AP® CHEMISTRY
2011 SCORING GUIDELINES

Question 6

In an experiment, all the air in a rigid 2.0 L flask is pumped out. Then some liquid ethanol is injected into the sealed flask, which is held at 35°C. The amount of liquid ethanol initially decreases, but after five minutes the amount of liquid ethanol in the flask remains constant. Ethanol has a boiling point of 78.5°C and an equilibrium vapor pressure of 100 torr at 35°C.

(a) When the amount of liquid ethanol in the flask is constant, is the pressure in the flask greater than, less than, or equal to 100 torr? Justify your answer.

The pressure would be equal to 100 torr. Because the quantity of liquid ethanol is not changing, the gas and liquid phases have reached equilibrium. Therefore the pressure of ethanol in the gas phase equals the vapor pressure.	1 point is earned for the correct choice with a valid justification.

(b) The flask is then heated to 45°C, and the pressure in the flask increases. In terms of kinetic molecular theory, provide TWO reasons that the pressure in the flask is greater at 45°C than at 35°C.

There are three possible reasons based on kinetic molecular theory. • At the higher temperature there are more ethanol molecules in the gas phase, so there will be more collisions with the flask walls, resulting in a greater pressure. • At the higher temperature the molecules will be moving faster on average, thus colliding with the flask walls more frequently, resulting in a greater pressure. • Because the molecules are moving faster on average, their collisions with the flask walls will exert a greater force, resulting in a greater pressure.	1 point is earned for each correct reason up to a maximum of 2 points.

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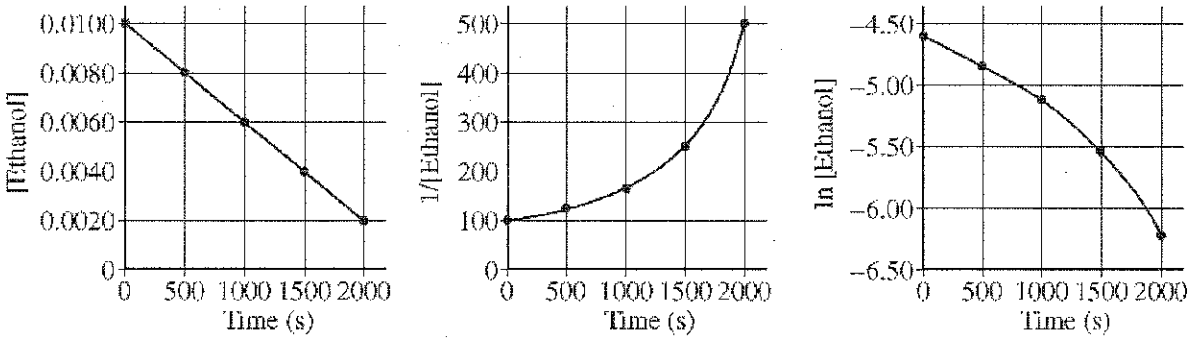
Question 6 (continued)

In a second experiment, which is performed at a much higher temperature, a sample of ethanol gas and a copper catalyst are placed in a rigid, empty 1.0 L flask. The temperature of the flask is held constant, and the initial concentration of the ethanol gas is 0.0100 *M*. The ethanol begins to decompose according to the chemical reaction represented below.

$$CH_3CH_2OH(g) \xrightarrow{Cu} CH_3CHO(g) + H_2(g)$$

The concentration of ethanol gas over time is used to create the three graphs below.



(c) Given that the reaction order is zero, one, or two, use the information in the graphs to respond to the following.

(i) Determine the order of the reaction with respect to ethanol. Justify your answer.

The order of the reaction is zero. The plot on the left is a straight line, indicating that the rate of decrease in [ethanol] is constant as [ethanol] changes. Therefore the rate of reaction does not depend on [ethanol].	1 point is earned for the correct choice with a valid justification.

(ii) Write the rate law for the reaction.

rate = k	1 point is earned for the correct rate law.

(iii) Determine the rate constant for the reaction, including units.

rate = $k = -\frac{\Delta[\text{ethanol}]}{\Delta t} = -\frac{(0.0020 - 0.0100)\ \text{mol/L}}{2000\ \text{s}}$ $= 4.0 \times 10^{-6}\ M\ \text{s}^{-1}$	1 point is earned for the correct setup. 1 point is earned for the correct units.

Question 6 (continued)

(d) The pressure in the flask at the beginning of the experiment is 0.40 atm. If the ethanol completely decomposes, what is the final pressure in the flask?

The final pressure is 0.80 atm (twice the original pressure because the products represent twice as many moles of gas as the reactant).	1 point is earned for the correct final pressure.