

# A comprehensive review on CO<sub>2</sub> capture process using amine-ionic liquids mixtures

Muthumari P.<sup>1</sup>, Dhanalakshmi J.<sup>2\*</sup>, Selvabharathi G.<sup>3</sup> and Achsa R S.<sup>4</sup>

<sup>1</sup>Department of Biotechnology, P.S.R. Engineering College, Sivakasi, Tamil Nadu, India

<sup>2</sup>Solvent Development for Clean Technology Lab, Department of Chemical Engineering, Sri Sivasubramaniya Nadar College of Engineering, Chennai, Tamil Nadu, India

<sup>3</sup>Department of Civil Engineering, SSM Institute of Engineering and Technology, Dindigul Tamil Nadu, India.

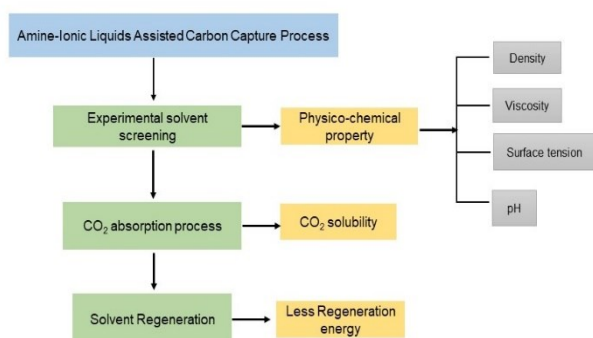
<sup>4</sup>Department of Biotechnology, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai, Tamil Nadu, India

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\*to whom all correspondence should be addressed: e-mail: dhanalakshmi83@gmail.com, +91 99400 83399

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## Graphical abstract



## Abstract

In recent years, there has been an increase in the earth's temperature due to the emission of CO<sub>2</sub> which causes global warming. With a 1.9°C temperature increase predicted by the Intergovernmental Panel on Climate Change, reducing of CO<sub>2</sub> is essential for all living species. Therefore, finding novel CO<sub>2</sub>-capturing strategies is the only way to eliminate this life threat. From post-combustion coal-fired power plants, CO<sub>2</sub> separation is employed by a solvent-based chemical absorption method using Monoethanolamine (MEA) as standard solvent, which is the most practically proven and reliable process. The utilization of other solvents as absorbents in the CO<sub>2</sub> absorption process such as amine solutions, ionic liquids (ILs), and amine-ILs solvent blend mixtures were reviewed. This review provides an overview of the CO<sub>2</sub> capture process, emphasizing the importance of developing efficient and sustainable methods to mitigate greenhouse gas emissions. It also highlights the potential of using amine-ionic liquids mixtures as promising candidates for CO<sub>2</sub> capture due to their unique properties for effective removal of CO<sub>2</sub> by increasing CO<sub>2</sub> absorption capacity as

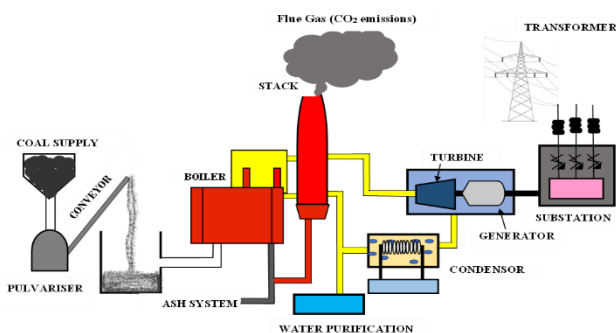
well as minimizing energy consumption during solvent regeneration.

**Keywords:** CO<sub>2</sub> capture, Ionic Liquids, amine, CO<sub>2</sub> absorption capacity, Regeneration energy

## 1. Introduction

The climatic challenges were caused by global warming, improper ecological cycle, economic and technological issues. This average rise in the earth's temperature leads to global warming. This temperature rise is due to the emission of Greenhouse Gases (GHG), mainly CO<sub>2</sub>. GHGs are caused by the fossil fuel, petrochemical, steel, transportation, and cement sectors. Nearly 88% of the world's energy consumption is based on fossil fuels such as coal, natural gas, and oil. The International Energy Agency (IEA) indicated in 2014 that coal and crude oil are the leading sources of CO<sub>2</sub> emissions. Coal, a fossil fuel, is very inexpensive and widely available (Aghaie *et al.* 2018; Kang *et al.* 2018). Rapid emission of GHG emissions result's in increasing sea levels, melting polar ice caps, global warming, glaciers, and catastrophic weather patterns in the atmosphere (Zhang *et al.* 2018). Among the different pollutants, high GHG emissions cause the earth's temperature to rise. According to the Paris Agreement, the atmospheric temperature should not exceed 2°C by 2100, with the goal of lowering the temperature to 1.5°C. Based on the IPCC report (Intergovernmental Panel on Climate Change), atmospheric CO<sub>2</sub> concentrations should be maintained at 450 ppm by 2100 to avoid global temperature rises of more than 2°C (Shivanna, 2022; Lv *et al.* 2020). Recent research has shown that the global CO<sub>2</sub> emissions from fossil fuels are expected to reach 40.2 GT (gigatonnes) by 2030 through electricity generation as shown in Figure 1. (Xiao *et al.* 2019; Chen *et al.* 2018). In order to overcome the issues, Carbon capture and storage (CCS) involves capturing CO<sub>2</sub> emissions and storing them in geological formations, aiming to minimize their release. Despite technical, regulatory, and economic challenges, developing efficient and cost-effective CCS technologies,

along with the promotion of carbon capture utilization and storage (CCUS), offers a promising solution to mitigate CO<sub>2</sub> emissions and combat climate change (Garba & Galadima, 2018; Fan *et al.* 2018). This CCS process has been performed using three different methods namely pre-combustion, post-combustion and oxy-combustion. The pre-combustion process, utilized in Integrated Gasification Combined Cycles (IGCC) for CO<sub>2</sub> removal before fuel combustion, faces challenges in industrial-scale implementation due to complex equipment and high capital costs (Orhan *et al.* 2017). Oxy-fuel combustion burns fossil fuels with pure oxygen to produce high CO<sub>2</sub> concentrations for easier separation, but its high costs for oxygen separation and capital investment limit its economic viability compared with other capture methods (Bajai *et al.* 2022). However, in the post-combustion process, CO<sub>2</sub> removal occurs after fuel combustion, particularly in coal, oil, and gas-fired power plants. Solvent-based post-combustion technology offers the advantage of low-pressure CO<sub>2</sub> generation and easier integration into existing power plants, making it a potential solution for reducing GHG emissions (Mukhtar *et al.* 2020). Some of the solvents used in CO<sub>2</sub> captures process are amines, non-amines and ionic liquids. Monoethanolamine (MEA) act as benchmark solvents for CO<sub>2</sub> but shows higher solvent degradation during regeneration. Hence, the combination of amines and ionic liquids in CO<sub>2</sub> capture processes presents a novel approach that addresses the limitations of traditional solvent-based methods. This solvent blend results in enhanced CO<sub>2</sub> absorption kinetics and selectivity. The chemical and thermal stability of ionic liquids also counteracts the degradation problems associated with amines, extending the lifespan of the solvent system. This amine-ionic liquid mixture holds promise for more efficient and sustainable CO<sub>2</sub> capture processes, paving the way for further advancements in the field.

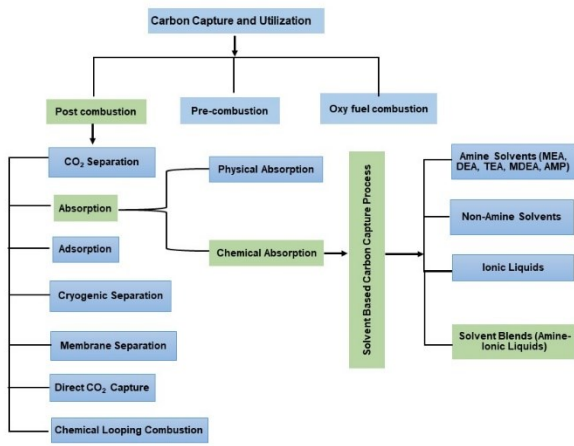


**Figure 1.** CO<sub>2</sub> emissions from coal fired power plants

The aim of this extensive review paper is to explore the potential use of amine-ionic liquid mixtures as solvents for CO<sub>2</sub> absorption process. This work focuses on efficient and sustainable methods to reduce greenhouse gas emissions, particularly CO<sub>2</sub>, a significant acidic gas that causes climate change. Addressing the overview of CO<sub>2</sub> capture methods and the distinctive properties of amine-ionic liquids mixtures for enhancing CO<sub>2</sub> capture would facilitate further research and advancements in sustainable carbon capture technologies.

## 2. Review methodology

Figure 2. indicates the review methodology adopted for the present work. In Figure 2, the highlighted content represents the potential of use amine-ionic liquids mixtures as promising candidates for CO<sub>2</sub> capture process because of their unique properties such as high selectivity, low volatility, and tunable chemical structures. It also compares the performance of amine-ionic liquids mixtures with conventional CO<sub>2</sub> capture methods. Carbon capture technology involves methods to capture carbon dioxide emissions from coal fired power plants, mitigating climate change by reducing greenhouse gas emissions. It includes post-combustion capture, pre-combustion capture, and oxy-fuel combustion, aiming to store or utilize captured CO<sub>2</sub> to prevent its release into the atmosphere. Post-combustion carbon capture technology holds significant importance compared to other methods due to its ability to capture carbon dioxide emissions after fuel combustion, particularly in existing coal, oil, and gas-fired power plants (Bhavsar *et al.* 2023). This approach offers advantages such as lower implementation costs, easier integration into existing infrastructure, and reduced risks associated with retrofitting. In post-combustion carbon capture processes, CO<sub>2</sub> separation typically involves extracting CO<sub>2</sub> from the flue gas emitted by industrial sources after the combustion of fossil fuels which was shown in Figure 2. Various methods are employed for CO<sub>2</sub> separation, including chemical absorption, absorption, membrane separation, cryogenic separation, and chemical looping combustion. Chemical absorption, using liquid solvents like alkanolamines, is a widely utilized technique where CO<sub>2</sub> is chemically captured by the solvent, forming stable compounds that can be separated from the flue gas. However, it shows some challenges such as high energy requirements for solvent regeneration, equipment corrosion, and solvent degradation (Perumal and Jayaraman, 2023). Recently, ionic liquids (ILs) have garnered significant interest in CO<sub>2</sub> capture due to their unique properties, such as negligible vapor pressure, high thermal stability, and tunable chemical structures. ILs can serve as promising solvents or sorbents for CO<sub>2</sub> capture processes, offering advantages such as low energy requirements for regeneration, high selectivity, and the potential for reuse. But it has some bottlenecks such as high cost, viscosity issues hindering mass transfer, potential toxicity, limited scalability, and stability. Many researchers are able to find an alternative solution to capture CO<sub>2</sub> by overcoming the above issues. Hence the present review focused on the use of solvent blends mainly amines with ionic liquids act as a promising avenue for enhancing carbon capture processes. The solvent combination may increase the CO<sub>2</sub> absorption capacity resulting in improved absorption kinetics and selectivity (Perumal *et al.* 2021). This blend also addresses limitations such as solvent degradation and corrosion, extending the lifespan of the solvent system.

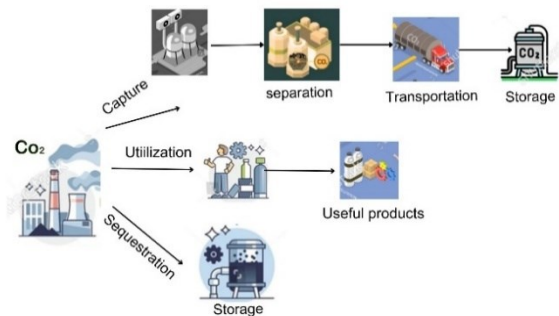


**Figure 2.** Overview of CO<sub>2</sub> capture process

### 2.1. Carbon capture, utilization and storage

CO<sub>2</sub> contributes significantly to global climate change. Capturing CO<sub>2</sub> emissions from power plants, transferring them to an injection location, and storing them in an appropriate geologic formation for long-term storage is an effective approach for minimizing CO<sub>2</sub> emissions. In the 1920s, this CCS strategy was implemented to eliminate the carbon dioxide found in natural gas deposits from commercial hydrocarbons. Fossil fuel power plants remain the largest source of CO<sub>2</sub> emissions (Hospital-Benito *et al.* 2020). As a result, there is a prospect of developing and implementing CO<sub>2</sub> capture, utilization, and storage (CCUS) technologies to reduce CO<sub>2</sub> emissions (Jiang *et al.* 2020). Therefore, it is crucial to develop efficient and economical technologies for CO<sub>2</sub> capture. CO<sub>2</sub> capture and storage (CCS) is frequently a demanding and more viable technology for decarbonizing the global economy. The use of CCS technology is considered a possibility for lowering anthropogenic CO<sub>2</sub> emissions. Collection of carbon dioxide from emitting sources, transferring it to a storage location and depositing it in an appropriate subterranean geological formation (Bhavsar *et al.* 2023). The large amount of CO<sub>2</sub> flow might be delivered for underground storage upon capture via the excavation of deep saline aquifers with no further practical application, as well as oil or gas reserves. A stable geological circumstance, capping bedrock exhibiting excellent sealing capacity, and reservoir stone with the proper porosity, width, and susceptibility are all prerequisites for the geological storage of CO<sub>2</sub>. The storage integrity of deep saline aquifers is uncertain. Oil and gas reservoirs, whether active or depleted, have a history of reliable storage, although they are not universally accessible. Furthermore, preserved carbon dioxide can be used in various products, including firefighting gases, drinks, food, and refrigeration. Implementation and popularization are effective methods for promoting carbon capture and storage technologies. The utilization of CO<sub>2</sub> Capture and Storage (CCS) technology is one solution that is utilized to minimize the release of carbon dioxide (CO<sub>2</sub>). The use of gas and biomass-based energy may also help lower carbon dioxide emissions. Technical constraints, legal and regulatory barriers, economic barriers, and public perception barriers all impact CCS. Considering the

technological cost of developing and operating a CCS is a crucial topic that must be considered. In addition, high CO<sub>2</sub> concentrations might have negative health effects and increase safety and health hazards. Economic and environmental reasons necessitate the use of efficient and appropriate CO<sub>2</sub> separation technology with minimal running costs and energy consumption. Generally, three types of CO<sub>2</sub> capture and storage: post-combustion (capture of CO<sub>2</sub> from exhaust gas), pre-combustion (collection of CO<sub>2</sub> from synthesis gas), and oxy-fuel combustion (oxygen combustion with exhaust gas recycling and CO<sub>2</sub> purification). Figure 3 indicates the overview of Carbon Capture Utilization and Storage (CCUS) technology, emphasizing the importance of capturing carbon dioxide (CO<sub>2</sub>) emissions from industrial sources to mitigate climate change thereby reducing CO<sub>2</sub> levels by capturing, trapping, and converting CO<sub>2</sub> into useful chemicals (Fu *et al.* 2022). Furthermore, it explored the utilization and storage aspects of CCUS, discussing how captured CO<sub>2</sub> can be utilized in various applications such as enhanced oil recovery (EOR), as well as the potential for storing CO<sub>2</sub> underground in geological formations.



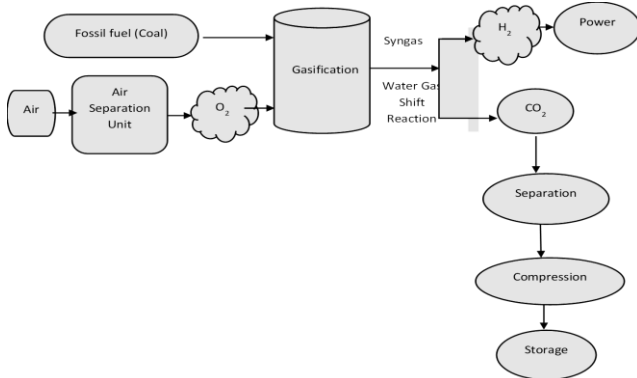
**Figure 3.** Carbon Capture Utilization and Sequestration

#### 2.1.1. Pre-combustion process

In this technique, removal of CO<sub>2</sub> takes place before the fuel is burnt. Coal, a fossil fuel, produces carbon monoxide instantly after reacting with air/oxygen. Carbon monoxide produced by the water gas shift process mixes with water to produce CO<sub>2</sub> and hydrogen gas (WGS) as shown in Figure 4. This method is used in several industrial processes, including the production of syngas, hydrogen, and natural gas. It is, nevertheless, extensively used in Integrated Gasification Combined Cycles (IGCC). Pre-combustion capture is used in IGCC power plants, although the efficiency loss is roughly 7–8%. CO<sub>2</sub> concentrations in IGCC plants are generally 40-50 percent CO<sub>2</sub>, and it can be separated from hydrogen. The separated hydrogen gas was then transformed into operational energy; however, this is not suitable for a comprehensive strategy. CO<sub>2</sub> removal is technically conceivable, but it is not yet ready for industrial scale.

Because of the presence of significant concentrations of CO<sub>2</sub>, high pressure gas permits the use of physical solvents to remove the CO<sub>2</sub>. Physical solvent absorption is performed under high pressure conditions, namely with a CO<sub>2</sub> partial pressure greater than 10 bar (Orhan *et al.* 2017). Solvent regeneration occurs through pressure reduction as opposed to heating. The benefits of the pre-

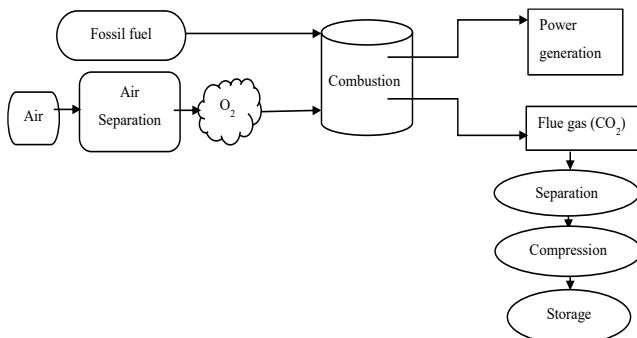
combustion process include high working pressure, which lowers pressurization costs, and a separation approach that uses less energy. However, because of the complexity of the process, the capital cost is significantly higher. In addition, the use of a complicated high-pressure WGS reactor and air separation equipment increased the cost.



**Figure 4.** Pre-Combustion Carbon Capture

### 2.1.2. Oxy-fuel combustion

The oxy-fuel method refers to the combustion of fossil fuels using pure oxygen. The purpose of the oxy-combustion process is to collect CO<sub>2</sub> from the flue gas stream and create high CO<sub>2</sub> concentrations using pure O<sub>2</sub> as an alternative to air for combustion as reported in Figure 5. The goal is to increase combustion efficiency to generate high quantities of CO<sub>2</sub> that can be easily separated. Flue gas with a CO<sub>2</sub> content of 70-95 percent generated by combusting the fuel with pure oxygen (Bajai *et al.* 2022).

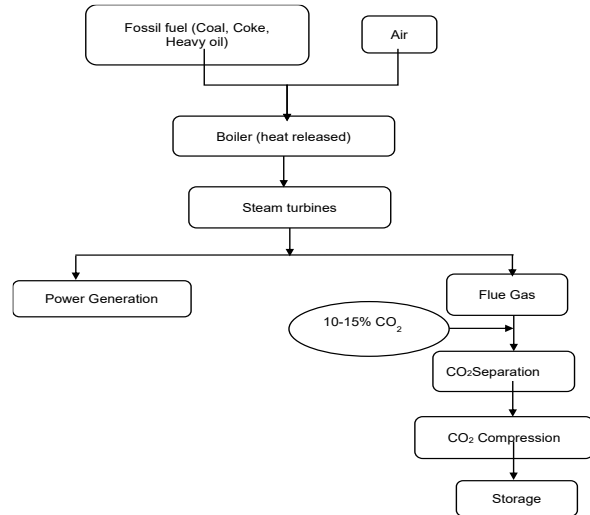


**Figure 5.** Oxy-Fuel Combustion Carbon Capture

At the end of the process, large concentrations of CO<sub>2</sub> and flue gas components, such as CO<sub>2</sub> and water vapor were generated. Hence, the water vapor is removed from the gas stream by cooling and compression. Finally, separation technologies are used to remove the high concentration of CO<sub>2</sub> released from flue gas. The merits of this process is that the flue gas flow rate is relatively modest, resulting in a smaller capture unit with a cheaper capital cost. In addition, as compared to other procedures, the NO<sub>x</sub> level in flue gas is lowered by 60-70 percent. This method is critical in power plant pre- and post-combustion procedures. The expense of purifying O<sub>2</sub> using an air separation device is more involved and costly. This raises the cost of O<sub>2</sub> separation as well as the energy demand. The large air separation unit enhances the plant's capital cost when compared to alternative capture technologies. This approach is costlier than other capturing methods (Orhan *et al.* 2017).

### 2.1.3. Post-combustion process

In this process, the fossil fuel (coal, coke, and heavy oil) is combusted in fired power plants to create electricity. The fossil fuel was burnt in the existence of air for this purpose. Heat was released during combustion to form the high-pressure stream that powers the steam turbines. Flue gas was released through the combustion of fossil fuels. Particulate matter, SO<sub>2</sub>, and CO<sub>2</sub> are all components of flue gas was shown in Figure 6. Scrubbing techniques and other particle materials collected by vacuum cleaning can be used to remove SO<sub>2</sub>.



**Figure 6.** Post-Combustion Carbon Capture

The cleansed flue gas from a natural gas-fired power plants constitutes 3-15% CO<sub>2</sub>, whereas coal-fired power plants emit 10-15% CO<sub>2</sub> to the environment. To lower the growth of CO<sub>2</sub> concentrations in the atmosphere. The removal of CO<sub>2</sub> is critical for reducing greenhouse gas emissions. Therefore, post-combustion technology was demonstrated on a limited scale, with the quantity of CO<sub>2</sub> collected averaging roughly 800 t/day (Mukhtar *et al.* 2020). This technology was used to remove CO<sub>2</sub> from the exhaust flue gases of fuel combustion plants namely as coal, oil, and fuel-fired thermal power plants. In terms of economics, the CO<sub>2</sub> absorption/desorption phase, which is largely a solvent regeneration phase, is the most expensive component of the CCS process at post-combustion. Furthermore, as compared to sequestration requirements, the post-combustion capture technology generates CO<sub>2</sub> at low pressures and can be easily fitted to an existing power plant (Haider *et al.* 2016).

## 2.2. CO<sub>2</sub> separation process

Post-combustion flue gas from a coal-fired power plant typically includes 12-15% CO<sub>2</sub>. Absorption, adsorption, membrane separation, direct air capture, chemical looping, and cryogenic are all methods for CO<sub>2</sub> separation. The details have been discussed below.

### 2.2.1. Adsorption

Adsorption is a separation technique utilized in the PCCC procedure (Post Combustion Carbon Capture). This adsorption method employs a packed column loaded with solid sorbents in CO<sub>2</sub> collection. The solid sorbent should

have high regeneration capacity, excellent selectivity, and a large specific surface area. Carbons and carbon nanotubes, clays and oxides, microporous zeolites and mesoporous molecular sieves and microporous metal-organic framework materials (MOFs). Adsorbent refers to the use of a solid material for CO<sub>2</sub> separation, while adsorbate refers to the gas that is adsorbed. Adsorption is based on the attraction of CO<sub>2</sub> molecules to solid sorbents via intermolecular forces. As a result, CO<sub>2</sub> is drawn to the sorbent and attaches to its surface. Following that, the solvent (solid sorbent) is regenerated in order to strip the CO<sub>2</sub> by temperature/pressure swing adsorption and reuse the solvent for further adsorption. The mechanism of desorption used to regenerate the adsorbent in CO<sub>2</sub> capture from post combustion flue gas can be characterized through a rise in temperature (temperature swing adsorption) or a decrease in pressure (pressure swing adsorption). CO<sub>2</sub> capture incorporating adsorbents in the pre-combustion phase helps enhance hydrogen gas production. The main disadvantage is that there is relatively little CO<sub>2</sub> adsorption capacity and selectivity for accessible solid adsorbents (Olajire, 2017).

### 2.2.2. Membrane separation

A membrane acts as a selective barrier, allowing different components from the flue gas stream to infiltrate at different speeds. Separation processes can be classified based on membrane structure. Simple process design, easy scaling, minimal energy use, and a lesser investment cost. The membrane separation process requires five distinct methods of separation, comprising molecular screening, Knudsen diffusion, solution and surface diffusion, capillary condensation. Beginning in 1970, carbon membranes are used to separate gases. It is considered a watershed moment in the field of membrane technology. Membrane performance is classified by two primary factors: selectivity and permeability. Selectivity and permeability were lowered during membrane production by increasing polymer concentration, temperature, and pressure. When membranes were combined with inorganic materials, significant chemical and thermal stability was discovered. The membrane functions as a semi-permeable filter in the separation of CO<sub>2</sub> from flue gas streams. It has various advantages, including low regeneration energy requirements, easy operation, no waste streams, and dual benefiting. Due to the higher surface area for molecular sieving properties at the gas-liquid interface, which are essential for gas separation, membrane technology process efficiency is quite high compared to conventional process (Haider *et al.* 2020). High-purity CO<sub>2</sub> separation may necessitate the use of many membranes with various properties. In order to combine the greatest qualities of membranes and solvent scrubbing, solvent aided membranes are being created. Much research is necessary before membranes can be employed on a broad basis for capture in power plants. Membrane technology is easy to use and small, making it ideal for large-scale CO<sub>2</sub> applications. However, it requires a high degree of separation for recycling, is particularly sensitive to sulphur compounds, is a high-cost module, suffers from membrane

degradation, is not appropriate for removing huge amounts of CO<sub>2</sub> gases, and is not long-lasting.

### 2.2.3. Cryogenic separation

Cryogenic separation is referred as low-temperature distillation. It is employed to separate CO<sub>2</sub> from flue gas effectively. Various gas components from the atmosphere may be separated using this approach. The cryogenic separation technique comprises gas mixture separation by fractional condensation followed by low temperature distillation (-73.3°C). The percentage of CO<sub>2</sub> in flue gas is often greater than 50% and is easily separated. The benefits of this method include great dependability, no need for chemical reagents, an easy scale-up procedure, and the recovery of pure CO<sub>2</sub>. The key disadvantages of this technique are the significant energy demand for cooling as well as the solidification of CO<sub>2</sub> at extremely low temperatures, as well as the cost inexpensive for the cooling process (Font-Palma *et al.* 2021).

### 2.2.4. Chemical looping combustion

Chemical looping combustion (CLC) is a potential method for avoiding CO<sub>2</sub> emissions by diluting flue gases. This strategy eliminates the direct contact of air and fuel combustion. It is also a viable alternative to traditional fuel combustion. It was discovered, however, to be helpful for CO<sub>2</sub> collection applications (An *et al.* 2023). In this approach, instead of air, oxygen carriers, typically metal oxides, are injected between fuel reactors, obviating the necessity for an Air Separation Unit (ASU). The main advantages of this technology are low energy loss and simplicity of CO<sub>2</sub> separation. However, maintaining reactor pressure to reduce air leakage in the fuel reactor and metal oxide deactivation due to unburned carbon accumulation on the surface of metal oxides is a challenge with this approach.

### 2.2.5. Direct capture of CO<sub>2</sub> from air

The CO<sub>2</sub> removal from the atmosphere using direct air capture is a technique (DAC). It has recently grabbed scientists' interest because it has the potential to relieve the issues associated with enormous quantities of CO<sub>2</sub> transfer from point-source emitters. Traditional capture methods focus on large point sources, reducing the pace of CO<sub>2</sub> buildup in the earth's atmosphere. This process is comparable to adsorption-based CO<sub>2</sub> collecting. Aqueous hydroxides, namely calcium hydroxide, sodium hydroxide and potassium hydroxide solution, as well as solid materials such as alkali and alkali-supported carbonates, metal oxides, and anionic-exchange resins, are used in this process (An *et al.* 2023). Temperature Swing Adsorption (TSA) and pressure swing adsorption (PSA) are used for CO<sub>2</sub> removal in the DAC process. According to thermodynamic research, TSA is more efficient than PSA for this technique since the heat of adsorption affinity grows at low CO<sub>2</sub> concentrations. However, the estimated cost of DAC is significantly higher than that of other major point sources. Furthermore, for this technology to be widely used, high durability of low-cost materials is essential. The disadvantages of the DAC method include significant energy usage during CO<sub>2</sub> separation.

### 2.2.6. Biological process

High CO<sub>2</sub> concentrations stimulate the creation of high-value biomolecules. At high CO<sub>2</sub> levels (often greater than 50%) and in the presence of SO<sub>x</sub> and NO<sub>x</sub>, green algae strains expanded rapidly. When algae species with high CO<sub>2</sub> fixing and solar energy conversion efficiency are utilized, the technique's commercial and environmental effectiveness can be maximized. These organisms must be capable of converting solar energy into H<sub>2</sub> and producing many useful proteins (Okeke *et al.* 2022). To employ solar energy for H<sub>2</sub> generation rather of creating biomass, photosynthesis is a little hindered. The retention duration of fixed CO<sub>2</sub> in agriculture is expected to be 50 to 100 years. In the lab, 260 mg l<sup>-1</sup> h<sup>-1</sup> of CO<sub>2</sub> fixation efficiency, or 26 kg per hour of CO<sub>2</sub> capture in a 100 m<sup>3</sup> bioreactor, was achieved. Because bio reactors are prohibitively expensive, this approach is not frequently employed.

### 2.2.7. Absorption

Absorption is the most cost-effective and commercialized separation strategy utilized in coal-fired power stations for post-combustion CO<sub>2</sub> collection (PCCC). By depressurizing or heating, the liquid sorbent absorbs CO<sub>2</sub> from the flue gas, and the CO<sub>2</sub> can be removed or the solvent regenerated. The CO<sub>2</sub> gas combines with the liquid sorbent, resulting in absorption from the gas to the liquid phase. The flue gas (including CO<sub>2</sub>) is chilled (between 318 and 323 K) and delivered into the absorption column (scrubber), wherein the solvent absorbs CO<sub>2</sub>. The CO<sub>2</sub>-rich solution is pumped through a heater to raise the temperature of the solution, and into a stripper column to liberate the CO<sub>2</sub>. The CO<sub>2</sub> that has been released is compressed, and the recovered absorbent mixture is chilled and transferred to the absorber column. The quantity of energy needed for post-combustion CO<sub>2</sub> collection is an essential factor. Thus, present investigations show that lowering the cost of this capture might be accomplished by developing appropriate solvents that can remove more CO<sub>2</sub> for a given mass while using less energy for stripping stage (Mukhtar *et al.* 2020). Flue gas relates to an absorbent during the process of absorption, and CO<sub>2</sub> is absorbed by this solvent. The absorbent, on the other hand, would possess an acceptable capacity for CO<sub>2</sub> intake, a high kinetic rate for CO<sub>2</sub> absorption, limited vapor pressure, great chemical and thermal resistance, as well as be safe for humans. There are mainly two types of solvents employed in CO<sub>2</sub> absorption: physical and chemical absorption.

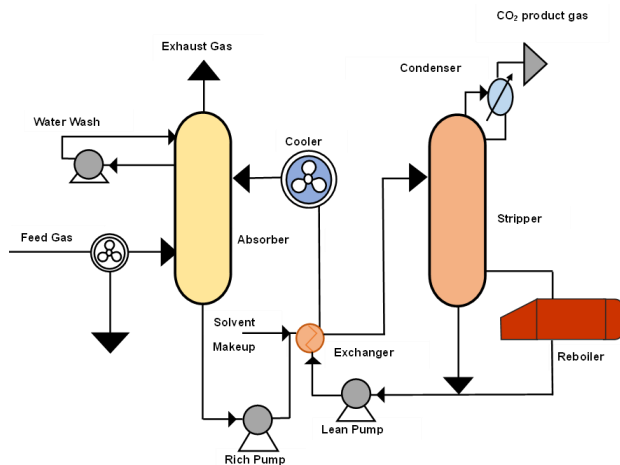
#### 2.2.7.1 Physical absorption

Physical solvents like Selexol, Rectisol, and N-Formylmorpholine (NFM) absorb acid gas components, primarily CO<sub>2</sub>, through physical interactions rather than chemical reactions. These solvents offer advantages such as requiring less energy for regeneration due to their physical solubility interactions, but they come with drawbacks including low CO<sub>2</sub> capacity, high capital and operational costs, solvent loss, and larger equipment. Physical absorption is suitable for removing acid gases from natural gas and synthesis gas used in hydrogen, ammonia, and methanol production. Despite its effectiveness at high

CO<sub>2</sub> partial pressures, physical absorption may not be cost-effective for gases with CO<sub>2</sub> partial pressures below 15% vol due to energy demands related to flue gas pressurization and equipment complexity. Additionally, while physical solvents exhibit great selectivity for hydrogen sulfide over carbon dioxide and can extract carbonyl sulfide, they require low temperatures and high vapor pressures, necessitating gas chilling before absorption and contributing to operational costs (Vega *et al.* 2018).

#### 2.2.7.2 Chemical absorption

In the absorber, the flue-gas meets the solvent, which absorbs the CO<sub>2</sub> and forms weakly intermediate chemicals through chemical processes. These chemical reactions are reversed by using heat to extract CO<sub>2</sub> from the solvents and regenerate them. In chemical absorption processes, the rate at which CO<sub>2</sub> is absorbed by the solvent is an essential characteristic. Because a higher CO<sub>2</sub> absorption rate reduces not only the capital costs of CO<sub>2</sub> collection, but it is also viewed as an asset for an absorption process that will be conducted on an industrial scale represented in Figure 7. The key benefits are the high CO<sub>2</sub> absorption capacity, greater absorption and response rate (Aghaie *et al.* 2018). According to the survey on separation approaches, absorption in PCCC plays a critical part in the CO<sub>2</sub> collection process. Solvents are used to carry out this absorption. Amine-based solvents, carbonate-based solvents, aqueous ammonia, and ionic liquid-based solvents are examples of chemical absorption solvents (Salvinder *et al.* 2019). As a result, a post-combustion carbon capture technology based on solvents is preferable.



**Figure 7.** Flow diagram of chemical absorption process for post-combustion carbon capture (Zheng *et al.* 2022)

### 2.3. Solvents based carbon capture process

The solvent-based post-combustion carbon capture process involves the use of liquid solvents to selectively absorb CO<sub>2</sub> from the flue gas emitted by power plants and industrial facilities. This method typically employs a chemical absorption process where the flue gas comes into contact with the solvent, allowing the CO<sub>2</sub> to be absorbed while other gases pass through. After absorption, the CO<sub>2</sub>-rich solvent is then regenerated, releasing the captured CO<sub>2</sub> for storage or utilization. Solvents commonly used in this process include aqueous amine, non-amine, ionic

liquids and solvent blends, which have high affinity for CO<sub>2</sub> molecules (Perumal and Jayaraman, 2023).

### 2.3.1. Amine solvents

Several alkanolamines are often used as absorbents in CO<sub>2</sub> collection methods. Because of its strong reactivity with CO<sub>2</sub> molecules, superior thermal stability, and cheap cost, it is less costly and has a larger absorption capacity. Solvent performance in absorption should have three major characteristics: (i) high solubility of gas compounds in the solvent; (ii) strong reactivity of gas compounds with the solvent; and (iii) absorbent cycle capacity. Because of their high chemical stability, which favors mass transfer kinetics, Monoethanolamine (MEA) and Diglycolamines (DGA) are the most often utilized main amines in PCCC. DGA need a high solvent concentration for a better absorption process (Vega *et al.* 2018)

MEA was revealed to be a benchmarking solvent for CO<sub>2</sub> absorption, that has an absorption efficacy of greater than 90%. The low price, high responsiveness, and rapid absorption all contribute to this. Nevertheless, it has certain drawbacks throughout operation, such as a high energy required for CO<sub>2</sub> removal, a higher entropy of reaction, equipment corrosion, and oxidative and thermal deterioration (Jang *et al.* 2021). Secondary alkanolamines have hydrogen atoms which bond directly to nitrogen atoms, such as Diethanolamine (DEA) and diisopropanolamine (DIPA). While DIPA consumes fewer energy during the recovery of solvent than MEA, DEA produces less heat of reaction, is more resistant to solvent degradation, and is less corrosive. Finally, tertiary amines having a high equivalent weight, like triethanolamine (TEA) and methyl diethanolamine (MDEA). Despite their high chemical stability, TEA and MDEA have a slow reaction rate and absorption capability (Vega *et al.* 2018). The primary difficulties in amine-based absorption technology for CO<sub>2</sub> separation are the solvent loss, degradation of solvent due to the presence of NO<sub>2</sub>, SO<sub>2</sub>, HCL, and HF in flue gas streams, volatile compound production, essential equipment deterioration, and high utilisation of energy throughout high temperature absorption. The zwitterion ion mechanism regulates CO<sub>2</sub> uptake in amines. When CO<sub>2</sub> combines with a primary or secondary amine, carbamate is generated as an intermediate product. Afterwards, the carbamate is hydrolyzed and separates into carbonate and bicarbonate. Khan *et al.* (2016) evaluated the CO<sub>2</sub> capture capability of four distinct aqueous solvents, including MEA, AMP, MDEA, and PZ. It was determined by altering the solvent content (10, 20, and 30 wt%), temperature (293-313K), and pressure (10-15KPa). According to the specific absorption rate, it was shown that MDEA-AMP-MEA-PZ's absorption performance shows a growing trend. The above solvents like MEA, DEA, and MDEA exhibit high CO<sub>2</sub> absorption efficacy, but it shows drawbacks such as high energy requirements for CO<sub>2</sub> removal, equipment corrosion, and solvent degradation due to the presence of contaminants in flue gas streams.

On the other hand, the sterically hindered amine such as 2-amino-2-methyl-1-propanol (AMP) function as alternative

conventional amines for CO<sub>2</sub> collection procedure. Because sterically hindered amines were unable to produce stable carbamate intermediate compounds during absorption. Karlsson *et al.* (2019) investigated the CO<sub>2</sub> absorption using the 2-amino-2-methyl-1-propanol (AMP) mixed with organic solvents. The obtained results were compared with the N-methyl-2-pyrrolidone (NMP). From the findings it was showed that the organic solvents with AMP, these solvents showed similar CO<sub>2</sub> absorption capacity to the AMP-NMP blends. The use of this amine reduces the energy consumption than amine based solvent regeneration, good absorption capacity, high selectivity but it has low absorption rate (Vega *et al.* 2018, Salvinder 2019).

### 2.3.2. Non-amine solvents

Non-amine-based solvents are chemical solvents that do not integrate with an amine group. Some examples are sodium hydroxide (NaOH), ammonia (NH<sub>3</sub>), potassium hydroxide (KOH), sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>), and potassium carbonate (K<sub>2</sub>CO<sub>3</sub>). MEA has a lower carbon concentration than Na<sub>2</sub>CO<sub>3</sub>. Sodium carbonate, on the other hand, absorbs CO<sub>2</sub> at a slower pace, resulting in a higher absorption column height. As a result, promoters are required to boost its absorption rate more than primary amines.

K<sub>2</sub>CO<sub>3</sub> is used as solvent due to its cost inexpensive, less energy demand, high resistance to solvent degradation and low toxicity. But it has poor absorption capacity. Hence, it acts as a promoter in CO<sub>2</sub> capture process with amines due to its low absorption capacity Ammonia used as a solvent in CO<sub>2</sub> absorption process. It has higher reaction rate with minimum regeneration energy than baseline MEA (Vega *et al.* 2018).

Piperazine (PZ) is an organic molecule having two nitrogen atoms in opposing places inside a 6-member heterocyclic ring that is used to absorb CO<sub>2</sub>. The reaction between piperazine and CO<sub>2</sub> increases absorption capacity compared to MEA and promotes the fast production of carbamates. However, it is a more volatile and expensive procedure than the baseline MEA (Salvinder 2019).

### 2.3.3. Ionic liquids

Ionic liquids (ILs) have recently developed as a novel type of physical solvents that are preferred over conventional physical solvents in CO<sub>2</sub> absorption. Ionic liquids are used as substitute solvents in the CO<sub>2</sub> capture process because of their beneficial characteristics, such as designability, non-flammability, low vapor pressure, good chemical and thermal stability, and comparatively low regeneration energy (Zhao & Baker, 2023; Li *et al.* 2021). When considering technological and economic issues, IL-based CO<sub>2</sub> collection is costlier than MEA. However, IL can save energy and utility costs throughout the regeneration phase (Salvinder 2019).

It is typically formed by the combinations of cations (Imidazolium, pyrrolidinium, pyridinium, phosphonium, ammonium) and anions (Fluorinated anions such as PF<sub>6</sub>, BF<sub>4</sub>, TF<sub>2</sub>N, non-fluorinated anions such as acetate (OAC), bromide (Br), chloride (Cl), hydroxide (OH) etc. The anion

serves the principal role, whereas the cation plays a minor part. As a physical solvent, these ILs reacted with CO<sub>2</sub>. As a result, the CO<sub>2</sub> solubility of ILs follows Henry's rule and necessitates high pressure and temperature. Amine functionalized ILs, on the other hand, boost absorption capacity with primary or secondary amine via the zwitterion idea. ILs are employed in the CO<sub>2</sub> capture process to minimize solvent loss and need less regeneration energy than baseline because of their chemical and thermal stability. MEA (Zeng *et al.* 2017). Despite their benefits, several disadvantages of ILs include high viscosity, which inhibits mass transfer kinetics. The development of a strong hydrogen bond between IL and CO<sub>2</sub> enhanced the viscosity following CO<sub>2</sub> absorption. It is

**Table 1.** Absorption of CO<sub>2</sub> using Ionic Liquids

S. No	Ionic liquids	Pressure	Temperature	CO <sub>2</sub> Solubility	References
1	Tributylammonium heptanoate	20 bar	298.15 K	0.74 mole of CO <sub>2</sub> /mole of solvent	[Rahim <i>et al.</i> 2023]
2	Triethyl (2-(2-methoxyethoxy) ethoxy) ethyl ammonium bis (trifluoromethane) sulfonimide	1bar	303K	0.55mole of CO <sub>2</sub> /mole of solvent	[Zhao <i>et al.</i> 2023]
3	Bis-(2-ethylhexyl) ammonium heptanoate ([BEHA][C7])	20 bar	298.15 K	0.78 mole of CO <sub>2</sub> /mole of solvent	[Zailani <i>et al.</i> 2022]
4	Bis(2-ethylhexyl) ammonium butyrate [BEHA][BA]	29 bar	298.15 K	0.486 mole of CO <sub>2</sub> /mole of solvent	[Yunus <i>et al.</i> 2019]
5	Ethanolammonium butyrate [EtOHA][BA],	29 bar	323.15K,	0.35 mole of CO <sub>2</sub> /mole of solvent	[Halim <i>et al.</i> 2018]

**Table 2.** Absorption of CO<sub>2</sub> using Ionic Liquids mixed with amine in atmospheric pressure

S. No	Ionic Liquids	Amine	Temperature	CO <sub>2</sub> Solubility	References
1	TetraButylAmmonium Acetate [TBA][OAc]	Monoethanolamine (MEA)	303K	0.459 mole of CO <sub>2</sub> /mole of solvent)	[Perumal and Jayaraman, 2023]
2	TetraButylAmmonium Hydroxide [TBA][OH]	Monoethanolamine (MEA)	303K	0.502 mole of CO <sub>2</sub> /mole of solvent	[Perumal <i>et al.</i> 2021]
3	Dimethylamino-1-propylamine acetate ([DMAHAH]-[OAc])	Ethanediamine (EDA)	323K	0.295 g CO <sub>2</sub> /g absorbent	[Li <i>et al.</i> 2021]
4	N-butylethylenediaminium bis(trifluoromethanesulfonyl)amide, [HButylen][Tf <sub>2</sub> N]	Ethylenediamine	308K	0.95 mmol CO <sub>2</sub> /g IL	[Voskian <i>et al.</i> 2020]
5	1-butyl-3-butylimidazolium tetrafluoroborate [BBIM][BF <sub>4</sub> ]	Methyldiethanolamine [MDEA]	298K	0.0168g/CO <sub>2</sub> g absorbent	[Xiao <i>et al.</i> 2019]

### 2.3.4. Solvent blends

The high-energy demand, low absorption capacity related to solvent degradation of amine, ILs and non-amine regeneration are the serious issue as mentioned in previous section. As a result, an attempt was made to employ solvent blends to improve absorption capacity while also regenerating the solvent with reduced energy usage represented in Table 2. In general, solvent regeneration is a high-energy process. Furthermore, CO<sub>2</sub> extraction from carbon-rich amine requires a greater amount of energy.

The addition of a small amount of tertiary amines (MDEA, TEA) to either primary or secondary amines (MEA, DEA) generates solvent blends that improve overall solvent behavior with regard to of absorption capacity, less demand on energy for solvent regeneration, and resistance to solvent degradation.

overcome by adding organic amine/water to IL, which reduces viscosity without affecting absorption capacity. Green solvents, such as Ionic Liquids (ILs), have currently gained more interest for the carbon capture process than alkanolamines due to attractive qualities such as cation and anion tuning, high chemical and thermal stability, non-volatility, minimal vapour loss, and non-flammability (Halim *et al.* 2018). The cations and anions of ILs have an influence on CO<sub>2</sub> solubility. As compared to the cation of ILs, the anion has a greater impact on CO<sub>2</sub> dissolution. Several research on the CO<sub>2</sub> solubility of IL have been published in peer-reviewed journals shown in Table 1.

MEA mixes with TEA, AMP, and MDEA are some of the other solvent blends used in the CO<sub>2</sub> collection process. It is feasible to speed up the reaction rate of these mixes when compared to separate solvents. MEA is the fastest solvent; however, its absorption rate is 50 times slower than that of PZ. As a result, a small amount of PZ boosts MEA absorption. Similarly, potassium carbonate boosted with PZ and AMP mix with PZ are regarded as potential solvents. Recently, IL-amine blends have improved absorption capacity and rate while using minimal energy for solvent regeneration (Haider *et al.* 2016). Because IL-amine mixtures absorb CO<sub>2</sub> fast, higher temperature and partial vacuum are required to desorb CO<sub>2</sub> (Camper *et al.* 2008). The addition of tertiary amine to ILs increases the solubility of CO<sub>2</sub>. The addition of ILs to an amine/non-amine solvent resulted in a high CO<sub>2</sub> cyclic capacity and a 30% reduction in the enthalpy of CO<sub>2</sub> dissolution (Gao *et al.* 2015). These amines and ILs mixes have excellent

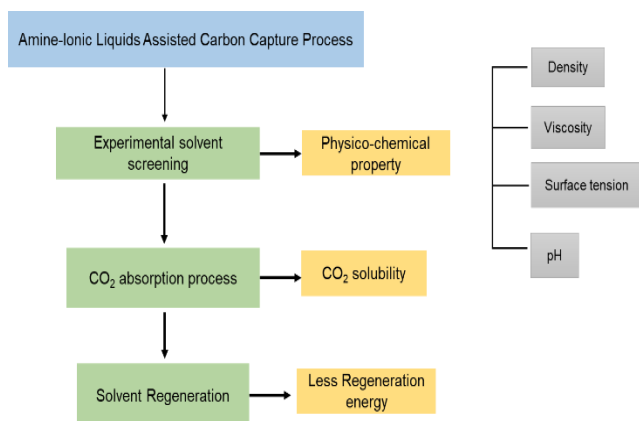


absorption and thermodynamic efficiency, a high absorption rate, minimal solvent degradation and corrosion, and low energy needs for solvent regeneration. ILs were coupled with amine, which has a lower regeneration energy than pure ILs and amine solvent, to increase CO<sub>2</sub> solubility with a faster reaction rate.

CO<sub>2</sub> absorption and desorption by aqueous solvent blends has received a significant consideration in the past few years. Similarly, in the case of amine with ILs blends have received a great attention. Hence, in this section, a detail review of literature performed regarding the aqueous amines, ILs and solvent blends as absorbents for CO<sub>2</sub> capture is presented. Finally, the conclusion that has been received based on the literature survey is specified.

### 3. Amine-ionic liquids assisted carbon capture process

The mitigation of CO<sub>2</sub> emission has been achieved through solvent based post combustion carbon capture process. The experimental screening of solvent plays a vital role in the development of potential solvent mixtures for efficient and sustainable CO<sub>2</sub> capture process. The screening has been performed through physico-chemical analysis namely density, viscosity, surface tension and pH as shown in Figure 8. This screening process enables the suitable selection of solvent blends especially amine-ionic liquids with high CO<sub>2</sub> absorption capacities and less energy needed for solvent regeneration.



**Figure 8.** Carbon capture process using amine-ionic liquids

#### 3.1. Solvent screening through physical and chemical properties

The determination of physical and chemical characteristics is critical for screening of sustainable solvents for design optimization and a better absorption process. Solvent physical parameters like as density, viscosity, and surface tension will vary during the absorption and desorption process. One of the physical characteristics that has a considerable impact on the kinetics of mass transfer and CO<sub>2</sub> solubility is density. When designing equipment and optimizing industrial processes, viscosity is a crucial factor. It is used to forecast diffusivity of CO<sub>2</sub> in a solution using a modified Stoke-Einstein equation. This equation establishes a fundamental relationship between diffusion coefficient, viscosity, and temperature. It also helps to know, how quickly CO<sub>2</sub> molecules diffused in the solution with influencing mass transfer rates. Therefore, this Stokes-Einstein equation facilitates the design and optimization of

CO<sub>2</sub> capture processes by providing a quantitative understanding of CO<sub>2</sub> diffusion behavior (Apaiyakul *et al.* 2021). It is also required to calculate mass transfer and kinetic characteristics. Understanding the chemical interactions that take place in solvents requires knowledge of surface tension. Additionally, it has a sizable effect on mass and heat transfer at the liquid-gas interface during distillation and absorption. For the physicochemical behavior of solvents in CO<sub>2</sub> absorption, it is therefore crucial.

Changes in these physical qualities will impact mass transfer at the bottom of the absorber and reaction kinetics in the stripper, raising the energy requirement of CCS. In order to determine the physical characteristics of absorption and desorption, it is required to measure them (Karunarthane *et al.* 2020). The following are some examples of physicochemical analyses related to CO<sub>2</sub> capture processes:

The study investigated the effects of fluorinated and non-fluorinated ionic liquid blends on surface properties. In comparison to non-fluorinated IL ([C, C, Im] [PF]), the incorporation of 9 mol% of fluorinated IL ([PFBMIm][PF]) enhanced viscosity and dropped surface tension, exposing nanosegregated structures at the surface.

Halim *et al.* (2018) investigated the four ammonium-based ILs (Ethanolammonium Acetate [EtOHA][AC], Ethanolammonium Butyrate [EtOHA][BA], Tributylammonium Acetate [TBA][AC] and Tributylammonium Butyrate [TBA][BA]). They measured temperatures ranging from 293.15K to 373.15K. According to the findings, when the temperature rose, the density and viscosity of ILs reduced due to an increase in IL volume. The presence of additional OH groups in [EtOHA][AC] and [EtOHA][BA] resulted in increased viscosity, which facilitates hydrogen bonding with H<sub>2</sub>O molecules. Because of its decreased viscosity, [EtOHA][BA] attained the maximum CO<sub>2</sub> absorption.

Aqueous Tetrabutylammonium Hydroxide [TBAOH], piperazine [PZ], and an aqueous-blend of [TBAOH] and [PZ] viscosities and densities were also tested at a temperature range of 303.15K to 333.15K. According to Safdar *et al.* (2015), all physical attributes dropped as temperature increased. At temperatures ranging from 298K to 350K, the surface tension of ammonium-based Room Temperature Ionic Liquids (RTILs) was determined. It was discovered that when the temperature rises, the surface tension of RTILs decreases. Changing anions has a negligible influence on surface tension during carbon loading. An increase in cation alkyl-chain length reduces surface tension in ammonium-based RTILs due to an increase in the Vander Waals to coulombic force ratio for an interaction between RTILs and CO<sub>2</sub> during absorption. In contrast, ILs with hydrocarbon tails on the cation showed an increase in surface tension. (Zailani *et al.* 2022; Ab Rahim *et al.* 2023)

For a temperature range of 303.15-343.15 K and at varying mass fractions, the physical characteristics of amine with ILs blends were investigated experimentally for 16 distinct absorbents. According to the findings, the CO<sub>2</sub> capture

procedure has significantly improved the solubility of CO<sub>2</sub>. With different IL-amines and temperatures, the density and viscosity of the IL-MEA hybrid solvent were measured. The outcomes showed that the density and viscosity of hybrid solvents increased as ionic liquid concentration was increased. According to Nookuea *et al.* (2017), the temperature effect has a tendency that is opposed to these characteristics.

### 3.2. CO<sub>2</sub> Absorption using amine- ionic liquids

For a variety of solvents, CO<sub>2</sub> absorption was conducted. Amines, ionic liquids, and solvent mixes are among the solvents employed. Amines use the zwitterion ion process. As an intermediate product of CO<sub>2</sub> reactions with primary or secondary amines, carbamate is formed. The carbamate next undergoes hydrolysis and dissociates into carbonate and bicarbonate. ILs were combined with amine to increase CO<sub>2</sub> solubility with a quicker reaction time. Previous study has also demonstrated the effectiveness of CO<sub>2</sub> collecting using Amine-IL mixtures (Perumal and Jayaraman, 2023). The combination of alkanolamine and ionic liquids promotes CO<sub>2</sub> capture even at low pressure since alkanolamine can dissolve and interact with CO<sub>2</sub> in ionic liquid mixtures (Huang *et al.* 2017).

Therefore, the combination of alkanolamine and ILs in the CO<sub>2</sub> capture process might address a number of disadvantages, including high viscosities, corrosion rate, and energy consumption for solvent recovery & reuse (Perumal *et al.* 2021). Another study found that at higher pressures, CO<sub>2</sub> dissolution is stronger in aqueous blends of MEA and ILs. CO<sub>2</sub> absorption was investigated using amine and IL mixtures at different partial pressures, and it was revealed that the activation energy of blends is lower compared with that of pure amine (MDEA).

Safdar *et al.* (2018) investigated the CO<sub>2</sub> absorption and physical characteristics of aqueous TBAOH blends incorporating Piperazine (PZ). A lower blend concentration (5% TBAOH and 5% PZ) demonstrated better solubility than a higher one (11.11% TBAOH and 11.11% PZ). Higher concentrations of TBAOH tend to have greater interactions between the cation and anion of IL, resulting in fewer interactions with CO<sub>2</sub>, which leads to lower solubility (Safdar *et al.* 2015).

### 3.3. Solvent regeneration

The regeneration efficacy of Amino Acid Ionic Liquid (AAIL) activated N-methyldiethanolamine (MDEA) solutions was examined to determine the impact of solution composition, recovery temperature, and regeneration rate. The solvent mixtures were prepared by varying IL and MDEA concentration comprises of 15 wt % [N1111] [Gly] + 30 wt % MDEA, 10 wt% [N1111] [Gly] + 30 wt% MDEA, and 10 wt % [N1111] [Gly] + 40 wt % MDEA were regenerated at 363 K, 373 K, and 378 K. According to the findings, thermal regeneration at around 378 K causes the majority of CO<sub>2</sub> in the liquid phase to be released before solution boiling. Additionally, the rates of CO<sub>2</sub> absorption in the regeneration solutions are increased by higher regeneration temperatures. Yang *et al.* (2014) investigated CO<sub>2</sub> desorption utilizing amine-IL blends to reduce energy

usage. The solvent blends consumed 37.2% less energy than the aqueous MEA solution. In addition, the limitations of ILs, such as high viscosity and high cost, can be resolved in the CO<sub>2</sub> capture process by utilizing amine-IL blends.

### 3.4. Solvent degradation

Fouling, foaming, and waste disposal are all challenges caused by solvent deterioration. The presence of chemicals that because solvent degradation can also increase pipework corrosion. In addition to the operating concerns, amines can be expelled with the cleaned gas because of their instability and may react under ambient circumstances via photo oxidation to generate nitrogen compounds. These chemicals have recently been recognized as possibly carcinogenic and hazardous to human health and the environment (Vega *et al.* 2016). As the deterioration rate increases, so does the amount of make-up solution that must be applied during the campaigns. Solvent degradation may be systematized into two primary types of reaction: 1) amine oxidative degradation through autoxidation pathways, and 2) oxidation in the presence of metal ions. At high temperatures and in the presence of CO<sub>2</sub>, thermal degradation predominantly occurs during solvent regeneration. Thermal degradation byproducts and some oxidative degradation byproducts are frequently more flammable than the amines themselves and therefore more prone to evaporate in the absorber. In amine scrubbing technique, MEA is the most often utilized amine (Voskian *et al.* 2020). Carbamate formation is the primary thermal breakdown mechanism for amines. Over a long period of time, the influence of acidic gases on amine deterioration should be considered. The MEA solutions combined with IL [bmim][BF<sub>4</sub>] need less energy for regeneration and have less solvent loss, according to Yang *et al.*'s 2014 research. Pure MEA solutions showed a greater rate of absorbent loss and energy consumption due to oxidative degradation and high reaction heat. In collaboration with IL, they discovered that energy usage may be reduced by 62.8% when compared to pure amine solutions.

## 4. Conclusions

The present study reviewed potential utilization of Amine-ionic liquid mixtures for CO<sub>2</sub> absorption process. The performance of amine-ionic liquid mixtures was compared with conventional solvents, which poses higher CO<sub>2</sub> solubility and lesser regeneration energy. This work may favor further research and developments for sustainable energy and environment.

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