3.2 Modelling a Gas

Mark Schemes

Course	DP IB Physics
Section	3. Thermal Physics
Topic	3.2 Modelling a Gas
Difficulty	Easy

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

1

The correct answer is **B** because:

- Pressure is defined as the force per unit area
  - $p = \frac{F}{A}$
- Rearranging this for the force *F* gives:
  - *F* = *pA*
- Substituting in the values gives:
  - *F* = (166 000) × 2.0 = 332 000 N

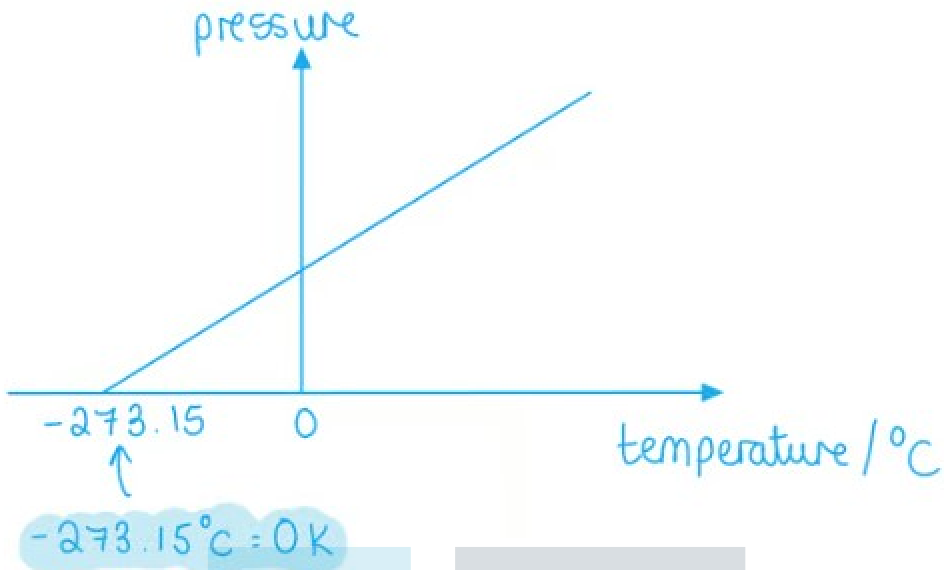
A is incorrect as	the area has divided by the pressure instead of multiplied
C is incorrect as	the area has divided by the pressure instead of multiplied and kPa is ×1000 not ÷ 1000
D is incorrect as	kPa is ×1000 not ÷ 1000

2

The correct answer is **C** because:

- At constant volume, the pressure is proportional to temperature
  - This means that as the pressure increases, the temperature increases, and vice versa
  - This eliminates graphs **B** and **D**
- The temperature is in kelvin (K), so the graph must go through the origin
  - When extrapolated, graph **A** will intercept the vertical axis above the origin
  - Graph **C** will go through the origin
  - Therefore, graph **C** is correct

If the temperature was in °C, then the pressure will be 0 at 0 K or −273.15 °C. This means that the temperature can be negative and the graph will look like this instead:



3

The correct answer is **D** because:

- *n* is the number of **moles**
- *N* is the number of **molecules**
- N_A is **Avogadro's constant** (6.02×10^{23} mol^{-1})

The equation that relates these three values is: $n = \frac{N}{N_A}$. This is also given on your data sheet.

4

The correct answer is **B** because:

- The average kinetic energy of a molecule is given by:
  - $E_k = \frac{3}{2} k_B T$
  - Where k_B is the Boltzmann constant (1.38×10^{-23} J K^{-1}) and *T* is the temperature of the gas
- Because the container is sealed, both the helium and neon molecules will be at the same temperature

- Temperature is the only variable that the kinetic energy depends on
  - Therefore, both types of molecules have the **same** average kinetic energy
- This means the ratio $\frac{\text{average kinetic energy of neon molecules}}{\text{average kinetic energy of helium molecules}}$ is 1

The mass given in the question is just a red herring. It is important to remember that the **average kinetic energy** only depends on the **temperature** of the gas, and not the mass or concentration of the molecules.

In any fraction, if the numerator and denominator are equal, the whole fraction is equal to 1. Therefore, we don't even require the temperature of the gas, because it is the same for both types of molecules (since they're part of the same mixture of gas).

5

The correct answer is **D** because:

- The momentum of a gas molecule is given by the equation:
  - $p = mv$
  - Where m is its mass and v is its velocity
- During a collision with a wall, a gas molecule **changes direction**
- Since momentum is a vector, this means the molecule changes its **momentum**
  - Therefore, the momentum of a given molecule varies upon a collision with the container
- The momentum change from the collisions between the molecules is ignored

A is incorrect as	the kinetic energy of a given molecule of the gas **varies** because each molecule will have a slightly different speed. Kinetic energy is equal to $\frac{1}{2}mv^2$ so depends on the speed.

B is incorrect as	the forces between between each gas molecule is assumed to be zero.
C is incorrect as	the intermolecular potential energy of the molecules in an ideal gas is assumed to be zero at all times i.e. constant.

6

The correct answer is **C** because:

- The temperature of the gas remains constant, so the speed and therefore average kinetic energy also remains constant
  - This is because average kinetic energy, $E_k = \frac{3}{2} k_B T$ where T is the temperature and k_B is the Boltzmann constant
  - This means statement I is false
- When the volume of the container decreases, the molecules collide more frequently with the walls of the container because there is less space for them to move between the walls
  - This means statement II is true
- The pressure of a gas is defined by the force per unit area that each molecule exerts on the walls of the container
  - If there are more frequent collisions, this increases the pressure of the gas
  - Therefore, statement III is also true
- This means answer option **C** is correct

7

The correct answer is **B** because:

- The correct assumption is:
  - The duration of collisions between particles is **negligible** or **zero** in comparison to the time between the collisions
  - Therefore, assumption **B** is incorrect

It is important you remember all the assumptions used in the kinetic model of ideal gases, as this is a very common exam question to recognise them and state them. Remember to read each assumption **properly** looking for key words such as 'constant', 'negligible' or 'zero'.

8

The correct answer is **C** because:

- When the temperature is constant, the pressure of a gas is **inversely proportional** to its volume
  - This is also known as Boyle's law
- This can be written as:
  - $p \propto \frac{1}{V}$
- Therefore, as the volume increases, the pressure decreases and vice versa
  - This is shown in graph **C**

A & **B** are incorrect as	the relationship between pressure and volume is $p \propto \frac{1}{V}$, so the graph of pressure against volume will be a curve and not a straight line. As the volume of the gas increases, the pressure decreases so the graph should have a negative gradient
D is incorrect as	As the volume of the gas increases, the pressure decreases so the graph should have a negative gradient

9

The correct answer is **A** because:

- A monoatomic gas such as argon can approximate to an ideal gas when it is at:
  - Low pressure
  - Moderate temperature
  - Low density
- Therefore, only **A** is correct

B & **D** are incorrect as	'moderate' temperature means that is it not too high or too low, hence these are incorrect
C is incorrect as	the approximation is only at low density, not high density

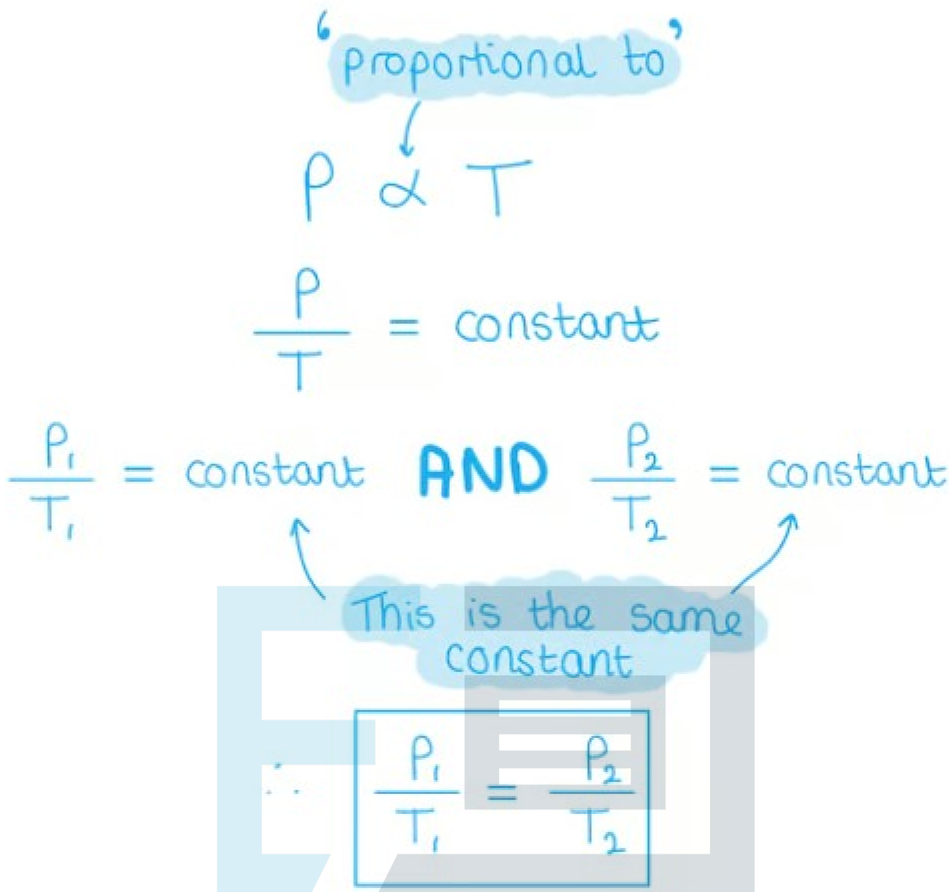
10

The correct answer is **B** because:

- At constant temperature, pressure, *p* is inversely proportional to volume, *V*
  - This means that $p \propto \frac{1}{V}$
- Rearranging this into an equation gives:
  - pV = constant
- Therefore, **B** is not a correct equation used for an ideal gas

A is correct as	this is the ideal gas equation, so is relevant for all ideal gases
B is correct as	at constant pressure, volume is directly proportional to temperature ($V \propto T$). Rearranging this into an equation gives $\frac{V}{T}$ = constant
C is correct as	From the ideal gas equation $pV = nRT$, R is the molar gas constant and n is the number of moles. Whilst pressure p, volume V and temperature T can all change in a gas, n and R are **always** constant. Therefore, the equation can be rearranged to give $\frac{pV}{T} = nR$ = constant

To change a proportionality relationship into an equation, remember to rearrange all the variables to one side, switch the 'proportional to' sign ($\propto$) into an equals sign (=) and equate the expression to a constant. Here is an example of pressure proportional to temperature at constant volume:


'proportional to'
$P \propto T$
$\frac{P}{T} = \text{constant}$
$\frac{P_1}{T_1} = \text{constant}$ AND $\frac{P_2}{T_2} = \text{constant}$
This is the same constant
$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2}$