Problem 3. (10 points total)
Consider a hypothetic reaction: A $\rightleftharpoons$ B with the $\Delta G^{o'} = -5$ kJ/mol for the forward reaction. The molar concentrations at the beginning of the reaction were [A] = 12 mM, [B] = 0.

(a) (4 pts) One hour later the concentrations were [A] = 10 mM, [B] = 2 mM. Calculate the ΔG of the reaction at this point. Has the reaction reached the equilibrium?

$$\Delta G = \Delta G'^{0} + RT \ln \frac{[B]}{[A]} = -5 \frac{kJ}{mol} + 8.315 \frac{J}{mol \cdot K} \cdot 298K \cdot \ln \frac{2}{10}$$

$$= -8.988 \frac{kJ}{mol}$$

$\Delta G \neq 0$, hence the reaction has not reached the equilibrium

(b) (6 pts) Calculate the molar concentrations of A and B at the equilibrium (show the calculations).

$$K'_{eq} = \frac{[B]_{eq}}{[A]_{eq}} = e^{-\Delta G'^{0}/RT} = 7.52$$

To determine $[B]_{eq}$ and $[A]_{eq}$ separately, use "matter conservation" law:

$$[A]_{eq} + [B]_{eq} = 12\ mM.$$

Let $[A]_{eq} = x$; then $[B]_{eq} = 7.52x$, and we have $(x + 7.52x) = 12\ mM$.

We get $[A]_{eq} = 1.4\ mM$

$[B]_{eq} = 10.6\ mM$