

MOLAR MASS OF A LIQUID

1. PURPOSE OF THE WORK

Determination of the molar mass of volatile liquids (ethanol and acetone).

2. THEORETICAL NOTIONS

The molar mass of a liquid is determined by evaporating the liquid at constant temperature and pressure, by measuring the volume of vapor formed, using a calibrated syringe.

The method for determining the molar mass of a pure liquid that can be completely evaporated without decomposing is based on the ideal gas theory. The equation of state of the ideal gas is given by

$$p \cdot V_{mol} = R \cdot T \quad (1)$$

or

$$p \cdot v = n \cdot R \cdot T \quad (2)$$

where p - pressure; v - total gas volume (extensive); V_{mol} - molar volume; R - universal gas constant; T - absolute temperature; n - the number of moles equal to

$$n = \frac{m}{M}$$

m – mass of gas, in this case mass of evaporated substance; M - molar mass.

Substituting in equation (1) results:

$$M = \frac{mRT}{pv} \quad (3)$$

Equation (3) is valid when the vapors behave as an ideal gas, in this case meaning at temperatures higher by 20 K above the boiling temperature.

The van der Waals equation is used to take into account the actual vapor behavior:

$$\left(p + \frac{a}{V_{mol}^2} \right) \cdot (V_{mol} - b) = R \cdot T \quad (4)$$

Processing the equation is obtained:

$$p \cdot V_{mol} = R \cdot T + \left(b - \frac{a}{R \cdot T} \right) \cdot p \cdot \quad (5)$$

where a and b are the van der Waals constants.

Knowing that

$V_{mol} = \frac{v}{n}$ and $n = \frac{m}{M}$, equation (5) can be written:

$$M = \frac{m \cdot R \cdot T}{p \cdot v} + \frac{m \left(b - \frac{a}{R \cdot T} \right)}{v} \quad (6)$$

This formula takes into account the actual behavior of a common gas in determining the molar mass.

3. EXPERIMENTAL PART

3.1. APPARATUS AND SUBSTANCES



- H-shaped stand
- 100 mL glass syringe
- Glass jacket
- Thermometer
- Syringe
- Heating hob
- Voltage regulator
- Berzelius glass
- Acetone ethanol

Fig. 1. Experimental installation

3.2. PROCEDURE

Move the plunger of the glass syringe to the 10 mL graduation. This small volume of air in the syringe allows the experiment to be performed more easily. Then close the capillary tube of the syringe with a rubber stopper. Distilled water (about two-thirds in height) is introduced into the glass cylinder (syringe jacket). The glass cylinder must have a hose attached so that the water that evaporates during heating can drain into a Berzelius glass. Thermometers are inserted into the vertical tubes of the glass cylinder (jacket). Turn the heater knob and adjust the power controller to 5-6. When the water has reached a constant temperature (boils), adjust the power regulator to 3-4 and make measurements.

Extract a volume of 0.15 mL of liquid to be investigated (ethanol and acetone, respectively) using a plastic syringe, taking care to remove air from the syringe. Then clean the needle of the syringe with a napkin and weigh the syringe with a balance of 0,1 mg. Note the volume of air contained in the glass syringe and inject the substance rapidly through the rubber stopper. After the substance has been completely injected into the glass syringe and

nothing is left in the capillary tube, leave the injection syringe in the rubber stopper until the volume changes. Read the volume after evaporation of the liquid, then re-weigh the empty plastic syringe and calculate the mass of the injected substance.

Perform three measurements for each of the two liquids in the same way. After each measurement, the rubber stopper of the glass syringe is removed and it is cleaned by filling with air and emptying, repeated at least 5 times. The data is collected in a table:

Substance	No.	Syringe mass with liquid, g	Syringe mass after injection, g	Injected liquid mass, m/g	Volume variation, mL
Ethanol	1				
	2				
	3				
Acetone	1				
	2				
	3				

4. EXPERIMENTAL DATA PROCESSING

4.1. The molar masses are calculated for the two studied liquids, ethanol and acetone, with the relations (3), respectively (6) for the ideal and real case for each determination.

4.2. Calculate the average molar masses for each substance.

4.3. Analyze the results obtained in terms of real and ideal vapor behavior.

Substance	No.	m, g	Volume variation, mL	M_{ideal} , g/mol	M_{real} , g/mol	$M_{average\ ideal}$, g/mol	$M_{average\ real}$, g/mol
Ethanol	1						
	2						
	3						
Acetone	1						
	2						
	3						

Data from the literature

(Van der Waals constants for real gases (a , b) and molar masses)

Ethanol:

$$a = 12,56 \text{ bar}\cdot\text{L}^2/\text{mol}^2$$

$$b = 0,0871 \text{ L/mol}$$

$$M = 46,07 \text{ g/mol}$$

Acetone:

$$a = 16,02 \text{ bar}\cdot\text{L}^2/\text{mol}^2$$

$$b = 0,1124 \text{ L/mol}$$

$$M = 58,09 \text{ g/mol}$$

Remarks

The constant a in relation (6) is expressed in $\text{atm} \cdot \text{L}^2 / \text{mol}^2$ by multiplying by $0.986 \text{ atm} / \text{bar}$.

The constant a in relation (6) is expressed in $\text{kPa} \cdot \text{L}^2 / \text{mol}^2$ by multiplying by $100 \text{ kPa} / \text{bar}$.

5. QUESTIONS

5.1. Is the behavior of ethanol and acetone vapors ideal, respectively? If not ideal, how have the calculations been affected? Explain.

5.2. If the volume of sample injected is used incorrectly, instead of the injected mass determined by weighing, what effect does it have on the calculated molar mass?

5.3. If the entire amount of liquid injected does not vaporize, will the calculated molar mass be too small or too large? Explain.

5.4. Solve the following issues:

5.4.1. How many moles of gas are in 890 mL at 21°C and 750 mmHg?

5.4.2. At what temperature will 0.654 moles of Ne occupy 12.3 L at 1.95 atm?