

AP[®] CHEMISTRY
2012 SCORING GUIDELINES

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.
$n = 6.09 \times 10^{-3} \text{ mol}$	1 point is earned for the numerical answer.

- (b) O₂(g) is introduced into the same vessel containing the hydrocarbon. After the addition of the O₂(g), the total pressure of the gas mixture in the vessel is 1.40 atm at 127°C. Calculate the partial pressure of O₂(g) in the vessel.

$P_{\text{O}_2} = 1.40 \text{ atm} - 0.200 \text{ atm} = 1.20 \text{ atm}$	1 point is earned for the correct pressure.
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The mixture of the hydrocarbon and oxygen is sparked so that a complete combustion reaction occurs, producing CO₂(g) and H₂O(g). The partial pressures of these gases at 127°C are 0.600 atm for CO₂(g) and 0.800 atm for H₂O(g). There is O₂(g) remaining in the container after the reaction is complete.

- (c) Use the partial pressures of CO₂(g) and H₂O(g) to calculate the partial pressure of the O₂(g) consumed in the combustion.

$\dots \text{C}_x\text{H}_y + \dots \text{O}_2 \rightarrow \dots \text{CO}_2 + \dots \text{H}_2\text{O}$	
before rxn: 0.200 atm 1.20 atm - -	
after rxn: 0 atm ? atm 0.600 atm 0.800 atm	
$0.600 \text{ atm CO}_2 \left(\frac{1 \text{ atm O}_2}{1 \text{ atm CO}_2} \right) = 0.600 \text{ atm O}_2$	
$0.800 \text{ atm H}_2\text{O} \left(\frac{1 \text{ atm O}_2}{2 \text{ atm H}_2\text{O}} \right) = 0.400 \text{ atm O}_2$	Total O ₂ consumed = 1.000 atm
OR , based on $PV = nRT$ and mole calculations:	
$n_{\text{H}_2\text{O}} = \frac{PV}{RT} = \frac{(0.800 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0244 \text{ mol H}_2\text{O} \times \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2\text{O}}$	
$= 0.0122 \text{ mol O}_2$	
$n_{\text{CO}_2} = \frac{PV}{RT} = \frac{(0.600 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0183 \text{ mol CO}_2 \times \frac{1 \text{ mol O}_2}{1 \text{ mol CO}_2}$	
$= 0.0183 \text{ mol O}_2$	
$\text{Total moles O}_2 = 0.0305; \quad P = \frac{nRT}{V} = \frac{(0.0305 \text{ mol})(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})}{1.00 \text{ L}}$	
$P = 1.00 \text{ atm O}_2$	

1 point is earned
for the correct
stoichiometry in
O₂ consumption.

1 point is earned
for the calculated
result.

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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.

<p>The partial pressures occur in the same proportions as the number of moles.</p> $P_{\text{hydrocarbon}} : P_{\text{O}_2} : P_{\text{CO}_2} : P_{\text{H}_2\text{O}}$ $0.200 \text{ atm} : 1.00 \text{ atm} : 0.600 \text{ atm} : 0.800 \text{ atm}$ $= 1 : 5 : 3 : 4$ $\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}$ <p style="text-align: center;">OR</p> $n_{\text{H}_2\text{O}} = \frac{PV}{RT} = \frac{(0.800 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0244 \text{ mol H}_2\text{O} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}}$ $= 0.0487 \text{ mol H}$ $n_{\text{CO}_2} = \frac{PV}{RT} = \frac{(0.600 \text{ atm})(1.00 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(400. \text{ K})} = 0.0183 \text{ mol CO}_2 \times \frac{1 \text{ mol C}}{1 \text{ mol CO}_2}$ $= 0.0183 \text{ mol C}$ $\frac{0.0487 \text{ mol H}}{0.0183 \text{ mol C}} = \left(\frac{2.66 \text{ mol H}}{1 \text{ mol C}} \right) \left(\frac{3}{3} \right) = \frac{8 \text{ mol H}}{3 \text{ mol C}} \Rightarrow \text{C}_3\text{H}_8$ $\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}$	<p>1 point is earned for the formula of the hydrocarbon.</p> <p>1 point is earned for a balanced equation with the correct proportions among reactants and products.</p>
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- (e) Calculate the mass of the hydrocarbon that was combusted.

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

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