Supplementary Data

This supplementary data is a part of paper entitled "Analysis Methods for Development of Certified Reference Material (CRM) Zircon Minerals Synthesis".

Appendix A. The prototype FTDICK

Consent form

We are conducting an investigation into students' understanding of chemical reaction kinetics. As you are currently studying this topic we would like you to attempt the following questions and, in some cases, explain the answers you have given. We will collect the answer sheets in at the end and mark them, but we may like to follow up this initial investigation by asking you a few questions. The results from the investigation will be used alongside data from other students to gain a better understanding of students' concepts of reaction rates and may be published in the educational literature. The outcomes would be completely anonymous and no participants will be identifiable.

If you are happy for your test results to contribute to our investigation, please tick the box below:

◯ **I am happy to take part in this investigation and for my test results to contribute to the investigation**

If you would be prepared to answer some further questions about your understanding of the topic please tick the box below:

◯ **I am happy to answer some further questions about my understanding and for the results to contribute to the investigation**

◯ **I understand the survey will be completely anonymous.**

Name & Signed: **date:**

Email address:

_____

GENERAL CONFIDENCE IN CHEMISTRY

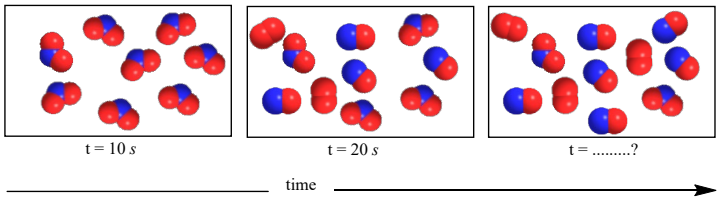
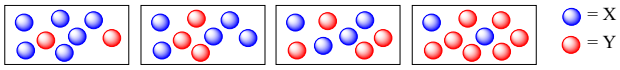
Instruction:

Before you answer the questions, please rate your confidence level in chemistry and chemical kinetics by circling the appropriate response.

1. Please rate your overall confidence in your ability to be successful in a chemistry degree course.
   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
2. Please rate how confident you are in physical chemistry as compared to other areas of chemistry (for example organic/inorganic/practical)
   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
3. Please rate how confident you are in chemical kinetics as compared to other areas of chemistry (for example atomic structure, acid-bases, organic nomenclature, organic mechanism, moles and concentration, etc.)
   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
4. Please rate how confident you are in chemical kinetics as compared to other areas of physical chemistry (for example equilibria, energy changes, gases, etc.)
   1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

INSTRUCTIONS: *answer the questions on the sheet about chemical kinetics. Circle the letter that represents the best answer in your view. Then circle the number that best represents how confident you are in your given answer. Don't worry if there are some questions you can't answer.*

No.	Question
1.	A 64 mg sample of radioactive material decays by first order reaction. After 10 minutes two half-lives are passed. What is the mass of sample that remains after 15 minutes? A. 24 mg B. 23 mg C. 16 mg D. 8 mg 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? A. After 10 minutes, half of the initial sample remained B. The rate of decay of this sample is a constant C. For each successive half-life, the mass of sample in a constant number D. The rate of decay of this sample increases as the mass of sample decreases E. For each successive half-life, the mass of sample decreases by a factor of 2 State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
2.	The decomposition of nitrogen dioxide to nitric oxide and oxygen at 300^0C is a second order reaction. $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$ What is the concentration of NO_2 at t = 10 minutes, if its initial concentration is 8.00×10^{-3} M and the rate constant is 0.54 $M^{-1}.s^{-1}$? A. 0.54 M B. 7.67×10^{-3} M C. 2.23×10^{-3} M D. 3.61×10^{-5} M 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? A. It obeys the equation $\ln[A]_t = \ln[A]_0 - kt$ B. It obeys the equation $\frac{1}{[A]_t} = \frac{1}{[A]_0} + kt$ C. It obeys the equation $[A]_t = [A]_0 - kt$ State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
3.	The decomposition of nitrogen dioxide to nitric oxide and oxygen at a certain temperature is shown pictorially below and is a second order reaction. $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$

	 The time at the final representation shown above is… A. 25 *s* B. 30 *s* C. 40 *s* D. 60 *s* 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? A. Each successive half-life is half the preceding one B. The value of t½ is constant C. The rate of disappearance of this sample increases with decrease in concentration D. The rate of disappearance of this sample decreases with decrease in concentration E. The value of each successive half-life is twice the preceding one. F. The value of of each successive half-life is 4 times the preceding one State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
4.	The second order reaction of $H_2O_2(aq) + 3I^-(aq) + 2H^+(aq) \rightarrow 2H_2O(l) + I_3^-(aq)$ 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. $Rate = k\,[H_2O_2]\,[I^-]^3\,[H^+]^2$ B. $Rate = k\,[H_2O_2]\,[I^-]$ C. $Rate = k\frac{[H_2O_2]^x[I^-]^y}{[H_2O_2][I^-]^3[H^+]^2}$ D. $Rate = k\,[H_2O_2]^x\,[I^-]^y\,[H^+]^z$ 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? A. The values of the exponents in the rate law are obtained from the coefficients in the balanced equation B. The rate law is expressed based on the law of mass action that describes the relationship between the concentrations of the reactants and products. C. The values of the exponents in the rate law are based on the order of the reactants which are determined experimentally D. The information which is provided in the question is inadequate to determine the rate law. State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
5.	The reaction $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ is second order with respect to NO_2, but zero order with respect to CO. If the concentration of NO_2 increases by a factor of 2 and the concentration of CO increases by a factor of 3, the reaction rate will…. A. Increase by a factor of 36 B. Increase by a factor of 12 C. Increase by a factor of 4 D. Remain constant 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? A. Only an increase in concentration of NO_2 affects the rate B. The higher the concentration of both reactants, the higher the rate C. The overall order of reaction is 2, therefore an increase in the concentration of both reactants increases the rate by the power of 2 D. There is no effect on the reaction rate as the order with respect to one reactant is zero State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
6.	For a hypothetical reaction: X + Y → Products, the rate of reaction is second order with respect to X but first order with respect to Y. Four experiments are carried out with different starting concentrations represented pictorially below in the boxes A, B, C and D. Which of the starting conditions (A, B, C or D) will result in the highest rate of reaction? A B C D  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? A. It has the highest concentration of the reactant which is 2nd order B. The concentrations of both reactants are the same, therefore the ratio of collision is more favourable C. The amount of X and Y and the average of each keep determine the rate D. The concentration of Y is much higher than the concentration of X and this leads to the reaction being completed faster State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
7.	The integrated rate law for a reaction can be expressed as $[A]_t = [A]_0 - kt$. If $[A]_0$ is the initial concentration, $[A]_t$ is the concentration at particular time, t is the time and *k* is the rate constant, then the expression of half-life for this reaction is…. A. $t\,½ = \frac{[A]_0}{2k}$ B. $t\,½ = -\frac{[A]_0}{k}$ C. $t\,½ = \frac{[A]_0}{2k}$ D. $t\,½ = -\frac{[A]_0 - [A]_t}{k}$ 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? A. The concentration of A at its half-life is twice its initial concentration B. The concentration of A at its half-life is a half of its initial concentration C. The concentration of A at its half-life is same as its initial concentration State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
8.	Hydrogen iodide dissociates at an elevated temperature according to the following equation: $2HI(g) \rightarrow H_2(g) + I_2(g)$ The reaction is carried out with different concentration at 435°C and the data obtained are given below.

[HI], M	0.04	0.02	0.01
Rate, $M.s^{-1}$	4.8×10^{-2}	1.2×10^{-2}	3.0×10^{-3}

The rate constant of this reaction is….

A. $4.8 \times 10^{-2}\ M^{-1}\ s^{-1}$ B. $3.3 \times 10^{-2}\ M^{-1}\ s^{-1}$ C. $1.2\ M^{-1}\ s^{-1}$ D. $30\ M^{-1}\ s^{-1}$

State the confidence rating of your answer

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

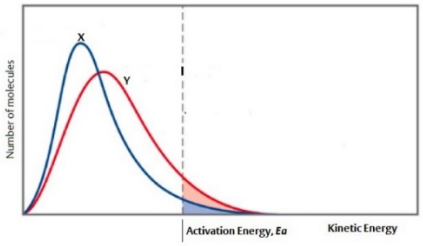
Which one of the following options is the reason for your answer to the question?

A. The data obey zero order reaction kinetics
B. The data obey first order reaction kinetics
C. The data obey second order reaction kinetics
D. The value of k will be equal to the concentration of reactant because it 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

9. The Boltzmann distribution curves below describe the distribution of the kinetic energies of molecules.



X and Y represent the same reaction carried out at a different temperature where X is lower than Y. Which the statement below is correct?

A. X has a higher rate of reaction than Y
B. Y has a higher rate of reaction than X
C. Both reactions have the same rate
D. There is insufficient information to determine the relative rates

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?

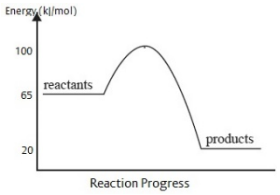
A. This reaction has the higher activation energy
B. The value of *k* and the number of molecules of both reactants are unknown
C. The higher the temperature, the higher the number of molecules with the *Ea*
D. The higher the temperature, the higher the activation energy (*Ea*)
E. This reaction has the lower activation energy
F. The value of activation energy is not determined the rate

State the confidence rating of your answer

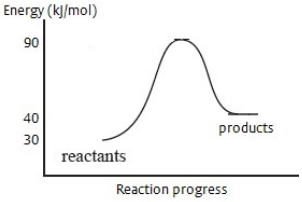
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

10. Consider four reactions as described in the energy profile of *Ea* and ΔH below. Assuming that all four reactions are carried out at the same temperature and the same Arrhenius factor A, which reaction is the slowest….

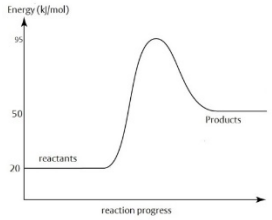
A.



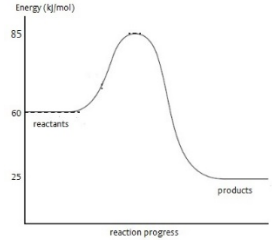
B.



C.



D.



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?

A. The reaction has the highest energy in its transition state
B. The reaction has the highest activation energy
C. The reaction has the lowest energy in its transition state
D. The reaction has the lowest activation energy
E. The reaction releases higher energy
F. The reaction releases lower energy
G. The reaction absorbs higher energy
H. The reaction absorbs lower energy

State the confidence rating of your answer

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

11. Consider two reactions with the values of *Ea* and ΔH are given below.
Reaction 1. *Ea* = 25 kJ.mol^{-1}; ΔH below = -65 kJ.mol^{-1}
Reaction 2. *Ea* = 25 kJ.mol^{-1}; ΔH below = + 10 kJ.mol^{-1}
Assuming both reactions are carried out at the same Arrhenius factor A, but the temperature of reaction 2 is higher.
Based on this information, which is the correct statement below?
A. Reaction 1 is exothermic and its rate is higher than the rate of reaction 2
B. Both reactions have the same rate
C. Reaction 2 is endothermic and its rate is lower than the rate of reaction 1
D. Reaction 2 is endothermic and its rate is higher than the rate of reaction 1
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?
A. Increase in temperature increases the activation energy
B. Increases in temperature decreases the activation energy
C. Increases in temperature increases the rate an endothermic reaction, but decreases the rate an exothermic one
D. Increases in temperature increases the rate an exothermic reaction, but decreases the rate an endothermic one
E. Increase in temperature increases the rate constant
F. Increases in temperature decreases the rate constant
G. As two reactions have the same value of activation energy, they also have the same rate constant
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

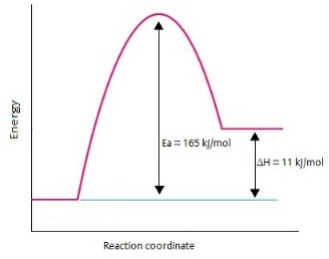
12. The formation of HI(g) follows the reaction $H_2 + I_2 \rightarrow 2HI$. This reaction may occur with the following mechanism:

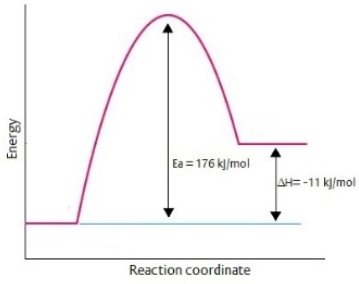
$$I_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} 2I \quad \text{fast}$$

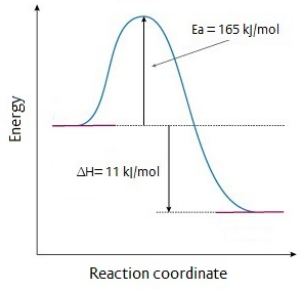
$$I + I + H_2 \xrightarrow{k_2} 2HI \quad \text{slow}$$

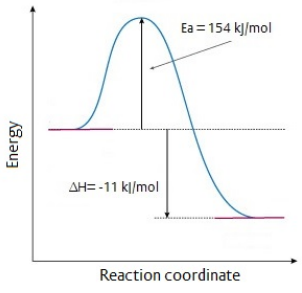
The overall rate law of this reaction is….
A. Rate = $k_2[I]^2[H_2]$ B. Rate = $k\frac{[HI]^2}{[I^2][H_2]}$ C. Rate = $k_2\frac{k_1}{k_{-1}}[I_2]\,[H_2]$ D. Rate = $k_1\,[I_2] - k_{-1}[I]^2$
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
Which one of the following options is the reason for your answer to the question?
A. The rate law is obtained directly from the slow step in the mechanism
B. The rate law is obtained from the fast step in the mechanism
C. The rate law is obtained from the law of mass action
D. The rate law is obtained from the slow step by considering any intermediates in a preceding step
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

13. The reaction $NO_2(g) + NO_3(g) \rightarrow N_2O_5(g)$ with ΔH = 11 kJ.mol^{-1} has the activation energy 165 kJ.mol^{-1}. The graph below that represents the energy profile for the **reverse reaction** is….

A.


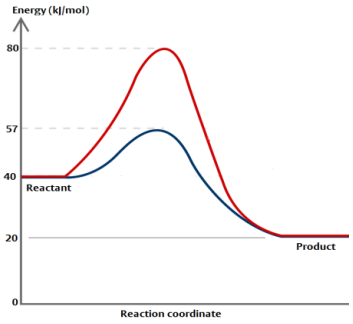
B.


C.


D.


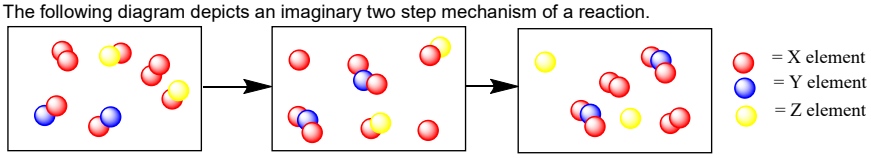
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
Which one of the following options is the reason for your answer to the question?
A. The reverse reaction is endothermic and the activation energy for this reverse reaction incorporates the value of ΔH
B. The reverse reaction is exothermic and the activation energy of this reverse reaction does not involve the value of ΔH.
C. The reverse reaction is endothermic and the activation energy for the forward and the reverse reactions are same
D. The reverse reaction is exothermic and the activation energy for this reverse reaction incorporates the value of ΔH
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

14. The energy profile below describes a catalysed and an uncatalysed pathway for a given reaction.



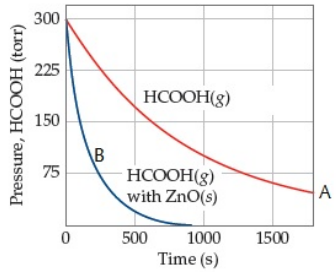
The value of the activation energy of the catalysed one is….
A. 60 kJ/mol B. 40 kJ/mol C. 37 kJ/mol D. 17 kJ/mol
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
Which one of the following options is the reason for your answer to the question?
A. The activation energy of a catalysed and an uncatalysed pathway is the same, but the mechanisms are different
B. The activation energy of a catalysed pathway is lower than an uncatalysed one and the mechanisms are the same
C. The activation energy of a catalysed pathway is lower than an uncatalysed one and these mechanisms are different
D. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are the same
E. The activation energy of a catalysed pathway is higher than an uncatalysed one and the mechanisms are different
F. Without an increase in temperature, the activation energies and mechanisms of a catalyst and an uncatalysed pathway are the same
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

15. The following diagram depicts an imaginary two step mechanism of a reaction.

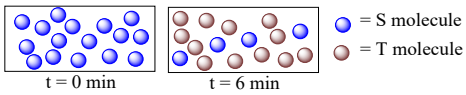
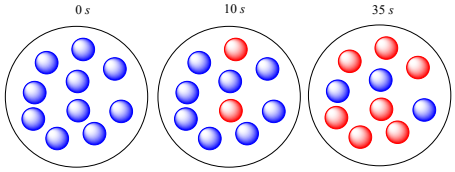


Based on the representation above, the substance that acts as a catalyst is….
A. X B. XZ C. X_2 D. XY
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
Which one of the following options is the reason for your answer to the question?
A. The substance does not undergo a permanent chemical change and is reformed in the last product
B. The substance is formed in one elementary reaction and consumed in the next
C. The substance increases the rate without involving chemically in the reaction
D. The substance is not present in the final product
State the confidence rating of your answer
1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

16. The variation in partial pressure of HCOOH for the decomposition of formic acid $HCOOH(g) \rightarrow CO_2(g) + H_2(g)$ 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?
A. This is an example of homogeneous catalysis and the rate of B is higher than the rate of A
B. This is an example of heterogeneous catalysis and the rate of B is higher than the rate of A
C. This is an example of homogeneous catalysis and the rate of A is higher than the rate of B
D. 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?
A. HCOOH, CO_2 and H_2 are in the same phase and the presence of ZnO increases the rate
B. HCOOH and ZnO are in different phases and the presence of ZnO decreases the rate
C. HCOOH, CO_2 and H_2 are present in the same phase and the presence of ZnO decreases the rate
D. 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
17.	The reaction of nitrogen dioxide and carbon monoxide $NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$ may occur according to the following mechanism: Step 1: $NO_2(g) + NO_2(g) \xrightarrow{k_1} NO_3(g) + NO(g)$ slow Step 2: $NO_3(g) + CO(g) \xrightarrow{k_2} NO_2(g) + CO_2(g)$ fast If k is the overall rate constant, the rate law for this reaction is…. A. Rate = $k[NO_2][CO]$ B. Rate = $k\,[NO_2]^2$ C. Rate = $k\,[NO_3]\,[CO]$ D. $\text{Rate} = k\,\frac{[NO_2]^2\,[CO]}{[NO][CO]_2}$ 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? A. Step 1 is the rate determining step B. Step 2 is the rate determining step C. The rate law is obtained directly from the overall reaction equation D. The rate law is derived from the law of mass action State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
18.	Consider the first order reaction S → T in which S molecules are converted to T molecules.  How many S (blue) molecules and T (brown) molecules are present at the half-life? A. Blue = 4 and brown = 12 B. Blue = 10 and brown = 6 C. Blue = 2 and brown = 14 D. Blue = 8 and brown = 8 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? A. The number of S molecules is a half of its initial number B. The number of S molecules is a half of its number at 6 minutes C. The number of S molecules that react is a half the number that react between 0 and 6 minutes D. The half-life is related to the concentration of a reactant at any time during the reaction State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident
19.	The hypothetical reaction G → 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? A. As time increases, the rate of conversion G molecules to H molecules also increases B. As time increases, the rate of conversion G molecules to H molecules decreases C. The rate of conversion of G molecules to H molecules persecond 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
20.	The decomposition of N_2O_5 in a solvent occurs according to the following equation $N_2O_5 \rightarrow 2NO_2 + ½\ O_2$ In the interval between 20 minutes and 40 minutes, the $[N_2O_5]$ decreases from 0.1 M to 0.080 M. Which of the following options is the correct expression of the average reaction rate? A. $\text{Rate} = \frac{d[N_2O_5]}{dt} = 0.001\ \text{M min}^{-1}$ B. $\text{Rate} = \frac{d[NO_2]}{dt} = 0.001\ \text{M min}^{-1}$ C. $\text{Rate} = \frac{d[O_2]}{dt} = 0.0005\ \text{M min}^{-1}$ D. $\text{Rate} = -\frac{d[NO_2]}{dt} = -0.002\ \text{M min}^{-1}$ 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? A. O_2 is produced twice as fast as N_2O_5 is consumed B. NO_2 is produced a half as fast as N_2O_5 is consumed C. The rate law can only be expressed by the rate of disappearing N_2O_5 D. N_2O_5 is consumed twice as fast as NO_2 is produced E. NO_2 is consumed twice as the rate of N_2O_5 is consumed F. O_2 is produced a half as fast as N_2O_5 is consumed State the confidence rating of your answer 1. Very unconfident 2. Not very confident 3. Average 4. Quite confident 5. Very confident

Appendix 1. Difficulty level and discriminatory index for the answer tier (A), the reason tier (R) and the combined tiers (B) of the prototype FTDICK instrument

Quest.	Difficulty Level (DL)			Discriminatory Index (DI)		
	A tier	R tier	B tier	A tier	R tier	B tier
1	0.18	0.11	0.01	0.33	0.04	0.04
2	0.55	0.61	0.46	0.38	0.36	0.59
3	0.26	0.07	0.04	0.04	0.16	0.08
4	0.51	0.44	0.32	0.58	0.45	0.66
5	0.56	0.46	0.35	0.53	0.44	0.74
6	0.16	0.20	0.06	0.22	0.04	0.15
7	0.48	0.51	0.26	0.47	0.34	0.47
8	0.32	0.36	0.20	0.40	0.48	0.38
9	0.51	0.19	0.07	0.19	0.07	0.14
10	0.42	0.39	0.17	0.18	0.26	0.05
11	0.39	0.07	0.03	0.45	0.08	0.11
12	0.44	0.30	0.17	0.41	0.30	0.30
13	0.08	0.16	0.01	0.03	0.12	0.03
14	0.25	0.30	0.06	0.16	0.40	0.12
15	0.32	0.37	0.14	0.27	0.41	0.23
16	0.37	0.28	0.13	0.40	0.33	0.26
17	0.28	0.27	0.16	0.47	0.52	0.38
18	0.28	0.27	0.12	0.40	0.42	0.30
19	0.32	0.19	0.08	0.25	0.08	0.08
20	0.17	0.06	0.03	-0.03	0.08	-0.01
Mean	**0.33**	**0.28**	**0.14**	**0.30**	**0.27**	**0.25**

Red = hard category; Green = moderate category; yellow = good; pink = poor; teal = fair; dark yellow = unsuitable

Appendix 2. Values of distractor effectiveness (%) of the Prototype FTDICK instrument

Question	1		2		3		4	
Option	A tier	R tier	A tier	R tier	A tier	R tier	A tier	R tier
A	26.94	25.09	4.80	16.24	34.69	11.44	9.23	19.93
B	10.33	22.88	18.08	61.25	33.95	35.06	50.55	21.03
C	39.85	10.70	54.61	7.01	25.83	20.66	24.35	44.28
D	18.08	18.08	5.17		2.95	13.65	11.81	7.01
E						7.38		
F						1.48		

Question	5		6		7		8	
Option	A tier	R tier	A tier	R tier	A tier	R tier	A tier	R tier
A	4.80	46.13	28.04	34.69	47.97	22.51	10.70	6.64
B	18.82	9.23	15.87	17.71	8.49	50.55	19.56	24.72
C	55.72	23.25	16.24	19.93	11.81	10.70	25.46	35.79
D	15.13	11.44	25.09	14.76	23.25		32.10	14.39

Question	9		10		11		12	
Option	A tier	R tier	A tier	R tier	A tier	R tier	A tier	R tier
A	26.20	12.18	18.45	11.07	19.93	12.18	19.19	21.77
B	50.55	8.12	13.28	39.11	13.28	15.13	19.56	19.93
C	6.27	18.82	41.70	9.23	18.82	29.15	43.91	11.07
D	10.33	14.02	19.19	12.18	39.48	15.13	5.90	29.89
E		25.83		7.38		6.64		
F		4.80		2.21		1.48		
G				5.17		4.43		
H				0.74				

Question	13		14		15		16	
Option	A tier	R tier	A tier	R tier	A tier	R tier	A tier	R tier
A	52.03	43.54	14.39	12.18	10.33	36.53	20.30	19.93
B	9.96	15.87	29.52	19.56	31.37	22.14	36.53	15.50
C	21.40	13.65	20.30	29.89	31.73	15.50	12.55	17.71
D	8.12	10.33	25.09	9.59	18.45	13.65	17.34	27.68
E				7.38				
F				2.95				

Que	17		18		19		20	
Option	A tier	R tier	A tier	R tier	A tier	R tier	A tier	R tier
A	19.19	27.31	24.35	27.31	6.27	25.09	36.90	7.38
B	28.41	18.82	19.19	19.19	39.85	31.37	18.82	18.82
C	16.97	30.63	12.92	21.03	31.73	19.19	16.61	19.56
D	21.40	4.43	28.04	11.07	4.80		11.81	18.82
E								8.12
F								5.90

Yellow font = distractor in the A tier selected by less than 5% students
Pink font = distractor in the R tier selected by less than 5% students

Appendix 3. The validity of each item/question of the prototype FTDICK instrument with a confidence level of 95%.

Question		1	2	3	4	5
A tier	r_{xy}	0.34	0.47	0.13	0.53	0.55
	category	Valid	Valid	Valid	Valid	Valid
R tier	r_{xy}	**0.07**	0.41	0.21	0.46	0.45
	category	**Invalid**	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.24	0.48	0.21	0.60	0.58
	category	Valid	Valid	Valid	Valid	Valid
Question		**6**	**7**	**8**	**9**	**10**
A tier	r_{xy}	0.28	0.39	0.38	0.33	0.23
	category	Valid	Valid	Valid	Valid	Valid
R tier	r_{xy}	0.09	0.41	0.47	0.18	0.30
	category	**Invalid**	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.31	0.42	0.46	0.27	0.26
	category	Valid	Valid	Valid	Valid	Valid
Question		**11**	**12**	**13**	**14**	**15**
A tier	r_{xy}	0.43	0.44	0.14	0.29	0.29
	category	Valid	Valid	Valid	Valid	Valid
R tier	r_{xy}	0.15	0.27	0.14	0.39	0.45
	category	Valid	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.35	0.36	0.17	0.20	0.33
	category	Valid	Valid	Valid	Valid	Valid
Question		**16**	**17**	**18**	**19**	**20**
A tier	r_{xy}	0.40	0.36	0.38	0.28	**0.06**
	category	Valid	Valid	Valid	Valid	**Invalid**
R tier	r_{xy}	0.39	0.47	0.50	0.17	0.19
	category	Valid	Valid	Valid	Valid	Valid
B tier	r_{xy}	0.39	0.50	0.48	0.24	**0.01**
	category	Valid	Valid	Valid	Valid	**Invalid**

Appendix 4. Students' confidence ratings of wrong answers

Question	Popular wrong answer								
	A tier			R tier			B tier		
	Option	**CR(T_A)**	**%**	**Option**	**CR(T_R)**	**%**	**Option**	**CR(T_B)**	**%**
1	C	3.34	39.9	A	2.79	25.1	CA	3.3	12.55
2	**B**	**2.84**	**18.1**	**A**	**2.59**	**16.2**	BB	3.3	9.60
3	**A**	**3.5**	**34.7**	B	2.83	35.1	BB	3.2	12.92
4	C	3.29	24.4	**B**	**2.98**	**21.0**	**BA**	**3.9**	**7.38**
5	B	2.45	18.8	**C**	**2.79**	**23.2**	CC	2.7	12.55
6	A	3.37	28	**A**	**3.28**	**34.7**	AA	3.3	16.97
7	**D**	**3.38**	**23.2**	**A**	**2.9**	**22.5**	**AA**	**3.3**	**13.28**
8	**C**	**2.91**	**25.5**	**B**	**2.9**	**24.7**	**CB**	**3.1**	**11.44**
9	**A**	**3.3**	**26.2**	E	3.24	25.8	BE	3.6	19.19
10	**D**	**3.38**	**19.2**	D	2.76	12.2	AB	3.3	9.23
11	A	3.09	19.9	C	2.82	29.2	DC	3.1	11.07
12	**B**	**3.21**	**19.6**	**A**	**2.81**	**21.8**	CA	2.8	9.23
13	A	3.43	52.03	A	2.87	43.54	AA	3.3	32.97
14	B	2.98	29.52	B	3.32	19.56	BC	3	12.92
15	**B**	**3.18**	**31.37**	B	2.83	22.14	BA	3.2	9.96
16	A	2.8	20.3	A	2.67	19.93	BC	2	8.12
17	D	3.07	21.4	**C**	**2.76**	**30.63**	DC	3.1	14.39
18	**A**	**3.33**	**24.35**	B	2.37	19.19	**AA**	**3.5**	**8.49**
19	**B**	**2.67**	**39.85**	B	2.38	31.37	BB	2.3	15.87
20	**A**	**3.1**	**36.9**	C	2.77	19.56	AD	2.8	11.81

Qustion	Wrong answer with highest CR								
	A tier			R tier			B tier		
	Option	**CR(T_A)**	**%**	**Option**	**CR(T_R)**	**%**	**Option**	**CR(T_B)**	**%**
1	B	3.79	10.3	C	3.21	10.7	BB	3.9	1.48
2	**B**	**2.84**	**18.1**	**A**	**2.59**	**16.2**	DB	3.8	1.85
3	**A**	**3.5**	**34.7**	F	3.0	1.48	AA	3.5	3.69
4	D	3.5	11.8	**B**	**2.98**	**21.0**	**BA**	**3.9**	**7.38**
5	A	3.0	4.8	**C**	**2.79**	**23.2**	DC	3.5	1.85
6	C	3.5	16.2	**A**	**3.28**	**34.7**	DA	3.8	8.49
7	**D**	**3.38**	**23.2**	**A**	**2.9**	**22.5**	**AA**	**3.3**	**13.28**
8	**C**	**2.91**	**25.5**	**B**	**2.9**	**24.7**	DB	3.7	3.32
9	**A**	**3.3**	**26.2**	F	3.31	4.8	DC	3.9	2.95
10	**D**	**3.38**	**19.2**	G	3.21	5.17	BD	3.8	1.11
11	**B**	**3.69**	**13.3**	G	3.92	4.43	BE	4.9	2.21
12	**B**	**3.21**	**19.6**	**A**	**2.81**	**21.8**	DC	3.9	1.85
13	**C**	**3.5**	**21.4**	D	2.96	20.3	DA	4.5	0.74
14	C	3.16	20.3	B	3.32	19.56	AE	3.6	3.32
15	**B**	**3.18**	**31.37**	C	2.93	15.5	BC	3.4	4.06
16	D	3.17	17.34	B	2.69	15.5	AD	3.4	5.54
17	C	3.22	16.97	**C**	**2.76**	**30.63**	CA	3.7	4.06
18	**A**	**3.33**	**24.35**	D	2.9	11.07	**AA**	**3.5**	**8.49**
19	**B**	**2.67**	**39.85**	A	2.93	25.09	DA	3.3	1.11
20	**A**	**3.1**	**36.9**	E	3.18	8.12	AF	3.5	1.48

% = the percentages of all students who participate in this study;
CR = confidence rating

Appendix 5. The values of confidence variables per item of the prototype FTDICK instrument

Question	A Tier				R Tier				B Tier			
	CF	**CFC**	**CFW**	**CDQ**	**CF**	**CFC**	**CFW**	**CDQ**	**CF**	**CFC**	**CFW**	**CDQ**
1	3.32	3.69	3.24	0.37	2.60	2.70	2.59	0.11	2.96	3.4	2.95	0.33
2	2.74	3.55	1.76	1.29	2.87	3.66	1.62	1.59	2.81	3.7	2	1.04
3	3.33	3.59	3.24	0.32	2.59	3.30	2.53	0.72	3	3.8	2.9	0.7
4	3.43	3.79	3.06	0.67	2.96	3.27	2.72	0.48	3.19	3.6	2.99	0.52
5	2.88	3.33	2.31	0.90	2.70	3.27	2.22	0.90	2.79	3.6	2.35	0.96
6	3.04	3.35	2.98	0.32	2.73	3.07	2.64	0.37	2.88	3.6	2.84	0.51
7	3.09	3.55	2.67	0.78	2.65	3.20	2.10	0.90	2.87	3.7	2.59	0.76
8	2.92	4.17	2.32	1.47	2.61	3.67	2.01	1.32	2.76	4.3	2.36	1.27
9	3.09	3.40	2.78	0.60	2.46	2.84	2.37	0.41	2.78	3.1	2.75	0.27
10	3.07	3.43	2.80	0.60	2.61	3.24	2.20	0.95	2.8	3.7	2.7	0.8
11	3.04	3.36	2.84	0.52	2.58	3.83	2.49	1.34	2.81	4.1	2.77	0.98
12	2.78	3.08	2.55	0.47	2.37	2.90	2.14	0.69	2.57	3.1	2.47	0.47
13	3.12	3.59	3.08	0.47	2.37	2.53	2.34	0.19	2.74	3.5	2.73	0.57
14	2.93	3.96	2.58	1.27	2.43	2.94	2.22	0.68	2.69	3.9	2.61	0.92
15	2.94	3.56	2.66	0.76	2.68	3.29	2.33	0.79	2.82	3.7	2.67	0.76
16	2.50	2.92	2.26	0.58	2.28	3.12	1.96	1.03	2.39	3.5	2.23	0.85
17	2.63	3.09	2.45	0.58	2.32	3.14	2.01	1.08	2.48	3.4	2.31	0.74
18	2.66	3.43	2.36	0.95	2.25	3.24	1.88	1.33	2.46	3.7	2.29	0.97
19	2.22	2.87	1.91	0.83	2.13	2.83	1.97	0.76	2.18	3.1	2.1	0.74
20	2.47	2.73	2.42	0.27	2.20	3.13	2.14	0.89	2.34	3.2	2.31	0.63
Mean	**2.91**	**3.42**	**2.61**	**0.70**	**2.52**	**3.26**	**2.22**	**0.83**	**2.72**	**3.59**	**2.55**	**0.74**
SD	**0.31**	**0.36**	**0.41**	**0.34**	**0.22**	**0.32**	**0.28**	**0.39**	**0.25**	**0.32**	**0.29**	**0.25**