Thermal Equation of state and critical points of Ethane gas

Aim- There are Three parts of this experiment.

They are:-

1. To measure a no. of p-v isotherms of Ethane.

2. Determine the critical points and critical quantities ethane.

3. Calculate the constants of the Vander Waals Equation(a & b), The Boyle-Temperature(T_B), The radius of the molecules(r) and the parameters of the interaction potential(σ(m) & ε).

Diagram:-

Set-up and procedure:-

Figure shows a photograph of the equipment for measuring the thermal equation of state of a gas. The equipment consists of a glass tube which has been filled with ethane gas. This tube is surrounded by a water jacket the temperature of which can be varied using the thermostat in the water bath. This allows you to control the temperature of the gas in the experiment. The pressure of the gas can be controlled using a mercury column which can be forced into the capillary tube containing the gas. Whenever you finish an experiment the piston must be lowered fully (i.e. the wheel turned as far anticlockwise as possible) The p-V-isotherms of ethane should be measured at 2°C increments from 25° to 40°C

Procedure:-

1. First check that the level of mercury is at the lowermost state in the tube. Now set the temperature of water in water bath at T=25°C. Now rotate the piston clockwise which causes the rise in the level of mercury level of the tube. At the difference of 0.2 cm^3 of mercury level note down the value of corresponding pressure from the pressure meter.

2.Now again set the temperature of water bath at 30°C and before proceeding, make sure that the level of mercury in the tube is at its lowermost position(which can be occur by rotating

the piston anticlockwise).

3. Similarly for T=35°C.

Note- It is essential that the pressure in the apparatus never rises above the 6Mpa.

Theory-

The equation of state of an ideal gas is given by-

$$pV(m) = RT \qquad .....(1)$$

where p = pressure

V(m) = molar volume

R = universal gas constant

T = Temperature

For the description of the real behavior, molecular interactions (mainly attraction forces) and the volume of the molecules must be taken into account. One widely used equation of state for real gases is the van-der waals equation,

$$(p+(a/(V(m)^2)))*(V(m)-b) = RT \qquad .....(2)$$

Where a & b are Van-der waals constant.

*The term a/(V(m))^2 refers to the attractive molecular forces(attraction acts like an additional pressure) and is called Cohesion pressure. The term b refers to the volume of the molecules and is Co volume. On the basis of co volume b, the radius of the Gas molecules can be calculated according to eq(3)-

$$b = 4N_A \times (4/3) \times \pi r^3 \qquad .....(3)$$

where N_A = Avogadro's constant

r = Van-der waal's radius of the molecule.

One way for the experimental determination of the Van-der waals constants and the interaction parameters is the measurement of the critical quantities of the water. The following relations can be derived-

$$V(cr) = (3RT(cr))/(8P(cr)) \qquad .....(4)$$

$$a = 3P(cr)((V(cr))^2) \qquad .....(5)$$

$$b = V(cr)/3 \qquad .....(6)$$

By expending of eq(1)-

p.V(m) = R×T + B(T)×p + C(T)×p^2……. ...(7)

a relation between the 2nd virial coefficient B(T) of eq(7) and the van-der waals constant a & b of eq(2) can be derived by simplification of eq(2) and comparison of coefficients-

B(T) = b - (a/(RT)) .....(8)

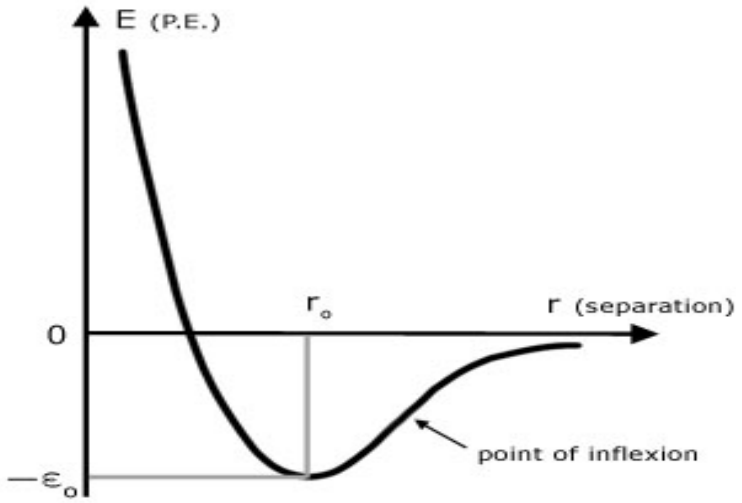

Fig- Interaction potential in dependence on the molecule distance.

The coefficient B(T) is a function of the temperature and according to eq(7), The gas shows a quasi ideal behaviour when B(T) = 0.

The temperature is called BOYLE-TEMPERATURE and can be calculated by-

T(B) = a/(bR) .....(8)

The interaction between the Gas molecules can also be described by an interaction potential function-

E(σ) = 4ε[(σ(m)/σ) - (σ(m)/σ)^6]

where ε and σ are parameters.

σ = Distance of the molecule centers.

Such a potential function and the meaning of the parameters ε & σ(m) are shown in figure-

where σ(m) = 0.841×(10^-8)×V(cr)^(1/3)

ε = 0.77kT(cr)

where k = Boltzmann constant = 1.38×10^-23 J/K

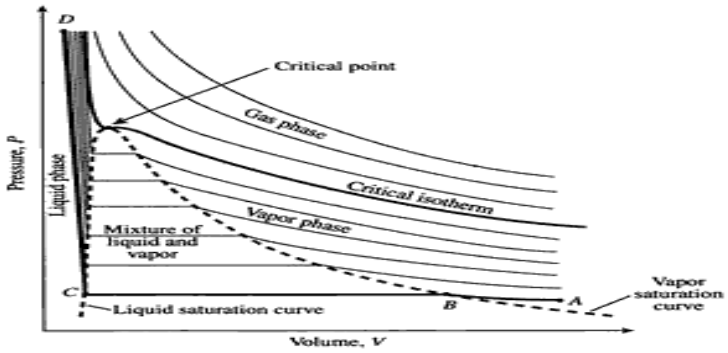

Fig- p-V isotherm of ethane gas at different values of temperature.

Precautions-

1. The water in the water bath should be filled up to at 2/3 level of its maximum capacity.
2. Pressure in the experiment should not rise above 6Mpa.