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|  | |  |  | | --- | --- | | **Physics A**  **Thermal Physics practise questions**  **50 marks** |  | | Please note that you may see slight differences between this paper and the original.  Candidates answer on the Question paper.  **OCR supplied materials:** Additional resources may be supplied with this paper.  **Other materials required:** •   Pencil •   Ruler (cm/mm) | **Duration:** 1 hour | |  | | |  |

## INSTRUCTIONS TO CANDIDATES

•   Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.  
•   Use black ink. HB pencil may be used for graphs and diagrams only.  
•   Answer **all** the questions, unless your teacher tells you otherwise.  
•   Read each question carefully. Make sure you know what you have to do before starting your answer.  
•   Where space is provided below the question, please write your answer there.  
•   You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number  
    and question number(s).

## INFORMATION FOR CANDIDATES

•   The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography   
    a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and  
    grammar and the use of specialist terminology* is assessed.  
•   The number of marks is given in brackets **[ ]** at the end of each question or part question.  
•   The total number of marks for this paper is **50**.  
•   The total number of marks may take into account some 'either/or' question choices.

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|  | |  |  | | --- | --- | |  |  | | **1.** | What is the correct unit for specific heat capacity?   1. m2s−2K−1 2. ms−2K−1 3. m2s−1K−1 4. m2s−2K   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **2.** | A gas syringe contains 2.0 moles of an ideal gas of volume of 0.040 m3. An additional amount of 0.5 moles of the same gas is added to the syringe. The temperature and pressure of the gas remain the same.  What is the final volume of gas in the syringe?     |  |  | | --- | --- | | **A** | 0.010 m3 | | **B** | 0.032 m3 | | **C** | 0.050 m3 | | **D** | 0.090 m3 |   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **3.** | A container has an ideal gas. The mean square speed of the gas molecules in the container is 3.0 × 105 m2 s−2.  Over a period of time, a third of the gas molecules escape from the container. The pressure and volume of the gas in the container remain the same.  What is the mean square speed of the molecules left in the container?     |  |  | | --- | --- | | **A** | 1.0 × 105 m2 s−2 | | **B** | 2.0 × 105 m2 s−2 | | **C** | 4.5 × 105 m2 s−2 | | **D** | 9.0 × 105 m2 s−2 |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **4.** | A solid molecular substance is supplied with energy and it starts to melt.  Which of the following pairs of quantities remains the same as the substance melts?     |  |  | | --- | --- | | **A** | Kinetic energy of molecules and internal energy of molecules. | | **B** | Potential energy of molecules and internal energy of molecules. | | **C** | Kinetic energy of molecules and temperature of substance. | | **D** | Potential energy of molecules and temperature of substance. |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **5.** | The kinetic theory of matter is a model used to describe the behaviour of particles (atoms or molecules) in an ideal gas. There are a number of assumptions made in the kinetic model for an ideal gas.  Which one of the following assumptions is **not** correct?     |  |  | | --- | --- | | A | The collisions of particles with each other and the container walls are perfectly inelastic. | | B | The electrostatic forces between particles are negligible except during collisions. | | C | The particles occupy negligible volume compared to the volume of the gas. | | D | There are a large number of particles in random motion. |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **6(a).** | The apparatus shown in **Fig. 20.1** is used to investigate the variation of the product PV with temperature in the range 20 °C to 100 °C. The pressure exerted by the air is P and the volume of air inside the flask is V.    Describe how this apparatus can be set up and used to ensure accurate results.                    **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | An investigation similar to that shown in **Fig. 20.1** gives measurements of the pressure P, volume V and temperature θ in degrees Celsius of a fixed mass of gas.  The results are used to plot the graph of PV against θ shown in **Fig. 20.2**.     1. Explain, in terms of the motion of particles, why the graph does **not** go through the origin.       **[2]**   1. The mass of a gas particle is 4.7 × 10−26 kg. Use the graph in **Fig 20.2** to calculate    1. the mass of the gas   mass = ............................. kg   * 1. the internal energy of the gas at a temperature of 100 °C.   internal energy = ............................. J   **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **7(a).** | Fig. 6.1 shows how the volume V of a fixed mass of an ideal gas at constant pressure varies with temperature θ from 0 °C to 120 °C.    Describe how this graph leads to the concept of an absolute zero of temperature.        **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | A mass of gas is enclosed in a tank. The gas is cooled until it becomes a liquid. During this process its internal energy changes.   1. State what is meant by the internal energy of the gas.       **[1]**   1. Explain why the internal energy of the gas differs from that of its liquid phase.           **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | A scuba diver uses air in which the percentage of nitrogen is reduced by adding helium to form a substance known as Trimix. A 1.2 × 10−2 m3 rigid steel scuba diving tank contains 45 mol of air at a temperature of 20 °C.   1. Calculate the pressure in the tank.      |  | | --- | | pressure = ........................................................... Pa **[2]** |  1. The tank is then connected to a cylinder of volume 2.0 × 10−3 m3 containing helium at a pressure of 5.0 × 107 Pa and a temperature of 20 °C as shown in Fig. 6.2.     The valve is opened allowing the gases to mix. When mixed the final temperature is 20 °C. Calculate the final pressure of the resulting Trimix in the scuba tank helium cylinder system.     |  | | --- | | pressure = ........................................................... Pa **[3]** |  1. Explain why you would expect this pressure to decrease when the tank is used by a diver in water where the temperature is 4 °C.       **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **8(a).** | A substance can exist as a crystalline solid, a liquid or a gas. A solid sample of the substance is placed in a sealed container and heated at a constant rate until it changes into a gas.  Fig. 21 shows the variation with time t of the temperature θ for the substance.     |  | | --- | | **Fig. 21** |   Use the kinetic theory of matter to describe the solid phase (section **AB**) and the liquid phase (section **CD**) in terms of the motion and arrangement of the molecules of the substance.     |  |  | | --- | --- | | Section **AB**: |  | |  | | |  | | |  | | |  | | |  | | | Section **CD**: |  | |  | | |  | | |  | | |  | | | **[4]** | | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Use Fig. 21 to explain how the specific heat capacity of the liquid compares with the specific heat capacity of the solid.        **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | State what is meant by the **internal energy** of the substance.      **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | Beyond the point **E** in Fig. 21, the substance behaves as an ideal gas.   1. The mass of a gas molecule is 4.8 × 10−26 kg. Calculate the root mean square speed of the gas molecules at a temperature of 250 ºC.      |  | | --- | | root mean square speed = ................................................ m s−1 **[3]** |  1. Calculate the internal energy of 1.3 moles of the gas at 250 ºC.      |  | | --- | | internal energy = ....................................................... J **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **9(a).** | A kiln used to harden ceramics is shown below.     The internal chamber is a cube. Each side of this cube has length 0.46 m. The chamber is sealed and full of argon. Argon behaves as an ideal gas.  The kiln is initially at 20 °C. The argon in the kiln has an initial pressure of 100 kPa.   1. Calculate the amount of argon n in the chamber in moles.   n = ................................................... mol **[2]**   1. The temperature of the kiln is increased from 20 °C to 1300 °C.  Calculate the pressure in kPa at 1300 °C.   pressure = .................................................. kPa **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | The temperature of the kiln is 1300 °C. A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber. The initial speed of this atom is 990 m s–1. After collision, it rebounds at the same speed.   1. Calculate the change in momentum Δp of this atom.    * mass of argon atom = 6.6 × 10–26 kg   Δp = ............................................ kg m s–1 **[2]**   1. Assume that this atom does not collide with any other argon atoms inside the chamber. Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.    * Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0 s.   **[1]**   * + Calculate the average force F on side **X** made by the atom.   F = ...................................................... N **[2]**   1. Without calculation, explain how your answer to **(ii)2** could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.         **[2]** | |

**END OF QUESTION PAPER**

# Mark scheme

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| --- | --- | --- | --- | --- | --- |
| **Question** | | | **Answer/Indicative content** | **Marks** | **Guidance** |
| 1 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 2 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 3 |  |  | **C** | 1 | **Examiner’s Comments** In this question, candidates should consider the equation pV = nRT. If the pressure and volume remain the same, this gives nT as a constant also. If the number of particles decreases to two thirds of the original number, then the temperature in kelvin, and thus the total kinetic energy and hence mean square speed must have increased by a factor of 1.5, giving option C. This question provided opportunities for middle-grade candidates. |
|  |  |  | **Total** | **1** |  |
| 4 |  |  | C | 1 | **Examiner’s Comments**  As a substance melts, the PE of the molecules increases, ruling out answers B and D. The temperature of a melting substance does not change and so the KE of the molecules cannot change, as the temperature and mean KE of molecules are directly proportional. This means that C must be correct. A cannot be correct since the internal energy is the sum of the KE and PE of the molecules. The KE is constant and the PE increases, meaning the internal energy must also increase. |
|  |  |  | **Total** | **1** |  |
| 5 |  |  | A | 1 |  |
|  |  |  | **Total** | **1** |  |
| 6 | a |  | Ensure largest possible proportion of flask is immersed. | B1 × 4 |  |
|  |  |  | Make volume of tubing small compared to volume of flask. |  |  |
|  |  |  | Remove heat source and stir water to ensure water at uniform temperature throughout. |  |  |
|  |  |  | Allow time for heat energy to conduct through glass to air before reading temperature. |  |  |
|  | b | i | Pressure is caused by collisions of particles with sides. | B1 |  |
|  |  | i | Velocity of particles (and volume of gas) are not zero at 0 °C. | B1 |  |
|  |  | ii | **1:** Gradient of graph 0.75 × 102 / 100 = 0.75 |  |  |
|  |  | ii | Number of moles of gas = gradient / R = 0.75 / 8.31 = 0.09 | C1 | Alternative method Internal energy = 3/2 × p × V |
|  |  | ii |  | A1 |  |
|  |  | ii | Mass of gas = 0.09 × 6.02 × 1023 × 4.7 × 10−27 = 2.5 × 10−4 (kg) |  | At θ = 100°C pV = 2.73 × 102 |
|  |  | ii | **2:** Internal energy = 3/2 × NkT |  | Internal energy = 1.5 × 2.73 × 102 = 410 (J) |
|  |  | ii | = 1.5 × 0.09 × 6.02 × 1023 × 1.38 × 10−23 × (100 + 273) | C1 |  |
|  |  | ii | = 410 (J) | A1 |  |
|  |  |  | **Total** | **10** |  |
| 7 | a |  | Idea of extrapolating graph back (to negative temperatures) | B1 | Can be shown on diagram |
|  |  |  | Volume is zero at absolute zero / negative volumes are impossible | B1 | Allow ‘negligible volume’ rather than zero and use of -273 ºC / 0 K  **Examiner's Comments**  Although the term 'extrapolate' was not commonly seen, most candidates understood the need to extend the line back until it cut the temperature axis in order to justify their comments about negative volumes and the temperature scale. Many referred to 'zero' or 'minimal volume' and this was credited by Examiners. A significant number of candidates talked about the kinetic energy and velocity of molecules in their answers and only loosely related this to the question. This was most unfortunate given that the graph given involved volume rather than either of these terms. |
|  | b | i | (Internal energy of a system) is the sum of the random (distribution of) kinetic and potential energies of (all) **atoms / molecules** (in the system) | B1 | **Allow:** particles  **Examiner's Comments**  This standard definition was poorly answered by many candidates. Candidates did not seem to be aware that a precise definition was required. Many candidates lost the mark as a result of omitting to specify that the energies were associated with the **molecules** of the gas and that the distributions were **random**, both of which are important features of internal energy. Since the question did not specify that the gas was ideal it was appropriate to include potential energy even though it is small for gases under 'normal' conditions. |
|  |  | ii | Any **two** from Comparison of kinetic energies in gas and liquid phases linked to temperature | B1 |  |
|  |  | ii | Potential energy of gas phase is greater than PE of liquid phase / energy must be supplied to change liquid into gas phase. | B1 | **Allow:** potential energy of gas phase is (‘close’ to) zero  **Examiner's Comments**  Although this was a topic that was well understood in general it was not common to see both marks scored. In most cases this was because only the most able candidates linked the kinetic energy of the molecules to temperature. Some candidates didn't distinguish clearly enough in their answers which phase had the higher internal energy by ambiguous use of 'it'. |
|  | c | i |  | C1 | **No credit** If temperature is not converted to kelvin |
|  |  | i | p = 9.1 × 106 (Pa) | A1 | **Examiner's Comments**  This calculation was very well answered, with only a small minority using temperature on the celsius scale. As in previous years the penalty of this serious error in physics was fairly high in this question. |
|  |  | ii |  | C1 | **Allow:** ECF if temperature is used in ºC only if penalised in (i) Otherwise max mark allowed is 1 out of 3 for n = 602 mol |
|  |  | ii |  | C1 | **Allow:** use of partial pressures |
|  |  | ii | ptrimix = 1.5 × 107 (Pa) | A1 | **Examiner's Comments**  Weaker students struggled with this question frequently managing only to score the mark for the number of moles of helium added. The most common error was to assume that the volume remained the same. Very few candidates attempted to solve the problem by using partial pressures and, of those who did, most only scored one mark, usually for determining the partial pressure of one of the gases. In some case it appeared that, although the calculation gave a correct partial pressure and consequently received a mark, the candidates were not actually aware that this could lead to the required total pressure value. A small minority attempted to use p1V1 /T1 = p2V2 /T2 apparently unaware that this formula is only applicable to situations in which the mass or number of molecules of gas is constant. In order to prevent an excessive penalty for the use of celsius temperatures in gas calculations on this paper Examiners ignored the use here, if it had been previously penalised. |
|  |  | iii | Internal / kinetic energy of molecules decreases (as temperature falls) | M1 | **Allow:** p ∝ T if (n and) V constant |
|  |  | iii | Hence pressure would decrease | A0 | **Examiner's Comments**  This was another case where it was clear that the majority of candidates knew the answer but almost half failed to score the mark because they did not make clear that volume must remain constant for the pressure to be proportional to the absolute temperature. |
|  |  |  | **Total** | **11** |  |
| 8 | a |  | Section **AB** Any two from   * Particles close together * Particle spacing increase with increasing time or increasing temperature * Particles in a fixed structure/(regular) lattice * Particles vibrate/perform SHM * Particles vibrate with increasing amplitude (from A to B)   Section **CD** Any two from   * Particles close together /(slightly) further apart (than in AB) * No regular structure /AW * Particles (are free to) move around / move past each other / flow * Particles move with increasing speed from C to D / greater KE | B1 x 2 B1 x 2 | **Not**: ‘vibrates more’ |
|  | b |  | E = mcΔθ (any subject) and gradient is larger for CD     The specific heat capacity of the liquid is less than that of the solid. | M1 A1 | **ORA** **Allow**: Δθ is larger for liquid in the same time interval or same energy supplied for “gradient” **Allow** c ∝ gradient-1 **Not:** c = 1 / gradient   **Examiner’s Comments**  Many candidates realised that the gradients of the lines AB and CD were related to the specific heat capacities of the solid and liquid states. Higher level responses included the formula relating energy change, mass, specific heat capacity and the temperature change, and how that formula related to the gradient of the line on a temperature-time graph. Once that link was established, the lower gradient indicates a larger specific heat capacity. |
|  | c |  | The sum of the (random) kinetic and potential energy of atoms or molecules in a substance | B1 | **Allow** ‘particles’   **Examiner’s Comments**  This is a simple definition that many candidates recalled well. Lower level responses missed out that this is to do with the kinetic energy and potential energy of **particles**. |
|  | d | i | ½ *m* cRMS2= 3/2 *kT*  cRMS2 = 3 x 1.38 x 10-23 x 523 / 4.8 x 10-26 (Any subject)  root mean square speed = 670 (m s-1) | C1 C1 A1 | **Allow** this mark even when *T* = 250 is used subsequently  **Not** 250ºC **Allow** c2 = 4.5 x 105   **Allow** 2 marks for 4.5 x 105; mean square speed calculated **Allow** 1 mark for 464; no conversion to kelvin  **Examiner’s Comments**  The key to this question is equating 2 formulae. The first is the familiar ½ m v2 for kinetic energy. In this case, the squared speed will be the mean squared speed of the particles. The second is the connection between average kinetic energy of a particle at absolute temperature, *T, Ek = 3/2 k T*.  If candidates did that, then they not only scored the first mark but also could go on to complete the question. A common error was to forget to find the square root, as the question asks for the root mean square speed. |
|  |  | ii | (number of molecules =) 1.3 x 6.02 x 1023 or 7.83 x 1023 mean KE = x 1.38 x 10-23 x 523  or  1.08 x 10-20  total kinetic energy = 8.5 x 103 (J) | C1 C1 A1 | **Not** 250ºC     **Allow** 8.4 x 103 for use of 670 m s-1 **Allow** full credit for use of total KE = 1.5n*RT* **Allow** full credit for use of Ek for one molecule = ½ m cRMS2 (which may include ECF for their cRMS in (d)(i) ) **Allow** 2 marks for 4.0(5...) x 103 (J) ; no conversion to kelvin.    **Examiner’s Comments**  There were 2 ways to answer this question. The first was to find the kinetic of one particle using the mean square speed and the second was to find the kinetic energy of one particle using the absolute temperature. Lower level responses stopped at that point, or there was misunderstanding how to scale that value up to the whole gas.  For either route, the value for one particle needed to be multiplied by the number of particles in the gas. This can be found by multiplying the number of moles by the Avagadro constant given in the data, formulae and relationship booklet. |
|  |  |  | **Total** | **13** |  |
| 9 | a | i | (pV = nRT)   100 × 103 × (0.46)3 = n × 8.31 × (273 + 20)  n = 4.0 | C1  A1 | **Note** T = 20 is XP  **Not** 1 SF answer of 4 **Note** answer is 4.00 to 3SF |
|  |  | ii | |  |  |  | | --- | --- | --- | |  | or | p × (0.46)3 = n × 8.31 × 1573 |   pressure = 540 (kPa) | C1   A1 | **Note** T = 1300 is XP   **Allow** use of correct, unrounded n |
|  | b | i | (p =) 6.6 × 10−26 × 990 **or** 6.5(3) × 10−23 (kg m s−1)   (Δp =) 2 × 6.6 × 10−26 × 990   Δp = 1.3 × 10−22 (kg m s−1) | C1       A1 | **Ignore** sign of answer |
|  |  | ii | 990/[2 × 0.46] (= 1080) (F = Δp/Δt) (F =) 1.3 × 10−22 × 1000 F = 1.3 × 10−19 N | B1  C1 A1 | Possible ECF from **(b)(i)**  **Note** 1080 would give 1.4 × 10−19 (N) |
|  |  | iii | |  |  |  | | --- | --- | --- | | Use of p = F/A | **or** | pressure = (total) force / area |   Idea of multiplying by total number of atoms | B1   B1 | **Allow** particles or molecules for atoms |
|  |  |  | **Total** | **11** |  |