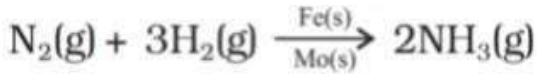
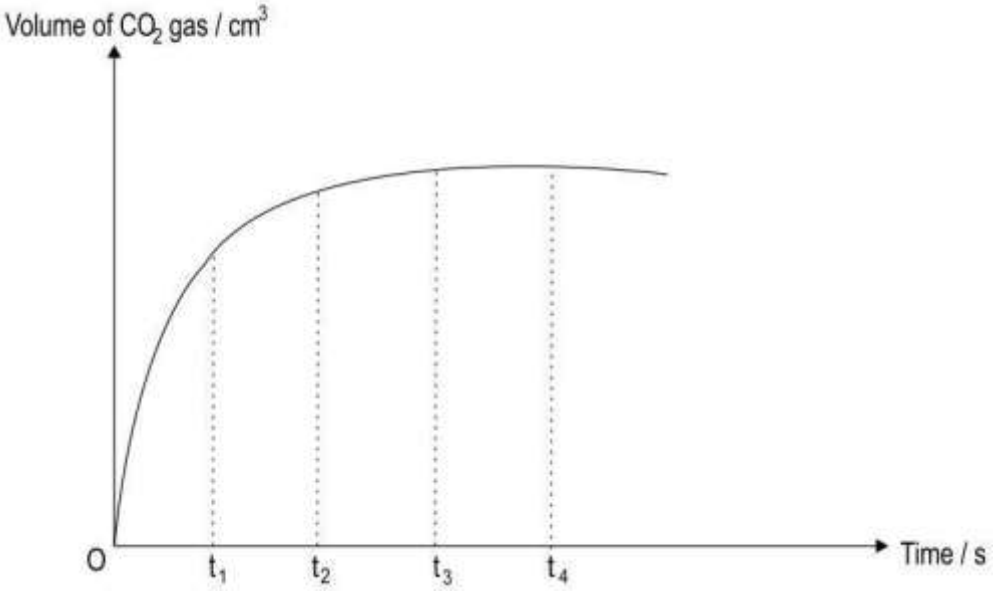
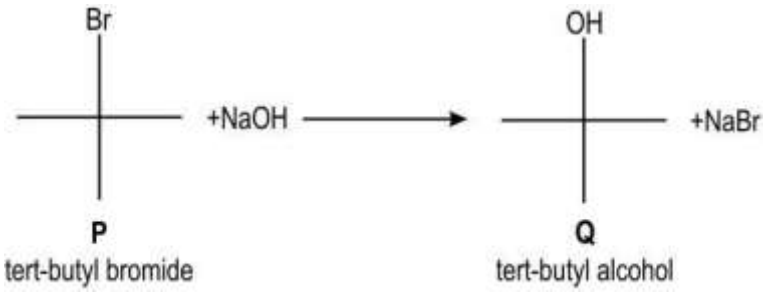
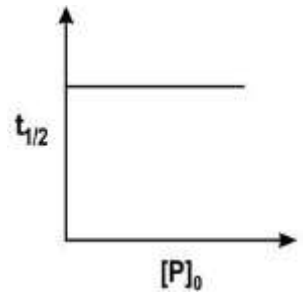
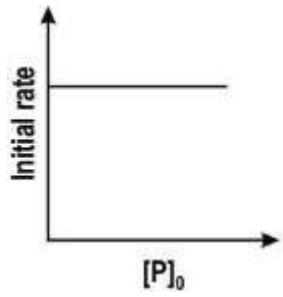
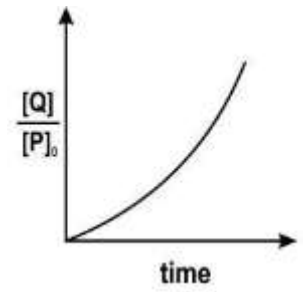
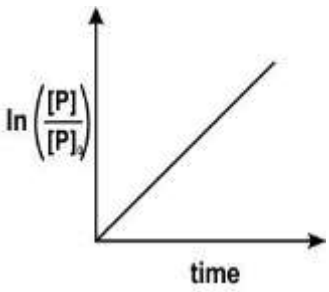
4. CHEMICAL KINETICS

Q. No	Question	Marks
	Multiple Choice Question	
Q.80	The reaction shown below illustrates the Haber process for manufacturing ammonia:  $N_2(g) + 3H_2(g) \xrightarrow[Mo(s)]{Fe(s)} 2NH_3(g)$ In this reaction, molybdenum acts as a promoter, and iron is used as a catalyst. Which of these is TRUE for the reaction? A. Iron changes the activation energy of reaction and molybdenum increases theefficiency of the catalyst. B. Iron changes the equilibrium constant and molybdenum changes the Gibbs energy ofthe reaction. C. Iron changes the enthalpy of reaction and molybdenum changes the equilibriumconstant. D. Iron and molybdenum change the Gibbs energy of the reaction.	1
Q.81	Which of the following can INCREASE the rate of a chemical reaction? P) increasing the temperature Q) increasing the concentration of products R) adding a catalyst S) increasing the concentration of reactants A. Q and S B. P and Q C. P, R, and S D. All- P, Q, R, and S	1
Q.82	The graph below shows the volume of carbon dioxide formed with time during a chemical reaction:	1

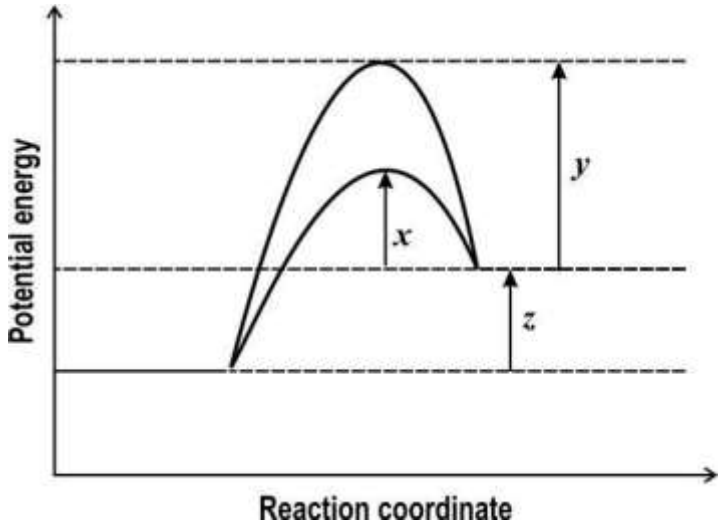
	 Based on the graph, at what time is the rate of reaction the highest? A. t1 B. t2 C. t3 D. t4	
Q.83	A living organism takes in different amounts of different isotopes of the same element from the environment. The organism takes these isotopes in the same relative proportion that existed naturally in the environment. For example, it takes carbon-12 and carbon-14 and once the organism dies, it stops replenishing its carbon supply, and the total carbon-14 content in the organism slowly disappears. This is because C-14 is radioactive in nature and it decays as it's less stable whereas C-12 is very stable and does not decay. Scientists can determine how long ago an organism died by measuring how much carbon-14 is left relative to carbon-12. Similarly, the organism's age can also be found by measuring how much potassium-40 or beryllium-10 is present in relation to potassium-39 and beryllium-9. Below is the half-life of: Carbon-14 = 5730 years Potassium-40 = 1.26 billion years Beryllium-10 = 1.52 billion years Based on the above data, which of the following dating methods can be used to determine the exact age of a living organism from its remains which are estimated to be 100,000 years old?	1

	(I) Carbon dating (II) Potassium dating (III) Beryllium dating A. I only B. I and II only C. II and III only D. All- I, II, and III	
Q.84	The hydrolysis of tert-butyl bromide with an aqueous NaOH solution (as shown below) is an example of SN1 reaction.  Which of the following graph correctly represents the above reaction?	1

 	
A	B
 	

	C	D

Q.85 The diagram below shows the potential energy variation for a reaction using a catalyst and for the same reaction without a catalyst.



Which of the following represents the enthalpy change (ΔH) and activation energy (Ea) for the reaction with a catalyst?

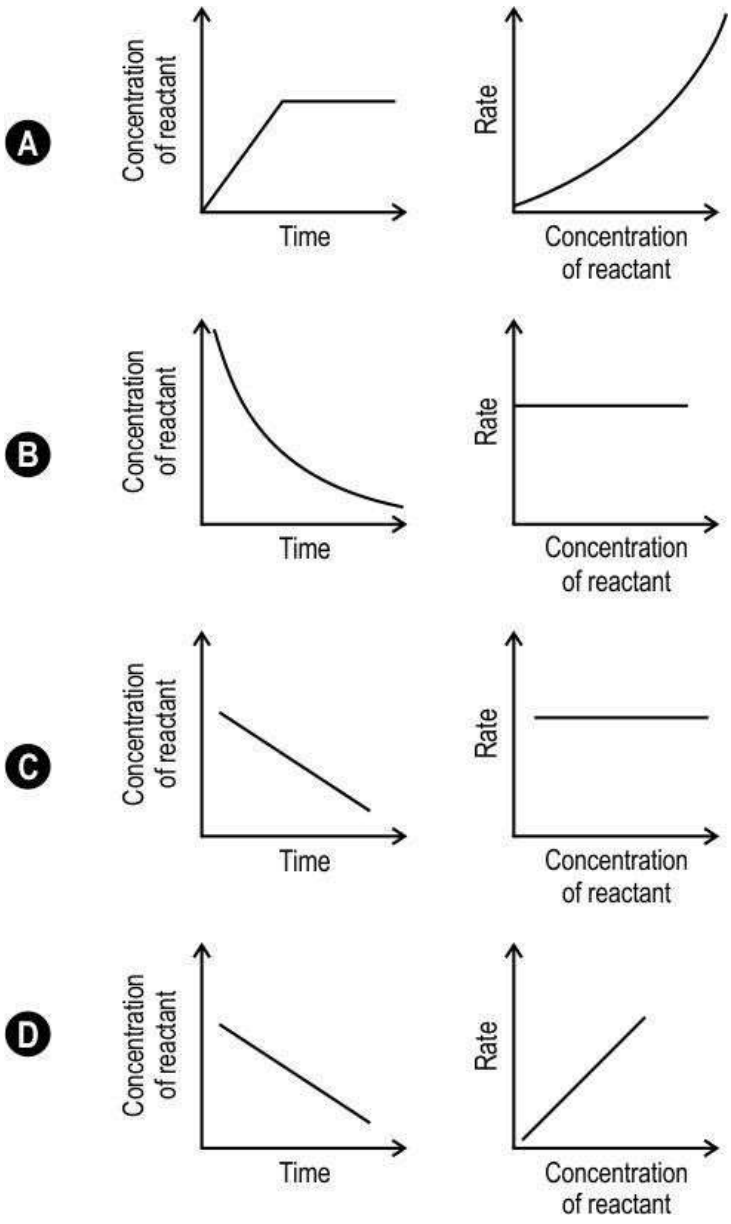
Option	ΔH	Ea with catalyst
P	z	x+z
Q	z	y+z
R	z+x	x
S	z	y

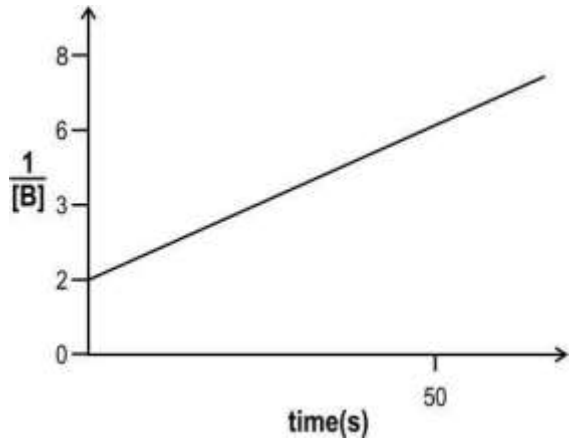
A. P

B. Q

C. R

D. S

Q.86	If the rate of a reaction 2A + 3B----- > C + 2D is $k[A]^0[B]$. By what factor will the rate of reaction increase if the concentration of A increases by a factor of 2 and that of B by a factor of 3? A. 5 B. 6 C. 3 D. 2	1
Q.87	Which of the following pairs of graphs represents the same order of reaction?  	1

	A. A B. B C. C D. D	
Q.88	Which of the following statements is/are correct? (i) A catalyst lowers the activation energy of a reaction. (ii) A catalyst allows the same rate of reaction to be achieved at a lower temperature. (iii) A catalyst mixes with the reactants and increases the overall concentration of reactants in the rate equation. A. i only B. i and ii only C. ii and iii only D. All- i, ii, and iii	1
Q.89	For a first order reaction A + B ----> C the rate of reaction depends only on the concentration of B.  If the reaction is 50% complete after 5.82 hours when the initial concentration of B is 4.46 mol/L, how much time will it take for the reaction to be 75% complete? A. 5.82 hours B. 17.5 hours C. 11.64 hours D. 8.71 hours	1
Free Response Question/ Subjective Type		

<table>
<tr><td>Q.90</td><td>The data in the table was obtained in a series of experiments on the rate of the reaction between compounds A and B at a constant temperature.

<table><tr><th>Experiment</th><th>The initial concentration of A / mol dm^{-3}</th><th>The initial concentration of B / mol dm^{-3}</th><th>Initial rate / mol dm^{-3} s^{-1}</th></tr><tr><td>1</td><td>0.12</td><td>0.26</td><td>2.10 x 10^{-4}</td></tr><tr><td>2</td><td>0.36</td><td>0.26</td><td>1.89 x 10^{-3}</td></tr><tr><td>3</td><td>0.72</td><td>0.13</td><td>3.78 x 10^{-3}</td></tr></table>
Show how this data can be used to derive the rate expression for the reaction between A and B.</td><td>3</td></tr>
<tr><td>Q.91</td><td>The manufacturers of canned food use anti-microbial compounds as preservatives to control the concentration of microbes, maintaining the quality of food. The food corporation of India mandates that the concentration of a microbe in any particular canned food would be unacceptable (and the food will be expired) with a maximum +40% change from the initial concentration value of the microbe.

Mitra bought canned food. She noted that the manufacturing date on the can was 1st April 2022. Based on this, what should be the expiry date of this food?

(Note: The average rate constant of microbial decay is 4 day^{-1}.)</td><td>2</td></tr>
<tr><td>Q.92</td><td>Carbon dating is used by archaeologists to date trees, plants, and animal remains as well as human artefacts made from wood and leather.

If an archaeologist found that the percentage of carbon-14 in the remains of an animal was 10% of what carbon-14 was in the animal's body when the animal died, find the age of this sample.

(Given the half-life of carbon-14= 5730 years)</td><td>2</td></tr>
<tr><td>Q.93</td><td>The gas-phase decomposition reaction of ethane is given below:

C_2H_6------ >C_2H_2 + 3H_2

This reaction is investigated at constant temperature and volume. The table below shows the partial pressure (PC_2H_6) observed for the above reaction at different times.</td><td>3</td></tr>
</table>

#	Time (in mins)	PC_2H_6 (in mm of Hg)
1	0	800
2	100	400
3	200	200

Based on the above data,

(i) What is the order of the reaction? Justify with reason.

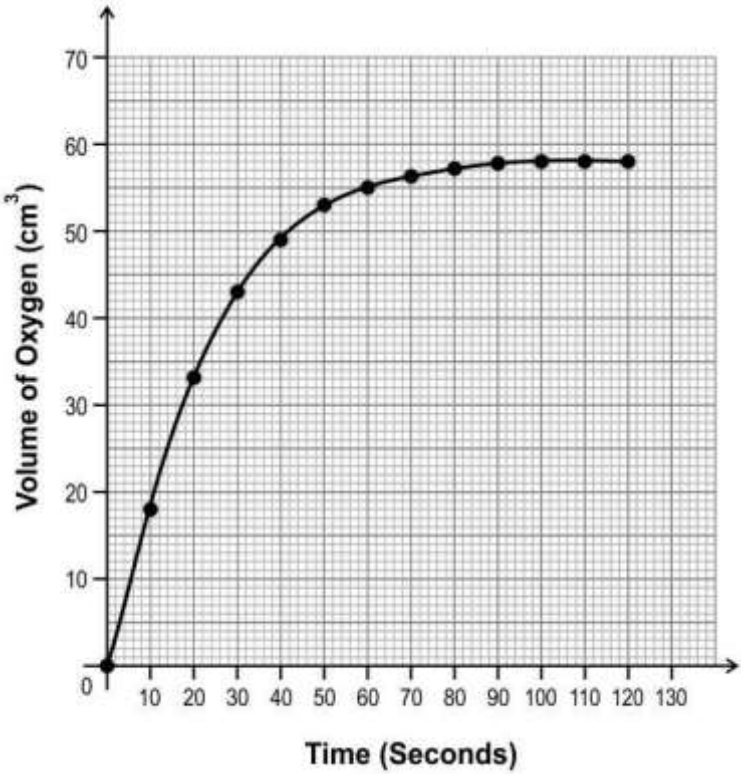
(ii) Calculate the rate constant of the reaction.

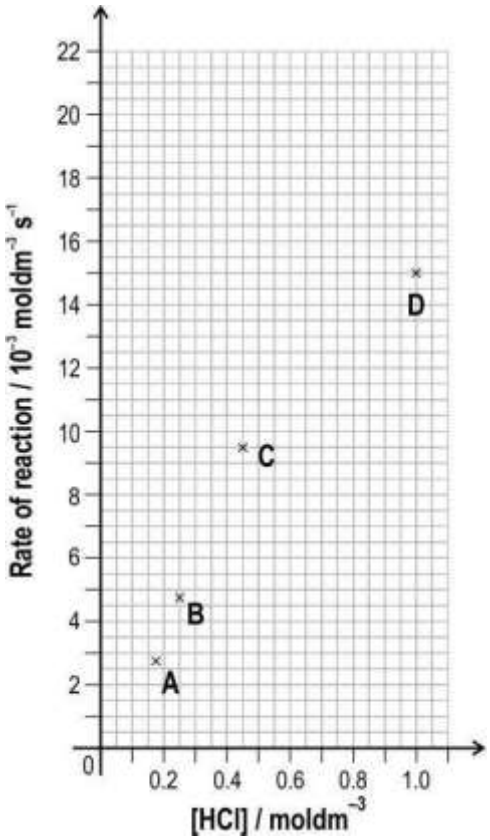
(iii) What is the ratio of the time required for the completion of 50% of the reaction to that of 75% of the reaction?

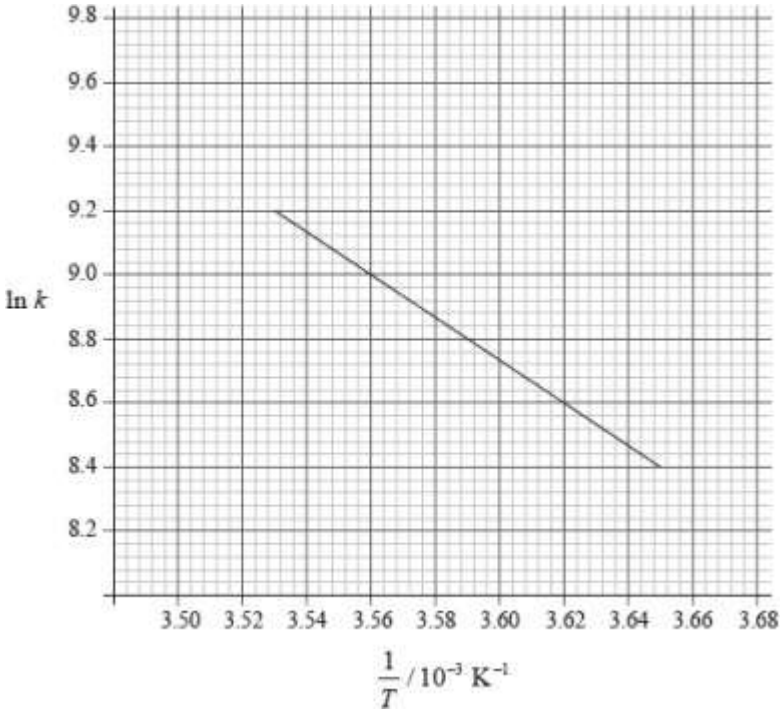
Q.94 The reaction shown below is the decomposition reaction of hydrogen peroxide. 3

$2H_2O_2\,(aq.) \text{-------} > 2H_2O\,(l) + O_2\,(g)$

The rate of decomposition can be monitored by measuring the volume of oxygen gas released. The graph shows the results obtained when a solution of hydrogen peroxide decomposed in the presence of a CuO catalyst.



	(i) Outline how the initial rate of reaction can be found from the graph. (ii) Explain how and why the rate of reaction changes with time.	
Q.95	Rohit wants to check how the rate of the reaction shown below is affected by changing the concentration of HCl. $CaCO_3$ (s) + 2HCl(aq) → $CaCl_2$ (aq) + H_2O(l) + CO_2 (g) He took 4 readings of rate of reaction vs concentration and plotted them as shown below.  (i) Based on his readings and assuming there is no human error, give one reason for point D being so far away from the other three points A, B, and C. (ii) Draw the best fit line for the above reaction.	2
Q.96	Nitrogen dioxide reacts differently with carbon monoxide at different temperatures. The equation below shows the original reaction and reaction mechanism at two different temperatures. Original reaction: NO_2 + CO > NO + CO_2 Reaction mechanism at T > 770 K:	2

	$NO_2 + CO$ ----> $NO + CO_2$ (slow) Reaction mechanism at T < 770 K: $2NO_2$---- > $NO + NO_3$ (slow) $NO_3 + CO$ ----> $NO_2 + CO_2$ (fast) Write down the equation for the rate of the reaction for: (a) T > 770 K (b) T < 770 K	
Q.97	Consider the following reaction: N_20_4----- > $2NO_2$ Based on the above reaction a graph of ln k vs 1/T is plotted as shown below.  (i) Calculate the activation energy for this reaction. (use R = 8.31 $Jmol^{-1}K^{-1}$) (ii) List two cases in which the rate of a reaction is equal to the rate constant. *(Note: This is not specific to only the reaction above.)*	3
Q.98	Calcium carbonate decomposes to CaO and CO2 as shown below: CaCO3---- > CaO + CO2 Liya took two different forms (as shown below) of CaCO3 as reactants to carry out this reaction and compare the rate of reaction for these two forms. In both forms, the mass of CaCO3 is the same.	3

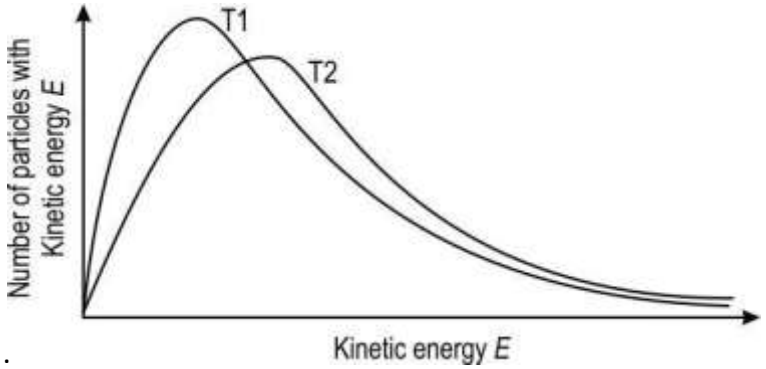
Form I

Form II

(i) Compare the rate of reaction for forms I and II.

(ii) Explain the reason behind the difference for both these two forms.

Q.99 The graph below shows the Maxwell-Boltzmann curve for a sample of nitrogen gas at temperatures T1 and T2. 3



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(i) Between T1 and T2, which is the higher temperature?

(ii) Based on your answer to part (i), explain the reason behind the two curves at different temperatures.

Q.100 For the equation, 4

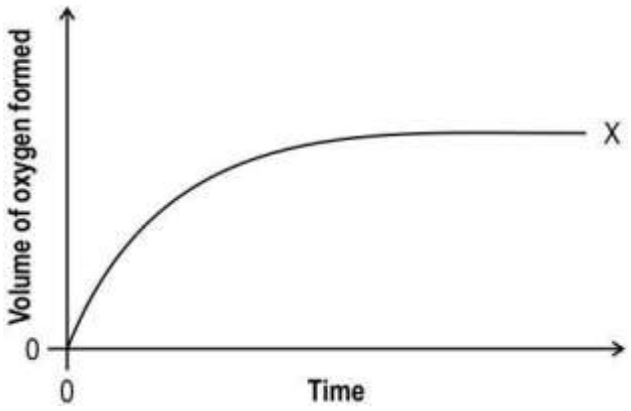
A + 2B -----> C + D + E

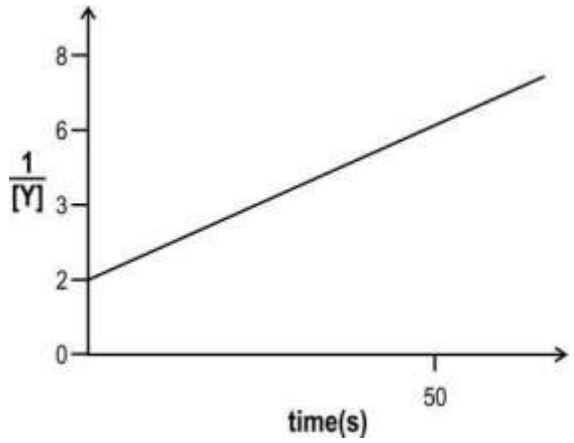
The following results were obtained to determine the initial rate of the reaction.

Experiment	[A] / mol dm^{-3}	[B] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	4	1	0.50
2	4	0.5	0.50
3	2	0.5	0.25

(i) What is the order of reaction with respect to A and B? Justify.

(ii) Write down the overall rate equation.

	(iii) Find the value of the rate constant for this reaction.	
Q.101	Graphically represent: (i) Concentration of a reactant X vs time for a ZERO order reaction. (ii) Rate of reaction vs concentration of a reactant X for a ZERO order reaction. (iii) Rate of reaction vs concentration of a reactant X for a FIRST order reaction.	3
Q.102	The rate of a reaction at 700K is 4 times faster than the rate at a lower temperature T. The energy of activation is 20.19×10^3 J/mol and the rate constant at 700K is $0.08s^{-1}$. (i) Calculate the rate constant at temperature T. (ii) Find temperature T. *(use R = 8.31 J/mol K)*	3
Q.103	In the following reaction K_3PO_4 ---- > $3K^+ + PO_4^{3-}$ the rate of formation of PO_4^{3-} is 50 mol $litre^{-1}s^{-1}$. (i) What is the rate of formation of potassium ions? (ii) What is the rate of loss of K_3PO_4?	3
Q.104	For the following reaction $2H_2O_2$---- > $O_2 + 2H_2O$ the curve below shows how the volume of oxygen formed varies with time.  (i) Explain the shape of the graph in terms of the rate of formation of oxygen.	2
Q.105	.For the first order reaction, X + Y ---- > Z the rate of reaction depends only on the concentration of Y.	3



(i) Identify the rate equation for this reaction. *(assume k as rate constant)*

(ii) If the above reaction is 75% complete in 1 hour then calculate the value of k?

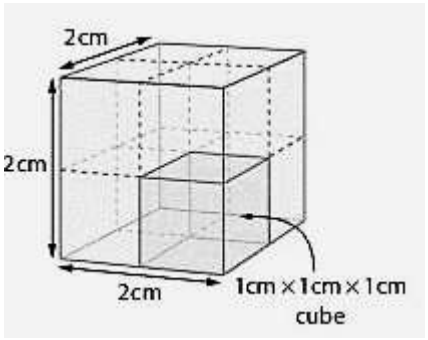
Q.106 The table below shows the result when 2g of powdered calcium carbonate were added to 50 cm^3 of 0.1 $moldm^{-3}$ HCl. — 3

Time/s	10	20	30	40	50	60	70	80
Volume of CO_2 given off/cm^3	25	45	60	70	75	78	80	80

(i) Plot a graph of the result and explain its shape.

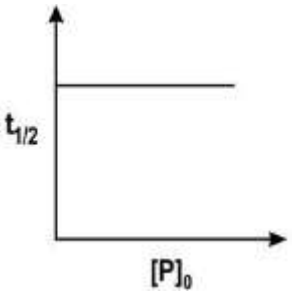
(ii) What is the rate at the start of the reaction?

Q.107 Calcium carbonate reacts with dilute HCl to produce CO_2. The image below shows a block of calcium carbonate with a dimension 2cm x 2cm x 2 cm. — 1

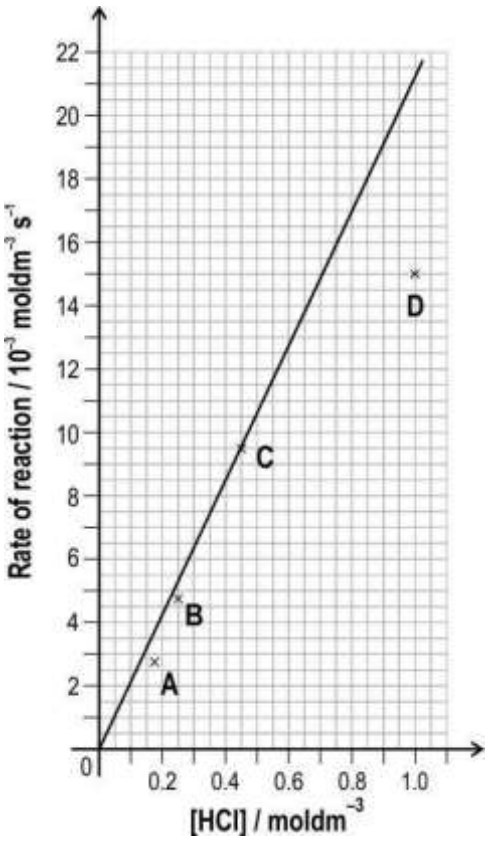


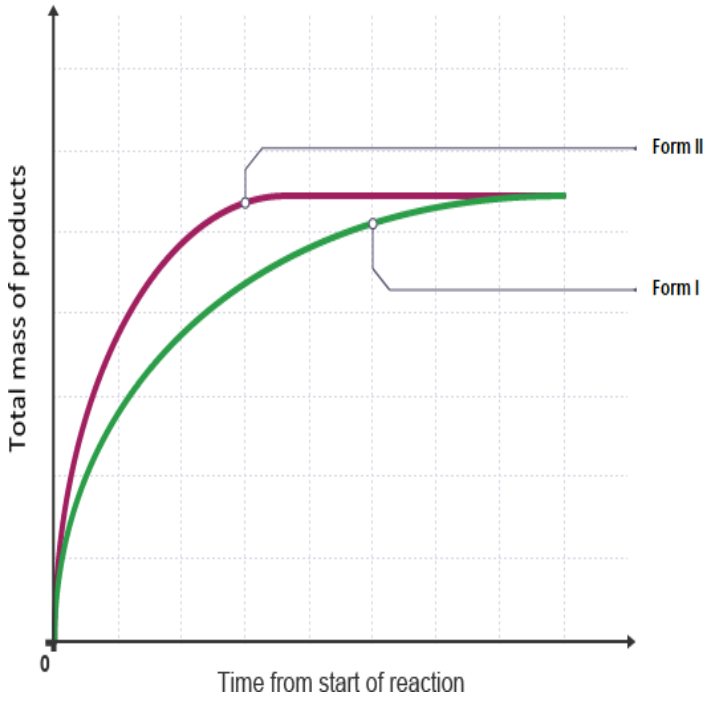
Suppose this cube is cut along the dashed line to make smaller cubes of 1cm x 1cm x 1cm. How will the rate of reaction of the bigger cube compare with that using all of the smaller cubes and why?

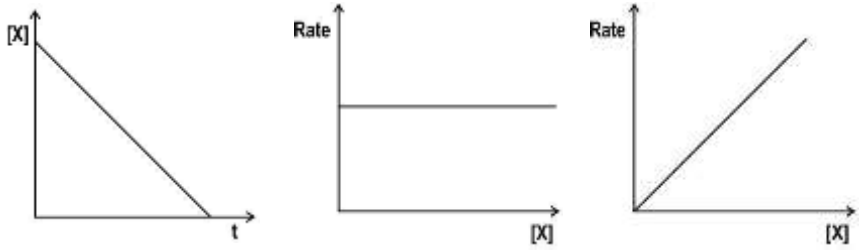
Answer Key & Marking Scheme

Q. No	Answers	Marks
Q.80	A. Iron changes the activation energy of reaction and molybdenum increases the efficiency of the catalyst.	1
Q.81	C. P, R, and S	1
Q.82	A. t1	1
Q.83	C. II and III only	1
Q.84	A. 	1
Q.85	A. P	1
Q.86	C. 3	1
Q.87	C. C	1
Q.88	B. i and ii only	1
Q.89	B. 17.5 hours	1
Q.90	Deducing rate expression: - Consider experiments 1 and 2: [B] = constant; [A] increases by 3; rate increases by 3^2 therefore 2^{nd} order with respect to A [1 mark] - Consider experiments 2 and 3: [A] increases by 2; the rate should increase × 2^2 but only increases × 2. Therefore, halving [B] halves rate and so 1^{st} order with respect to B [1 mark] - Rate equation: rate = $k[A]^2[B]$ [1 mark]	3
Q.91	The expiry date of food:	2

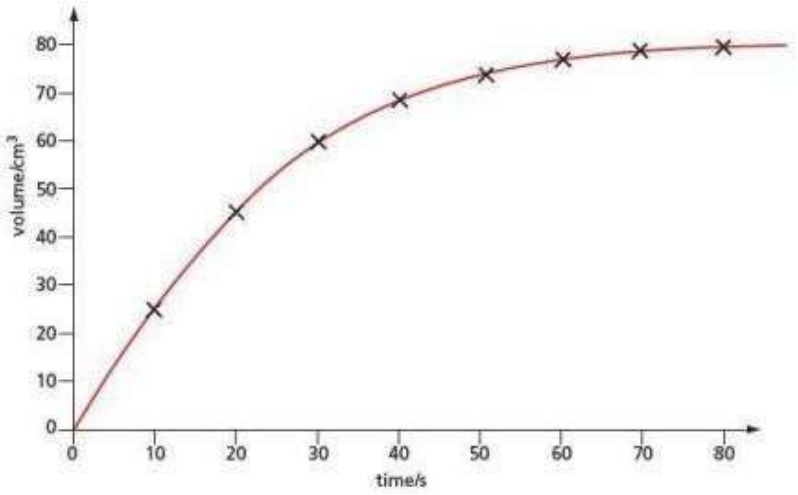
	- Average rate of reaction = average change in concentration/Δt [1 mark] - Δt = 40/4 per day = 10 days - Expiry date = 10th April 2022 [1 mark]	
Q.92	**Age of sample** - Since the concentration of ^{14}C decays with time at a particular rate (which depends on initial concentration), the kinetics for first-order could be used to identify the time required to change in the concentration of ^{14}C. => k = 0.693/ $t_{1/2}$ = 0.693 / 5730 [1 mark] => t = (2.303/k) log(A_0/A) => t = (2.303 x 5730/0.693) x log 100/10 => t = 19042 years (approx) [1 mark]	2
Q.93	(i) Order of reaction: - Based on the table, the decrease in partial pressure of ethane is constant over time that is $t_{1/2}$ is constant. So it's a first-order reaction. [1 mark] *(No marks if the reason is not given)* (ii) Rate constant: - For first-order reaction, rate constant (k) is given by 0.693/$t_{1/2}$ => k = 0.693/100 = 0.00693 min^{-1} or => k = 0.00011 s^{-1} [1mark] *give 1 mark for any value in mins or seconds* (iii) Ratio: - Time required for the completion of 50% of the reaction = 1 x $t_{1/2}$ - Time required for the completion of 75% of the reaction = 2 x $t1_{/2}$ - So the ratio = 1/2 [1 mark]	3
Q.94	(i) how to find the rate of reaction from a graph: - Draw a tangent to the curve at (0,0) - Calculate the slope of the tangent. The slope of the tangent is the rate of reaction (ii) Reason for rate change: - Rate decreases with time	3

	- concentration/number of (reactant) molecules per unit volume decreases (with time) *[Do not accept "number of molecules decreases" or "amount of reactant decreases".]* - collisions (between reactant molecules/reactant and catalyst) become less frequent.	
Q.95	(i) Give 1 mark for writing any one of the following: -Reaction is fast at high concentration and may be difficult to measure accurately - The large quantity of bubbles of CO_2 produced inhibit contact of HCl(aq) with $CaCO_3$ (s) - Calcium carbonate has been used up/is a limiting reagent and there is not enough calcium carbonate to react with the high concentration of HCl - HCl is in excess (ii) Draw a straight line going through the origin and as close to A, B, C as possible  	2
Q.96	Rate of reaction for T > 770 K Rate = k $[NO_2][CO]$ Rate of reaction for T < 770 K Rate = k $[NO_2]^2$	2

Q.97	(i) Activation energy: - Since it's a first-order reaction, the slope of the curve is equal to $-E_a/R$ (where Ea is activation energy and R is the gas constant) [1 mark] => Slope = $(9.2 - 8.4)/(3.53 \times 10^{-3} - 3.65 \times 10^{-3}) = -6.67 \times 10^3$ => So $E_a = 8.31 \times 6.67 \times 10^3 = 55.4$ kJ/mol [1 mark] (ii) Two cases are: - When the concentration of all reactants is 1 unit [0.5] - When the order of the reaction is 0 [0.5]	3
Q.98	(i) Graph:  - give 0.5 mark for representing form I with the proper label - give 0.5 mark for representing form II with the proper label *Deduct 0.5 marks if labels are absent* (ii) Reason: - For the given mass/volume of solid, Form I has a smaller surface area than Form II. [1] - More reactant particles are exposed at the surface in Form II, increasing the collision rate, and hence the rate increases. [1] - Higher the rate, the higher will be the value of the tangent of the curve during the initial phase. [1]	3

Q.99	(i) T2>T1 (ii) Explanation: - Mean Kinetic energy of the gaseous particle is directly proportional to the temperature of the reaction mixture. So higher energy means a wider spread of values. - Higher the energy, the higher will be the proportion of successful collisions. -This means, a higher proportion of the particles possess the minimum amount of energy (activation energy) to cause a chemical reaction - Hence, with higher temperatures, the Boltzmann distribution curve flattens, and the peak shifts to the right. *Note: give 0.5 marks for each point*	3
Q.100	(i) Order of reaction: - For exp. 1 and 2, [A] is constant, but [B] is halved. However, rate is constant. So, it's zero-order wrt B. [1 mark] - For experiments 2 and 3, [A] is halved with constant [B] and rate is also halved, so it's 1st order wrt A. [1 mark] (ii) Rate of reaction = k[A] (iii) k = 0.50/4 = 0.125 s^{-1}	4
Q.101	 (i) (ii) (iii)	3
Q.102	(i) Let the rate constant at 700K be k1 and that at T be k2. => k1/k2 = 4 => k2 = 0.08/4 = 0.02 [1 mark] (ii) Temperature: => As per the Arrhenius equation, $k1/k2 = e^{-Ea/(R \times 700)} / e^{-Ea/(R \times T)}$ => $4 = e^{-Ea/(R \times 700)} / e^{-Ea/(R \times T)}$ [1mark]	3

	Solving for T gives, T = 500 K [1 mark]	
Q.103	The overall rate of a reaction is given by: $-1/1\ \Delta[K_3PO_4]/\Delta t = +1/3\ \Delta[K^+]/\Delta t = +1/1\ \Delta[PO_4^{3-}]/\Delta t$ [1 mark] (i) rate of formation of potassium ions $\Rightarrow +1/3\ \Delta[K^+]/\Delta t = +50$ $\Rightarrow \Delta[K^+]/\Delta t = 150$ mol litre^{-1}s^{-1}[1 mark] (ii) Rate of loss of K_3PO_4 $\Rightarrow -1/1\ \Delta[K_3PO_4]/\Delta t = +50$ $\Rightarrow \Delta[K_3PO_4]/\Delta t = -50$ gs^{-1} [1 mark]	3
Q.104	(i) Explanation: - the slope of the curve defines the rate of formation of oxygen. Initially, the slope is high which means the rate of formation is high. [0.5] - After some time slope is constant/zero, which means the reactants are exhausted and the reaction is completed so the volume is constant. [0.5]	2
Q.105	(i) Rate equation Rate = $k[Y]^2$ (ii) Time for completion to 75% For second order, $1/[A_0] = 1/[A] + kt$; where A is initial concentration, A_0 is concentration of A left after 1 hour. [1 mark] $\Rightarrow 1/0.25 = 1/1 + k \times 1$ $\Rightarrow k = 3$ Lmol^{-1}h^{-1} [1 mark]	3
Q.106	(i) Graph:	3

	 [1] Explanation: - The rate decreases with time because the acid becomes more dilute. The reaction stops when all acid is used up. [1] (ii) From the graph, the rate at the start = 25/10 = 2.5 cm^3s^{-1} [1]	
Q.107	(i) Rate of the reaction using smaller cubes will be faster than that using bigger cube. - Breaking up the solid increases its surface area in contact with reactant gas and liquid. This results in more collision per second and hence faster rate.	1