4(a)(i)	thermodynamic temperature
4(a)(ii)	molar gas constant
4(b)(i)	*m*: mass of one molecule (of the gas)
	$\langle c^2 \rangle$: mean-square speed (of molecules)
4(b)(ii)	$NBT / A = \frac{1}{3} Nm\langle c^2 \rangle$
	clear use of $E_K = \frac{1}{2} m\langle c^2 \rangle$ leading to $E_K = 3BT / 2A$
4(c)	line with positive gradient passing through the origin
	smooth curve with decreasing positive gradient

3(a)	(gas that obeys) $pV \propto T$ (at all values of *p*, *V* and *T*)
	where *T* is thermodynamic temperature
3(b)(i)	$pV = ⅓\, Nm\langle c^2 \rangle$ **and** $Nm / V = \rho$ $(p = ⅓\, \rho \langle c^2 \rangle)$
	r.m.s. speed = $\sqrt{\langle c^2 \rangle}$
	$1.6 \times 10^5 = ⅓ \times 1.9 \times \langle c^2 \rangle$ leading to r.m.s. speed = 500 m s^{-1} **or** r.m.s. speed = $\sqrt{(3 \times 1.6 \times 10^5 / 1.9)}$ = 500 m s^{-1}
3(b)(ii)	$(pV =)\ ⅓\, Nm\langle c^2 \rangle = NkT$ (so) $½\, m\langle c^2 \rangle = (3 / 2)\, kT$
	$½ \times 4.7 \times 10^{-26} \times 503^2 = (3 / 2) \times 1.38 \times 10^{-23} \times T$ T = 290 K
	or
	$pV = NkT$ **and** $Nm / V = \rho$ (so) $T = pm / \rho k$
	$T = 1.6 \times 10^5 \times 4.7 \times 10^{-26} / (1.9 \times 1.38 \times 10^{-23})$ = 290 K
3(c)	potential energy (of molecules) is zero
	$U = N \times ½\, m\langle c^2 \rangle = 6.0 \times 6.02 \times 10^{23} \times ½ \times 4.7 \times 10^{-26} \times 503^2$ **or** $U = N \times (3 / 2)\, kT = 6.0 \times 6.02 \times 10^{23} \times (3 / 2) \times 1.38 \times 10^{-23} \times 287$ **or** $U = n \times (3 / 2)\, RT = 6.0 \times (3 / 2) \times 8.31 \times 287$
	U = 21000 J

4(a)	• particles are in (continuous) random motion • particles have negligible volume (compared with the gas) • negligible forces between particles (except during collisions) • (all) collisions (perfectly) elastic • time of collision negligible (in comparison with time between collisions) *Any two points, 1 mark each*
4(b)(i)	(general starting equation) $pV = nRT$
	$T = (2pV / nR)$ where *R* is the (molar) gas constant
4(b)(ii)	sketch: straight vertical line XY from (*V*, 2*p*) to (*V*, *p*)
	straight horizontal line YZ from (*V*, *p*) to (2*V*, *p*)
	curve with gradient increasing from Z to X from (2*V*, *p*) to (*V*, 2*p*)
4(b)(iii)	XY work done on gas correct (= 0)
	ZX increase in internal energy correct (= 0)
	YZ work done on gas correct (= $-pV$)
	XY increase in internal energy such that the increase in internal energy column adds up to zero
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: (see table below))

change	ΔU	Q	w
X to Y	$-U$	$-U$	0
Y to Z	[$+U$]	$U + pV$	$-pV$
Z to X	0	$-W$	[$+W$]