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| **1.** | (a) | M1: gas molecules are in constant motion in random directionsM2: 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 collisionsM3: the total energy of the particles in a closed system remains constant at a given temperatureM4: the average kinetic energy of the particles is directly proportional to the temperatureAny 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 temperaturesM5: gases which are small, light and monatomic (any two)[5] |
| **2.** | (a) | M1: PV = nRTM2: An equation which relates the physical state of a material to physical conditions |
|  | (b) | M3: PV = $\frac{mRT}{m\_{r}}$ so $\frac{m}{V}$ = ρ = $\frac{Pm\_{r}}{RT}$ = (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 containerforce on container = change in momentum per unit timeM5: change in momentum = 2mvx and time between collisions = 2l/vxM6: so force per collision = $\frac{mv\_{x}^{2}}{l}$ but particle is also colliding with opposite wall so F = $\frac{2mv\_{x}^{2}}{l}$M7: so total force per collision in all dimensions = $\frac{2mv\_{x}^{2}}{l}$ + $\frac{2mv\_{y}^{2}}{l}$ + $\frac{2mv\_{z}^{2}}{l}$ = $\frac{2mu^{2}}{l}$M8: so total force = $\frac{2mNu^{2}}{l}$ = $\frac{2m\_{r}nu^{2}}{l}$M9: P = F/A, A = 6l2 so P = $\frac{2m\_{r}nu^{2}}{6l^{3}}$ = $\frac{2m\_{r}nu^{2}}{6V}$ = $\frac{m\_{r}nu^{2}}{3V}$ so PV = $\frac{m\_{r}nu^{2}}{3}$ |
|  | (d) | (i) | M10: KE = $\frac{mNu^{2}}{2}$ = $\frac{m\_{r}nu^{2}}{2}$ = nkTM11: So $\frac{2nkT}{3}$ = $\frac{m\_{r}nu^{2}}{3}$ = PVM12: If $\frac{2k}{3}$ = R, then PV = nRT |
|  |  | (ii) | M13: KE = nkTM14: $\frac{2k}{3}$ = R so k = $\frac{3R}{2}$ so KE = $\frac{3nRT}{2}$ |
|  | (e) | M15: Δ(KE) = $\frac{3nRΔT}{2}$ so $\frac{Δ(KE)}{nΔT}$ = $\frac{3R}{2}$ = CvM16: At constant pressure, must do additional work to expand gas: Work = PΔV = nRΔTM17: $\frac{Δ(work)}{nΔT}$ = R; so Cp = Cv + R = $\frac{5R}{2}$Max 15 marks[15] |
| **3.** | (a) | M1: Mr (butane) = 58 and mr (oxygen) = 32M2: pbut = $\frac{n\_{but}RT}{V}$ = (5/58 x 8.31 x 353 / 0.01)M3: = 25.3 kPaM4: pox = $\frac{n\_{ox}RT}{V}$ = (10/32 x 8.31 x 353 / 0.01)= 91.7 kPaM5: P = pbut + pox = 117 kPa |

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|  | (b) | M6: KE = $\frac{3nRT}{2}$ = 3/2 x 10/32 x 8.31 x 353M7: = 1.38 kJ |
|  | (c) | M8: $\frac{3nRT}{2}$ = $\frac{m\_{r}nu^{2}}{2}$ so 3RT = mru2 so u =$\sqrt{\frac{3RT}{m\_{r}}}$M9: u = √(3 x 8.31 x 353 / 0.032)M10: = 524 ms-1[10] |
| **4.** | (a) |  | M1: probability or N labelled on y-axisM2: velocity or speed labelled on x-axisM3: line through originM4: decreasing gradually to p = 0 after maximum and with a tail on the RHS |
|  | (b) | M5: Starts at origin and line lower than (a) initiallyM6: Peak lower than (a) and to the rightM7: Line always above (a) after peakAll 3 = 2, any 2 = 1 |
|  | (c) | M8: Starts at origin and line higher than (a) initiallyM9: Peak higher than (a) and to the leftM10: Line always below (a) after peakAll 3 = 2, any 2 = 1 |
|  | (d) | M11: Maxwell: entropy contributionM12: more ways for greater energy states to exist so they are more probableM13: Boltzmann: enthalpy contributionM14: probability of a single high energy state existing decreases exponentially with increasing energy |
|  | (e) | M15: vrms =$\sqrt{\frac{3RT}{m\_{r}}}$ = √(3 x 8.31 x 273 / 0.016) = 652 ms-1M16: vav =$\sqrt{\frac{8RT}{πm\_{r}}}$ = √(8/π x 8.31 x 273 / 0.016) = 601 ms-1M17: vmp =$\sqrt{\frac{2RT}{m\_{r}}}$ = √(2 x 8.31 x 273 / 0.016) = 533 ms-1  [15] |

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| **5.** | (a) | M1: Collision area = πd2M2: Relative velocity of molecules = v√2M3: Collision volume per second = πd2v√2M4: N/V x πd2v√2 = $\frac{πd^{2}vN\sqrt{2}}{V}$ |
|  | (b) | (i) | M5: Total number of colliding particles per unit volume per second = N/V x $\frac{πd^{2}vN\sqrt{2}}{V}$ = $\frac{πd^{2}vN^{2}\sqrt{2}}{V^{2}}$ = $(\frac{N}{V})^{2}$πd2v√2M6: Number of collisions per unit volume per second = $(\frac{N}{V})^{2}$ $\frac{πd^{2}v\sqrt{2}}{2}$ = $\left(\frac{N}{V}\right)^{2}\frac{πd^{2}v}{\sqrt{2}}$ |
|  |  | (ii) | M7: Distance travelled between collisions = velocity x time and time interval between collisions = $\frac{V}{πd^{2}vN\sqrt{2}}$M8: Distance travelled between collisions = $\frac{V}{πd^{2}vN\sqrt{2}}$ x v = $\frac{1}{\frac{N}{V}πd^{2}\sqrt{2}}$ |
|  | (c) | Calculate the mean free path, and the collision frequency per unit volume, in a vessel containing N2O4 at 40 oC and 1 kPaM9: 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-1M10: vav =$\sqrt{\frac{8RT}{πm\_{r}}}$ = √(8/π x 8.31 x 313 / 0.092) = 267 ms-1No further calculations possible as d not given[10] |

**TOTAL 55 MARKS**