Exam Papers Practice

Gas Laws

Mark Schemes

Course	HL IB Physics
Section	The Particulate Nature of Matter
Topic	Gas Laws
Difficulty	Medium

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

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The correct answer is **B** because:

- Using the ideal gas equation: $pV = nRT$
- We can see that $p \propto T$
  - $4p \rightarrow 4T$
  - Therefore, if p is quadrupled then T is also quadrupled
- We can also see that: $V \propto T$
  - $\left(\frac{V}{2}\right) \rightarrow \frac{T}{2}$
  - Therefore, if V is halved then T is also halved
- So, for T:
  - $pV \propto T$
  - $(4p)\left(\frac{V}{2}\right) \rightarrow 2T$
- Therefore, overall T will be doubled

2

The correct answer is **D** because:

- An isovolumetric change means the volume remains constant
  - We know that $p \propto T$
  - 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 T has 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
  - $pV = nRT$
  - 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:
  - $\frac{pV}{T}$ = constant
- Which means:
  - $\frac{pV}{T} = \frac{p_2V_2}{T_2}$
- If the final pressure, p_2, increases to twice the initial pressure, p, then:
  - $p_2 = 2p$
- We know that:
  - $2p \propto \frac{2T}{V}$ (1)
  - $p_2 \propto \frac{T_2}{V_2}$ (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:
  - $\frac{2T}{V} = \frac{T_2}{V_2}$
- 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
- Consider option **D**:
  - $V_2 = \frac{V}{4}$
  - $T_2 = \frac{T}{2}$
- Substituting into $\frac{T_2}{V_2}$ we get:
  - $\frac{T_2}{V_2} = \frac{T}{2} \div \frac{V}{4}$
  - $\frac{T_2}{V_2} = \frac{T}{2} \times \frac{4}{V}$
  - $\frac{T_2}{V_2} = \frac{4T}{2V}$
  - $\frac{T_2}{V_2} = \frac{2T}{V}$
- This is in line with the expression $p_2 = 2p$, hence the correct answer is **D**

A is incorrect as

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

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*
  - $pV = nRT$
- To convert a temperature in °C into Kelvin we add 273, hence the ideal gas equation becomes
  - $pV = nR(\theta + 273)$
  - Where θ is the temperature in °C
- Multiplying out the bracket gives:
  - $pV = nR\theta + 273nR$
- There is 1 mole of each gas, therefore $n = 1$, hence the equation becomes:
  - $pV = R\theta + 273R$
- Applying linear mapping to this equation we get:
  - y-axis = pV
  - x-axis = θ
  - gradient = R
  - 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

5

The correct answer is **C** because:

- The ideal gas law equation is given by:
  - $pV = nRT$
- The relationship between the number of moles, n, the molar mass, M_r and the mass of the gas, M is
  - $n = \frac{M}{M_r}$
- Substituting this into the ideal gas equation:
  - $pV = \left(\frac{M}{M_r}\right) RT$
- Rearrange for mass, M:
  - $M = \frac{pVM_r}{RT}$
- Write an expression for the mass of the gas in **X**:
  - $M_X = \frac{p(2V)M_r}{R(200)}$
- Write an expression for the mass of the gas in **Y**:
  - $M_Y = \frac{pVM_r}{R(400)}$
- Divide the expressions for M_X and M_Y:
  - $\frac{M_X}{M_Y} = \frac{p(2V)M_r}{R(200)} \div \frac{pVM_r}{R(400)}$
  - $\frac{M_X}{M_Y} = \frac{p(2V)M_r}{R(200)} \times \frac{R(400)}{pVM_r}$
  - $\frac{M_X}{M_Y} = \frac{2 \times 400}{200} = 4$

6

The correct answer is **D** because:

- The ideal gas law equation is given by:
  - $pV = nRT$
- Rearrange this to match the equation of a straight-line y = mx + c
  - $\frac{1}{p} = \left(\frac{1}{nRT}\right)V$
- If the temperature is doubled (T → 2T) and the amount of gas is doubled (n → 2n) the new equation would be:
  - $\frac{1}{p} = \left(\frac{1}{(2n)R(2T)}\right)V$
  - $\frac{1}{p} = \frac{1}{4}\left(\frac{1}{nRT}\right)V$
- Therefore, the new gradient would be $\frac{1}{4}$ that of the original graph
  - 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

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The correct answer is **D** because:

- The ideal gas law equation is given by:
  - $pV = nRT$
- The relationship between the number of moles, n, the molar mass, M_r and the mass of the gas, M is
  - $n = \frac{M}{M_r}$
- Substituting this into the ideal gas equation:
  - $pV = \left(\frac{M}{M_r}\right) RT$
- Rearrange this for pressure, p:
  - $p = \frac{\left(\frac{M}{M_r}\right) RT}{V}$
  - $p = \frac{\left(\frac{16}{32}\right) \times 8 \times (27 + 273)}{0.1^3}$
  - $p = \frac{\frac{1}{2} \times 8 \times 300}{\frac{1}{1000}}$
  - $p = \frac{1}{2} \times 8 \times 300 \times 1000 = 1\,200\,000$ Pa
  - $p = 1200$ kPa

8

The correct answer is **A** because:

- The volume of a cylinder is given by:
  - $V = \pi r^2 L$
- We can see that $V \propto r^2$, so:
  - 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 $T \propto V$
- Therefore, if the volume decreases by a factor of 4 ($V \rightarrow \frac{V}{4}$), then T also decreases by a factor of 4 ($T \rightarrow \frac{T}{4}$)

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The correct answer is **A** because:

- The ideal gas law equation is given by:
  - $pV = nRT$
- The relationship between the number of moles, n, the number of gas particles, N, and Avogadro's number, N_A, is
  - $n = \frac{N}{N_A}$
- Rearrange $pV = nRT$ to match the equation of a straight line y = mx + c using y = T and x = p
  - $T = p\left(\frac{V}{nR}\right)$
- Substitute n for $\frac{N}{N_A}$:
  - $T = p\left(\frac{V}{nR}\right) = p\left(\frac{VN_A}{NR}\right)$
- Therefore, the gradient is equal to $\frac{VN_A}{NR}$

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

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

From $pV = nRT$, we can see that:

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

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

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