2. Gas (6 points) — *Solution by Jaan Kalda.*

i) *(2 points)* Immediately after stopping, all the gas molecules move with the speed v. In the box's frame, the total energy of the molecules is conserved, so the average energy of each of the molecules is conserved, too: $\langle T\rangle = mv^2/2$. On the other hand, after thermalisation, this will be equal to $\frac{3}{2}kT$, hence $T = \frac{1}{3}mv^2/k = \frac{1}{3}\mu v^2/R$.

Grading: relating final average energy of the molecules to the initial energy in the box's frame or in another way showing that this energy gives rise to the temperature: 1 pt; relating this to the internal energy of monomolecular gas: 0.5 pt; expressing final answer: 0.5 pt. Solutions which used $\frac{1}{2}kT$ or kT instead of $\frac{3}{2}kT$ as the internal energy but otherwise correct get 1.5 pts.

ii) *(2 points)* Immediately after stopping, all the molecules move towards the wall with the same speed v. Hence, during time interval t, the molecules inside the near-wall region of thickness vt and volume $W = Avt$ (where A stands for the area of the wall) are hitting the wall. There are $N = \nu N_a W/V = \nu N_a Avt/V$ such molecules. After hitting, the molecules depart from the wall with the opposite velocity, hence each of them transfers momentum $\Delta p_0 = 2mv$ to the wall. So, the total transferred momentum is $\Delta p = N\Delta p_0 = 2\nu N_a Amv^2t/V$ which corresponds to the pressure $P = \Delta p/At = 2\nu N_a mv^2/V = 2\nu\mu v^2/V$.

Grading: expressing the number of molecules hitting a wall during time period t: 0.5 pts; finding the momentum transferred by each molecule: 0.5 pts; expressing the pressure in terms of the transferred momentum: 0.5 pts; bringing all these components together to get the final answer: 0.5 pts. Solutions that forget that particles obtain a velocity $-v$ after bouncing on the wall that are otherwise correct get 1.5 pts in total.

iii) *(2 points)* Fast molecules escape the trapping region, only molecules whose x-, y-, and z-components of velocity are smaller by modulus than $u = \frac{1}{2}V^{1/3}/\tau = 100\,\mathrm{m/s}$ get trapped. This is much smaller than the thermal speed $v_T = \sqrt{RT/\mu} \approx 790\,\mathrm{m/s}$. In that range of velocities, the Maxwell distribution is almost constant, hence we may assume that the trapped molecules have velocity components evenly distributed from $-u$ to u. Hence,

$$\left\langle v_x^2 \right\rangle = \frac{1}{u}\int_0^u u^2 \mathrm{d}u = \frac{1}{3}u^2,$$

so that the total average kinetic energy is $\frac{1}{2}m(v_x^2+v_y^2+v_z^2) = \frac{1}{2}mu^2$. On the other hand, this is equal to $\frac{3}{2}kT$, hence $T = \frac{1}{3}mu^2/k = \frac{1}{3}\mu u^2/R \approx 1.6\,\mathrm{K}$.

Grading: realising that only slow molecules get trapped: 0.3 pts; finding the maximal velocity projection of trapped molecules: 0.3 pts; noting that velocity distribution function of trapped molecules is a constant: 0.3 pts; finding $\left\langle v_x^2 \right\rangle$: 0.3 pts; expressing hence the kinetic energy: 0.2 pts; relating this to $\frac{3}{2}kT$: 0.3 pts bringing all these components together to get the final answer: 0.3 pts.