Fractional Distillation

An example of a simple distillation is the separation of a solution of salt and water into two separate pure substances. When the salt water solution is heated to boiling, water vapor from the mixture reaches the condenser (see Figure 1) and the cold water circulating around the inside tube causes condensation of water vapor into droplets of liquid water. The liquid water is then collected at the lower end of the condenser. The non-volatile salt remains in the flask.

In this experiment, the initial mixture you distill contains two volatile liquids: ethanol and water. In this distillation, *both* of the liquids will evaporate from the boiling solution. Ethanol and water have normal boiling temperatures of 79°C and 100°C, respectively. One objective of the experiment is to observe what happens when a liquid-liquid mixture is heated and allowed to boil over a period of time. Throughout the distillation, volumes of distillate, called *fractions*, will be collected. The percent composition of ethanol and water in each fraction will be determined from its density. Water has a density of 1.00 g/cm^3 (at 20°C) and ethanol has a density of 0.79 g/cm^3 (at 20°C). The fractions you collect will have densities in this range.

OBJECTIVES

In this experiment, you will

- Observe what happens when a liquid-liquid mixture is heated and allowed to boil over a period of time.
- Determine percent composition of ethanol and water in the fraction from its density.

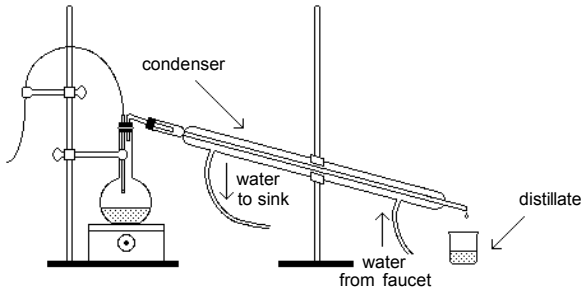

Figure 1

MATERIALS

computer
Vernier computer interface
Logger*Pro*
Temperature Probe
condenser with two hoses
hot plate
ethanol, C_2H_5OH, denatured (94-96%)
water
bent-glass tubing
three 100 mL beakers
500 mL flask
2 ring stands
3 utility clamps
50 mL graduated cylinder
100 mL graduated cylinder
3–4 boiling chips
2-hole stopper

PROCEDURE

1. Obtain and wear goggles! **CAUTION:** The compounds used in this experiment are flammable and poisonous. Avoid inhaling their vapors. Avoid contacting them with your skin or clothing. Be sure there are no open flames in the lab during this experiment. Notify your teacher immediately if an accident occurs.

2. Assemble the distillation apparatus as shown in Figure 1. Do not begin heating until your teacher has checked your apparatus.

3. Use a 100 mL graduated cylinder to obtain 60 mL of ethanol. Pour the ethanol into the flask. Put 60 mL of tap water into the same flask. Add 3–4 boiling chips to ensure the formation of many small bubbles during the boiling.

4. Make sure the stopper fitting the probe into the flask and the stopper fitting the glass bend into the condenser are tightly in place. Turn on the cold tap water so that it slowly flows up through the condenser.

5. Use a third utility clamp, fitted at the top of the ring stand, to secure the Temperature Probe wire as far as possible from the hot plate.

6. Connect the probe to the computer interface. Prepare the computer for data collection by opening the "08 Fractional Distillation" file from the *Chemistry with Vernier* folder of Logger*Pro*.

7. Label the three 100 mL beakers 1–3. Put Beaker 1 in place at the end of the condenser. Have your teacher check your set-up, and then turn the hot plate on to its maximum setting. **CAUTION:** Do not burn yourself or the probe wire with the hot plate.

8. Click ▸ Collect to begin data collection. When the temperature reaches 50°C, turn the hot plate down to a medium setting.

9. When 30 mL of liquid (distillate) have been collected in Beaker 1, remove it and insert Beaker 2 in its place. This 30 mL portion is called Fraction 1. Set it aside until Step 12.

10. After you have collected 30.0 mL of Fraction 2 in Beaker 2, quickly replace it with beaker #3. Set Fraction 2 aside until Step 13.

11. After you have collected 30.0 mL of Fraction 3 in Beaker 3, click ■ Stop to end data collection. Turn off the hot plate.

12. Determine and record the mass of a clean, dry 50 mL graduated cylinder. Pour the contents of Fraction 1 into the graduated cylinder. Read and record its volume, to the nearest 0.1 mL. Then determine and record the mass of the distillate plus the graduated cylinder. Discard the distillate as directed by your teacher.

13. Pour the contents of Fraction 2 into the 50 mL graduated cylinder. Read and record its volume, to the nearest 0.1 mL. Then determine and record the mass of the distillate plus the graduated cylinder. Discard the distillate as directed by your teacher.

14. Repeat the Step-13 procedure for Fraction 3.

15. Print a graph of temperature *vs.* time for the distillation. Enter your name(s) and the number of copies of the graph you want.

16. Find the initial boiling temperature of the mixture (the point where the rapidly rising initial temperature ends, and the slow increase in temperature begins). Click the Examine button,

. As you move the mouse pointer along the curve, examine the data values in the display box on the graph. When you determine the initial boiling temperature, label this value on your printed copy of the graph.

DENSITY OF ETHANOL AND WATER MIXTURES (20°C)

Ethanol (%)	Density (g/cm^3)	Ethanol (%)	Density (g/cm^3)	Ethanol (%)	Density (g/cm^3)
0	0.998	34	0.947	68	0.872
2	0.995	36	0.943	70	0.868
4	0.991	38	0.939	72	0.863
6	0.988	40	0.935	74	0.858
8	0.985	42	0.931	76	0.853
10	0.982	44	0.927	78	0.848
12	0.979	46	0.923	80	0.843
14	0.977	48	0.918	82	0.839
16	0.974	50	0.913	84	0.834
18	0.971	52	0.909	86	0.828
20	0.969	54	0.905	88	0.823
22	0.966	56	0.900	90	0.818
24	0.964	58	0.896	92	0.813
26	0.960	60	0.891	94	0.807
28	0.957	62	0.887	96	0.801
30	0.954	64	0.882	98	0.795
32	0.950	66	0.877	100	0.789

PROCESSING THE DATA

1. After finding the mass of the distillate by subtracting the mass of the graduated cylinder from the mass of the graduated cylinder + distillate, calculate the density of each fraction using the formula: density = mass/volume.

2. Using the density table above, determine the *% ethanol* corresponding to the density of each fraction. Record these values.

3. Using the values of % ethanol obtained in the previous step, determine the *% water* for each fraction.

4. What is the primary component of the first fraction you collected? Explain why it is not pure.

5. Did the density of the fractions increase or decrease as the experiment progressed? Explain.

6. What happened to the % of ethanol in the collected fractions as the experiment progressed? What happened to the % of water?

7. What could be done to subsequently increase the purity of the ethanol (reduce the water) in the first fraction? Explain.

8. In Step 16 of the procedure, you found (and recorded on your graph) the initial boiling temperature of the mixture. Is this value lower or higher than the normal boiling temperature of pure ethanol (79°C)?

DATA AND CALCULATIONS

	Fraction 1	Fraction 2	Fraction 3
Mass of distillate plus graduated cylinder	g	g	g
Mass of graduated cylinder	g	g	g
Mass of distillate	g	g	g
Volume of distillate	cm^3	cm^3	cm^3
Initial boiling temperature	°C		

Density	g/cm^3	g/cm^3	g/cm^3
Percent ethanol	%	%	%
Percent water	%	%	%

OBSERVATIONS