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| **1.** | (a) | M1: gas molecules are in constant motion in random directions  M2: they frequently collide with one another and these collisions are elastic, but energy can be transferred from one molecule to another as a result of these collisions  M3: the total energy of the particles in a closed system remains constant at a given temperature  M4: the average kinetic energy of the particles is directly proportional to the temperature  Any 3 = 1 mark; all four = 2 marks | |
|  | (b) | M3: The volume of the molecules is negligible compared to the volume of the container AND the intermolecular forces are of negligible strength | |
|  | (c) | M4: Low pressures and Relatively high temperatures  M5: gases which are small, light and monatomic (any two)  [5] | |
| **2.** | (a) | M1: PV = nRT  M2: An equation which relates the physical state of a material to physical conditions | |
|  | (b) | M3: PV = so = ρ = = (100000 x 0.044) / (8.31 x 298)  M4 = 1.78 kgm-3 (2 or 3 sf, no rounding errors | |
|  | (c) | m = mass of molecule, vx = velocity of molecule in x-direction, l = length of a cubic container  force on container = change in momentum per unit time  M5: change in momentum = 2mvx and time between collisions = 2l/vx  M6: so force per collision = but particle is also colliding with opposite wall so F =  M7: so total force per collision in all dimensions = + + =  M8: so total force = =  M9: P = F/A, A = 6l2 so P = = = so PV = | |
|  | (d) | (i) | M10: KE = = = nkT  M11: So = = PV  M12: If = R, then PV = nRT |
|  |  | (ii) | M13: KE = nkT  M14: = R so k = so KE = |
|  | (e) | M15: Δ(KE) = so = = Cv  M16: At constant pressure, must do additional work to expand gas: Work = PΔV = nRΔT  M17: = R; so Cp = Cv + R =  Max 15 marks  [15] | |
| **3.** | (a) | M1: Mr (butane) = 58 and mr (oxygen) = 32  M2: pbut = = (5/58 x 8.31 x 353 / 0.01)  M3: = 25.3 kPa  M4: pox = = (10/32 x 8.31 x 353 / 0.01)  = 91.7 kPa  M5: P = pbut + pox = 117 kPa | |

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|  | (b) | M6: KE = = 3/2 x 10/32 x 8.31 x 353  M7: = 1.38 kJ | |
|  | (c) | M8: = so 3RT = mru2 so u =  M9: u = √(3 x 8.31 x 353 / 0.032)  M10: = 524 ms-1  [10] | |
| **4.** | (a) |  | M1: probability or N labelled on y-axis  M2: velocity or speed labelled on x-axis  M3: line through origin  M4: decreasing gradually to p = 0 after maximum and with a tail on the RHS |
|  | (b) | M5: Starts at origin and line lower than (a) initially  M6: Peak lower than (a) and to the right  M7: Line always above (a) after peak  All 3 = 2, any 2 = 1 | |
|  | (c) | M8: Starts at origin and line higher than (a) initially  M9: Peak higher than (a) and to the left  M10: Line always below (a) after peak  All 3 = 2, any 2 = 1 | |
|  | (d) | M11: Maxwell: entropy contribution  M12: more ways for greater energy states to exist so they are more probable  M13: Boltzmann: enthalpy contribution  M14: probability of a single high energy state existing decreases exponentially with increasing energy | |
|  | (e) | M15: vrms = = √(3 x 8.31 x 273 / 0.016) = 652 ms-1  M16: vav = = √(8/π x 8.31 x 273 / 0.016) = 601 ms-1  M17: vmp = = √(2 x 8.31 x 273 / 0.016) = 533 ms-1  [15] | |

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| **5.** | (a) | M1: Collision area = πd2  M2: Relative velocity of molecules = v√2  M3: Collision volume per second = πd2v√2  M4: N/V x πd2v√2 = | |
|  | (b) | (i) | M5: Total number of colliding particles per unit volume per second = N/V x = = πd2v√2  M6: Number of collisions per unit volume per second = = |
|  |  | (ii) | M7: Distance travelled between collisions = velocity x time and time interval between collisions =  M8: Distance travelled between collisions = x v = |
|  | (c) | Calculate the mean free path, and the collision frequency per unit volume, in a vessel containing N2O4 at 40 oC and 1 kPa  M9: n/V = P/RT so N/V = LP/RT = (6.02 x 1023 x 1000 / (8.31 x 313)) = 2.31 x 1023 m-3s-1  M10: vav = = √(8/π x 8.31 x 313 / 0.092) = 267 ms-1  No further calculations possible as d not given  [10] | |

**TOTAL 55 MARKS**