Question 3
(9 points)

Answer the following questions about glucose, $C_6H_{12}O_6$, an important biochemical energy source.

(a) Write the empirical formula of glucose.

CH_2O	1 point is earned for the correct formula.

In many organisms, glucose is oxidized to carbon dioxide and water, as represented by the following equation.

$$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$$

A 2.50 g sample of glucose and an excess of $O_2(g)$ were placed in a calorimeter. After the reaction was initiated and proceeded to completion, the total heat released by the reaction was calculated to be 39.0 kJ.

(b) Calculate the value of $\Delta H°$, in kJ mol^{-1}, for the combustion of glucose.

$2.50\ g \times \frac{1\ mol\ C_6H_{12}O_6}{180.16\ g\ C_6H_{12}O_6} = 0.0139\ mol\ C_6H_{12}O_6$ $\frac{-39.0\ kJ}{0.0139\ mol} = -2{,}810\ kJ\ mol^{-1}$	1 point is earned for the correct answer.

(c) When oxygen is not available, glucose can be oxidized by fermentation. In that process, ethanol and carbon dioxide are produced, as represented by the following equation.

$$C_6H_{12}O_6(s) \rightarrow 2\ C_2H_5OH(l) + 2\ CO_2(g) \qquad \Delta H° = -68.0\ kJ\ mol^{-1}\ at\ 298\ K$$

The value of the equilibrium constant, K_p, for the reaction at 298 K is 8.9×10^{39}.

(i) Calculate the value of the standard free-energy change, $\Delta G°$, for the reaction at 298 K. Include units with your answer.

$\Delta G° = -RT \ln K$ $= -(8.31\ J\ mol^{-1}\ K^{-1})(298\ K)(\ln 8.9 \times 10^{39})$ $= -228{,}000\ J\ mol^{-1} = -228\ kJ\ mol^{-1}$	1 point is earned for correct setup. 1 point is earned for correct answer.

Question 3 (continued)

(ii) Calculate the value of the standard entropy change, $\Delta S°$, in J K^{-1} mol^{-1}, for the reaction at 298 K.

$\Delta G° = \Delta H° - T\Delta S°$ $\Delta S° = \dfrac{\Delta H° - \Delta G°}{T}$ $= \dfrac{(-68.0 \text{ kJ mol}^{-1}) - (-228 \text{ kJ mol}^{-1})}{298 \text{ K}}$ $= 0.537 \text{ kJ K}^{-1} \text{ mol}^{-1} = 537 \text{ J K}^{-1} \text{ mol}^{-1}$	1 point is earned for the correct setup. 1 point is earned for the correct answer.

(iii) Indicate whether the equilibrium constant for the fermentation reaction increases, decreases, or remains the same if the temperature is increased. Justify your answer.

$\Delta H°$ is negative, so when the temperature increases, the equilibrium for the reaction is shifted to the left (according to Le Châtelier's principle). This means that the equilibrium constant decreases.	1 point is earned for the correct answer with justification.

(d) Using your answer for part (b) and the information provided in part (c), calculate the value of $\Delta H°$ for the following reaction.

$$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(l)$$

$C_6H_{12}O_6(s) + 6\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l) \quad \Delta H° = -2{,}810 \text{ kJ mol}^{-1}$ $2\ C_2H_5OH(l) + 2\ CO_2(g) \rightarrow C_6H_{12}O_6(s) \quad \Delta H° = 68.0 \text{ kJ mol}^{-1}$ ――――――――――――――――――――――――― $2\ C_2H_5OH(l) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 6\ H_2O(l) \quad \Delta H° = -2{,}740 \text{ kJ mol}^{-1}$, thus $\Delta H°$ for the reaction as written in (d) is $-1{,}370 \text{ kJ mol}^{-1}$.	1 point is earned for the correct setup. 1 point is earned for the correct answer.