1) Photosynthesis can be represented by the following reaction:

$$6 \text{CO}_2 (g) + 6 \text{H}_2\text{O} (l) \rightleftharpoons \text{C}_6\text{H}_{12}\text{O}_6 (s) + 6 \text{O}_2 (g) \quad \Delta H^\circ = 2801 \text{kJ/mol}$$

a.) Write the equilibrium expression, $K_{eq}$, for the reaction. (1)
b.) Explain how the equilibrium would be affected by the following changes (0.5 each)
   i.) Increasing the concentration of carbon dioxide.
   ii.) Removing water vapor from the system.
   iii.) Removing sucrose from the reaction.
   iv.) Decreasing the temperature of the system.
   v.) Reducing the volume of the system.
   vi.) Adding a catalyst.

2) Combustion reactions are famous for releasing enough gas to cause a drastic change in volume (aka moving the piston in your engine) The following is the unbalanced combustion of methane:

$$\text{CH}_4 (g) \rightarrow 75 \text{kJ/mol} + \text{O}_2 (g) \rightarrow \text{CO}_2 (g) \rightarrow 393.5 \text{kJ/mol} + \text{H}_2\text{O} (l) \rightarrow 286 \text{kJ/mol}$$

a. How much work is performed if the gas expands from 300 mL to 570 mL at a constant pressure of 2 atm? Is work performed on the system or work done by the system? (1)
b. Calculate the $\Delta \text{H}^\circ_f$ for the combustion of methane at STP. Is it exothermic or endothermic? (1)
c. Calculate the $\Delta E$ of the reaction at STP. (1)
3) The formation of methanol can be represented by the following **exothermic** reaction:

\[
C \text{ (graphite)} + 2 \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CH}_3\text{OH} (l)
\]

Using the following combustion reactions (1), (2), and (3), determine the standard enthalpy of reaction, \(\Delta_r H^\circ\), for the process above and standard enthalpy of formation of methanol, \(\Delta_f H^\circ\). (3)

(1) \(\text{CH}_3\text{OH} (l) + \frac{3}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O} (l)\) \(\Delta_r H^\circ = -726.4 \text{ kJ/mol}\)

(2) \(\text{C (graphite)} + \text{O}_2(g) \rightarrow \text{CO}_2(g)\) \(\Delta_r H^\circ = -393.5 \text{ kJ/mol}\)

(3) \(\text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O} (l)\) \(\Delta_r H^\circ = -285.8 \text{ kJ/mol}\)
1) Consider the following reaction:

\[ 3A(g) \leftrightarrow B(g) + 4C(g) \]

If 0.294 mols of A is placed in a rigid container of 4.0 L initially:
Write an equation for \( K_{eq} \). Also, given that \( K_{eq} = 5.4 \times 10^3 \), what is the equilibrium amount of C(g) present (in mols)? (3)

2) Determine the enthalpy for the combustion of Benzene (from the bond energies.
Bond Energies in kJ/mol:
- H-H \( \rightarrow \) 432; C-H \( \rightarrow \) 413; C-C \( \rightarrow \) 347
- C-O \( \rightarrow \) 358; C=C \( \rightarrow \) 614; O=O \( \rightarrow \) 745
- C=O \( \rightarrow \) 799; O-H \( \rightarrow \) 467
3) You have the following exothermic reaction

\[ A \rightleftharpoons 2B + C \]

Where A is the reactant and B and C are products

a) Write the equilibrium constant for the reaction? (1)

b) Will the formation of products or reactants be favored if the temperature is lowered? (0.5)

c) If A and C are both aqueous, and product B is a gas, which way will the reaction be driven? (0.5)

d) If A, B, and C are all gasses and you decrease the volume, which way will the reaction be driven? (0.5)

e) If A, B, and C are all gasses and you add an inert gas, which way will the reaction be driven? (0.5)
1) Hank Hill is getting ready to train a new employee at Strickland Propane, but he needs to calculate the standard heat of formation of propane (C₃H₈) first. From the following data, calculate the standard heat of formation of propane (C₃H₈) via the following data (4):

\[3\text{C (s, graphite)} + 4\text{H}_2 (g) \rightarrow \text{C}_3\text{H}_8 (g); \Delta H_f^o = ?\]

\[\text{C}_3\text{H}_8 (g) + 5\text{O}_2 (g) \rightarrow 3\text{CO}_2 (g) + 4\text{H}_2\text{O} (g); \Delta H = -2044.5 \text{ kJ/mol}\]

\[\text{H}_2 (g) + \frac{1}{2}\text{O}_2 (g) \rightarrow \text{H}_2\text{O} (g); \Delta H = -242 \text{ kJ/mol}\]

\[\text{C (s, graphite)} + \text{O}_2 (g) \rightarrow \text{CO}_2 (g); \Delta H = -393.5 \text{ kJ/mol}\]

2) Number of degrees of freedom per molecule of H₂O at very high temperatures is 9. Justify this answer. (Hint: draw water and think about the structure of water for its different motions) (3)
3) Give the Mass Action Laws for the following *unbalanced* reactions:

a) \( \text{NO} (g) + \text{Cl}_2 (g) \rightarrow \text{NOCl} (g) \)

b) \( \text{BaSO}_4 (s) \rightarrow \text{Ba}^{2+} (\text{aq}) + \text{SO}_4^{2-} (\text{aq}) \)

c) \( \text{Al} (s) + \text{Fe}_2\text{O}_3 (\text{aq}) \rightarrow \text{Al}_2\text{O}_3 (s) + \text{Fe} (l) \)