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SUPPLEMENTARY MATERIAL TO
**Pictorial based learning: Promoting conceptual change in
chemical kinetics**

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THE FTDICK INSTRUMENT

Consent form

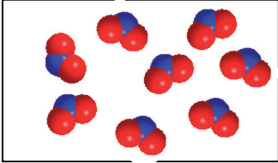
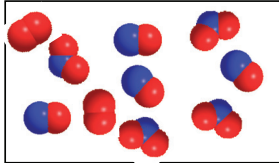
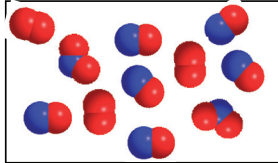
We are conducting an investigation into students' understanding of chemical reaction kinetics. As you will be studying/have studied this topic we would like you to attempt the following questions and choose reasons for your answers. The results from the investigation will be used alongside the data from other students to gain a better understanding of students' understanding of reaction rates and may be published in the educational literature. The outcomes will be completely anonymous and no participants will be identifiable. If you would like your results to contribute to our investigation, please tick the box below:

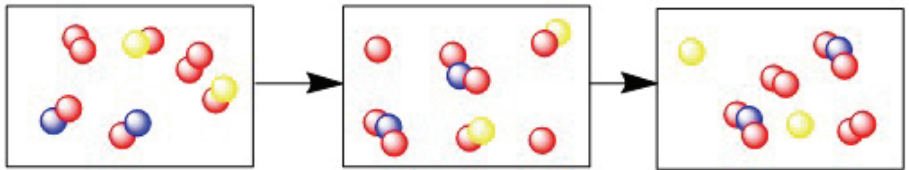
- I am happy to take part in this investigation and for my results to contribute to the investigation

Signed:

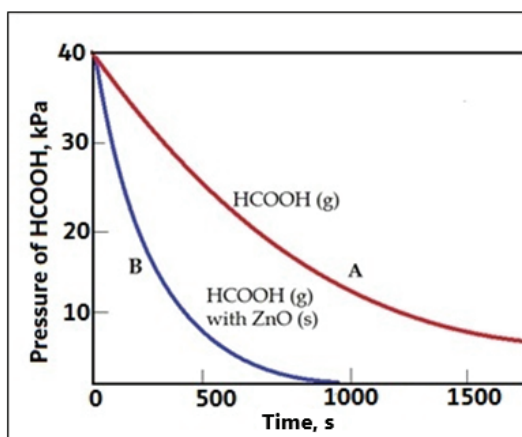
Date:

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No.	Question
1.	<p>A 64 mg sample of radioactive material decays by first order reaction. After 10 minutes two half-lives have passed. What is the mass of the sample that remains after 15 minutes? A. 24 mg B. 23 mg C. 16 mg D. 8 mg</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question? After 10 minutes, half of the initial sample remained The rate of decay of this sample is a constant For each successive half-life, the mass change of sample is a constant The rate of decay of this sample increases as the mass of sample decreases For each successive half-life, the mass of sample decreases by a factor of 2</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>
2.	<p>The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is shown pictorially below and is a second order reaction and the equation for the reaction is: $2\text{NO}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  <p>$t = 10 \text{ s}$</p> </div> <div style="text-align: center;">  <p>$t = 20 \text{ s}$</p> </div> <div style="text-align: center;">  <p>$t = \dots\dots\dots?$</p> </div> </div> <p style="text-align: center;">time \longrightarrow</p> <p>The time at the final representation shown above is... A. 25 s B. 30 s C. 40 s D. 50 s</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question? The value of each successive half-life is half the preceding one The value of $t_{1/2}$ is constant The rate of disappearance of this sample increases with decrease in concentration The value of each successive half-life is twice the preceding one.</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>
3.	<p>The second order reaction of $\text{H}_2\text{O}_2(\text{aq}) + 3\text{I}^-(\text{aq}) + 2\text{H}^+(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + \text{I}_3^-(\text{aq})$ is first order in H_2O_2, first order in I^- and zero order in H^+. The rate law expression for this reaction is.... A. Rate = $k c_{\text{H}_2\text{O}_2} (c_{\text{I}^-})^3 (c_{\text{H}^+})^2$ B. Rate = $k c_{\text{H}_2\text{O}_2} c_{\text{I}^-}$ C. Rate = $k \frac{c_{\text{H}_2\text{O}_2} c_{\text{I}^-}}{c_{\text{H}^+}}$ D. Rate = $k (c_{\text{H}_2\text{O}_2})^x (c_{\text{I}^-})^y (c_{\text{H}^+})^z$ (x, y, z are $\neq 0$)</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question? The values of the exponents in the rate law are obtained from the coefficients in the balanced equation The rate law is expressed based on the law of mass action that describes the relationship between the concentrations of the reactants and products. The values of the exponents in the rate law are based on the order of the reactants which are determined experimentally The information which is provided in the question is inadequate to determine the rate law.</p> <p>State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>

4.	<p>The decomposition of nitrogen dioxide to nitric oxide and oxygen takes place by second order kinetics:</p> $2\text{NO}_2(\text{g}) \rightarrow 2\text{NO}(\text{g}) + \text{O}_2(\text{g})$ <p>At time, $t = 10$ s the pressure of NO_2 is 10.66 kPa and after 5 seconds the pressure has dropped to 5.33 kPa. Determine the time at which the pressure of NO_2 is 2.66 kPa</p> <p>A. 17.5 s B. 20 s C. 25 s D. 30 s</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question?</p> <p>The value of each successive half-life is half the preceding one</p> <p>The value of $t_{1/2}$ is constant</p> <p>The rate of disappearance of this sample increases with decrease in concentration</p> <p>The value of each successive half-life is twice the preceding one.</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>
5.	<p>The formation of $\text{HI}(\text{g})$ follows the reaction $\text{H}_2 + \text{I}_2 \rightarrow 2\text{HI}$. This reaction may occur with the following mechanism:</p> $\text{I}_2 \xrightleftharpoons[k_{-1}]{k_1} 2\text{I} \quad \text{fast}$ $\text{I} + \text{I} + \text{H}_2 \xrightarrow{k_2} 2\text{HI} \quad \text{slow}$ <p>The overall rate law of this reaction is....</p> <p>A. Rate = $k_2 (C_{\text{I}})^2 (C_{\text{H}_2})$ B. Rate = $k (C_{\text{I}})^2 (C_{\text{H}_2})$</p> <p>C. Rate = $k_2 \frac{k_1}{k_{-1}} (C_{\text{I}_2}) (C_{\text{H}_2})$ D. Rate = $k_1 (C_{\text{I}_2}) - k_{-1} (C_{\text{I}})^2$</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question?</p> <p>The rate law is obtained directly from the slow step in the mechanism</p> <p>The rate law is obtained from the fast step in the mechanism</p> <p>The rate law is obtained from the law of mass action</p> <p>The rate law is obtained from the slow step by considering any intermediates in preceding steps</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>
6.	<p>The following diagram depicts an imaginary two step mechanism of a reaction.</p>  <p>Based on the representation above, the substance that acts as a catalyst is....</p> <p>X B. XZ C. X_2 D. XY</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question?</p> <p>The substance does not undergo a permanent chemical change and is reformed in the final product</p> <p>The substance is formed in one elementary reaction and consumed in the next</p> <p>The substance increases the rate without being involved chemically in the reaction</p> <p>The substance is not present in the final product</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>

7. The variation in partial pressure of HCOOH for the decomposition of formic acid $\{\text{HCOOH}(g) \rightarrow \text{CO}_2(g) + \text{H}_2(g)\}$ in the gas phase as a function of time at 838 K is described in the graph below.



A graph of the partial pressure of HCOOH versus time is shown as the red curve, A. Assuming that ZnO(s) is the catalyst, when a small amount of solid ZnO is added, the partial pressure of HCOOH versus time varies as shown by the blue curve, B. Based on this information, which is the correct statement below?

- This is an example of homogeneous catalysis and the rate of B is higher than the rate of A
 This is an example of heterogeneous catalysis and the rate of B is higher than the rate of A
 This is an example of homogeneous catalysis and the rate of A is higher than the rate of B
 This is an example of heterogeneous catalysis and the rate of A is higher than the rate of B

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

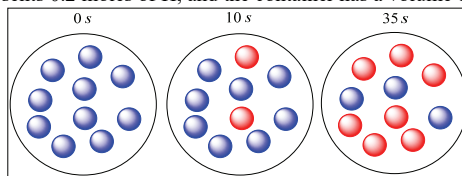
Which one of the following options is the reason for your answer to the question?

- HCOOH, CO₂ and H₂ are in the same phase and the presence of ZnO increases the rate
 HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate
 HCOOH, CO₂ and H₂ are present in the same phase and the presence of ZnO decreases the rate
 HCOOH and ZnO are in different phases and the presence of ZnO increases the rate

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

8. The hypothetical reaction $G \rightarrow H$ is depicted pictorially below. Each blue sphere represents 0.2 moles of G and each red sphere represents 0.2 moles of H, and the container has a volume of 1.00 L.



The number of moles of G and H respectively in the mixture after 32 s is....

- A. 1.280 mol; 0.720 mol B. 0.544 mol; 1.456 mol C. 0.720 mol; 1.280 mol D. 1.456 mol; 0.544 mol

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Which one of the following options is the reason for your answer to the question?

- As time increases, the rate of conversion of G molecules to H molecules also increases
 As time increases, the rate of conversion of G molecules to H molecules decreases
 The rate of conversion of G molecules to H molecules per second is a constant

State the confidence rating of your answer

1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

<p>9. The decomposition of N_2O_5 in a solvent occurs according to the following equation</p> $\text{N}_2\text{O}_5 \rightarrow 2\text{NO}_2 + \frac{1}{2} \text{O}_2$ <p>In the interval between 20 minutes and 40 minutes, the $[\text{N}_2\text{O}_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is the correct expression of the average reaction rate?</p> <p>A. Rate = $\Delta C_{\text{N}_2\text{O}_5} / \Delta t = 0.001 \text{ M min}^{-1}$ B. Rate = $\Delta C_{\text{NO}_2} / \Delta t = 0.001 \text{ M min}^{-1}$ C. Rate = $\Delta C_{\text{O}_2} / \Delta t = 0.0005 \text{ M min}^{-1}$ D. Rate = $\Delta C_{\text{NO}_2} / \Delta t = -0.002 \text{ M min}^{-1}$</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p> <p>Which one of the following options is the reason for your answer to the question?</p> <p>O_2 is produced twice as fast as N_2O_5 is consumed NO_2 is produced a half as fast as N_2O_5 is consumed The rate law can only be expressed by the rate of disappearance of N_2O_5 N_2O_5 is consumed twice as fast as NO_2 is produced NO_2 is consumed twice as fast as N_2O_5 is consumed O_2 is produced a half as fast as N_2O_5 is consumed</p> <p>State the confidence rating of your answer</p> <p>1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident</p>

Note: The complete FTDICK instrument used in the pre-test is available in the previous paper of Habiddin and Page.¹

REFERENCES

1. H. Habiddin, E. M. Page, *Indones. J. Chem.* **19** (2019) 720–736 (<https://doi.org/10.22146/ijc.39218>).