and mining wastes: glass-ceramics and glass- and rock-wool fibre. *Int. J. Miner. Process.*, 1998, vol. 53, iss. 1-2, pp. 121–134. DOI: https://doi.org/10.1016/S0301-7516(97)00062-8

[25] Yalcin N., Sevinc V. Utilization of bauxite waste in ceramic glazes. *Ceram. Int.*, 2000, vol. 26, iss. 5, pp. 485–493. DOI: https://doi.org/10.1016/S0272-8842(99)00083-8

[26] Ayres R.U., Holmberg J., Andersson B. Materials and the global environment: waste mining in the 21st century. *MRS Bulletin*, 2001, vol. 26, no. 6, pp. 477–480.
DOI: https://doi.org/10.1557/mrs2001.119

[27] Cundi W., Hirano Y., Terai T., et al. Preparation of geopolymeric monoliths from red mud–PFBC ash fillers at ambient temperature. *Proc. World Congress Geopolymer*, 2005, pp. 85–87.

[28] Lyon R.E., Balaguru P.N., Foden A., et al. Fire resistant aluminosilicate composites. *Fire Mater.*, 1997, vol. 21, pp. 67–73.

[29] Giancaspro J., Balaguru P.N., Lyon R.E. Use of inorganic polymer to improve the fire response of balsa sandwich structures. *J. Mater. Civ. Eng.*, 2006, vol. 18, pp. 390–397. DOI: https://doi.org/10.1061/(ASCE)0899-1561(2006)18:3(390)

[30] Buchwald A., Hohmann M., Kaps C., et al. Stabilized foam clay material with high performance thermal insulation properties. *Ceramic Forum International*, 2004, vol. 81, no. 8, pp. 39–42.

[31] Barbosa V.F.F., MacKenzie K.J.D. Synthesis and thermal behaviour of potassium sialate geopolymers. *Mater. Lett.*, 2003, vol. 57, no. 9, pp. 1477–1482.
DOI: https://doi.org/10.1016/S0167-577X(02)01009-1

[32] Zhang S.Z., Gong K.C., Lu H.W. Novel modification method for inorganic geopolymer by using water soluble organic polymers. *Mater. Lett.*, 2004, vol. 58, iss. 7-8, pp. 1292–1296. DOI: https://doi.org/10.1016/j.matlet.2003.07.051

[33] Bonenfant D., Kharoune L., Sauve S., et al. CO_2 sequestration by aqueous red mud carbonation at ambient pressure and temperature. *Ind. Eng. Chem. Res.*, 2008, vol. 47, iss. 20, pp. 7617–7622. DOI: https://doi.org/10.1021/ie7017228

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