Question 2
(10 points)

A sample of a pure, gaseous hydrocarbon is introduced into a previously evacuated rigid 1.00 L vessel. The pressure of the gas is 0.200 atm at a temperature of 127°C.

(a) Calculate the number of moles of the hydrocarbon in the vessel.

$n = \frac{PV}{RT} = \frac{(0.200 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})}$	1 point is earned for the setup.
$n = 6.09 \times 10^{-3}$ mol	1 point is earned for the numerical answer.

(b) $O_2(g)$ is introduced into the same vessel containing the hydrocarbon. After the addition of the $O_2(g)$, the total pressure of the gas mixture in the vessel is 1.40 atm at 127°C. Calculate the partial pressure of $O_2(g)$ in the vessel.

P_{O_2} = 1.40 atm – 0.200 atm = 1.20 atm	1 point is earned for the correct pressure.

The mixture of the hydrocarbon and oxygen is sparked so that a complete combustion reaction occurs, producing $CO_2(g)$ and $H_2O(g)$. The partial pressures of these gases at 127°C are 0.600 atm for $CO_2(g)$ and 0.800 atm for $H_2O(g)$. There is $O_2(g)$ remaining in the container after the reaction is complete.

(c) Use the partial pressures of $CO_2(g)$ and $H_2O(g)$ to calculate the partial pressure of the $O_2(g)$ consumed in the combustion.

	. . . C_xH_y + . . . O_2 → . . . CO_2 + . . . H_2O before rxn: 0.200 atm, 1.20 atm, -, - after rxn: 0 atm, ? atm, 0.600 atm, 0.800 atm $0.600 \text{ atm } CO_2 \left(\frac{1 \text{ atm } O_2}{1 \text{ atm } CO_2}\right) = 0.600 \text{ atm } O_2$ $0.800 \text{ atm } H_2O \left(\frac{1 \text{ atm } O_2}{2 \text{ atm } H_2O}\right) = 0.400 \text{ atm } O_2$ Total O_2 consumed = 1.000 atm **OR**, based on $PV = nRT$ and mole calculations: $n_{H_2O} = \frac{PV}{RT} = \frac{(0.800 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0244 \text{ mol } H_2O \times \frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O}$ $= 0.0122 \text{ mol } O_2$ $n_{CO_2} = \frac{PV}{RT} = \frac{(0.600 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0183 \text{ mol } CO_2 \times \frac{1 \text{ mol } O_2}{1 \text{ mol } CO_2}$ $= 0.0183 \text{ mol } O_2$ Total moles O_2 = 0.0305; $P = \frac{nRT}{V} = \frac{(0.0305 \text{ mol})(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})}{1.00 \text{ L}}$ $P = 1.00 \text{ atm } O_2$	1 point is earned for the correct stoichiometry in O_2 consumption. 1 point is earned for the calculated result.

Question 2 (continued)

(d) On the basis of your answers above, write the balanced chemical equation for the combustion reaction and determine the formula of the hydrocarbon.

The partial pressures occur in the same proportions as the number of moles. $P_{hydrocarbon} : P_{O_2} : P_{CO_2} : P_{H_2O}$ 0.200 atm : 1.00 atm : 0.600 atm : 0.800 atm = 1 : 5 : 3 : 4 $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$ **OR** $n_{H_2O} = \frac{PV}{RT} = \frac{(0.800\text{ atm})(1.00\text{ L})}{(0.0821\text{ L atm mol}^{-1}\text{ K}^{-1})(400.\text{ K})} = 0.0244\text{ mol } H_2O \times \frac{2\text{ mol H}}{1\text{ mol } H_2O}$ $= 0.0487$ mol H $n_{CO_2} = \frac{PV}{RT} = \frac{(0.600\text{ atm})(1.00\text{ L})}{(0.0821\text{ L atm mol}^{-1}\text{ K}^{-1})(400.\text{ K})} = 0.0183\text{ mol } CO_2 \times \frac{1\text{ mol C}}{1\text{ mol } CO_2}$ $= 0.0183$ mol C $\frac{0.0487\text{ mol H}}{0.0183\text{ mol C}} = \left(\frac{2.66\text{ mol H}}{1\text{ mol C}}\right)\left(\frac{3}{3}\right) = \frac{8\text{ mol H}}{3\text{ mol C}} \Rightarrow C_3H_8$ $C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$	1 point is earned for the formula of the hydrocarbon. 1 point is earned for a balanced equation with the correct proportions among reactants and products.

(e) Calculate the mass of the hydrocarbon that was combusted.

mass = (number of moles)(molar mass) $= (6.09 \times 10^{-3}\text{ mol})(44.1\text{ g/mol}) = 0.269\text{ g}$	1 point is earned for using the number of moles combusted from part (a). 1 point is earned for the calculated mass.

(f) As the vessel cools to room temperature, droplets of liquid water form on the inside walls of the container. Predict whether the pH of the water in the vessel is less than 7, equal to 7, or greater than 7. Explain your prediction.

The pH will be less than 7 because CO_2 is soluble in water, with which it reacts to form H^+ ions.	1 point is earned for the correct choice and explanation.