1. **Figure 1** and **Figure 2** show apparatus used in an experiment to confirm the distribution of atom speeds in a gas at a particular temperature.

Figure 1

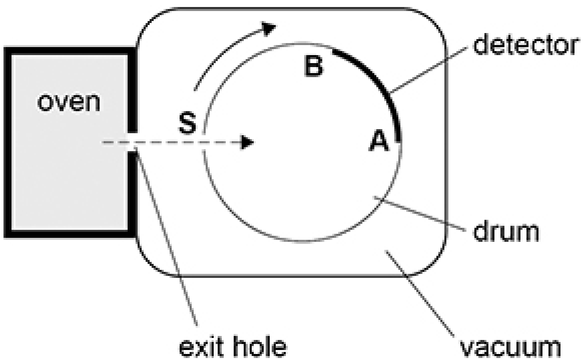
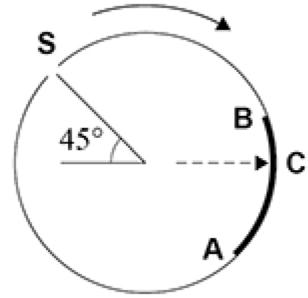


Figure 2



The oven contains an ideal gas kept at a constant temperature. Atoms of the gas emerge from the oven and some pass through the narrow slit **S** in a rapidly rotating drum. The drum is in a vacuum.

(a) Explain why the drum must be in a vacuum.

____

____

____

____

____

(1)

One atom leaves the oven, enters the drum through **S** and travels in a straight line across the drum.
In the time taken for the atom to move from **S** to the detector **AB**, the drum rotates through 45°.
The atom hits the detector at point **C**, as shown in **Figure 2**.

drum diameter = distance from **S** to **A** = 0.500 m
drum rotational speed = 120 revolutions per second

(b) Show that the atom is moving at a speed of about 500 m s^{-1}.

(2)

(c) The speed of the atom in part (b) is equal to c_{rms}, the root mean square speed of the atoms of the gas in the oven.
The molar mass of the gas is 0.209 kg mol^{-1}.

Calculate the temperature of the gas in the oven.

temperature = _______________ K

(3)

(d) The oven temperature is kept constant during the experiment but the pressure in the oven decreases as atoms leave through the exit hole.

Explain, using the kinetic theory, why the pressure decreases.

____

____

____

____

____

____

____

(2)

(e) The pressure of gas in the oven is initially 5.0×10^4 Pa.
The volume of the oven is 2.7×10^{-2} m^3.
During the experiment the pressure in the oven decreases to 4.5×10^4 Pa.

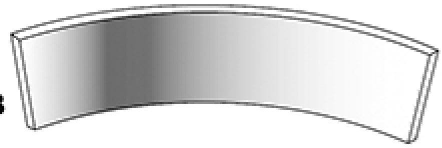
Calculate, in mol, the amount of gas that has emerged from the oven.

amount of gas = _______________ mol

(1)

(f) Atoms enter the drum every time **S** passes the exit hole. The detector darkens at the point where an atom strikes it.
After a time, the detector is removed from the drum.
Figure 3 shows the appearance of the detector.

Figure 3



A new detector is placed in the drum and the experiment is repeated with a new sample of the same gas at a higher temperature.

Describe and explain the appearance of this detector when the experiment is repeated.

____

____

____

____

____

____

____

____

(2)
(Total 11 marks)

2. A solar panel transfers energy at a rate of 1.2 kW to liquid passing through it. The liquid has a specific heat capacity of 4.0 kJ kg^{-1} K^{-1}.

When the liquid flows through the solar panel, its temperature increases by 3.0 K.

The flow rate of the liquid is

A 0.10 kg s^{-1}. ⬭

B 1.1 kg s^{-1}. ⬭

C 10 kg s^{-1}. ⬭

D 100 kg s^{-1}. ⬭

(Total 1 mark)

3. A gas occupies a volume V. Its particles have a root mean square speed (c_{rms}) of u. The gas is compressed at constant temperature to a volume $0.5V$.

What is the root mean square speed of the gas particles after compression?

A $\frac{u}{2}$ ○

B u ○

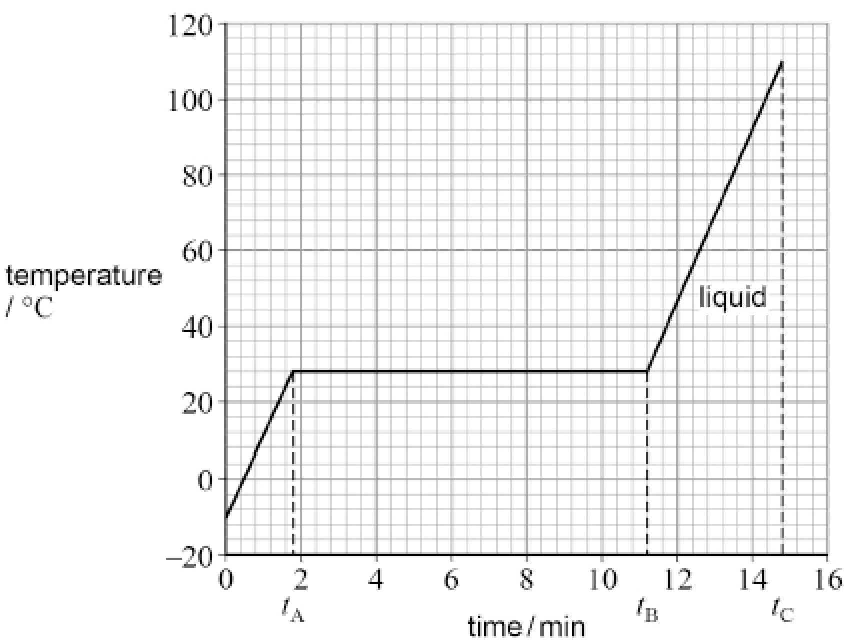
C $2u$ ○

D $4u$ ○

(Total 1 mark)

4. A perfectly insulated flask contains a sample of metal **M** at a temperature of –10 °C.

The figure shows how the temperature of the sample changes when energy is transferred to it at a constant rate of 35 W.



(a) State the melting temperature of **M**.

temperature = ____________ °C

(1)

(b) Explain how the energy transferred to the sample changes the arrangement of the atoms during the time interval t_A to t_B.

____

____

____

____

(1)

(c) State what happens to the potential energy of the atoms and to the kinetic energy of the atoms during the time interval t_A to t_B.

____

____

____

____

____

____

(2)

(d) Describe how the motion of the atoms changes during the time interval t_B to t_C.

____

____

____

(1)

(e) The sample has a mass of 0.25 kg.

Determine the specific heat capacity of **M** when in the liquid state. State an appropriate SI unit for your answer.

specific heat capacity = _______________ unit = __________

(3)

(f) The table shows the specific latent heats of fusion l for elements that are liquid at similar temperatures to **M**.

Element	Caesium	Gallium	Mercury	Rubidium
l / kJ kg^{-1}	16	80	11	26

M is known to be one of the elements in the table above.

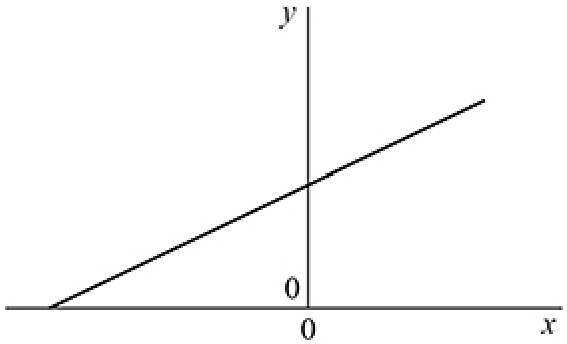
Identify **M**.

M = _______________

(2)

(Total 10 marks)

5. A fixed mass of gas is heated at constant volume. The graph is drawn for this process.

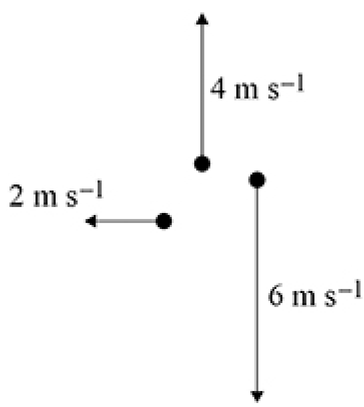


What do x and y represent?

	x	y	
A	pressure in Pa	temperature in °C	⬭
B	temperature in °C	pressure in Pa	⬭
C	pressure in Pa	temperature in K	⬭
D	temperature in K	pressure in Pa	⬭

(Total 1 mark)

6. Three particles are travelling in the same plane with velocities as shown in the vector diagram.



What is the root mean square speed of the particles?

A 4.3 m s^{-1}

B 7.5 m s^{-1}

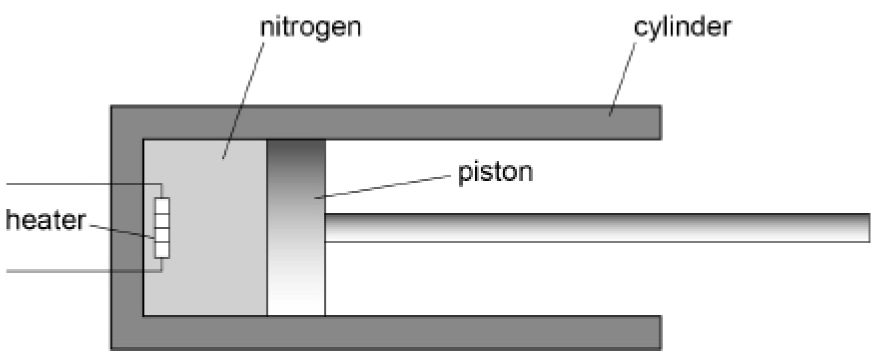
C 19 m s^{-1}

D 56 m s^{-1}

(Total 1 mark)

7. The diagram shows a perfectly insulated cylinder containing 0.050 kg of liquid nitrogen at a temperature of 70 K.
A heater transfers energy at a constant rate of 12 W to the nitrogen.
A piston maintains the pressure at 1.0×10^5 Pa during the heating process.

not to scale



(a) The nitrogen is heated from 70 K and is completely turned into a gas after 890 s.

Calculate the specific heat capacity of liquid nitrogen.
Give an appropriate unit for your answer.

specific latent heat of vaporisation of nitrogen = 2.0×10^5 J kg^{-1}

boiling point of nitrogen = 77 K

specific heat capacity = ____________________ unit = ___________

(5)

(b) The work done by the nitrogen in the cylinder when expanding due to a change of state is **X**.
The energy required to change the state of the nitrogen from a liquid to a gas is **Y**.

Deduce which is greater, **X** or **Y**.

density of liquid nitrogen at its boiling temperature = 810 kg m^{-3}

density of nitrogen gas at its boiling temperature = 3.8 kg m^{-3}

____

____

(4)
(Total 9 marks)

8. An ideal gas is contained in a cubical box of side length a. The gas has N molecules each of mass m.

What is the pressure exerted by the gas on the walls of the box?

A $\dfrac{mNa^3}{2} \times c_{rms}{}^2$ ⬭

B $\dfrac{mNa^2}{2} \times c_{rms}{}^2$ ⬭

C $\dfrac{mN}{3a^2} \times c_{rms}{}^2$ ⬭

D $\dfrac{mN}{3a^3} \times c_{rms}{}^2$ ⬭

(Total 1 mark)

9. Which statement is true about an experiment where Brownian motion is demonstrated using smoke particles in air?

A The experiment makes it possible to see the motion of air molecules. ⬭

B The motion is caused by the collisions of smoke particles with each other. ⬭

C The motion is caused by collisions between air molecules and smoke particles. ⬭

D The motion occurs because air is a mixture of gases and the molecules have different masses. ⬭

(Total 1 mark)

10. (a) State what is meant by the internal energy of a gas.

____

____

____

(2)

(b) Absolute zero of temperature can be interpreted in terms of the ideal gas laws or the kinetic energy of particles in an ideal gas.

Describe these two interpretations of absolute zero of temperature.

____

____

____

____

____

____

____

(2)

(c) A mixture of argon atoms and helium atoms is in a cylinder enclosed with a piston. The mixture is at a temperature of 310 K.

Calculate the root mean square speed (c_{rms}) of the argon atoms in the mixture.

molar mass of argon = 4.0×10^{-2} kg mol^{-1}

c_{rms} = ____________________ m s^{-1}

(2)

(d) Compare the mean kinetic energy of the argon atoms and the helium atoms in the mixture.

____

____

____

(2)

(e) Explain, in terms of the kinetic theory model, why a pressure is exerted by the gas on the piston.

(3)

(f) The mixture of gases in the cylinder stays the same.

Explain, using the kinetic theory model, **two** changes that can be made independently to reduce the pressure exerted by the gas.

(3)

(Total 14 marks)

11. Which is **not** an assumption about gas particles in the kinetic theory model for a gas?

A They collide elastically with the container walls. ☐

B They have negligible size compared to the distance between the container walls. ☐

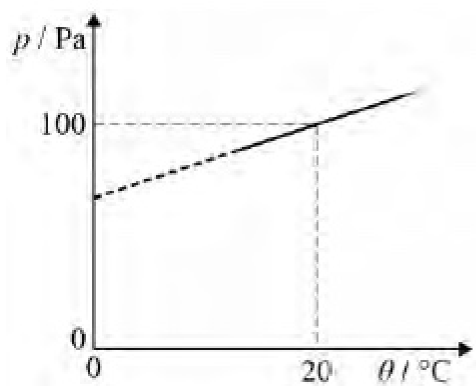
C They travel between the container walls in negligibly short times. ☐

D They collide with the container walls in negligibly short times. ☐

(Total 1 mark)

12. The graph shows the variation of pressure p with temperature θ for a fixed mass of an ideal gas at constant volume.

What is the gradient of the graph?



A 0.341 ☐

B 0.395 ☐

C 2.93 ☐

D 5.00 ☐

(Total 1 mark)

13. (a) Explain what is meant by specific latent heat of fusion.

____

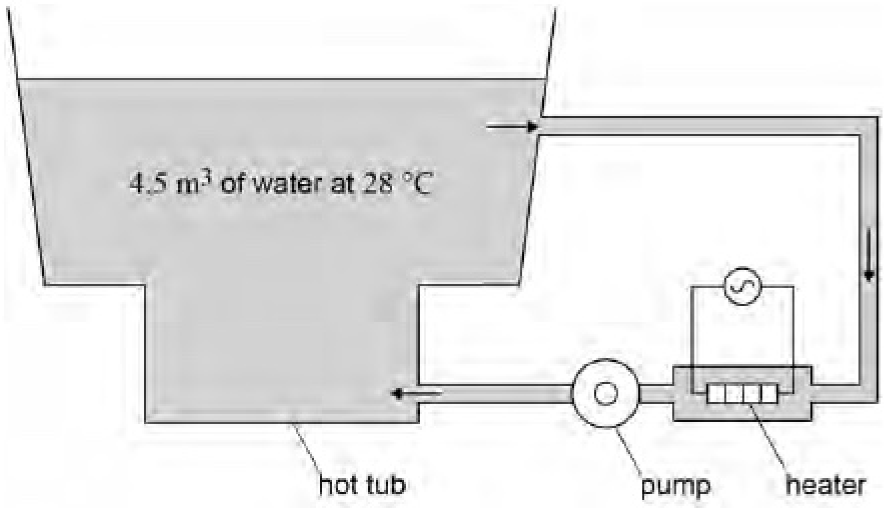
____

____

____

(2)

(b) The diagram shows how the temperature of the water is maintained in a hot tub.



The hot tub system has a volume of 4.5 m^3 and is filled with water at a temperature of 28 °C

The heater transfers thermal energy to the water at a rate of 2.7 kW while a pump circulates the water.

Assume that no heat is transferred to the surroundings.

Calculate the rise in water temperature that the heater could produce in 1.0 hour.

density of water = 1000 kg m^{-3}
specific heat capacity of water = 4200 J kg^{-1} K^{-1}

temperature rise = ____________________ K

(3)

(c) The pump can circulate the water at different speeds.
When working at higher speeds the rise in temperature is greater.

Explain why.
Again assume that no heat is transferred to the surroundings.

____

____

____

____

____

(2)
(Total 7 marks)

14. Two flasks **X** and **Y** are filled with an ideal gas and are connected by a tube of negligible volume compared to that of the flasks. The volume of **X** is twice the volume of **Y**.
X is held at a temperature of 150 K and **Y** is held at a temperature of 300 K

What is the ratio $\dfrac{\text{mass of gas in } \mathbf{X}}{\text{mass of gas in } \mathbf{Y}}$?

A 0.125 ⬭

B 0.25 ⬭

C 4 ⬭

D 8 ⬭

(Total 1 mark)

15. The average mass of an air molecule is 4.8×10^{-26} kg

What is the mean square speed of an air molecule at 750 K?

A 3.3×10^{5} m^{2} s^{-2} ⬭

B 4.3×10^{5} m^{2} s^{-2} ⬭

C 6.5×10^{5} m^{2} s^{-2} ⬭

D 8.7×10^{5} m^{2} s^{-2} ⬭

(Total 1 mark)

16. A transparent illuminated box contains small smoke particles and air.
The smoke particles are observed to move randomly when viewed through a microscope.

What is the cause of this observation of Brownian motion?

A Smoke particles gaining kinetic energy by the absorption of light. ⬭

B Collisions between smoke particles and air molecules. ⬭

C Smoke particles moving in convection currents caused by the air being heated by the light. ⬭

D The smoke particles moving randomly due to their temperature. ⬭

(Total 1 mark)

17. (a) A number of assumptions are made when explaining the behaviour of a gas using the molecular kinetic theory model.

State **one** assumption about the size of molecules.

___

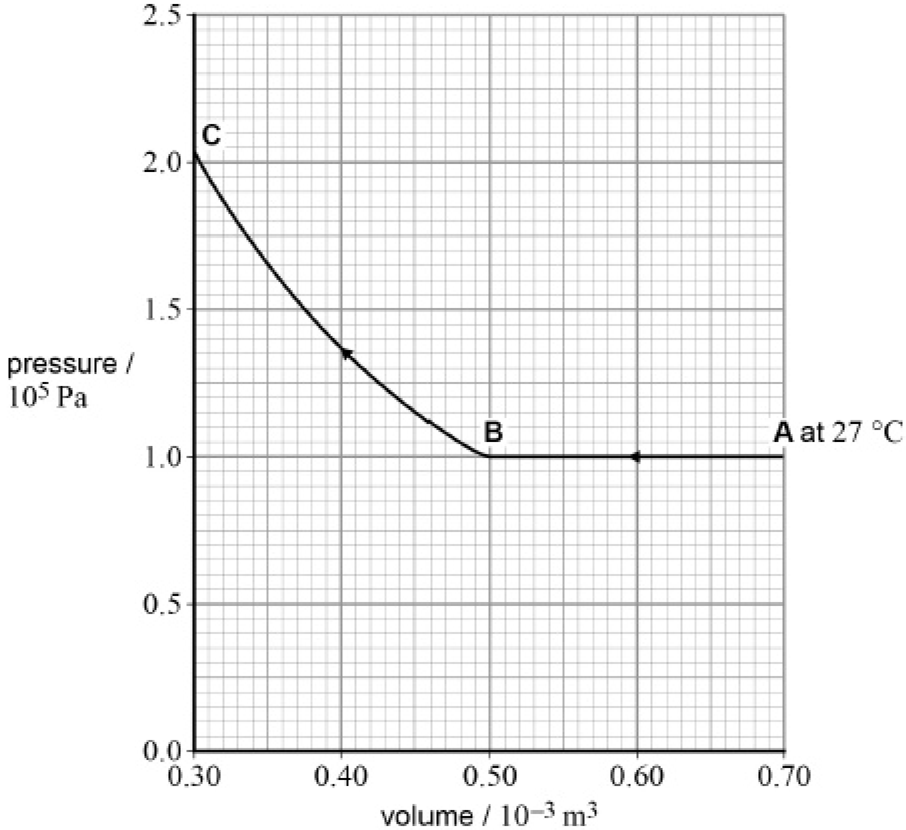
___

___

(1)

The graph shows how the pressure changes with volume for a fixed mass of an ideal gas.

At **A** the temperature of the gas is 27 °C. The gas then undergoes two changes, one from **A** to **B** and then one from **B** to **C**.



(b) Calculate the number of gas molecules trapped in the cylinder using information from the initial situation at **A**.

number of molecules = ______________________

(2)

(c) Calculate, in K, the change in temperature of the gas during the compression that occurs between **A** and **B**.

change in temperature = ______________________ K

(2)

(d) Deduce whether the temperature of the gas changes during the compression from **B** to **C**.

(2)

(e) Compare the work done on the gas during the change from **A** to **B** with that from **B** to **C** on the graph.

(3)

(Total 10 marks)

18. A continuous stream of water falls through a vertical distance of 100 m.
Assume no thermal energy is transferred to the surroundings.
The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the temperature difference of the water between the top and bottom of the waterfall?

A 0.023 K

B 0.23 K

C 2.3 K

D 4.3 K

(Total 1 mark)

19. A student measures the power of a microwave oven. He places 200 g of water at 23 °C into the microwave and heats it on full power for 1 minute. When he removes it, the temperature of the water is 79 °C.

The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

What is the average rate at which thermal energy is gained by the water?

A 780 W

B 840 W

C 1.1 kW

D 4.6 kW

(Total 1 mark)

20. (a) State **two** assumptions made about the **motion** of the molecules in a gas in the derivation of the kinetic theory of gases equation.

____

____

____

____

(2)

(b) Use the kinetic theory of gases to explain why the pressure inside a football increases when the temperature of the air inside it rises. Assume that the volume of the ball remains constant.

____

____

____

____

(3)

(c) The 'laws of football' require the ball to have a circumference between 680 mm and 700 mm. The pressure of the air in the ball is required to be between 0.60×10^5 Pa and 1.10×10^5 Pa above atmospheric pressure.

A ball is inflated when the atmospheric pressure is 1.00×10^5 Pa and the temperature is 17 °C. When inflated the mass of air inside the ball is 11.4 g and the circumference of the ball is 690 mm.

Assume that air behaves as an ideal gas and that the thickness of the material used for the ball is negligible.

Deduce if the inflated ball satisfies the law of football about the pressure.

molar mass of air = 29 g mol^{-1}

(6)
(Total 11 marks)

21. Which of the following is **not** used as valid assumption when deriving the equation $P = \frac{1}{3} Nm\,(c_{rms})^2$ in the simple kinetic theory of gases?

A The molecules suffer negligible change of momentum on collision with the walls of the container.

B Attractive forces between molecules are negligible.

C The duration of a collision is negligible compared with the time between collisions.

D The volume of the molecules is negligible compared with the volume of the gas.

(Total 1 mark)

22. A liquid flows continuously through a chamber that contains an electric heater. When the steady state is reached, the liquid leaving the chamber is at a higher temperature than the liquid entering the chamber. The difference in temperature is Δt.

Which of the following will increase Δt with no other change?

A Increasing the volume flow rate of the liquid

B Changing the liquid to one with a lower specific heat capacity

C Using a heating element with a higher resistance

D Changing the liquid to one that has a higher density

(Total 1 mark)