St. Lawrence High School
A Jesuit Christian Minority Institution
Study Material – 3
Term : 1st

Class – X | Subject – Physical Science
Chapter – Thermal Phenomena | Date – 08.05.20
Topic – Thermal expansion of gas

❖ Expansion of gas:

To heat certain amount of gas, the gas needs to be taken inside a gas container. Hence the volume of the container also increases along with the gas. But, we do not consider the expansion of the container here, as the expansion of the container is negligibly small compared to the expansion of the gas.

Hence we will only be concerned with the volume expansion of the gas and the expansion coefficient of the gas.

Let, $V_1 = The\ initial\ volume\ of\ certain\ amount\ of\ a\ gas\ at\ temperature\ t_1$, and heat is given, then the gas expands and at temperature t_2, the final volume becomes V_2.

Then,

$$V_2 - V_1 = \gamma V_1 (t_2 - t_1)$$

So,

$$\gamma = \frac{V_2 - V_1}{S_1 (t_2 - t_1)}$$

- γ is called the coefficient of Volume expansion of gas.
- S.I. Unit of γ is $\Rightarrow$ $/K$ or K^{-1}
- C.G.S Unit of γ is $\Rightarrow$ $/°C$ or $°C^{-1}$

- **Definition of γ -**

  It is defined as the change (or increase) in volume of a gas over the unit initial volume a, per degree change (or rise) in temperature.

- Alternative definition – It is defined as the relative change in volume per degree change in temperature.

- **Concept of volume expansion of gas and the Charle's law**

  In the above discussion, certain amount of gas is taken at atmospheric pressure and then the temperature of the gas is changed. Therefore, in this process, the mass of the gas remains constant as certain amount of gas is enclosed in a container and the pressure on the gas also remains constant as the whole experiment is done at atmospheric pressure.

  Hence, the mass and pressure remains constant in this process, and volume of the gas changes as the temperature is changed. This situation is then exactly similar to what we have discussed in **Charle's Law.** If we compare the concept of volume expansion of gas with **Charle's Law ,** then the outcome is very significant, as discussed below –

  Let, $\boldsymbol{v_0}$ = volume of certain amount of ideal gas at temperature **0**°C
  When, heat is given, the temperature increases to $\boldsymbol{t}$°C and the volume at that temperature is found to be $\boldsymbol{v_t}$.
  Then –

From the concept of thermal expansion –	From Charle's Law –
Initial volume = v_0 Initial temperature = 0°C Final volume = v_t Final temperature = t°C	Initial volume = v_0 Initial temperature = 0°C Final volume = v_t Final temperature = t°C
Then, change in volume = $(v_t - v_0)$ Initial volume = v_0 Change in temperature = $(t - 0)$°C	So, $v_t = v_0\left(1 + \frac{t}{273}\right)$
So, $(v_t - v_0) \propto v_0(t - 0)$ Or, $(v_t - v_0) = \gamma v_0(t - 0)$	Or, $v_t = v_0 + v_0 . \frac{t}{273}$
Or, $(v_t - v_0) = \gamma . v_0 . t$ ……….(1)	Or, $(v_t - v_0) = \frac{1}{273} . v_0 . t$ ……….(2)

Now, comparing equation – (1) and equation – (2), we can conclude $\gamma = \frac{1}{273}$ °C^{-1}

Therefore, we are getting a numerical value of γ for any ideal gas and most interestingly, the value is same for any ideal gas, as we have not considered here a specific gas. It means, all the ideal gasses expand at same rate when heated – but why? Remember the volume expansion coefficient of the solids and liquids are not same for any solid or any liquid, but when it is a gas, the expansion coefficient is same for all.

Actually, the rate of expansion depends on the intermolecular force of attraction of a material. Now, different materials have different intermolecular force of attraction, hence their γ differ. But for ideal gas, the molecules do not exert any force of attraction on each other, so when heated, all of them expand at same rate, and the expansion coefficient becomes equal.

❖ Important Questions and Answers

➢ Very Sort Answer Questions (1mark each)

1. What is the CGS unit of volume expansion coefficient of a gas?
   Ans: /°C or °C^{-1}

2. What is the numerical value of volume expansion coefficient of any ideal gas at fixed pressure? – WBBSE, 2017
   Ans: $\frac{1}{273}$ /°C or $\frac{1}{273}/K$

3. At very high temperature and very low pressure The rate of expansion of O_2 and H_2 gas will be different – write true or false.
   Ans: False. They will be equal as they can be then considered as ideal gas. And for any ideal gas the volume expansion coefficient is equal.

4. If the pressure is changed, then the volume expansion coefficient may not be equal to $\frac{1}{273}$/°C for ideal gas. – write True or False.
   Ans: True

➢ **Sort Answer Questions (each of 2 marks)**

1. What quantities remain constant in the definition of volume expansion coefficient of gas? 2019
   Ans: I) The mass of the gas and ii) Pressure on the gas

2. The expansion coefficient for any ideal gas is equal – why?
   Ans: The rate of expansion depends on the intermolecular force of attraction of a material. Now, different materials have different intermolecular force of attraction, hence their γ differ. But for ideal gas, the molecules do not exert any force of attraction on each other, so when heated, all of them expand at same rate, and the expansion coefficient becomes equal.

3. Define coefficient of volume expansion of any gas.
   Ans: It is defined as the change (or increase) in volume of a gas over the unit initial volume a, per degree change (or rise) in temperature.

4. State the factors on which the volume expansion of gas depends.
   Ans: It depends on i) the initial volume of gas ii) temperature difference and iii) pressure on the gas

5. What are the factors on which the volume expansion coefficient of gas depends?
   Ans: At constant pressure, it is a constant for all ideal gas. But, if the pressure is varied, then it will not be constant at any pressure. Hence it depends on the pressure on the gas.

6. If O_2 gas is considered to be an ideal gas, then what will be the increase in volume of $1m^3$ of O_2 gas when heated from 0°C to 1°C?
   Ans: From the definition of volume expansion coefficient of ideal gas, in this case the increment will be $\frac{1}{273}\ m^3$.

7. What will be change in volume over 500 ml of H_2 gas when the gas is heated from 0°C to 273°C?
   Ans: We know, $(v_t - v_0) = \frac{1}{273} . v_0 . t$
   Here, $v_0 = 500\ ml$, $t = (273 - 0)$°C $= 273$°C

   So, change in volume = $(v_t - v_0) = \frac{1}{273} \times 500 \times 273\ ml = 500ml$

8. At what condition, we can compare the volume expansion of gas to Charle's law?
   Ans: If the mass of the gas and pressure of the gas remain unchanged, then only we can compare the volume expansion of gas to Charle's law.

____________________________End____________________________

Name of the teacher – Soumitra Maity