$\boxed{\Delta V_a = \Delta V_{gas}}$ ✓

$V \neq$ const ⟶ we allow the volume to change

At $P =$ const if temp is increased :

For ideal gas $PV = \mu RT$ $\mu \rightarrow$ no. of moles

$$\frac{d}{dT}(PV) = \frac{d}{dT}\cdot(\mu RT)$$

$$P\frac{dV}{dT} = \mu R\frac{dT}{dT} \Rightarrow P\cdot\frac{dV}{dT} = \mu R$$

Dividing the equation by PV $\Rightarrow$ $\dfrac{P\, dV/dT}{PV} = \dfrac{\mu R}{PV}$

$$\frac{dV}{V\cdot dT} = \frac{\mu R}{\mu RT}$$

$$\frac{dV}{V\cdot dT} = \frac{1}{T}$$

$$\boxed{\gamma_p = \frac{1}{T}}$$