MOLECULAR WEIGHT DETERMINATION BY THE VICTOR MEYER METHOD

OBJECTIVE: To determine the molecular weight of an unknown liquid using the Victor Meyer apparatus.

INTRODUCTION: The Victor Meyer method consists of vaporiizing a known weight of liquid in a chamber maintained at an appropriate and constant high temperature. The air displaced from the chamber by the vaporized sample is cooled to room temperature, and its volume carefully measured. Substitution of air for the actual vapor thus provides a means of determining the volume the known mass of vapor would occupy at room temperature if it could be cooled without condensation.

A modified form of the Victor Meyer apparatus is shown in Figure 1. It consists of four parts: (a) a syringe used to inject a known volume of a volatile liquid, (b) a vaporizer chamber which contains the vapor after the sample is injected, (c) a gas burette for measuring the volume of air displaced by the vapor of the sample injected, and (d) a steam generator connected to a heating jacket surrounding the vaporizer chamber.

The volatile liquid is injected into the vaporizer chamber which is surrounded by a steam jacket whereupon the liquid (which should have a boiling point below 100°C) volatilizes completely. Connected to the chamber is a vertical tube tall enough to prevent the vapor, which should be denser than air; from diffusing to any significant extent to the top of the tube where the connection is made to a gas burette. The gas burette contains water as the indicating liquid and has associated with it a side tube of the same diameter open to the atmosphere. A leveling bulb permits equalization of the pressure inside and outside the apparatus before each reading of the burette.

Since the pressure, temperature, and volume inside the heated chamber are the same before and after the sample is injected, the number of moles of gas (air or air plus vapor) in the chamber is essentially the same before and after volatilization, by Avogadro's law. The volume occupied by the liquid before volatilization is assumed to be negligible. Thus, a quantity of air, equal in number of moles to the quantity of liquid volatilized, is expelled into the gas burette.

It should be noted that it is not necessary that the temperature of the vaporization chamber be known, but it must be constant.

PROCEDURE: The apparatus should be assembled as in Figure 1. As much space as possible should be left between the gas burette and the rest of the apparatus to minimize temperature variations in the area of the gas burette. The flushing hose should be connected to the vacuum line **only when necessary for flushing between runs.**

The volatile liquid sample is injected using a syringe (this will be demonstrated to you in the laboratory). It is desired to have an amount of liquid which will give a vapor volume of 15 to 20 mL. The liquids you will be using are: dichloromethane, ethyl acetate, and methanol. From the densities of the liquids, their molecular masses and assuming room temperature to be 20°C, calculate the volume of liquid to be injected for each to give a vapor volume of 15 to 20 ml.

Liquid	Molar Mass	Density at 20°C
Dichloromethane	84.93	1.3266 g/mL
Ethyl acetate	88.12	0.9003 g/mL
Methanol	32.04	0.7914 g/mL
Acetone	58.08	0.7899 g/mL

Once the vaporizing chamber has reached a constant temperature you are ready to begin the experiment. At this point the screw clamp on the flushing hose should be closed. After steam has passed through the outer jacket and is emerging from the lower end; the leveling funnel is lowered from its highest to its lowest point and allowed to remain there a minute; this process should be repeated several times. The purpose of this is to saturate the air in the upper part of the apparatus with water vapor at room temperature in order to avoid a volume increase due to water vaporization in the burette during the run. After the water level has been finally brought to a point near the top of the burette scale, the clamp holding the funnel is tightened.

The initial burette reading is taken after drift has ceased. Before taking a reading the leveling funnel should be raised or lowered so that the water levels in the burette are the same. To test for leaks, the leveling funnel is lowered to its lowest position for a minute or so, then returned and the burette reread.

A measured volume of the volatile liquid is injected into the vaporizing chamber. As the sample is vaporized the water level in the gas burette falls, the leveling funnel should be lowered so as to maintain equal pressure inside and outside the apparatus. When the hot air displaced into the gas burette cools, a slight contraction may be noted. When drift ceases (but not later than 1 or 2 minutes after injection of the sample), the final burette reading is taken. **Make sure that the levels of the liquid are** **carefully adjusted to the same height**. After the apparatus has stood for a longer time, the volume of the measured air may decrease, because of diffusion of the vapor from the vaporizing chamber into the cooler parts of the apparatus where it condenses.

The final reading of the gas burette is taken before such condensation occurs. The temperature in the gas burette should also be recorded using the thermometer provided on the apparatus.

To flush out the vapor in preparation for the next run, the screw clamp connection to the vacuum line is established, and the screw clamp opened. ***MAKE CERTAIN THAT THE VALVE TO THE GAS BURETTE IS CLOSED BEFORE YOU BEGIN FLUSHING OUT THE VAPOR USING THE WATER ASPIRATOR!!!!***

Four or five runs should be carried out for each liquid until consistent results are obtained.

The barometer should be read during the laboratory period. The reading should be corrected to O°C for thermal expansion of the mercury and scale. (See Appendix).

CALCULATIONS: The molar mass M of the vapor is calculated from the familiar equation for an ideal gas

$$PV = (\text{sample mass/Molar Mass})RT$$

where P is the pressure read from the barometer and corrected to 0°C.

V = volume of displaced air, (in L)

T = absolute temperature at which volume is measured

sample mass = mass of liquid used

R = 0.08206 L-atm- mol^{-1}K^{-1}

If done with care this experiment gives results sufficiently precise to demonstrate deviations from ideal gas behavior in the vapor concerned. For substance whose critical temperatures and pressures are known, the gas imperfections can be estimated roughly from Berthelot's equation. A convenient form of this equation is

$$M = \frac{gRT}{PV}\left[1 + \frac{9PT_c}{128P_cT_s}\left(1 - 6\frac{T_c^2}{T_s^2}\right)\right]$$

where P_c = critical pressure of the substance used
            T_c = critical temperature of the substance used
            T_s = temperature of steam jacket

Substance	P_c(atm)	T_c(°C)
Dichloromethane	60	237
Ethyl acetate	37.8	250.4
Methanol	78.5	240
Acetone	47	235.5

APPENDIX

BAROMETER CORRECTIONS

The entries in the table below are calculated on the assumption that the barometer has a brass scale graduated to be accurate at 0°C. These corrections should be subtracted from the observed barometer readings. (If the brass scale is accurate at 20°C, the appropriate corrections are approximately 0.3 mm greater than those given).

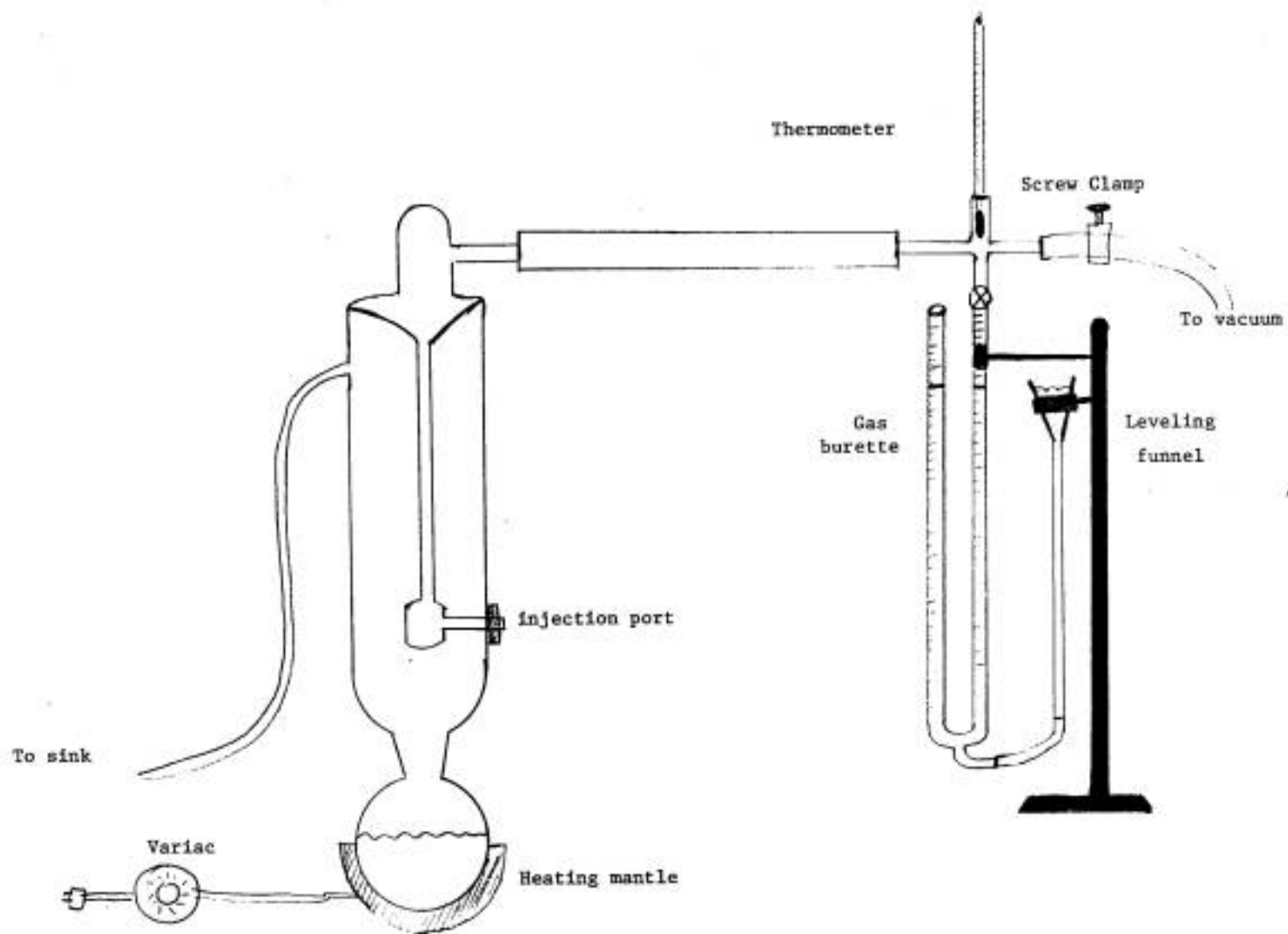| T,°C	720 mm	740 mm	760 mm	780 mm
16	1.88	1.93	1.98	2.03
17	1.99	2.05	2.10	2.16
18	2.11	2.17	2.23	2.29
19	2.23	2.29	2.35	2.41
20	2.34	2.41	2.47	2.54
21	2.46	2.53	2.60	2.67
22	2.58	2.65	2.72	2.79
23	2.69	2.77	2.84	2.92
24	2.81	2.89	2.97	3.05
25	2.93	3.01	3.09	3.17
26	3.04	3.13	3.21	3.30
27	3.16	3.25	3.34	3.42
28	3.28	3.37	3.46	3.55
29	3.39	3.49	3.58	3.68
30	3.51	3.61	3.71	3.80

FIGURE 1. Victor Meyer Apparatus