

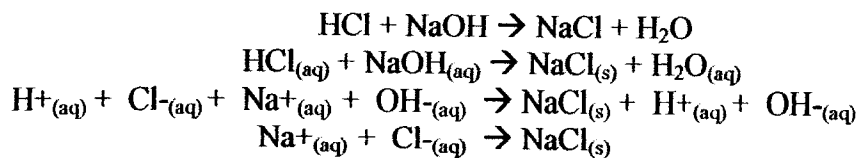
UNIT 6

EQUILIBRIUM APPLICATIONS

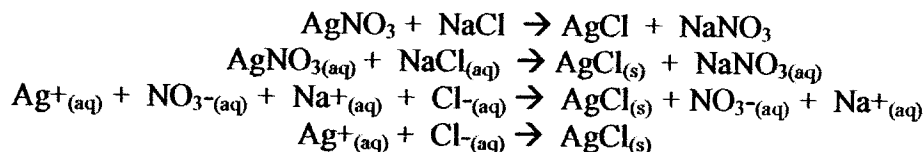
ANSWERS

Types of Equations

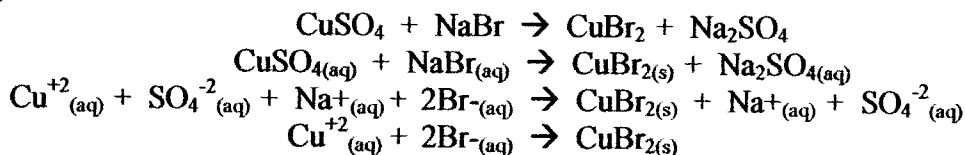
(1)



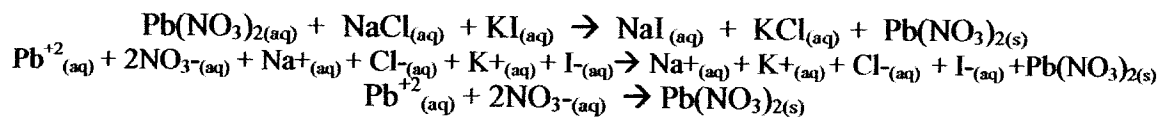
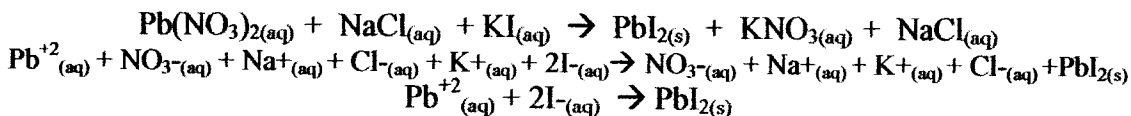
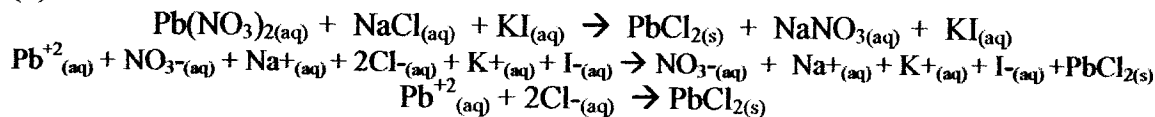
(2)



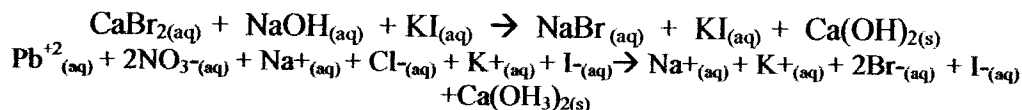
(3)



(4)



(5)



Solubility and Solubility Product Problems

① $120 \text{ mL} = 0.12 \text{ L}$

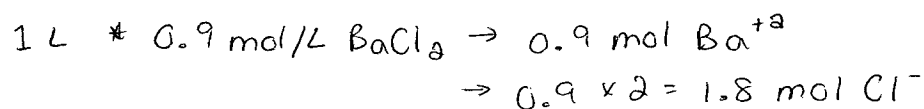
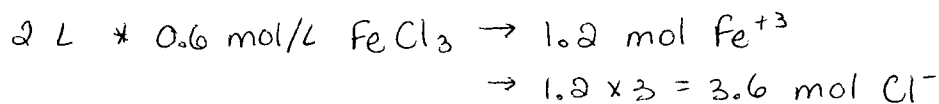
$$\frac{0.12 \text{ L} * 6 \text{ mol/L}}{2.0 \text{ L}} = 0.36 \text{ mol/L}$$

② $5.0 \text{ L} * 0.1 \text{ mol/L} = 0.5 \text{ mol needed}$

$$\begin{array}{ll} 1 \text{ L} \rightarrow 12 \text{ mol} & x = 0.5 \text{ mol} / 12 \text{ mol} \\ x \text{ L} \rightarrow 0.5 \text{ mol} & = 0.04167 \text{ L} \end{array}$$

$\therefore$ you need to add 41.67 mL of 12M HCl

③ Original amounts:

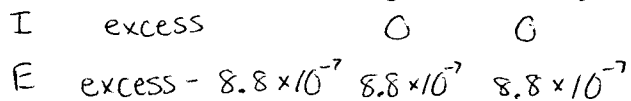
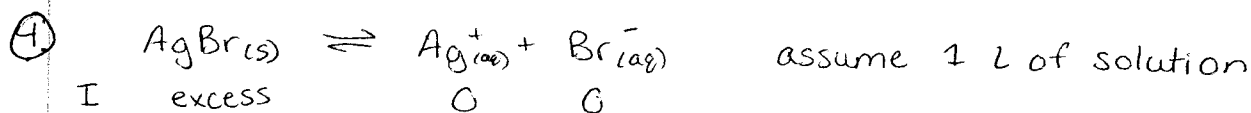


...but now all of them are in 3 L (2 L + 1 L)...

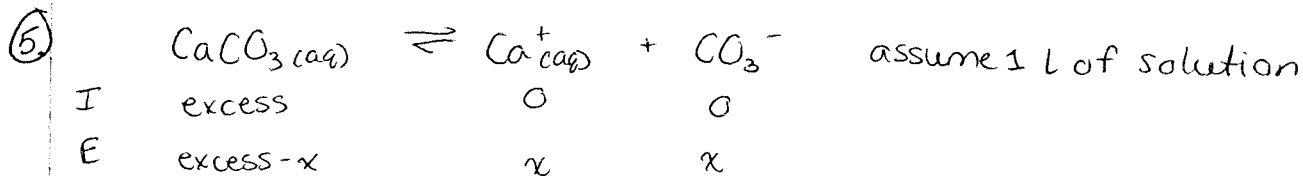
$$\frac{1.2 \text{ mol Fe}^{+3}}{3 \text{ L}} = 0.4 \text{ M Fe}^{+3}$$

$$\frac{5.4 \text{ mol Cl}^-}{3 \text{ L}} = 1.8 \text{ M Cl}^-$$

$$\frac{0.9 \text{ mol Ba}^{+2}}{3 \text{ L}} = 0.3 \text{ M Ba}^{+2}$$



$$K_{sp} = [\text{Ag}^+_{(aq)}][\text{Br}^-_{(aq)}] = (8.8 \times 10^{-7})^2 = 7.744 \times 10^{-13} (\text{mol/L})^2$$

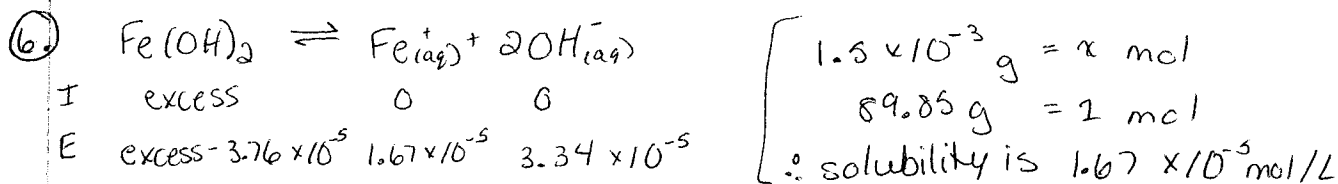


$$K_{sp} = [\text{Ca}^+_{(aq)}][\text{CO}_3^-_{(aq)}]$$

$$4.8 \times 10^{-9} = x^2$$

$$x = 6.928 \times 10^{-5}$$

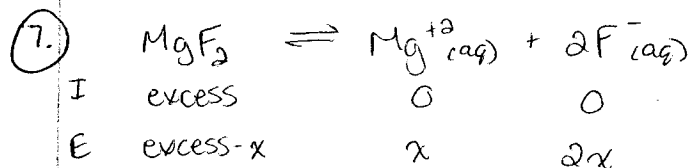
$\therefore$ the solubility of CaCO_3 is $6.928 \times 10^{-5} \text{ mol/L}$



$$K_{sp} = [\text{Fe}^+_{(aq)}][\text{OH}^-_{(aq)}]^2$$

$$= (1.67 \times 10^{-5})(3.34 \times 10^{-5})^2$$

$$= 1.86 \times 10^{-14} \text{ mol}^3/\text{L}^3$$



$$K_{sp} = [\text{Mg}^{+2}_{(aq)}][\text{F}^-_{(aq)}]^2$$

$$6.4 \times 10^{-9} = 4x^3$$

$$x = 1.17 \times 10^{-3} \text{ mol/L}$$

$$1.17 \times 10^{-3} \text{ mol} = x \text{ g}$$

$$1 \text{ mol} = 62.3 \text{ g}$$

$$x = (1.17 \times 10^{-3})(62.3)$$

$$= 0.072891 \text{ g/L}$$

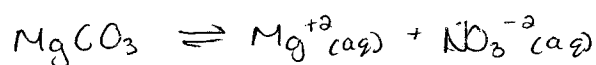
$\therefore$ the solubility of MgF_2 in g/L is 0.072891 g/L

$$\textcircled{8} \quad [\text{Mg}^{+2}(\text{aq})] = \frac{0.04 \text{ L} * 8 \times 10^{-3} \text{ mol/L}}{0.1 \text{ L}}$$

$$= 0.0032 \text{ mol/L}$$

$$[\text{NO}_3^{-2}] = \frac{0.06 \text{ L} * 1 \times 10^{-2} \text{ mol/L}}{0.1 \text{ L}}$$

$$= 0.006 \text{ mol/L}$$



$$\text{but } K_{sp} = 2.6 \times 10^{-5} = [\text{Mg}][\text{NO}_3]$$

$$\text{L.S.}$$

$$= 2.6 \times 10^{-5}$$

$$\text{R.S.}$$

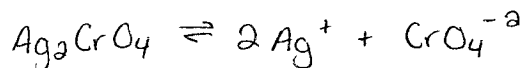
$$= (0.0032)(0.006)$$

$$= 1.92 \times 10^{-5}$$

Since $RS < LS$, no ppt forms.

$$\textcircled{9} \quad [\text{Ag}] = \frac{0.025 \text{ L} * 4 \times 10^{-3} \text{ mol/L}}{0.1 \text{ L}} \quad [\text{CrO}_4^{-2}] = \frac{0.075 \text{ L} * 2 \times 10^{-4} \text{ mol/L}}{0.1 \text{ L}}$$

$$= 0.001 \text{ mol/L} \quad = 0.00015 \text{ mol/L}$$



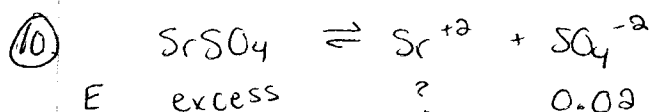
$$\text{but } K_{sp} = 9.0 \times 10^{-12} = [\text{Ag}^+]^2 [\text{CrO}_4^{-2}]$$

$$\text{L.S.} = 9.0 \times 10^{-12}$$

$$\text{R.S.} = (0.001)^2 (0.00015)$$

$$= 1.5 \times 10^{-10}$$

Since $RS > LS$, a ppt will form



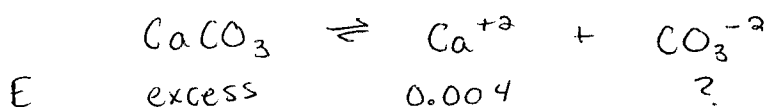
$$K_{sp} = [\text{Sr}^{+2}][\text{SO}_4^{-2}]$$

$$7.6 \times 10^{-7} = [\text{Sr}^{+2}](0.02)$$

$$[\text{Sr}^{+2}] = 0.000038$$

$\therefore$ the maximum $[\text{Sr}^{+2}]$ is $3.8 \times 10^{-5} \text{ mol/L}$ before a ppt occurs.

⑪ Assume K_{sp} of $\text{MgCO}_3 > K_{sp}$ of CaCO_3



$$K_{sp} = [\text{Ca}^{+2}][\text{CO}_3^{-2}]$$

$$4.8 \times 10^{-9} = (0.004)[\text{CO}_3^{-2}]$$

$$[\text{CO}_3^{-2}]_{\text{max}} = 1.2 \times 10^{-6} \text{ mol/L}$$

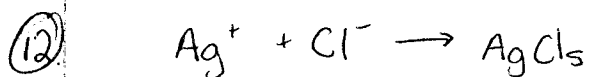
Since there are 5 L of water, the max amount of $[\text{CO}_3^{-2}]$ is $(5 * 1.2 \times 10^{-6} \text{ mol/L}) = 6 \times 10^{-6} \text{ mol/L}$

$$x_g = 6 \times 10^{-6} \text{ mol}$$

$$106 \text{ g} = 1 \text{ mol}$$

$$x = 6.36 \times 10^{-4} \text{ g}$$

$\therefore$ only $6.36 \times 10^{-4} \text{ g}$ of Na_2CO_3 can be added before a ppt forms.



$\therefore$ # of moles of Ag^+ = # of moles of Cl^-

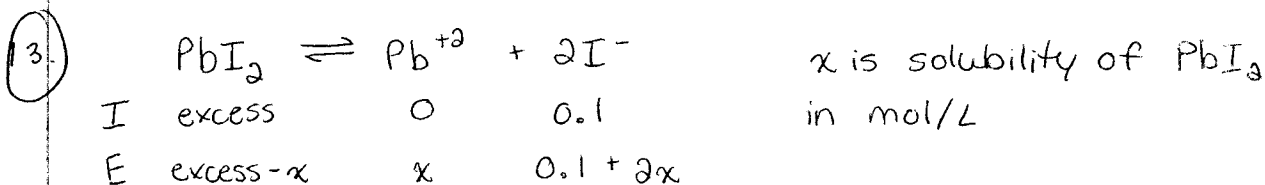
of moles of Ag^+ :

$$0.02364 \text{ L} * 0.1 \text{ mol/L}$$

$$= 0.002364 \text{ mol Ag}^+ \longrightarrow \therefore 0.002364 \text{ mol Cl}^-$$

$$[\text{Cl}^-] = \frac{0.002364 \text{ mol}}{0.125 \text{ L}} = 0.018912 \text{ mol/L}$$

$\therefore$ the $[\text{Cl}^-]$ in the sample is 0.018912 mol/L



$$K_{sp} = [\text{Pb}^{+2}][\text{I}^-]^2$$

$$7.9 \times 10^{-9} = (x)(0.1 + 2x)^2 \leftarrow 2x^3 \text{ assume } x \text{ is small}$$

$$7.9 \times 10^{-9} = 0.01 x$$

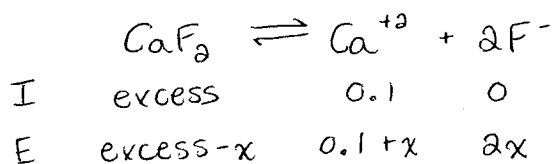
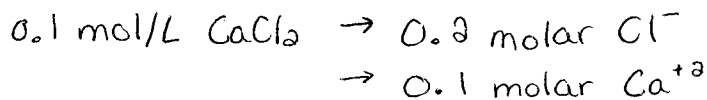
$$x = 7.9 \times 10^{-7}$$

use 5% rule to check

$$\checkmark \text{ check: } \frac{7.9 \times 10^{-7}}{0.1} \times 100\% = 7.9 \times 10^{-4}\%$$

$\therefore$ the solubility of PbI_2 in the I^- solution is $7.9 \times 10^{-7} \text{ mol/L}$

④ CaCl_2 is soluble



$$K_{sp} = [\text{Ca}^{+2}][\text{F}^-]^2$$

$$3.9 \times 10^{-11} = (0.1+x)(2x)^2 \leftarrow \text{assume } x \text{ is small}$$

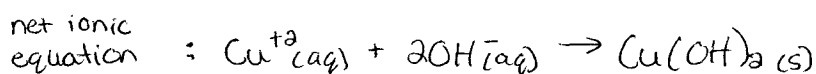
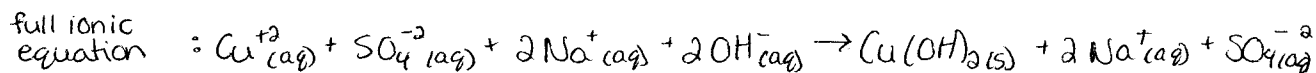
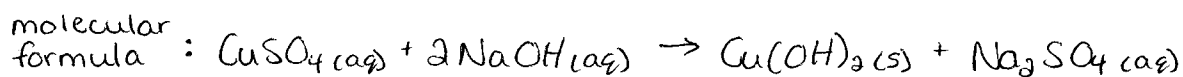
$$3.9 \times 10^{-11} = 0.4x^2$$

$$9.75 \times 10^{-11} = x^2$$

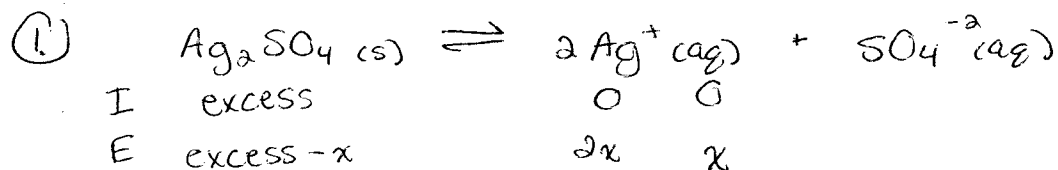
$$x = 9.874 \times 10^{-6} \text{ mol/L}$$

$$\therefore \text{the maximum } [\text{F}^-] \text{ is } 2x \Rightarrow 2(9.874 \times 10^{-6}) = 1.975 \times 10^{-5} \text{ mol/L}$$

⑤ Yes, a $\text{Cu}(\text{OH})_2$ ppt will probably occur if the concentrations are high enough



K_{sp} Problems



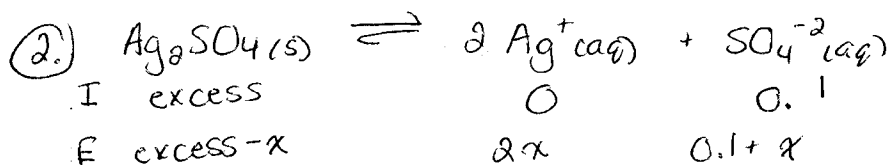
$$K_{sp} = 1.2 \times 10^{-5}$$

$$K_{sp} = [\text{Ag}^+]^2 [\text{SO}_4^{2-}]$$

$$1.2 \times 10^{-5} = [2x]^2 [x]$$

$$1.2 \times 10^{-5} = 4x^3$$

$$x = 0.01440$$



$$K_{sp} = 1.2 \times 10^{-5}$$

$$K_{sp} = [\text{Ag}^+]^2 [\text{SO}_4^{2-}]$$

$$1.2 \times 10^{-5} = [2x]^2 [0.1 + x] \leftarrow \text{assume } x \text{ is small compared to } 0.1$$

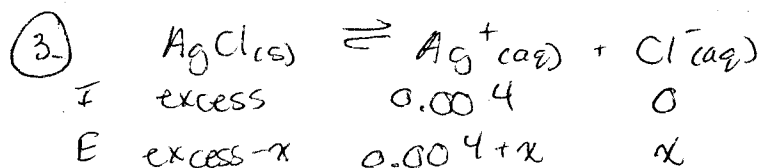
$$1.2 \times 10^{-5} = 0.4 x^2$$

$$x = 0.005477$$

$$\frac{0.005477}{1 \text{ L}} = \frac{x}{0.5 \text{ L}}$$

$$x = 2.73 \times 10^{-3} \text{ mol}$$

∴ the solubility of $\text{Ag}_2\text{S}(s)$ is $2.73 \times 10^{-3} \text{ mol}$



$$K_{sp} = 1.8 \times 10^{-10}$$

$$K_{sp} = [\text{Ag}^+_{(aq)}][\text{Cl}^-_{(aq)}]$$

$$1.8 \times 10^{-10} = (0.004+x)(x) \leftarrow \text{assume } x \text{ is small compared to } 0.004$$

$$x = 4.5 \times 10^{-8} \times 0.2 \text{ L}$$

$$= 9 \times 10^{-9}$$

$$\text{mm: } 22.98$$

$$+ \frac{35.04}{58.38}$$

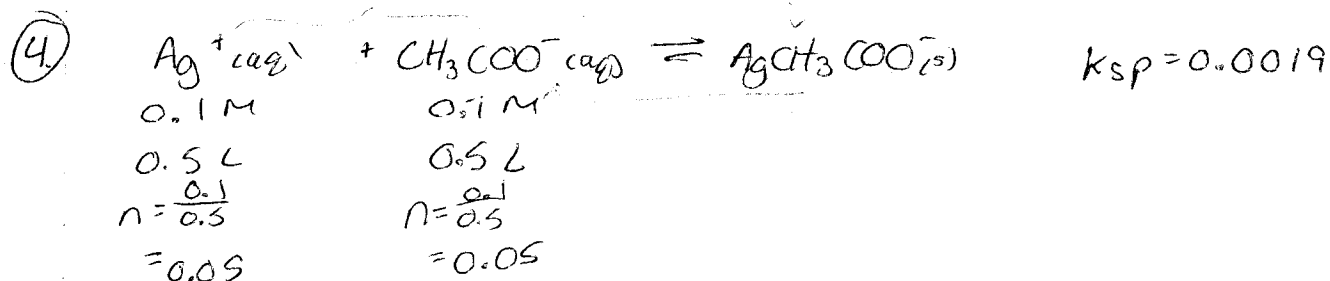
$$58.38$$

$$m_i = n \times \text{mm}$$

$$= 9 \times 10^{-9} \times 58.38$$

$$= 5.25 \times 10^{-7}$$

$\therefore$ the mass of table salt needed to precipitate the silver as silver chloride is $5.25 \times 10^{-7} \text{ g}$



after mixing:

$$C = \frac{0.05}{1}$$

$$= 0.05 \text{ M}$$

$$C = \frac{0.05}{1}$$

$$= 0.05 \text{ M}$$

$$Q = [\text{Ag}^+_{(aq)}][\text{CH}_3\text{COO}^-_{(aq)}]$$

$$= (0.05)^2$$

$$= 0.0025$$

$$Q > K_{sp}$$

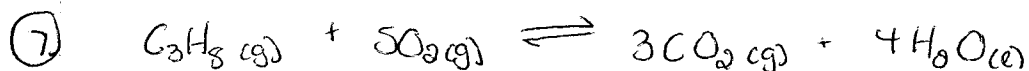
$\therefore$ a precipitate forms

⑤ Ca^{+2} ion precipitates last because it has the greatest K_{sp} value (2.4×10^{-5})

⑥ Find the $[\text{SO}_4^{-2}]$
 $K_{sp} = [\text{Sr}^{+2}][\text{SO}_4^{-2}]$
 $3.4 \times 10^{-7} = [\text{Sr}^{+2}][\text{SO}_4^{-2}]$
 3.4×10^{-6}

Put this value into PbSO_4 to find $[\text{Pb}^{+2}]$
 $K_{sp} = [\text{Pb}^{+2}][\text{SO}_4^{-2}]$
 $1.8 \times 10^{-5} = [\text{Pb}^{+2}][3.4 \times 10^{-6}]$
 $[\text{Pb}^{+2}] = 5.29 \times 10^{-3}$

$\therefore [\text{Pb}^{+2}]$ when Sr^{+2} begins to precipitate is $5.29 \times 10^{-3} \text{ mol/L}$



Bonds broken = energy absorbed

$$\begin{aligned} 2(\text{C}-\text{C}) &= 2(348) = 696 \\ 8(\text{C}-\text{H}) &= 8(412) = 3296 \\ 5(\text{O}=\text{O}) &= 5(498) = \underline{2490} \\ &+ 6482 \end{aligned}$$

Bonds formed = energy released

$$\begin{aligned} 6(\text{C}=\text{O}) &= 6(740) = 4440 \\ 8(\text{O}-\text{H}) &= 8(464) = \underline{3712} \\ &- 8152 \end{aligned}$$

$$\begin{aligned} \therefore \text{net heat} &= +6482 - 8152 \\ &= -1670 \text{ KJ} \end{aligned}$$

$$(8.) \quad T = \frac{\Delta H}{\Delta S} = \frac{+44000 \text{ J/mol}}{118.89 \text{ J/mol/K}} = +370.9 \text{ K} = 97.75^\circ\text{C}$$

$$\begin{aligned} \Delta H &= \sum \Delta H_f^\circ \text{ prod} - \sum \Delta H_f^\circ \text{ react} \\ &= 1(-241.8) - 1(-285.8) \\ &= +44 \text{ kJ} \\ &= +44000 \text{ J/mol} \end{aligned}$$

$$\begin{aligned} \Delta S &= \sum nS \text{ prod} - \sum nS \text{ react} \\ &= 1(188.84) - 1(69.95) \\ &= 118.89 \text{ J/mol/K} \end{aligned}$$