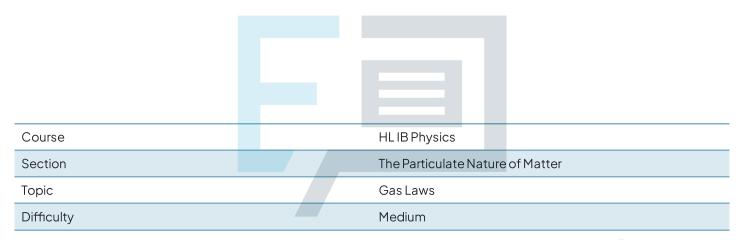


## **Gas Laws**

### **Mark Schemes**



# **Exam Papers Practice**

To be used by all students preparing for HL IB Physics Students of other boards may also find this useful 1

### The correct answer is B because:

- Using the ideal gas equation: pV = nRT
- - $0.4p \rightarrow 4T$
  - o Therefore, if p is quadrupled then T is also quadrupled
- - $\circ \left(\frac{V}{2}\right) \to \frac{T}{2}$
  - Therefore, if Vis halved then Tis also halved
- So, for T:
  - o pVaT
  - $\circ (4p)\left(\frac{V}{2}\right) \rightarrow 27$
- Therefore, overall Twill be doubled

2

### The correct answer is D because:





- So, when the volume is constant,  $\frac{p}{T}$  = constant
- Therefore, if pressure decreases then the temperature will decrease
- · Temperature is directly proportional to internal energy
  - Therefore, if temperature decreases then internal energy will decrease
- The direction of thermal energy transfer is always from the higher temperature to the lower temperature
  - Since Thas decreased, the direction of energy transfer is from the gas (to the surroundings)

3

### The correct answer is **D** because:

- The gas law equation is given as
  - o pV=nRT
  - Where p is the pressure of the gas, V is the volume of the gas, R is the molar gas constant and T is the absolute temperature of the gas
- · For a fixed mass of gas:
  - o  $\frac{pV}{T}$  = constant
- · Which means:
  - $o \frac{pV}{T} = \frac{p_2 V_2}{T_2}$
- If the final pressure, p2, increases to twice the initial pressure, p, then:
  - o p2=2p
- · We know that:

  - o  $2p \propto \frac{2T}{V}$  (1) o  $p_2 \propto \frac{T_2}{V_2}$  (2)
  - Where  $T_2$  is the final temperature of the gas and  $V_2$  is the final volume of the gas
- Setting (1) and (2) equal to each other gives:
- Hence,  $\frac{T_2}{V_2}$  must be equal to  $\frac{2T}{V}$  for the final pressure of the gas to be double the magnitude of the initial pressure

pers Practice

· Consider option D:

- Substituting into  $\frac{T_2}{V_2}$  we get:
- This is in line with the expression  $p_2 = 2p$ , hence the correct answer is

D

### A is incorrect as

$$\frac{\frac{T_2}{V_2}}{\frac{T_2}{V_2}} = \frac{\frac{2T}{4V}}{\frac{T}{2V}}$$

B is incorrect as

$$\frac{T_2}{V_2} = \frac{T}{4} \div 2V$$

$$\frac{T_2}{V_2} = \frac{T}{4} \times \frac{1}{2V}$$

$$\frac{T_2}{V_2} = \frac{T}{8V}$$

C is incorrect as

$$\frac{T_2}{V_2} = 4T \div \frac{V}{2}$$

$$\frac{T_2}{V_2} = 4T \times \frac{2}{V}$$

$$\frac{T_2}{V_2} = \frac{8T}{V}$$

4

The correct answer is **D** because:

- The ideal gas equation, shown below, links the values of pressure p, volume V and Kelvin temperature T
  - $\circ pV = nRT$
- To convert a temperature in °C into Kelvin we add 273, hence the ideal gas equation becomes
  - $\circ$   $pV = nR(\theta + 273)$
  - $\circ$  Where  $\theta$  is the temperature in  $^{\circ}$ C
- Multiplying out the bracket gives:
  - $\circ pV = nR\theta + 273nR$
- There is 1 mole of each gas, therefore n = 1, hence the equation becomes:
  - o pV= Rθ+ 273R
- Applying linear mapping to this equation we get:
  - o y-axis = pV
  - o x-axis =  $\theta$
  - $\circ$  gradient = R
  - o y-intercept = 273R
- Graphs for both chlorine and nitrogen will have the same gradient and the same y-intercept as R is the molar gas constant
  - Therefore, graph D is correct

### The correct answer is C because:

- The ideal gas law equation is given by:
  - o pV=nRT
- The relationship between the number of moles, n, the molar mass,  $M_r$ and the mass of the gas, Mis

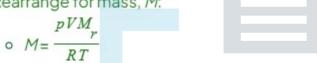
$$\circ n = \frac{M}{M_r}$$

· Substituting this into the ideal gas equation:

$$\circ \ \rho V = \left(\frac{M}{M_r}\right) RT$$

Rearrange for mass, M:

$$\circ M = \frac{pVM_{\gamma}}{RT}$$



• Write an expression for the mass of the gas in X:

$$\circ M_X = \frac{p(2V)M_r}{R(200)}$$

- Write an expression for the mass of the gas in Y:  $PVM_{p}$  $OM_Y = \frac{7}{R(400)}$ 
  - Divide the expressions for M<sub>X</sub> and M<sub>Y</sub>.

$$\circ \ \frac{M_X}{M_Y} = \frac{p(2V)M_r}{R(200)} \div \frac{pVM_r}{R(400)}$$

$$\circ \frac{M_X}{M_Y} = \frac{p(2V)M_r}{R(200)} \times \frac{R(400)}{pVM_r}$$

$$\circ \ \frac{M_X}{M_Y} = \frac{2 \times 400}{200} = 4$$

6

The correct answer is D because:

- The ideal gas law equation is given by:
  - o pV=nRT
- Rearrange this to match the equation of a straight-line y = mx + c

$$\circ \ \frac{1}{p} = \left(\frac{1}{nRT}\right)V$$

 If the temperature is doubled (T → 2T) and the amount of gas is doubled (n → 2n) the new equation would be:

$$\circ \frac{1}{p} = \left(\frac{1}{(2n)R(2T)}\right)V$$

$$\circ \quad \frac{1}{p} = \frac{1}{4} \left( \frac{1}{nRT} \right) V$$

- Therefore, the new gradient would be  $\frac{1}{4}$  that of the original graph
  - o This is shown in graph D

You can confirm the gradient of **D** is  $\frac{1}{4}$  that of the original graph by checking the numbers. Since the original graph passes through points (2, 0.2) and (4, 0.4), the gradient is

$$\frac{\Delta y}{\Delta x} = \frac{0.4 - 0.2}{4 - 2} = \frac{1}{10}$$

Graph D passes through points (2, 0.05) and (4, 0.1), so the gradient is

$$\frac{\Delta y}{\Delta x} = \frac{0.1 - 0.05}{4 - 2} = \frac{1}{40}$$

This clearly shows that the new gradient is 4 times less than the original gradient

### The correct answer is **D** because:

- The ideal gas law equation is given by:
  - o pV=nRT
- The relationship between the number of moles, n, the molar mass,  $M_r$ and the mass of the gas, Mis

$$\circ n = \frac{M}{Mr}$$

· Substituting this into the ideal gas equation:

o 
$$pV = \left(\frac{M}{M_T}\right) RT$$

· Rearrange this for pressure, p:

$$\circ p = \frac{\left(\frac{M}{M_r}\right)RT}{V}$$





### The correct answer is A because:

- The volume of a cylinder is given by:
  - $\circ V = \pi r^2 L$
- - o If r is halved,  $\left(\frac{1}{2}r\right)^2 \rightarrow \frac{1}{4}r^2$
  - Therefore, the volume also decreases by a factor of 4



- If p is constant, as stated in the question, then T ∝ V
- Therefore, if the volume decreases by a factor of 4 (V → <sup>V</sup>/<sub>4</sub>), then Talso decreases by a factor of 4 (T → <sup>T</sup>/<sub>4</sub>)



The correct answer is A because:

- · The ideal gas law equation is given by:
  - o pV=nRT
- The relationship between the number of moles, n, the number of gas particles, N, and Avogadro's number, N<sub>A</sub>, is

$$\circ n = \frac{N}{N_A}$$

 Rearrange pV = nRT to match the equation of a straight line y = mx + c using y = Tand x = p

$$\circ T = p\left(\frac{V}{nR}\right)$$

• Substitute n for  $\frac{N}{N_A}$ :

$$\circ T = p\left(\frac{V}{nR}\right) = p\left(\frac{VN_A}{NR}\right)$$

• Therefore, the gradient is equal to  $\frac{VN_A}{NR}$ 

## **Exam Papers Practice**

You could also tackle this problem by considering the gradient of the graph instead of the equation of a straight line:

$$\frac{\Delta y}{\Delta x} = \frac{T}{v}$$

From pV = nRT, we can see that:

$$\frac{T}{p} = \frac{V}{nR}$$

Substituting in  $n = \frac{N}{N_A}$  gives:

$$\frac{T}{p} = \frac{V}{nR} = \frac{VN_A}{NR}$$