

February 3, 2016

## Purifying Chemicals by Distillation

### Experiment #2

#### **Introduction**

One method used by chemists to separate compounds of different boiling points is distillation. Due to the different boiling points of the compounds, the vaporization occurs at different temperatures, allowing for the separation. In this experiment, we separate a solution of 50:50 2-propanol and 1-butanol. 2-propanol has a boiling point of around 80°C while 1-butanol has a boiling point of around 120°C. We first used simple distillation, which proved ineffective in a separation that allowed us to distinguish between the two compounds; the temperature rose at a steady rate, with little difference in the temperature for every 2mL that was distilled. We then used fractional distillation which effectively separated the two compounds. We also found the density of both compounds during fractional distillation by measuring their volumes and masses earlier on, then later on in the distillation. The earlier compound was solely 2-propanol, and the later was 1-butanol.

#### **Observation and Results**

1. After setting up all the equipment, we commenced the simple distillation when the temperature was 84°C.
2. We monitored the results until the volume of distilled solution in the graduated cylinder was 30 mL.
3. We set up for fractional distillation, commenced this, and monitored temperature every 2 mL. We started the distillation at 80°C.
4. At 18.7 mL, in between 18 and 20 mL, we weighed the graduated cylinder with the liquid, then resumed the experiment. This way, we could measure the density of the 2-propanol.
5. We continued the distillation, and replaced the graduated cylinder with a new empty one after 24 mL, so that we could gather the remnant 1-butanol in its own cylinder.
6. At 10.2 mL, we weighed this graduated cylinder so that we could obtain the density of the 1-butanol, since it was the independent compound in the flask now.
7. We stopped the distillation when a total of 34 mL had been distilled.

#### **Density Calculations**

### 2-propanol

18.7 mL weighs 19.17 g  
 $19.17/18.7 = 1.025 \text{ g/cm}^3$

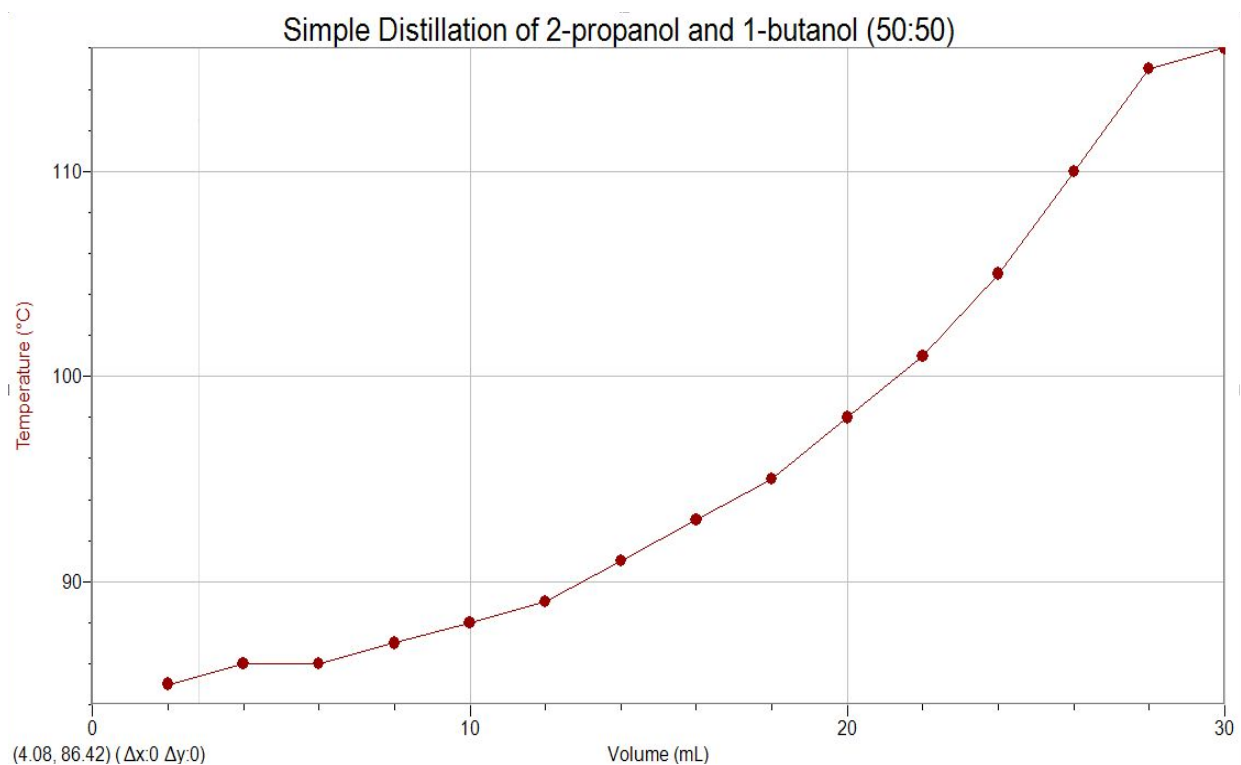
The density of 2-propanol is  $1.025 \text{ g/cm}^3$ .

### 1-butanol

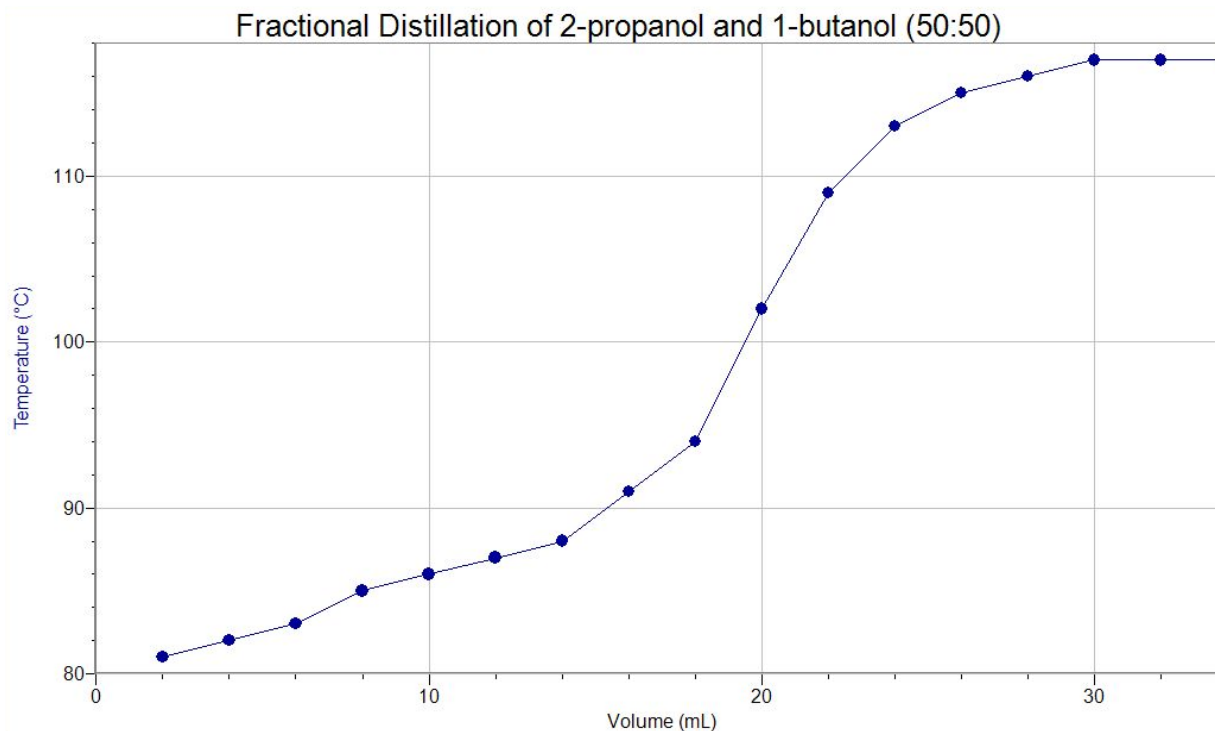
10.2 mL weighs 7.36 g  
 $7.36/10.2 = 0.721 \text{ g/cm}^3$

The density of 1-butanol is  $0.721 \text{ g/cm}^3$ .

## Distillation Curves



Curve from simple distillation, showing an evenly distributed range of temperatures, and a fairly smooth curve.



Curve from fractional distillation, showing a leap, and two distinct temperatures that the distillation occurs at.

### Discussion

In this lab, we obtained two different distillation curves, one from simple distillation and one from fractional distillation. For simple distillation, the curve expected would be smooth, with no sharp or clear cut off points. There would not be any jump in the temperatures, they would raise fairly steadily they whole time, except for perhaps a small increase in the rate at the end due to the last bit vaporizing being only 1-butanol. This is exactly the type of curve I got from my data for the simple distillation. The reason the curve looks like this is because simple distillation is not as effective in completely separating the compounds that have almost similar boiling points (30°C is not that much of a temperature difference). Since the compounds are not being separated very efficiently, and the temperature difference is small, the distillation curve will prove to be smooth and even, since the compounds are being distilled simultaneously for the most part.

For fractional distillation, we expect a curve that does have a cut off point, and a clear jump between the two temperatures, those that are the boiling points of the compounds. This is exactly what we see in the resulting distillation curve from the data collected from fractional distillation. This occurs because fractional distillation is much more exact, due to the fractioning column which, in short, completes several distillations in one. With the surface area of the wire substance in the fractioning column, the

condensing surfaces are increased and the distillation process is much more refined. This means that the compounds will be separated much better, and there will be a clear difference in the boiling points on the curve.

There were no differences between our results and what we should have obtained, except for the predicted boiling point of 1-butanol. We see that distillation of 2-propanol begins at around 80°C, the boiling point of this compound, but it seems that 1-butanol, according to the fractional distillation curve, begins to boil and turn to vapor at around 112°C or 113°C. The original predicted boiling point of 1-butanol was said to be 120°C, but it turns out that it was closer to 112°C.

### Questions

- 1) It is important to have liquid flowing back through the fractioning column for proper separation in order to control temperature, and prevent it from getting too hot. If the temperature rises too much and the fractioning column is too hot, the liquid will refrain from flowing down the column. This happens because the vapor moving up the column increases the density and makes it more difficult for the liquid to flow the opposite direction.
- 2) In order for a fractional column to work efficiently, they must be insulated to maintain a smooth temperature gradient. Maintaining this smooth temperature gradient is important because in order for the vapor, moving up the column, to reach the top, the temperature being consistent through the column is favorable. If the vapor is moving up the top and suddenly reached a cold spot, its temperature would drop and it could liquify and slow down the entire process.
- 3) At the boiling point of a substance, the vapour pressure should be the same as the surrounding pressure, or the ambient pressure. In this case, if we assume the atmosphere is the surrounding medium, then the vapour pressure of benzene at 81°C is 760 torr.
- 4) Since atmospheric pressure is equal to vapour pressure at the boiling point of a liquid, if we increase atmospheric pressure we are also increasing vapour pressure. Increasing vapour pressure results in an increase in the boiling point. Therefore, an increase in atmospheric pressure would increase the boiling point of a liquid.
- 5) It is important to have the cooling water enter the bottom of the condenser because, if the water were to enter from the top, the condenser would never be completely filled with cold water. The flow of water can clearly be observed in the condenser if it is entered from the top, unlike if it enters from the bottom - in this case, you can barely see the flow of water. When the water enters from the bottom of the condenser, it is completely filled with cold water, and the cooling system is effective.

6) mole fraction A = 0.75 , mole fraction B = 0.25  
vapour pressure =  $(0.75)(350) + (0.25)(150) = 300$

The vapour pressure of the 3:1 mixture of A and B at 95°C is 300 mmHg.

### **Conclusion**

The boiling point of 2-propanol is 80°C and that of 1-butanol is 112°C. The density of 2-propanol is 1.025 g/cm<sup>3</sup> and the density of 1-butanol is 0.721 g/cm<sup>3</sup>.

**\* raw data on following page \***



### Simple Distillation

2 mL → 85°C  
4 mL → 86°C  
6 mL → 86°C  
8 mL → 87°C  
10 mL → 88°C  
12 mL → 89°C  
14 mL → 91°C  
16 mL → 93°C  
18 mL → 95°C  
20 mL → 98°C  
22 mL → 101°C  
24 mL → 105°C  
26 mL → 110°C  
28 mL → 115°C  
30 mL → 116°C



### 1. Density Calculation

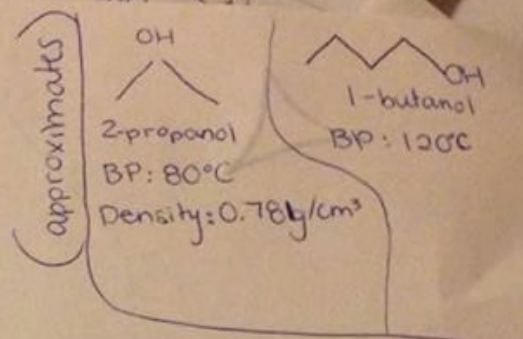
at 18.7 mL

with liquid → 87.49 g

cylinder alone 68.32 g

liquid alone = 19.17 g

$$d = 0.975 \text{ g/cm}^3$$



### Fractional Distillation

2 mL → 81°C  
4 mL → 82°C  
6 mL → 83°C  
8 mL → 85°C  
10 mL → 86°C  
12 mL → 87°C  
14 mL → 88°C  
16 mL → 91°C  
18 mL → 94°C  
20 mL → 102°C  
22 mL → 109°C  
24 mL → 113°C  
26 mL → 115°C  
28 mL → 116°C  
30 mL → 117°C  
32 mL → 117°C  
34 mL → 117°C

### 2. Density

→ 81.04 w liquid  
→ 73.68 without liquid  
→ 10.2 mL liquid  
d =

### 1. procedure

→ ECS referency