AP® CHEMISTRY
2008 SCORING GUIDELINES

Question 1

$$C(s) + CO_2(g) \rightleftarrows 2\,CO(g)$$

Solid carbon and carbon dioxide gas at 1,160 K were placed in a rigid 2.00 L container, and the reaction represented above occurred. As the reaction proceeded, the total pressure in the container was monitored. When equilibrium was reached, there was still some $C(s)$ remaining in the container. Results are recorded in the table below.

Time (hours)	Total Pressure of Gases in Container at 1,160 K (atm)
0.0	5.00
2.0	6.26
4.0	7.09
6.0	7.75
8.0	8.37
10.0	8.37

(a) Write the expression for the equilibrium constant, K_p, for the reaction.

$K_p = \dfrac{(P_{CO})^2}{P_{CO_2}}$	One point is earned for the correct expression.

(b) Calculate the number of moles of $CO_2(g)$ initially placed in the container. (Assume that the volume of the solid carbon is negligible.)

$n = \dfrac{PV}{RT} = \dfrac{(5.00\text{ atm})(2.00\text{ L})}{(0.0821\ \frac{\text{L atm}}{\text{mol K}})(1{,}160\text{ K})} = 0.105\text{ mol}$	One point is earned for the correct setup. One point is earned for the correct answer.

(c) For the reaction mixture at equilibrium at 1,160 K, the partial pressure of the $CO_2(g)$ is 1.63 atm. Calculate

(i) the partial pressure of $CO(g)$, and

$P_{CO_2} + P_{CO} = P_{total}$ $P_{CO} = P_{total} - P_{CO_2} = 8.37\text{ atm} - 1.63\text{ atm} = 6.74\text{ atm}$	One point is earned for the correct answer supported by a correct method.

Question 1 (continued)

(ii) the value of the equilibrium constant, K_p.

$K_p = \frac{(P_{CO})^2}{P_{CO_2}} = \frac{(6.74 \text{ atm})^2}{1.63 \text{ atm}} = 27.9$	One point is earned for a correct setup that is consistent with part (a). One point is earned for the correct answer according to the setup.

(d) If a suitable solid catalyst were placed in the reaction vessel, would the final total pressure of the gases at equilibrium be greater than, less than, or equal to the final total pressure of the gases at equilibrium without the catalyst? Justify your answer. (Assume that the volume of the solid catalyst is negligible.)

The total pressure of the gases at equilibrium with a catalyst present would be equal to the total pressure of the gases without a catalyst. Although a catalyst would cause the system to reach the same equilibrium state more quickly, it would not affect the extent of the reaction, which is determined by the value of the equilibrium constant, K_p.	One point is earned for the correct answer with justification.

In another experiment involving the same reaction, a rigid 2.00 L container initially contains 10.0 g of C(s), plus CO(g) and CO_2(g), each at a partial pressure of 2.00 atm at 1,160 K.

(e) Predict whether the partial pressure of CO_2(g) will increase, decrease, or remain the same as this system approaches equilibrium. Justify your prediction with a calculation.

$Q = \frac{(P_{CO})^2}{P_{CO_2}} = \frac{(2.00 \text{ atm})^2}{2.00 \text{ atm}} = 2.00 < K_p \ (= 27.9)$, therefore P_{CO_2} will decrease as the system approaches equilibrium.	One point is earned for a correct calculation involving Q or ICE calculation. One point is earned for a correct conclusion based on the calculation.