16. Thermodynamics

16.2 The first law of thermodynamics

Paper 4

Marking Scheme

Q1.

(b)(i)	$W = p\Delta V$	**C1**
	$= 1.0 \times 10^5 \times 0.017 = 1700$ J $= 1.7$ kJ	**A1**
(b)(ii)	$\Delta U = Q + W$	**C1**
	$Q = 17.6 + 1.7$ $= 19.3$ kJ	**A1**

Q2.

(b)(ii)	sketch: straight vertical line XY from (V, $2p$) to (V, p)	**B1**
	straight horizontal line YZ from (V, p) to ($2V$, p)	**B1**
	curve with gradient increasing from Z to X from ($2V$, p) to (V, $2p$)	**B1**
(b)(iii)	XY work done on gas correct (= 0)	**B1**
	ZX increase in internal energy correct (= 0)	**B1**
	YZ work done on gas correct (= $-pV$)	**B1**
	XY increase in internal energy such that the increase in internal energy column adds up to zero	**B1**
	all three thermal energies transferred such that $\Delta U = q + w$ in each row (completely correct answer: change / ΔU / Q / w X to Y: $-U$ / $[+U]$ / $-U$ / 0 Y to Z: 0 / 0 / $U + pV$ / $-pV$ Z to X: $[+U]$ / $-W$ / $[+W]$)	**B1**

Q3.

(a)	change in internal energy = work done + energy transfer by heating	**C1**
	increase in internal energy = work done on system + energy transferred to the system by heating	**A1**
(b)(i)	AB change in internal energy: decrease	**B1**
	AB work done on gas: positive	**B1**
	BC change in internal energy: increase	**B1**
	BC work done on gas: zero	**B1**
(b)(ii)	more work done by gas in CD than is done on gas in AB **or** (no work done on gas in BC and DA so) (overall) gas does work	**B1**
	(overall) change in internal energy is zero	**B1**
	(must be an overall) input of thermal energy	**B1**

Q4.

(b)(i)	work done $= p\Delta V$ $= (2.0 \times 10^5) \times (0.063 - 0.038) = 5000$ J	**A1**
(b)(ii)	gas is expanding (against external pressure)	**B1**
	gas does work / work is done by gas, so (work done on gas is) negative	**B1**
(b)(iii)	$\Delta U = q + W$	**C1**
	$7600 = q + (-5000)$ $q = 12\,600$ J	**A1**
(c)	same gain in internal energy so same temperature rise	**B1**
	no change in volume so no work done **or** no work done so less thermal energy needed (for same change in internal energy)	**B1**
	less thermal energy needed (for same temperature change) so lower specific heat capacity	**B1**

Q5.

(b)(i)	no thermal energy transferred	**B1**
	work is done on the spring (increasing the potential energy of particles)	**M1**
	so internal energy increases	**A1**
(b)(ii)	thermal energy transferred to water	**B1**
	work is done by water (expanding against atmosphere as it vaporises)	**B1**
	more thermal energy transferred than work done so internal energy increases	**B1**

Q6.

(b)(i)	work done $= p\Delta V$	**C1**
	$= 1.2 \times 10^5 \times (0.24 - 0.08) = 19200$ J (= 19.2 kJ)	**A1**
(b)(ii)	AB work done correct (19.2)	**A1**
	BC work done correct (0)	**A1**
	CA increase in internal energy correct (0) **and** CA thermal energy correct (31.6)	**A1**
	AB increase in internal energy calculated correctly from work done – 48.0	**A1**
	BC increase in internal energy correctly calculated so the final column adds up to zero **and** BC thermal energy same as increase in internal energy (Fully correct table: AB 19.2 –48.0 –28.8 BC 0 28.8 28.8 CA –31.6 31.6 0)	**A1**

Q7.

(b)(iii)	$w = p\Delta V$	**C1**
	$= 1.0 \times 10^5 \times 0.64$ $= 6.4 \times 10^4$ J	**A1**
(b)(iv)	(water does work against atmosphere so) work done on water is negative	**B1**
	increase in internal energy $= (8.5 - 0.64) \times 10^5 = 7.9 \times 10^5$ J	**A1**
(c)	valid reasoning of how work done by water is affected	**M1**
	correct use of first law to draw conclusion about effect on specific latent heat that is consistent with work done	**A1**

Q8.

(b)(i)	work done correct (0)	**B1**
	increase in internal energy correct (+E)	**B1**
(b)(ii)	work done correct (–W) **and** increase in internal energy same as **(b)(i)**	**B1**
	thermal energy correct so that it adds to work done to give increase in internal energy	**B1**

Q9.

(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**

Q10.

(c)	$\Delta U = q + w$	**M1**
	$q = 0$ so $\Delta U = w$	**A1**

Q11.

(c)(i)	increase in internal energy = Q + work done	**B1**
	constant volume so no work done	**B1**
(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**

Q12.

(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**

Q13.

(a)	+q: thermal energy transfer to system	**B1**
	+w: work done on system	**B1**
(b)(i)	(W =) $2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3} = 390$ J	**A1**
(c)	A to B row all correct (1370, – 390, 980)	**B1**
	B to C row all correct (0, 550, 550)	**B1**
	C to A row: ΔU adds to the other two ΔU values to give zero	**B1**
	C to A row: $w = 0$ **and** q adds to w to give ΔU value complete correct answer:	**B1**

change	q / J	w / J	ΔU / J
A to B	(+)1370	–390	(+)980
B to C	0	(+)550	(+)550
C to A	–1530	0	–1530

Q14.

(c)(i)	$\Delta W = p\Delta V$ $= 2.60 \times 10^5 \times (2.30 - 3.80) \times 10^{-3}$	**C1**
	$= (-)390$ J	**A1**
	negative because work is done by gas **or** negative because work is done against atmospheric pressure **or** negative because volume of gas increases	**B1**
(c)(ii)	$\Delta U = (980 - 390)$ $= 590$ J	**A1**

Q15.

(a)(iii)	$W = p\Delta V$ $= 3.0 \times 10^5 \times (210 - 140) \times 10^{-6}$	**C1**
	$= 21$ J	**A1**
(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)**
	$\Delta U = (-)32$ J	**A1**

Q16.

(a)(i)	**1.** energy transfer <u>to</u> the system by heating	**B1**
	2. (external) work done <u>on</u> the system	**B1**
(a)(ii)	<u>decrease</u> in internal energy	**B1**
(b)(ii)	work done $= p\Delta V$ $= (-)1.6 \times 10^5 \times (2.4 - 0.87) \times 10^{-3}$	**C1**
	$= (-)240$ 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**

Q17.

(c)(i)	zero	**A1**
(c)(ii)	87.3 J **or** 87.5 J	**A1**
	increase	**B1**

Q18.

(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**