PHY 3513
Test I – 23 Sept. 2016

– Solutions –

(1)(a) $P_{in}V_{in} = nRT_{in}$ with $P_{in} = 1.00\times10^5$ Pa, $V_{in} = 10.0\ m^3$ and $T_{in} = 300$ K $\Rightarrow$ $\boxed{n = P_{in}V_{in}/RT_{in} = 401 \text{ moles}}$ 5/

$P_fV_f = nRT_f$ with $P_f = 2.00\times10^5$ Pa, $V_f = 4.0\ m^3$

$\Rightarrow$ $\boxed{T_f = P_fV_f/nR = 240\ K}$

(b) $P_f - P_{in} = \alpha(V_f - V_{in}) \Rightarrow \boxed{\alpha = (P_f - P_{in})/(V_f - V_{in}) = -1.67\times10^4\ Pa/m^3}$ 5/

$\boxed{V_0 = V_{in} - P_{in}/\alpha = 16.0\ m^3}$

(c) $W = -\int_{V_{in}}^{V_f} P\,dV = -\alpha\int_{V_{in}}^{V_f}(V - V_0)\,dV = -\alpha\left(\frac{V^2}{2} - VV_0\right)\Big|_{V_{in}}^{V_f}$ 6/

$\Rightarrow$ $\boxed{W = -\alpha\left[\frac{V_f^2 - V_{in}^2}{2} - V_0(V_f - V_{in})\right] = 900\ kJ}$

(d) For a monatomic gas, $\Delta U = \frac{3}{2}nR(\Delta T)$ 4/

$\Delta T = -60$ K $\Rightarrow$ $\boxed{\Delta U = -300\ kJ}$ $\Rightarrow$ $\boxed{Q = \Delta U - W = -1200\ kJ}$

(2)(a) $\rho_{ice} = m/V_{ice}$ with $m = 100$ kg, $\rho_{ice} = 916.23\ kg/m^3$ 6/

$\Rightarrow V_{ice} = m/\rho_{ice} = 0.10914\ m^3$

$\rho_{water} = 999.84 \Rightarrow V_{water} = 0.10002\ m^3$

$\Rightarrow$ $\boxed{\Delta V = V_{water} - V_{ice} = -9.13\times10^{-3}\ m^3}$

(b) $W = -P(\Delta V)$ for an isobaric process 5/

$P = 1.013\times10^5$ Pa $\rightarrow$ $\boxed{W = 925\ J}$

(c) $Q = mL_{ice\to water}$ with $L_{ice\to water} = 334\ kJ/kg$ 5/

isobaric process $\rightarrow$ $\boxed{\Delta H = Q = 3.34\times10^7\ J}$

(d) $\Delta U = Q + W = \Delta H + W$ 4/

$\Rightarrow \Delta U - \Delta H = W \Rightarrow (\Delta U - \Delta H)/\Delta U = W/\Delta U \cong W/\Delta H$

$\rightarrow$ $\boxed{\text{frac diff} = 2.77\times10^{-5}}$ $\rightarrow$ $\underline{\Delta U \text{ larger}}$

(3) (a) $P_{in} = 2.00\times10^5$ Pa, $V_{in} = 2.0\ m^3$, $T_{in} = 300$ K

10/ Iso thermal $\Rightarrow$ $\boxed{T_f = T_{in} = 300\ K}$ $\Rightarrow P_f V_f = P_{in} V_{in}$

$P_f = 2P_{in} \Rightarrow \boxed{V_f = 1/2\ V_{in} = 1.0\ m^3}$

$$W = -\int_{V_{in}}^{V_f} P\,dV = -nRT\ln\left(\frac{V_f}{V_{in}}\right) = -P_{in}V_{in}\ln(1/2) \Rightarrow \boxed{W = 277\ kJ}$$

Iso thermal $\Rightarrow \boxed{\Delta U = 0} \Rightarrow \boxed{Q = -W = -277\ kJ}$

(b) adiabatic $\Rightarrow P_f V_f^{\gamma} = P_{in} V_{in}^{\gamma}$ with $\gamma = 5/3$ (monatomic gas)

10/ $\Rightarrow V_f = V_{in}(P_{in}/P_f)^{3/5} \Rightarrow \boxed{V_f = V_{in}(1/2)^{3/5} = 1.32\ m^3}$

$n = P_{in}V_{in}/RT_{in} = 160$ moles $\Rightarrow \boxed{T_f = P_f V_f / nR = 396\ K}$

$$\boxed{W_{ad} = \frac{P_f V_f - P_{in}V_{in}}{\gamma - 1} = \frac{nR(\Delta T)}{\gamma - 1} = 192\ kJ}$$

adiabatic $\Rightarrow \boxed{Q = 0} \Rightarrow \boxed{\Delta U = W = 192\ kJ}$

(4) (a) $(m_c C_{cu} + m_w C_{water})(T_f - T_w) + m_B C_{cu}(T_f - T_B) = 0$

10/ $m_c = 0.250$ kg, $m_w = 0.500$ kg, $T_w = 20°C$, $T_f = 35°C$

$C_{cu} = 0.39$ kJ/kg-K, $C_{water} = 4.19$ kJ/kg-K

$\Rightarrow (m_c C_{cu} + m_w C_{water})(T_f - T_w) = 32.89$ kJ

$T_B = 120°C \Rightarrow \boxed{m_B = 32.89\ kJ / C_{cu}(85°C) = 0.99\ kg}$

(b) Final temp, $T_f = 0°C \Rightarrow \Delta T_{ice} = 30°C$

10/ Heat transf to ice $\rightarrow Q_{ice} = m_{ice} C_{ice} \Delta T_{ice} + m_w L_{ice\to water}$

$m_{ice} = 2.00$ kg, $m_w = 1.20$ kg, $C_{ice} = 2.10$ kJ/kg-K

$L_{ice\to water} = 334$ kJ/kg $\Rightarrow Q_{ice} = 526.8$ kJ

$\rightarrow Q_{ice} + m_{cu} C_{cu}(T_f - T_{cu}) = 0$

$m_{cu} = 15.00$ kg, $C_{cu} = 0.39$ kJ/kg-K

$\Rightarrow \boxed{T_{cu} = T_f + Q_{ice}/(m_{cu} C_{cu}) = 90.1°C}$