

Experiment No. 2
GAS ABSORPTION

1. Objective:

To measure the absorption of carbon dioxide into water flowing down the tower using the gas analysis equipment provided.

2. Intended Learning Outcomes (ILOs):

The students shall be able to:

2.1 study the basic operation of gas absorption.

2.2 determine the different factors affecting the rate of absorption of carbon dioxide into water flowing down the tower.

3. Discussion:

Gas absorption, also known as scrubbing is an operation in which a gas mixture is contacted with a liquid for the purpose of preferentially dissolving one or more components of the gas mixture and to provide a solution of them in the liquid. Therefore, we can see that there is a mass transfer of the components of the gas from the gas phase to the liquid phase. There are two types of absorption processes, physical absorption and chemical absorption, depending on whether there is any chemical reaction between the solute and the solvent (absorbent).

When water and hydrocarbons are used as absorbent, no significant chemical reactions occurs between the absorbent and the solute, and the process is commonly referred to as physical absorption when aqueous sodium hydroxide (a strong base) is used as the absorbent. To dissolve an acid gas, absorption is accompanied by a rapid and irreversible neutralization reaction in the liquid phase and the process is referred to chemical absorption.

In gas absorption, two components of a gas are separated by contact with a liquid in which one component is preferentially soluble. The solute is recovered from the liquid by distillation, and the absorbing liquid can either be discarded or reused. Sometimes a solute is removed from a liquid by bringing the liquid into contact with an inert gas; this operation is called reverse gas absorption or gas stripping.

In certain operations, a common apparatus used in gas absorption is the packed tower. The packing provides a large area between the liquid and gas for intimate contact between phases. The solute in the rich gas is absorbed by the fresh liquid entering the tower, and concentrated liquid called strong liquor, leaves the bottom of the tower through the liquid outlet.

In a tower containing a given packing and being irrigated with a definite flow of liquid, there is an upper limit to the rate of gas flow. The gas velocity corresponding to this limit is called the flooding velocity.

The rate of absorption can be expressed in different ways using individual coefficients or overall coefficients based on the gas or liquid phases. Volumetric coefficients are used for most calculations, because it is more difficult to determine coefficients per unit area, and because the purpose of the design calculation is to determine the total absorber volume.

The rate of absorption of carbon dioxide can be calculated using the equation below,

$$V'Y_1 - V'Y_2 = CO_{2\text{ absorbed}}$$

where V' is the Molar Flow Rate of Dry Gas, which is air, Y_1 is the mole fraction ratio of solute in rich gas while Y_2 is the mole fraction of solute in lean gas.

4. Resources:

Equipment: Gas Absorption Column
Carbon Dioxide Cylinder

Materials: 300 ml of 0.1 M NaOH Solution
Fresh Tap Water

5. Procedure:

1. First, fill the gloves of the absorption analysis equipment on the left of the panel with 1.0 M caustic soda. Wear gloves and goggles while doing this. Adjust the level in the gloves to the 0 mark on the right tube using drain valve into a flask to do this.
2. Fill the liquid reservoir tank to three-quarters full with fresh tap water.
3. With gas flow control valve C2 and C3 closed, start the liquid pump and adjust the water flow through the column to approximately 6 liters per minute on the flow meter F1 by adjusting flow control valve C1.
4. Start the compressor and adjust the control valve C2 to give air flow to approximately 10% of full scale on flow meter F2.
5. Carefully open the pressure regulating valve on the carbon dioxide cylinder, and adjust valve to give a C3 on the flow meter F3 approximately one half of the airflow F2. Ensure the liquid seal at the base of the absorption column is maintained by, if necessary, adjust of control valve C4.
6. After 15 mins, or so of steady operation, take samples of gas simultaneously from sample points S1 and S2. Analyze this consecutively for CO₂ content in these gas samples.
7. Flush the sample lines by repeated sucking from the line, using the gas piston and expelling the contents of the cylinder to the atmosphere. Note that the volume of the cylinder is about 100 mL. Estimate the volume of the tube leading to the device. Then decide how many times you need to suck and expel.
8. With the absorption glove isolated and vent to the atmosphere closed, fill the cylinder from the selected line by drawing the piston cut slowly. Note the volume taken into cylinder V_1 , which should be approximately 20 mL for this particular experiment. Wait at least 2 minutes to allow the gas to come to the atmosphere/temperature of the cylinder. If the concentration of CO₂ in the gas sampled is greater than 8%, it is possible to suck liquid into the cylinder. This will ruin your experiment and takes time to correct. Stop it at a particular mark, example, $Y_1 = 20$ on the coarse scale and read the fine scale.
9. Isolate the cylinder from the column and the absorption glove and vent the cylinder to atmosphere pressure. Close after 10 seconds.
10. Connect cylinder to absorption glove, the liquid level should not change. If it does not change, briefly open to atmosphere again.
11. Wait until the level in the indicator is on zero showing that the pressure in the cylinder
12. Slowly close the piston to empty the cylinder into the absorption glove. Slowly draw the piston out again. Note the level in the indicator tube. Repeat steps 5 and 6 until no significant change in level occurs. Read the indicator tube marking, V , this represent the volume of the gas sampled.
13. Repeat the experiment for trials 2 and 3.

6. Data and Results:**Course:****Experiment No:****Group No:****Section:****Group Members:****Date Performed:****Date Submitted:****Instructor:**

Absorption of carbon dioxide into water flowing down the tower using the gas analysis equipment

Trial	Mole Fraction of CO ₂		CO ₂ Absorbed (gmol/min)
	Inlet (Bottom)	Outlet (top)	
1			
2			
3			

7. Calculations:

8. Conclusion:

9. Questions/Problems:

1. Discuss the following:
 - a. Loading point
 - b. Flooding point
 - c. Hydronamics
 - d. Channeling
2. Differentiate packed columns and tray columns.
3. Dry gas containing 75% air and 25% NH_3 vapor enters the bottom of cylindrical packed absorption tower that is 2 ft in diameter. Nozzles in the top of the tower distribute water over packing. A solution of NH_3 in water is drawn from the bottom of the column, and scrubbed gas leaves the top. The gas enters 80°F and 730 mmHg. The leaving gas contains 1% NH_3 .
 - a. If the entering gas flows through the empty column at an average velocity of 1.5 ft/s, how many ft^3 of entering gas are treated per hour?
 - b. How many pounds of ammonia are absorbed per hour?
4. A gas mixture containing 1% acetone and 99% dry air by volume is contacted with pure water in a plate gas absorber in which 90% of the acetone is recovered. The inlet gas flow rate is 30 kmol/hr and the inlet water flow rate is 90 kmol/hr. The absorber operates at 27°C and 1 atm. The equilibrium curve is given by $y^* = 2.53x$
 - a. What is the concentration of the strong liquor?
 - b. What is the number of theoretical plates required?
5. A mixture of benzene vapor and flue gas contains 12.7 mole % benzene and is to be scrubbed continuously in a packed tower operated at atmospheric pressure at 43°C . The tower is to be designed to treat 36000 ft^3 per hour of entering gas and the exit gas is to contain 1.5 mole % benzene and will be supplied at the rate of 28 lbmol/hr. The solution of benzene in oil may be assumed to follow Raoult's law and the vapor pressure of pure solvent at 43°C is 0.263 atm. It is agreed that the maximum allowable superficial velocity of the gas is 1 ft/sec. Calculate the height of the tower required, assuming that the height of a transfer unit is 2 ft.

10. Answers:

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11. Further Readings:

- Cao, E. (2010). *Heat transfer in process engineering*. Boston: McGraw-Hill Professional.
- Cengel, Y.A. and Ghajar, A.J. (2011). *Heat and mass transfer: fundamentals and applications (4th ed.)*. New York: McGraw-Hill.
- Hellemans, M. (2009). *The safety relief valve handbook: design and use of process safety valves to ASME*. Massachusetts: Butterworth-Heinemann.
- Kakac, S., Liu, H., and Pramuanjaroenkij, A. (2012). *Heat exchangers: selection, rating and thermal design*. Boca Raton, Florida: CRC Press.
- Kothandaraman, C.P. and Rudramoorthy, R. (2011). *Fluid mechanics and machinery (3rd ed.)*. United Kingdom: New Academic Science.
- Strathmann, H. (2011). *Introduction to membrane science and technology*. Germany: Wiley-VCH Verlag & Co.

12. Assessment (Rubric for Laboratory Performance):

CRITERIA	BEGINNER 1	ACCEPTABLE 2	PROFICIENT 3	SCORE
I. Laboratory Skills				
Manipulative Skills	Members do not demonstrate needed skills.	Members occasionally demonstrate needed skills.	Members always demonstrate needed skills.	
Experimental Set-up	Members are unable to set-up the materials.	Members are able to set-up the materials with supervision.	Members are able to set-up the material with minimum supervision.	
Process Skills	Members do not demonstrate targeted process skills.	Members occasionally demonstrate targeted process skills.	Members always demonstrate targeted process skills.	
Safety Precautions	Members do not follow safety precautions.	Members follow safety precautions most of the time.	Members follow safety precautions at all times.	
II. Work Habits				
Time Management / Conduct of Experiment	Members do not finish on time with incomplete data.	Members finish on time with incomplete data.	Members finish ahead of time with complete data and time to revise data.	
Cooperative and Teamwork	Members do not know their tasks and have no defined responsibilities. Group conflicts have to be settled by the teacher.	Members have defined responsibilities most of the time. Group conflicts are cooperatively managed most of the time.	Members are on tasks and have defined responsibilities at all times. Group conflicts are cooperatively managed at all times.	
Neatness and Orderliness	Messy workplace during and after the experiment.	Clean and orderly workplace with occasional mess during and after the experiment.	Clean and orderly workplace at all times during and after the experiment.	
Ability to do independent work	Members require supervision by the teacher.	Members require occasional supervision by the teacher.	Members do not need to be supervised by the teacher.	
Other Comments / Observations:			TOTAL SCORE	
			RATING = $\left(\frac{TotalScore}{24}\right) \times 100\%$	