3.12 Physics: Thermal Physics and Gases: Test Pack

AQA 7408 · Calculator allowed · about 40 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 This question is about temperature scales.

(a) State the value of absolute zero in degrees Celsius. **(1)**

(b) Explain, in terms of the kinetic theory model of matter, what happens to the particles of a substance as its thermodynamic temperature approaches absolute zero. **(2)**

(c) A patient's body temperature is recorded by a sensor as 310 K. State this temperature in degrees Celsius. **(1)**

(d) State two differences between the Celsius scale of temperature and the thermodynamic (kelvin) scale of temperature. **(2)**

(Total for Question 1 is 6 marks)

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2 This question is about the gas laws for a fixed mass of gas.

(a) Describe the shape of a graph of pressure p against volume V for a fixed mass of ideal gas held at constant temperature, and name the law this relationship illustrates. **(2)**

(b) State the two conditions that must be kept constant for Boyle's law to apply to a sample of gas. **(1)**

(c) State Charles's law in words. **(2)**

(d) Explain why temperature must be measured in kelvin, not degrees Celsius, when using the ideal gas equations pV = nRT, V/T = constant and p/T = constant. **(2)**

(Total for Question 2 is 7 marks)

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3 A 0.250 kg block of ice at -12.0°C is heated, in a sealed, well-insulated container, until it becomes steam at 100°C, all at atmospheric pressure. Use the following data:
specific heat capacity of ice = 2100 J/(kg K)
specific heat capacity of water = 4200 J/(kg K)
specific latent heat of fusion of ice = 3.34×10^5 J/kg
specific latent heat of vaporisation of water = 2.26×10^6 J/kg

(a(i)) Calculate the thermal energy required to warm the ice from -12.0°C to 0°C. **(2)**

(a(ii)) Calculate the thermal energy required to melt the ice at 0°C. **(2)**

(a(iii)) Calculate the thermal energy required to heat the resulting water from 0°C to 100°C. **(2)**

(a(iv)) Calculate the thermal energy required to vaporise the water at 100°C. **(2)**

(b) Calculate the total thermal energy required for the whole process, from ice at -12.0°C to steam at 100°C. **(1)**

(c) The heater used has a constant power output of 500 W, and all its energy output goes into heating the ice/water/steam (no losses). Calculate the total time taken for the whole process. **(3)**

(d) Describe how the temperature of the sample would change over the whole process, stating during which stages it remains constant, and explain why, in terms of the energy supplied and the internal energy of the substance. **(3)**

(Total for Question 3 is 15 marks)

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Mark scheme · 3.12 Physics: Thermal Physics and Gases: Test Pack

Question 1

(a) -273°C (accept -273.15°C) **B1**

(a) Answer: -273°C

(b) the (random, translational) kinetic energy of the particles decreases as the temperature falls (oe) **B1**

(b) at absolute zero the particles have the minimum possible (theoretically zero) kinetic energy, i.e. this is the lowest temperature that is theoretically possible (oe) **B1**

(b) Answer: As the thermodynamic temperature falls towards absolute zero, the mean kinetic energy of the particles decreases; at absolute zero itself the particles have the minimum (theoretically zero) kinetic energy, so no lower temperature is possible.

(c) 37°C, cao **A1**

(c) Answer: 37°C

(d) the kelvin scale has no negative values and starts at absolute zero (0 K), whereas the Celsius scale can take negative values and its zero point (0°C) is not the lowest possible temperature (oe) **B1**

(d) a change of 1 K is equal in size to a change of 1°C (the divisions are the same size), but the two scales have different zero points: 0°C = 273 K (oe). Any two creditable differences. **B1**

(d) Answer: The kelvin scale starts at absolute zero and has no negative values, whereas the Celsius scale can be negative; a temperature change of 1 K equals a change of 1°C, but the scales have different zero points (0°C = 273 K).

Question 2

(a) the graph is a curve that falls from a high pressure at low volume, decreasing continuously as V increases (an inverse/hyperbola-shaped curve, p proportional to 1/V), never touching either axis **B1**

(a) this is Boyle's law (pV = constant, at constant temperature and for a fixed mass of gas) **B1**

(a) Answer: A falling curve where p is inversely proportional to V (a hyperbola); this is Boyle's law, pV = constant.

(b) the temperature of the gas and the mass (amount/number of moles) of the gas must both be kept constant **B1**

(b) Answer: The temperature of the gas and the mass (amount) of gas must both be kept constant.

(c) for a fixed mass of gas at constant pressure, the volume of the gas is directly proportional to its thermodynamic (kelvin/absolute) temperature (oe) **B1**

(c) correctly names/states the condition (constant pressure, fixed mass) alongside the proportionality V/T = constant **B1**

(c) Answer: For a fixed mass of gas held at constant pressure, its volume is directly proportional to its thermodynamic (kelvin) temperature: V/T = constant.

(d) these equations express direct proportionality (e.g. V directly proportional to T), which is only valid when temperature is measured on an absolute scale starting from absolute zero (oe) **B1**

(d) 0°C is not the temperature at which volume or pressure would become zero (it is an arbitrary reference point), so using Celsius values would give incorrect ratios/results; only kelvin gives V = 0 (or p = 0) at T = 0 as the equations require (oe) **B1**

(d) Answer: The gas law equations express direct proportionality between quantities and temperature, which only holds when temperature is measured from true zero (absolute zero). Celsius has an arbitrary zero point (0°C is not where V or p would become zero), so using Celsius values would give incorrect ratios.

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Question 3

(a(i)) correct substitution into E = mcDeltaTheta, with DeltaTheta = 12.0 K **M1**

(a(i)) E1 = 6300 J, cao **A1**

(a(i)) Answer: E1 = 6300 J

(a(ii)) correct substitution into E = mL **M1**

(a(ii)) E2 = 8.35 x 10^4 J (83500 J), cao **A1**

(a(ii)) Answer: E2 = 8.35 x 10^4 J

(a(iii)) correct substitution into E = mcDeltaTheta, with DeltaTheta = 100 K **M1**

(a(iii)) E3 = 1.05 x 10^5 J (105000 J), cao **A1**

(a(iii)) Answer: E3 = 1.05 x 10^5 J

(a(iv)) correct substitution into E = mL **M1**

(a(iv)) E4 = 5.65 x 10^5 J (565000 J), cao **A1**

(a(iv)) Answer: E4 = 5.65 x 10^5 J

(b) total = E1 + E2 + E3 + E4 = 7.60 x 10^5 J (759800 J), ft from candidate's (a)(i)-(a)(iv) **B1**

(b) Answer: Total = 7.60 x 10^5 J

(c) rearranges P = E/t to t = E/P **M1**

(c) correct substitution, using candidate's total energy from (b), ft **M1**

(c) t = 1520 s (25.3 minutes), awrt 3 sf, ft **A1**

(c) Answer: t = 1520 s (about 25.3 minutes)

(d) the temperature rises steadily while warming the ice and while warming the water, but remains constant (a plateau) during melting (at 0°C) and during boiling (at 100°C) **B1**

(d) correctly identifies that these plateaus occur during the change of state, i.e. while melting and while boiling **B1**

(d) during a change of state, the energy supplied increases the potential energy of the particles (breaking or weakening the bonds between them) rather than their kinetic energy, so the temperature (which depends on mean kinetic energy) does not change even though energy continues to be transferred in **B1**

(d) Answer: Temperature rises steadily while warming the ice and the water, but stays constant during melting (at 0°C) and boiling (at 100°C). During these changes of state, the energy supplied increases the particles' potential energy (breaking/weakening bonds) rather than their kinetic energy, so the temperature does not change even though energy is still being transferred in.

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