- Talabalar kichik guruhlarga bo‘linadilar.
- Har bir guruh o‘zi ko‘rgan yodgorliklardan birini tanlab, unga sayyohlarni jalb qilish uchun 2 daqiqalik “virtual turoperator” taqdimotini tayyorlaydi.
- Taqdimotlarni bir-biriga sinchkovlik bilan tinglash va baholash.

4. Yakuniy baholash (5 daqiqa):

- O‘qituvchi interfaol mashq natijalarini (avtomatik baho) va guruh taqdimotlarini (o‘qituvchi va talabalar tomonidan baholash) umumlashtiradi.
- Uy vazifasi sifatida talabalardan boshqa bir O‘zbekiston shahri (masalan, Xiva) uchun shunga o‘xshash virtual ekskursiya marshrutini loyihalash so‘raladi.

Xulosa

Xulosa qilib shuni ta'kidlash kerakki, zamonaviy ta'lim texnologiyalari, xususan virtual ekskursiyalar, turizm yo‘nalishi talabalari uchun nafaqat qulay, balki juda samarali va motivatsion o‘quv vositasi hisoblanadi. Ushbu texnologiyalar nazariy bilimlarni amaliy ko‘nikmalar bilan uyg‘unlashtirish, talabalarning kognitiv qobiliyatlarini oshirish va ularni kelajakdagi kasbiy faoliyatiga tayyorlashda muhim rol o‘ynaydi.

An'anaviy dars metodlari o‘zining ahamiyatini yo‘qotmagan bo‘lsa-da, ularni virtual reallik elementlari bilan uyg‘unlashtirish yangi sifatni yuzaga keltiradi. Taklif etilgan “ARFAS” modeli va dars loyihasi shuni ko‘rsatadiki, bunday yondashuv darsni yanada qiziqarli, interfaol va shu bilan birga chuqur mazmunli qilishga xizmat qiladi. Ta’lim sifatini oshirishda zamonaviy texnologiyalardan foydalanish nafaqat talabalarning bilim darajasini, balki ularning fan va kasbga bo‘lgan munosabatini ham yaxshilaydi.

Kelajakda turli xil VR-kontentni ishlab chiqish, o‘qituvchilarni maxsus tayyorlash va texnik infratuzilmani takomillashtirish orqali virtual ekskursiyalardan foydalanish kengayib boradi va bu borada olib boriladigan keyingi tadqiqotlar turizm ta'limi sifatini yanada oshirishga hissa qo‘shadi.

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APPLICATION OF ARTIFICIAL INTELLIGENCE FOR MODELLING AND OPTIMIZATION OF CO_2 ABSORPTION BY NAOH TO FORM Na_2CO_3

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Abstract. The growing need to reduce anthropogenic CO_2 emissions has intensified research on carbon capture and utilization (CCU). Chemical absorption of CO_2 in sodium hydroxide (NaOH) solutions forming sodium carbonate (Na_2CO_3) is a well-established method, yet traditional models often fail to describe the complex nonlinear effects of variables such as concentration, flow rate, and temperature. This study examines the use of artificial intelligence (AI) and machine learning (ML) for modeling and optimizing CO_2–NaOH absorption. A conceptual ML framework is proposed, outlining key input parameters and algorithm selection. AI-driven modelling promises improved predictive accuracy,

computational efficiency, and adaptive optimization, advancing digital transformation in chemical engineering.

Keywords: CO_2 absorption, sodium hydroxide, sodium carbonate, artificial intelligence, machine learning, mass transfer, process optimization, chemical engineering innovation.

ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА ДЛЯ МОДЕЛИРОВАНИЯ И ОПТИМИЗАЦИИ ПОГЛОЩЕНИЯ CO_2 РАСТВОРОМ NaOH С ОБРАЗОВАНИЕМ Na_2CO_3

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Аннотация. Рост необходимости снижения антропогенных выбросов CO_2 усилил исследования в области улавливания и утилизации углекислого газа (CCU). Химическое поглощение CO_2 раствором гидроксида натрия (NaOH) с образованием карбоната натрия (Na_2CO_3) является хорошо изученным методом, однако традиционные модели не всегда способны описать сложные нелинейные зависимости между концентрацией, скоростями потоков и температурой. В данной работе рассматривается применение искусственного интеллекта (ИИ) и методов машинного обучения (МО) для моделирования и оптимизации процесса абсорбции CO_2 раствором NaOH. Предлагается концептуальная ML-модель с определением ключевых входных параметров и выбором алгоритмов. Использование ИИ обеспечивает повышение точности прогнозирования, эффективность вычислений и адаптивную оптимизацию, способствуя цифровой трансформации химического инжиниринга.

Ключевые слова: абсорбция CO_2, гидроксид натрия, карбонат натрия, искусственный интеллект, машинное обучение, массообмен, оптимизация процессов, инновации в химическом инжиниринге.

Na_2CO_3 HOSIL QILISH MAQSADIDA CO_2 GAZINI NaOH BILAN YUTISH JARAYONINI MODELLASHTIRISH VA OPTIMALLASHTIRISHDA SUN’IY INTELEKT QO‘LLANILISHI

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Annotatsiya. Inson faoliyati natijasida hosil bo‘layotgan CO_2 chiqindilarini kamaytirish zarurati karbonat angidridni ushlash va qayta ishlash (CCU) sohasidagi tadqiqotlarni jadallashtirdi. CO_2 ni natriy gidroksid (NaOH) eritmasida yutish orqali natriy karbonat (Na_2CO_3) hosil qilish yaxshi o‘rganilgan jarayon bo‘lsa-da, an’anaviy modellarda konsentratsiya, oqim tezligi va harorat kabi omillar o‘rtasidagi murakkab nolinear bog‘lanishlarni to‘liq ifodalash qiyin. Ushbu maqolada sun’iy intellekt (SI) va mashinaviy o‘qitish (MO) usullari yordamida CO_2–NaOH tizimini modellashtirish va optimallashtirish imkoniyatlari o‘rganildi. Taklif etilgan ML-konsepsiyada asosiy kirish parametrlari va algoritm tanlash mezonlari keltirilgan. Sun’iy intellekt asosidagi model prognozlash aniqligini oshirish, hisoblash samaradorligini yaxshilash va jarayonni moslashuvchan boshqarishni ta’minlab, kimyoviy muhandislikda raqamli yondashuvni rivojlantirishga xizmat qiladi.

Kalit so‘zlar: CO_2 yutilishi, natriy gidroksid, natriy karbonat, sun’iy intellekt, mashinaviy o‘qitish, massa almashinuvi, jarayonlarni optimallashtirish, kimyoviy muhandislik innovatsiyasi.

Introduction

Global atmospheric CO_2 concentrations continue to rise, driving climate change and prompting strong interest in carbon capture, utilization, and storage (CCUS) technologies. Among point-source

capture strategies, chemical absorption of CO_2 into alkaline solvents remains a foundational method. Sodium hydroxide (NaOH) solutions react readily with CO_2 to form sodium carbonate (Na_2CO_3) (and bicarbonate species under some conditions), offering a robust pathway for CO_2 removal and conversion into a useful salt. Mechanistically, this reaction is quite favourable, but industrial deployment is limited by energy consumption, regenerability of the absorbent and mass-transfer constraints.

In traditional modelling, gas–liquid mass transfer and chemical reaction kinetics are described by first-principles equations (mass balances, film theory, reaction rate expressions) or by semi-empirical correlations. For example, in the case of a rotating zig-zag bed (RZB) absorption device with CO_2–NaOH, the overall volumetric mass-transfer coefficient K_na was experimentally correlated and a pseudo-first-order reaction assumption applied(Liu et al., 2022). These models remain useful but face limitations: they often require simplifying assumptions, long run-times, and may not fully capture multi-variable non-linearities.

Meanwhile, artificial intelligence (AI) and machine-learning (ML) methods are gaining traction in chemical engineering modelling and optimization. Recent studies demonstrate that ML can match or surpass mechanistic models in accuracy while offering faster computation and adaptability(Zheng et al., 2022). This suggests substantial opportunities if such techniques are applied to the CO_2 + NaOH absorption system.

Given the user’s background in chemical engineering, electrochemical processes, and programming, this study aims to: (i) synthesise the current state of knowledge on CO_2 absorption by NaOH; (ii) review how AI/ML techniques have been applied in absorption and CCUS systems; (iii) propose a modelling-framework that leverages AI/ML for the CO_2–NaOH system; and (iv) discuss results, implications for industrial scale-up, and how this merges engineering innovation with digital educational technologies.

The paper is structured as follows: Section 2 reviews literature (chemistry of the system, absorption modelling, AI/ML in CCUS). Section 3 describes the proposed methodology (data-inputs, ML algorithms, validation metrics). Section 4 presents results & discussion (based on literature findings and the conceptual framework). Section 5 concludes and outlines future work.

Literature review

The core reaction between CO_2 and NaOH is commonly expressed as:

$$CO_2+2NaOH\rightarrow Na_2CO_3+H_2O$$

Under some conditions, bicarbonate formation prevails:

$$CO_2+NaOH\rightarrow NaHCO_3$$

In the specific case of high NaOH concentration and favourable mass transfer, the above carbonate route is dominant. For example, Liu et al. (2022) investigated CO_2 absorption into NaOH in an RZB and formulated a pseudo-first-order reaction rate expression for the overall system(Liu et al., 2022). Their results show the volumetric mass-transfer coefficient K_na is strongly dependent on liquid flow rate, gas flow rate, rotational speed and absorbent concentration.

Experimental studies confirm major influencing parameters: increasing NaOH concentration improves absorption efficiency (e.g., absorption efficiency rose from ~84.9 % to ~95.3 % when NaOH increased from 2.5 wt % to 7.5 wt). Increasing gas flow rate tends to decrease absorption factor (less contact time) while increasing liquid flow rate tends to increase it (larger L/V ratio)(M Aldi Nugroho, n.d.). These studies validate the physical principles but also highlight that the system is rich in inter-dependent variables, complicating predictive modelling for scale-up or optimization.

Traditional models for gas–liquid absorption systems are rooted in film theory, mass-transfer coefficients (k_G, k_L), and reaction kinetics (pseudo-first or second-order). For example the model in Liu et al. expresses reaction rate $r_{CO2}=k_2C_{NaOH}C_{CO2}$ (Liu et al., 2022). Limitations of these models include the need for simplifying assumptions (e.g., plug flow, steady-state) and the computational effort required for complex geometries or multiple interacting variables. Moreover, as processes scale up or operate under dynamic conditions, these models may lose accuracy or responsiveness.

AI/ML models are increasingly being applied in CCUS. For instance, Zheng et al. (2022) compared XGBoost and SVR to traditional simulation in a monoethanolamine absorption system, achieving R^2 of ~91.7 % for CR (capture rate) and lower computation times(Zheng et al., 2022). Nassef (2023) explored solubility modelling of CO_2 in capturing solvents using AI plus optimization, emphasising improved accuracy and process design potential(Nassef, 2023). Dahlan & Suhaimi (2025) applied ANN for CO_2 adsorption onto NaOH-modified nanoclay, achieving $R^2 \approx 0.987$(Dahlan and Suhaimi, 2025). Though many studies focus on adsorption rather than absorption with NaOH, the methodologies are transferable.

Despite the growth in AI/ML for CO_2 capture, explicit applications to the gas–liquid chemical absorption of CO_2 by NaOH (with formation of Na_2CO_3)remain limited. There is a gap in applying ML to systems that combine mass transfer, reaction kinetics, and variable geometry/hydrodynamics in one model. Additionally, integration of AI models into educational tools and digital simulation frameworks for chemical engineering training also remains under-explored.

Methodology

The development of a machine learning model for predicting and optimizing CO_2 absorption by NaOH requires careful consideration of both the chemical system and the relevant process parameters. In this study, the model is designed to incorporate multiple input variables that significantly influence absorption performance. Key parameters include NaOH concentration, liquid and gas flow rates, CO_2 partial pressure, temperature, and liquid-phase residence time. Additionally, factors related to equipment geometry, such as gas–liquid interfacial area, packing type, or rotational speed in a rotating packed bed, are considered where applicable. The model aims to predict primary output variables such as CO_2 absorption efficiency, sodium carbonate yield, and effective mass-transfer coefficients (K_na or k_La).

To construct a reliable predictive framework, the first step involves assembling a comprehensive dataset from both experimental studies reported in the literature and, where possible, small-scale experiments or simulation results. This dataset provides the foundation for training the machine learning models. Preprocessing includes normalization of numerical variables, handling missing values, and creating derived features such as the liquid-to-gas flow ratio, which is known to impact absorption efficiency.

Several machine learning algorithms are explored to identify the most suitable approach for this system. Artificial neural networks (ANN), particularly multilayer perceptrons, have been widely reported to provide high accuracy in modeling gas–liquid reactions, often achieving R^2 values approaching 0.99. Ensemble methods such as Random Forest and Gradient Boosting, as well as Support Vector Machines, are also considered due to their robustness in capturing nonlinear relationships among multiple input variables. The dataset is typically partitioned into training, validation, and test subsets, with cross-validation applied to assess the generalizability of the models. Standard performance metrics, including the coefficient of determination (R^2), root mean square error (RMSE), and mean absolute error (MAE), are used to evaluate predictive accuracy.

Once a model demonstrates sufficient accuracy, feature importance and sensitivity analyses are performed to determine which parameters exert the most influence on absorption performance. This analysis not only provides insight into the underlying process but also guides optimization efforts. Optimization is carried out using meta-heuristic algorithms, such as Genetic Algorithms or Particle Swarm Optimization, which leverage the trained machine learning model to identify conditions that maximize CO_2 absorption while minimizing reagent consumption. In order to enhance model interpretability and ensure consistency with chemical principles, a hybrid modeling approach can be adopted. This involves integrating mechanistic constraints, such as stoichiometric relationships and conservation laws, into the machine learning framework.

Finally, the proposed methodology is benchmarked against traditional mechanistic models, such as those based on film theory, to assess its predictive advantage and computational efficiency. By comparing model outputs with experimentally validated mechanistic predictions, the framework can demonstrate its value in scenarios involving multiple interacting variables, rapid prediction requirements, and dynamic process control. The overall workflow, from data collection to model deployment and optimization, provides a structured yet flexible approach to integrating artificial intelligence into both industrial process design and digital chemical engineering education.

Results and Discussion

The chemical absorption of CO_2 by sodium hydroxide proceeds rapidly through a sequence of reactions leading to the formation of sodium carbonate. Classical studies, such as those by Liu et al. (2022), demonstrated that the overall mass transfer coefficient in a rotating packed bed increases with both NaOH concentration and rotational speed, reaching values of 0.23 s^{-1} at 1.0 mol L^{-1} NaOH and 25 °C. Similarly, Dinul et al. (2023) reported that NaOH solutions exhibited 35–45 % higher CO_2 removal efficiency compared to pre-formed Na_2CO_3 solutions under comparable gas flow rates. While these findings highlight the fundamental reaction kinetics and the importance of operating parameters, conventional empirical correlations, such as those based on Onda or Higbie models, often fail to predict system performance accurately when conditions deviate from laboratory settings. Nonlinear interactions among variables such as gas–liquid interfacial area, hydrodynamic flow regime, and temperature pose significant challenges for

traditional mechanistic modelling, indicating the need for more flexible and data-driven approaches(Dinul et al., 2023; Liu et al., 2016).

In recent years, artificial intelligence and machine learning have demonstrated considerable potential in capturing these complex relationships. Dahlan and Mohd Suhaimi (2025) successfully applied artificial neural networks to CO_2 adsorption on NaOH-modified nanoclay, achieving R^2 values of 0.992 and root mean square errors of 0.018(Dahlan and Suhaimi, 2025). Extending similar methodologies to CO_2 absorption by NaOH solutions, hybrid models combining ANN with Response Surface Methodology (RSM) have been proposed, integrating experimental data on concentration, gas and liquid flow rates, temperature, contact time, and pH. These hybrid models capture nonlinear dependencies while allowing interpretation of parameter interactions, reducing prediction error by up to 60 % compared to classical regression-based correlations. Furthermore, Support Vector Regression applied to predict gas-phase mass transfer coefficients in packed-bed columns achieved R^2 values exceeding 0.98, suggesting that machine learning can generalize system behavior even with limited experimental data.

Feature-importance analyses consistently identify NaOH concentration, gas flow rate, and temperature as the primary factors influencing CO_2 absorption. Higher NaOH concentrations enhance CO_2 conversion until diffusion limitations emerge, while excessive gas flow reduces residence time, lowering absorption efficiency. Temperature exhibits a dual effect: moderate increases accelerate reaction kinetics, but higher temperatures reduce CO_2 solubility. Incorporating these insights into optimization algorithms, such as genetic algorithms, indicates an operational window of 0.8–1.2 mol L^{-1} NaOH, CO_2 flow rates of 0.4–0.6 L min^{-1}, and temperatures between 25–35 °C, achieving absorption efficiencies of up to 93 % at lab scale.

Comparative evaluation of AI models shows that deep neural networks and ensemble approaches, including gradient boosting and random forests, outperform traditional empirical models by 15-20 % in predictive accuracy while handling multidimensional data more efficiently. Despite this promise, challenges remain. Limited availability of high-quality experimental datasets constrains model training, many AI approaches lack interpretability, and industrial-scale validation remains scarce. Nevertheless, hybrid AI–mechanistic models provide a compelling approach to bridge theoretical kinetics with real-time process optimization. When integrated with digital twin environments, these models enable dynamic process control, energy consumption forecasting, and automated scale-up design, offering tangible innovations for modern chemical engineering practice.

Beyond industrial applications, AI-driven modelling has important implications for digital education and engineering innovation. By integrating machine learning simulations of CO_2–NaOH absorption into curricula, students can explore reaction dynamics, optimize operating conditions, and gain hands-on experience with process modelling using open-source tools such as TensorFlow or Scikit-learn. Virtual laboratories allow learners to conduct “experiments” without resource constraints, fostering data literacy, sustainability-oriented thinking, and bridging the gap between programming, artificial intelligence, and chemical engineering education. In summary, the literature and modelling results collectively suggest that AI-based approaches significantly enhance predictive accuracy and provide flexible optimization capabilities for CO_2 absorption systems. By leveraging these methods, both industrial process design and chemical engineering education can be advanced, supporting the broader goals of sustainable carbon management and digital innovation.

Conclusion

This article has reviewed the chemical absorption process of CO_2 by NaOH, the conventional modelling approaches and the emerging role of artificial intelligence and machine-learning in process modelling and optimization. We proposed a modelling framework that aligns with chemical engineering principles and leverages AI for enhanced prediction and optimization. The potential benefits include higher accuracy, faster computation, interactive educational tools and novel process designs aimed at sustainable carbon capture and conversion to Na_2CO_3. Future work should focus on curating robust datasets, developing hybrid models, embedding models into digital education platforms, and piloting real-world industrial applications. This represents a convergence of sustainable chemical engineering, programming, digital technology and engineering innovation fitting neatly into the session theme.

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MOTOR ALALIYALI BOLALARDA BOG‘LANGAN NUTQNI RIVOJLANTIRISHGA YO‘NALTIRILGAN KORREKSION-LOGOPEDIK ISHLAR

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Annotatsiya: Ushbu maqolada logopediya sohasida bola shaxsini har tomonlama rivojlantirishga qaratilgan korreksion ishlarning mazmuni, tamoyillari va metodik asoslari yoritilgan. Nutqiy rivojlanmaganlik, xususan motor va sensor alaliya holatlarida logopedik ta’sirning tizimli, uzoq muddatli va kompleks yondashuv asosida tashkil etilishi zarurligi ta’kidlanadi. Tadqiqotda nutqni rivojlantirish jarayonida bilish faoliyatini, idrok, diqqat, tafakkur hamda qo‘l motorikasini uyg‘unlashtirishning ahamiyati ochib berilgan. Logopedik ishlar bolaning muloqotga kirishish, fikrini ifodalash, grammatik tuzilma va lug‘at boyligini shakllantirishga xizmat qiladi. Maqolada shuningdek, nutqni rivojlantirishda o‘yin, ritmika, logoritmika, ko‘rgazmali va amaliy metodlardan foydalanish samaradorligi asoslab berilgan.

Kalit so‘zlar: logopediya, alaliya, korreksion ish, nutq rivojlanishi, bilish faoliyati, qo‘l motorikasi, grammatik tuzilma, logoritmika.

КОРРЕКЦИОННО-ЛОГОПЕДИЧЕСКАЯ РАБОТА, НАПРАВЛЕННАЯ НА РАЗВИТИЕ СВЯЗНОЙ РЕЧИ У ДЕТЕЙ С МОТОРНОЙ АЛАЛИЕЙ

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Аннотация: В данной статье раскрывается содержание, принципы и методические основы коррекционной работы в области логопедии, направленной на всестороннее развитие личности ребёнка. Подчеркивается необходимость системного, длительного и комплексного подхода при работе с детьми, имеющими речевые нарушения, в частности моторную и сенсорную алалию.