Name ____________________ Class _____________ Date _________

Activity C24: Determine the Molecular Mass of a Compound – The Dumas Bulb Method
(Pressure Sensor, Temperature Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
The Mole	C24 Molecular Mass.DS	C24 Dumas Bulb	C24_DUMA.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Pressure Sensor (CI-6532A)	1	Rubber stopper, two-hole	1
Temperature Sensor (CI-6505A)	1	**Thermometer (SE-9084)**	1
Beaker, 1 L	1	**Tubing, plastic (w/sensor)**	1
Bottle or flask, 250 mL	2	Protective gear	PS
Connector, rubber stopper (w/sensor)	1		
Coupling, quick-release (w/sensor)	1	**Chemicals and Consumables**	**Qty**
Graduated cylinder, 10 mL	1	Acetone	1 mL
Graduated cylinder, 100 mL	1	Glycerin	1 mL
Hot plate	1	Water	600 mL

What Do You Think?

In this activity, a known mass of a volatile liquid is placed in a sealed container. The liquid is then placed in a water bath of known temperature so that the liquid vaporizes and fills the container. Knowing the mass, the temperature, pressure and the value of R, the Gas Constant, can you use the Ideal Gas Law to determine the molecular mass of the liquid?

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

Background

The molecular mass (grams per mole) of a compound is one of the most important variables needed to identify and characterize a chemical. The molecular mass of an unknown compound allows a chemist to determine the molecular formula of the compound. The molecular formula can then be used to determine the structure and possible physical and chemical properties of the compound.

One of the earliest methods of determining the molecular mass of a compound is the Dumas Bulb method. This method uses a rigid container of known volume. The pressure and temperature of a volatile liquid are measured, and the Ideal Gas Law is used to determine the number of moles of the substance.

In this arrangement of the Ideal Gas Law, n is the number of moles, P is the pressure in atmospheres, V is the volume in liters, R is the Gas Constant, and T is the absolute temperature.

SAFETY REMINDERS

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

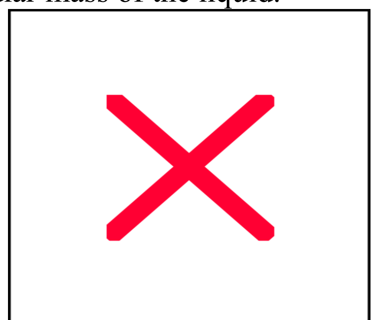
For You To Do

Prepare the Water Bath

- Make a water bath of about 600 mL of water in a 1 liter beaker. Heat the water bath to 65 ˚C and maintain this temperature. Use a thermometer to check the progress of the water bath as you set up the rest of the equipment.

Use the Pressure Sensor to measure the change in vapor pressure in a rigid container and use the Temperature Sensor to measure the change of temperature inside the container. First, measure the change for a sample of air when the container is immersed in hot water. Then measure the changes for a sample of air mixed with vaporized acetone. Use *DataStudio* or *ScienceWorkshop* to record and display the data. Use the data to determine the molecular mass of the liquid.

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;

DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
C24 Molecular Mass.DS	C24 Dumas Bulb	C24_DUMA.SWS

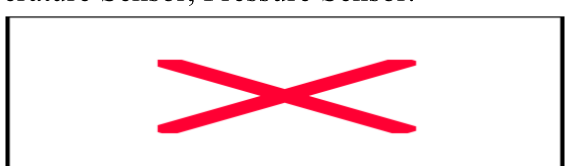
- The *DataStudio* file has a Graph display. Read the Workbook display for more information.
- The *ScienceWorkshop* document has a Graph display with a plot of the pressure versus time and a plot of the temperature versus time.
- Data recording is set at ten measurements per second (10 Hz). Data measurement is set to stop automatically at 120 seconds.

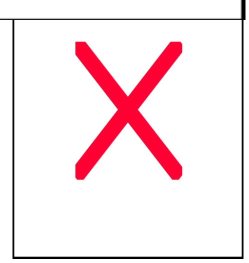
PART II: Sensor Calibration and Equipment Setup

You do not need to calibrate the sensors.

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.

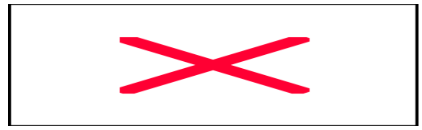


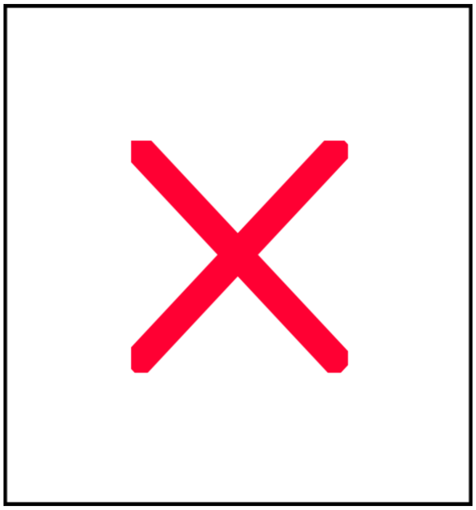


1. Put a drop of glycerin on the barb end of a quick release coupling. Put the end of the quick release coupling into one end of a piece of plastic tubing (about 15 cm) that comes with the Pressure Sensor.
2. Put a drop of glycerin on the barb end of the connector. Push the barb end of the connector into the other end of the plastic tubing.
3. Fit the end of the connector into one of the holes in the rubber stopper.
4. Put a drop of glycerin into the other hole of the stopper and slide the

Temperature Sensor through the hole.

5. 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).





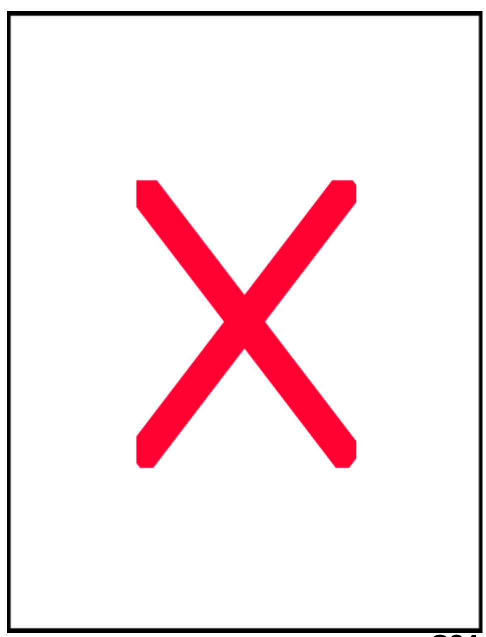
- Pressure Sensor and Temperature Sensor with two-hole rubber stopper.

PART IIIA: Data Recording – Air Only

1. When you are ready to begin, place the two-hole rubber stopper with sensors into the top of the first bottle and place the bottle in the hot water bath.
2. Start recording data. (Hint: Click ‘Start’ in *DataStudio* or click ‘REC’ in *ScienceWorkshop*.)
3. Allow the heating to continue for 120 seconds.
4. Remove the bottle from the hot water bath. Slowly open the bottle to allow the heated air to escape.
5. Remove the rubber stopper from the first bottle.

PART IIIB: Data Recording – Air and Acetone

1. Put 0.3 mL of acetone in the second bottle.
2. Place the two-hole rubber stopper with sensors into the top of the second bottle and place the bottle in the hot water bath.
3. Start recording data. Allow the heating to continue for 120 seconds.
4. Remove the bottle from the hot water bath. Slowly open the bottle to allow the vapors to escape.
5. Rinse the bottle.



6. Use the large graduated cylinder to add water to the bottle to determine the actual volume of the bottle. Record the volume in the Lab Report section. (Hint: Be sure to account for the space occupied by the bottom of the stopper and by the sensor.)

Analyzing the Data

- The Graph has two plots showing pressure and temperature data for air alone and pressure and temperature data for air and acetone.

1. Use the Graph's analysis tools to find the maximum pressure for the air alone, the maximum pressure for the air and acetone, and the final temperature of the air and acetone. (Hint: Use the 'Smart Tool' in *DataStudio* or the 'Smart Cursor' in *ScienceWorkshop*. Or, use the 'Statistics menu' to select 'Maximum'.)
2. Record the values for maximum pressure and temperature in the Lab Report section.
3. Convert the values of pressure from kilopascals to atmospheres (1 atm = 101 kPa). Convert the value of temperature from Celsius to Kelvin (K = 273 + C). Convert the volume of the container from milliliters to liters (1 L = 1000 mL).
4. Convert the volume of the acetone to a mass using the density of acetone (0.79 g/mL).
5. Use the data to determine the number of moles of acetone and then calculate the molecular mass of the acetone.

Record your results in the Lab Report section.

Name ____________________ Class ______________ Date _________

Lab Report - Activity C24: Determine the Molecular Mass of a Compound – The Dumas Bulb Method

What Do You Think?

In this activity, a known mass of a volatile liquid is placed in a sealed container. The liquid is then placed in a water bath of known temperature so that the liquid vaporizes and fills the container. Knowing the mass, the temperature, pressure and the value of R, the Gas Constant, can you use the Ideal Gas Law to determine the molecular mass of the liquid?

Answers will vary.

Data and Calculations

Data	Measurement	Value
1	Maximum pressure of air alone	kPa
2	Maximum pressure of air and acetone	kPa
3	Change in pressure (Data 2 - Data 1)	kPa
4	Change in pressure in atmospheres (Data 3 x 1 atm/101 kPa)	atm
5	Final temperature of air and acetone	˚C
6	Final temperature in K (Data 5 + 273)	K
7	Volume of gas in mL	mL
8	Volume of gas in L (Data 7 x 1 Liter/1000 mL)	L
9	Gas Constant, R	0.082 atm L/mole K
10	Mass of acetone (0.3 mL x 0.79 g/mL)	g
11	Moles of acetone ()	moles
12	Molecular mass of acetone (g/mole)	g/mole
13	% difference (See below)	%

Question

1. What is the percent difference between your measured value and the accepted value for the molecular mass of acetone?