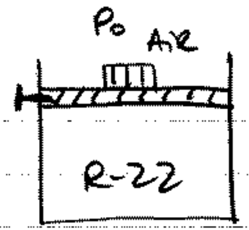
4.106



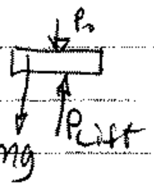
$m_p = 61.18$ kg
10L of R-22 at 10°C & 90% quality
$P_o = 100$ kPa
$A_p = 0.006\ m^2$

$T_2 = 10°C$ & find P_2, V_2 & ${}_1W_2$

State ①: $v_1 = 0.0008 + 0.9(0.03471 - 0.0008)$ (Table B.4.1)
$= 0.03132\ m^3/kg$

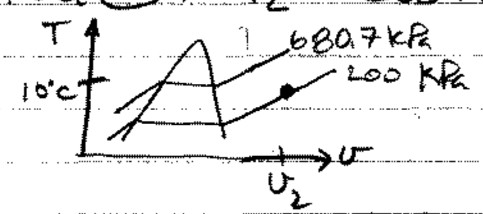
$$m = V_1/v_1 = \frac{0.010\ m^3}{0.03132\ m^3/kg} = 0.319\ kg$$

Since the piston can move freely, $P_2 = P_{Lift}$.
From a force balance on the piston:



$$\Sigma F_y = 0 \Rightarrow P_{Lift}A_p = P_oA_p + mg$$
$$P_{Lift} = P_o + \frac{mg}{A_p}$$
$$= 100 \times 10^3 + \frac{61.18(9.81)}{0.006}$$
$$\underline{\underline{P_{Lift} = 200\ kPa = P_2}}$$

State ②: $P_2 = 200$ kPa & $T_2 = 10°C$

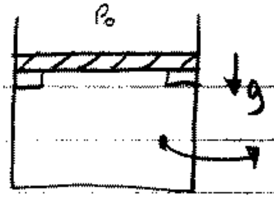


$v_2 = 0.13129\ m^3/kg$ (Table B.4.2)

$V_2 = v_2 m_2 = 0.13129 \times 0.319$
$= 0.04188\ m^3$
$= 41.88\ L$

$${}_1W_2 = \int P dV = P_{Lift}(V_2 - V_1)$$
$$= 200 \times 10^3 (0.04188 - 0.010)$$
$$= 6376\ J$$
$$\underline{\underline{{}_1W_2 = 6.38\ kJ}}$$

4.114



1 kg H_2O
20°C, 0.1 m^3

$P_{Lift} = 400$ kPa
T to Lift piston?
if sat. vapor, find T_2, V_2 & ${}_1W_2$.

P to Lift = 400 kPa

$$\left.\begin{aligned} v_f &= 0.001084 \\ v_g &= 0.46246 \end{aligned}\right\} \text{Table B.1.2}$$

$$v_1 = V_1/m_1 = 0.1/1 = 0.1\ m^3/kg$$

$\therefore v_f < v_1 < v_g$ & $T = T_{SAT}$
$= \underline{\underline{143.63°C}}$

If we have saturated vapor, $T = T_{sat} = 143.63°C$
and $v_2 = v_g = 0.46246\ m^3/kg$

$$\therefore V_2 = v_2 m = 0.46246 \times 1$$
$$= 0.46246\ m^3$$

Work will be done by a constant pressure from the initial to final volumes:

$${}_1W_2 = \int P dV = P_{Lift}(V_2 - V_1)$$
$$= 400 \times 10^3 (0.46246 - 0.1)$$
$$= 144\,984\ J$$

$${}_1W_2 = 145\ kJ$$

5.42/ Given: R-22 state 1: $V_1 = 10L$ (Rigid tank) $= V_2 = V$
$T_1 = -10°C$
$X_1 = 0.8$

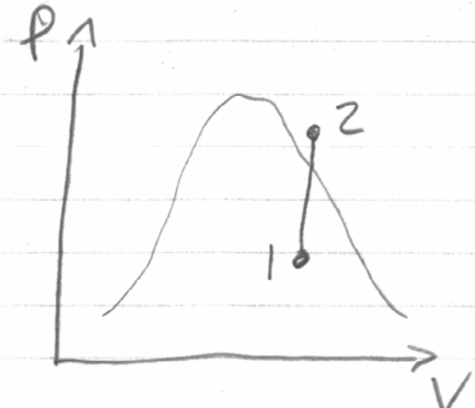
heating process: 10A, 6V battery for $t = 10$ min

State 2: $T_2 = 40°C$

Assumptions 1. conservation of mass $m_1 = m_2 = m$
2. conservation of energy
$\Delta E = \Delta U + \Delta KE + \Delta PE = Q_{12} - W_{12}$
3. tank is stationary $\therefore \Delta KE = \Delta PE = 0$
and $\Delta E = \Delta U = m(u_2 - u_1)$

Find: Q_{12}

Solution: process: constant V
no boundary work, but there is electrical work.



State 1 from table B.4.1

$v_1 = v_f + x v_{fg} = 0.000759 + 0.8(0.06458) = 0.05242 \, m^3/kg$
$u_1 = u_f + x u_{fg} = 32.74 + (0.8)(190.25) = 184.9 \text{ kJ/kg}$

$\therefore m = \frac{V}{v_1} = \frac{0.010}{0.05242} = 0.1908 \text{ kg}$

State 2: from table B.4.2 (super-heated vapour)
at $T_2 = 40°C$ and $v_2 = v_1 = 0.05242\ m^3/kg$

interpolate to find P_2 and u_2

$$P_2 = 500 + 100\frac{(0.05242 - 0.05636)}{(0.04628 - 0.05636)} = 535\ kPa$$

$$u_2 = 250.51 + 0.35(249.48 - 250.51) = 250.2\ kJ/kg$$

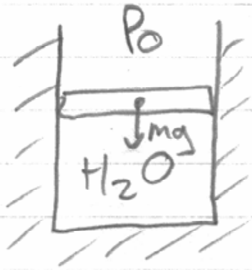
Work $W_{12} = -\text{power} \times \Delta t = -IVt = -\frac{(10)(6)(60)(10)}{1000}$

$$W_{12} = -36\ kJ$$

$\therefore Q_{12} = m(u_2 - u_1) + W_{12} = (0.1908)(250.2 - 184.9) - 36$

$$\boxed{Q_{12} = -23.5\ kJ}$$

5.50/ Given:



$$P_0 + \frac{mg}{A_p} = 150\ kPa$$

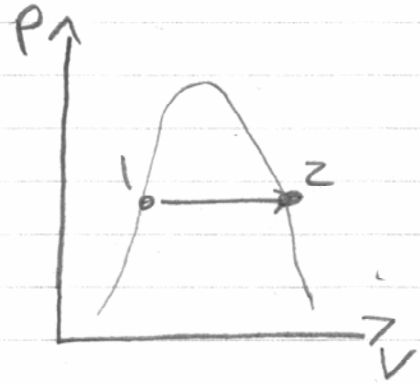
State 1: $T_1 = -2^\circ C$ (compressed liquid)

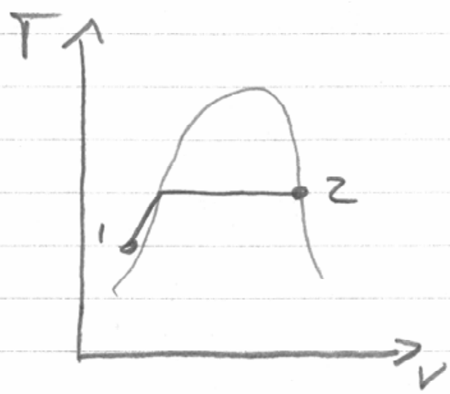
State 2: Sat vapour ; $x = 1$

Find: T_2 and w_{12} and q_{12}

Assumptions:
1. Conservation of mass. $m_1 = m_2$
2. conservation of energy
$$\Delta E = \Delta U + \Delta KE + \Delta PE = Q_{12} - W_{12}$$
3. $\Delta KE = \Delta PE = 0$ (CV is stationary)
$$\therefore Q_{12} - W_{12} = \Delta U = m(u_2 - u_1)$$
or on a per mass basis:
$$q_{12} - w_{12} = u_2 - u_1$$
4. piston is in quasi equilibrium and is frictionless $\therefore$ process is constant pressure, $P_2 = P_1$

Sol'n:





$$P_1 = P_2 = P_0 + \frac{mg}{A_p} = 150\ kPa$$

since piston is in equilibrium

$$\Sigma F_y = 0 = P_{inside} \cdot A_p - P_0 A_p + mg$$

for state 1 ⇒ from table B.1.5

$v_1 = 0.00109\ m^3/kg \quad u_1 = -337.62\ kJ/kg$

for state 2, $P_2 = P_1$ constant P

$P_2 = 150\ kPa$

∴ from table B.1.2, $v_2 = v_g(P_2) = 1.1593\ m^3/kg$

and $T_2 = 111.4°C$, $u_2 = 2519.7\ kJ/kg$

Specific work $= w_{12} = P\int \frac{dV}{m} = P(v_2 - v_1)$

$w_{12} = 150(1.1593 - 0.00109)$

$$\boxed{w_{12} = 173.7\ kJ/kg}$$

specific heat transfer $= q_{12} = u_2 - u_1 + w_{12}$

$q_{12} = 2519.7 + 337.62 + 173.7$

$$\boxed{q_{12} = 3031\ kJ/kg}$$

5.52/ Given: ammonia in steel bottle (Rigid)

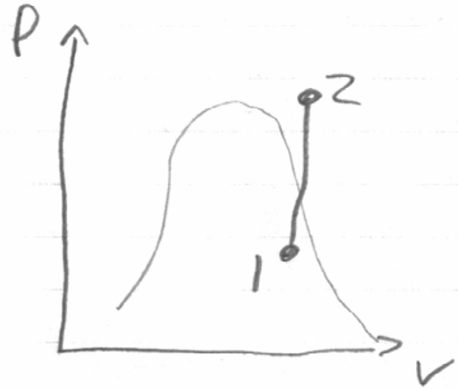
State 1: $T_1 = -20°C$
$x_1 = 0.20$
$V_1 = 0.05\,m^3$

State 2: $P_2 = 1.4\,MPa$
$V_2 = V_1$

Find: T_2 and Q_{12}

Assumptions: 1. constant mass from $1 \to 2$, $m_1 = m_2 = m$
2. Conservation of energy $\Delta E = \Delta U + \Delta KE + \Delta PE = \Delta Q - \Delta W$
3. Assume C.V. is stationary $\therefore \Delta KE = \Delta PE = 0$
$\therefore \Delta E = \Delta U = Q_{12} - W_{12} = m(u_2 - u_1)$

Soln: constant volume process



for state 1 from table B.2.1

$v_1 = v_f + x\,v_{fg} = 0.001504 + (0.2)(0.62184)$
$v_1 = 0.1259\,m^3/kg$

$\therefore m = \frac{V_1}{v_1} = \frac{0.05}{0.1259} = 0.397\,kg$

also, $u_1 = u_f + x\,u_{fg} = 88.76 + (0.2)(1210.7) = 330.9\,kJ/kg$

for State 2: $v_2 = v_1 = 0.1259\ m^3/kg$

from table B.2.2 (super heated vapour)
interpolate to find T_2 and u_2

$$T_2 = 100°C + 20\left(\frac{0.1259 - 0.12172}{0.12986 - 0.12172}\right)$$

$$\boxed{T_2 = 110°C}$$

$$u_2 = 1481 + 0.51(1520.7 - 1481) = 1501.25\ kJ/kg$$

$$\therefore Q_{12} = m(u_2 - u_1) + \cancel{W_{12}}^{0}$$ (const vol ∴ No work)

$$Q_{12} = (0.397\ kg)(1501.25 - 330.9)$$

$$\boxed{Q_{12} = 464.6\ kJ}$$

5.56 Given: R-134a in Piston Cylinder $M = 5\,kg$

State 1: $T_1 = 20°C$ $\quad$ State 2: $T_2 = T_1$

$P_1 = 0.5\,MPa$ $\quad$ $X_2 = 0.5$

also, $Q_{12} = -500\,kJ$

Find: W_{12}, V_1, + V_2

Assumptions: 1. conservation of mass: $m_1 = m_2 = M$

2. conservation of energy

$$\Delta E = \Delta U + \Delta KE + \Delta PE = Q_{12} - W_{12}$$

3. C.V is stationary $\therefore \Delta KE = 0,\ \Delta PE = 0$

$$\therefore \Delta E = \Delta U = m(u_2 - u_1) = Q_{12} - W_{12}$$

Sol'n: state 1, from table B.5.2 (superheated)

$v_1 = 0.04226\,m^3/kg$, $u_1 = 390.52\,kJ/kg$

$$\therefore V_1 = m v_1 = (5\,kg)(0.04226\,m^3/kg)$$

$$\boxed{V_1 = 0.211\,m^3}$$

state 2; from table B.5.1

$$u_2 = u_f + x_2 u_{fg} = 227.03 + 0.5(162.16) = 308.11\,kJ/kg$$

$$v_2 = v_f + X_2 v_{fg} = 0.000817 + 0.5(0.03524)$$

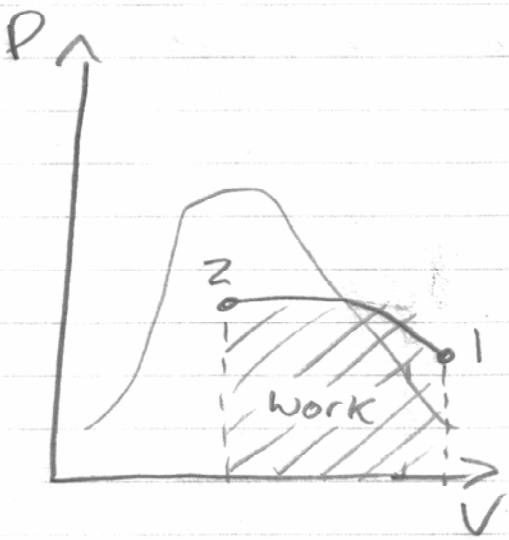
$$v_2 = 0.018437\,m^3/kg$$

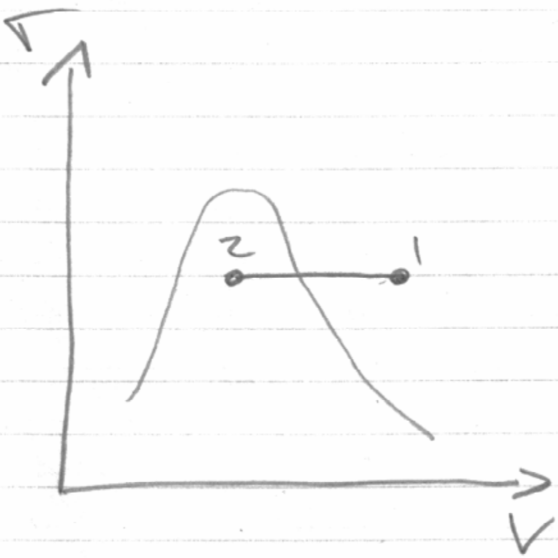
$$\therefore V_2 = m v_2 = (5\,kg)(0.018437\,m^3/kg)$$

$$\boxed{V_2 = 0.0922\,m^3}$$

Work $W_{12} = Q_{12} - m(u_2 - u_1)$
$= -500\text{ kJ} - (5\text{ kg})(308.11 - 390.52)$

$$\boxed{W_{12} = -87.9\text{ kJ}}$$



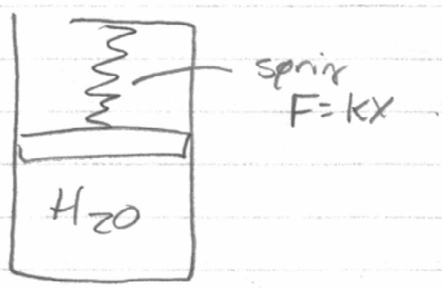


5.57/ Given; Sat. vapor water, $m = 0.5\,kg$

State 1: $T_1 = 120°C$ State 2 $P_2 = 500\,kPa$

$X_1 = 1$

System: $A_p = 0.05\,m^2$, $K_s = 15\,kN/m$



Find: T_2 and Q_{12}.

Assumptions: 1. continuity $m_1 = m_2 = m$

2. Conservation of energy

$$\Delta E = \Delta U + \Delta KE + \Delta PE = Q_{12} - W_{12}$$

3. C.V. is stationary

$$\therefore \Delta KE = 0, \quad \Delta PE = 0$$

$$\therefore \Delta E = \Delta U = m(u_2 - u_1) = Q_{12} - W_{12}$$

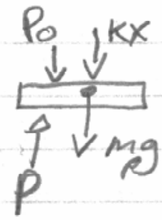
4. assume massless piston, $m_p = 0$

Sol'n: State 1 from table B.1.1

$v_1 = 0.89186\,m^3/kg$, $u_1 = 2529.2\,kJ/kg$

$P_1 = 198.5\,kPa$

process: force balance on piston



$$\Sigma F_y = PA_p - P_0 A_p - kx - \cancel{m_p}\overset{0}{g} = 0$$

$$\therefore P_1 A_p - P_0 A_p - kx_1 = P_2 A_p - P_0 A_p - kx_2$$

$$\therefore P_2 = P_1 + \frac{k \Delta X}{A_p}$$

where ΔX = change in height of piston.

$$\Delta X = \frac{\Delta V}{A_p}$$ (since area is constant)

$$\therefore P_2 = P_1 + \frac{km(v_2 - v_1)}{A_p^2}$$

Re-arrange to find v_2

$$\frac{(v_2 - v_1)\, km}{A_p^2} = P_2 - P_1$$

$$v_2 = \frac{(P_2 - P_1) A_p^2}{km} + v_1$$

$$v_2 = \frac{(500 - 198.5)(0.05)^2}{15 \times 0.5} + 0.89186$$

$$v_2 = 0.9924 \ m^3/kg$$

from table B.1.3 Interpolate to find T_2 and u_2

$$T_2 = 800 + 100\left(\frac{0.9924 - 0.98959}{1.08217 - 0.98959}\right)$$

$$\boxed{T_2 = 803°C}$$

$$u_2 = 3662.17 + (3853.63 - 3662.17)\frac{3}{100}$$

$$u_2 = 3668 \ kJ/kg$$

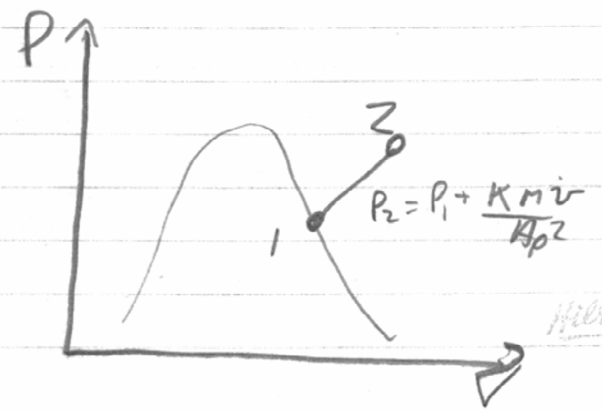
Work, $W_{12} = \int P\,dV = P_{avg}\int dV = \left(\frac{P_1 + P_2}{2}\right) m(v_2 - v_1)$

$$W_{12} = \left(\frac{198.5 + 500}{2}\right)(0.5)(0.9924 - 0.89186)$$

$$W_{12} = 17.56 \ kJ$$

heat, $Q_{12} = m(u_2 - u_1) + W_{12} = (0.5 kg)(3668 - 2529.2) + 17.56$

$$\boxed{Q_{12} = 587 \ kJ}$$



5.58/ Given: C.V is rigid tank

Comp. A: water, state 1: $P_{A1} = 200\,kPa$

$v_{A1} = 0.5\,m^3/kg$

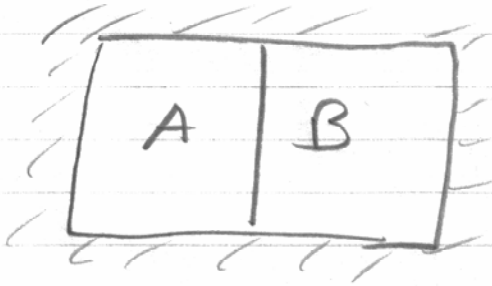
$V_{A1} = 1\,m^3$

Comp. B: water, state 2: $m_{B1} = 3.5\,kg$

$P_{B1} = 0.5\,MPa$

$T_{B1} = 400°C$

State 2: $T_2 = 100°C$, $V_2 = V_{A1} + V_{B1}$ (Rigid Tank)



Find: Q_{12}

Assumptions 1. Conservation of mass $m = m_2 = m_{A1} + m_{B1}$

2. Conservation of energy

$\Delta E = \Delta U + \Delta KE + \Delta PE = Q_{12} - W_{12}$

3. C.V. is stationary $\therefore \Delta KE = 0, \Delta PE = 0$

$\therefore \Delta E = \Delta U = Q_{12} - W_{12}$

Sol'n: state 1A: from table B.1.2, $m_{A1} = \dfrac{V_{A1}}{v_{A1}} = \dfrac{1}{0.5} = 2\,kg$

quality $X_{A1} = \dfrac{v - v_f}{v_{fg}} = \dfrac{0.5 - 0.001061}{0.88467} = 0.564$

$\therefore u_{A1} = u_f + X_{A1} u_{fg} = 504.47 + 0.564(2025.02) = 1646.6\,kJ/kg$

State 1B from table B.1.3 $\Rightarrow v_{B1} = 0.6173$

$u_{B1} = 2963.2$

and $V_{B1} = m_{B1} v_{B1} = (3.5)(0.6173)$

$V_{B1} = 2.16\,m^3$

process is total constant volume and mass

$\therefore$ at <u>state 2</u>: $V_{tot} = V_{A1} + V_{B1} = 1m^3 + 2.16m^3 = 3.16\,m^3$

$$m_2 = m_{A1} + m_{B1} = 2kg + 3.5kg = 5.5\,kg$$

$$\therefore v_2 = V_2/m_2 = (3.16/5.5) = 0.5746\ m^3/kg$$

also, since total vol is constant, work is zero

$$W_{12} = \int P\,dV = 0$$

from table B.1.1, looking up T_2 and v_2 we see that we have a mixed phase $v_f < v_2 < v_g$

$$\therefore X_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{0.5746 - 0.001044}{1.67185} = 0.343$$

$$u_2 = u_f + X_2 u_{fg} = 418.91 + 0.343(2087.58) = 1134.95\ kJ/kg$$

$$\therefore Q_{12} = \Delta U + \cancel{W_{12}}^{\,0} = \Delta U = m_2 u_2 - (m_{A1} u_{A1} + m_{B1} u_{B1})$$

$$Q_{12} = (5.5)(1134.95) - (2)(1646.6) - (3.5)(2963.2)$$

$$\boxed{Q_{12} = -7421\ kJ}$$

5.89/ Given: Methane
b)

State 1: $V_1 = 250L$
$T_1 = 500k$
$P_1 = 1500\ kPa$

State 2: $V_2 = V_1 = V$ (Rigid tank)
$T_2 = 300k$

Find: m and Q_{12} using methane tables

Assumptions: 1. conservation of mass $m_1 = m_2 = m$
2. conservation of energy
$$\Delta E = \Delta Q - \Delta W$$
3. C.V. is stationary ∴ $\Delta KE = 0$, $\Delta PE = 0$
$$\therefore \Delta E = \Delta U + \Delta KE + \Delta PE = \Delta U$$

Sol'n: from table B.7.2, $v_1 = 0.17273\ m^3/kg$

$$\therefore \boxed{m = \frac{V}{v_1} = \frac{0.25\ m^3}{0.17273\ m^3/kg} = 1.4473\ kg}$$

energy equation
$$\Delta E = \Delta U = \Delta Q - \Delta W$$
$$m(u_2 - u_1) = \Delta Q - \cancel{\int P dV}^{\,0}$$
$$\therefore \Delta Q = m(u_2 - u_1)$$

from table B.7.2: $u_1 = 872.37\ kJ/kg$

for State 2, $v_2 = v_1$ and 300k is between 800 and 1000 kPa
∴ interpolate to find u_2

$$u_2 = 466.65\ kJ/kg$$

$\therefore\ Q_{12} = m(u_2 - u_1)$

$= (1.4473\,kg)(466.65 - 872.37)$

$$\boxed{Q_{12} = -587.2\ kJ}$$

a) Using Ideal gas Law: $PV = RT$

Constant volume process

$$P_2 = \frac{P_1 T_2}{T_1} = \frac{(1500)(300)}{(500)} = 900\ kPa$$

$$m = \frac{P_1 V}{R T_1} = \frac{(1500)(0.25)}{(0.5183)(500)} = 1.447\ kg$$

$$Q_{12} = m(u_2 - u_1) = m C_v (T_2 - T_1)$$

$$= (1.447\,kg)(1.736)(300 - 500)$$

$$\boxed{Q_{12} = -502.4\ kJ}$$