AQA A-LEVEL PHYSICS · 7408

PHYSICS



EXAM QUESTION PACK

3.6.2 THERMAL PHYSICS

SCORE	PERCENTAGE
/97	%

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Q1.

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

_____

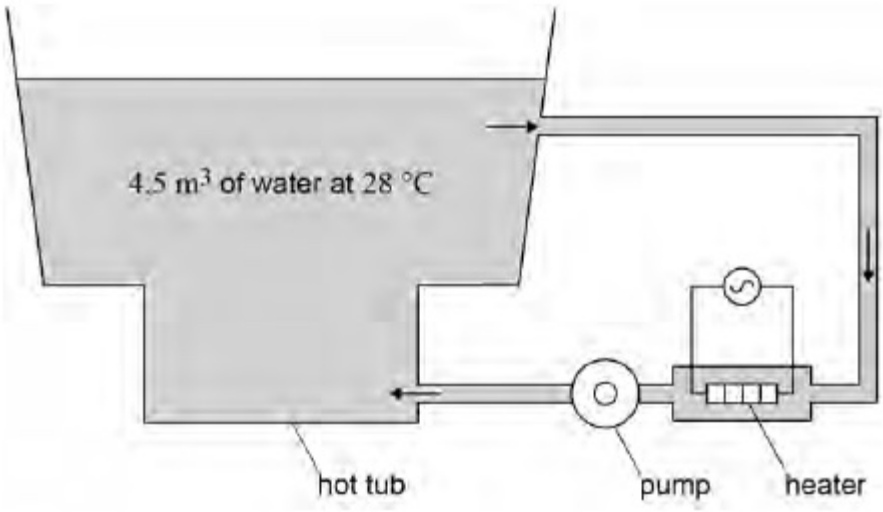
_____

_____

_____

(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

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(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.

_____

_____

_____

_____

_____

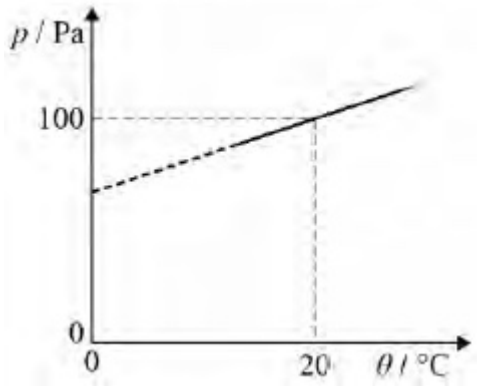
(2)

(Total 7 marks)

Q2.

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)

Q3.

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

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

A 0.125 ⬭

B 0.25 ⬭

C 4 ⬭

D 8 ⬭

(Total 1 mark)

Q4.

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)

Q5.

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. ⬭

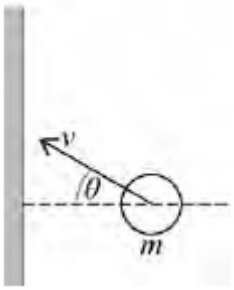
D The smoke particles moving randomly due to their temperature. ⬭

(Total 1 mark)

Q6.

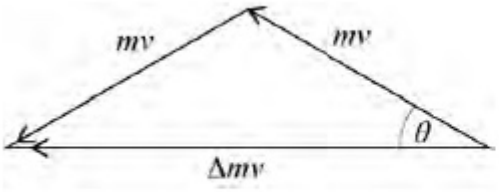
The diagram shows a gas particle about to collide elastically with a wall.

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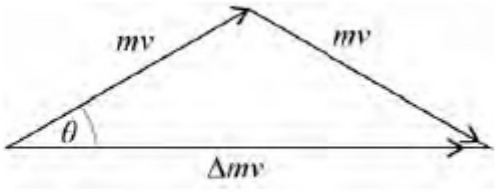


Which diagram shows the correct change in momentum Δmv that occurs during the collision?

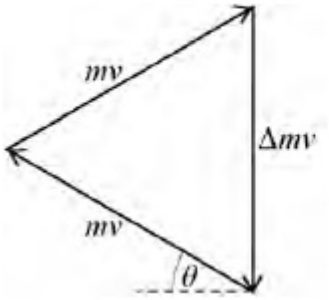
A



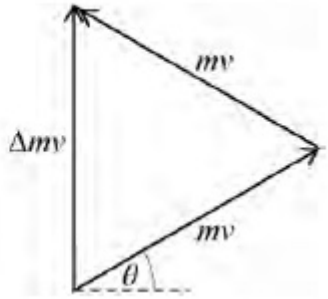
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q7.

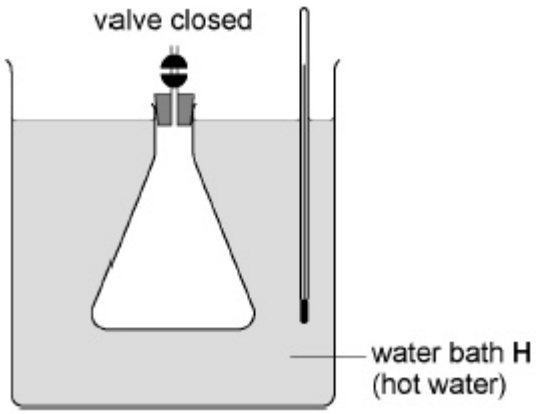
This question is about an experiment to estimate absolute zero.

Figures 1a to 1d show the stages in the procedure carried out by a student.

An empty flask fitted with a tube and an open valve is placed in water bath **H** containing hot water. The air inside the flask is allowed to come into thermal equilibrium with the water.
The valve is then closed, trapping a certain volume of air, as shown in **Figure 1a**.

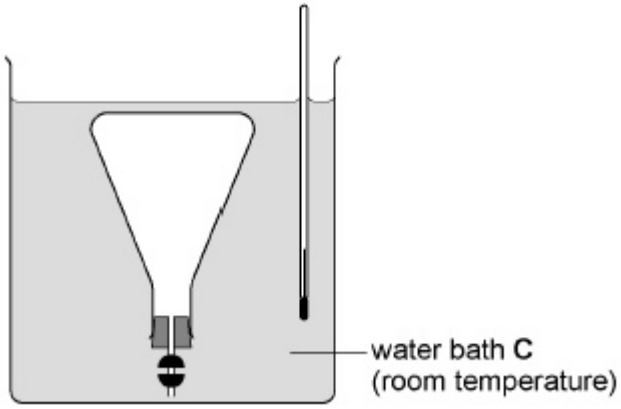
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Figure 1a



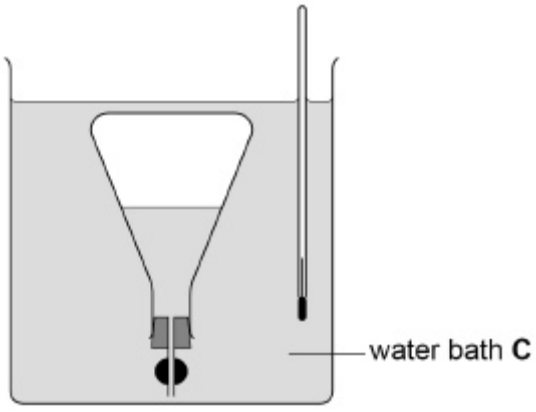
The flask is inverted and placed in water bath **C** in which the water is at room temperature.
The air inside the flask is again allowed to come into thermal equilibrium with the water, as shown in **Figure 1b**.

Figure 1b



The valve is opened and some water enters the flask, as shown in **Figure 1c**.

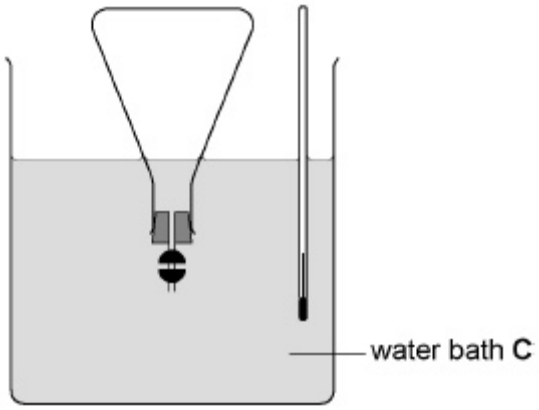
Figure 1c



The depth of the inverted flask is adjusted until the level of water inside the flask is the same as the level in the water bath.
The valve is then closed, trapping the air and the water inside the flask, as shown in **Figure 1d**.

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Figure 1d



(a) Explain why the volume of the air in the flask in **Figure 1c** is less than the volume of the air in the flask in **Figure 1d**.

(2)

(b) Explain why Charles's Law can be applied to compare the air in the flask in **Figure 1a** with the air in the flask in **Figure 1d**.

(2)

(c) The flask is removed from water bath **C** and the valve and stopper are removed.

The volume of the water in the flask is V_1

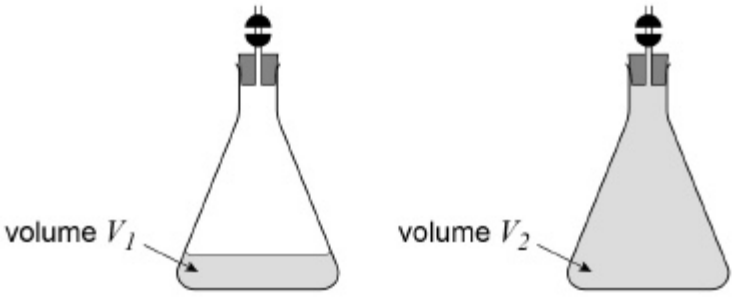
The flask is then completely refilled with water and the valve and stopper replaced.

The volume of the water now in the flask is V_2

The volumes V_1 and V_2 are shown by the shaded parts in **Figure 2**.

Figure 2

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Explain how V_1 and V_2 can be determined.

In your answer you should

- identify a suitable measuring instrument
- explain a suitable procedure to eliminate possible systematic error.

(3)

(d) Plot on **Figure 3** points to show the volume V and the temperature θ of the air in the flask when

- the flask is as shown in **Figure 1a**
- the flask is as shown in **Figure 1d**.

The temperature of the hot water bath is 86 °C

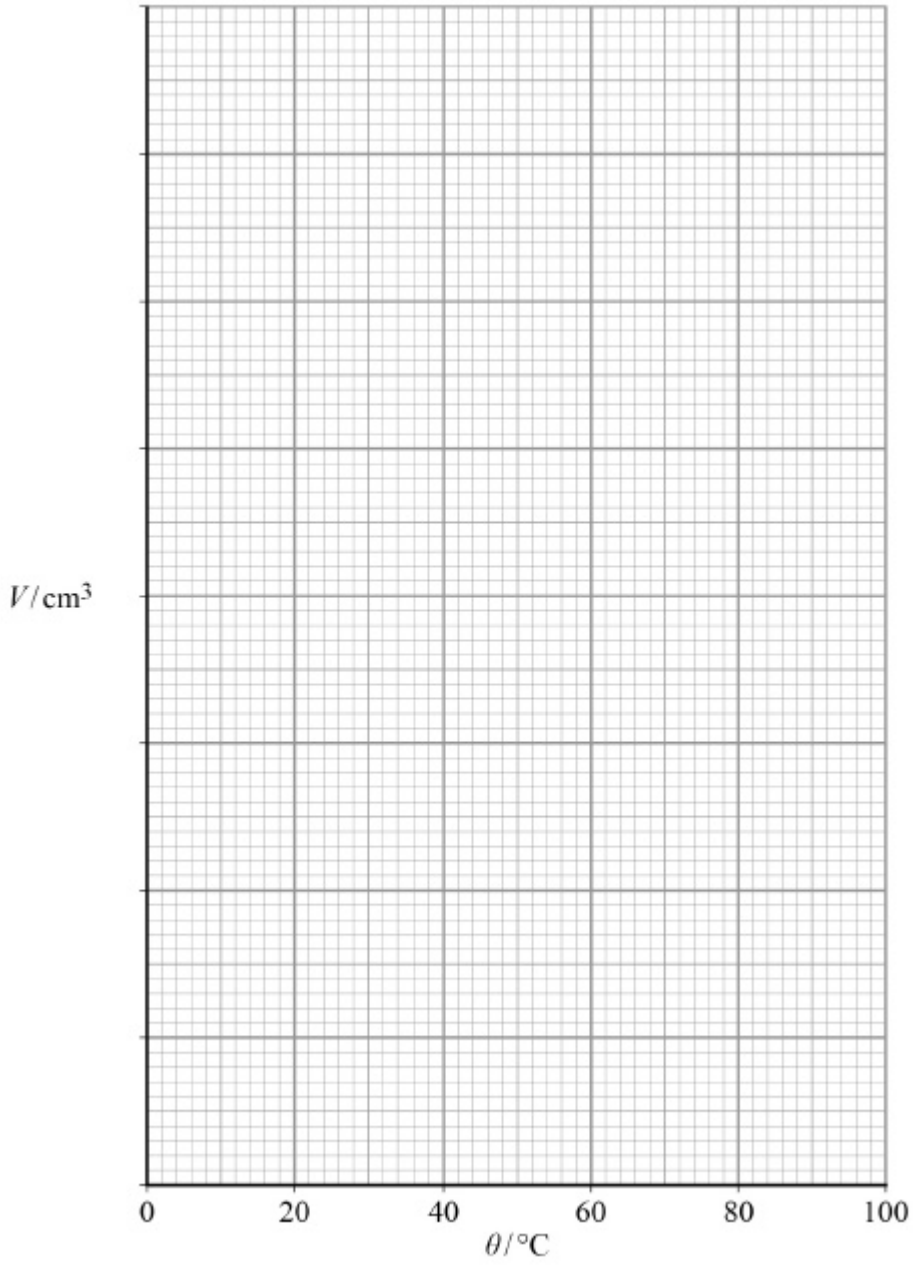
Room temperature is 19 °C

V_1 = 48 cm^3

V_2 = 255 cm^3

Figure 3

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(3)

(e) Add a best fit line to your graph in **Figure 3** to show how V should vary with θ according to Charles's Law.

(1)

(f) Determine the value of absolute zero in °C using your graph in **Figure 3**.

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value of absolute zero = _____ °C

(3)

(Total 14 marks)

Q8.

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)

Q9.

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)

Q10.

An ice cube of mass 0.010 kg at a temperature of 0 °C is dropped into a cup containing 0.10 kg of water at a temperature of 15 °C.

What is the maximum estimated change in temperature of the contents of the cup?

specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific latent heat of fusion of ice = 3.4×10^5 J kg^{-1}

A 1.5 K ⬭

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B 8.7 K ⬭

C 13.5 K ⬭

D 15.0 K ⬭

(Total 1 mark)

Q11.

Specimens **P** and **Q** of the same gas exert the same pressure. **P** is at a temperature of 280 K and contains 10^{20} molecules per unit volume. The temperature of **Q** is 350 K.

What is the number of molecules per unit volume in **Q**?

A 0.09×10^{20} ⬭

B 0.75×10^{20} ⬭

C 0.80×10^{20} ⬭

D 1.25×10^{20} ⬭

(Total 1 mark)

Q12.

Which of the following is **not** used as valid assumption when deriving the equation $P = \frac{1}{3} Nm\,(c_{\text{rms}})^2$ 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)

Q13.

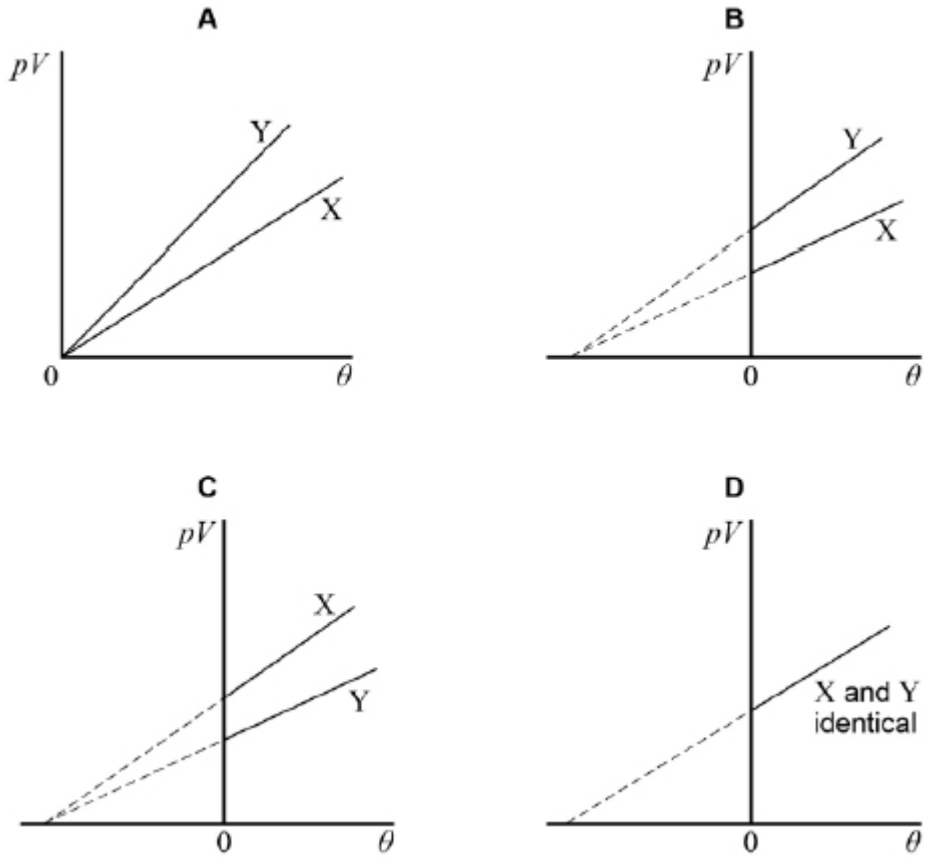
One mole of gas occupies a volume V at a pressure p and Celsius temperature θ.

The graphs, **A** to **D**, show variation of pV with θ.
Line X is for one mole of nitrogen and line Y is for one mole of oxygen.

Relative molecular mass of nitrogen = 28
Relative molecular mass of oxygen = 32

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Which graph is correct?



A ⬭

B ⬭

C ⬭

D ⬭

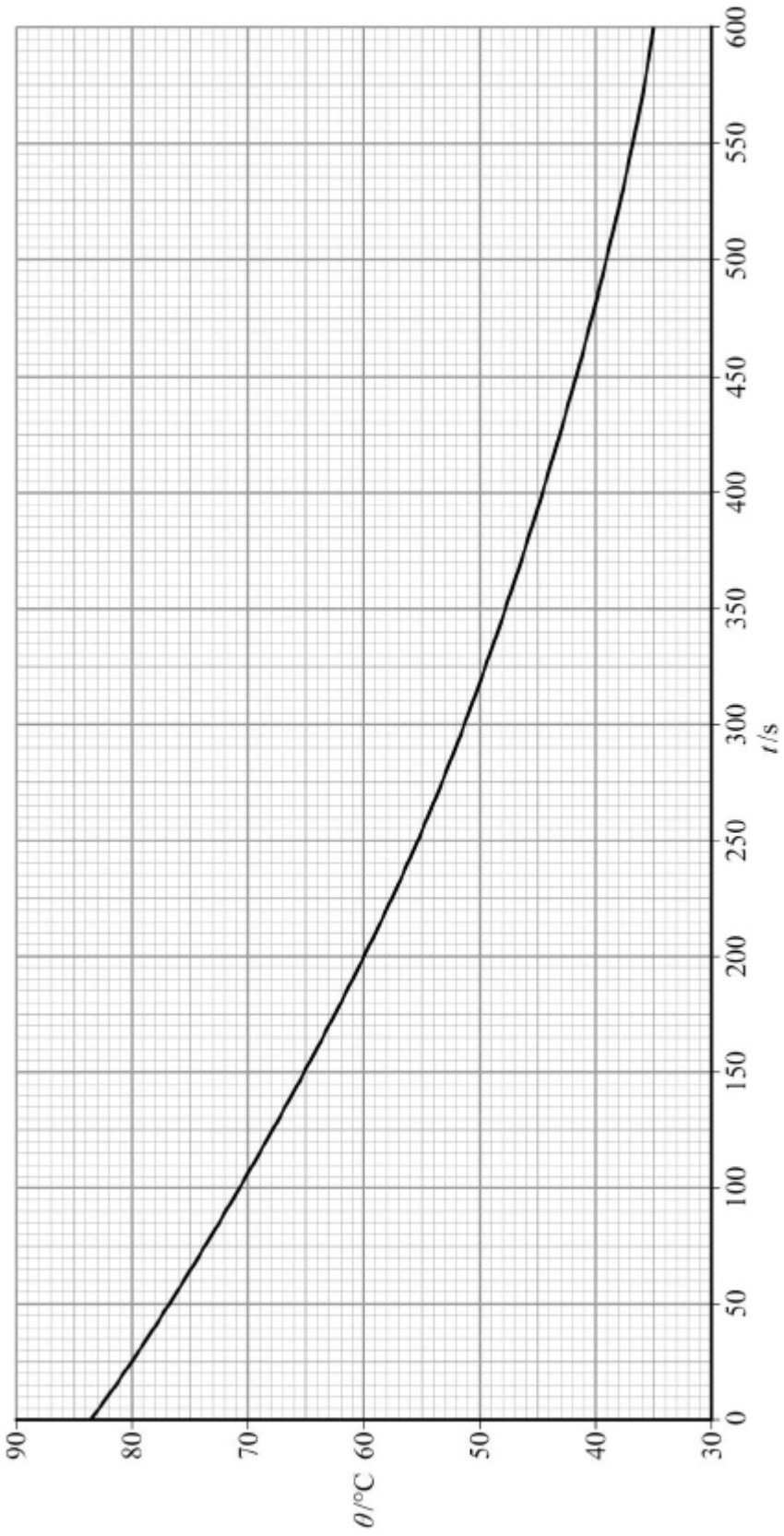
(Total 1 mark)

Q14.

A temperature sensor is connected to a data logger to monitor how the temperature θ of a fixed mass of recently−boiled water varies with time t, over an interval of 600 s. These data are processed to produce the graph shown in **Figure 1**.

Figure 1

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(a) Determine the temperature θ_1 of the water when t is 190 s.

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θ_1 = _____ °C

(1)

(b) Determine the gradient G_1 of the graph at t is 190 s.

G_1 _____

(3)

(c) When t = 370 s the temperature θ_2 = 46.6 °C and the gradient G_2 = − 0.0645.

The room temperature θ_R is given by $\frac{G_1\theta_2 - G_2\theta_1}{G_1 - G_2}$

Evaluate θ_R.

θ_R = _____ °C

(1)

(d) It can be shown that when a hot object at a temperature θ is allowed to cool in a draught, the rate at which the temperature decreases is directly proportional to the temperature difference ($\theta - \theta_R$) between the object and the surroundings.

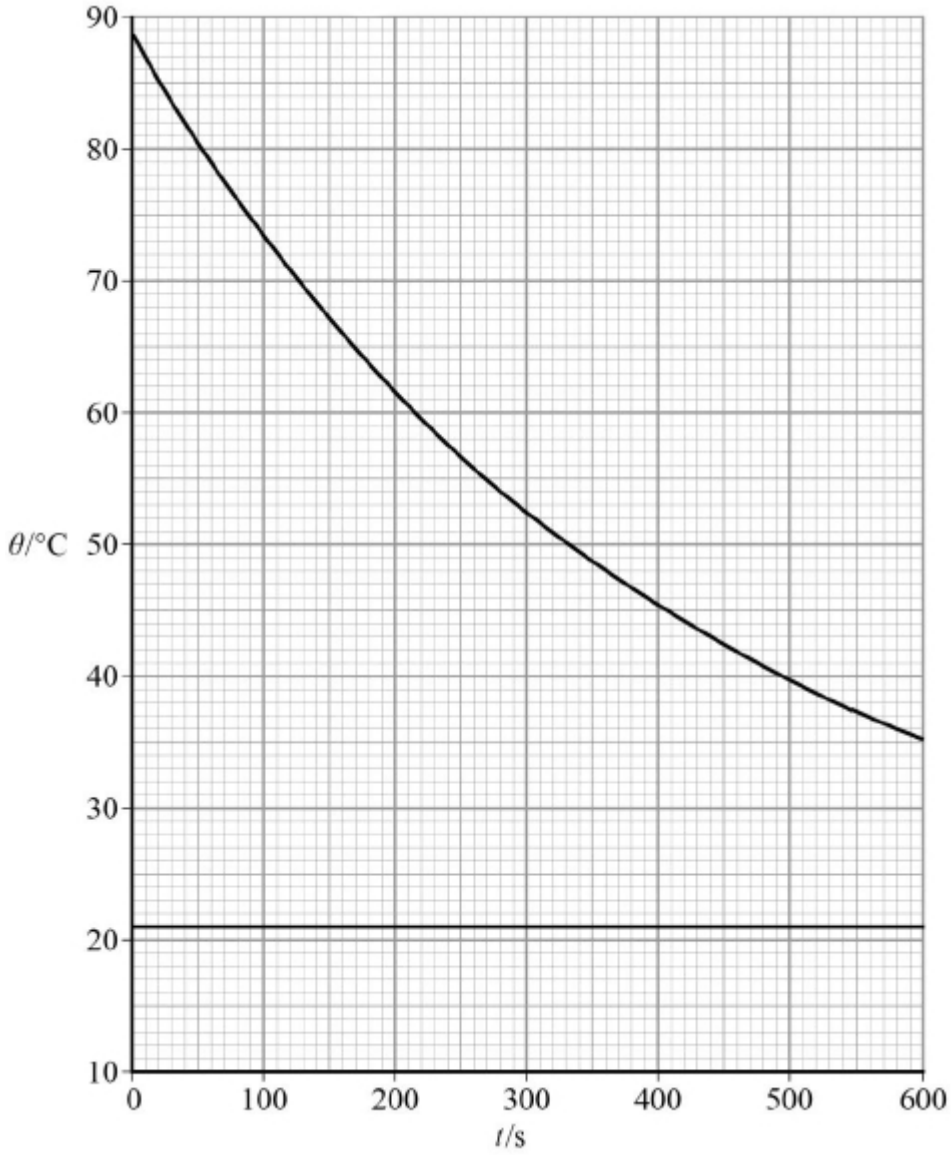
A student realises that ($\theta - \theta_R$) will decrease exponentially with time and designs an experiment in which two temperature sensors are connected to a data logger.

- Sensor 1 is placed in a beaker of recently−boiled water.
- Sensor 2 measures the air temperature in the room.
- The data logger is programmed to record the output from the sensors as the water cools for 600 s.

The output data from the sensors are processed to produce the graph shown in **Figure 2**.

Figure 2

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($\theta - \theta_R$) will decrease exponentially in the same way that the potential difference (pd) across a discharging capacitor decreases with time.

When a capacitor discharges, the pd across the capacitor falls to $\frac{1}{e}$ of an initial value in a time called the **time constant**. Electronic engineers assume that a capacitor becomes fully discharged in a time equal to **5 time constants**.

Estimate the time taken for the water to cool down to room temperature.

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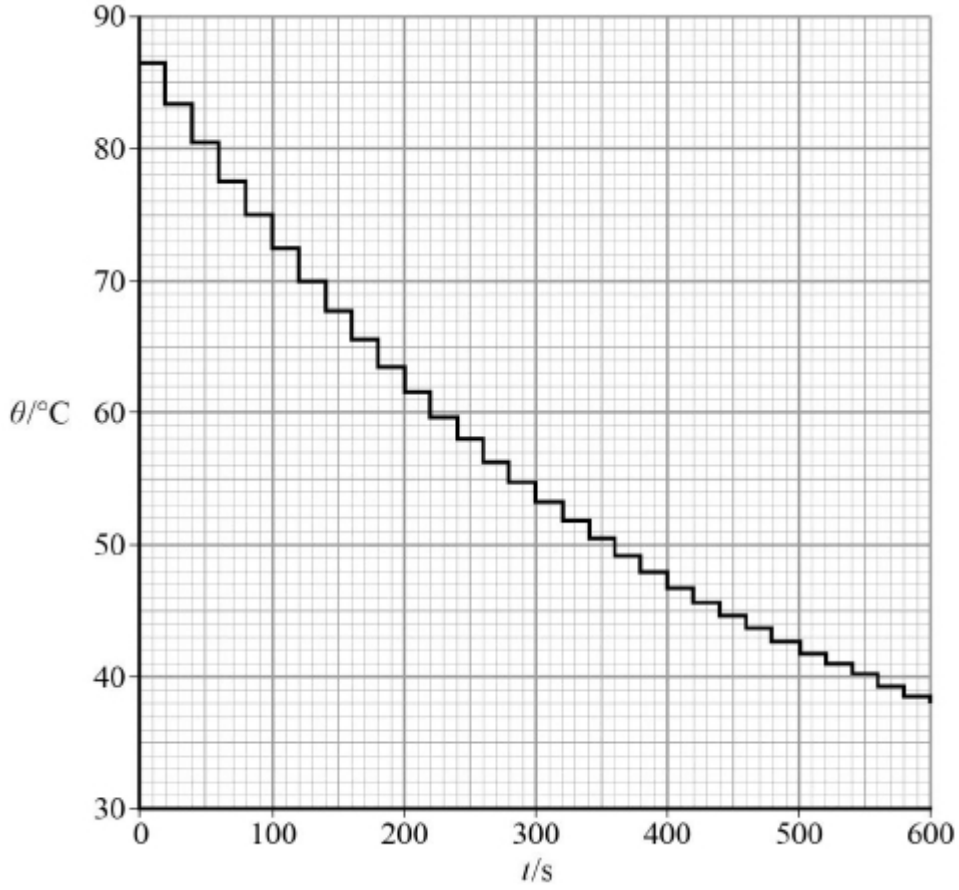
time taken = _____ s

(4)

(e) Another student carries out the experiment using the same mass of recently−boiled water and beaker as before.

The output data for sensor 1 from this student's experiment are shown in **Figure 3**.

Figure 3



Account for the differences between these results and the way they are displayed, with those shown in **Figure 2**.

You should include appropriate quantitative detail in your answer.

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_____

_____

_____

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(5)

(Total 14 marks)

Q20.

(a) 'The pressure of an ideal gas is inversely proportional to its volume', is an incomplete statement of Boyle's law.

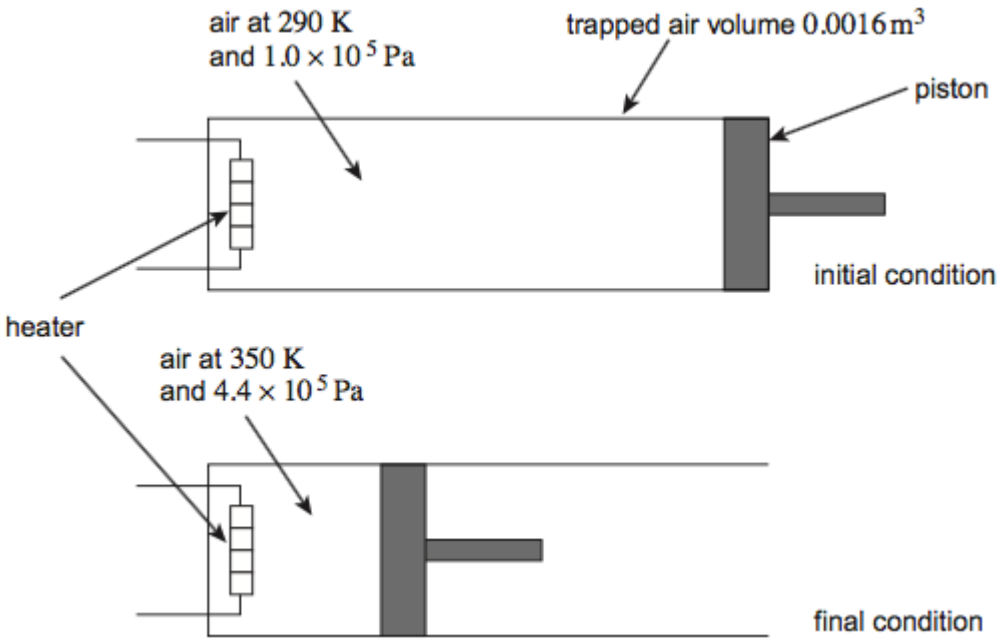
State **two** conditions necessary to complete the statement.

1. _____

2. _____

(2)

(b) A volume of 0.0016 m^3 of air at a pressure of 1.0×10^5 Pa and a temperature of 290 K is trapped in a cylinder. Under these conditions the volume of air occupied by 1.0 mol is 0.024 m^3. The air in the cylinder is heated and at the same time compressed slowly by a piston. The initial condition and final condition of the trapped air are shown in the diagram.



In the following calculations treat air as an ideal gas having a molar mass of 0.029 kg mol^{-1}.

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(i) Calculate the final volume of the air trapped in the cylinder.

volume of air = _____ m^3

(2)

(ii) Calculate the number of moles of air in the cylinder.

number of moles = _____

(1)

(iii) Calculate the initial density of air trapped in the cylinder.

density = _____ kg m^{-3}

(2)

(c) State and explain what happens to the speed of molecules in a gas as the temperature increases.

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 9 marks)

Q21.

(a) Which statement explains why energy is needed to melt ice at 0°C to water at 0°C?

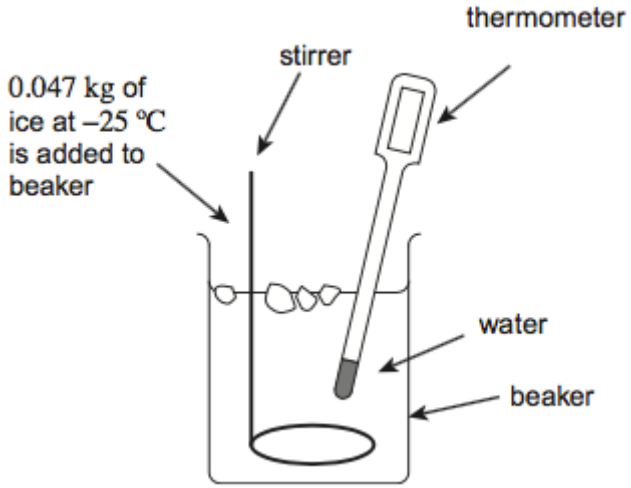
Place a tick (✓) in the right-hand column to show the correct answer.

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	✓ if correct
It provides the water with energy for its molecules to move faster.	
It breaks all the intermolecular bonds.	
It allows the molecules to vibrate with more kinetic energy.	
It breaks some intermolecular bonds.	

(1)

(b) The diagram shows an experiment to measure the specific heat capacity of ice.



A student adds ice at a temperature of –25°C to water. The water is stirred continuously. Ice is added slowly until all the ice has melted and the temperature of the water decreases to 0°C. The mass of ice added during the experiment is 0.047 kg.

(i) Calculate the energy required to melt the ice at a temperature of 0°C.
The specific latent heat of fusion of water is 3.3×10^5 J kg^{-1}.

energy = _____ J

(1)

(ii) The water loses 1.8×10^4 J of energy to the ice during the experiment. Calculate the energy given to the ice to raise its temperature to 0°C. Assume that no energy is transferred to or from the surroundings and beaker.

energy = _____ J

(1)

(iii) Calculate the specific heat capacity of the ice.
State an appropriate unit for your answer.

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specific heat capacity = _____ unit = _____

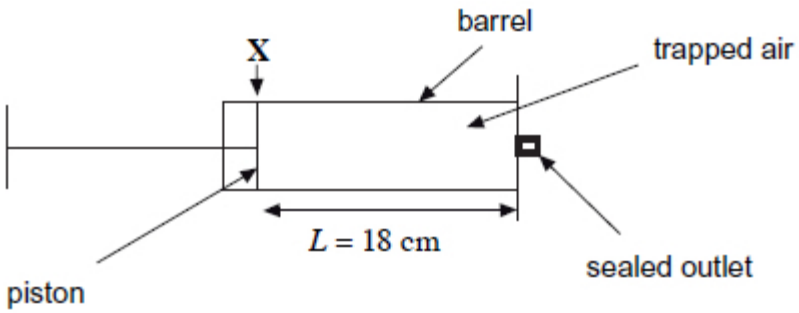
(2)

(Total 5 marks)

Q22.

Figure 1 shows the cross-section of a bicycle pump with a cylindrical barrel. The piston has been pulled to the position marked **X** and the outlet of the pump sealed.

Figure 1



The length L of the column of trapped air is 18 cm and the volume of the gas is 1.7×10^{-4}m^3 when the piston is at position **X**. Under these conditions the trapped air is at a pressure p of 1.01×10^5 Pa and its temperature is 19°C.

Assume the trapped air consists of identical molecules and behaves like an ideal gas in this question.

(a) (i) Calculate the internal diameter of the barrel.

diameter _____ m

(2)

(ii) Show that the number of air molecules in the column of trapped air is approximately 4×10^{21}.

(3)

(iii) The ratio $\frac{\text{total volume of the air molecules}}{\text{volume occupied by the column of trapped air}}$ equals 7.0×10^{-4}.

Calculate the volume of one air molecule.

volume _____ m^3

(2)

(iv) The ratio in part **(a)(iii)** is important in supporting assumptions made in the

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kinetic theory of ideal gases.

Explain how the value of the ratio supports **two** of the assumptions made in the kinetic theory of ideal gases.

_____

_____

_____

_____

_____

_____

(3)

(b) The mass of each air molecule is 4.7×10^{-26} kg.

Calculate the mean square speed of the molecules of trapped air when the length of the column of trapped air is 18.0 cm.
Give an appropriate unit for your answer.

mean square speed _____ unit _____

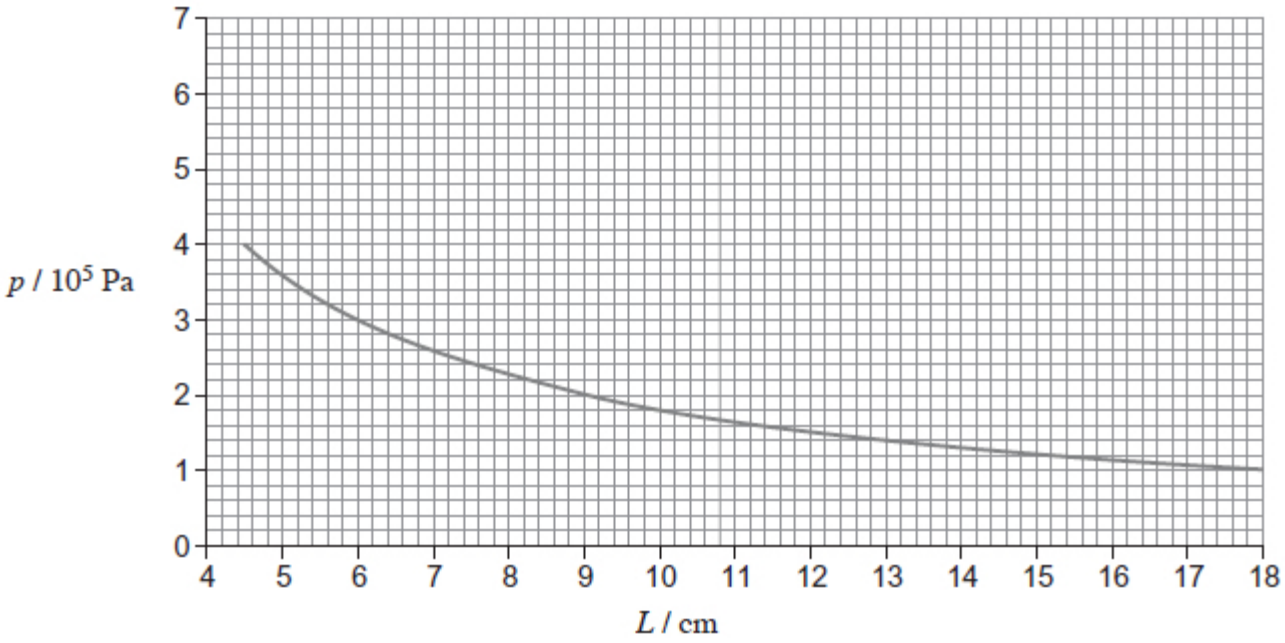
(4)

(c) The piston is pushed slowly inwards until the length L of the column of trapped air is 4.5 cm.

Figure 2 shows how the pressure p of the trapped air varies as L is changed during this process.

Figure 2

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(i) Use data from **Figure 2** to show that p is inversely proportional to L.

(3)

(ii) Name the physical property of the gas which must remain constant for *p* to be inversely proportional to L.

_____

(1)

(d) Explain how the relationship between p and L shown in **Figure 2** can be predicted using the kinetic theory for an ideal gas.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 22 marks)

Q23.

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(a) Lead has a specific heat capacity of 130 J kg^{-1} K^{-1}.

Explain what is meant by this statement.

_____

_____

_____

_____

(1)

(b) Lead of mass 0.75 kg is heated from 21 °C to its melting point and continues to be heated until it has all melted.

Calculate how much energy is supplied to the lead.
Give your answer to an appropriate number of significant figures.

melting point of lead = 327.5 °C
specific latent heat of fusion of lead = 23 000 J kg^{-1}

energy supplied _____ J

(3)

(Total 4 marks)

Q24.

(a) The concept of an absolute zero of temperature may be explained by reference to the behaviour of a gas.
Discuss **one** experiment that can be performed using a gas which would enable you to explain absolute zero and determine its value.
It is not necessary to give full details of the apparatus. Your answer should:

- include the quantities that are kept constant
- identify the measurements to be taken
- explain how the results may be used to find absolute zero
- justify why the value obtained is absolute zero.

The quality of your written communication will be assessed in your answer.

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(6)

(b) (i) State **two** assumptions about the **movement** of molecules that are used when deriving the equation of state, $pV = \frac{1}{3} N m (c_{rms})^2$ for an ideal gas.

1. _____

_____

2. _____

_____

(2)

(ii) Three molecules move at the speeds shown in the table below.

molecule	speed / m s^{-1}
1	2000
2	3000
3	7000

Calculate their mean square speed.

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mean square speed _____ $m^2\ s^{-2}$

(1)

(c) The average molecular kinetic energy of an ideal gas is 6.6×10^{-21} J.
Calculate the temperature of the gas.

temperature _____ K

(2)

(Total 11 marks)

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