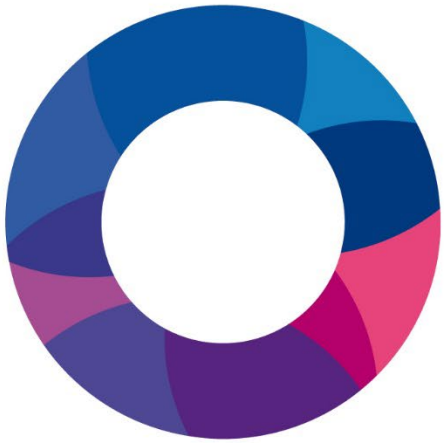

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Open Literature Survey

Q4 – 2024

IN THE LITERATURE SURVEY TODAY:

Reported PI Technologies vs. Products/Processes
(Numbers correspond to paper item #)

PRODUCTS & PROCESSES / PI TECHNOLOGIES	Bio diesel	Deep eutectic solvent	Methanol	Peptides	H_2 production	Dispersant	Membrane fouling	Design	Review	Effluent treatment	Methanation	Desalination	Phenolic compounds	General
Reactive evaporation						9								
Intensified reaction				3										
Electrodialysis		12												
RPB														1
Reactive crystallization								5						
Reverse flow reactor									13					
Microwave reactors					4									
Sorption reactor											16			
Cavitation reactor										11				
Joule reactor														2
Microreactors	7													
Photoreactor			6		18									
Micro distillation								14						
Electrochemical membranes									10					
Membrane distillation												17		
Ultrasound extraction													19	
Artificial intelligence							8	15						

1. RPB

Pressure drop analysis for potential heat transfer applications using metallic foam packing in rotating packed bed

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Abstract

Rotating packed beds (RPBs) enable more compact, efficient mass transfer vs. traditional packed columns by utilizing centrifugal acceleration to improve fluid flow and contact. However, RPB applications in heat transfer remain limited despite the analogies between heat and mass transfer processes. Cooling towers in particular are vital in the thermal management of many engineering applications, and operate on a similar principle as traditional distillation columns in chem. industries, providing process intensification opportunities. This study explores the feasibility of reducing the size of cooling towers using RPB technol. An exptl. investigation was conducted to analyze air pressure drop characteristics in an RPB. The study systematically examined the effects of gas flow rate (0-67.78 m^3/h), rotor rpm (0-2000 rpm), and liquid flow rate (0-10 lpm) on the pressure drop behavior of RPB. Copper metal foam with 95% porosity was used as the packing material, and its performance was compared against wire mesh packing. The copper foam exhibited significantly lower pressure drop under wet bed conditions, attributed to its higher porosity. A semiempirical model accurately predicted the total pressure drop across the RPB with a precision of ± 8% compared to exptl. results. The study offers valuable insights for the advancement of RPB technol. in heat transfer applications.

PI Classification code number: 2.3.7

Keywords: Rotating packed bed; Metallic foam; Heat transfer applications; Process intensification

J Braz. Soc. Mech. Sci. Eng. 46, 617 (2024)

https://doi.org/10.1007/s40430-024-05194-1

2. Joule heated reactor

Computational insights into steady-state and dynamic Joule-heated reactors

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Abstract

Joule-heated reactors could drive high-temperature endothermic reactions without heat transfer limitations to the catalyst and with high energy efficiency and fast dynamics under suitable conditions. We use 3D computational fluid dynamics (CFD) to investigate the power distribution, temperature field, and flow patterns in continuous steady-state and rapid-pulse Joule heated reactors with carbon fiber paper as the heating element. The model is in good agreement with published exptl. data. We demonstrate flow recirculation under typical conditions and derive criteria for their suppression. We showcase rapid (seconds or shorter) and uniform heating to very high temperatures (>1500°C) with minimal heating of the flowing gas, which could reduce undesired gas-phase chem. A simple energy model indicates that a high applied voltage and heating elements of high elec. conductivity and low volumetric heat capacity accelerate heating. We report heat transfer enhancement during rapid pulsing, a form of process intensification enabled by dynamic operation.

PI Classification code number: 2.3.6

Keywords: Joule heated reactor, CFD

React. Chem. Eng., 2024, 9, 2380-2392

https://doi.org/10.1039/D4RE00114A

3. Selective oxydation

Selective Oxidation Using In Situ-Generated Hydrogen Peroxide

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Abstract

Hydrogen peroxide (H_2O_2) for industrial applications is manufactured through an indirect process that relies on the sequential reduction and reoxidation of quinone carriers. While highly effective, production is typically centralized and entails numerous energy-intensive concentration steps. Furthermore, the overhydrogenation of the quinone necessitates periodic replacement, leading to incomplete atom efficiency. These factors, in addition to the presence of propriety stabilizing agents and concerns associated with their separation from product streams, have driven interest in alternative technologies for chem. upgrading. The decoupling of oxidative transformations from com. synthesized H_2O_2 may offer significant economic savings and a reduction in greenhouse gas emissions for several industrially relevant processes. Indeed, the production and utilization of the oxidant in situ, from the elements, would represent a pos. step toward a more sustainable chem. synthesis sector, offering the potential for total atom efficiency, while avoiding the drawbacks associated with current industrial routes, which are inherently linked to com. H_2O_2 production Such interest is perhaps now more pertinent than ever given the rapidly improving viability of green hydrogen production The application of in situ-generated H_2O_2 has been a long-standing goal in feedstock valorization, with perhaps the most significant interest placed on propylene epoxidation Until very recently a viable in situ alternative to current industrial oxidative processes has been lacking, with prior approaches typically hindered by low rates of conversion or poor selectivity toward desired products, often resulting from competitive hydrogenation reactions. Based on over 20 years of research, which has led to the development of catalysts for the direct synthesis of H_2O_2 that offer high synthesis rates and >99% H_2 utilization, we have recently turned our attention to a range of oxidative transformations where H_2O_2 is generated and utilized in situ. Indeed, we have recently demonstrated that it is possible to rival state-of-the-art industrial processes through in situ H_2O_2 synthesis, establishing the potential for significant process intensification and considerable decarbonization of the chem. synthesis sector. We have further established the potential of an in situ route to both bulk and fine chem. synthesis through a chemo-catalytic/enzymic one-pot approach, where H_2O_2 is synthesized over heterogeneous surfaces and subsequently utilized by a class of unspecific peroxygenase enzymes for C-H bond functionalization. Strikingly, through careful control of the chemo-catalyst, it is possible to ensure that competitive, nonenzymic pathways are inhibited while also avoiding the regiospecific and selectivity concerns associated with current energy-intensive industrial processes, with further cost savings associated with the operation of the chemo-enzymic approach at near-ambient temperatures and pressures. Beyond traditional applications of chemo-catalysis, the efficacy of in situ-generated H_2O_2 (and associated oxygen-based radical species) for the remediation of environmental

pollutants has also been a major interest of our laboratory, with such technol. offering considerable improvements over conventional disinfection processes. We hope that this Account, which highlights the key contributions of our laboratory to the field over recent years, demonstrates the chemistries that may be unlocked and improved upon via in situ H_2O_2 synthesis and it inspires broader interest from the scientific community.

PI Classification code number: 3.1.1

Keywords: Alcohols; Catalysts; Oxidation; Peptides and proteins; Selectivity

Acc. Chem. Res. 2024, 57, 106−119

https://doi.org/10.1021/acs.accounts.3c00581

4. Micro wave reactor/ H_2

Microwave-intensified hydrolysis for high efficiency hydrogen generation over magnetically separable Co_3O_4-carbon nanotube composites

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Abstract

Microwave (MW)-assisted process intensification technol. has the potential to improve catalytic conversion under mild reaction conditions. In this study, a series of MW-sensitive CNTs-Co_3O_4 composites were designed and synthesized as catalysts for the conversion of $NaBH_4$ to H_2. It was found that MW irradiation leads to a 19.6 (35°C) to 49.5% (55°C) increase in the hydrogen generation rate (HGR) of $NaBH_4$ hydrolysis catalyzed by the CC14, which is attributed to the combined contribution of thermal and non-thermal effects of microwave irradiation Moreover, the $NaBH_4$ hydrolysis catalyzed by CC14 catalyst at different heating modes followed the zero-order kinetic model, and the pre-exponential factor of $NaBH_4$ hydrolysis catalyzed by CC14 catalyst under MW irradiation was approx. 157 times higher than under conventional heating, indicating that microwave irradiation increased the effective collision frequency at the reaction interface of CC14 catalyst. In addition, the selective and instantaneous heating of microwave irradiation was demonstrated by using a specially designed pseudo-homogeneous low temperature reaction system. Moreover, DFT calculations show that the rate-determining step of $NaBH_4$ hydrolysis is H_2O dissociation.

PI Classification code number: 2.1.3

Keywords: Microwave reactor, Hydrogen generation, $NaBH_4$ hydrolysis

International Journal of Hydrogen Energy Volume 49, Part A, 2 January 2024, Pages 1085-1100

https://doi.org/10.1016/j.ijhydene.2023.08.266

5. Crystallization

Separation performance evaluation of green crystallization technique: Model configuration and process design

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Abstract

Layer melt crystallization (LMC) is deemed a green separation technique and is widely used in the purification of crude chem. products. This work optimizes the separation of LMC based on process design and model configurations. Firstly, the central temperature is monitored with the crystal layer growth, where the temperature change is divided into two stages. The main heat exchange and crystal growth occur in stage 1. Then two kinetics models are established based on the temperature and concentration difference, to describe the features of crystal layer growth. Both kinetic models can successfully correlate the driving force and kinetic parameters. Further, the temperature effect and composition of the feed mixture on the separation performance are analyzed. The proposed separation coefficients accurately figure out the underlying correlations of the tech. variables and target products. The optimized operating trajectory based on the model analyses and experiments is given to guide the separation process. Finally, four process intensification strategies are proposed to improve separation efficiency, where the incorporation of the stirring operation into LMC is more suitable for industrial production.

PI Classification code number: 3.4.4

Keywords: Layer melt crystallization, Green technology, Impurity migration, Process intensification, Separation performance

Separation and Purification Technology Volume 330, Part C, 1 February 2024, 125397

https://doi.org/10.1016/j.seppur.2023.125397

6. Photocatalysis/ Methane reforming

Life cycle environmental performance of methanol production through photocatalytic dry methane reforming

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Abstract

Photocatalytic dry methane reforming uses light energy and a nanostructured photocatalyst to convert both carbon dioxide and methane gas to syngas for production of fuels and value-added chems.The conversion of these two greenhouse gases (GHG) makes photocatalytic dry methane reforming a potentially environmentally attractive process; however, little research has been done to assess its life cycle environmental impacts in comparison to conventional commodity chem. production methods.Further, practical research has been limited to lab scale studies, which do not fully reflect the tech. and environmental performance of com. scale systems.In this work, a simulation describing the production of methanol from a photocatalytic dry reforming process is used to inform a life cycle assessment to estimate its potential environmental impacts at scale.Results indicate that for methanol produced via photocatalytic dry methane reforming to have the same life cycle GHG intensity as methanol produced through conventional steam methane reforming, a combination of improved technol. performance and process intensification is required.This includes increased chem. conversion, electricity grid decarbonization, and the use of low greenhouse gas intensive feedstocks.Promisingly, results indicate that methanol produced using a photocatalytic dry methane reforming process that employs landfill gas as a feedstock and 100% renewable electricity, could potentially produce methanol with a neg. global warming potential.

PI Classification code number: 2.2.9

Keywords: Photocatalytic Dry Methane Reforming; Methanol Production; Emerging Technology Assessment; Life Cycle Assessment; Solar Modeling; Chemical Process Modeling. Carbon Capture and Utilization

Journal of CO2 Utilization Volume 79, January 2024, 102638

https://doi.org/10.1016/j.jcou.2023.102638

7. Micro reactor/ Biodiesel

Smart scale-up of micromixers for efficient continuous biodiesel synthesis: A numerical study for process intensification

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Abstract

This study focuses on developing continuous processes for biodiesel synthesis, overcoming limitations of conventional batch reactions, such as biphasic reaction and thermodn. equilibrium, and reducing production costs. While microreactors are promising for enhancing mixing and transfer rates at smaller scales, scaling up to larger channels results in decreased efficiency and product yield. Microfluidic devices, useful in continuous biodiesel production, lose mixing efficiency when scaled up, affecting product yield. The present study proposes a novel microreactor design with static elements, aiming to improve fluid mixing and reaction performance at higher volumes The smart scale-up strategy includes an optimized micromixer design, enlarged channel cross-sectional area, and an addnl. obstacle-free channel. Using a Fractional Design followed by a Central Compound Rotational Design, optimal values for key design variables are identified. Computational tests show a high mixing index ($M > 0.77$) across a wide range of Reynolds numbers ($Re = 0.1$-100). Numerical simulations under optimal conditions indicate high conversions (>91%) for residence times above 60 s. This design promises advancements in industrial-scale biodiesel production, with improved flow and reactant distribution, potentially reducing the number of micro/millidevices needed.

PI Classification code number: **1.2.5; 1.2.7**

Keywords: Micro reactor; Biodiesel synthesis; Chaotic advection; Micromixers

Chemical Engineering and Processing - Process Intensification Volume 196, February 2024, 109664

https://doi.org/10.1016/j.cep.2024.109664

8. Membrane/ AI

The intelligent prediction of membrane fouling during membrane filtration by mathematical models and artificial intelligence models

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Abstract

A review. Recently, membrane separation technol. has been widely utilized in filtration process intensification due to its efficient performance and unique advantages, but membrane fouling limits its development and application. Therefore, the research on membrane fouling prediction and control technol. is crucial to effectively reduce membrane fouling and improve separation performance. This review first introduces the main factors (operating condition, material characteristics, and membrane structure properties) and the corresponding principles that affect membrane fouling. In addition, math. models (Hermia model and Tandem resistance model), artificial intelligence (AI) models (Artificial neural networks model and fuzzy control model), and AI optimization methods (genetic algorithm and particle swarm algorithm), which are widely used for the prediction of membrane fouling, are summarized and analyzed for comparison. The AI models are usually significantly better than the math. models in terms of prediction accuracy and applicability of membrane fouling and can monitor membrane fouling in real-time by working in concert with image processing technol., which is crucial for membrane fouling prediction and mechanism studies. Meanwhile, AI models for membrane fouling prediction in the separation process have shown good potential and are expected to be further applied in large-scale industrial applications for separation and filtration process intensification. This review will help researchers understand the challenges and future research directions in membrane fouling prediction, which is expected to provide an effective method to reduce or even solve the bottleneck problem of membrane fouling, and to promote the further application of AI modeling in environmental and food fields.

PI Classification code number: 3.1.4

Keywords: Membrane fouling; Artificial intelligence models; Mathematical models;

Membrane fouling prediction; Neural networks; Separation and purification

ChemosphereVolume 349, February 2024, 141031

https://doi.org/10.1016/j.chemosphere.2023.141031

9. Reactive evaporator/ dispersants

Process intensification for production of dispersants via integration of reaction and separation in a horizontal thin film evaporator

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Abstract

Process intensification can be achieved in specialty chems. manufacturing via transition from batch-to-continuous processing. However, the absence of headspace in a continuous tubular reactor limits the ability to remove volatile byproducts from the reacting liquid flow. Previous studies showed that the production of succinimide dispersants follows a two-step amidation-dehydration pathway in which water is formed as a byproduct. The inability to remove this water imposed a thermodn. equilibrium limitation on the dehydration step, and hence necessitated a downstream drying step to obtain a dehydrated dispersant product within com. specifications. In the present study, the use of an agitated, horizontal thin film evaporator (TFE) was investigated as a continuously operated reactive separator which combines reaction and dehydration into a single operating unit, reducing the overall cost and phys. footprint of the process. The continuous TFE unit was first exptl. investigated as a stand-alone, integrated reactor-separator. Using this configuration, the obtained imide yield consistently exceeded the maximum thermodn. yield at each operating temperature, confirming the efficiency of the integrated reaction and separation steps in the TFE. Next, the unit was modeled by integrating reaction kinetics with mass and energy balance equations, using appropriate correlations for heat and mass transfer from the literature which were verified for the exptl. set-up. This model provided insights into the system characteristics across different operating conditions, including the role of forward and reverse reactions along the TFE unit length. The model was then used to confirm the feasibility of replacing the two-step tubular reactor-evaporator process with a single TFE unit as an intensified reactive separator, further reducing the phys. footprint of the process by enabling compact modular process designs.

PI Classification code number: **3.3.6**

Keywords: Dispersant production, Reaction separation, Integration thin film evaporator, Intensification

Chemical Engineering Journal Volume 489, 1 June 2024, 151541

https://doi.org/10.1016/j.cej.2024.151541

10. Membrane/ electrochemistry

Electrochemically switched ion separation technologies: A review on electroactive ion exchange materials and system architectures

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Abstract

Efficient and selective ion separation from complex aqueous solutions is highly relevant for resource recovery, energy storage, and environment protection. The emerging electrochemically switched ion separation (ESIS) technologies have attracted widespread attention due to their high selectivity, energy efficiency, and environmental friendliness. Basic research on ESIS focuses primarily on the design of electroactive ion exchange materials (EIXMs) and the innovation of electrochemical system architectures. The well-tailored EIXMs for film/membrane electrodes rely on Faradaic redox reactions to capture ions selectively. Significant advancement has been achieved in the transition from intermittent operation in electrochemically switched ion exchange (ESIX) to continuous running in electrochemically switched ion permselective membrane (ESIPM) with the regarding of system architectures. This review systematically outlines the research and development of ESIS technologies from four key aspects: EIXMs development, system architectures, ion selectivity mechanisms, and prospects. First, the principles and categories of EIXMs are summarized. Next, the evolutions of system architectures in terms of cell designs, driving mode optimization, and practical application are emphasized. Then, the ion selectivity mechanisms explored with the aid of experimental and computational approaches are elucidated. Finally, the challenges and prospects of ESIS including ion separation mechanisms, film/membrane electrodes, module development, and process intensification and scaling up are discussed.

PI Classification code number: 3.1.3; 2.4.4

Keywords: Electrochemically switched separation, Electroactive exchange architecture

Chemical Engineering Journal Volume 490, 15 June 2024, 151708

https://doi.org/10.1016/j.cej.2024.151708

11. Cavitation/ bio-refractory

Treatment of Bio-Refractory Real Effluent from Polymer Processing Industry Using Cavitation-Based Hybrid Treatment Techniques

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Abstract

The current study presents a pioneering approach to industrial effluent treatment by harnessing cavitation-based hybrid methods for treatment of two different bio-refractory real effluents from polymer processing industry for the first time. Laboratory-scale optimization tailored for distinct effluents using acoustic cavitation (AC) revealed the optimum operating parameters as 120W as ultrasonic power, pH of 7, a 70% duty cycle and a 120-min treatment duration. By incorporating oxidants, the AC + O_3 + H_2O_2 approach achieved impressive chemical oxygen demand (COD) reduction of 56.45% and 63.19% for Effluent-1 and Effluent-2, respectively, outperforming alternative methods. Additionally, the utilization of hydrodynamic cavitation in the combined approach (HC + O_3 + H_2O_2 approach) resulted in COD reductions of 62.16% for Effluent-1 and 66.37% for Effluent-2, highlighting the potential for process intensification and commercial utilization. Overall, the effective approach for the treatment of polymer processing industrial effluent utilizing cavitation combined with other AOPs has been demonstrated.

PI Classification code number: 2.2.4

Keywords: Biorefractory real effluent, Polymer processing industry, Cavitation, Hybrid treatment

Arabian Journal for Science and Engineering Volume 49, pages 7893–7912, (2024)

https://doi.org/10.1007/s13369-023-08478-1

12. Electrodialysis/ Deep eutectic solvent

Deep eutectic solvent assisted electrodialysis towards selective resource recovery from model spent batteries effluents

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Abstract

Critical minerals will remain major active ingredients to most battery technologies for decades and innovation to improve extractive operations during spent battery effluent recycling must be carried out. Although the recovery of metal-ions in aqueous solutions has been demonstrated with membrane systems, including electrodialysis, process intensification to increase the diffusion rate at the membrane/liquid interface must be achieved to improve recovery efficiency. This manuscript presents a unique approach to increase the rate of recovery and transfer of Li^{+} and Co^{2+} ions from a membrane bulk phase to an organic liquid phase by applying deep eutectic solvent (DES) instead of an aqueous solution as the permeate stream during electrodialysis. The DES, based on choline chloride and urea at a molar ratio of 1:2, is considered green and relatively non-toxic valuable for solvent extraction purpose. Here, electrodialysis tests were conducted with this solvent on the permeate side using com. Neosepta and laboratory-made cobalt selective membranes. The DES significantly affected cobalt transport across the membranes and separation factor which increased from 247 to 516, leading to cobalt recovery as high as 66%. Furthermore, the use of DES on the permeate side greatly improved the energy efficiency increasing the amount of recovered cobalt per J of energy by over 20%.

PI Classification code number: 3.3.22

Keywords : Deep eutectic solvent, Electrodialysis, Spent battery effluent

Desalination Volume 580, 1 July 2024, 117559

https://doi.org/10.1016/j.desal.2024.117559

13. Reverse flow reactor

Process intensification in reverse flow reactors to boost various industrial applications: A review

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Abstract

Reverse flow reactors are notable for their dynamic operation under unsteady state conditions, the minimization of energy use, and reduction of harmful greenhouse emissions. The main advantages offered by reverse flow reactors over conventional fixed bed reactors include enhanced reaction rates and reduced waste due to superior mixing and more efficient heat transfer. Sophisticated application of key principles of process intensification has facilitated the use of reverse flow reactors in numerous industrial applications including the oxidation of volatile organic compounds emissions, sulfuric acid production, reduction of NOx emissions from nitric acid production, steam-methane reforming for hydrogen production, and partial oxidation of methane for syngas production This paper explores the potential of reverse flow reactors to promote sustainable chem. manufacturing processes with a reduced environmental impact across numerous industrial applications.

PI Classification code number: 4.3.2

Keywords: Reverse flow reactors

Chemical Engineering and Processing - Process Intensification Volume 208, February 2025, 110097

https://doi.org/10.1016/j.cep.2024.110097

14. Zero gravity distillation

Separation process intensification for zero-gravity distillation through sandwich internal structure with ordered hierarchical metal foam

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Abstract

To cope with small production quantities of specialized chems., modular production plants have gained increasing attention in recent years. Zero-gravity distillation (ZGD) is a small-scale distillation process, which offers high separation efficiency, proving advantageous for modularizing processes. In this research, the study of ZGD process intensification is conducted. A ZGD exptl. setup was established and the separation of ethanol/water mixtures was chosen as an example to investigate the effects of metal foam material, liquid filling rate, and PPI of metal foam on the separation performance, which was quantified by height equivalent to a theor. plate (HETP). The results reveal that under constant feed volume (50 mL) and the mole fraction of ethanol (0.2), employing 40 PPI copper foam and 100 % liquid filling rate results in HETP of 5.56 cm for ZGD unit, demonstrating superior separation performance. Subsequently, an optimization strategy adopting sandwich internal structure with ordered hierarchical meta foam is proposed to further intensify the separation process. In contrast to the case of employing 40 PPI copper foam and liquid filling rate of 100 %, the optimization strategy can further reduce HETP by approx. 18.17 %, being 4.55 cm. This finding provides a theor. foundation and tech. guidance for developing zero-gravity distillation technol.

PI Classification code number: 1.2.9

Keywords: Zero gravity distillation, Heat pipe, Capillary structure

Separation and Purification Technology Volume 360, Part 2, 8 July 2025, 131060

https://doi.org/10.1016/j.seppur.2024.128858

15. AI/ Solvent design

Deep learning-driven green solvent design and process intensification towards isopropyl alcoholwater azeotrope system

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Abstract

Extraction distillation and azeotropic distillation are two important methods for separating iso-Pr alc. (IPA) and water azeotrope. However, azeotropic distillation is generally more energy-intensive than extractive distillation separation process. Therefore, solvent design and process intensification for the extractive distillation process are the keys to addressing the problems of azeotropic separation and reducing energy consumption. In this contribution, a deep learning-based solvent high throughput screening framework was proposed to design the green solvent for separating the IPA/water mixtures All properties, such as thermodn. properties and EH&S properties, used for screening were predicted by the deep learning-based predictive models. From more than 10^8 individual mols., five green solvent candidates were screened for the separation of IPA/water azeotrope. The energy consumption anal. of 5 solvents shows that ethylene glycol as solvent has the lowest separating energy consumption. Finally, the heat integration and heat pump distillation of the extractive distillation separation process was carried out, and the energy-saving potential reached 45.86%.

PI Classification code number: 3.4.4

Keywords: AI, Extractive distillation, Solvent design, IPA-water separation

Separation and Purification Technology Volume 360, Part 2, 8 July 2025, 131103

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16. Sorption enhanced reactor/ Methanation

Modelling of a continuous sorption-enhanced methanation process in an adiabatic packed-bed reactor system

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Abstract

The present study investigates a sorption-enhanced methanation process and successive solid regeneration stages using a dual-function catalyst containing nickel as a catalyst and zeolite 13X for water removal. An adiabatic packed bed, modeled by a dynamical and heterogeneous model, has been considered, and a five-stage sequence describes the sorption-enhanced methanation and successive solid regeneration. First, methanation occurs with in-situ water removal; then, the catalyst drying using a pressure and temperature swing approach implemented by blowdown, purge, cooling, and pressurization stages. In adiabatic operation, heat management is crucial; on the other hand, the heat produced can be efficiently used to dry the zeolite. Process intensification is pursued by addressing the effect of gas inlet temperature, pressure, and gas hourly space velocity on system performance. Achieving an average purity of 99% of the methane for pressures > 2 bar is possible for long-time operation, with productivity averaging 0.8 mol/(kg_{ads} min) at the highest gas hourly space velocity investigated.

PI Classification code number: 3.3.13

Keywords: Synthetic natural gas, Sorption enhanced methanation, Mathematical model, Bifunctional catalyst, Packed bed reactor, 13X zeolite

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17. Membrane distillation / Desalination

Synergistic optimization of membrane distillation-reverse electrodialysis for sustainable desalination and salinity gradient power generation

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Abstract

Water desalination, dominated by seawater reverse osmosis, presents issues such as low water recovery (~50 %), brine management challenges, and high energy consumption. In this study, an optimized strategy integrating membrane distillation (MD) and reverse electrodialysis (RED) is proposed to reduce the energy demands and environmental footprint of MD brine. Extensive lab-scale experiments on MD and RED demonstrated a novel parametric optimization of feed concentrations, temperatures, and flow conditions to maximize water recovery and energy output. The MD design achieved a maximum flux of 27 L per square meter per h (LMH), enhancing water recovery by up to 80 %. The RED stack reached an open circuit voltage of 0.55 V and a maximum power d. of 0.47 W/m^2 at 60 °C and 5 M MD brine concentration The study emphasizes the process intensification achieved through the integration of MD and RED, where synergistic interactions between desalination and energy recovery significantly enhance system efficiency. Moreover, specific thermal energy consumption calculations indicate that using low-grade waste heat is synergistic with process intensification and aligns with the circular economy paradigm.

PI Classification code number: 3.3.19

Keywords: Membrane distillation, Reverse electrodialysis, Process optimization, Sustainable desalination, Salinity gradient energy

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18. Photoelectrocatalytic reactor / H2

Photoelectrocatalytic water splitting for efficient hydrogen production: A strategic review

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Abstract

Hydrogen generation via water splitting is the most captivating one, out of the different technologies employed for its production, owing to the abundance of the essential raw material (water) on our planet. Photoelectrocatalysis (PEC), which combines two powerful advanced oxidation processes, viz., photocatalysis and electrocatalysis, has the potential to use solar energy to split water into Oxygen and Hydrogen at ambient temperature and pressure. This article is a strategic review that discusses the ingenious techniques for increasing the overall efficiency of a PEC process for the purpose of Hydrogen production via water splitting. It analyses the various schemes and parameters of electrode engineering, electrolyte effects and cell architecture. The principal emphasis is on skilled photoelectrode development and process intensification by synergistic operations. This review provides a reference for a comparative study of novel developments and new directions in PEC for the production of Hydrogen, thus encouraging propitious research and rewarding commercialization.

PI Classification code number: 2.2.9

Keywords: Hydrogen, Photoelectrocatalysis, Solar energy, Advanced oxidation process, Photoelectrode

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19. Ultra sound Extraction / Phenolic compounds

Ultrasound assisted intensified enzymatic extraction of total phenolic compounds from pomegranate peels

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Abstract

Pomegranate peels contain a considerable amount of bioactive chemicals, such as phenolic compounds including gallic acid and ellagic acid. The current study aims to optimize the extraction of total phenolic content (TPC) and its antioxidant capacity from a Pomegranate peel using various approaches involving enzyme and ultrasound, also focusing on process intensification using combination. The optimal parameters for ultrasound treatment were established as treatment time of 25 min, 130 W power, 50 % duty cycle, and a liquid–solid ratio of 50:1 at a fixed 22 kHz frequency, resulting in maximum TPC (21.521 mg GAE/ml) and antioxidant capacity (17.962 mg GAE/ml). Similarly, enzymatic treatment was optimized resulting in best conditions of a time of 55 min, 50 °C as temperature, pH of 5, and a 2 % enzyme concentration. Ultrasound-assisted enzymatic extraction (UAEE) experiments revealed that combining 25 min of ultrasonic treatment with 25 min of enzymatic treatment yielded the highest TPC (30.608 mg GAE/ml) and antioxidant capacity (27.703 mg GAE/ml). It was clearly demonstrated that UAEE outperformed EAE and UAE in terms of Total Phenolic Compound extraction and antioxidant capacity, with the order of efficiency being UAEE > EAE > UAE.

PI Classification code number: 2.2.3

Keywords: Phenolic compounds, Pomegranate peel, Enzymatic extraction, Ultrasound, Process intensification

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