CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



MARK SCHEME

16 THERMODYNAMICS

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	Answer	Marks
(c)(ii)	$\langle c^2 \rangle \propto T$	C1
	$\langle c^2 \rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	C1
	$c_{r.m.s.}$ at 177 °C = 1.68×10^3 m s^{-1}	A1

51. 9702_m21_MS_42 Q: 3

	Answer	Marks
(a)	Any 2 from: • particles / atoms / molecules / ions (very) close together / touching • regular, repeating pattern • vibrate about a fixed point	B2
(b)	(much) greater increase in spacing of molecules (for vaporisation compared with fusion)	B1
(c)(i)	–100 °C	B1

	Answer	Marks
(c)(ii)	time = 8.5 – 3.0 = 5.5 min	C1
	$Pt = mL$ energy = power × time = 150 × 5.5 × 60 = 49 500 J $L = \frac{E}{m}$ $= \frac{49500}{0.045}$	C1
	$= 1100\,kJ\,kg^{-1}$	A1
(c)(iii)	gas has a higher specific heat capacity (than liquid)	B1

52. 9702_m20_MS_42 Q: 2

	Answer	Marks
(a)	n = 110 / 0.032 or 110000 / 32 or 3440	C1
	$pV = nRT$	C1
	$T = (1.0 \times 10^5 \times 85) / (8.31 \times (110 / 0.032)) = 300$ K	A1
(b)	$E = mc\Delta\theta$ $= 110 \times 0.66 \times 50$	C1
	= **3600** J	A1
(c)	Any 3 from: • molecule collides with wall • momentum of molecule changes during collision (with wall) • force on molecule so force on wall • many forces act over surface area of container exerting a pressure	B3
(d)	$KE \propto T$ $v \propto \sqrt{T}$	C1
	ratio = √(350 / 300) = **1.1**	A1

53. 9702_w19_MS_41 Q: 3

	Answer	Marks
(a)	(thermal) energy per (unit) mass (to change state)	**B1**
	(heat transfer during) change of state at constant temperature	**B1**
(b)(i)	32 g	**A1**
(b)(ii)	temperature difference (between liquid and surroundings) does not change	**B1**
(b)(iii)	$VIt = mL$	**C1**
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	**C1**
	$86 \times 600 = (56 - 32) \times L$	**C1**
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	**(C1)**
	$276 - 190 = (24 \times L) / 600$	**(C1)**
	$L = 2200\ \text{J g}^{-1}$	**A1**

	Answer	Marks
(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ **or** $190 \times 1.0 \times 600 = (32 \times 2150) + H$	**C1**
	$H = 45200$ rate = 45200 / 600 = 75 W	**A1**
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	**(C1)**
	rate (= P) = 75 W	**(A1)**

54. 9702_w19_MS_42 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to change state)	**B1**
	change of state without any change of temperature	**B1**
(b)(i)	140 g	**A1**
(b)(ii)	temperature difference (between apparatus and surroundings) does not change	**B1**
(b)(iii)	$VIt = mL$	**C1**
	$(\{15.1 \times 3.6\} + R) \times 600 = 140 \times L$ **or** $(\{7.3 \times 1.8\} + R) \times 600 = 65 \times L$	**C1**
	$41.22 \times 600 = 75 \times L$	**C1**
	$L = 330\ \text{J g}^{-1}$	**A1**
(b)(iv)	$15.1 \times 3.6 \times 600 = (140 \times 330) - H$ **or** $7.3 \times 1.8 \times 600 = (65 \times 330) - H$	**C1**
	$H = 13600$ rate of gain = 13600 / 600 = 23 W	**A1**

55. 9702_w19_MS_43 Q: 3

	Answer	Marks
(a)	(thermal) energy per (unit) mass (to change state)	B1
	(heat transfer during) change of state at constant temperature	B1
(b)(i)	32 g	A1
(b)(ii)	temperature difference (between liquid and surroundings) does not change	B1
(b)(iii)	$VIt = mL$	C1
	$230 \times 1.2 \times 60 \times 10 = (56 \times L) + H$ **or** $190 \times 1.0 \times 60 \times 10 = (32 \times L) + H$	C1
	$86 \times 600 = (56 - 32) \times L$	C1
	or	
	$230 \times 1.2 = (56 \times L) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times L) / (60 \times 10) + P$	(C1)
	$276 - 190 = (24 \times L) / 600$	(C1)
	$L = 2200\ \text{J g}^{-1}$	A1

	Answer	Marks
(b)(iv)	$230 \times 1.2 \times 600 = (56 \times 2150) + H$ **or** $190 \times 1.0 \times 600 = (32 \times 2150) + H$	C1
	$H = 45\,200$ rate = 45 200 / 600 = 75 W	A1
	or	
	$230 \times 1.2 = (56 \times 2150) / (60 \times 10) + P$ **or** $190 \times 1.0 = (32 \times 2150) / (60 \times 10) + P$	(C1)
	rate (= P) = 75 W	(A1)

56. 9702_s18_MS_42 Q: 3

	Answer	Marks
(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
(b)(i)	($\Delta Q =$) $mc\Delta\theta$	C1
	loss = $(160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ = 2.3×10^4 J	A1
(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$ $L = 350\ \text{J g}^{-1}$	A1

57. 9702_w18_MS_42 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause change of state)	B1
	(energy transfer during) change of state between solid and liquid at constant temperature	B1
(b)(i)	Any one from: • rate of increase in mass (of beaker and water) is constant • level of water rises at a constant rate • volume of water (in beaker) increases at a constant rate • constant time between drops • constant rate of dripping	B1
(b)(ii)	(electrical power supplied =) 12.8×4.60 (= 58.9 W)	C1
	(rate of transfer to ice =) $[(185.0 - 121.5) \times 332] / [5.00 \times 60]$ (= 70.3 W)	C1
	1. rate = 70.3 W	A1
	2. rate = 70.3 – 58.9 = 11.4 W	A1

58. 9702_s17_MS_42 Q: 2

	Answer	Marks
(a)(i)	mean/average square speed/velocity	B1
(a)(ii)	$pV = NkT$ **or** $pV = nRT$	B1
	$\rho = Nm / V$ **or** $\rho = nN_Am / V$ **and** $k = nR / N$	B1
	$E_K = \frac{1}{2} m\langle c^2 \rangle$ with algebra to $(3 / 2)kT$	B1
(b)(i)	no (external) work done **or** $\Delta U = q$ **or** $w = 0$	B1
	$q = N_A \times (3 / 2)k \times 1.0$	M1
	$N_Ak = R$ so $q = (3 / 2)R$	A1
(b)(ii)	specific heat capacity = $\{(3 / 2) \times R\} / 0.028$	C1
	= 450 J kg^{-1} K^{-1}	A1

59. 9702_w17_MS_41 Q: 1

	Answer	Marks
(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	B1
(a)(ii)	uses a property (of a substance) that changes with temperature	B1
(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	B2
(c)(i)	$Pt = mc(\Delta)\theta$	C1
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	M1
	$\Delta\theta = 56$ °C so final temperature = 56 + 24 = 80 °C	A1
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	(M1)
	so final temperature or $\theta = 80$ °C	(A1)

	Answer	Marks
(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J loss = (95 × 6 × 60) – 24400 = 9800 J	**(A1)**

60. 9702_w17_MS_43 Q: 1

	Answer	Marks
(a)(i)	direction or rate of transfer of (thermal) energy **or** (if different,) not in thermal equilibrium/energy is transferred	**B1**
(a)(ii)	uses a property (of a substance) that changes with temperature	**B1**
(b)	• temperature scale assumes linear change of property with temperature • physical properties may not vary linearly with temperature • agrees only at fixed points *Any 2 points.*	**B2**
(c)(i)	$Pt = mc(\Delta)\theta$	**C1**
	$95 \times 6 \times 60 = 0.670 \times 910 \times \Delta\theta$	**M1**
	$\Delta\theta = 56$ °C so final temperature = 56 + 24 = 80 °C	**A1**
	or	
	$95 \times 6 \times 60 = 0.67 \times 910 \times (\theta - 24)$	**(M1)**
	so final temperature or $\theta = 80$ °C	**(A1)**

	Answer	Marks
(c)(ii)	**1.** sketch: straight line from (0,24) to (6,80)	**B1**
	2. temperature drop due to energy loss = (80 – 64) = 16 °C	**C1**
	energy loss = 0.670 × 910 × (80 – 64) = 9800 J	**A1**
	or	
	energy to raise temperature to 64 °C = 0.670 × 910 × (64 – 24)	**(C1)**
	= 24400 J loss = (95 × 6 × 60) – 24400 = 9800 J	**(A1)**

61. 9702_s21_MS_41 Q: 2

	Answer	Marks
(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)**
(b)	speed of molecule decreases on impact with moving piston	**B1**
	mean square speed (directly) proportional to (thermodynamic) temperature **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature	**B1**
	kinetic energy (of molecules) decreases (so temperature decreases)	**B1**
(c)(i)	$\Delta U = 3/2 \times k \times \Delta T \times N$	**C1**
	$= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$	**C1**
	= – 64 J	**A1**
(c)(ii)	decrease in internal energy is less than work done by gas	**M1**
	(thermal energy is) transferred to the gas (during the expansion)	**A1**

62. 9702_s21_MS_42 Q: 2

	Answer	Marks
(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
(b)(ii)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (190 - 290) \times 6.6 \times 10^{23}$	C1
	$= -1400$ J	A1
(c)	$\Delta U = q + w$	M1
	$q = 0$ so $\Delta U = w$	A1

63. 9702_s21_MS_43 Q: 2

	Answer	Marks
(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)
(b)	speed of molecule decreases on impact with moving piston	B1
	mean square speed (directly) proportional to (thermodynamic) temperature **or** mean square speed (directly) proportional to kinetic energy (of molecules) **or** kinetic energy (of molecules) (directly) proportional to (thermodynamic) temperature	B1
	kinetic energy (of molecules) decreases (so temperature decreases)	B1
(c)(i)	$\Delta U = 3/2 \times k \times \Delta T \times N$	C1
	$= 3/2 \times 1.38 \times 10^{-23} \times (288 - 310) \times 1.4 \times 10^{23}$	C1
	$= -64$ J	A1
(c)(ii)	decrease in internal energy is less than work done by gas	M1
	(thermal energy is) transferred to the gas (during the expansion)	A1

64. 9702_w21_MS_41 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	(T =) pV / Nk	B1
(b)(ii)	(pV =) $NkT = \frac{1}{3}Nm\langle c^2\rangle$ **or** $pV = NkT$ **and** $pV = \frac{1}{3}Nm\langle c^2\rangle$	M1
	leading to $\frac{1}{2}m\langle c^2\rangle = (3/2)kT$ and $\frac{1}{2}m\langle c^2\rangle = E_K$	A1
(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) **or** no forces between molecules	B1
	potential energy of molecules is zero	B1
(c)(i)	increase in internal energy = Q + work done	B1
	constant volume so no work done	B1
(c)(ii)	$c = Q / Nm\Delta T$	C1
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	A1
(d)	(as it expands) gas does work (against the atmosphere/external pressure)	B1
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	B1

65. 9702_w21_MS_43 Q: 3

	Answer	Marks
(a)	(thermal) energy per unit mass (to cause temperature change)	B1
	(thermal) energy per unit change in temperature	B1
(b)(i)	(T =) pV / Nk	B1
(b)(ii)	(pV =) $NkT = \frac{1}{3}Nm\langle c^2\rangle$ **or** $pV = NkT$ **and** $pV = \frac{1}{3}Nm\langle c^2\rangle$	M1
	leading to $\frac{1}{2}m\langle c^2\rangle = (3/2)kT$ and $\frac{1}{2}m\langle c^2\rangle = E_K$	A1
(b)(iii)	internal energy = ΣE_K (of molecules) + ΣE_P (of molecules) **or** no forces between molecules	B1
	potential energy of molecules is zero	B1
(c)(i)	increase in internal energy = Q + work done	B1
	constant volume so no work done	B1
(c)(ii)	$c = Q / Nm\Delta T$	C1
	$= [N \times (3/2)k\Delta T] / (Nm\Delta T) = 3k / 2m$	A1
(d)	(as it expands) gas does work (against the atmosphere/external pressure)	B1
	for same temperature rise) more (thermal) energy needed, so larger specific heat capacity	B1

66. 9702_s20_MS_41 Q: 2

	Answer	Marks
(a)	total potential energy and kinetic energy (of molecules/atoms)	M1
	reference to random motion of molecules/atoms	A1
(b)	(in ideal gas,) no intermolecular forces	B1
	no potential energy (so change in kinetic energy is change in internal energy)	B1
(c)	(random) potential energy of molecules does not change	M1
	(random) kinetic energy of molecules does not change	M1
	so internal energy does not change	A1
	or	
	decrease in total potential energy = gain in total kinetic energy	(M1)
	no external energy supplied	(M1)
	so internal energy does not change	(A1)
	or	
	no compression (of ball) so no work done on the ball	(M1)
	no resistive forces so no heating of the ball	(M1)
	so internal energy does not change	(A1)

	Answer	Marks
(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	(M1)
	no temperature rise so kinetic energy (of molecules) unchanged	(M1)
	so internal energy does not change	(A1)

67. 9702_s20_MS_42 Q: 3

	Answer	Marks
(a)	(little/no volume change so) little/no external work done	B1
	thermal energy supplied to provide latent heat	M1
	internal energy increases	A1
(b)	(rapid) increase in volume	B1
	gas does work against the atmosphere	M1
	internal energy decreases	A1

68. 9702_s20_MS_43 Q: 2

	Answer	Marks
(a)	total potential energy and kinetic energy (of molecules/atoms)	M1
	reference to random motion of molecules/atoms	A1
(b)	(in ideal gas,) no intermolecular forces	B1
	no potential energy (so change in kinetic energy is change in internal energy)	B1
(c)	(random) potential energy of molecules does not change	M1
	(random) kinetic energy of molecules does not change	M1
	so internal energy does not change	A1
	or	
	decrease in total potential energy = gain in total kinetic energy	(M1)
	no external energy supplied	(M1)
	so internal energy does not change	(A1)
	or	
	no compression (of ball) so no work done on the ball	(M1)
	no resistive forces so no heating of the ball	(M1)
	so internal energy does not change	(A1)

	Answer	Marks
(c)	**or**	
	no change of state so potential energy (of molecules) unchanged	(M1)
	no temperature rise so kinetic energy (of molecules) unchanged	(M1)
	so internal energy does not change	(A1)

69. 9702_s19_MS_41 Q: 2

	Answer	Marks
(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
(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21$ J	A1

	Answer	Marks
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32\ \text{J}$	A1

70. 9702_s19_MS_42 Q: 2

	Answer	Marks
(a)(i)	**1.** energy transfer to the system by heating	B1
	2. (external) work done on the system	B1
(a)(ii)	decrease in internal energy	B1
(b)(i)	no change (in internal energy)	B1
	(because) no change in temperature	B1
(b)(ii)	work done $= p\Delta V$ $= (-)1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3}$	C1
	$= (-)240\ \text{J}$	A1
(b)(iii)	first row all correct (0, 480, 480)	A1
	second row all correct (–1100, 0, –1100)	A1
	final column of third row calculated correctly from the two values above it, so that the final column adds up to 0	A1
	second column in final row correct, with correct negative sign **and** first column in final row calculated correctly so that it adds to the second column to give the third column (fully correct table is: 0 | 480 | 480 –1100 | 0 | –1100 860 | –240 | 620)	A1

71. 9702_s19_MS_43 Q: 2

	Answer	Marks
(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
(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	C1
	$= 21$ J	A1

	Answer	Marks
(b)	$\Delta U = w + q$	C1
	$= 21 - 53$	C1
	or	
	$\Delta U = (nN_A) \times (3/2)k\Delta T$	(C1)
	$= (0.0281 \times 6.02 \times 10^{23}) \times (3/2) \times 1.38 \times 10^{-23} \times (180 - 270)$	(C1)
	or	
	$\Delta U = (3/2)nR\Delta T$	(C1)
	$= (3/2) \times 0.0281 \times 8.31 \times (180 - 270)$	(C1)
	$\Delta U = (-)32\ \text{J}$	A1

72. 9702_w19_MS_42 Q: 2

	Answer	Marks
(a)(i)	specks of light moving haphazardly	B1
(a)(ii)	(gas) molecules collide with (smoke) particles **or** random motion of the (gas) molecules	M1
	causes the (haphazard) motion of the smoke particles **or** causes the smoke particles to change direction	A1
(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
(b)(ii)	energy transfer $= (0.349$ **or** $0.35) \times 12.5 \times (310 - 290)$	C1
	$= 87.3$ J **or** 87.5 J	A1
(c)(i)	zero	A1
(c)(ii)	87.3 J **or** 87.5 J	A1
	increase	B1

73. 9702_m18_MS_42 Q: 2

	Answer	Marks
(a)	$pV = nRT$ $T = (5.60 \times 10^5 \times 3.80 \times 10^{-2}) / (5.12 \times 8.31)$	C1
	T = **500 K**	A1
(b)(i)	V / T is constant $V = (3.80 \times 10^4) \times (500 + 125) / 500$	C1
	V = **4.75** × **10^4** cm^3	A1
(b)(ii)	(for ideal gas,) change in internal energy is change in (total) kinetic energy (of molecules)	B1
	ΔU = 3 / 2 × 1.38 × 10^{-23} × 125 × 5.12 × 6.02 × 10^{23}	C1
	= **7980** J	A1
(c)(i)	w = $p\Delta V$ = 5.60 × 10^5 × (4.75 – 3.80) × 10^{-2}	C1
	= **5320** J	A1
(c)(ii)	total = 7980 + 5320 = **13300** J	A1

74. 9702_s18_MS_41 Q: 3

	Answer	Marks
(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
(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

75. 9702_s18_MS_43 Q: 3

	Answer	Marks
(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
(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

76. 9702_w18_MS_43 Q: 2

	Answer	Marks
(a)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
(b)(i)	final temperature = initial temperature	B1
	no change in internal energy	B1
(b)(ii)	**1.** work done on gas (P→Q): 0	A1
	increase in internal energy (P→Q): (+)97.0 J	A1
	2. increase in internal energy (Q→R): –42.5 J	A1
	3. increase in internal energy (R→P): –54.5 J	A1
	thermal energy supplied (R→P): –91.5 J	A1

77. 9702_m17_MS_42 Q: 2

	Answer	Marks
(a)	$+\Delta U$ increase in internal energy $+q$ heat (energy) transferred to the system / heating of system $+w$ work done on system	B2
(b)(i)	$W = p\Delta V$ $= 5.2 \times 10^5 \times (5.0 - 1.6) \times 10^{-4}$ (=177 J)	B1
	$\Delta U = q + w$ $= 442 - 177 = 265$ J	A1
(b)(ii)	no (molecular) potential energy	B1
	internal energy decreases so (total molecular) kinetic energy decreases	B1
	(mean molecular) kinetic energy decreases so temperature decreases	B1

	Answer	Marks
(b)(iii)	$\Delta U + 265 - 313 = 0$ $\Delta U = 48\,\text{J}$	A1
(b)(iv)	$pV = NkT$ or $pV = nRT$ and $N = nN_A$	C1
	$5.2\times10^5 \times 1.6\times10^{-4} = N \times 1.38\times10^{-23} \times (273 + 227)$ *or* $5.2\times10^5 \times 1.6\times10^{-4} = n \times 8.31 \times (273 + 227)$ and $n = N / 6.02\times10^{23}$ $N = 1.2 \times 10^{22}$	A1

78. 9702_w17_MS_42 Q: 2

	Answer	Marks
(a)	(thermal) energy per (unit) mass (to cause change of state)	B1
	(energy required to cause/released in) change of state at constant temperature	B1
(b)(i)	**1.** (work done on/against) the atmosphere	B1
	2. water as it turns from liquid to vapour	M1
	as potential energy of molecules increases	A1
	or	
	surroundings as its temperature rises	(M1)
	as energy is lost/transferred to surroundings	(A1)
(b)(ii)	$VI - h = M / t \times L$ (where h = power loss) **or** $L = (VIt - Q)/M$ (where Q = energy loss)	C1
	$(14.2 \times 6.4) - (11.5 \times 5.2) = (9.1 - 5.0) \times L/300$ **or** $L = [(14.2 \times 6.4) - (11.5 \times 5.2)] \times 300/(9.1 - 5.0)$	C1
	$L = 2300\,\text{J g}^{-1}$	A1

79. 9702_m16_MS_42 Q: 2

(a) (i) sum of kinetic and potential energy of atoms/molecules M1
reference to random (distribution) A1 [2]

(ii) no forces (of attraction or repulsion) between molecules B1 [1]

(b) $pV = NkT$ *or* $pV = nRT$ *and* $R = kN_A$, $n = N/N_A$ B1
$^1/_3\, Nm\langle c^2\rangle = NkT$ *or* $^1/_3\, m\langle c^2\rangle = kT$ B1
$\langle E_K\rangle = {}^1/_2\, m\langle c^2\rangle$ so $\langle E_K\rangle = {}^3/_2\, kT$ B1 [3]

(c) (i) $\langle E_K\rangle = {}^3/_2 \times 1.38 \times 10^{-23} \times (273 + 12)$ C1
$= 5.9\ (5.90) \times 10^{-21}\,\text{J}$ A1 [2]

(*use of* $T = 12\,\text{K}$ *not* $T = 285\,\text{K}$ scores 0/2)

(ii) number $= (17/32) \times 6.02 \times 10^{23}$ C1
$= 3.2\ (3.20) \times 10^{23}$ A1 [2]

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(iii) internal energy $= 5.9 \times 10^{-21} \times 3.2 \times 10^{23}$
$= 1900\ (1890)\,\text{J}$ A1 [1]

80. 9702_w16_MS_41 Q: 2

(a) (i) $p \propto T$ *or* pV/T = constant *or* $pV = nRT$ C1

$T\ (= 5 \times 300 =)\ 1500\ \text{K}$ A1 [2]

(ii) $pV = nRT$

$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$
or
$5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$ C1

$n = 0.016\ \text{mol}$ A1 [2]

(b) (i) 1. heating/thermal energy supplied B1

2. work done on/to system B1 [2]

(ii) 1. 240 J A1

2. same value as given in **1.** (= 240 J) **and** zero given for **3.** A1

3. zero A1 [3]

81. 9702_w16_MS_42 Q: 3

(a) (sum of/total) potential energy and kinetic energy of (all) molecules/particles M1
reference to random (distribution) A1 [2]

(b) (i) no heat enters (gas)/leaves (gas)/no heating (of gas) B1

work done by gas (against atmosphere as it expands) M1

internal energy decreases A1 [3]

(ii) volume decreases so work done on ice/water B1
(*allow work done negligible because* ΔV *small*)

heating of ice (to break rigid forces/bonds) M1

internal energy increases A1 [3]

82. 9702_w16_MS_43 Q: 2

(a) (i) $p \propto T$ *or* pV/T = constant *or* $pV = nRT$ C1

T (= 5 × 300 =) 1500 K A1 [2]

(ii) $pV = nRT$

$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$
or
$5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$ C1

n = 0.016 mol A1 [2]

(b) (i) 1. heating/thermal energy supplied B1

2. work done on/to system B1 [2]

(ii) 1. 240 J A1

2. same value as given in **1.** (= 240 J) **and** zero given for **3.** A1

3. zero A1 [3]

83. 9702_m21_MS_42 Q: 4

	Answer	Marks
(a)	acceleration and displacement are in opposite directions	**B1**
(b)(i)	$F = kx$ $= 8.0 \times (0.060 - 0.048)$ *or* $8.0 \times (0.060 + 0.048)$ or 8.0×0.012 *or* 8.0×0.108	**M1**
	$\Sigma F = (8.0 \times 0.012) - (8.0 \times 0.108) = 0.77\,N$ or $\Sigma F = 0.864 - 0.096 = 0.77\,N$	**A1**

Q1.

2	(a)	✗ ✗ ✓ ✓ (-1 for each error or omission) B2		[2]
	(b)	heat lost by liquid gold = $0.95m \times 129 \times \Delta T$ ..... C1 heat gained (silver) = $0.05m \times 235 \times (1340 - 300) + 0.05m \times 105\,000$..C1, C1 $122.5m\Delta T = 17\,470m$ $\Delta T = 143$ K ..... C1 temperature = 143 + 1340 = 1483 K A1		[5]
	(c)	e.g. thermocouple/resistance thermometer B1		[1]

Q2.

6	0	-	+	(-1 for each error)		B2	
	+	+	0	(-1 for each error)		B2	
	+	+	0	(-1 for each error)		B2	[6]
					Total		[6]

Q3.

3	(a)		(thermal) energy/heat required to convert unit mass/1 kg of solid to liquid	**M1**	
			with no change in temperature/at melting point	**A1**	**[2]**
	(b)	(i)	energy required to warm ice = $24 \times 10^{-3} \times 2.1 \times 10^{3} \times 15$ (= 756 J)	**C1**	
			energy required to melt ice at 0 °C = $24 \times 10^{-3} \times 330 \times 10^{3}$ (= 7920 J)	**C1**	
			total energy = 8700 J	**A1**	**[3]**
		(ii)	energy lost by warm water = $200 \times 10^{-3} \times 4.2 \times 10^{3} \times (28 - T)$	**C1**	
			$200 \times 4.2 \times (28 - T) = 24 \times 4.2 \times T + 8676$	**C1**	
			T = 16 °C	**A1**	**[3]**
			[allow 2 marks if ΔT calculated]		
			[allow 2 marks if (24 x 4.2 x T) omitted]		
			[allow 1 mark for 224 x 4.2 x (28 - T) = 8676, T - 19 °C]		

Q4.

3	(a)	gradient of graph is (a measure of) the sensitivity	M1	
		the gradient varies with temperature	A1	**[2]**
	(b)	2040 ± 20 Ω corresponds to 15.0 ± 0.2 °C	C1	
		T / K = T / °C + 273.15 (allow 273.2)	C1	
		temperature is 288.2 K	A1	**[3]**

Q5.

2 (a) (on melting,) bonds between molecules are broken/weakened
or molecules further apart/are able to slide over one another B1
kinetic energy unchanged so no temperature change B1
potential energy increased/changed so energy required B1 [3]

(b) thermal energy/heat required to convert unit mass of solid to liquid M1
with no change in temperature/ at its normal boiling point A1 [2]

(c) (i) thermal energy lost by water = $0.16 \times 4.2 \times 100$
$= 67.2$ kJ C1
$67.2 = 0.205 \times L$ C1
$L = 328$ kJ kg^{-1} A1 [3]

(ii) more energy (than calculated) melts ice M1
so, (calculated) L is lower than the accepted value A1 [2]

Q6.

3 (a) increasing separation of molecules / breaking bonds between molecules B1
(allow atoms/molecules, overcome forces)
doing <u>work</u> against atmosphere (during expansion) B1 [2]

(b) (i) 1 *either* bubbles produced at a <u>constant rate</u> / mass evaporates/lost at <u>constant rate</u>
or find mass loss more than once and this rate should be constant
or temperature of liquid remains constant B1 [1]
2 to allow/cancel out/eliminate/compensate for heat losses (to atmosphere) B1 [1]
(do not allow 'prevent'/'stop')

(ii) use of *power* × *time* = *mass* × *specific latent heat* C1
$(70 - 50) \times 5 \times 60 = (13.6 - 6.5) \times L$ C1
$L = 845$ J g^{-1} A1 [3]

Q7.

3 (a) (i) 1 deg C corresponds to $(3840 - 190) / 100\ \Omega$ C1
for resistance 2300 Ω, temperature is $100 \times (2300 - 3840) / (190 - 3840)$
temperature is 42 °C A1 [2]

(ii) *either* 286 K ≡ 13 °C *or* 42 °C ≡ 315 K B1
thermodynamic scale does not depend on the property of a substance M1
so change in resistance (of thermistor) with temperature is non-linear A1 [3]

(b) heat gained by ice in melting = $0.012 \times 3.3 \times 10^5$ J C1
= 3960 J
heat lost by water = $0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ C1
$3960 + (0.012 \times 4.2 \times 10^3 \times \theta) = 0.095 \times 4.2 \times 10^3 \times (28 - \theta)$ C1
$\theta = 16$°C A1 [4]
(answer 18°C – melted ice omitted – allow max 2 marks)
(use of (θ – T) then allow max 1 mark)

Q8.

4	(a)	$+\Delta U$: increase in internal energy	B1	
		$+q$: thermal energy / heat supplied to the system	B1	
		$+w$: work done on the system	B1	[3]
	(b) (i)	(thermal) energy required to change the state of a substance	M1	
		per unit mass	A1	
		without any change of temperature	A1	[3]
	(ii)	when evaporating		
		greater change in separation of atoms/molecules	M1	
		greater change in volume	M1	
		identifies each difference correctly with ΔU and w	A1	[3]

Q9.

3	(a)	(numerically equal to) quantity of (thermal) energy required to change the state of unit mass of a substance	M1	
		without any change of temperature	A1	[2]
		(Allow 1 mark for definition of specific latent heat of fusion/vaporisation)		
	(b) *either*	energy supplied = 2400 × 2 × 60 = 288000 J	C1	
		energy required for evaporation = 106 × 2260 = 240000 J	C1	
		difference = 48000 J		
		rate of loss = 48000 / 120 = 400 W	A1	
	or	energy required for evaporation = 106 × 2260 = 240000 J	(C1)	
		power required for evaporation = 240000 / (2 × 60) = 2000 W	(C1)	
		rate of loss = 2400 – 2000 = 400 W	(A1)	[3]

Q10.

3	(a)	sum of potential energy and kinetic energy of atoms/molecules/particles	M1	
		reference to random (distribution)	A1	[2]
	(b) (i)	as lattice structure is 'broken'/bonds broken/forces between molecules reduced (not molecules separate)	B1	
		no change in kinetic energy, potential energy increases	M1	
		internal energy increases	A1	[3]
	(ii) *either*	molecules/atoms/particles move faster/ $<c^2>$ is increasing		
	or	kinetic energy increases with temperature (increases)	B1	
		no change in potential energy, kinetic energy increases	M1	
		internal energy increases	A1	[3]

Q11.

1 (a) (i) $Q = mc\Delta\theta$ C1
$2300 = 0.75 \times c \times (100 - 20) / 120$ ...(if uses ±273, then –2)..... C1
$c = 4600\ \text{J kg}^{-1}\ \text{K}^{-1}$ ...(allow 1 sf)..... A1
(ii) $Q = mL$ C1
$2300 = (0.375 / 420) \times L$
$L = 2.6 \times 10^6\ \text{J kg}^{-1}$ ...(alow 1 sf)..... A1 [5]

(b) e.g. heat losses, power not constant etc M1
(do not allow if releated to s.h.c., rather than l.h.c.)
effect on value for L ..... A1 [2]

Q12.

3 (a) pV/T = constant..... C1
$T = (6.5 \times 10^6 \times 30 \times 300)/(1.1 \times 10^5 \times 540)$..... C1
= 985 K..... A1 [3]
(*if uses °C, allow 1/3 marks for clear formula*)

3 (b) (i) $\Delta U = q + w$
symbols identified correctly..... M1
directions correct..... A1 [2]

(ii) q is zero B1
w is positive OR $\Delta U = w$ and U increases B1
ΔU is rise in kinetic energy of atoms M1
and mean kinetic energy $\propto T$ ..... A1 [4]
(*allow one of the last two marks if states 'U increases so T rises'*)

Q13.

7 (a) variation is non-linear 1
two possible temperatures 1 **[2]**

(b) e.g. 1. small thermal capacity/measure $\Delta\theta$ of small object /short response time
2 readings taken at a point/physically small
3 can be used to measure temperature difference
4 no power supply required
etc. (any two, 1 mark each) 2 **[2]**

Q14.

3	(a)	correct statement, words or symbols	B1	**[1]**
	(b)(i)	$w = p\Delta V$	C1	
		$= 1.03 \times 10^5 \times (2.96 \times 10^{-2} - 1.87 \times 10^{-5})$		
		$= (-)\ 3050$ J	A1	**[2]**
	(ii)	$q = 4.05 \times 10^4$ J	B1	**[1]**
	(iii)	$\Delta U = 4.05 \times 10^4 - 3050 = 37500$ J ...no e.c.f. from **(a)**.....	A1	**[1]**
		penalise 2 sig.fig. once only		
	(c)	number of molecules = N_A	C1	
		energy $= 37500 / (6.02 \times 10^{23})$		
		$= 6.2 \times 10^{-20}$ J (accept 1 sig.fig.)	A1	**[2]**

Q15.

2	(a)	(i) idea of heat lost (by oil) = heat gained (by thermometer)	C1	
		$32 \times 1.4 \times (54 - t) = 12 \times 0.18 \times (t - 19)$	C1	
		$t = 52.4$°C	A1	[3]
		(ii) *either* ratio (= 1.6/54) = 0.030 *or* (=1.6/327) = 0.0049	A1	[1]
	(b)	thermistor thermometer (allow 'resistance thermometer')	B1	
		because small mass/thermal capacity	B1	[2]
	(c)	boiling point temperature is constant	M1	
		further comment		
		e.g. heating of bulb would affect only rate of boiling	A1	[2]

Q16.

2	(a)	(Thermal) energy / heat required to convert unit mass of solid to liquid	M1	
		at its normal melting point / without any change in temperature	A1	[2]
		(*reference to 1 kg or to ice → water scores max 1 mark*)		
	(b)	(i) To <u>make allowance</u> for heat gains from the atmosphere	B1	[1]
		(ii) e.g. constant rate of production of droplets from funnel		
		constant mass of water collected per minute in beaker		
		(*any sensible suggestion, 1 mark*)	B1	[1]
		(iii) mass melted by heater in 5 minutes $= 64.7 - \frac{1}{2} \times 16.6 = 56.4$ g	C1	
		$56.4 \times 10^{-3} \times L = 18$	C1	
		$L = 320$ kJ kg^{-1}	A1	[3]
		(*Use of m = 64.7, giving L = 278 kJ kg^{-1}, scores max 1 mark*		
		use of m = 48.1, giving L = 374 kJ kg^{-1}, scores max 2 marks)		

Q17.

4 (a) $\Delta U = q + w$ (*allow correct word equation*) B1 [1]

(b) *either* kinetic energy constant because temperature constant M1
potential energy constant because no intermolecular forces M1
so no change in internal energy A1 [3]
or kinetic energy and potential energy both constant (M1)
so no change in internal energy (A1)
reason for *either* constant k.e. *or* constant p.e. given (A1)

Q18.

3 (a) e.g. two objects of different masses at same temperature (M1)
same material would have different amount of heat (A1)
e.g. temperature shows direction of heat transfer (M1)
from high to low regardless of objects (A1)
e.g. when substance melts/boils (M1)
heat input but no temperature change (A1)
any two, M1 + A1 each, max 4 ..... [4]

(b) (i) energy losses (to the surroundings) M1
either increase as the temperature rises
or rise is zero when heat loss = heat input .....A1 [2]

(ii) idea of input power = maximum rate of heat loss C1
power = $m \times c \times \Delta\theta / \Delta t$
$54 = 0.96 \times c \times 3.7 / 60$ C1
$c = 910\ \text{J kg}^{-1}\ \text{K}^{-1}$ .....A1 [3]

[Total: 9]

Q19.

2 (a) sum of kinetic and potential energies of molecules / particles / atoms M1
random (distribution) .....A1 [2]

(b) $+\Delta U$: increase in internal energy B1
$+q$: heating of / heat supplied to system B1
$+w$: work done on system .....B1 [3]

(c) (i) work done = $p\Delta V$ C1
$= 1.0 \times 10^5 \times (2.1 - 1.8) \times 10^{-3}$
= 30 J M1
$w = 30$ J, $q = 0$ so $\Delta U = 30$ J .....A1 [3]

(ii) these three marks were removed, as insufficient data was given in the question.

[Total: 8]

Q20.

2 (a) temperature scale calibrated assuming linear change of property with temperature B1
neither property varies linearly with temperature B1 [2]

(b) (i) does not depend on the property of a substance B1 [1]

(ii) temperature at which atoms have minimum/zero energy B1 [1]

(c) (i) 323.15 K A1 [1]

(ii) 30.00 K A1 [1]

Q21.

3 (a) temperature of the spheres is the same B1
no (net) transfer of energy between the spheres B1 [2]

(b) (i) power = $m \times c \times \Delta\theta$ where m is mass per second C1
3800 = $m \times 4.2 \times (42 - 18)$ C1
m = $38\,g\,s^{-1}$ A1 [3]

(ii) some thermal energy is lost <u>to the surroundings</u> M1
so rate is an overestimate A1 [2]

Q22.

3 (a) *either* change in volume = $(1.69 - 1.00 \times 10^{-3})$
or liquid volume << volume of vapour M1
work done = $1.01 \times 10^5 \times 1.69 = 1.71 \times 10^5$ (J) A1 [2]

(b) (i) **1.** heating of system/thermal energy supplied to the system B1 [1]

2. work done on the system B1 [1]

(ii) $\Delta U = (2.26 \times 10^6) - (1.71 \times 10^5)$ C1
$= 2.09 \times 10^6$ J (*3 s.f. needed*) A1 [2]

Q23.

3 (a) resonance B1 [1]

(b) $Pt = mc\Delta\theta$ C1
$750 \times 2 \times 60 = 0.28 \times c \times (98 - 25)$ C1
$c = 4400\,\text{J kg}^{-1}\,\text{K}^{-1}$ A1 [3]

(*use of* $\Delta\theta = 73 + 273$ *max. 1/3*)
(*use of* $t = 2s$ *not* $120\,s$ *max. 2/3*)

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(c) e.g. some microwave leakage from the cooker
e.g. container for the water is also heated
(*any sensible suggestion*) B1 [1]

Q24.

3 (a) initially, $pV/T = (2.40 \times 10^5 \times 5.00 \times 10^{-4})/288 = 0.417$ M1
finally, $pV/T = (2.40 \times 10^5 \times 14.5 \times 10^{-4})/835 = 0.417$ M1
ideal gas because pV/T is constant A1 [3]
(*allow 2 marks for two determinations of* V/T *and then 1 mark for* V/T *and* p *constant, so ideal*)

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(b) (i) work done $= p\Delta V$
$= 2.40 \times 10^5 \times (14.5 - 5.00) \times 10^{-4}$ C1
$= 228\,\text{J}$ (*ignore sign, not 2 s.f.*) A1 [2]

(ii) $\Delta U = q + w$ $= 569 - 228$
$= 341\,\text{J}$ M1
increase A1 [2]