

Activity C13: Raoult's Law (Pressure Sensor, Temperature Sensor)

Concept	<i>DataStudio</i>	<i>ScienceWorkshop (Mac)</i>	<i>ScienceWorkshop (Win)</i>
Gas laws	C13 Raoult's Law.DS	C13 Raoult's Law	C13_RAOU.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Pressure Sensor (CI-6532A)	1	Stirring rod	1
Temperature Sensor (CI-6505A)	1	Thermometer (SE-9084)	1
Balance (SE-8723)	1	Tubing, plastic (w/sensor)	1
Beaker, 150 mL	2	Protective gear	PS
Beaker, 1 L	1		
Bottle (or flask), 250 mL	3	Chemicals and Consumables	Qty
Connector, rubber stopper (w/sensor)	1	Acetone	100 mL
Coupling, quick-release (w/sensor)	1	Glycerin	1 mL
Graduated cylinder	1	Label	5
Hot plate	1	Para-dichlorobenzene	6 g
Rubber stopper, two-hole	1	Water	1 L

What Do You Think?

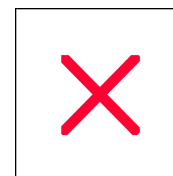
How will the vapor pressure of a pure solvent change when an unknown amount of solute is dissolved in the solvent?



Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

The vapor pressure of a liquid in a closed system depends on molecules of a liquid that have sufficient energy to overcome the intermolecular attractive forces and escape from the surface of the liquid as gas molecules. When a nonionic solute is added to the liquid the intermolecular attractive forces between the solvent and the solute molecules are different than the forces between molecules in a pure solvent.



Raoult's Law describes the relationship between the vapor pressure of a solution and the amount of nonionic solute in the solution. For a solvent and a non-volatile solute the relationship is based on the mole fraction, X_i , of the solvent in the solution. The mole fraction is the number of moles of the solvent divided by the total moles (both solvent and solute) in the solution.

Raoult's Law is as follows:

$$P_t = \sum X_i P_i$$

where P_t is the total vapor pressure, \sum means "the sum of", X_i is the mole fraction, and P_i is the individual vapor pressure of the pure solvent at that temperature.

For example, pure toluene has a vapor pressure of 2.93 kPa at 25 °C. If 0.2 mole of naphthalene (a non-volatile solid) is added to one mole of toluene, the vapor pressure of the toluene will **decrease**. In fact, the more solute added to the solvent, the lower the vapor pressure of the solvent.

$$P_t = \sum X_i P_i = 1.0 \text{ mole toluene} / 1.2 \text{ total moles} \times 2.93 \text{ kPa}$$

$$P_t = 2.44 \text{ kPa}$$

SAFETY REMINDERS

- Wear protective gear.
- Follow directions for using the equipment.
- Handle and dispose of all chemicals and solutions properly.

For You To Do

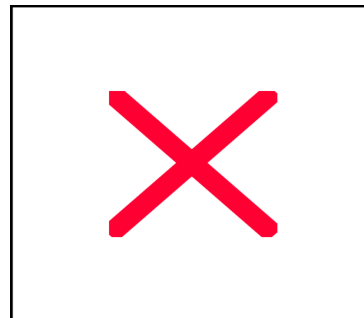
Prepare the Water Bath

- Make a water bath of about 600 mL of water in a 1 liter beaker. Heat the water bath to 60 °C and maintain this temperature. Use a thermometer to check the progress of the water bath as you set up the rest of the lab materials.

Use the Pressure Sensor to measure the change in vapor pressure in a rigid container containing a liquid. Use the Temperature Sensor to measure the change of temperature inside the container. Measure the pressure and temperature for a pure solvent first, and then measure the pressure and temperature for a solution with different amounts of a solute added to the solvent. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use the data to determine the relationship between the change in vapor pressure and the amount of the solute for a given temperature.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the DIN plug of the Temperature Sensor to Analog Channel A on the interface. Connect the DIN plug of the Pressure Sensor to Analog Channel B on the interface.
3. Open the file titled as shown;



<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (Win)
C13 Raoult's Law.DS	C13 Raoult's Law	C13_RAOU.SWS

- The *DataStudio* file has a Graph display. Read the Workbook display for more information.
- The *ScienceWorkshop* document has a Graph display with a plot of the pressure versus temperature.
- Data recording is set at one measurement per second (1 Hz).

PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensors.

Prepare the Solutions

- For this part you need the following: balance, graduated cylinder, beakers (150 mL), stirring rod, labels, para-dichlorobenzene, acetone
1. In the first beaker, dissolve 2 g of para-dichlorobenzene (PDCB) in 20 mL of acetone. Label this as solution as "Solution #1".

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2. In the second beaker, dissolve 4 g of para-dichlorobenzene in 20 mL of acetone. Label this solution as "Solution #2".

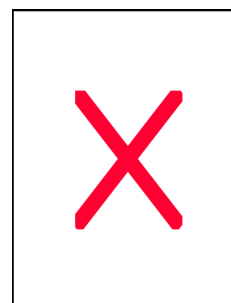
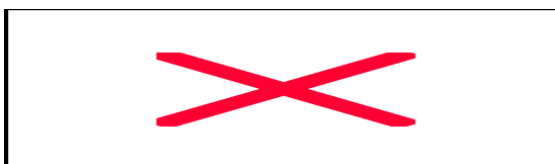
3. Label each bottle:

Bottle	Label	Contents
1	Solvent	3 mL of acetone
2	Solution #1	3 mL of Solution #1 (acetone + 2-g PDCB)
3	Solution #2	3 mL of Solution #2 (acetone + 4-g PDCB)

4. Put 3 mL of acetone in the first bottle. Put 3 mL of Solution #1 in the second bottle. Put 3 mL of Solution #2 in the third bottle.

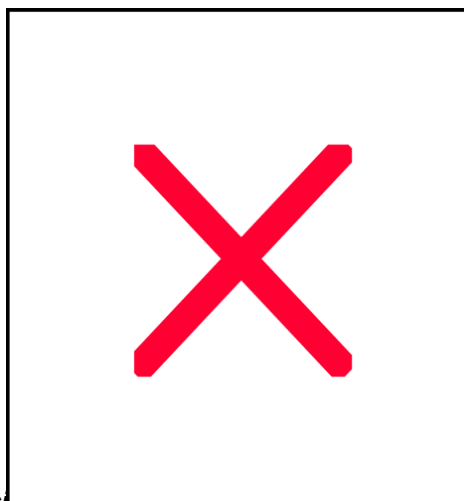
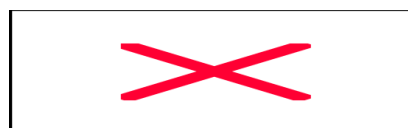
Set Up the Equipment

- For this part you will need the following: glycerin, quick-release coupling, connector, plastic tubing, two-hole rubber stopper, Temperature Sensor, Pressure Sensor.
- Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the quick release coupling into one end of a piece of plastic tubing (about 15 cm) that comes with the



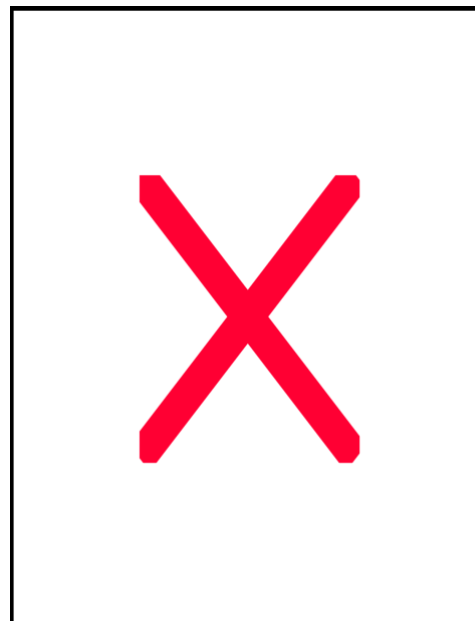
Pressure Sensor.

- Put a drop of glycerin on the barb end of the connector. Push the barb end of the connector into the other end of the plastic tubing.
 - Fit the end of the connector into one of the holes in the rubber stopper.
 - Put a drop of glycerin into the other hole of the stopper and slide the Temperature Sensor through the hole.
 - Align the quick-release coupling on the end of the plastic tubing with the pressure port of the Pressure Sensor. Push the coupling onto the port, and then turn the coupling clockwise until it clicks (about one-eighth turn).
- Pressure Sensor and Temperature Sensor with two-hole rubber stopper.



PART IIIA: Data Recording - Solvent

1. When you are ready to begin, place the two-hole rubber stopper with sensors into the top of Bottle 1. Place Bottle 1 in the hot water bath.
 - **Predict how the pressure - temperature graph will look for the solvent.**
2. Start recording data. (Hint: Click 'Start' in *DataStudio* or click 'REC' in *ScienceWorkshop*.)
3. Allow the heating to continue for only 60 seconds. Stop recording data.
4. Remove Bottle 1 from the hot water bath.
5. Slowly open the bottle to allow the vapors to escape. Remove the rubber stopper from Bottle 1 and place it in the top of Bottle 2.

**PART IIIB: Data Recording – Solution #1**

1. Place Bottle 2 in the hot water bath. Begin recording data.
 - **Predict how the pressure – temperature graph for solution #1 will differ from the graph for the solvent.**
2. Allow the heating to continue for only 60 seconds. Stop recording data.
3. Remove Bottle 2 from the hot water bath.
4. Slowly open the bottle to allow the vapors to escape. Remove the rubber stopper from Bottle 2 and place it in the top of Bottle 3.

PART IIIC: Data Recording – Solution #2

1. Place Bottle 3 in the hot water bath. Begin recording data.
 - **Predict how the pressure - temperature graph for solution #2 will differ from the graph for solution #1.**

The third curve will have vapor pressures that are lower than the other samples at the same temperature.

2. Allow the heating to continue for only 60 seconds. Stop recording data.
3. Remove Bottle 3 from the hot water bath. Turn off the heat source for the hot water bath.
4. Slowly open the bottle to allow the vapors to escape. Remove the rubber stopper from Bottle 3.
5. Dispose of the remaining liquid in each bottle by pouring the liquid into a beaker labeled **waste solution**. Rinse the bottles.

Analyzing the Data

- Use the data in the Graph display and your observations to answer the questions in the Lab Report section.

Record your predictions and results in the Lab Report section.

Lab Report - Activity C13: Raoult's Law

What Do You Think?

How will the vapor pressure of a pure solvent change when an unknown amount of solute is dissolved in the solvent?

Predictions

- Predict how the pressure - temperature graph will look for the solvent.

- Predict how the pressure - temperature graph for solution #1 will differ from the graph for the solvent.

- Predict how the pressure - temperature graph for solution #2 will differ from the graph for solution #1.

Questions

1. What is the general relationship between the vapor pressure of acetone and the amount of solid dissolved?

2. What do you think are the limitations of Raoult's Law?

3. Think about an automobile. Where is Raoult's Law an important consideration in the design of a car?

4. You made two solutions of acetone and p - dichlorobenzene.
Solution #1 = 2 g of p - dichlorobenzene in 20 mL of acetone.
Solution #2 = 4 g of p - dichlorobenzene in 20 mL of acetone.
- Acetone has a density of 0.80 g/mL. What is the mole fraction of acetone in each solution?

Solution #1

The mole fraction of acetone for Solution #1 is

Solution #2

The mole fraction of acetone for Solution #2 is

5. Pick a temperature that is in the range of your data (e.g., 35 °C). Use the 'Smart Tool' in *DataStudio* or the 'Smart Cursor' in *ScienceWorkshop* to measure the pressure at that temperature. Use the mole fraction of acetone for Solution #1 to calculate the theoretical vapor pressure of Solution #1 and the mole fraction of acetone for Solution #2 to calculate theoretical vapor pressure of Solution #2 for that temperature.

Solution	Actual Pressure	Theoretical Pressure	% difference
Acetone	kPa		
Acetone + 2 g PDCB	kPa	kPa	
Acetone + 4 g PDCB	kPa	kPa	

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6. How do your experimental results compare with your calculations?