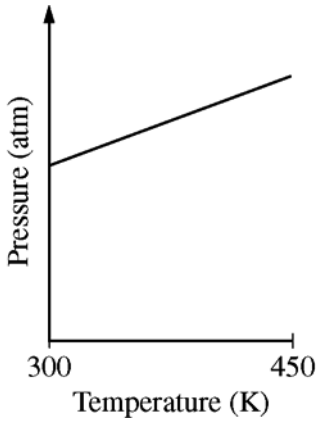
AP® CHEMISTRY
2013 SCORING GUIDELINES

Question 5
(8 points)

A sample of $C_2H_4(g)$ is placed in a previously evacuated, rigid 2.0 L container and heated from 300 K to 450 K. The pressure of the sample is measured and plotted in the graph below.



(a) Describe TWO reasons why the pressure changes as the temperature of the $C_2H_4(g)$ increases. Your descriptions must be in terms of what occurs at the molecular level.

Two reasons are: (1) As the temperature increases, the average speed of the molecules increases and the molecules collide more frequently with the container walls. (2) As the temperature increases, the average kinetic energy of the molecules increases and the molecules strike the walls of the container with greater force.	1 point is earned for <u>each</u> correct reason.

$C_2H_4(g)$ reacts readily with $HCl(g)$ to produce $C_2H_5Cl(g)$, as represented by the following equation.

$$C_2H_4(g) + HCl(g) \rightarrow C_2H_5Cl(g) \qquad \Delta H° = -72.6 \text{ kJ/mol}_{rxn}$$

(b) When $HCl(g)$ is injected into the container of $C_2H_4(g)$ at 450 K, the total pressure increases. Then, as the reaction proceeds at 450 K, the total pressure decreases. Explain this decrease in total pressure in terms of what occurs at the molecular level.

The decrease in pressure after the initial increase is a consequence of the reaction that produces fewer gas molecules than it consumes. When fewer gas molecules are present, there are fewer collisions with the container walls, resulting in a decrease in pressure.	1 point is earned for the correct reason.

Question 5 (continued)

It is proposed that the formation of $C_2H_5Cl(g)$ proceeds via the following two-step reaction mechanism.

Step 1: $C_2H_4(g) + HCl(g) \rightarrow C_2H_5^+(g) + Cl^-(g)$ *rate-determining step*
Step 2: $C_2H_5^+(g) + Cl^-(g) \rightarrow C_2H_5Cl(g)$ *fast step*

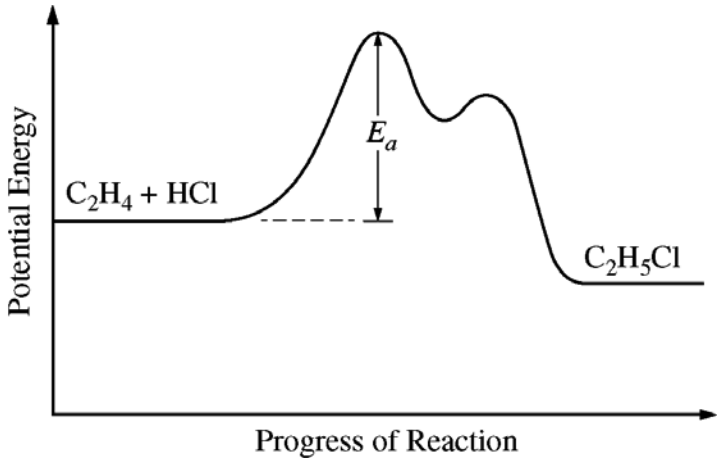
(c) Write the rate law for the reaction that is consistent with the reaction mechanism above.

rate $= k[C_2H_4][HCl]$	1 point is earned for the correct rate law.

(d) Identify an intermediate in the reaction mechanism above.

$C_2H_5^+(g)$ or $Cl^-(g)$	1 point is earned for identification of either species.

(e) Using the axes provided below, draw a curve that shows the energy changes that occur during the progress of the reaction. The curve should illustrate both the proposed two-step mechanism and the enthalpy change of the reaction.



See drawing above.	1 point is earned for the potential energy of the product being lower than the potential energy of the reactants (exothermic reaction). 1 point is earned for a reaction-energy curve that reflects a two-step process.

(f) On the diagram above, clearly indicate the activation energy, E_a, for the rate-determining step in the reaction.

See drawing above in part (e).	1 point is earned for the correct identification of E_a in Step 1.