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Distillation, an effective process for water purification

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Purpose. We all agree on the principle that water is life. Noting that, obtaining drinking water that meets the World Health Organization standard is a difficult and sometimes expensive process. The main objective of this research work is separation of constituents from a mixture of solution in the first instance and our tendency is water purification in the other side. **Methods.** Given that the purification of solutions represents a major challenge for them, based on basic knowledge of the chemistry of solutions. We have conducted some separation tests in the laboratory with the aim of eliminating harmful elements. For this reason, a comparative study was carried out on two different separation techniques in a water-ethanol solution of 10 ml. In the first one, a simple distillation test was carried out at a temperature above than 78.5 °C and at a low pressure from which only 0.6 ml of distillate (ethanol) was recovered (too low yield). However, in the second experimental protocol three assays were conducted using a distillation column with different volumes of water-ethanol mixture. The varieties of parameters and experimental protocols carried out with well-defined objectives and direct impacts on the results obtained. **Results.** Overall, we can say that the results obtained are clear and significant. In addition, the tests carried out made it possible to obtain satisfactory results in terms of yield and purification. Furthermore, the best results were obtained in the solution of 6 ml ethanol and 4 ml water with Distillate = 6 ml and Residue = 0 ml (maximum recovery of ethanol from the solution). This is the reason why distillation is the best technique for separation, purification and extraction from the solution mixture. **Conclusions.** From the assembled results we can conclude that the distillation is a one of the best separation methods commonly employed, simple distillation (with simple separation apparatus design), by principle and methodology, is applied only if the boiling points of the constituents are different, in the opposite case; fractional distillation process (devices with complex, precise and critical components) is highly recommended.

Keywords: *distillation; ebullition point; ethanol; purification; water.*

Introduction

Use of gas, solid, or solution requires their separation. For this reason, several methods have been suggested in this recent years such as: electrostatic precipitation, gravimetric separation (based on density), electrostatic separation (based on electrical conductivity), magnetic separation (magnetic susceptibility), separation by flotation (physic-chemical properties of the surface), biological separation (by bacteria), hydraulic process carried out in water by dissolution, thermal process carried out at high temperature (roasting and fusion), pneumatic process by the use of compressed air, in the extreme cases we call for more complicated process like: optical separation (sorting according to object color) and why not radiometric separation; the use of rays to carry out a differentiation [1–4]. These techniques defined by the principle, means involved, objective of the study, the separation factor, expected results and their effects on the environment. As industry, meet certain quality criteria [5, 6].

Nowadays, distillation occupies an important place in water purification process, this later must be stable in terms of color, pH, taste, odor and it must not contain pathogenic bacteria or heavy metals [7, 8]. Distillation is one of the oldest and favorable methods for water treatment from reasons: its reliability, flexibility, mobility, availability as well as its competitive cost price [9]. It consists in vaporizing a liquid at temperature greater than or equal to the boiling point. Then, condensing the vapor known by the name of

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the head in special ducts by collecting to make up the distillate, the remaining solution is impure called: the residue [10–12]. Depending on the feeding mode and the intended objective, this distillation can be simple or fractional, continuous or discontinuous. The largest disciplines users of this process are the petroleum, agrifood and pharmaceutical industries [13–15].

To do this, several tests by distillation were conducted on simple distillation assembly that do not require a sophisticated assembly to carry out the separation and at a fractional distillation set-up using a distillation column known by its power to separate solutions which have a close boiling temperature. The purpose of which was to separate a homogeneous mixture and to calculate the overall and partial assessment samples to verify the properties of the column of distillation and evaluate their effectiveness.

The results obtained are broadly encouraging, they give positive indicators on the possibility of separating the ethanol from the solution, while minimizing the loss of weight during the distillation experience and ensuring an optimal extraction of the product without undesirable impurity with of course minimum expenditure in terms of energy and operation time.

Materials and research methods

Distillation process

Several separation techniques have recently been proposed for the separation of a mixture or for the purification of a fluid, the latter are based on principles such as; vacuum forces, capillary forces, centrifugal forces as well as the effect of gravity [16, 17]. The distillation process was used in all purification operations, other methods have carried the same standard such as; filtration, crystallization, extraction and sublimation [18, 19], here are some varieties of distillation processes:

Due to its low energy consumption and flexibility, extractive distillation is strongly recommended [20, 21]. In addition, solar energy for desalination by membrane distillation is an efficient process for arid areas [22]. In fact, membrane distillation is a strong separation technique during which a feed solution is brought into contact with one side of the porous hydrophobic membrane [23, 24]. However, distillation columns have already been employed for the recovery and purification of lactic acid [25]. Note that, trays Distillation are distinguished by a degree of efficiency ranging from 10–90% [26], the assembly is shown in figure 1 [27], commonly employed distillation methods can be summarized as follows:

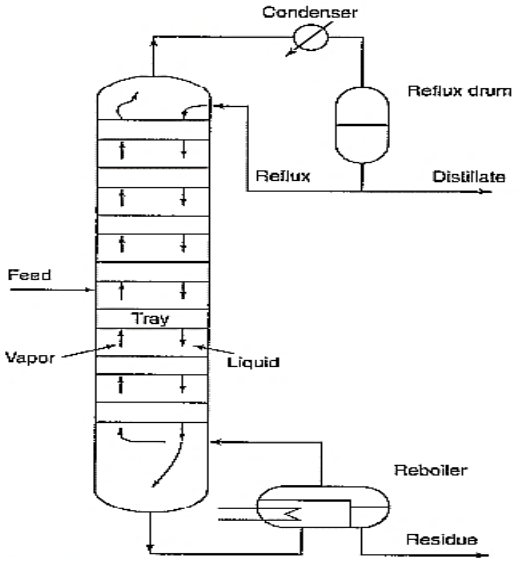

Fig. 1. Tray distillation column

Continuous distillation

The feed mixture is continuously injected into the column. The most volatile component is gradually extracted at the top of the column, while the less volatile product is continuously removed at the bottom of the column [28–30].

Differential distillation

The best-known batch distillation subcategory is a single-stage differential distillation, starting with a still, a mixture to be distilled is fed into the boiler, then it is heated at a constant rate. In this process, the vapor formed during the boiling of the liquid escapes from the system, it is rich in the most volatile component [31].

Fractional distillation

It is based on the use of the necessary heat, by conducting the heat in channels where the boiling points are reached, by revaporizing the fractions until the desired separation is obtained [32–34].

Distillation principle

For separation of water-ethanol mixture constituted of a negligible volume of water with $V = 10$ ml, the experimental set-up presented in figure 2 was required. The main materials used are; thermometer, two-necked flask, beaker, magnetic stirrer, burette, refrigerant, condenser, electric tank heater and as product we use ethanol and distillated water.

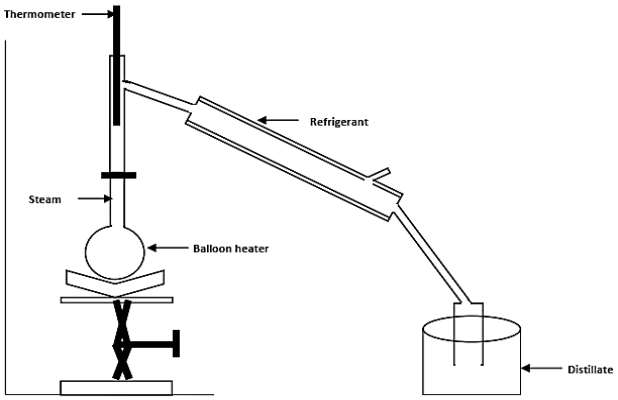

Fig. 2. Simple distillation setup

Principle

During the first experience: In the heating flask of installation, we add 10 ml of mixture (3% by volume of ethanol and 7% by volume of water); we put in place all the necessary slides. We turn on the water cooler and the tank heater thermostat. We control the thermometer for a few minutes. The distillate is in the erlenmeyer flask and the residue in the flask.

For the second experience: by changing the volume (6% Ethanol and 4% of water). While, in third experience: by changing the volume (9% ethanol and 1% of water). It should be noted that the lifting support placed under the balloon heater makes it possible to cut off heating from mixture very quickly (figure 3).

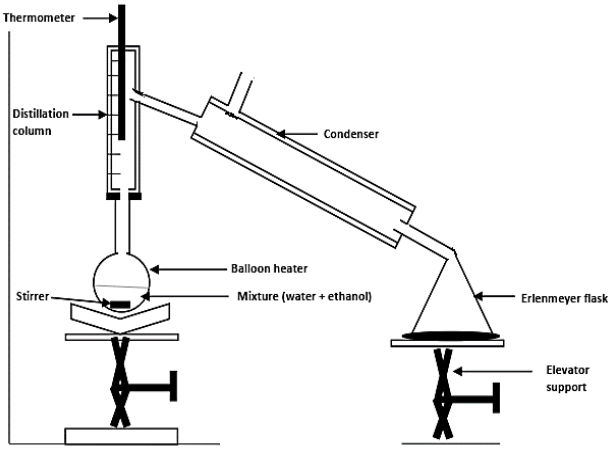

Fig. 3. Setup a fractional distillation test

Research results

Simple distillation test

Several In this case, small volume of ethanol was recovered only 0.6 ml from 10 ml solution with a temperature greater than 78.37% °C and low applied pressure, the most volatile product is ethanol (head of the product). However, water is constituted the tail of the product.

Fractional distillation test

The results of the experimental tests carried out are classified as follows: in the first experience $V_{eth} = 2$ ml and $V_{H_2O} = 8$ ml. Then in the second experience, the product obtained $V_{eth} = 6$ ml = and $V_{H_2O} = 4\ ml$. But in the third assay, the product obtained is $V_{eth} = 8$ ml and $V_{H_2O} = 2$ ml.

The overall assessment is calculated with this relation: Charge = Distillate + Residue

The partial assessment is determinate by these equations:

Ethanol: $C_{eth} = D_{eth} + R_{eth}$ idem for *Water*: $C_{H_2O} = D_{H_2O} + R_{H_2O}$

Therefore, the partial assessment for these tests is calculated by:

In the first one; $3\ ml_{eth} = 2ml_{eth} + 1ml_{eth}$

In the second one; $6ml_{eth} = 6ml_{eth} + 0ml_{eth}$ (Better separation of ethanol from the solution).

In the third one; $9ml_{eth} = 8ml_{eth} + 1ml_{eth}$

During the experiment, the following observations were obtained: Percentage determined optically to know the constituents of distillate and residue can be measured by the refractmeter, the change in the color of ethanol (transparent - blue), loss of the ethanol volume as well as the stirring role is to distribute the heat throughout the ball.

In this part, we will explain the main results obtained from these experiments. Our objective through this study is to examine the separation of ethanol from a water-ethanol mixture in order to water purify using the distillation process.

First of all, a simple distillation test was carried out on a mixture of water ethanol solution, where only 0.6 ml of ethanol could be recovered, this is explained by the low separation power of the experimental setup used.

Subsequently, three fractional distillation tests were carried out using a distillation unit known for its high extraction power.

Primarily, in volume of 10 ml of solution, 3% volume ethanol + 7% volume water were used), the result obtained shows that only 2 ml of ethanol was recovered, it is a question of separation with loss of 1 ml of ethanol.

In the second test, we have use 6% ethanol + 4% water, there we have recoved 6 ml of ethanol, and it is considered as an optimal recovery.

In the last experiment, we have used the mixture consisting of 9% ethanol + 1% water, and we collect 8 ml of ethanol. We can say there that it is an extraction with a loss of 1ml of ethanol.

Averagely, we notice that the extraction rate of ethanol in fractional distillation is better than compared to the simple distillation process (optimization of separation rate).

Conclusions

From the results obtained previously, we can conclude that the distillation is a one of the best separation methods. It is important to note also that simple distillation is applied only if the boiling points of the constituents are different, in the opposite case; fractional distillation is required.

In this paper, we compared the separation efficiency of the mixture constituents using different separation approaches such as; simple and fractional distillation. In the finale, our main goal is to separate the different constituents of a liquid mixture based on the difference in volatility of the latter by using very specific experimental equipment.

This research can correspondingly confirm the notion that there are sets of factors, which affected the distillation process such as; the state of the experimental set-up, the boiling point of a solution, the pressure, the concentration, PH, etc.

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Мета. Ми всі згодні з принципом, що вода − це життя. При цьому, отримання питної води, яка відповідає стандартам Всесвітньої організації охорони здоров'я, є складним, а часом і дорогим процесом. Основною метою цього дослідження було виділення складових компонентів із розчину, з одного боку, і очищення води, з іншого боку. **Методи.** Враховуючи те, що очищення розчинів є складною проблемою, було виконано лабораторні експерименти з метою вилучення шкідливих елементів. У порівняльному дослідженні вивчали два різні методи розділення у водно-етанольному розчині 10 мл. За першим методом виконували дистиляцію при низькому тиску й температурі вище 78,5 °C, у результаті якого було виділено лише 0,6 мл дистиляту (етанолу), що є дуже низьким виходом. За другим методом було виконано три аналізи з використанням дистиляційної колонки з різними об'ємами суміші вода-етанол. Використовували різні параметри й експериментальні методики з чітко визначеними цілями та безпосереднім впливом на отримані результати. **Результати.** Загалом можна сказати, що отримані результати чіткі та значимі. Крім того, проведені випробування дозволили отримати задовільні результати щодо виходу й очищення. Крім того, найкращі результати були отримані в розчині 6 мл етанолу та 4 мл води з дистилятом = 6 мл і залишком = 0 мл (максимальне вилучення етанолу з розчину). Це та причина, з якої дистиляція є найкращим методом для розділення, очищення та вилучення речовин із суміші розчинів. **Висновки.** На підставі отриманих результатів ми можемо зробити висновок про те, що дистиляція є одним із найкращих методів розділення, які практикуються. Проста дистиляція (з простою конструкцією апарату для розділення), за принципом і методологією, застосовується лише в тому випадку, якщо точки кипіння компонентів різні. В іншому випадку рекомендується застосовувати процес фракційної дистиляції (апарати складної конструкції).

Ключові слова: *дистиляція; точка кипіння; етанол; очищення; вода.*

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