1)

(a) The ideal gas equation may be written as

$$pV = nRT.$$

State the meaning of the terms n and T.

n ....

T .... **[2]**

(b) Fig. 6.1 shows a cylinder that contains a fixed amount of an ideal gas. The cylinder is fitted with a piston that moves freely. The gas is at a temperature of 20 °C and the initial volume is $1.2 \times 10^{-4}\,\text{m}^3$. Fig. 6.2 shows the cylinder after the gas has been heated to a temperature of 90 °C under constant pressure.

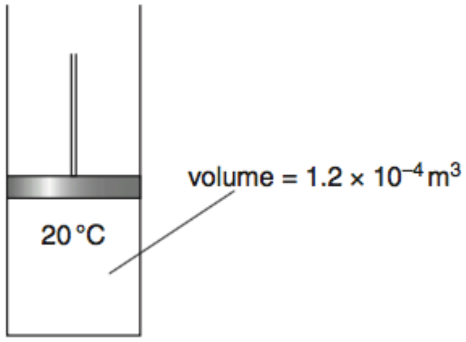


Fig. 6.1

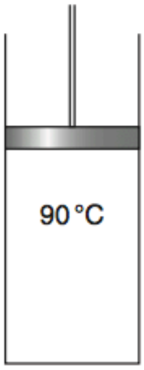


Fig. 6.2

(i) Explain in terms of the motion of the molecules of the gas why the volume of the gas must increase if the pressure is to remain constant as the gas is heated.

....

....

....

....

....

....

....

....

....

.... **[4]**

(ii) Calculate the volume of the gas at 90 °C.

volume = ... m^3 **[2]**

(c) The mass of each gas molecule is 4.7×10^{-26} kg. Estimate the average speed of the gas molecules at 90 °C.

speed = ... $m\,s^{-1}$ **[3]**

[Total: 11]

2)

(a) A student investigates Brownian motion by observing through a microscope smoke particles suspended in air.

(i) Describe the behaviour of the smoke particles as observed by the student.

In your answer, you should use appropriate technical terms spelled correctly.

....

.... **[1]**

(ii) State how the observations lead to conclusions about the nature and properties of the molecules of a gas.

....

....

....

....

....

....

....

.... **[3]**

(b) The molar masses of hydrogen and oxygen are $0.0020\,\text{kg mol}^{-1}$ and $0.032\,\text{kg mol}^{-1}$ respectively. The mean speed of hydrogen molecules at room temperature is $1800\,\text{m s}^{-1}$.

Calculate the mean speed of oxygen molecules at the same temperature.

mean speed = ... m s^{-1} **[3]**

[Total: 7]

3)

(a) **(i)** State Boyle's law.

....

.... **[2]**

(ii) For a gas which obeys Boyle's law, sketch

1 on Fig. 6.1 a graph of pressure p against volume V

2 on Fig. 6.2 a graph of p against $1/V$. **[3]**

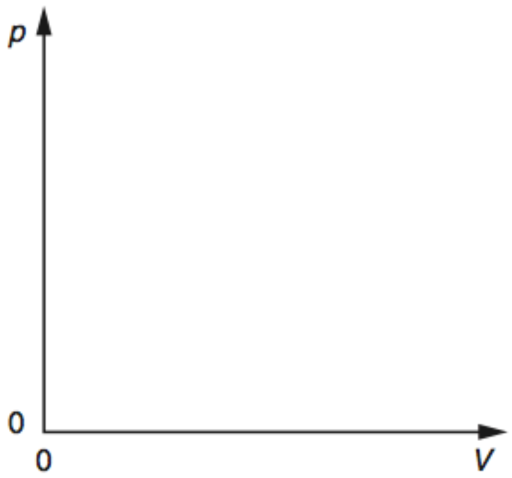


Fig. 6.1

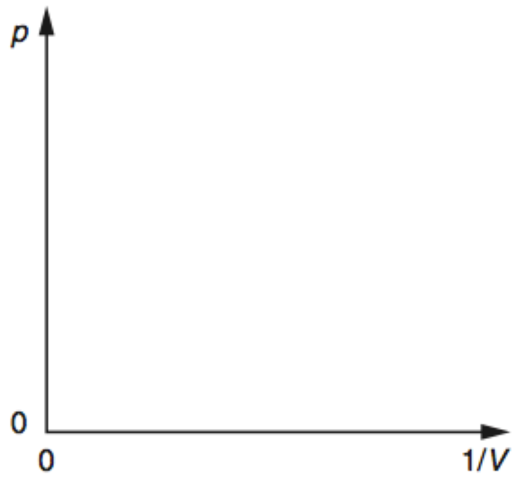


Fig. 6.2

(b) A cylinder of fixed volume $0.040\,\text{m}^3$ is filled with nitrogen gas at a pressure of $5.0 \times 10^5\,\text{Pa}$ and temperature 15 °C. The molar mass of nitrogen is $0.028\,\text{kg}\,\text{mol}^{-1}$.

(i) Calculate the number of moles of nitrogen in the cylinder.

number of moles = ... **[2]**

(ii) After a period of 100 days the pressure has fallen to $4.5 \times 10^5\,\text{Pa}$, at the same temperature, because of leakage. Calculate the mass of nitrogen that has escaped.

mass = ... kg **[3]**

[Total: 10]

4)

(a) **(i)** State what is meant by a *perfectly elastic collision*.

....

.... **[1]**

(ii) Explain, in terms of the behaviour of **molecules**, how a gas exerts a pressure on the walls of its container.

....

....

....

....

....

....

.... **[4]**

(iii) Explain, in terms of the behaviour of **molecules**, why the pressure of a gas in a container of constant volume increases when the temperature of the gas is increased.

....

....

....

....

.... **[2]**

(b) A weather balloon is filled with helium gas. Just before take-off the pressure inside the balloon is 105 kPa and its internal volume is $5.0 \times 10^3\,m^3$. The temperature inside the balloon is 20 °C. The pressure, volume and temperature of the helium gas change as the balloon rises into the upper atmosphere.

(i) The balloon expands to a volume of $1.2 \times 10^4\,m^3$ in the upper atmosphere where the temperature inside the balloon is –30° C. Calculate the pressure inside the balloon.

pressure = ... kPa **[3]**

(ii) Suggest why it is necessary to release helium from the balloon as it continues to rise.

....

....

.... **[1]**

[Total: 11]

5)

(a) The molar mass of hydrogen gas is 2.02×10^{-3} kg mol^{-1}. Calculate the mass of a hydrogen molecule.

mass = ... kg **[2]**

(b) The temperature of the Earth's upper atmosphere is about 1100 K. Show that at this temperature the mean kinetic energy of an air molecule is about 2×10^{-20} J.

[2]

(c) Show that the speed of a helium atom of mass 6.6×10^{-27} kg at a temperature of 1100 K is about 2.5 km s^{-1}.

[2]

(d) The *escape velocity* from the Earth is 11 km s^{-1}. The escape velocity is the minimum vertical velocity a particle must have in order to escape from the Earth's gravitational field. Explain why helium atoms still escape from the Earth's atmosphere.

....

....

....

....

.... **[2]**

[Total: 8]

6)

(a) **(i)** The pressure p and volume V of a quantity of an ideal gas at absolute temperature T are related by the equations $pV = nRT$ and $pV = NkT$. In these equations identify the symbols n and N.

n ....

N..
[1]

(ii) Choose one of the equations in **(i)** and show how Boyle's law follows from it.

....

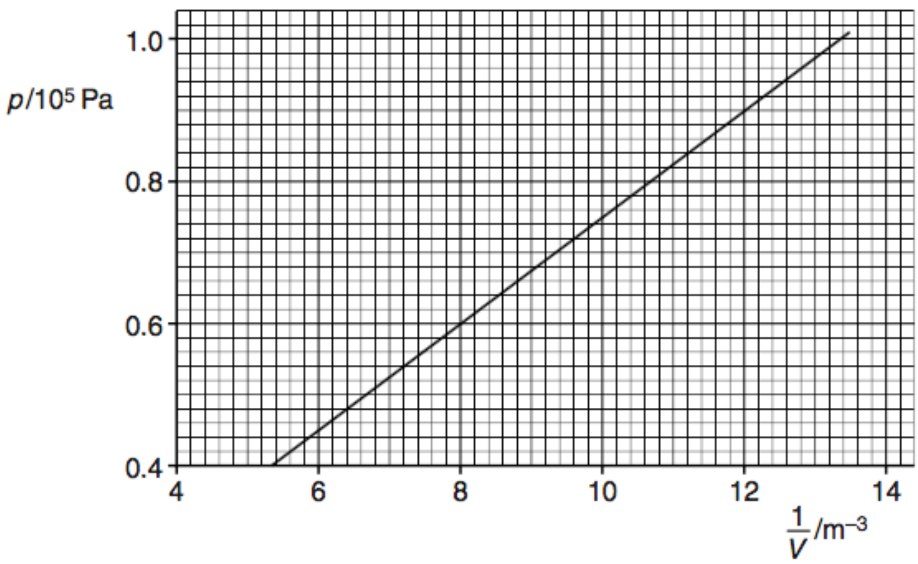
....

.... **[2]**

(iii) Show that the product of pV has the same units as work done.

[1]

(b) The graph in Fig. 5.1 shows the variation of pressure, p, with the reciprocal of volume, $1/V$, of 0.050 kg of oxygen behaving as an ideal gas.



(i) Use the graph to show that the variation of p with $\frac{1}{V}$ is taking place at constant temperature.

[2]

(ii) The molar mass of oxygen is 0.016 kg mol^{-1}. Calculate the temperature, in °C, of the oxygen in **(i)**.

temperature = ... °C **[3]**

[Total: 9]

7)

Fig. 4.1 shows smoke particles suspended in air. The arrows indicate the directions in which the smoke particles are moving at a particular instant. The lengths of the arrows indicate the different speeds of the particles.

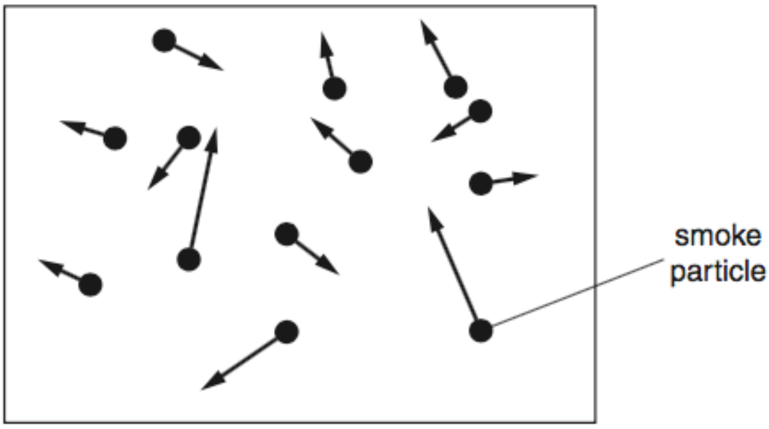


Fig. 4.1

(a) **(i)** State the name given to this type of random motion of smoke particles in air.

In your answer, you should use appropriate technical terms spelled correctly.

....

.... **[1]**

(ii) State **two** conclusions about the air molecules that may be deduced from the observed motion of the smoke particles.

....

....

....

.... **[2]**

(b) **(i)** The radius of an inflated football is 0.11 m. The temperature of the air inside the ball is 17 °C. Calculate the mass of air in the ball when the pressure inside it is 2.6×10^5 Pa.

The mass of one mole of air is 0.028 kg.

mass of air = ... kg **[4]**

(ii) The football is left in a room at a temperature of 0 °C until it reaches thermal equilibrium.

1 Explain the term *thermal equilibrium.*

....

....

.... **[1]**

2 Calculate the pressure exerted by the air inside the football when the temperature drops to 0 °C.

pressure = ... Pa **[2]**

[Total: 10]

8)

(a) One assumption required for the development of the kinetic model of a gas is that molecules undergo perfectly elastic collisions with the walls of their containing vessel and with each other.

(i) Explain what is meant by a *perfectly elastic collision*.

....

.... **[1]**

(ii) State **three** other assumptions of the kinetic theory of gases.

1. ....

....

2. ....

....

3. ....

.... **[3]**

(b) Fig. 5.1 shows a cubical box of side length 0.20 m. The box contains one molecule of mass 4.8×10^{-26} kg moving with a constant speed of 500 m s^{-1}. The molecule collides elastically at right angles with the opposite faces **X** and **Y** of the box.

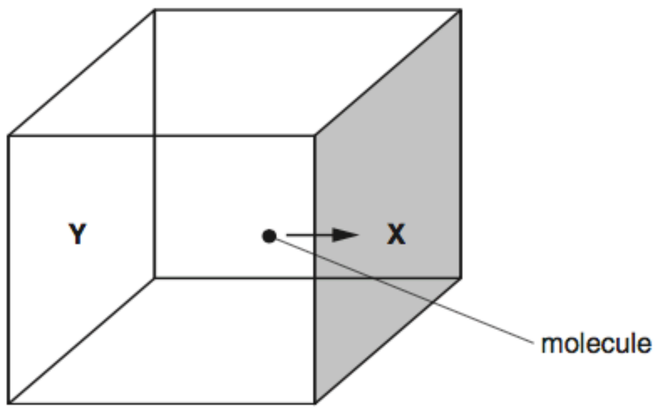


Fig. 5.1

(i) Calculate the change of momentum each time the molecule collides with face **X**.

change of momentum = ... kg m s^{-1} **[2]**

(ii) Calculate the number of collisions made by the molecule with face **X** in 1.0 s.

number = ... **[1]**

(iii) Calculate the mean force exerted on the molecule by face **X**.

force = ...N **[2]**

(iv) Hence state the force exerted on face **X** by the molecule. Justify your answer.

....

.... **[1]**

(c) The single molecule in the box in **(b)** is replaced by 3 moles of air at atmospheric pressure.

(i) Calculate the number of air molecules in the box.

number = ... **[1]**

(ii) Suggest why the pressure exerted by the air on each of the six faces of the box is the same.

....

.... **[1]**

(iii) The temperature of the air inside the box is increased. Explain in terms of the **motion** of the air molecules how the pressure exerted by the air will change.

....

....

.... **[2]**

[Total: 14]

9)

(a) **(i)** A container has **1 mole** of an ideal gas. The volume of the container is *V* cubic metres (m^3) and the gas exerts pressure *p* pascal (Pa). On Fig. 6.1, show the relationship between the product *pV* and the absolute temperature *T* of the gas. **[1]**

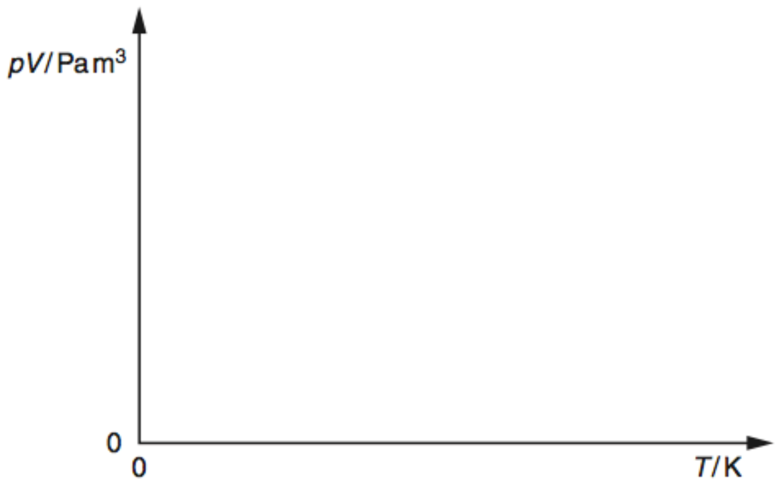


Fig. 6.1

(ii) State the value of the gradient of this graph.

.... **[1]**

(b) The volume of 1.5 moles of an ideal gas at –40 °C is 2.4×10^{-2} m^3. The gas is now heated at constant pressure *p*. Calculate

(i) the new volume of the gas at a temperature of 250 °C

volume = ... m^3 **[3]**

(ii) the value of the pressure *p*.

p = ... Pa **[2]**

[Total: 7]

(a) State a conclusion about the movement of gas molecules provided by observations of Brownian motion.

In your answer, you should use appropriate technical terms, spelled correctly.

....

....

.... **[1]**

(b) Fig. 5.1 shows a gas contained in a cylinder enclosed by a piston. The volume of the gas inside the cylinder is 120 cm^3. The pressure inside the cylinder is 350 kPa.

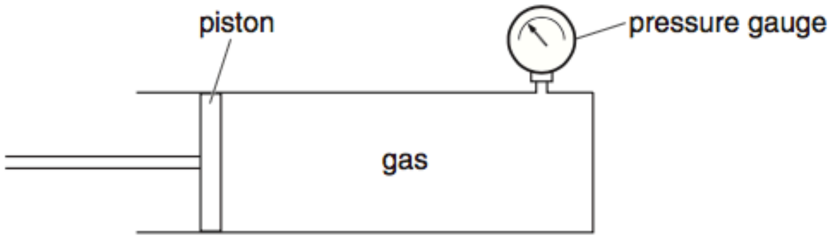


Fig. 5.1

(i) State a necessary condition for Boyle's law to apply to a fixed quantity of gas.

....

....

.... **[1]**

(ii) The piston in Fig. 5.1 is moved quickly so that the gas occupies a volume of 55 cm^3. Use Boyle's law to calculate the new pressure of the gas.

pressure = ...kPa **[2]**

(iii) In practice, the quick movement of the piston during compression of the gas causes an increase in the temperature of the gas. Explain this increase in temperature in terms of the **movement of the piston** and **the motion of the gas molecules**.

....

....

....

.... **[2]**

[Total: 6]

10)