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CO_2 capture by debole base and ethanol solution

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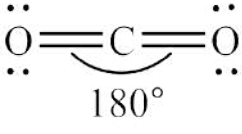
ABSTRACT:
Considering the serious poblem of the excess of CO_2 in the atmosphere due to increase of emissions by the industries, we propose a useful idea to capture the CO_2 so we can reuse it later.
Our method provide for the absorption of CO_2 through the use of a debole base and water solution whit the addition of ethanol. Ethanol lowers the polarity of the solvent and consequently the carbon dioxide will be absorbed and released more easily. This method is characterized by debole base selectivity which, in contact with a gas mixture, reacts only with CO_2 .

INTRODUCTION

Carbon dioxide is an acid oxide and is a molecule composed of a carbon atom bonded to two oxygen atoms via covalent double bonds as follows:



The carbon dioxide present in nature derives from the combustion of organic material and from the fermentation and cellular respiration of some organisms and is used by plants in respiration. In recent years, the concentration of CO_2 in the atmosphere has increased as the latter is produced by fuels in industries. In order to decrease the concentration of CO_2 in the atmosphere, alternative solutions are being sought to capture, store, transport and use it, therefore special plants are being designed.

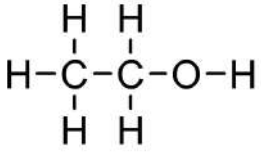
Nowadays we hear more and more about problems related to CO_2. Starting from the industrial revolution, in fact, the use of oil and gas has increased, from the combustion of fuels various gases are emitted, including CO_2.
CO_2 is a greenhouse gas naturally present in the atmosphere and helps to maintain the temperature on earth in order to allow life.
In 2018, however, the concentration of carbon dioxide in the atmosphere exceeded 408 ppm, 45% more than the concentration at the beginning of the industrial revolution.
The increase of CO_2 in the atmosphere has led to various consequences including:

- Melting of glaciers and consequent rise in sea level;
- Climate change deriving from the alteration of the greenhouse effect with consequent increase of desertification;
- Increase of extreme natural phenomena;
- Acidification of oceans.

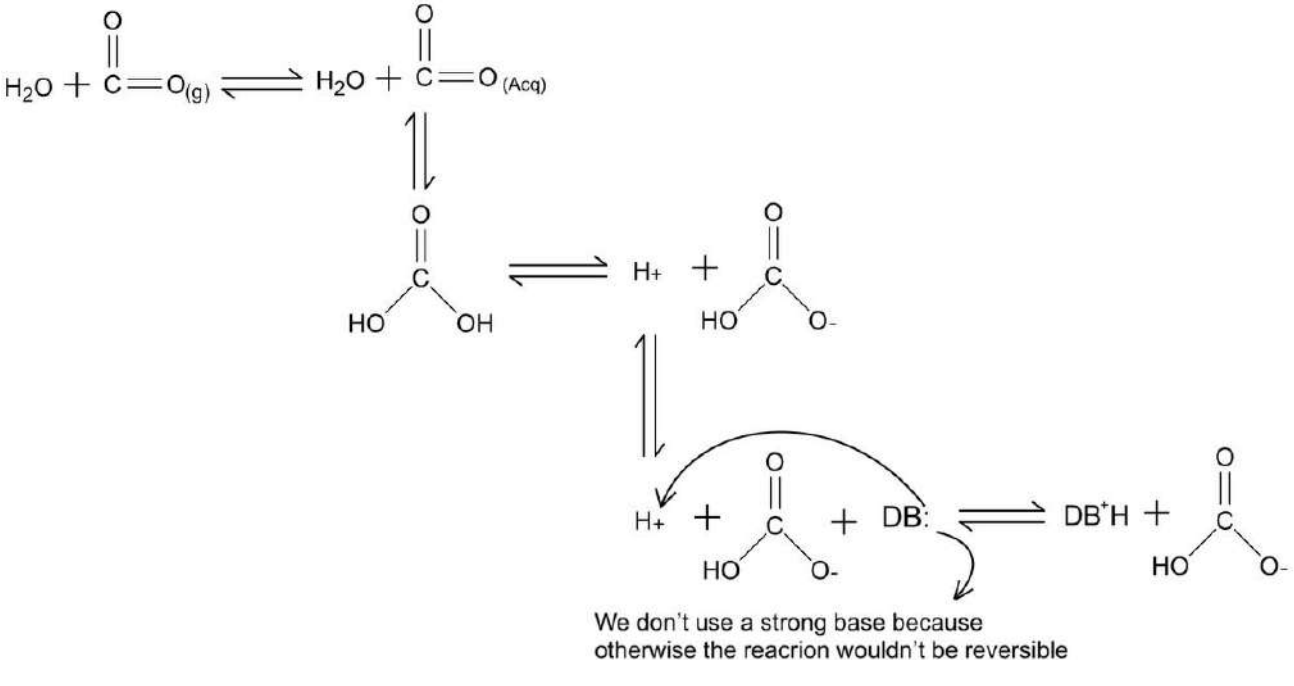
To reduce these effects, the goal is to reduce CO_2 emissions or/and reuse it, but in order to be reused it must first be captured.

To capture CO_2 we use solution of a debole base and ethanol.

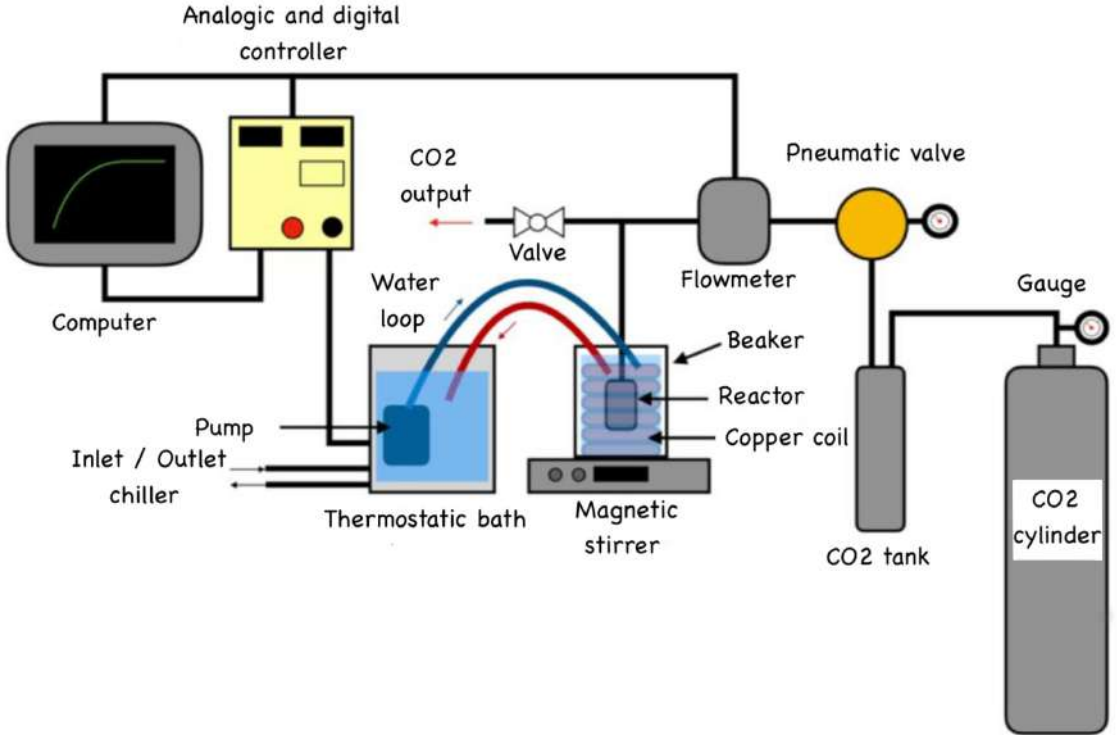
Ethanol is a linear chain alcohol with the chemical formula of CH_3CH_2OH, at room temperature it's in the form of a colorless liquid characterized by a pungent odor. Ethanol is soluble in water since both are polar liquids which can form hydrogen bonds. Furthermore, ethanol may play, as in our case, the role of co-solvent since it is capable of modifying the polarity of the reaction medium so as to favor the stability of the intramolecular interactions that take place between water and debole base.

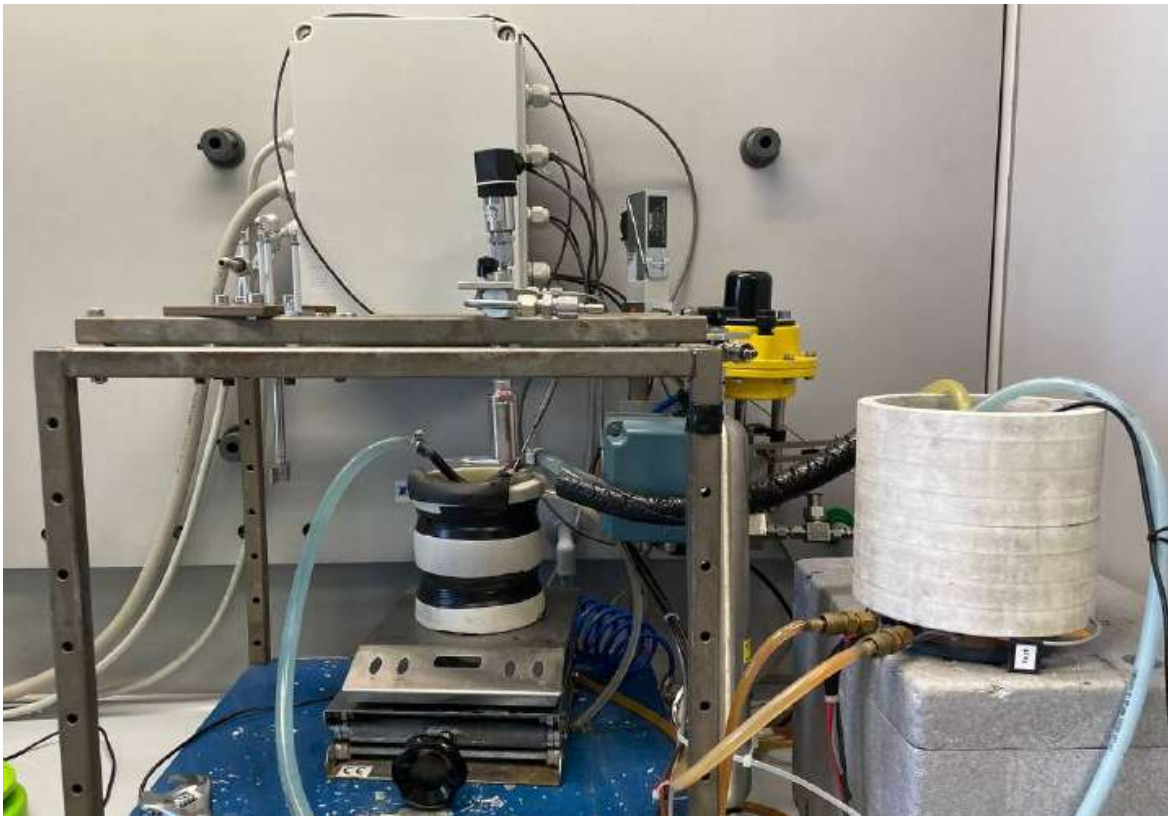


When we insert one of these solutions into the "CCUS machine" they come into contact with carbon dioxide and the following reactions occur:



EXPERIMENTAL SECTION





This device allows us to determine when a solution is capable of capturing CO_2 by measuring the amount of gas absorbed using the flowmeter. The principle of this instrument is based on maintaining constant pressure and temperature inside the reactor which contains the analyzed solution; the pressure must be kept constant in the reactor because when the solution absorbs the CO_2 it would tend to decrease.

To supply the CO_2 to the system, a cylinder containing the gas is used to load the smallest tank of the instrument, this tank is connected to a pneumatic valve which, thanks to the flowmeter, determines the quantity of CO_2 entering the reactor. The reactor has a maximum capacity of 10 mL and is immersed in a beaker containing water and a copper coil which maintains the desired temperature.

This water loop forms a thermostatic bath having a pump and is placed on an elevator, the beaker is also placed above a magnetic stirrer. The flowmeter and the thermostatic bath are regulated by an analogical and digital controller which allows us to establish the temperature and pressure at which the analyzes will be carried out.

Solutions were prepared by mixing debole base, ethanol and water at different ratios. The first mixture was prepared with a ratio of debole base to water 1:2 and the concentration of debole base is 8M. Solution 1 is prepared by solubilizing 5.44g of debole base in 34g of H_2O and adding ethanol until a total volume of 10 mL is reached. Solution 1 was added into the stainless steel reactor and the stir bar was added into the mixture. The reactor is connected to the "CCUS machine" and the CO_2 tank is filled. Before the analysis started the system was purged to remove any air in the sample. The analysis started and we waited for the next day.

Analyzing the graph, we realized that it did not reflect the trend we expected, because the quantity of CO_2 released continued to increase and the solution could not absorb so much CO_2. Thinking about the incident we realized that it was a leak in the CO_2 outlet valve that we had to replace in order to repeat the experiment. To try again to make the analysis we had reused the same solution of the first attempt given that it had already released the absorbed CO_2, therefore the solution had been put under vacuum and then in the reactor. The carbon dioxide stream has been started to begin the analysis. The trial with solution 1 was repeated again.

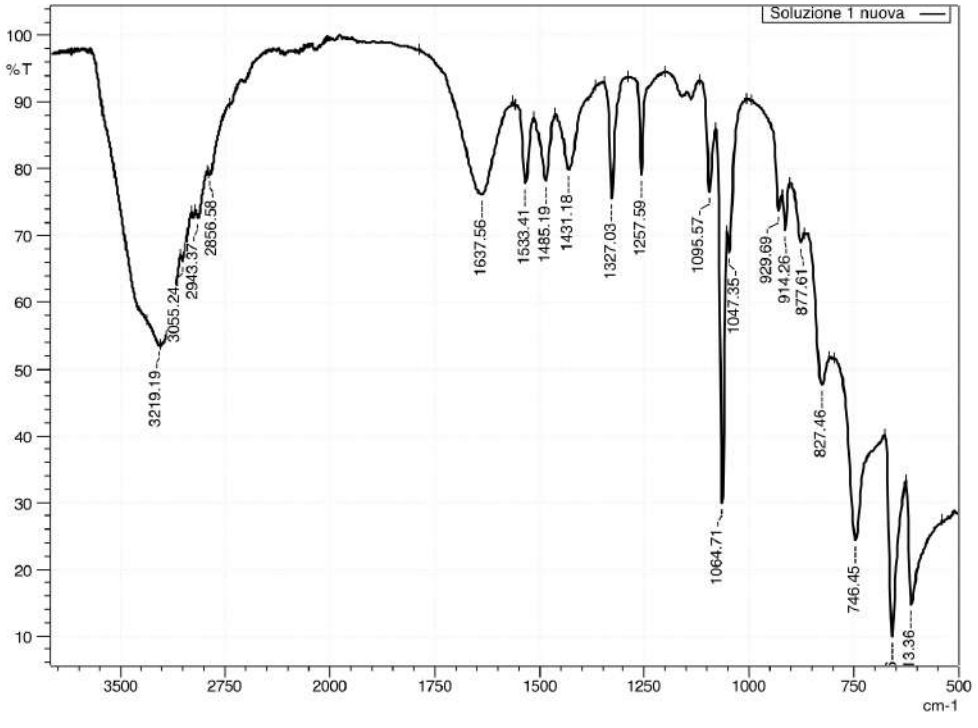
Other solutions with the ratio of debole base to H_2O 1:3 were prepared. To prepare solution 2, 4.08g of debole base and 3.24g of water were weighed out with 6M debole base concentration and ethanol was added until 10mL. While we were waiting for the results of the analysis of solution 2 we had passed the results of analysis of solution 1 to Excel.

We have to obtain the mg of carbon dioxide that had been absorbed by the sample excluding the mass of CO_2 that was needed to keep the pressure constant. The mg of CO_2 absorbed by the sample had been calculated by adding an inert material to the reactor (of the same volume as the sample inserted) and bringing the system to 20bar. The CO_2 that had been used to bring the system to 20bar has a mass of 306mg, the value obtained had been subtracted from the analysis values.

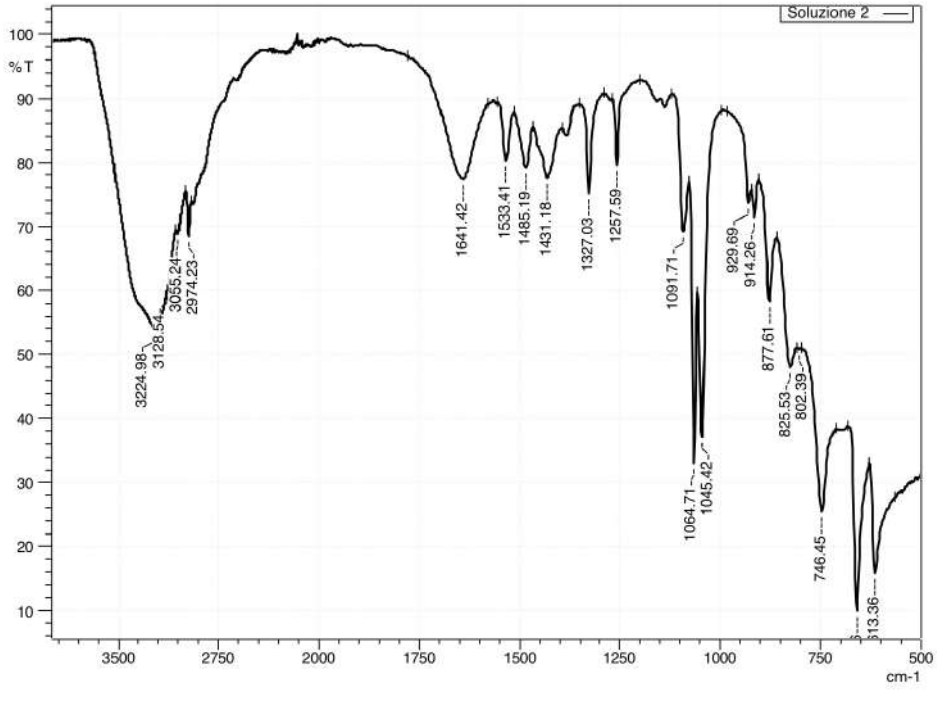
We thought it was usefull to prepare a solution similar to solution 2 but with an 8M debole base concentration so all analyzes were repeated with solution 3.

To conclude the experiment, the analyzes with Raman and infrared spectroscopy were carried out on all the prepared solutions and the spectra obtained are reported in "RESULTS AND DISCUSSION".

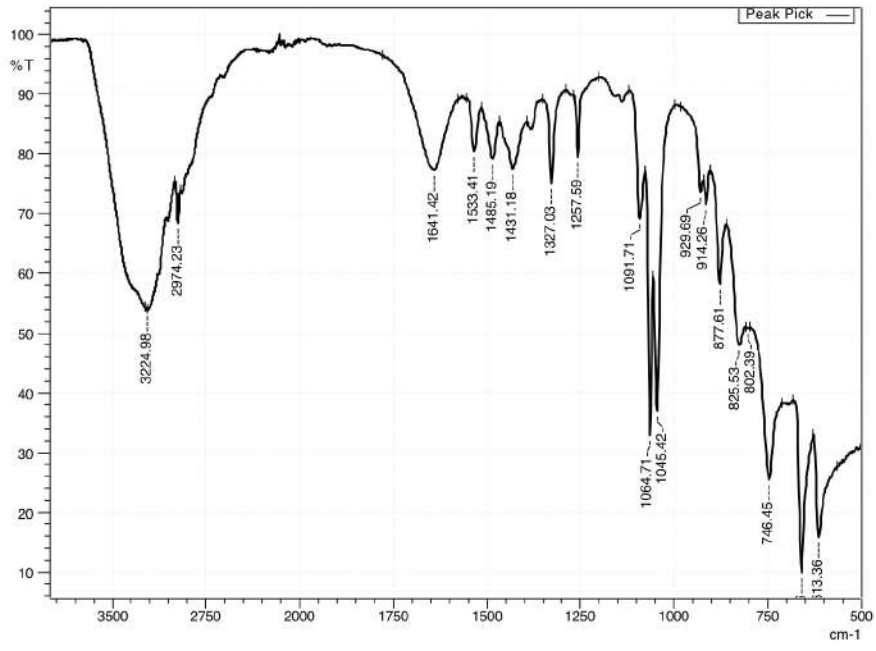
RESULTS AND DISCUSSION



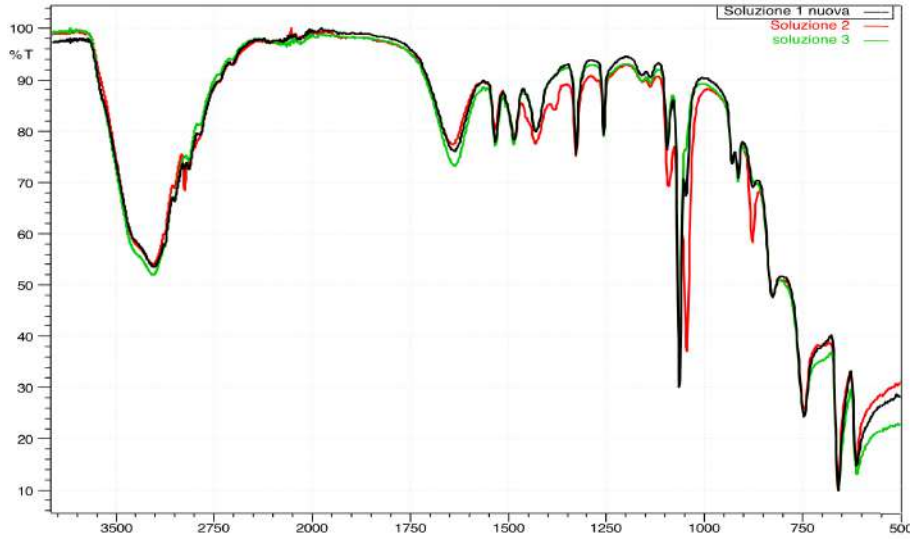
↑ IR spectrum solution 1

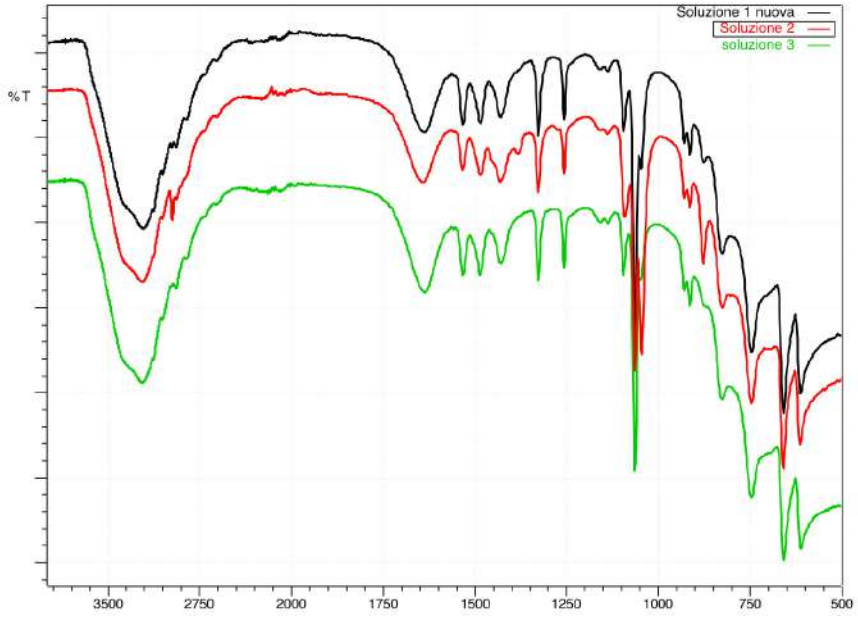


↑ IR spectrum solution 2



↑ IR spectrum solution 3





STRETCHING O-H (REFERRED TO ETHANOL)**=** 3200 cm-1

STRERCHING C=C (REFERRED TO AROMATHIC RING OF DEBOLE BASE)**=~**1500 cm-1

STRETCHING C-N (REFERRED TO DEBOLE BASE)**=** 1060 cm-1

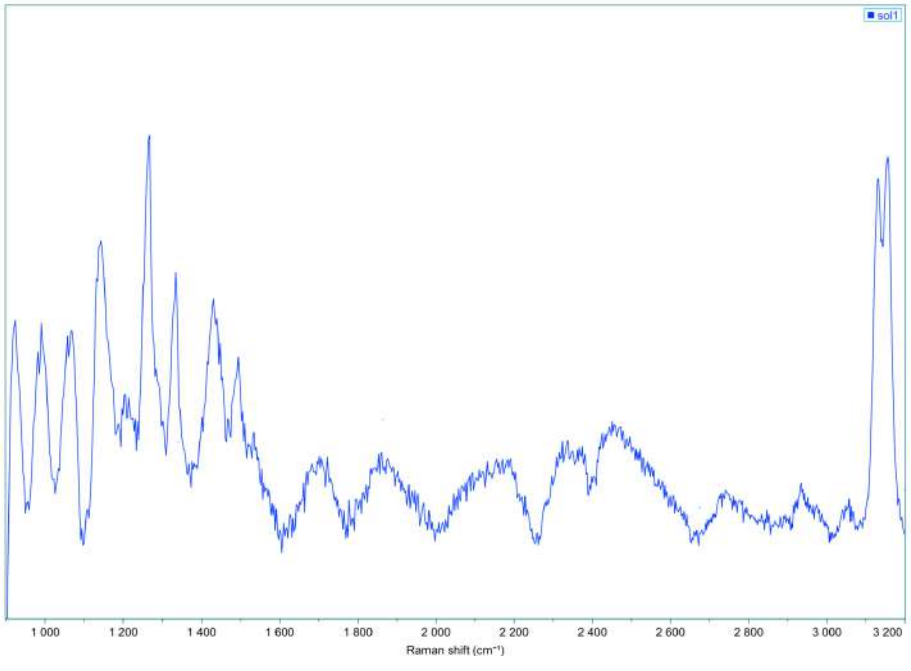
BENDING C-H (REFERRED TO DEBOLE BASE)**=** 1450 cm-1

BENDING CH2 (REFERRED TO ETHANOL)**=** 1390 cm-1

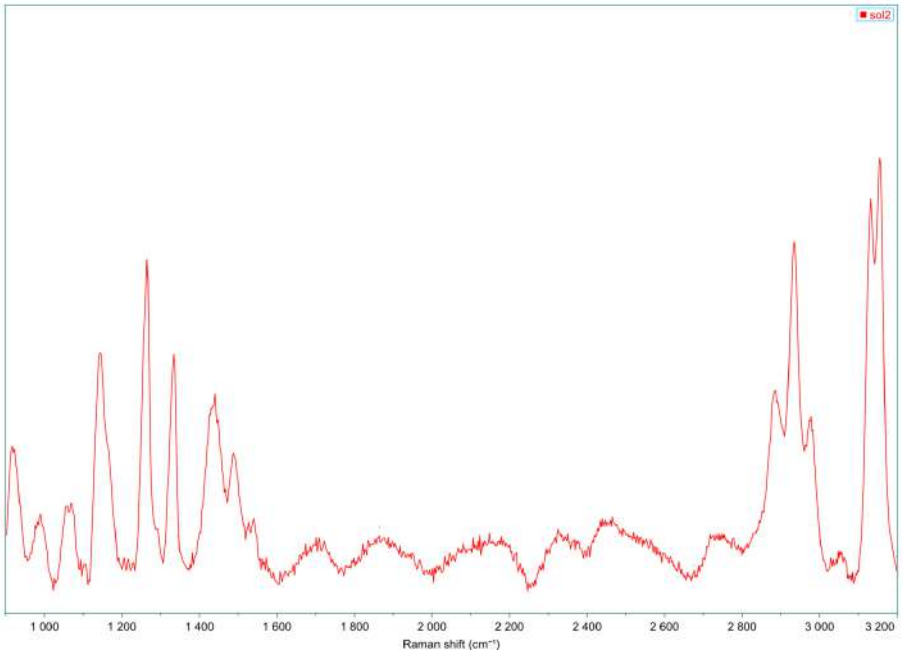
STRETCHING C-O (REFERRED TO ETHANOL)**=**1100-1040 cm-1

BENDING N-H (REFERRED TO ETHANOL)**=**1635 cm-1

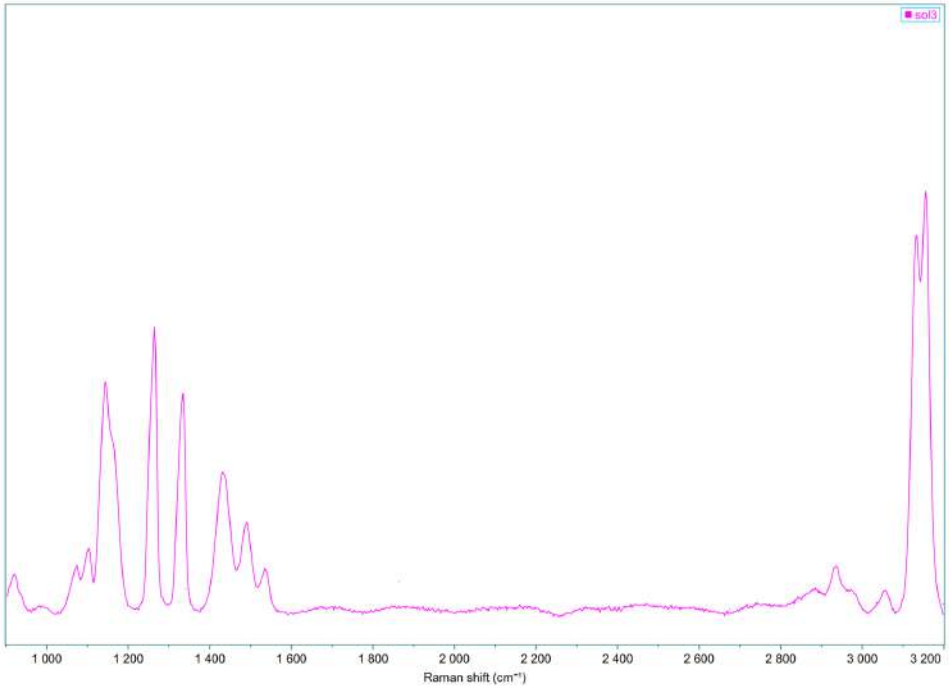
Stretching of the N-H bond is superimposed by stretching of the O-H bond.



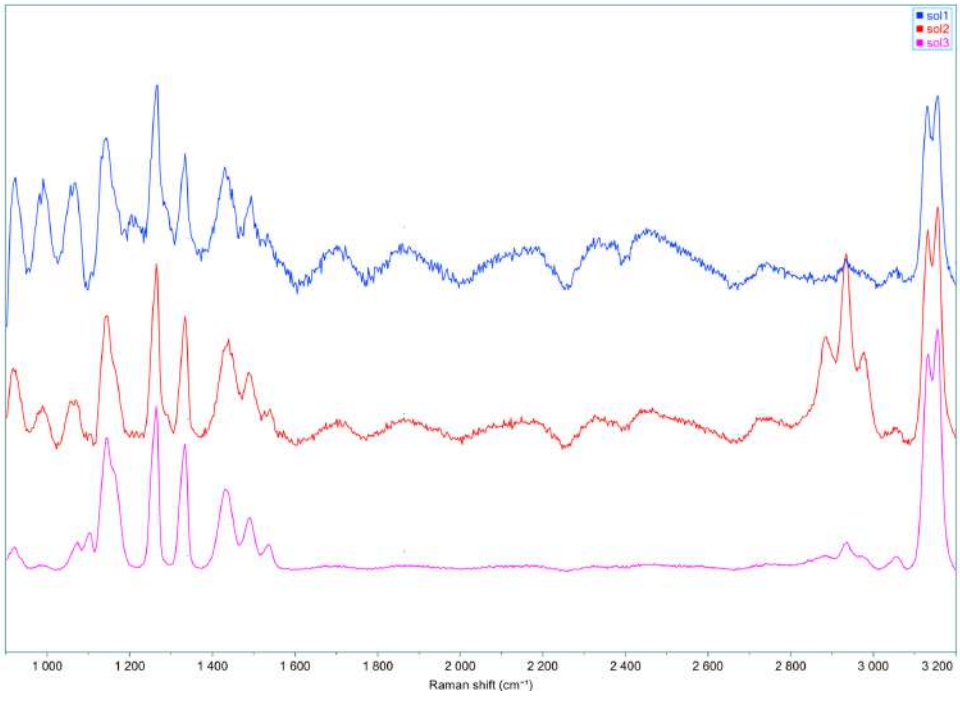
↑ Raman spectrum solution 1



↑ Raman spectrum solution 2



↑ Raman spectrum solution 3



~ 980= ring deformation;

~ 1100= C-O stretching;

~ 1250-1350= C-C stetching;

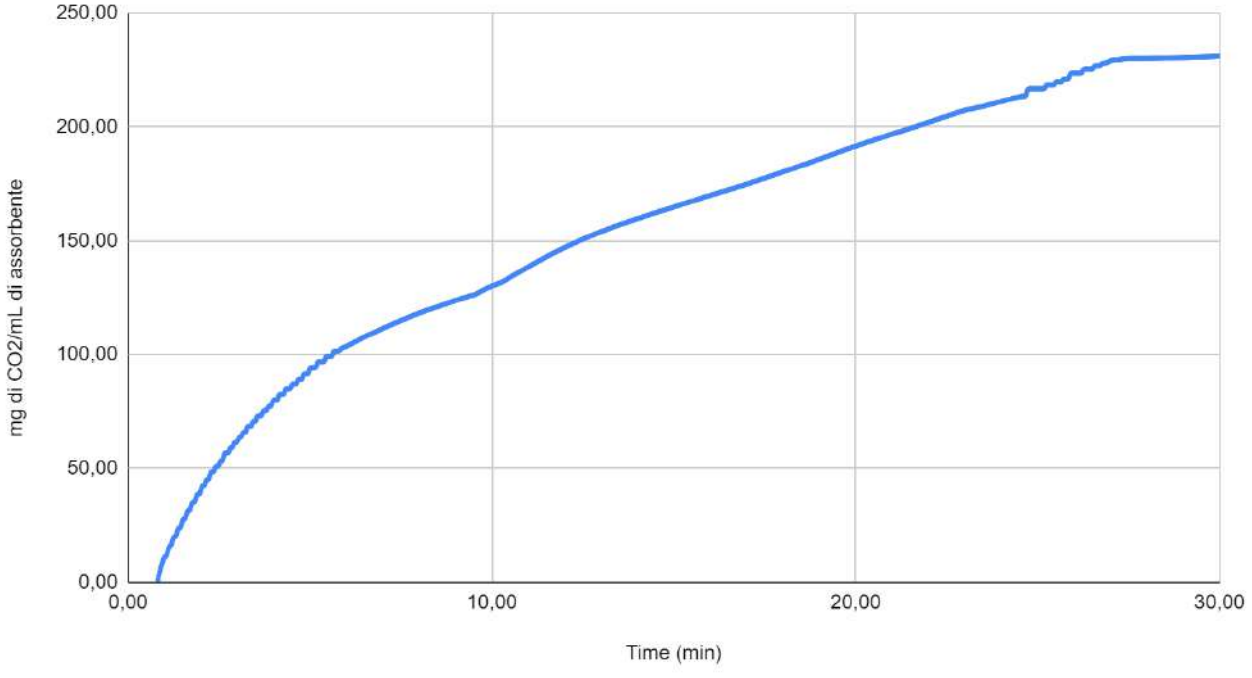
~ 1400-1600= C-N stretching + C-H wagging + N-H wagging;

~ 1600-2600= fluorescence bands that fade with increasing concentration (interference);

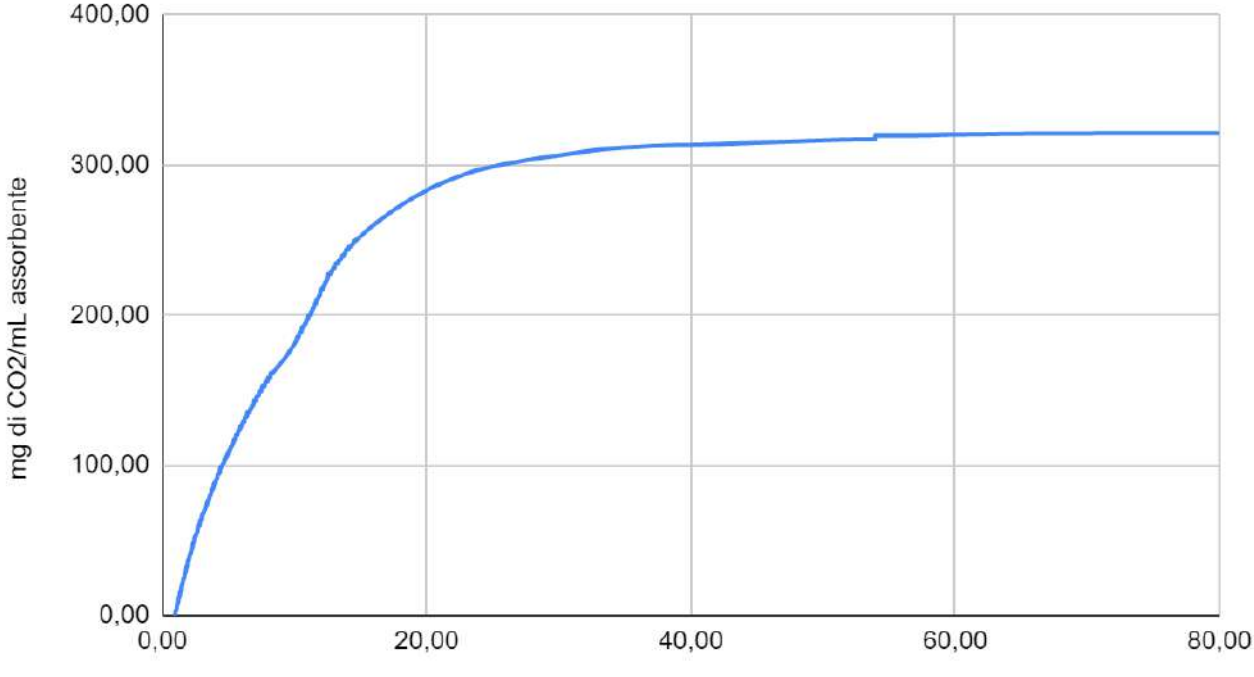
~ 2900- 3100= the peaks are seen only in the second solution because there is a higher concentration of ethanol and they rapesent the C-H stretches;

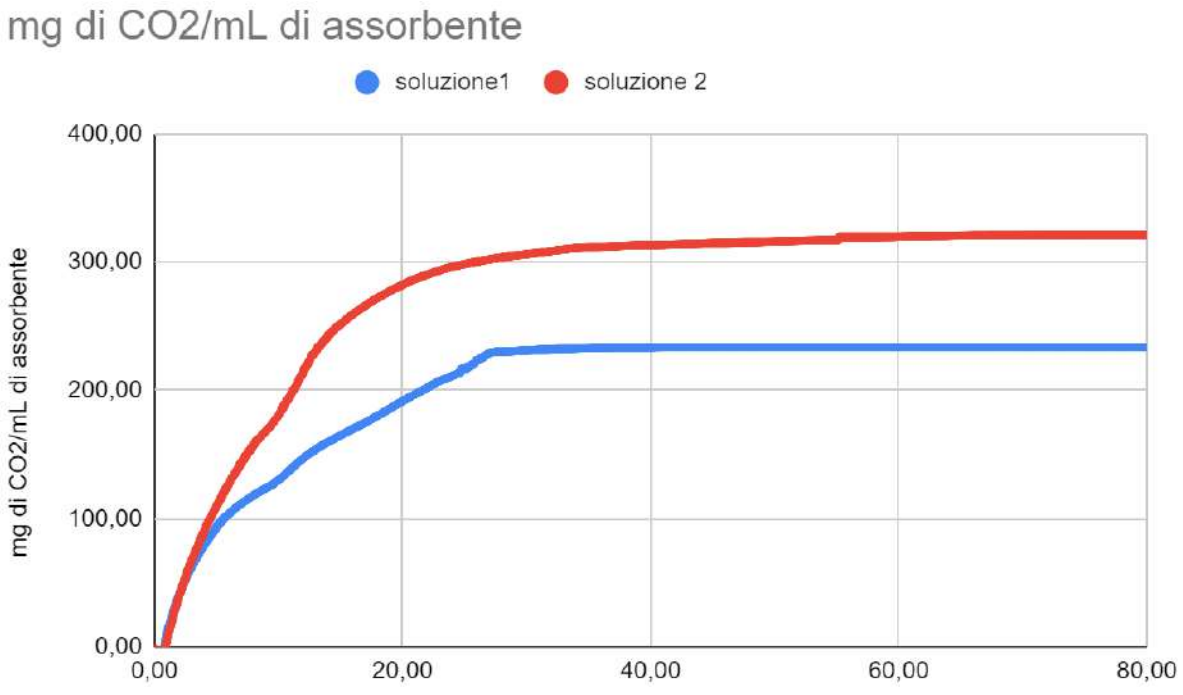
~ 3200=N-H stretching;

mg di CO2/mL di assorbente soluzione 1



mg di CO2/mL assorbente soluzione 3





↑ The trend in the graph shows the absorption of CO_2 as a function of time and the mg of CO2 absorbed by the solutions.

CONCLUSIONS

The method that we had studied to capture CO_2 was especially effective with the 8M solution with the ratio of debole base to water 1:3. The solutions had been shown to be effective for both the capture and release of carbon dioxide due to the choice of a weak base which makes the reactions reversible. Since CO_2 is weakly acidic compared to other waste gases and has a closer affinity to debole base, this method is therefore selective towards CO_2. The studied method has advantages when applied to industries because if they produce a mixture of waste gases only CO_2 will be captured. This method of capturing CO_2 is environmentally sustainable as the solution after it releases the CO_2 will be able to absorb for several cycles.

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