15. Ideal Gases

15.2 Equation of state

Paper 4

Question Paper

1 **(a)** **(i)** State what is meant by an ideal gas.

.....

.....

..... [2]

(b) A sample of $0.26\,m^3$ of an ideal gas is at pressure $2.0 \times 10^5\,Pa$ and temperature $290\,K$.

Determine:

(i) the number N of molecules of the gas

N = ... [2]

2 **(b)** Two cylinders X and Y each contain a sample of an ideal gas. The samples are in thermal equilibrium with each other.

X has a volume of $0.0260\,m^3$ and contains 0.740 mol of gas at a pressure of 1.20×10^5 Pa. Y has a volume of $0.0430\,m^3$ and contains gas at a pressure of 2.90×10^5 Pa. Data for the two cylinders are shown in Fig. 2.1.



Fig. 2.1

(i) Show that the temperature of the gas in X is 234 °C.

[3]

(ii) Determine the number N of molecules of the gas in Y. Explain your reasoning.

N = ... [3]

3 **(a)** **(ii)** State the relationship between the Avogadro constant N_A, the molar gas constant R and the Boltzmann constant k.

[1]

(b) Two samples X and Y of ideal gases are both at thermodynamic temperature T.

Sample X has volume V and consists of N molecules, each of mass m.
Sample Y has volume $2V$ and consists of $2N$ molecules, each of mass $2m$.

(i) Complete Table 3.1 by giving expressions, in terms of some or all of N, m, T, V and the constants in **(a)(ii)**, for the quantities indicated.

Table 3.1

	sample X	sample Y
pressure		
amount of substance		
mean-square speed of molecules		
internal energy		

[4]

4 **(b)** An ideal gas has amount of substance n.
The gas is initially in state X, with pressure $2p$ and volume V.
The gas is cooled at constant volume to state Y, with pressure p.
The gas is then heated at constant pressure to state Z, with volume $2V$.
Finally, the gas returns at constant temperature to state X.

(i) Determine an expression for the temperature T of the gas in state X, in terms of n, p and V.
Identify any other symbols that you use.

[2]

5 **(a)** **(i)** State what is meant by an ideal gas.

.....

.....

..... [2]

(b) A sealed vessel contains a mass of 0.0424 kg of an ideal gas at 227 °C.
The pressure of the gas is 1.37×10^5 Pa and the volume of the gas is 0.640 m^3.

Calculate:

(i) the number of molecules of the gas in the vessel

number of molecules = ... [3]

6 A fixed mass of an ideal gas is initially at a temperature of 17 °C.
The gas has a volume of 0.24 m^3 and a pressure of 1.2×10^5 Pa.

(a) (i) State what is meant by an ideal gas.

.....

.....

..... [2]

(ii) Calculate the amount n of gas.

n = ... mol [2]

7 **(b)** The specific latent heat of vaporisation of water at atmospheric pressure of 1.0×10^5 Pa is 2.3×10^6 J kg^{-1}. A mass of 0.37 kg of liquid water at 100 °C is provided with the thermal energy needed to vaporise all of the water at atmospheric pressure.

(ii) The mass of 1.0 mol of water is 18 g. Assume that water vapour can be considered to behave as an ideal gas.

Show that the volume of water vapour produced is 0.64 m^3.

[3]

8 **(a)** The equation of state for an ideal gas can be written as

$$pV = NkT.$$

State the meaning of each of the symbols in this equation.

p: .....

V: .....

N: .....

k: .....

T: .....

[3]

9 An ideal gas is contained in a cylinder by means of a movable frictionless piston, as illustrated in Fig. 2.1.

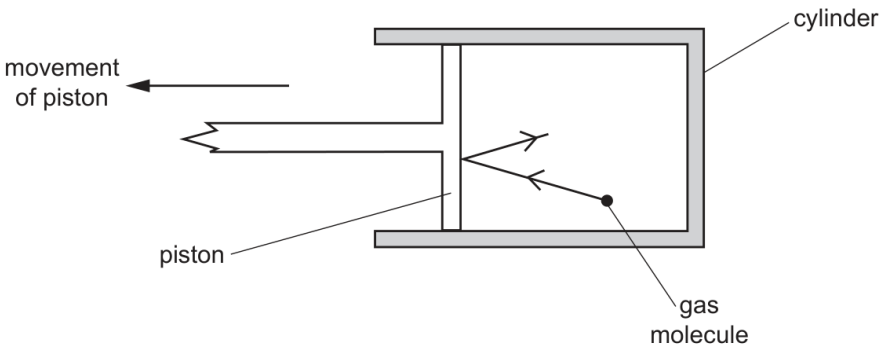


Fig. 2.1

Initially, the gas has a volume of $1.8 \times 10^{-3}\,m^3$ at a pressure of $3.3 \times 10^5\,Pa$ and a temperature of 310 K.

(a) Show that the number of gas molecules in the cylinder is 1.4×10^{23}.

[2]

10 An ideal gas has a volume of $3.1 \times 10^{-3}\,m^3$ at a pressure of $8.5 \times 10^5\,Pa$ and a temperature of 290 K, as shown in Fig. 2.1.

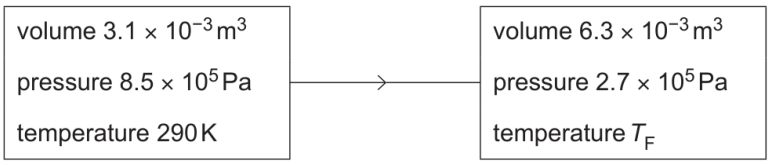


Fig. 2.1

The gas suddenly expands to a volume of $6.3 \times 10^{-3}\,m^3$. During the expansion, no thermal energy is transferred. The final pressure of the gas is $2.7 \times 10^5\,Pa$ at temperature T_F, as shown in Fig. 2.1.

(a) Show that the number of gas molecules is 6.6×10^{23}.

[3]

(b) **(i)** Show that the final temperature T_F of the gas is 190 K.

[1]

11 (b) A sealed container of fixed volume V contains N molecules, each of mass m, of an ideal gas at pressure p.

(i) State an expression, in terms of V, N, p and the Boltzmann constant k, for the thermodynamic temperature T of the gas.

..... [1]

12 (b) An ideal gas has volume, pressure and temperature as shown in Fig. 2.1.

volume $6.0 \times 10^{-3}\,m^3$
pressure $3.0 \times 10^{5}\,Pa$
temperature 17 °C

Fig. 2.1

The mass of the gas is 20.7 g.

Calculate the mass of one molecule of the gas.

mass = ... g [4]

13 (b) The atoms of an ideal gas occupy a container of volume $2.30 \times 10^{-3}\,m^3$ at pressure $2.60 \times 10^5\,Pa$ and temperature 180 K, as illustrated in Fig. 2.1.

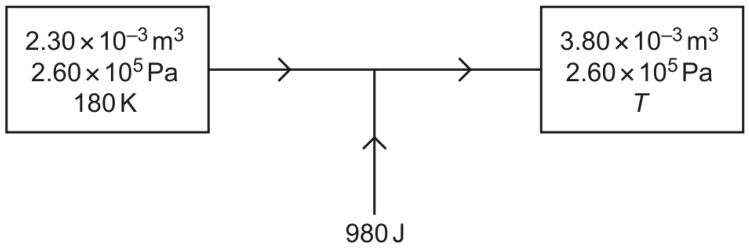


Fig. 2.1

The gas is heated at constant pressure so that its volume becomes $3.80 \times 10^{-3}\,m^3$ at a temperature T.

For the fixed mass of gas, calculate:

(i) the amount of substance, in mol

amount = ... mol [2]

(ii) the temperature T, in K.

T = ... K [2]

14 A fixed mass of an ideal gas has volume 210 cm^3 at pressure 3.0×10^5 Pa and temperature 270 K.

The volume of the gas is reduced at constant pressure to 140 cm^3, as shown in Fig. 2.1.

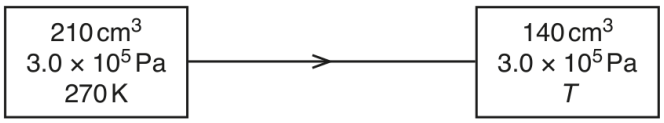


Fig. 2.1

The final temperature of the gas is T.

(a) Determine:

(i) the amount of gas

amount = ... mol [3]

(ii) the final temperature T of the gas

T = ...K [2]

15 (b) An ideal gas occupies a volume of $2.40 \times 10^{-2}\,m^3$ at a pressure of $4.60 \times 10^5\,Pa$ and a temperature of 23 °C.

(i) Calculate the number of molecules in the gas.

number = ... [3]

16 (b) A fixed mass of an ideal gas has volume $2.40 \times 10^3\,cm^3$ at pressure $3.51 \times 10^5\,Pa$ and temperature 290 K. The gas is heated at constant volume until the temperature is 310 K at pressure $3.75 \times 10^5\,Pa$, as illustrated in Fig. 2.1.

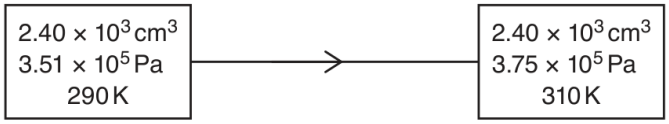


Fig. 2.1

The quantity of thermal energy required to raise the temperature of 1.00 mol of the gas by 1.00 K at constant volume is 12.5 J.

Calculate, to three significant figures:

(i) the amount, in mol, of the gas

amount = ... mol [3]

17 (b) A cylinder of volume $1.8 \times 10^4\,\text{cm}^3$ contains helium gas at pressure $6.4 \times 10^6\,\text{Pa}$ and temperature 25 °C.
Helium gas may be considered to be an ideal gas consisting of single atoms.

Calculate the number of helium atoms in the cylinder.

number = ...[3]

18 **(b)** The average translational kinetic energy E_K of a molecule of an ideal gas is given by the expression

$$E_K = \frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$$

where m is the mass of a molecule and k is the Boltzmann constant.

State the meaning of the symbol

(ii) T.

.....[1]

(c) A cylinder of constant volume $4.7 \times 10^4\,\text{cm}^3$ contains an ideal gas at pressure $2.6 \times 10^5\,\text{Pa}$ and temperature 173 °C.

The gas is heated. The thermal energy transferred to the gas is 2900 J. The final temperature and pressure of the gas are T and p, as illustrated in Fig. 2.1.



Fig. 2.1

(i) Calculate

1. the number N of molecules in the cylinder,

N = ...[3]

2. the increase in average kinetic energy of a molecule during the heating process.

increase = ... J [1]

19 **(a)** State what is meant by an *ideal gas*.

.....

.....

.....[2]

(b) An ideal gas comprised of single atoms is contained in a cylinder and has a volume of $1.84 \times 10^{-2}\,m^3$ at a pressure of $2.12 \times 10^{7}\,Pa$.
The mass of gas in the cylinder is 3.20 kg.

(ii) The temperature of the gas in the cylinder is 22 °C.

Determine, to three significant figures,

1. the amount, in mol, of the gas,

amount = ... mol [2]

2. the mass of one atom of the gas.

mass = ... kg [2]