IB Chemistry – HL
Topic 6 Questions

1. The reaction between NO_2 and F_2 gives the following rate data at a certain temperature. What is the order of reaction with respect to NO_2 and F_2?

$[NO_2]$/mol dm^{-3}	$[F_2]$/mol dm^{-3}	Rate /mol dm^{-3} min^{-1}
0.1	0.2	0.1
0.2	0.2	0.4
0.1	0.4	0.2

	NO_2 order	**F_2 order**
A.	first	first
B.	first	second
C.	second	first
D.	second	second

2. Which step in a multi-step reaction is the rate determining step?

A. The first step

B. The last step

C. The step with the lowest activation energy

D. The step with the highest activation energy

3. The rate expression for a reaction is shown below.

$$\text{rate} = k[A]^2[B]^2$$

Which statements are correct for this reaction?

I. The reaction is second order with respect to both A and B.

II. The overall order of the reaction is 4.

III. Doubling the concentration of A would have the same effect on the rate of reaction as doubling the concentration of B.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

4. Values of a rate constant, k, and absolute temperature, T, can be used to determine the activation energy of a reaction by a graphical method. Which graph produces a straight line?

A. k versus T

B. k versus $\frac{1}{T}$

C. $\ln k$ versus T

D. $\ln k$ versus $\frac{1}{T}$

5. The rate expression for a particular reaction is

$$\text{Rate} = k[\text{P}][\text{Q}]$$

Which of the units below is a possible unit for k?

A. $\text{mol}^{-2}\ \text{dm}^{6}\ \text{min}^{-1}$

B. $\text{mol}^{-1}\ \text{dm}^{3}\ \text{min}^{-1}$

C. $\text{mol}\ \text{dm}^{3}\ \text{min}^{-1}$

D. $\text{mol}^{-2}\ \text{dm}^{-6}\ \text{min}^{-1}$

6. The reaction $2\text{X(g)} + \text{Y(g)} \rightarrow 3\text{Z(g)}$ has the rate expression

$$\text{rate} = k\,[\text{X}]^2[\text{Y}]^0$$

The concentration of X is increased by a factor of three and the concentration of Y is increased by a factor of two. By what factor will the reaction rate increase?

A. 6 B. 9

C. 12 D. 18

7. A reaction occurs in four steps. The steps and their rates are shown in the table

Step	Rate
1	$0.01\ \text{mol}\ \text{dm}^{-3}\ \text{s}^{-1}$
2	$0.10\ \text{mol}\ \text{dm}^{-3}\ \text{s}^{-1}$
3	$0.01\ \text{mol}\ \text{dm}^{-3}\ \text{min}^{-1}$
4	$0.10\ \text{mol}\ \text{dm}^{-3}\ \text{min}^{-1}$

Which is the rate-determining step?

A. Step 1 B. Step 2

C. Step 3 D. Step 4

8. The rate expression for a reaction is

$$\text{rate} = k[CH_3Br][OH^-]$$

Which is a possible unit for k?

A. $mol^2\ dm^{-6}\ min^{-1}$ B. $mol\ dm^{-3}\ min^{-1}$

C. $mol^{-1}\ dm^3\ min^{-1}$ D. $mol^{-2}\ dm^6\ min^{-1}$

9. What happens to the rate constant (k) and activation energy (E_a) of a reaction when the temperature is increased?

A. k increases and E_a is unaffected. B. k decreases and E_a is unaffected.

C. E_a increases and k is unaffected. D. E_a decreases and k is unaffected.

10. The mechanism of a reaction is

$$XY_2 + XY_2 \rightarrow X_2Y_4$$
$$X_2Y_4 \rightarrow X_2 + 2Y_2$$
$$X_2 + Y_2 \rightarrow 2XY$$

What is the overall equation for the reaction?

A. $X_2Y_4 \rightarrow 2XY_2$ B. $2XY_2 \rightarrow X_2 + 2Y_2$

C. $2XY_2 \rightarrow 2XY + Y_2$ D. $X_2Y_4 \rightarrow 2XY + Y_2$

11. Consider the reaction

$$2I^-(aq) + H_2O_2(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

In the presence of $S_2O_3^{2-}(aq)$ and starch solution, the time taken for a blue colour to form was observed at various reactant concentrations.

Experiment	$[I^-]$ / mol dm^{-3}	$[H_2O_2]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Time / s
1	0.10	0.12	0.01	25
2	0.05	0.12	0.01	50
3	0.10	0.06	0.01	100

What is the correct order with respect to I^- and H_2O_2?

I^-	H_2O_2

A.	1	2
B.	$\frac{1}{2}$	$\frac{1}{4}$
C.	2	1
D.	2	4

12. Which statement is correct about the rate expression for a chemical reaction?

A. It can be determined from its chemical equation.

B. It can be predicted from the value of $\Delta H^{\ominus}$ for the reaction.

C. It can be calculated from the effect of temperature on the reaction.

D. It can be determined by measuring the change in concentration of a reactant or product over time.

13. For the reaction $2NO_2(g) + F_2(g) \rightarrow 2NO_2F(g)$ the accepted mechanism is

$NO_2(g) + F_2(g) \rightarrow NO_2F(g) + F(g)$ slow
$NO_2(g) + F(g) \rightarrow NO_2F(g)$ fast

What is the rate expression for this reaction?

A. rate = $k[NO_2]^2[F_2]$ B. rate = $k[NO_2][F_2]$

C. rate = $k[NO_2][F]$ D. rate = $k[NO_2]^2$

14. The activation energy, of a reaction can be obtained from the rate constant, *k*, and the absolute temperature, *T*. Which graph of these quantities produces a straight line?

A. *k* against *T*

B. *k* against $\frac{1}{T}$

C. ln *k* against *T*

D. ln *k* against $\frac{1}{T}$

15. What is the order of reaction with respect to $NO_2(g)$ and $F_2(g)$ given the following rate data at a certain temperature?

$[NO_2(g)]$ / mol dm^{-3}	**$[F_2(g)]$ / mol dm^{-3}**	**Rate / mol dm^{-3} min^{-1}**
0.1	0.2	0.1
0.2	0.2	0.4

0.1	0.4	0.2

	Order with respect to $NO_2(g)$	Order with respect to $F_2(g)$
A.	first	first
B.	first	second
C.	second	first
D.	second	second

16. Nitrogen(II) oxide reacts with hydrogen as shown by the following equation.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The table below shows how the rate of reaction varies as the reactant concentrations vary.

Experiment	Initial [NO] / mol dm^{-3}	Initial [H_2] / mol dm^{-3}	Initial rate / mol N_2 dm^{-3} s^{-1}
1	0.100	0.100	2.53×10^{-6}
2	0.100	0.200	5.05×10^{-6}
3	0.200	0.100	10.10×10^{-6}
4	0.300	0.100	22.80×10^{-6}

(a) Determine the order of reaction with respect to NO and with respect to H_2. Explain how you determined the order for NO.

NO .....

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H_2 .....

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(3)

(b) Write the rate expression for the reaction.

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(1)

(c) Calculate the value for the rate constant, including its units.

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(2)

(d) A suggested mechanism for this reaction is as follows.

$H_2 + NO \rightleftharpoons X$ fast step
$X + NO \rightarrow Y + H_2O$ slow step
$Y + H_2 \rightarrow N_2 + H_2O$ fast step

State and explain whether this mechanism agrees with the experimental rate expression in (b).

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(4)

(e) Explain why a single step mechanism is unlikely for a reaction of this kind.

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(2)

(f) Deduce how the initial rate of formation of $H_2O(g)$ compares with that of $N_2(g)$ in experiment 1. Explain your answer.

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(2)
(Total 14 marks)

17. The oxidation of nitrogen monoxide takes place as follows:

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$

The following experimental data was obtained at 101.3 kPa and 298 K.

Experiment	Initial [NO] / mol dm^{-3}	Initial [O_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	3.50×10^{-2}	1.75×10^{-2}	3.75×10^{-3}
2	3.50×10^{-2}	3.50×10^{-2}	7.50×10^{-3}

3	7.00×10^{-2}	7.00×10^{-2}	6.00×10^{-2}

(a) Deduce the order of reaction with respect to O_2.

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(1)

(b) Deduce the order of reaction with respect to NO.

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(1)

(c) State the rate expression for the reaction.

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(1)

(d) Calculate the value of the rate constant and state the units.

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(2)

(e) Suggest a possible mechanism that is consistent with the rate expression. Indicate which of the steps is the rate-determining step.

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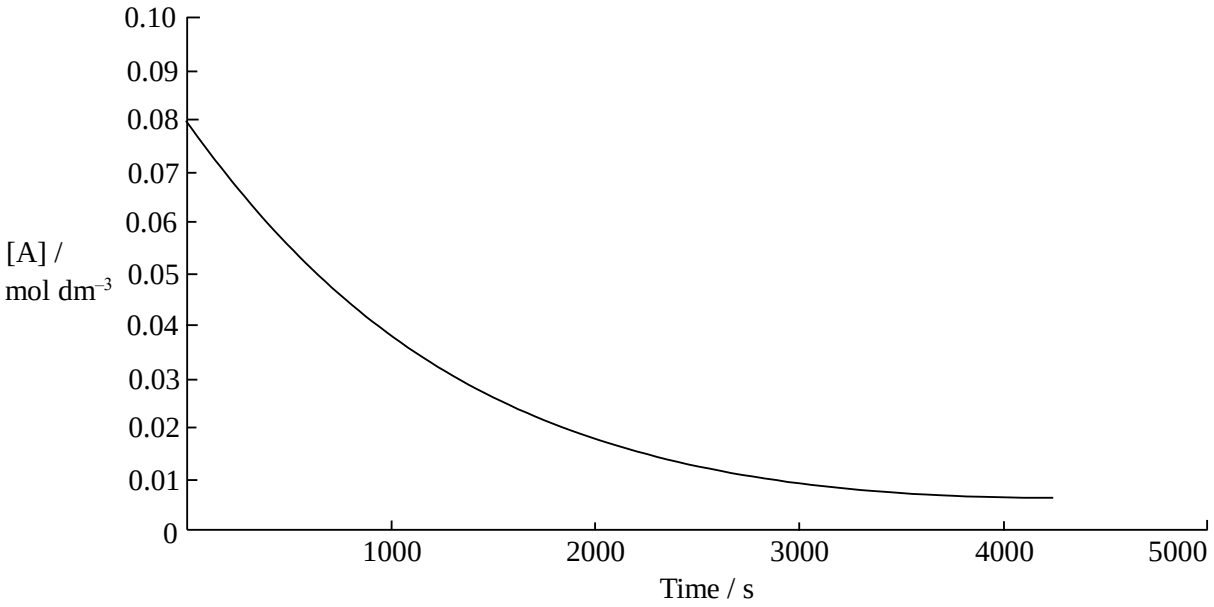
(3)
(Total 8 marks)

18. An equation for the decomposition of substance **A** is

$$\mathbf{2A \rightarrow 2B + C}$$

A graph showing the change in concentration of **A** against time as the reaction proceeds at a particular temperature is shown below.



(a) Define the term *half-life* of reaction.

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(1)

(b) Use the graph to measure values of half-life of reaction, starting from

time = zero .....

time = 1000 s .....

(2)

(c) Deduce the order of the reaction with respect to **A**, giving a reason for your choice, and write the rate expression for the reaction.

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(3)

(d) For a different reaction, between compounds **D** and **E**, the rate expression is

$$\text{rate} = k[\text{D}]^2[\text{E}]$$

Calculate the value of k, including units, for the reaction when the concentrations of both **D** and **E** are 1.35×10^{-2} mol dm^{-3} and the reaction rate is 3.75×10^{-5} mol dm^{-3} min^{-1}.

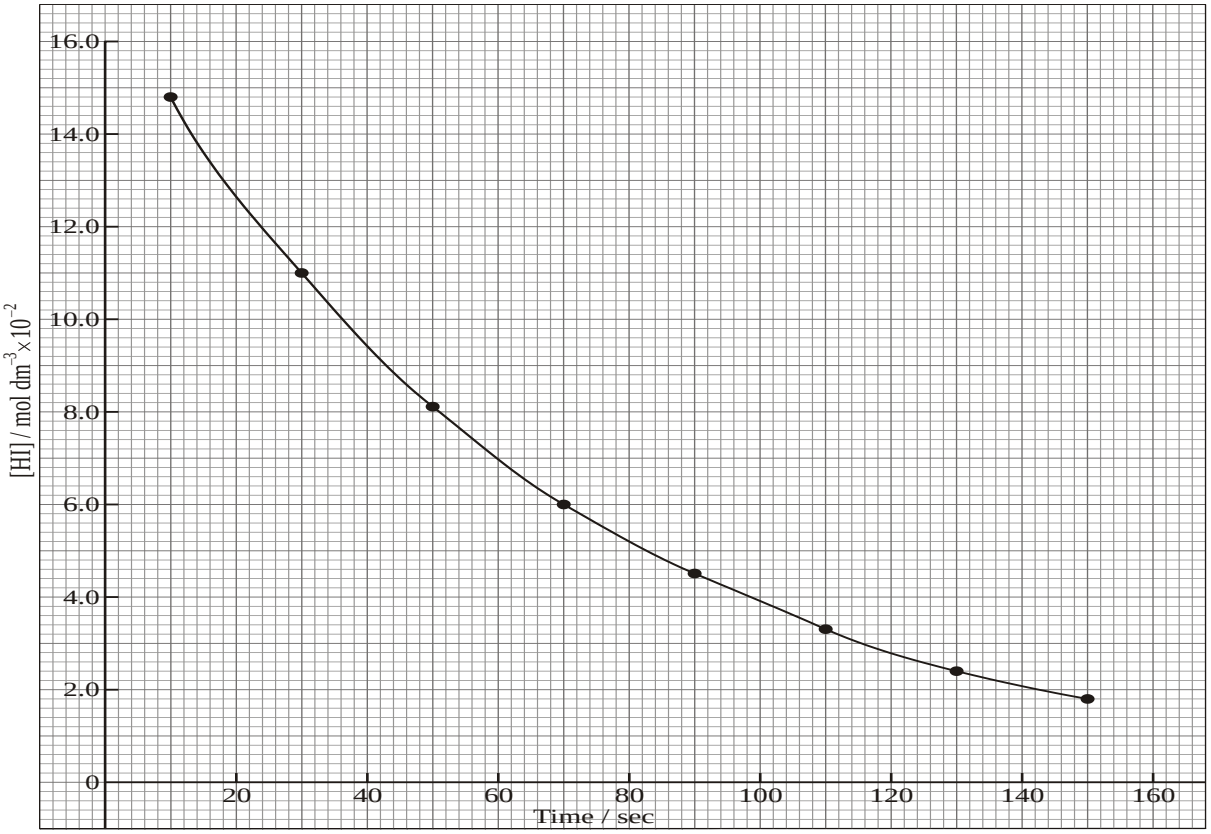
(3)
(Total 9 marks)

19. In a particular experiment, various concentrations of HI(aq) are reacted with a constant

$H_2O_2(aq)$ concentration according to the following equation:

$$H_2O_2(aq) + 2HI(aq) \rightarrow I_2(aq) + 2H_2O(I)$$

A graph of [HI] against time is as follows:



(a) Use the graph to deduce the order of reaction with respect to HI. Give a reason for your answer.

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(2)

(b) The order with respect to H_2O_2 is the same as HI. Deduce the rate expression for this reaction.

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(1)

(c) Determine the half-life of the reaction from the graph and calculate the value for the rate constant.

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(2)
(Total 5 marks)

20. (a) The table below shows kinetic data for the following reaction

$$C + D \rightarrow E + F$$

Experiment	**[C] / mol dm^{-3}**	**[D] / mol dm^{-3}**	**Initial rate / mol dm^{-3} min^{-1}**
1	2.0×10^{-3}	3.0×10^{-3}	1.0×10^{-6}
2	4.0×10^{-3}	3.0×10^{-3}	2.0×10^{-6}
3	6.0×10^{-3}	6.0×10^{-3}	3.0×10^{-6}

(i) Deduce the order of reaction with respect to both **C** and **D**, giving a reason in each case.

C .....

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D .....

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(4)

(ii) Deduce the rate expression for this reaction.

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(1)

(iii) Use data from Experiment 1 to calculate a value for the rate constant for this reaction and deduce its units.

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(3)

(b) Define the term *half-life* and calculate the half-life for a first-order reaction with a rate constant of 3.3×10^{-2} min^{-1}.

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(2)

(Total 10 marks)

21. Nitrogen(II) oxide reacts with hydrogen according to the following equation:

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

The table shows how the rate of reaction varies as the concentrations of the reactants are changed.

Experiment	**Initial [NO] / mol dm^{-3}**	**Initial [H_2] / mol dm^{-3}**	**Initial rate / mol (N_2) dm^{-3} s^{-1}**
1	0.100	0.100	253×10^{-6}
2	0.100	0.200	5.05×10^{-6}
3	0.200	0.100	1.01×10^{-5}
4	0.300	0.100	2.28×10^{-5}

(a) Determine the order of reaction with respect to H_2 and with respect to NO.

H_2 .....

NO .....

(2)

(b) Write the rate expression for the reaction.

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(1)

(c) Calculate the value for the rate constant, and state its units using the data from experiment 1.

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(2)

(d) A suggested mechanism for this reaction is as follows.

$H_2 + NO \rightleftharpoons X$ fast step
$X + NO \rightarrow Y + H_2O$ slow step
$Y + H_2 \rightarrow N_2 + H_2O$ fast step

State and explain whether this mechanism agrees with the experimental rate expression in (b).

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(4)

(e) Explain why a single step mechanism is unlikely for a reaction of this kind.

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(2)

(f) Deduce and explain how the initial rate of formation of H_2O compares with that of N_2.

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(2)
(Total 13 marks)

22. The data below refer to a reaction between X and Y.

	Initial concentration / mol dm^{-3}		**Initial rate of reaction / mol dm^{-3} s^{-1}**
Experiment	**X**	**Y**	
1	0.25	0.25	10×10^{-2}
2	0.50	0.25	4.0×10^{-2}

3	0.50	0.50	8.0×10^{-2}

(i) Define the term *order of reaction.*

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(1)

(ii) Deduce the order of reaction with respect to **both** X and Y. Explain your reasoning.

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(4)

(iii) Write the rate expression for the reaction and calculate the rate constant, including its units.

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(4)

(iv) Calculate the initial rate of reaction when the initial concentrations of X and Y are 0.40 mol dm^{-3} and 0.60 mol dm^{-3} respectively.

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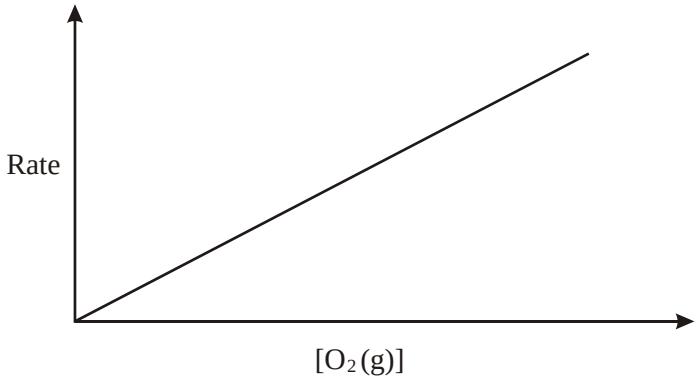
(2)

(Total 11 marks)

23. Oxygen and nitrogen monoxide react together to form nitrogen dioxide.

$$O_2(g) + 2NO(g) \rightarrow 2NO_2(g)$$

The graph below shows how the initial rate of reaction changed during an experiment in which the initial [NO(g)] was kept constant whilst the initial [O_2(g)] was varied.



(a) Deduce, giving a reason, the order of reaction with respect to O_2

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(2)

(b) In a series of experiments, the initial $[O_2(g)]$ was kept constant while the initial [NO(g)] was varied. The results showed that the reaction was second order with respect to NO. Sketch a graph to show how the rate of reaction would change if the initial [NO(g)] was increased.

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(2)

(c) Deduce the overall order of this reaction.

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(1)

(d) State and explain what would happen to the initial rate of reaction if the initial concentration of NO was doubled and that of O_2 was halved.

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(3)

(e) When the initial values are $[O_2(g)] = 1.0\times10^{-2}$ mol dm^{-3} and $[NO(g)] = 3.0\times10^{-2}$ mol dm^{-3}, the initial rate of reaction is 6.3×10^{-4} mol $dm^{-3}s^{-1}$. Write the rate expression for

this reaction and calculate the rate constant, stating its units.

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(4)

(Total 12 marks)

24. The compound iodine chloride, ICl, reacts with hydrogen to form iodine and hydrogen chloride.

(i) Deduce the equation for this reaction.

(1)

(ii) The kinetics of this reaction were studied at a certain temperature, when all the reactants and products were in the gas phase. The table shows the initial rate of reaction for different concentrations of reactants.

Experiment	[ICl] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.100	0.0500	5.00×10^{-3}
2	0.200	0.0500	1.00×10^{-2}
3	0.200	0.0250	2.50×10^{-3}

Deduce and explain the order of reaction with respect to ICl and to H_2.

(4)

(iii) Write the rate expression for the reaction.

(1)

(iv) Use information from Experiment 1 to determine the value, with units, of the rate constant for the reaction.

(2)

(v) Determine the rate of reaction when the concentrations of reactants in Experiment 1 are both doubled.

(1)

(Total 9 marks)

25. (a) The variation of the rate constant, *k*, for a reaction with temperature is shown by the Arrhenius equation. Two versions of this equation are shown in Table 1 of the Data Booklet.

(i) Explain the significance of the Arrhenius constant, *A*, in this equation.

(1)

(ii) Explain what is meant by the term *activation energy*,E_a.

(1)

(iii) Describe how, using a graphical method, values of *A* and E_a can be obtained for a reaction.

(5)

(b) The equation for a reaction used in industry is

$$CH_2CH_2 + Cl_2 \rightarrow CH_2ClCH_2CL \quad \Delta H^{\Theta} = -185 \text{ kJ}$$

Iron(III) chloride can be used as a catalyst for the reaction.

(i) Explain the difference between the terms *homogeneous* and *heterogeneous* when applied to a catalyst.

(1)

(ii) Draw an enthalpy level diagram for this reaction, including labels for ΔH^{Θ}, E_a and the activation energy when a catalyst is used, E_{cat}.

(4)
(Total 12 marks)

26. Nitrogen(II) oxide reacts with bromine according to the following equation.

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g) \qquad \Delta H = \text{negative}$$

The data below were obtained for the reaction between NO(g) and $Br_2(g)$ at a specified temperature and pressure.

Experiment	Initial [NO] / mol dm^{-3}	Initial [Br_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	2.00×10^{-2}	5.00×10^{-3}	3.20×10^{-3}
2	2.00×10^{-2}	2.50×10^{-3}	1.60×10^{-3}
3	4.00×10^{-2}	5.00×10^{-3}	1.30×10^{-2}

(a) Determine, giving a reason, the order of reaction with respect to NO and the order of reaction with respect to Br_2.

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(2)

(b) Derive the rate expression for the reaction between NO and Br_2.

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(1)

(c) Calculate the rate constant for the rate expression using experiment 1 and state its units.

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(2)

(d) If the total volume of the reaction mixture was doubled at constant temperature, state the effect, if any, on

(i) the rate constant.

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(1)

(ii) the rate of change of the $Br_2(g)$ concentration.

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(1)

(e) Draw a labelled enthalpy level diagram for the reaction between NO(g) and $Br_2(g)$, with and without the use of a catalyst.

(3)
(Total 10 marks)

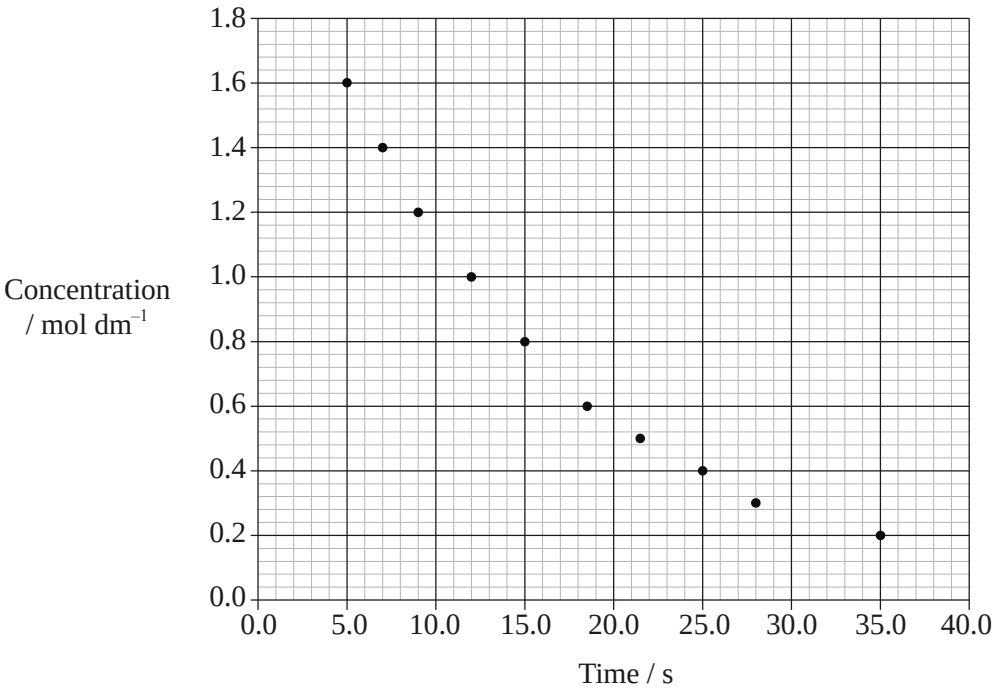
27. (i) The reaction between propanone, CH_3COCH_3 and bromine, Br_2 in the presence of acid, H^+, is found to be second order overall, but the rate is independent of the bromine concentration. Write **three** possible rate expressions for the reaction.

(3)

(ii) The concentration of each of the three reactants was doubled in three separate experiments. Choose **one** of the rate expressions in (i) and predict the effect on the rate of the reaction of each of these changes.

(2)

(iii) The graph below shows how the concentration of propanone changes with time in a reaction.



Use the graph to confirm that the reaction is first order with respect to propanone showing your working.

(2)

(iv) The overall reaction is:

$$CH_3COCH_3(aq) + Br_2(aq) \xrightarrow{H^+(aq)} CH_3COCH_2Br(aq) + HBr(aq)$$

Describe **one** observation that would allow you to follow the progress of the reaction.
State and explain the role of the acid in the reaction.

(4)
(Total 11 marks)