15. Ideal Gases

15.2 Equation of state

Paper 4

Marking Scheme

Q1.

(a)(i)	gas for which $pV \propto T$	**M1**
	where T is thermodynamic temperature	**A1**
(b)(i)	$pV = NkT$	**C1**
	$N = (2.0 \times 10^5 \times 0.26) / (1.38 \times 10^{-23} \times 290)$ $= 1.3 \times 10^{25}$	**A1**

Q2.

(b)(i)	$pV = nRT$	**C1**
	$T = (1.20 \times 10^5 \times 0.0260) / (0.740 \times 8.31)$ (= 507 K)	**M1**
	temperature = 507 – 273 = 234 °C	**A1**
(b)(ii)	thermal equilibrium so temperatures (of X and Y) are equal	**B1**
	$pV = NkT$	**C1**
	$N = (2.90 \times 10^5 \times 0.0430) / (1.38 \times 10^{-23} \times 507)$ $= 1.78 \times 10^{24}$	**A1**

Q3.

(a)(ii)	$N_A = R / k$	**B1**
(b)(i)	X pressure and Y pressure both = NkT / V	**B1**
	X amount = N / N_A **and** Y amount = $2N / N_A$	**B1**
	X mean-square speed = $3kT / m$ **and** Y mean-square speed = $3kT / 2m$	**B1**
	X internal energy = $3NkT / 2$ **and** Y internal energy = $3NkT$	**B1**

Q4.

(b)(i)	(general starting equation) $pV = nRT$	**C1**
	$T = (2pV / nR)$ where R is the (molar) gas constant	**A1**

Q5.

(a)(i)	(gas that obeys) $pV \propto T$ (for all values of p, V and T)	**M1**
	where T is thermodynamic temperature	**A1**
(b)(i)	$pV = NkT$	**C1**
	$N = (1.37 \times 10^5 \times 0.640) / (1.38 \times 10^{-23} \times (227 + 273))$	**C1**
	$= 1.27 \times 10^{25}$	**A1**

Q6.

(a)(i)	a gas that obeys $pV \propto T$	**M1**
	where p = pressure, V = volume, T = thermodynamic temperature	**A1**
(a)(ii)	$T = (273 + 17)$ K	**C1**
	$n = pV / RT$ $= (1.2 \times 10^5 \times 0.24) / [8.31 \times (273 + 17)]$ = 12 mol	**A1**

Q7.

(b)(ii)	$pV = nRT$ **and** $T = 373$ K	**C1**
	$n = 370 / 18$	**C1**
	$V = [(370 / 18) \times 8.31 \times 373] / (1.0 \times 10^5) = 0.64$ m^3	**A1**

Q8.

(a)	p = pressure (of gas), V = volume (of gas) **and** k = Boltzmann constant	**B1**
	N = number of molecules	**B1**
	T = thermodynamic temperature	**B1**

Q9.

(a)	$pV = NkT$	**C1**
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5) / (1.38 \times 10^{-23} \times 310) = 1.4 \times 10^{23}$	**A1**
	or	
	$pV = nRT$ **and** $nN_A = N$	**(C1)**
	$N = (1.8 \times 10^{-3} \times 3.3 \times 10^5 \times 6.02 \times 10^{23}) / (8.31 \times 310) = 1.4 \times 10^{23}$	**(A1)**

Q10.

(a)	$pV = nRT$	**C1**
	$pV = nRT$ **and** $N = nN_A$ **or** $pV = NkT$	**C1**
	$3.1 \times 10^{-3} \times 8.5 \times 10^5 = (N \times 290 \times 8.31) / (6.02 \times 10^{23})$ so $N = 6.6 \times 10^{23}$ **or** $3.1 \times 10^{-3} \times 8.5 \times 10^5 = N \times 1.38 \times 10^{-23} \times 290$ so $N = 6.6 \times 10^{23}$	**A1**
(b)(i)	$(3.1 \times 10^{-3} \times 8.5 \times 10^5) / 290 = (6.3 \times 10^{-3} \times 2.7 \times 10^5) / T$ so $T = 190$ K **or** $6.3 \times 10^{-3} \times 2.7 \times 10^5 = 6.6 \times 10^{23} \times 1.38 \times 10^{-23} \times T$ so $T = 190$ K	**A1**

Q11.

(b)(i)	(T =) pV / Nk	**B1**

Q12.

(b)	$pV = NkT$	**C1**
	$N = (3.0 \times 10^5 \times 6.0 \times 10^{-3}) / (1.38 \times 10^{-23} \times 290)$	**C1**
	$= 4.5 \times 10^{23}$	**C1**
	mass $= 20.7 / (4.5 \times 10^{23})$ $= 4.6 \times 10^{-23}$ g	**A1**

Q13.

(b)(i)	$pV = nRT$	**C1**
	$2.60 \times 10^5 \times 2.30 \times 10^{-3} = n \times 8.31 \times 180$ $n = 0.400$ mol	**A1**
(b)(ii)	$(2.30 \times 10^{-3}) / 180 = (3.80 \times 10^{-3}) / T$ **or** $2.60 \times 10^5 \times 3.80 \times 10^{-3} = 0.400 \times 8.31 \times T$	**C1**
	$T = 297$ K	**A1**

Q14.

(a)(i)	$pV = nRT$	**C1**
	$n = (3.0 \times 10^5 \times 210 \times 10^{-6}) / (8.31 \times 270)$	**C1**
	$= 0.028$ mol	**A1**
(a)(ii)	$V \propto T$ **or** $T = pV / nR$ with value of n from **(i)**	**C1**
	$T = (140 / 210) \times 270$ **or** $T = (3.0 \times 10^5 \times 140 \times 10^{-6}) / (8.31 \times 0.028)$ $= 180$ K	**A1**

Q15.

(b)(i)	$pV = NkT$	**C1**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = N \times 1.38 \times 10^{-23} \times (273 + 23)$	**C1**
	or	
	$pV = nRT$	**(C1)**
	$4.60 \times 10^5 \times 2.40 \times 10^{-2} = n \times 8.31 \times (273 + 23)$ $n = 4.49$ (mol) $N = nN_A$ $= 4.49 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.7 \times 10^{24}$	**A1**

Q16.

(b)(i)	$pV = nRT$	**C1**
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (8.31 \times 310)$	**C1**
	or	
	$pV = NkT$	**(C1)**
	$n = (3.51 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 290)$ **or** $n = (3.75 \times 10^5 \times 2.40 \times 10^{-3}) / (1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 310)$	**(C1)**
	$n = 0.350$ mol **or** 0.349 mol	**A1**

Q17.

(b)	$pV = NkT$	**C1**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	**C1**
	or	
	$pV = nRT$ **and** $N = n \times N_A$	**(C1)**
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.8 \times 10^{25}$	**A1**

Q18.

(b)(ii)	kelvin/thermodynamic/absolute temperature	**B1**
(c)(i)1.	$pV = NkT$	**C1**
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = N \times 1.38 \times 10^{-23} \times 446$	**C1**
	or	
	$pV = nRT$ **and** $N = nN_A$ $4.7 \times 10^{-2} \times 2.6 \times 10^5 = n \times 8.31 \times 446$ $n = 3.3$ (mol)	**(C1)**
	$N = 3.3 \times 6.02 \times 10^{23}$	**(C1)**
	$N = 2.0 \times 10^{24}$	**A1**
(c)(i)2.	average increase $= 2900 / (2.0 \times 10^{24})$ $= 1.5 \times 10^{-21}$ J	**A1**

Q19.

(a)	gas that obeys equation pV = constant $\times T$	**M1**
	symbols p, V and T explained	**A1**
(b)(ii)	**1.** $pV = nRT$ **and** $T = (22 + 273)$ K	**C1**
	$n = (2.12 \times 10^7 \times 1.84 \times 10^{-2}) / (8.31 \times 295)$ $= 159$ mol	**A1**
	2. mass $= 3.20 / (159 \times 6.02 \times 10^{23})$ **or** mass $= [2 \times (3/2) \times 1.38 \times 10^{-23} \times 295] / 605^2$	**C1**
	mass $= 3.34 \times 10^{-26}$ kg	**A1**