Distillation
Experiment

Chemistry

Objectives

- Understand the three classical phases of matter, phase changes, and heating and cooling curves.
- Investigate the technique of distillation and learn how to separate the components of a mixture.
- Study the chemical differences between ethanol and water.

Modules and Sensors

- PC + NeuLog application
- USB-200 USB module (or BLT-202 Bluetooth module)
- NUL-203 Temperature logger sensor

Equipment and Accessories

▪ Utility stand	1
▪ Right-angle clamp	1
▪ Extension clamp	1
▪ Still head	1
▪ Round bottom flask	1
▪ Condenser	1

▪ Receiver	1
▪ 50ml beaker	2
▪ Alcohol lamp	1
▪ Safety goggles	-
▪ Boiling stone	4

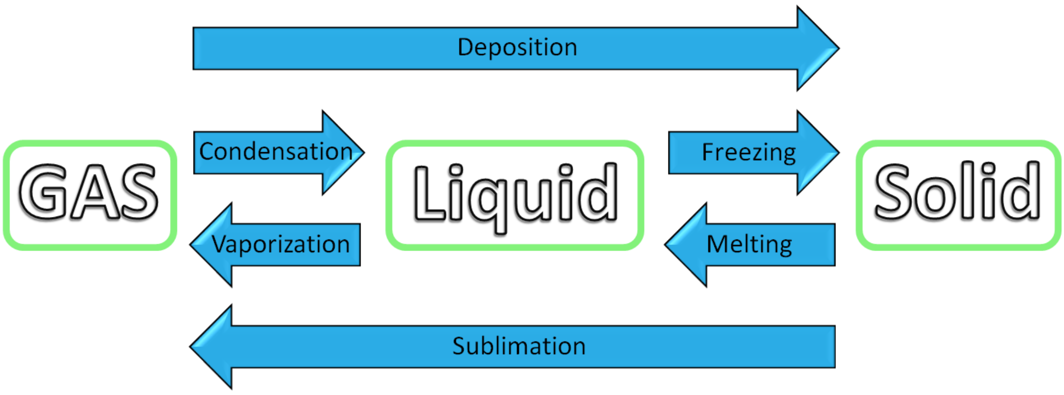
- The items above are included in the NeuLog Distillation kit, DST-KIT (four safety goggles are included in the NeuLog Utility accessories kit, UTL-KIT).

Materials

▪ Drops of food coloring
▪ 100ml of 96% Ethanol
▪ Tap water
▪ Lighter

Introduction

The three classical phases of matter are solid, liquid and gas. Gas particles are well separated, liquid particles are closer together, and solid particles are tightly packed in a rigid structure. The diagram below illustrates different phase changes:



A heating or a cooling curve shows the temperature of a substance changes as it is heated or cooled. Sloped regions correspond to temperature changes in one of the different states. in a single phase, while flat regions represent phase changes, where the temperature remains constant.

Distillation is a purification method for liquids and separating liquid mixtures. It separates components of a mixture based on their boiling points (the temperature in which liquid changes into gas). It's widely used both in laboratories and industrially, such as for refining crude oil or concentrating alcohol.

The general principle of distillation is starting with a mixture of liquids with different boiling points, heating the mixture to the first boiling point, cool down the vapor and collect the condensed liquid. This liquid is enriched with the lower boiling point component. The liquid that is left behind is enriched with the higher boiling point component.

In this experiment, we will use a distillation kit to observe the distillation process by separating ethanol and food coloring from a solution.

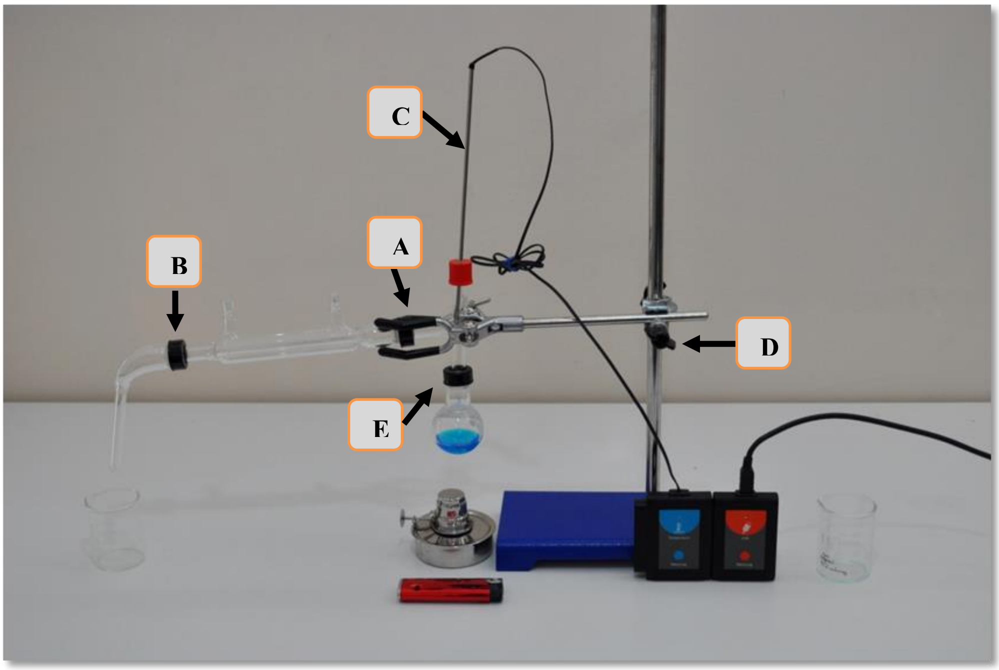
Procedure

Experiment setup

Caution:

You will be working with an open flame. Make sure not to have any flammable material in the proximity of the experiment. Be very careful when working with high temperatures. It is recommended to wear personal protective equipment. Material Safety Data Sheets (MSDS) are available online.

1. Set up the experiment as shown in the picture below.



2. Make sure you have a beaker with 10ml of 96% ethanol with 5 drops of food coloring and 4 boiling stones.

3. Insert the side tube of the still head into the condenser adaptor and screw the black cap (the caps should be screwed tightly but carefully) (A).

4. Insert the other side of the condenser into the receiver and screw the black cap (B).

5. Insert the temperature sensor's probe in the still head through the hole in the top cap up to where the still head and the condenser meet. Screw this cap to hold the probe in place (C).

6. Install the assembled system on the utility stand, using the extension clamp (D).

7. Pour the colored ethanol into the round bottom flask and put the boiling stones inside as well. Insert the still head into it and screw the black cap (E).

8. Place a clean 50ml beaker under the receiver, and a closed alcohol lamp filled with 30ml of 96 % ethanol around 4 cm under the round bottom flask.

Sensor setup

9. Connect the USB-200 interface module to the PC or MAC.
You can use the BLT-202 as an interface module by wire connection or wirelessly.

10. Check that the temperature sensor is connected to the interface module.

Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

11. Run the NeuLog application and check that the temperature sensor is identified.

Settings

12. Click on the **Run Experiment** icon and set the:

Experiment duration to: **10 minutes**
Sampling rate to: **1 per second**

Testing and measurements

13. Open the alcohol lamp and pull out (using the handle) a little bit of wick.

14. Click on the **Record** icon to start the measurement.

15. Click on the **Arrows** icon in order to see the sensor's values during the measurement.

16. You can click on the **Zoom fit** icon during the measurement to see better how the graph changes.

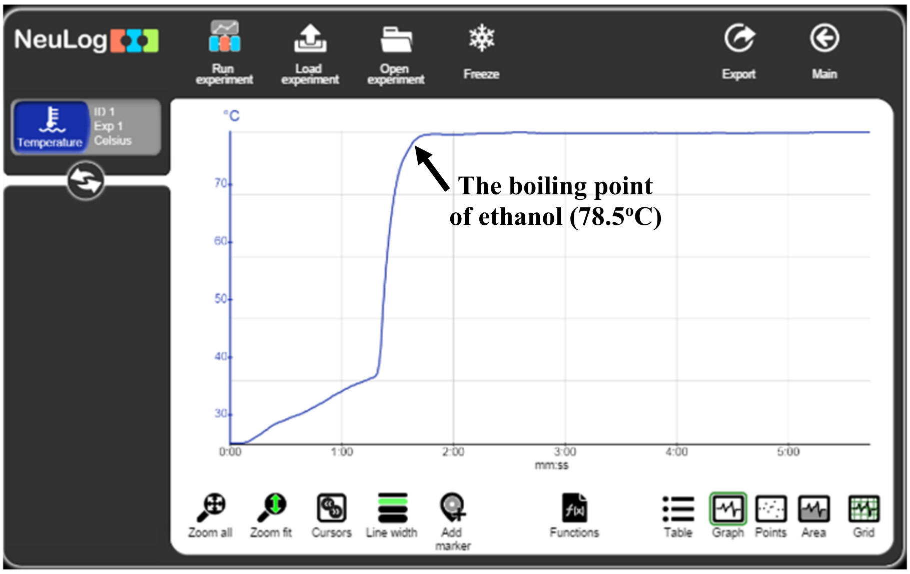
17. To see the entire graph after one minute, use the mouse's scroll wheel.

18. Make sure that there isn't any exposed ethanol near the working space. Very carefully light the alcohol lamp and adjust the flame so that it will be around 1 cm bellow the flask.

19. Turn off the alcohol lamp at the end of the measurement. If all the ethanol boils before the time is over, (only a little bit of food coloring with water should remain) stop the experiment.

20. Click on the **Zoom fit** icon.

21. Your graph should be similar to the following:



22. Click on the **Export** icon  and then on the **Save value table (.CSV)** button to save your graph.

23. Click on the  icon to go back to the graph.

24. After finishing the experiment loosen the cap before separating each part.

25. The measurement starts at room temperature, after lighting the alcohol lamp, the probe is heated by the flame.

    After reaching 37ºC there is a sharper rise in temperature, the ethanol heats up until the temperature reaches 78.5ºC – the boiling point of ethanol, and remains constant throughout the boiling process.

    The reason that the temperature stays at 78.5ºC is latent heat. Latent heat is the amount of energy absorbed or released by a substance during a change in its physical state without a change in temperature. The temperature was constant because heat was absorbed as latent heat of vaporization.

Summary questions

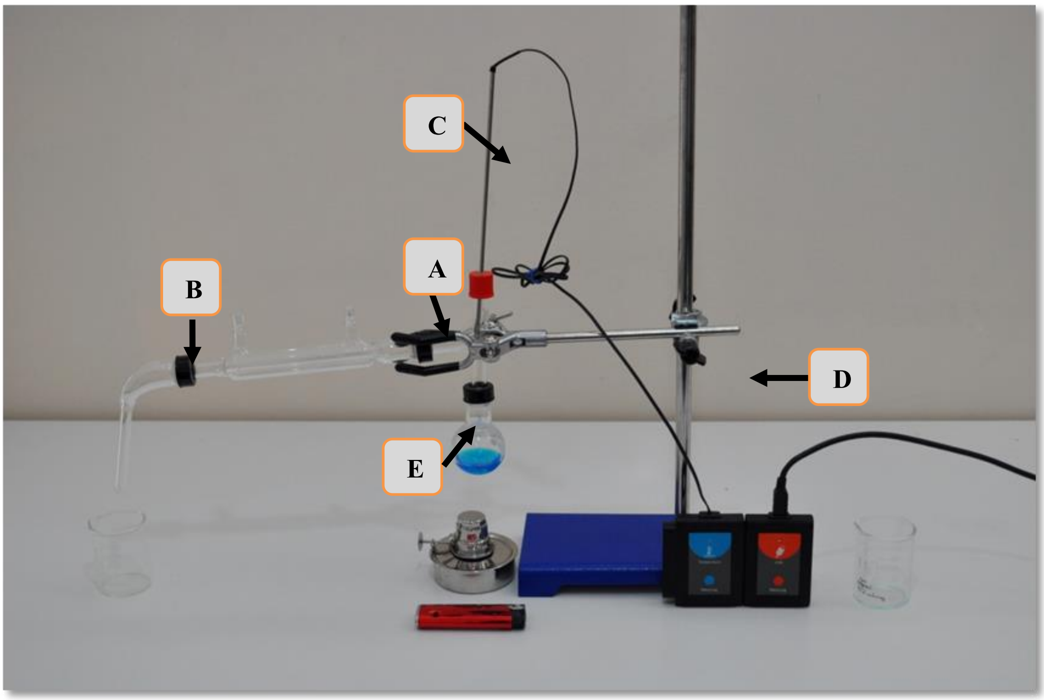
1. Why didn't the food coloring (with water) vaporize and drip into the beaker?

2. What will happen if we use two solutions with the same boiling point for this experiment?

3. How does the strength of intermolecular forces affect the boiling point of a chemical substance? Give an example and explain.

Distillation experiment

1. Set up the experiment as shown in the picture below.



2. Make sure you have a beaker with 5ml of 96% ethanol, 5ml of tap water, 5 drops of food coloring and 4 boiling stones.

3. Insert the side tube of the still head into the condenser adaptor and screw the black cap (the caps should be screwed tightly but carefully) (A).

4. Insert the other side of the condenser into the receiver and screw the black cap (B).

5. Insert the temperature sensor's probe in the still head through the hole in the top cap up to where the still head and the condenser meet. Screw this cap to hold the probe in place (C).

6. Install the assembled system on the utility stand, using the extension clamp (D).

7. Pour the solution into the round bottom flask and put the boiling stones inside as well. Insert the still head into it and screw the black cap (E).

8. Wash the beaker that contained the solution and place it under the receiver.

9. Place a closed alcohol lamp filled with 30ml of 96 % ethanol around 4 cm under the round bottom flask.

Settings

10. Click on the **Run Experiment** icon and set the:

Experiment duration to:	**30 minutes**
Sampling rate to:	**1 per second**

Testing and measurements

11. Open the alcohol lamp and pull out (using the handle) a little bit of wick.

12. Click on the **Record** icon to start the measurement.

13. Click on the **Arrows** icon in order to see the sensor's values during the measurement.

14. You can click on the **Zoom fit** icon during the measurement to see better how the graph changes.

15. To see the entire graph after one minute, use the mouse's scroll wheel.

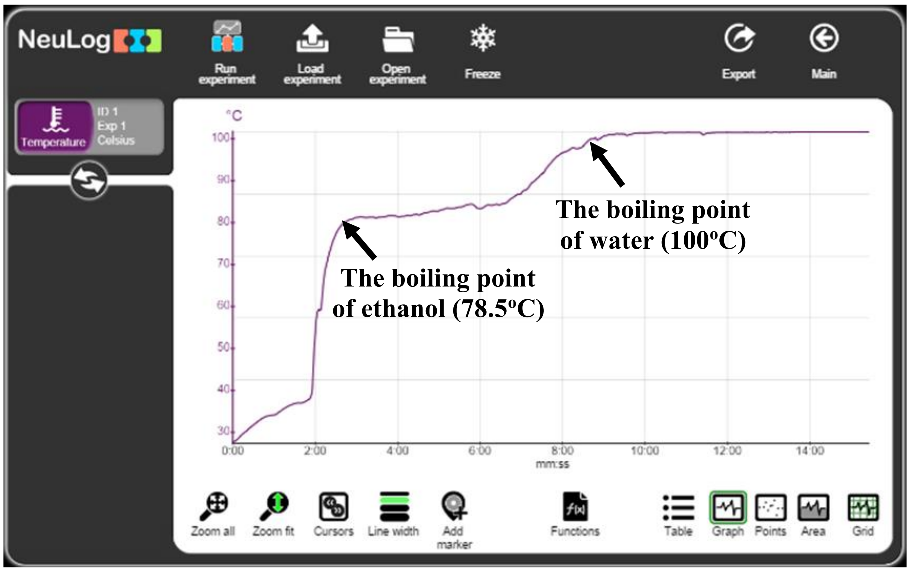
16. Make sure that there isn't any exposed ethanol near the working space. Very carefully light the alcohol lamp and adjust the flame so that it will be around 1cm bellow the flask.

17. The graph should include two flat regions (one for the boiling of ethanol and one for the boiling of water). Replace the first beaker when the second flat region begins.

18. Stop the measurement when only a little bit of food coloring with water remains in the round bottom flask and turn off the alcohol lamp.

19. Click on the **Zoom fit** icon.

20. Your graph should be similar to the following.



21. Click on the **Export** icon and then on the **Save value table (.CSV)** button to save your graph.

22. Click on the  icon to go back to the graph.

23. After finishing the experiment loosen the cap before separating each part.

24. The measurement starts at room temperature, after lighting the alcohol lamp, the probe is heated by the flame.

    After reaching 38ºC there is a sharper rise in temperature, the solution heats up until the temperature is around 78.5ºC – the boiling point of ethanol, and remains constant throughout the boiling process. Mostly ethanol comes out at the first flat region.

    The temperature continues to rise slowly until it is around 100ºC – the boiling point of water, and again stays constant throughout the boiling process. Mostly water comes out at the second flat region.

    The reason that the temperature stays constant throughout the boiling processes is latent heat. Latent heat is the amount of energy absorbed or released by a substance during a change in its physical state without a change in temperature. The temperature was constant because heat was absorbed as latent heat of vaporization.

Summary questions

1. Why does ethanol have a lower boiling point than water?

2. Can we separate ethanol and water completely by using this method?

3. Give another example of a mixture that can be separated by distillation.