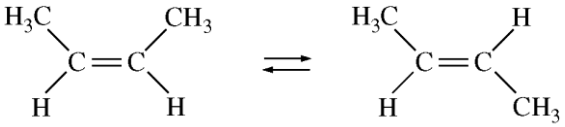
AP® CHEMISTRY
2014 SCORING GUIDELINES

Question 7
(4 points)



cis-2-butene ⇌ *trans*-2-butene

The half-life ($t_{1/2}$) of the catalyzed isomerization of *cis*-2-butene gas to produce *trans*-2-butene gas, represented above, was measured under various conditions, as shown in the table below.

Trial Number	Initial $P_{cis\text{-}2\text{-butene}}$ (torr)	V (L)	T (K)	$t_{1/2}$ (s)
1	300.	2.00	350.	100.
2	600.	2.00	350.	100.
3	300.	4.00	350.	100.
4	300.	2.00	365	50.

(a) The reaction is first order. Explain how the data in the table are consistent with a first-order reaction.

For a first-order reaction, the half-life is independent of reactant concentration (or pressure) at constant T, as shown in trials 1, 2, and 3.	1 point is earned for a correct explanation.

(b) Calculate the rate constant, k, for the reaction at 350. K. Include appropriate units with your answer.

$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{100.\text{ s}} = 0.00693\text{ s}^{-1}$	1 point is earned for correct numerical answer with units.

(c) Is the initial rate of the reaction in trial 1 greater than, less than, or equal to the initial rate in trial 2 ? Justify your answer.

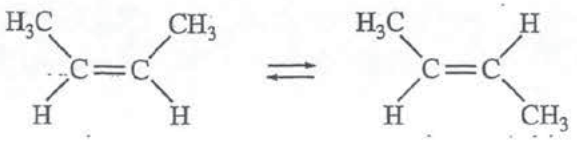
The initial rate in trial 1 is less than that in trial 2 because rate = k [*cis*-2-butene] or rate = $k\,P_{cis\text{-}2\text{-butene}}$ (with reference to values from both trials). OR because the initial concentration of *cis*-2-butene in trial 1 is less than that in trial 2 and k is constant.	1 point is earned for the correct answer with justification.

(d) The half-life of the reaction in trial 4 is less than the half-life in trial 1. Explain why, in terms of activation energy.

The temperature is higher in trial 4, meaning that the KE_{avg} of the molecules is greater. Consequently, in this trial a greater fraction of collisions have sufficient energy to overcome the activation energy barrier, thus the rate is greater.	1 point is earned for a correct answer with justification.

7A

rate = k[ ]



cis-2-butene ⇌ *trans*-2-butene

7. The half-life ($t_{1/2}$) of the catalyzed isomerization of *cis*-2-butene gas to produce *trans*-2-butene gas, represented above, was measured under various conditions, as shown in the table below.

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(a) The reaction is first order. Explain how the data in the table are consistent with a first-order reaction.

(b) Calculate the rate constant, k, for the reaction at 350. K. Include appropriate units with your answer.

(c) Is the initial rate of the reaction in trial 1 greater than, less than, or equal to the initial rate in trial 2? Justify your answer.

(d) The half-life of the reaction in trial 4 is less than the half-life in trial 1. Explain why, in terms of activation energy.

a) The half life is constant at a given temperature (350 K)

b) $k = \frac{0.693}{t_{1/2}} = \frac{0.693}{100} = 0.00693\ s^{-1}$

c) The initial rate of reaction in trial 1 is less than that in trial 2, since the partial pressure in trial 2 is higher.

d) Since the temperature is increased in trial 4, a higher proportion of collisions have enough energy to surpass the activation energy of the reaction, and the reaction happens faster.

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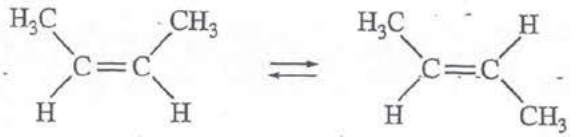
7B,



cis-2-butene ⇌ *trans*-2-butene

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(a) The reaction is first order. Explain how the data in the table are consistent with a first-order reaction.

(b) Calculate the rate constant, k, for the reaction at 350. K. Include appropriate units with your answer.

(c) Is the initial rate of the reaction in trial 1 greater than, less than, or equal to the initial rate in trial 2? Justify your answer.

(d) The half-life of the reaction in trial 4 is less than the half-life in trial 1. Explain why, in terms of activation energy.

a) Rate = k[Trans-2-butene] The rate is constant because, as pressure is halved and volume is doubled, the same number of molecules react, which proves it is a first order reaction.

b) $t_{1/2} = \frac{0.693}{k}$ for first order

$100\ s = \frac{0.693}{k}$

$\boxed{k = 6.93 \times 10^{-3}}$

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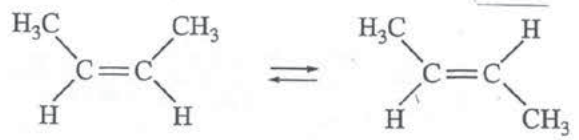
c) The initial rate of trial 1 is less than the rate of trial two because trial 2 had the higher pressure of cis-2-butene. Therefore, since V and T remain constant, there are more cis-2-butene molecules, and the rate is greater than the rate in trial 1 with less cis-2-butene molecules.

d) The half-life of trial 4 is less than that of trial 1 because of a higher temperature. This increase in temperature increases the probability that the cis-2-butene molecules collide with sufficient amount of energy to overcome the required activation energy. Thus, the reaction would occur faster than the other trials.

7C,



cis-2-butene ⇌ *trans*-2-butene

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(a) The reaction is first order. Explain how the data in the table are consistent with a first-order reaction.

(b) Calculate the rate constant, k, for the reaction at 350. K. Include appropriate units with your answer.

(c) Is the initial rate of the reaction in trial 1 greater than, less than, or equal to the initial rate in trial 2? Justify your answer.

(d) The half-life of the reaction in trial 4 is less than the half-life in trial 1. Explain why, in terms of activation energy.

a) The given values increase and decrease consistenty with one another

b) $t_{1/2} = \frac{.693}{k}$ $100_s = \frac{.693}{k}$ $k = 6.93 \times 10^{-3}$ moles/second

c) Equal to because in the formula $t_{1/2} = \frac{.693}{k}$ the difference in pressure plays no part.

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7C2

ADDITIONAL PAGE FOR ANSWERING QUESTION 7

d) With an increased temperature more molecules have the reauired activation energy when they collide increasing the rate of reaction and decreasing the half life

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AP® CHEMISTRY
2014 SCORING COMMENTARY

Question 7

Overview

The question required students to interpret kinetic data in the isomerization reaction of *cis*-2-butene to *trans*-2-butene under various conditions in the gaseous state. Four trials were presented in a table that listed the initial pressure of *cis*-2-butene, the volume of the reaction chamber, temperature, and half-life of the reaction. Part (a) stated that the reaction is first order and asked for an explanation of how the data was consistent with this fact. In part (b) students calculated the rate constant k for the reaction at 350 K. Part (c) assessed students' knowledge of the relationship between reaction rates, rate constant, and concentration by asking for a prediction, with justification, about whether the initial rate of reaction in trial 1 would be greater than, less than, or equal to that in trial 2. (Relative to trial 1, trial 2 had an identical volume, temperature and half-life, but twice the initial partial pressure of reactant.) In part (d) students needed to explain why, in terms of activation energy, the half-life of the reaction in trial 4 is less than the half-life of trial 1. This part examined the ability to logically associate a higher temperature with greater average kinetic energy of reactant molecules and thus a greater fraction of molecules able to collide with enough energy to overcome the activation energy barrier.

Sample: 7A
Score: 4

This response received all 4 possible points: 1 point in part (a), 1 point in part (b), 1 point in part (c), and 1 point in part (d).

Sample: 7B
Score: 2

Part (a) did not earn a point because it omits any mention of half-life and makes no clear reference to relevant data from the table. The answer to part (b) did not earn a point because, although it provides a valid setup with the correct numerical value of k, it does not include units. The points were earned in parts (c) and (d).

Sample: 7C
Score: 1

In part (a) the point was not earned because the response makes only vague references to the data and does not mention half-life specifically. Part (b) did not earn the point because, although the setup and numerical answer are correct, the answer has incorrect units. The point was not earned in part (c) because the student said the initial rates are equal. The point was earned in part (d).