IG.P9 Kinetic Theory of Gases and the Gas Laws

EDEXCEL 4PH1 · Calculator allowed · about 50 minutes

Total Marks

Name: ________________________________ Date: ____ / ____ / ______

Answer ALL questions. Show all your working.

1 State one assumption of the kinetic theory model for an ideal gas in a sealed container.

(Total for Question 1 is 1 mark)

2 State what produces the pressure of a gas in a container, according to kinetic theory.

(Total for Question 2 is 1 mark)

3 Explain using the kinetic theory why increasing the temperature of a gas in a fixed-volume container increases its pressure.

(Total for Question 3 is 2 marks)

4 Convert a temperature of 25 degrees C to kelvin for use in the pressure-temperature law at constant volume.

(Total for Question 4 is 2 marks)

5 Convert an absolute temperature of 100 K to degrees Celsius and state whether this temperature is above or below typical laboratory room temperature (about 20 degrees C).

(Total for Question 5 is 2 marks)

6 State the meaning of absolute zero in the context of kinetic theory of gases.

(Total for Question 6 is 1 mark)

7 A sealed 500 cm3 container holds a gas at a pressure of 100 kPa. The gas is compressed to 200 cm3 at the same temperature. Calculate the final pressure using Boyle's law, showing equation, substitution and final unit.

(Total for Question 7 is 3 marks)

8 A helium balloon has volume 2.0 m3 at pressure 101 kPa. It is taken down a mine where the pressure increases to 150 kPa at the same temperature. Calculate the balloon volume in the mine using Boyle's law. Show equation, substitution and unit.

(Total for Question 8 is 3 marks)

9 A fixed-volume container holds a gas at pressure 120 kPa and temperature 300 K. The gas is heated at constant volume to 450 K. Calculate the new pressure using the pressure-temperature law p1/T1 = p2/T2. Show equation, substitution and unit.

(Total for Question 9 is 3 marks)

10 Convert a temperature of -40 degrees C to kelvin and state whether this temperature is above absolute zero.

(Total for Question 10 is 3 marks)

11 A trapped gas at 80 kPa occupies 600 cm3 at constant temperature. The external pressure is increased to 160 kPa so the gas is compressed further. Calculate the new volume using Boyle's law. Show equation, substitution and unit.

(Total for Question 11 is 3 marks)

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12 Explain using kinetic theory why decreasing the volume of a gas at constant temperature increases its pressure.

(Total for Question 12 is 2 marks)

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13 A student measures pressure at constant volume and obtains p = 100 kPa at T = 273 K, and p = 200 kPa at T = 546 K. Use the pressure-temperature law to predict the pressure at T = 1092 K for the same volume. Show equation, substitution and unit.

(Total for Question 13 is 4 marks)

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14 Discuss the limitations of the kinetic theory model for real gases and explain under what conditions real gases deviate most from the ideal behaviour assumed by the model.

(Total for Question 14 is 6 marks)

Mark scheme · IG.P9 Kinetic Theory of Gases and the Gas Laws

Question 1

- **B1** particles are in constant random motion
- **Answer: Particles are in constant random motion**

Question 2

- **B1** collisions of particles with the container walls
- **Answer: Collisions of particles with the container walls produce the pressure**

Question 3

- **B1** higher temperature means particles have higher average kinetic energy / move faster
- **B1** faster particles collide with walls more frequently and with greater force, increasing pressure
- **Answer: At higher temperature particles have higher average kinetic energy and move faster; they hit the walls more often and with greater force so pressure increases**

Question 4

- **M1** states or uses conversion T(K) = T(degrees C) + 273
- **A1** 298 K cao
- **Answer: 298 K**

Question 5

- **M1** uses conversion degrees C = K - 273
- **A1** 100 K = -173 degrees C and this is below room temperature
- **Answer: -173 degrees C, which is well below room temperature**

Question 6

- **B1** the temperature at which particles have minimum possible kinetic energy (zero average kinetic energy)
- **Answer: Absolute zero is the temperature where particles have zero average kinetic energy**

Question 7

- **M1** states Boyle's law p1V1 = p2V2
- **M1** substitutes values and rearranges, p2 = p1V1 / V2 = 100 kPa x 500 cm3 / 200 cm3
- **A1** final answer p2 = 250 kPa cao
- **Answer: 250 kPa**

Question 8

- **M1** states Boyle's law p1V1 = p2V2
- **M1** substitutes values and rearranges, V2 = p1V1 / p2 = 101 kPa x 2.0 m3 / 150 kPa
- **A1** final answer V2 = 1.35 m3 cao (awrt)
- **Answer: 1.35 m3**

Question 9

- **M1** states p1/T1 = p2/T2
- **M1** substitutes values and rearranges, p2 = p1 x T2 / T1 = 120 kPa x 450 K / 300 K
- **A1** final answer p2 = 180 kPa cao
- **Answer: 180 kPa**

Question 10

- **M1** states the conversion T(K) = T(degrees C) + 273 and substitutes -40 + 273
- **A1** 233 K cao
- **B1** states that 233 K is above absolute zero (0 K)
- **Answer: 233 K, which is above absolute zero**

Question 11

- **M1** states p1V1 = p2V2
- **M1** rearranges and substitutes V2 = p1V1 / p2 = 80 kPa x 600 cm3 / 160 kPa
- **A1** final answer V2 = 300 cm3 cao
- **Answer: 300 cm3**

Question 12

- **B1** reducing volume means particles have less space so they collide with the container walls more frequently
- **B1** more frequent collisions per unit area increase the force per unit area, so pressure increases
- **Answer: Smaller volume reduces the distance between wall collisions so particles hit the walls more often; more collisions per unit time increase the force per unit area and so pressure rises**

Question 13

- **M1** states p1/T1 = p2/T2
- **M1** substitutes values and rearranges, p2 = p1 x T2 / T1 = 100 kPa x 1092 K / 273 K
- **M1** evaluates numeric ratio 1092 / 273 = 4 and multiplies to get 400
- **A1** final answer p2 = 400 kPa cao
- **Answer: 400 kPa**

Question 14

- **Level 1** (1-2): Limited statements about ideal gas assumptions or a simple identification of one limitation, with little or no linking to conditions where deviations occur.
- **Level 2** (3-4): Several correct points about limitations and some explanation of how attractive forces or particle volume cause deviations, with partial linkage to pressure and temperature conditions.
- **Level 3** (5-6): Well developed discussion that explains multiple limitations of the kinetic theory, why they arise, and clearly explains when and why real gases deviate from ideal behaviour under high pressure or low temperature conditions.
- **Indicative content:**
  - Assumptions of the kinetic theory: point particles with no volume, no intermolecular forces, elastic collisions, rapid random motion
  - Real gas particles have finite size and experience intermolecular attractions and repulsions, which the ideal model ignores
  - At high pressure the finite volume of particles becomes significant compared with the container volume, reducing free space and causing pressure to differ from ideal predictions
  - At low temperature intermolecular attractions become more important; particles slow and attract each other, reducing pressure compared with the ideal prediction at the same temperature
  - Deviations are largest at high pressure and low temperature, and smallest at low pressure and high temperature where the ideal assumptions are more valid
  - Reference to condensation as an extreme deviation where gas laws no longer apply because the gas liquefies
  - How corrections are made in real gas equations such as van der Waals, qualitative mention only, not required