Electronic Supplementary Material (ESI) for Chemistry Education Research and Practice.

Diagnostic Test on Reaction Kinetics in 4-tier format

Name: _____ **Year**_____

Junior College/ Institute _____

Objective of this diagnostic test

The objective of this study is to uncover some of the common misconceptions harbored by A-level students in the topic of reaction kinetics. Knowledge of the misconceptions harbored by students in this topic will be useful for coming up with suitable teaching strategies to address these misconceptions.

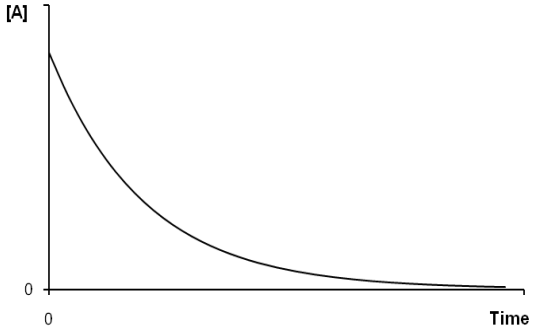
Your performance in this test will not in any way affect your grade in Chemistry.

Instructions for completing diagnostic test

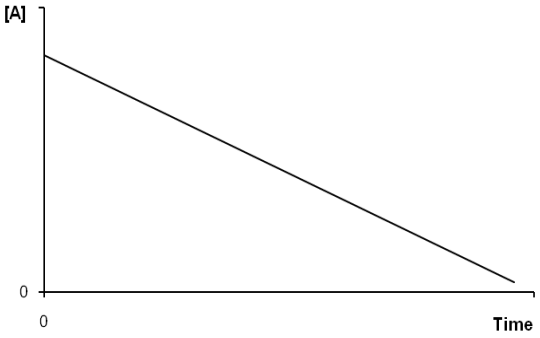
1. For each multiple choice question,
   (a) Select the answer that best fits your understanding by circling the appropriate alphabet.
   (b) Indicate your confidence level for your answer by circling the appropriate number.
   (c) Select the best reason for your choice of answer by circling the appropriate alphabet.
   (d) Indicate your confidence level for your reason by circling the appropriate number.

2. Answer ALL questions

1. Which of the following graphs is/are correct for the first-order reaction **A** $\rightarrow$ **B** + **C**?



(i)



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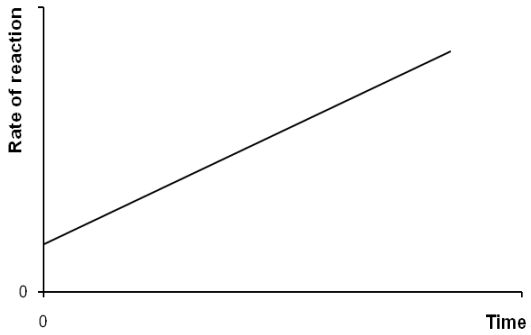

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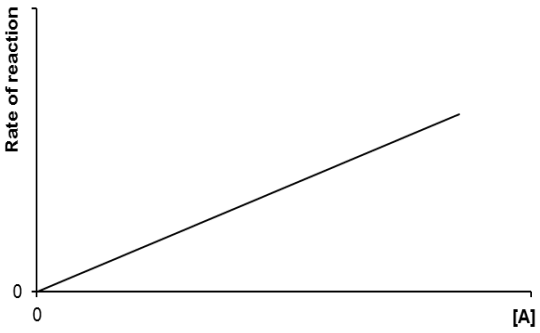


(iv)

Answer

(a) (i)

(b) (i) and (iv)

(c) (ii) and (iv)

(d) (i), (iii) and (iv)

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) A first-order reaction has a constant half-life, so the time it takes for the reactant concentration to drop to half its initial value is constant.

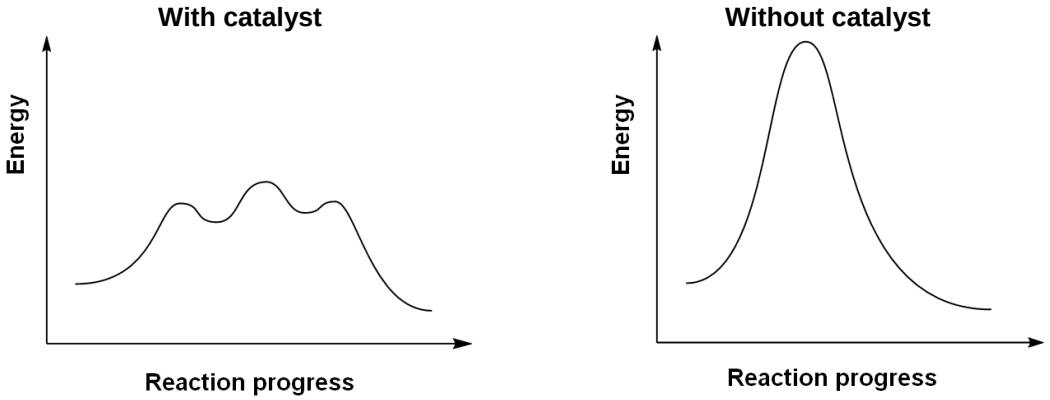
(b) A first-order reaction has a constant half-life, so the reactant concentration decreases at a constant rate.

(c) A first-order reaction has a constant half-life, and the rate of reaction is directly proportional to time and concentration.

(d) A first-order reaction has a constant half-life, and the rate of reaction is directly proportional to concentration.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

2. The energy profile diagrams for the reaction, **A** + **B** $\rightarrow$ **C** + **D**, with and without a catalyst, are shown below.



Which one of the following statements about the catalyst is **correct**?

Answer

(a) It could be an enzyme, a homogeneous catalyst or a heterogeneous catalyst.

(b) It could be either a homogeneous or heterogeneous catalyst.

(c) It could be either a heterogeneous catalyst or an enzyme.

(d) It could be either a homogeneous catalyst or an enzyme.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason

(a) These substances lower the energy barrier of the reaction and increase the frequency of collision of reactant molecules.

(b) These substances lower the energy barrier of the reaction by providing a pathway of lower enthalpy change.

(c) These substances lower the energy barrier of the reaction without changing the mechanism.

(d) These substances lower the energy barrier of the reaction by changing the mechanism.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

3. The rate of production of ozone in the reaction below is 2.0×10^{-7} mol dm^{-3} s^{-1}:

$$3\ O_2\,(g) \rightarrow 2\ O_3\,(g)$$

The rate of disappearance of oxygen is 3.0×10^{-7} mol dm^{-3} s^{-1}. True or False?

Answer

(a) True

(b) False

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) Rate of disappearance of oxygen is equal to the rate of production of ozone.

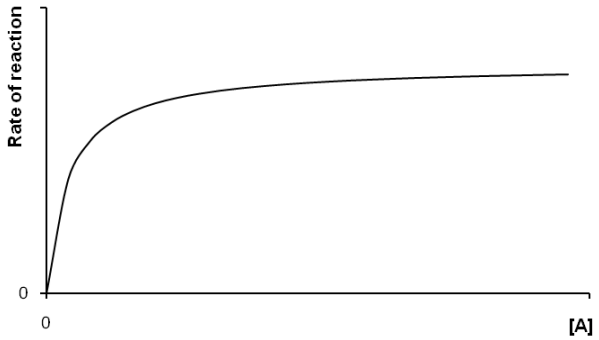
(b) Rate of disappearance of oxygen is two-thirds the rate of production of ozone.

(c) Rate of production of ozone is two-thirds the rate of disappearance of oxygen.

(d) Rate of production of ozone is 1.5 times the rate of disappearance of oxygen.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

4. The reaction, **A + B → C + D,** is catalyzed by substance **X**. Ten beakers containing the same amounts of **B**, **X** and an inert solvent, but with different amounts of **A**, were set up. The rates of reaction in the beakers were measured and plotted against the initial concentration of **A** to give the graph below.



Substance **X** could be an enzyme, a homogeneous catalyst or a heterogeneous catalyst. True or False?

Answer

(a) False

(b) True

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) There is an optimum reactant concentration at which an enzyme would work at maximum efficiency.

(b) Catalysts work at near maximum efficiency at high reactant concentrations.

(c) Rate of reaction is proportional to reactant concentration in the presence of homogeneous catalysts.

(d) Rate of reaction is independent of reactant concentration in the presence of heterogeneous catalysts.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

5. Which one of the following statements in the answer below about the Haber process is **true** for the manufacture of ammonia?

$$N_2 + 3\,H_2 \rightleftharpoons 2\,NH_3 \qquad \Delta H < 0$$

Answer

(a) At higher pressure, the percentage yield goes down but the rate of production of ammonia is faster.

(b) At higher temperature, the percentage yield goes down but the rate of production of ammonia is faster.

(c) In the presence of a catalyst, the percentage yield goes up and the rate of production of ammonia is faster.

(d) Increasing the surface area of the catalyst increases the percentage yield of ammonia.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason

(a) Under this condition, the rates of the forward and reverse reactions both increase.

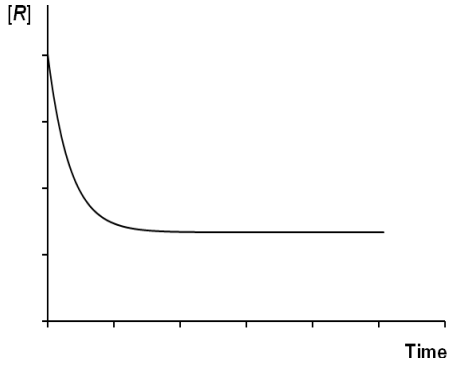
(b) Under this condition, frequency of collision of reactant molecules increases, and the reverse reaction is favoured.

(c) Under this condition, frequency of effective collisions of all molecules increases, but the increase is greater for the product molecules.

(d) Under this condition, the activation energy of the reverse reaction decreases more than the activation energy of the forward reaction.

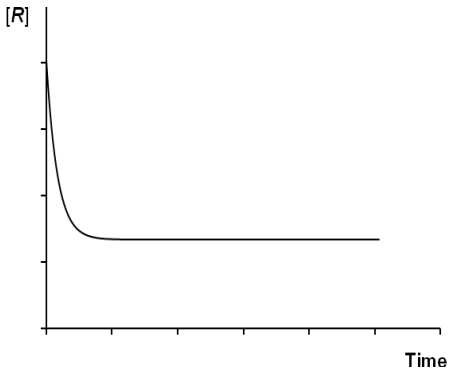
Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

6. The concentration of a reactant **R** was plotted against time as it reacted exothermically with **S** to reach equilibrium:

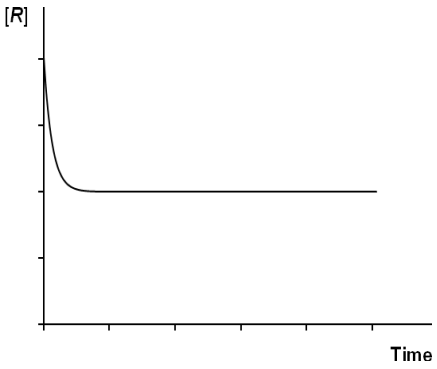


Which one of the following graphs could be obtained if the reaction was repeated at a higher temperature but with the same initial concentrations of **R** and **S**?

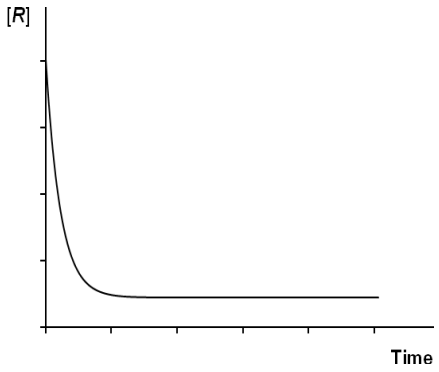
(a)



(b)



(c)



Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) Increasing temperature favours the reverse reaction and slows down the forward reaction.

(b) Increasing temperature reduces the time taken to reach equilibrium and allows more reactant molecules to have enough energy to react.

(c) Increasing temperature reduces the time taken to reach equilibrium and favours the reverse reaction.

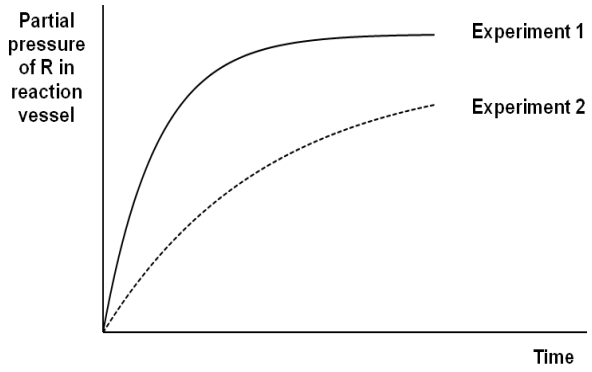
(d) Since the initial concentrations of **R** and **S** are not changed, increasing the temperature only reduces the time taken for the reaction to reach equilibrium.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

7. The stoichiometry of a catalyzed reaction is shown by the equation below:

$$\mathbf{P}\,(g) + \mathbf{Q}\,(g) \rightleftharpoons \mathbf{R}\,(g) + \mathbf{S}\,(g)$$

Two experiments were carried out in which the partial pressure of **R** was measured at different times. The results are shown below:



Which of the following independent changes in the conditions from Experiment 1 to Experiment 2 might explain the results obtained?

(i) Less of **P** was used
(ii) Product **S** was continuously removed from the reaction vessel
(iii) A different catalyst was used

Answer:

(a) (i) and (ii)
(b) (i) and (iii)
(c) (ii) and (iii)

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason

(a) Rate of reaction will decrease and position of equilibrium will change under these conditions.

(b) Rate of reaction remains the same but position of equilibrium will change under these conditions.

(c) Rate of reaction will decrease but position of equilibrium will remain the same under these conditions.

(d) Rate of reaction will increase and position of equilibrium will change under these conditions.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

8. Two reactions with different activation energies have the same rate constant at room temperature. Which statement below in the answer correctly describes the rate constants of these two reactions at the same higher temperature?

Answer

(a) The reaction with the smaller activation energy will have a higher rate constant

(b) The reaction with the higher activation energy will have a higher rate constant

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason

(a) As temperature is increased, the molecules collide more frequently, and there will be a larger percentage increase in proportion of molecules with energy greater than or equal to the activation energy, for this reaction.

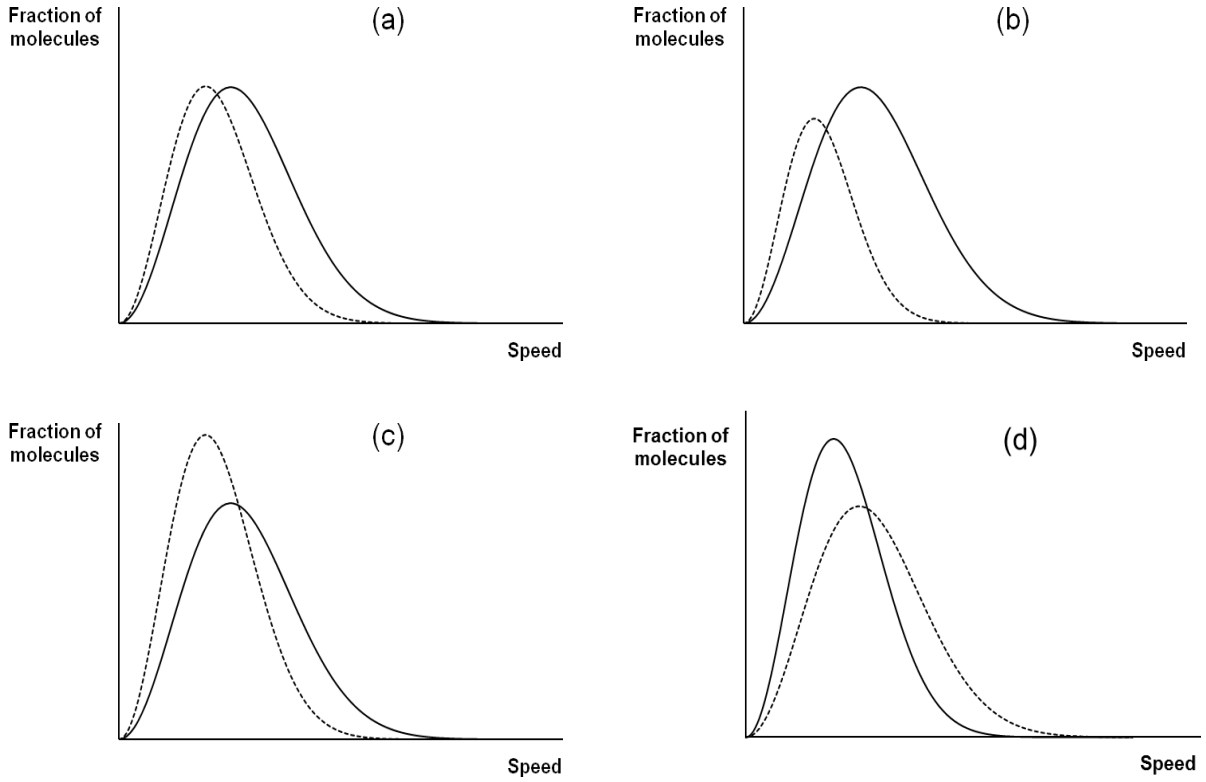
(b) As temperature is increased, more molecules will collide with the right orientation for this reaction.

(c) As temperature is increased, there will be a larger percentage increase in proportion of molecules with energy greater than or equal to the activation energy for this reaction.

(d) As temperature is increased, the molecules collide more frequently for this reaction.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

9. Which one of the following graphs below most accurately represents the distribution of molecular speeds in a sample of gas at 500 K if the dotted curve represents the distribution for the same sample at 300K?



Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason

(a) When temperature is increased, there is a wider spread of molecular energies.

(b) An increase in temperature will increase the average energy of the molecules but the total number of molecules remains constant.

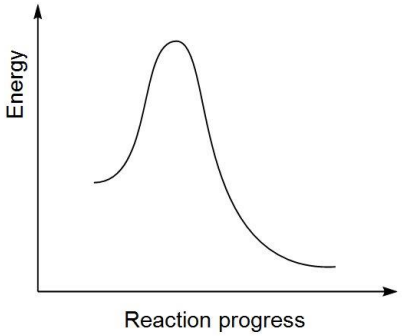
(c) An increase in temperature will increase the fraction of molecules with high energy.

(d) When temperature is increased, the most common energy value increases.

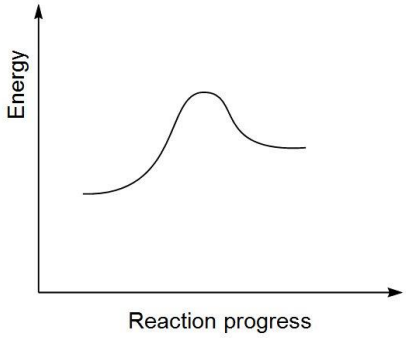
Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

10. Which one of the reversible reactions represented in the figures below will show the greatest percentage increase in rate of reaction for a given increase in temperature?

Reaction 1



Reaction 2



Answer

(a) Reaction 1 forward
(b) Reaction 1 backward
(c) Reaction 2 forward
(d) Reaction 2 backward

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) The more exothermic the reaction is, the larger is the percentage increase in rate of reaction when temperature is increased.

(b) The more endothermic the reaction is, the larger is the percentage increase in rate of reaction when temperature is increased.

(c) The higher the activation energy, the larger is the percentage increase in fraction of molecules with energy greater than or equal to the activation energy, when temperature is increased.

(d) The lower the activation energy, the larger is the percentage increase in fraction of molecules with energy greater than or equal to the activation energy, when temperature is increased.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

11. The reaction of hydrogen and iodine monochloride is represented by the equation:

$$H_2\,(g) + 2\,ICl\,(g) \rightarrow 2\,HCl\,(g) + I_2\,(g)$$

The reaction is first order with respect to H_2 (g) and also first order with respect to ICl (g).

Which of the following proposed mechanisms can be consistent with the given information about this reaction?

Mechanism 1: $2\,ICl\,(g) \rightarrow Cl_2\,(g) + I_2\,(g)$ slow
$Cl_2\,(g) + H_2\,(g) \rightarrow 2\,HCl\,(g)$ fast

Mechanism 2: $H_2\,(g) + ICl\,(g) \rightarrow HCl\,(g) + HI\,(g)$ slow
$HI\,(g) + ICl\,(g) \rightarrow HCl\,(g) + I_2\,(g)$ fast

Answer
(a) 1 and 2
(b) 1 only
(c) 2 only

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident

Reason:

(a) The mechanism(s) is/are consistent with the given overall reaction.
(b) The rate-determining step(s) is/are consistent with the rate law.
(c) The reaction intermediate(s) proposed has/have high reactivity.
(d) The slow step(s) involve(s) bonds that are hard to break.

Confidence Rating	1	2	3	4	5	6
	Just Guessing	Very Unconfident	Unconfident	Confident	Very Confident	Absolutely Confident