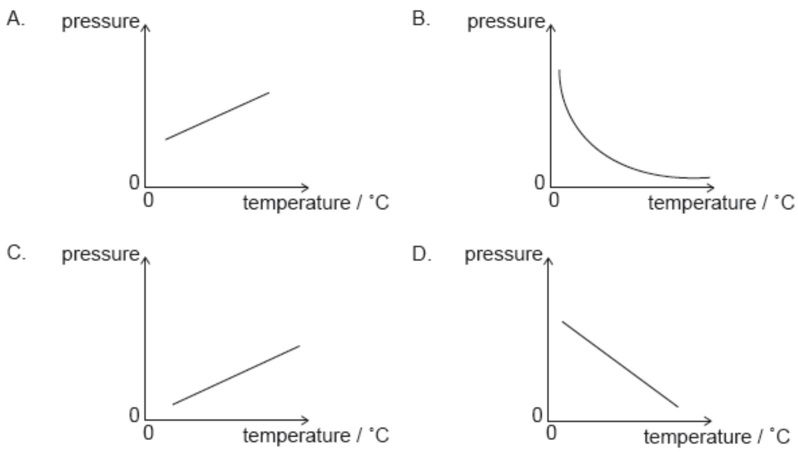
R2019_3 *[64 marks]*

1. A fixed mass of an ideal gas is trapped in a cylinder of constant volume and its temperature is varied. Which graph shows the variation of the pressure of the gas with temperature in degrees Celsius? *[1 mark]*



2. What are the units of the ratio $\frac{\text{specific heat capacity of copper}}{\text{specific latent heat of vaporization of copper}}$? *[1 mark]*

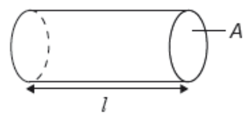
A. no units

B. k

C. k^{-1}

D. k^{-2}

3. A sealed cylinder of length *l* and cross-sectional area *A* contains *N* molecules of an ideal gas at kelvin temperature *T*. *[1 mark]*



What is the force acting on the area of the cylinder marked *A* due to the gas?

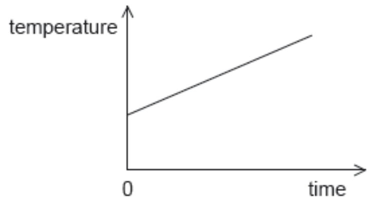
A. $\frac{NRT}{l}$

B. $\frac{NRT}{lA}$

C. $\frac{Nk_BT}{lA}$

D. $\frac{Nk_BT}{l}$

4. The graph shows how the temperature of a liquid varies with time when energy is supplied to the liquid at a constant rate *P*. The gradient of the graph is *K* and the liquid has a specific heat capacity *c*. *[1 mark]*



What is the mass of the liquid?

A. $\frac{P}{cK}$

B. $\frac{PK}{c}$

C. $\frac{Pc}{K}$

D. $\frac{cK}{P}$

5. A sealed container contains water at 5 °C and ice at 0 °C. This system is thermally isolated from its surroundings. What happens to the total internal energy of the system? *[1 mark]*

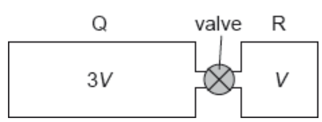
A. It remains the same.

B. It decreases.

C. It increases until the ice melts and then remains the same.

D. It increases.

6. Q and R are two rigid containers of volume 3 *V* and *V* respectively containing molecules of the same ideal gas initially at the same temperature. The gas pressures in Q and R are *p* and 3*p* respectively. The containers are connected through a valve of negligible volume that is initially closed. *[1 mark]*



The valve is opened in such a way that the temperature of the gases does not change. What is the change of pressure in Q?

A. $+p$

B. $\frac{+p}{2}$

C. $\frac{-p}{2}$

D. $-p$

A closed box of fixed volume 0.15 m^3 contains 3.0 mol of an ideal monatomic gas. The temperature of the gas is 290 K.

7a. Calculate the pressure of the gas. *[1 mark]*

When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is 3.1 kJ kg^{-1} K^{-1}.

7b. Calculate, in kg, the mass of the gas. *[1 mark]*

7c. Calculate the average kinetic energy of the particles of the gas. *[1 mark]*

7d. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. *[3 marks]*

An ideal monatomic gas is kept in a container of volume 2.1×10^{-4} m^3, temperature 310 K and pressure 5.3×10^5 Pa.

8a. State what is meant by an ideal gas. *[1 mark]*

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8b. Calculate the number of atoms in the gas. *[1 mark]*

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8c. Calculate, in J, the internal energy of the gas. *[2 marks]*

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The volume of the gas in (a) is increased to 6.8×10^{-4} m^3 at constant temperature.

8d. Calculate, in Pa, the new pressure of the gas. *[1 mark]*

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8e. Explain, in terms of molecular motion, this change in pressure. *[2 marks]*

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When the gas is supplied with 0.86 kJ of energy, its temperature increases by 23 K. The specific heat capacity of the gas is 3.1 kJ kg^{-1} K^{-1}.

9a. Determine, in kJ, the total kinetic energy of the particles of the gas. *[3 marks]*

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9b. Explain, with reference to the kinetic model of an ideal gas, how an increase in temperature of the gas leads to an increase in pressure. *[3 marks]*

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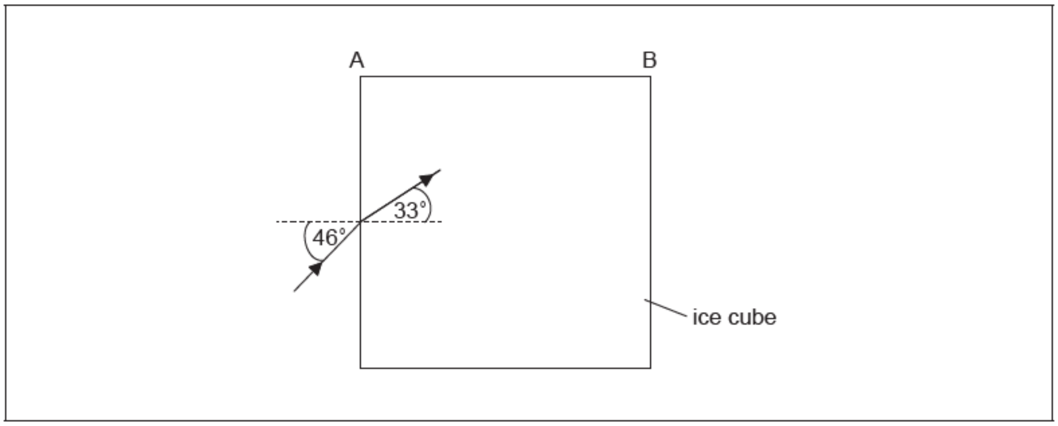
A large cube is formed from ice. A light ray is incident from a vacuum at an angle of 46˚ to the normal on one surface of the cube. The light ray is parallel to the plane of one of the sides of the cube. The angle of refraction inside the cube is 33˚.



10a. Calculate the speed of light inside the ice cube. *[2 marks]*

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10b. Show that no light emerges from side AB. *[3 marks]*

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10c. Sketch, on the diagram, the subsequent path of the light ray. *[2 marks]*

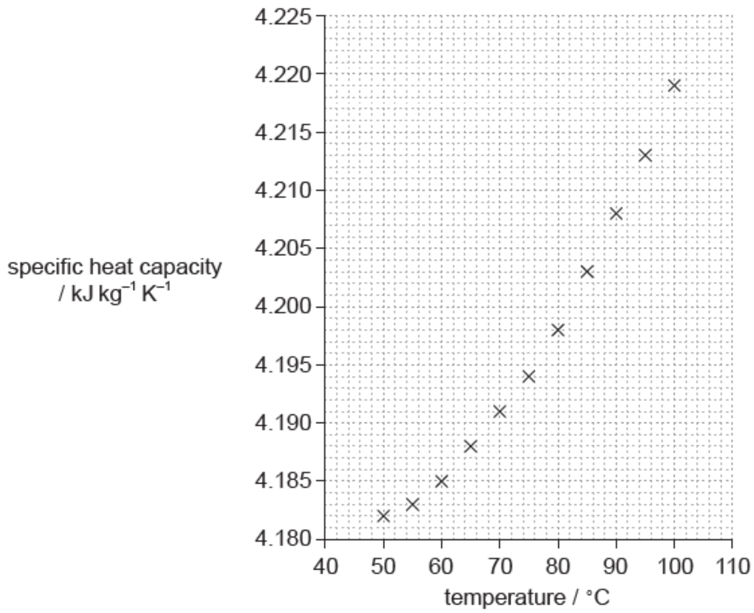
Each side of the ice cube is 0.75 m in length. The initial temperature of the ice cube is –20 °C.

10d. Determine the energy required to melt all of the ice from –20 °C to water at a temperature of 0 °C. *[4 marks]*

Specific latent heat of fusion of ice = 330 kJ kg $^{-1}$
Specific heat capacity of ice = 2.1 kJ kg $^{-1}$ k^{-1}
Density of ice = 920 kg m $^{-3}$

10e. Outline the difference between the molecular structure of a solid and a liquid. *[1 mark]*

In an experiment, data were collected on the variation of specific heat capacity of water with temperature. The graph of the plotted data is shown.



11a. Draw the line of best-fit for the data. *[1 mark]*

11b. Determine the gradient of the line at a temperature of 80 °C. *[3 marks]*

11c. State the unit for the quantity represented by the gradient in your answer to (b)(i). *[1 mark]*

The uncertainty in the values for specific heat capacity is 5%.

Water of mass (100 ± 2) g is heated from (75.0 ± 0.5) °C to (85.0 ± 0.5) °C.

11d. Calculate the energy required to raise the temperature of the water from 75 °C to 85 °C. *[1 mark]*

11e. Using an appropriate error calculation, justify the number of significant figures that should be used for your answer to (c)(i). *[3 marks]*

12a. Define *internal energy.* *[2 marks]*

12b. 0.46 mole of an ideal monatomic gas is trapped in a cylinder. The gas has a volume of 21 m^3 and a pressure of 1.4 Pa. *[4 marks]*

(i) State how the internal energy of an ideal gas differs from that of a real gas.

(ii) Determine, in kelvin, the temperature of the gas in the cylinder.

(iii) The kinetic theory of ideal gases is one example of a scientific model. Identify **one** reason why scientists find such models useful.

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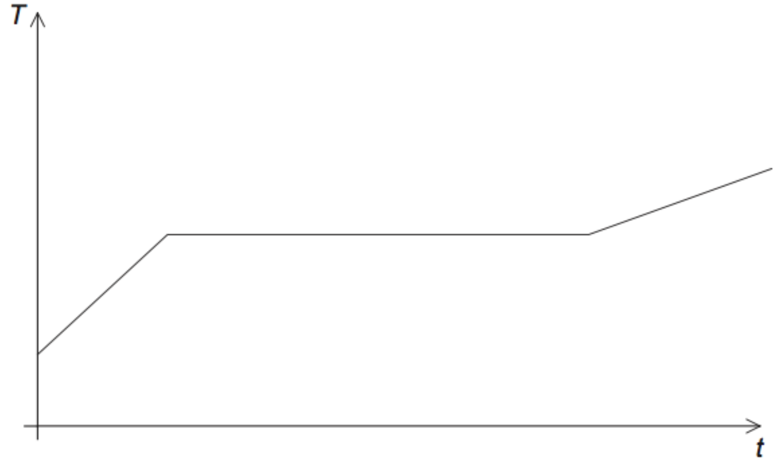
13. A substance is heated at constant power. The graph shows how the temperature *T* of the substance varies with time *t* as the state of the substance changes from liquid to gas. *[1 mark]*



What can be determined from the graph?

A. The specific heat capacity of the gas is smaller than the specific heat capacity of the liquid.

B. The specific heat capacity of the gas is larger than the specific heat capacity of the liquid.

C. The specific latent heat of fusion of the substance is less than its specific latent heat of vaporization.

D. The specific latent heat of fusion of the substance is larger than its specific latent heat of vaporization.

14. Which of the following is **not** an assumption of the kinetic model of ideal gases? *[1 mark]*

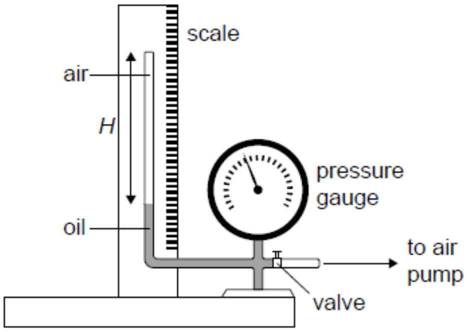
A. All particles in the gas have the same mass.

B. All particles in the gas have the same speed.

C. The duration of collisions between particles is very short.

D. Collisions with the walls of the container are elastic.

The equipment shown in the diagram was used by a student to investigate the variation with volume, of the pressure *p* of air, at constant temperature. The air was trapped in a tube of constant cross-sectional area above a column of oil.



The pump forces oil to move up the tube decreasing the volume of the trapped air.

15a. The student measured the height *H* of the air column and the corresponding air pressure *p*. After each reduction in the volume the student waited for some time before measuring the pressure. Outline why this was necessary. *[1 mark]*

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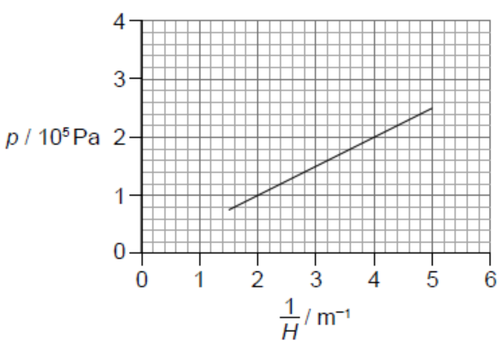
15b. The following graph of *p* versus $\frac{1}{H}$ was obtained. Error bars were negligibly small. *[3 marks]*



The equation of the line of best fit is $p = a + \frac{b}{H}$.

Determine the value of *b* including an appropriate unit.

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15c. Outline how the results of this experiment are consistent with the ideal gas law at constant temperature. *[2 marks]*

15d. The cross-sectional area of the tube is $1.3 \times 10^{-3}\,m^2$ and the temperature of air is 300 K. Estimate the number of moles of air in the tube. *[2 marks]*

15e. The equation in (b) may be used to predict the pressure of the air at extremely large values of $\frac{1}{H}$. Suggest why this will be an unreliable estimate of the pressure. *[2 marks]*