1. (15) Consider the reaction, \( \text{N}_2 + 3 \text{H}_2 \rightleftharpoons 2 \text{NH}_3 \) (where all components are gases).

(a) Write the reaction equilibrium condition in a closed system. (Be specific for this reaction.)
\[
\sum \nu_i \mu_i = 0 \implies \mu(\text{N}_2) + 3 \mu(\text{H}_2) = 2 \mu(\text{NH}_3)
\]

(b) Suppose that initially a reaction vessel contains just 5.80 mol \( \text{N}_2 \) and 6.20 mol \( \text{NH}_3 \). At a later time 6.50 mol of \( \text{N}_2 \) is present. How much of each of the other components is present, and what is the extent of reaction \( \xi \)?
\[
\Delta n_{\text{N}_2} = 0.70 \text{ mol} \implies \Delta n_{\text{H}_2} = 3 \times 0.70 \text{ mol} = 2.10 \text{ mol}
\]
\[
\text{and} \quad \Delta n_{\text{NH}_3} = -2 \times 0.70 \text{ mol} = -1.40 \text{ mol}
\]
\[
\xi = 2.10 \text{ mol} \quad \therefore \quad \text{NH}_3 = 4.80 \text{ mol}
\]
\[
\xi = \nu_1 \xi \implies \xi = -0.70 \text{ mol}
\]

(c) Suppose the reaction is rewritten, \( \text{NH}_3 \rightleftharpoons \frac{1}{2} \text{N}_2 + \frac{3}{2} \text{H}_2 \). Repeat the calculations of (b) for the same initial and final amounts of \( \text{N}_2 \) and \( \text{NH}_3 \).

Same final amounts of all 3 components.

Consider \( \text{N}_2 \) : \( \Delta n_i = 0.70 \text{ mol} = \xi \nu = \xi \left( \frac{1}{2} \right) \)
\[
\xi = 1.40 \text{ mol}
\]

2. (7) For each of the following — \( \text{CCl}_4(l), \text{H}(g), \text{N}_2(g) \) —

(a) Write the reaction of formation from reference-form elements at room \( T \).
\[
\text{C (graphite)} + 2 \text{O}_2 (g) \rightarrow \text{CCl}_4 (l)
\]
\[
\frac{1}{2} \text{H}_2 (g) \rightarrow \text{H} (g)
\]
\[
\text{N}_2 (g) \rightarrow \text{N}_2 (g)
\]

(b) Is \( \Delta H_f^\circ = 0 \) for any of these at 50°C? If so, which ones?
  yes — \( \text{N}_2(g) \)

3. (4) For each of the following closed systems, write the conditions for material equilibrium between phases:

(a) ice in equilibrium with liquid water.
\[
\mu[\text{H}_2\text{O}(s)] = \mu[\text{H}_2\text{O}(l)]
\]

(b) ice in equilibrium with an aqueous solution of sucrose.
\[
\mu[\text{H}_2\text{O}(s)] = \mu[\text{H}_2\text{O}(\text{soln})]
\]
\[
\{ + \mu[\text{sucrose (soln)}] = \mu[\text{sucrose (ice)}]\}
\]

(c) a two-phase system of ether and water, with each phase saturated with the other component.
\[
\mu[\text{H}_2\text{O}(aq)] = \mu[\text{H}_2\text{O}(\text{eth})]
\]
\[
\mu[\text{ether (aq)}] = \mu[\text{ether (eth)}]
\]