3.12 Physics: Thermal Physics and Gases: 1-hour Pack

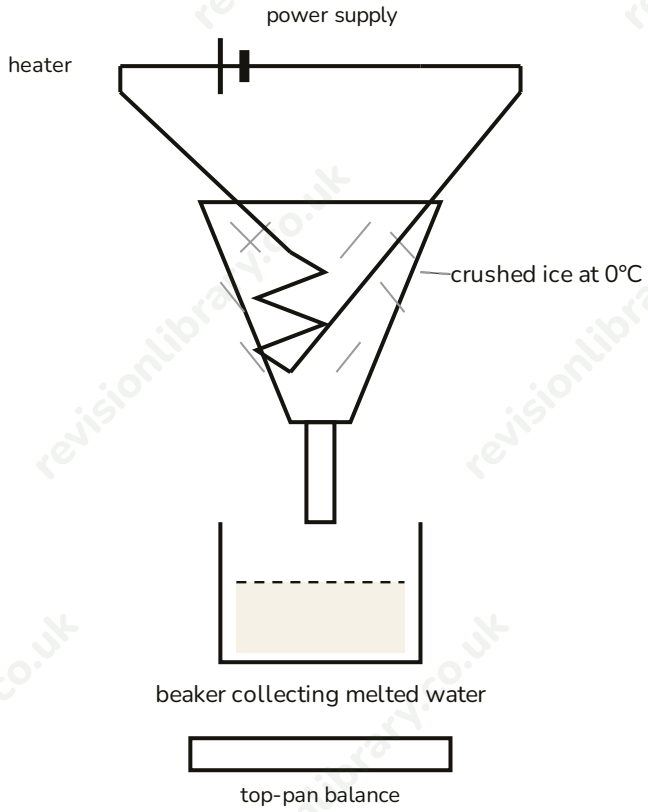
AQA 7408 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 In an experiment to determine the specific latent heat of fusion of ice, a 60 W electrical heater is placed in a funnel of crushed melting ice at 0°C, and the melted water (plus any water from background melting) is collected and weighed. With the heater switched on, 58.0 g of ice melts in 5.0 minutes. In a control run, with the heater switched off (but everything else unchanged), 4.0 g of ice melts in the same time due to heat gained from the surroundings.



(a) Explain, in terms of the kinetic theory model, why the temperature of the ice-water mixture remains at 0°C throughout the melting process, even though thermal energy is continuously being supplied. **(2)**

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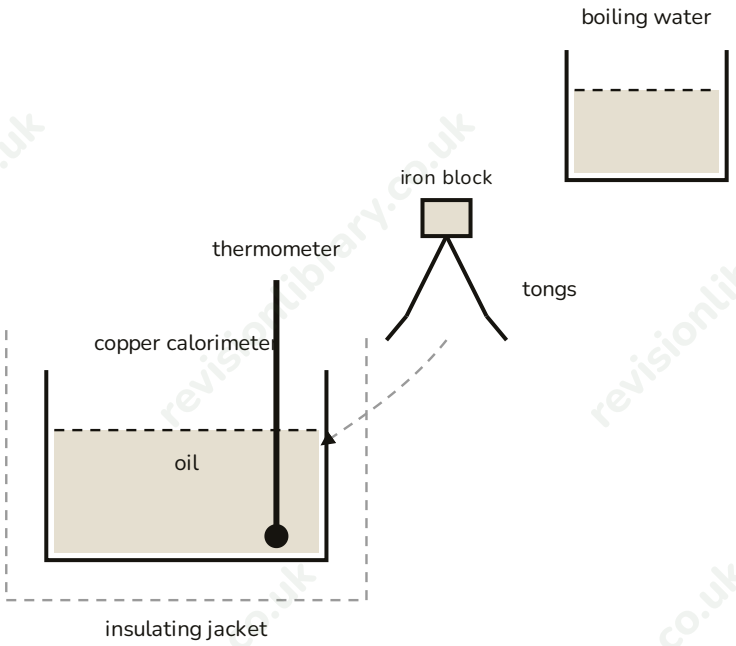
(b) Explain why a control run is carried out with the heater switched off, and how the result of this control run is used in the calculation. **(2)**

(c) Using the data given, calculate a value for the specific latent heat of fusion of ice. **(4)**

(Total for Question 1 is 8 marks)

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2 A student uses the method of mixtures to find the specific heat capacity of an oil. A copper calorimeter of mass 0.150 kg (specific heat capacity of copper = 385 J/(kg K)) contains 0.200 kg of the oil, both initially at 18.0°C. A 0.080 kg block of iron (specific heat capacity of iron = 450 J/(kg K)), heated to 96.0°C in boiling water, is quickly transferred into the oil. The mixture reaches a final steady temperature of 28.0°C. Assume no heat is lost to the surroundings.



(a) Calculate the thermal energy released by the iron block as it cools from 96.0°C to 28.0°C. **(2)**

(b) Calculate the thermal energy gained by the copper calorimeter as its temperature rises from 18.0°C to 28.0°C. **(2)**

(c) Assuming no heat losses, use your answers to parts (a) and (b) to calculate the specific heat capacity of the oil. **(4)**

(d) State and explain one modification to the method that would reduce the systematic error caused by heat loss to the surroundings. **(2)**

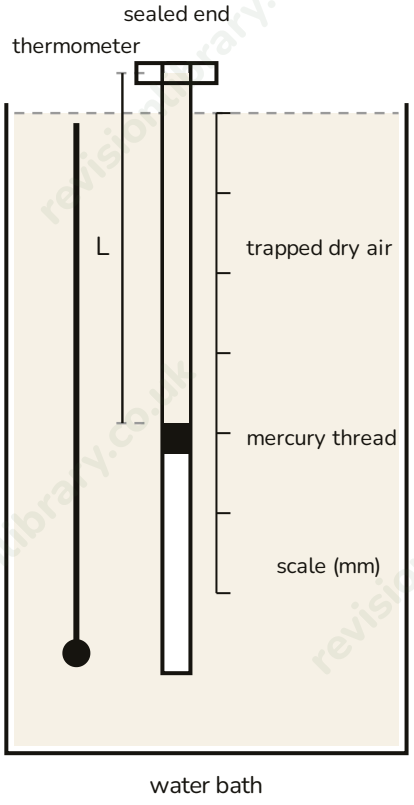
(Total for Question 2 is 10 marks)

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3 This question is based on the required practical: investigation of Charles's law. A fixed mass of dry air is trapped by a short thread of mercury in a capillary tube, sealed at one end, held vertically with the sealed end up. The tube is placed in a water bath, and the length L of the trapped air column is measured (using a scale alongside the tube) at each of several temperatures θ. The results are:

θ / °C : 20.0, 40.0, 60.0, 80.0, 100.0
L / mm : 117.2, 125.2, 133.2, 141.2, 149.2

A graph of L against θ is found to be a straight line.



(a) Explain why the length L of the trapped air column can be used as a measure of the volume of the trapped gas. **(1)**

(b) Explain why it is important that the pressure of the trapped gas remains constant throughout this experiment. **(2)**

(c) Calculate the gradient of the graph of L against θ. **(3)**

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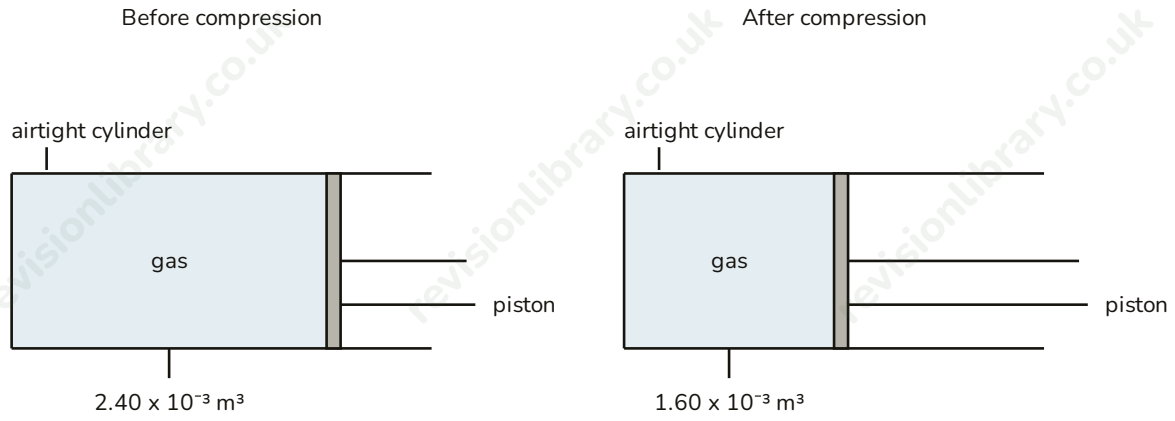
(d) By extrapolating the graph (or using the equation of the line), determine the value of absolute zero, in degrees Celsius, suggested by these results. **(3)**

(Total for Question 3 is 9 marks)

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4 A fixed mass of an ideal gas is held in a cylinder fitted with a frictionless, airtight piston. Take the molar gas constant R = 8.31 J/(mol K) and the Avogadro constant $N_A = 6.02 \times 10^{23}$ /mol.

Diagram NOT accurately drawn



(a) State two of the basic assumptions of the kinetic theory model of a gas that lead to the ideal gas laws. **(2)**

(b) Explain what is meant by the term ideal gas. **(2)**

(c) Initially the gas has a volume of 2.40×10^{-3} m^3 at a pressure of 1.5×10^5 Pa and a temperature of 300 K. The piston is pushed in, at constant temperature, until the volume becomes 1.60×10^{-3} m^3. Calculate the new pressure of the gas. **(3)**

(d) The gas is then heated at constant volume (1.60×10^{-3} m^3) from 300 K until its pressure becomes 3.00×10^5 Pa. Calculate the final temperature of the gas. **(3)**

(e) Use the initial conditions ($p = 1.5 \times 10^5$ Pa, $V = 2.40 \times 10^{-3}$ m^3, T = 300 K) with the ideal gas equation pV = nRT to calculate the amount, in moles, of gas in the cylinder. **(3)**

(f) Given that the molar mass of the gas is 32 g/mol, calculate the mass of gas in the cylinder, in grams. **(2)**

(Total for Question 4 is 15 marks)

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Mark scheme · 3.12 Physics: Thermal Physics and Gases: 1-hour Pack

Question 1

(a) while melting, the energy supplied increases the potential energy of the particles (by weakening/breaking the bonds holding them in the fixed structure of the solid), not their kinetic energy (oe) **B1**

(a) since temperature depends on the mean kinetic energy of the particles, and this is unchanged during melting, the temperature stays constant at 0°C until all the ice has melted (oe) **B1**

(a) Answer: The energy supplied during melting increases the potential energy of the particles (breaking the bonds of the solid structure) rather than their kinetic energy. Since temperature depends on mean kinetic energy, the temperature stays at 0°C until all the ice has melted.

(b) some ice melts anyway due to (background) heat gained from the surroundings (the room, the funnel, etc.), even without the heater; this is a systematic error/confounding effect that would otherwise be wrongly attributed to the heater **B1**

(b) the mass melted in the control run is subtracted from the mass melted with the heater on, to find the mass melted due to the heater alone **B1**

(b) Answer: Ice melts due to heat gained from the surroundings even without the heater, which would otherwise be wrongly credited to the heater. The mass melted in the control run is subtracted from the mass melted with the heater on, isolating the mass melted by the heater's energy alone.

(c) mass melted due to the heater alone = 58.0 - 4.0 = 54.0 g = 0.0540 kg **M1**

(c) electrical energy supplied E = Pt = 60 x 300 = 18000 J **M1**

(c) correct substitution into L = E/m **M1**

(c) L = 3.3 x 10^5 J/kg (accept 3.2-3.4 x 10^5 J/kg), awrt 2 sf **A1**

(c) Answer: L = 3.3 x 10^5 J/kg

Question 2

(a) correct substitution into E = mcDeltaTheta, with DeltaTheta = 96.0 - 28.0 = 68.0 K **M1**

(a) E = 2448 J, cao **A1**

(a) Answer: E = 2448 J

(b) correct substitution into E = mcDeltaTheta, with DeltaTheta = 28.0 - 18.0 = 10.0 K **M1**

(b) E = 577.5 J (accept 578 J), cao **A1**

(b) Answer: E = 577.5 J

(c) applies energy conservation: energy gained by oil = energy released by iron - energy gained by calorimeter, ft from (a) and (b) **M1**

(c) correctly finds the temperature rise of the oil, DeltaTheta = 10.0 K **M1**

(c) rearranges c = E/(mDeltaTheta) and substitutes correctly **M1**

(c) c(oil) = 935 J/(kg K), awrt 3 sf, ft **A1**

(c) Answer: c(oil) = 935 J/(kg K)

(d) a valid modification, e.g. use a lid on the calorimeter, add extra insulating lagging around the calorimeter, or transfer the iron block as quickly as possible **B1**

(d) explains this reduces heat loss to the surroundings during the experiment, so the energy assumed to be gained by the oil (and hence the calculated specific heat capacity) is closer to the true value (rather than an overestimate) **B1**

(d) Answer: For example, fit a lid to the calorimeter (or add more lagging around it). This reduces heat loss to the surroundings during the experiment, so the calculated specific heat capacity of the oil is closer to its true value, rather than being overestimated.

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Question 3

(a) the capillary tube has a constant (uniform) cross-sectional area A, so the volume of the trapped gas V = A x L is directly proportional to its length L **B1**

(a) Answer: The tube has a uniform cross-sectional area, so volume V = A x L is directly proportional to length L.

(b) Charles's law (V/T = constant) is only valid at constant pressure; with the trapped air above the mercury thread, its pressure is atmospheric pressure minus the (roughly constant) pressure head of the mercury thread: pGas = pAtm - ρ g h, where ρ is the mercury density and h is the vertical height of the thread **B1**

(b) if the pressure changed during the experiment, any change in L could be caused (at least partly) by the pressure change rather than only by the temperature change, so the relationship being tested (V proportional to T) would not be validly investigated **B1**

(b) Answer: Charles's law only holds at constant pressure. If the pressure of the trapped gas changed during the experiment, changes in L could be due to the pressure change rather than solely the temperature change, invalidating the test of V proportional to T.

(c) selects two data points (e.g. first and last) and identifies rise (change in L) and run (change in θ) **M1**

(c) correct substitution, e.g. (149.2 - 117.2)/(100.0 - 20.0) **M1**

(c) gradient = 0.400 mm/°C, cao (allow any consistent correct pair of points) **A1**

(c) Answer: gradient = 0.400 mm/°C

(d) finds the intercept L0 of the line at θ = 0, using L = L0 + (gradient x θ) and a data point, e.g. L0 = 117.2 - (0.400 x 20.0) **M1**

(d) sets L = 0 (the theoretical volume at absolute zero) and rearranges to find θ = -L0/gradient **M1**

(d) θ = -273°C (accept -270 to -277°C), consistent with the accepted value of absolute zero **A1**

(d) Answer: θ = -273°C

Question 4

(a) the volume occupied by the gas molecules themselves is negligible compared with the volume occupied by the gas (oe) **B1**

(a) there are no (negligible) intermolecular forces between molecules except during collisions, and collisions between molecules (and with the container walls) are perfectly elastic (oe). Any two creditable assumptions. **B1**

(a) Answer: For example: the volume of the gas molecules is negligible compared with the volume of the container; there are no intermolecular forces except during (perfectly elastic) collisions.

(b) a gas that obeys the ideal gas equation pV = nRT exactly, at all pressures, volumes and temperatures (oe) **B1**

(b) equivalently, a theoretical gas whose molecules have negligible volume and no intermolecular forces except during (elastic) collisions, i.e. one that perfectly matches the kinetic theory model (oe) **B1**

(b) Answer: An ideal gas is one that obeys pV = nRT exactly under all conditions; its molecules are treated as having negligible volume and no intermolecular forces except during perfectly elastic collisions.

(c) applies Boyle's law: p1V1 = p2V2 **M1**

(c) correct substitution: $p2 = (1.5 \times 10^5 \times 2.40 \times 10^{-3})/(1.60 \times 10^{-3})$ **M1**

(c) $p2 = 2.25 \times 10^5$ Pa, cao **A1**

(c) Answer: $p2 = 2.25 \times 10^5$ Pa

(d) applies the pressure law at constant volume: p2/T2 = p3/T3 **M1**

(d) correct substitution, using $p2 = 2.25 \times 10^5$ Pa (ft from (c)): $T3 = 300 \times (3.00 \times 10^5/2.25 \times 10^5)$ **M1**

(d) T3 = 400 K, cao (allow ft from candidate's (c)) **A1**

(d) Answer: T3 = 400 K

(e) rearranges pV = nRT to n = pV/(RT) **M1**

(e) correct substitution: $n = (1.5 \times 10^5 \times 2.40 \times 10^{-3})/(8.31 \times 300)$ **M1**

(e) n = 0.144 mol, awrt 3 sf **A1**

(e) Answer: n = 0.144 mol

(f) mass = n x molar mass, using candidate's n from (e), ft **M1**

(f) mass = 4.62 g, awrt 3 sf **A1**

(f) Answer: mass = 4.62 g

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