Chapters 2 - Homework Solutions

2.1 **(a)** P_{ex} = 30 kPa ΔV = 3.3 L

w = $-P_{exp}\Delta V$ = -(30 kPa)(3.3 L) = -99 kPa-L = -99 J

(b) n = 4.50 g / 16 g/mol = 0.281 mol T = 310 K
V_1 = 12.7 L V_2 = 12.7 + 3.3 = 16.0 L

$$w = -nRT\ln\left(\frac{V_2}{V_1}\right) = -(0.281\,mol)(8.314\,J/mol\cdot K)(310\,K)\ln\left(\frac{16.0\,L}{12.7\,L}\right) = -167\,J$$

2.2 $Mg(s) + 2\,HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$

n_{Mg} = 12.5 g / 24.3 g/mol = 0.514 mol Mg

$$n_{H_2} = 0.514\,mol\,Mg\cdot\frac{1\,mol\,H_2}{1\,mol\,Mg} = 0.514\,mol\,H_2$$

T = 20.2 ^oC = 293 K
$V_{Rct} \approx 0$ [Because the volumes of solid Mg and aqueous HCl are negligible]
$V_{Prod} \approx V_{H2}$ [Because the volume of aqueous $MgCl_2$ is negligible]

$$w = -P[V_{Prod} - V_{Rct}] \approx -PV_{H_2} = -n_{H_2}RT = -(0.514\,mol)(8.314\,J/mol\cdot K)(293\,K)$$
$$= -1250\,J = -1.25\,kJ$$

2.3 n = 250 g /18 g/mol = 13.9 mol $C_{P,m}$ = 75.3 J/mol-K ΔT = 65 ^oC - 25 ^oC = 40 ^oC = 40 K

q = $nC_{P,m}\Delta T$ = (13.9 mol)(75.3 J/mol-K)(40 K) = 41,900 J = 41.9 kJ

2.4 q_P = 229 J n = 3.0 mol ΔT = 2.55 K

$$q_P = nC_{P,m}\Delta T \;\rightarrow\; C_{P,m} = \frac{q_P}{n\Delta T} = \frac{229\,J}{(3.0\,mol)(2.55\,K)} = 29.9\,J/mol\cdot K$$

$C_{V,m} = C_{P,m}$ - R = 29.9 - 8.3 = 21.6 J/mol-K

2.5 $C_{P,m}$ = 29.4 J/mol-K   n = 3.0 mol ΔT = 285 K - 260 K = 25 K

$\Delta H = nC_{P,m}\Delta T$ = (3.0 mol)(29.4 J/mol-K)(25 K) = 2205 J = 2.2 kJ

q = ΔH = 2205 J = 2.2 kJ [since P = const.]

$\Delta U = \Delta H - \Delta(PV) = \Delta H - \Delta(nRT) = \Delta H - nR\Delta T$
= 2200 J - (3.0 mol)(8.314 J/mol-K)(25 K) = 2205 - 620 = 1585 J = 1.6 kJ

An equivalent way to calculate ΔU is to calculate $C_{V,m} = C_{P,m} - R$
and then use $\Delta U = nC_{V,m}\Delta T$.

2.6 n = m/M = 45 g/ 18 g/mol = 2.50 mol $C_{P,m}$ = 33.6 J/mol-K   q = 2800 J

$$q = n \cdot C_{P,m} \cdot \Delta T \quad \rightarrow \quad \Delta T = \frac{q}{n \cdot C_{P,,m}} = \frac{2800\,J}{2.5\,mol \cdot 33.6\,J/mol \cdot K} = 33.3\,K = 33.3\,{}^oC$$

$T_{fin} = T_{init} + \Delta T$ = 150 °C + 33.3 °C = 183.3 °C

2.7
(a) q < 0   w > 0 $\Delta U < 0$ $\Delta H < 0$
(b) q > 0   w ≈ 0 $\Delta U > 0$ $\Delta H > 0$
(c) q < 0   w > 0 $\Delta U = 0$ $\Delta H = 0$
(d) q = 0   w < 0 $\Delta U < 0$ $\Delta H < 0$

2.8 Since T = 323 K = constant, $P_2V_2 = P_1V_1$ or $V_2/V_1 = P_1/P_2$ = 1 bar/20 bar = 0.05
n = m/M = 50 g/32 g/mol = 1.56

$$w = -nRT\ln(V_2/V_1) = -nRT\ln(P_1/P_2) = -1.56\,mol(8.314\,J/mol \cdot K)(323\,K)\ln(0.05) = +12{,}550\,J = 12.6\,kJ$$

$\Delta U = nC_{V,m}\Delta T = 0$ $\Delta H = nC_{P,m}\Delta T = 0$ $q = \Delta U - w = -w$ = -12.6 kJ

2.9 n = 1.56 mol   T = 323 K P_1 = 1 bar = 100 kPa P_2 = 20 bar = 2000 kPa

$$V_1 = \frac{nRT}{P_1} = \frac{1.56\,mol(8.314\,kPa \cdot L/mol \cdot K)(323\,K)}{100\,kPa} = 41.9\,L$$ Similarly, V_2 = 2.1 L

$w = -P(V_2 - V_1)$ = -2000 kPa(2.1 L - 41.9 L) = +79,600 kPa-L = 79,600 J = 79.6 kJ

$\Delta U = nC_{V,m}\Delta T = 0$ $\Delta H = nC_{P,m}\Delta T = 0$ $q = \Delta U - w = -w$ = -79.6 kJ

2.10 n = 1.56 mol P = 1 bar = 100 kPa T_1 = 323 K T_2 - 473 K

$C_{P,m} = C_{V,m}$ + R = 21.1 + 8.3 = 29.4 J/mol-K

$\Delta U = nC_{V,m}\Delta T$ = 1.56 mol x 21.1 J/mol-K x (473 K - 323 K) = 4940 J = 4.94 kJ

$\Delta H = nC_{P,m}\Delta T$ = 1.56 mol x 29.4 J/mol-K x (473 K - 323 K) = 6880 J = 6.88 kJ

Since P = const, q = ΔH = 6.88 kJ

w = ΔU - q = 4.94 - 6.88 = -1.94 kJ
(Alternatively, could evaluation V_1 and V_2 and use w = -P(V_2 - V_1))

2.11 T_1 = 323 K T_2 = 473 K

$\Delta U = nC_{V,m}\Delta T$ = 1.56 mol x 21.1 J/mol-K x (473 K - 323 K) = 4940 J = 4.94 kJ

$\Delta H = nC_{P,m}\Delta T$ = 1.56 mol x 29.4 J/mol-K x (473 K - 323 K) = 6880 J = 6.88 kJ

Since V = const, q = ΔU = 4.94 kJ and w = 0

2.12 n = 1.56 mol P_1 = 1 bar = 100 kPa V_1 = 42 L P_2 = 5 bar = 500 kPa V_2 = 16 L

$$T_1 = \frac{P_1V_1}{nR} = \frac{100\,kPa \cdot 42\,L}{1.56\,mol \cdot 8.314\,kPa \cdot L/mol \cdot K} = 324\,K$$ Similarly, T_2 = 617 K

$\Delta U = nC_{V,m}\Delta 18T$ = 1.56 mol x 21.1 J/mol-K x (617 K - 324 K) = 9640 J = 9.64 kJ

$\Delta H = nC_{P,m}\Delta T$ = 1.56 mol x 29.4 J/mol-K x (617 K - 324 K) = 13,440 J = 13.4 kJ

Since process is adiabatic, q = 0 w = ΔU - q = ΔU = 9.64 kJ