A2 CHEMISTRY

TOPIC 5.1.1 HOW FAST!

BOOKLET OF PAST EXAMINATION QUESTIONS II

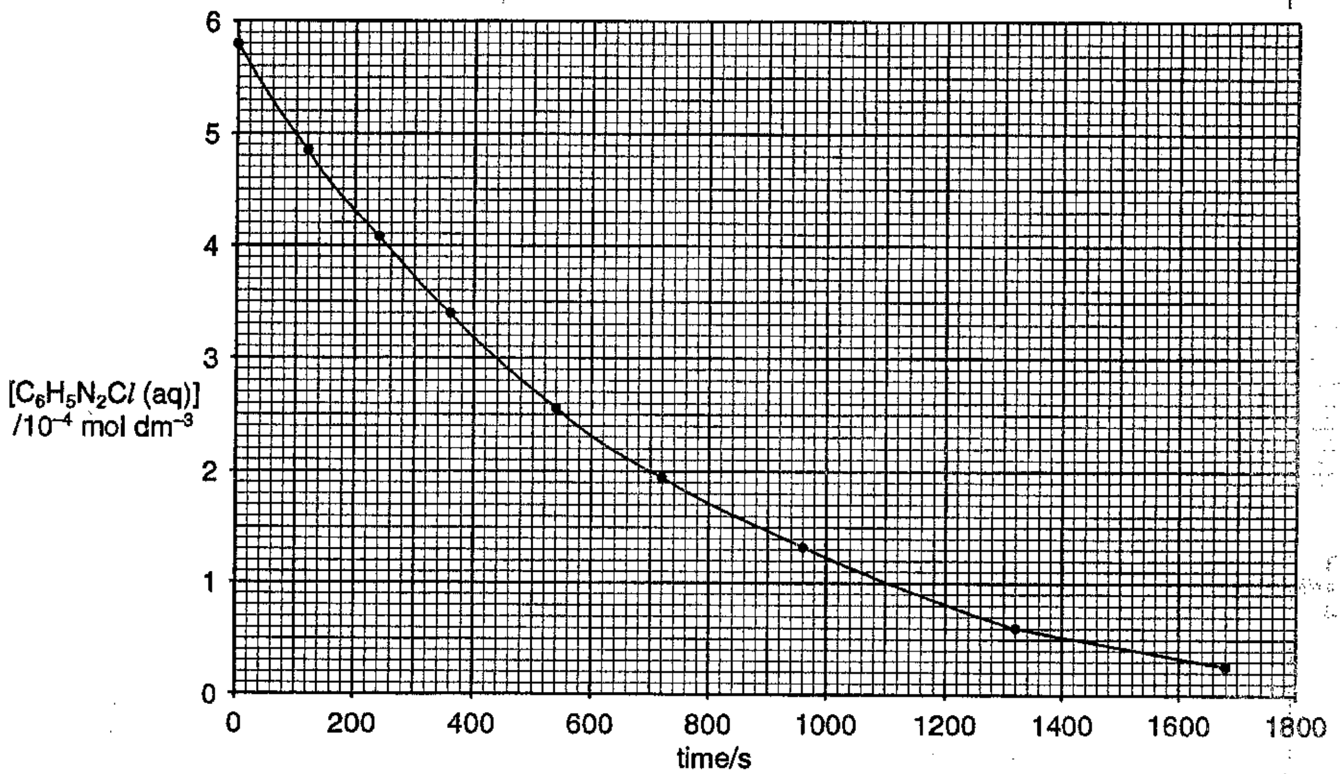
ANSWER ALL QUESTIONS

TOTAL 61 MARKS

2 Benzenediazonium chloride, $C_6H_5N_2Cl$, decomposes above 10 °C, releasing nitrogen gas.

$$C_6H_5N_2Cl(aq) + H_2O(l) \longrightarrow C_6H_5OH(aq) + N_2(g) + HCl(aq)$$

The graph below shows how the concentration of $C_6H_5N_2Cl$ changes with time at 50 °C.



(a) This reaction is first order with respect to $C_6H_5N_2Cl$. This can be confirmed from the graph using half-lives.

(i) What is meant by the *half-life* of a reaction, $t_{½}$?

....

....[1]

(ii) Use this graph to show that this reaction is first order with respect to $C_6H_5N_2Cl$. You should mark on the graph any working.

....

....

....

....[3]

(iii) What would be the effect on the half-life of this reaction of doubling the initial concentration of $C_6H_5N_2Cl$?

....[1]

(b) For a first order reaction, the rate constant, k, can be found using the following relationship.

$$kt_{½} = 0.693$$

Calculate the value for the rate constant, k, of this reaction. Include the units of k in your answer.

[2]

(c) Write down the expression for the rate equation of this reaction.

....[1]

(d) The rate of this reaction can be calculated by using the graph and the rate equation together.

(i) Read from the graph the concentration of $C_6H_5N_2Cl$ after 800 s.

....[1]

(ii) Use the rate equation to calculate the rate of this reaction after 800 s. Include units in your answer.

[2]

(iii) How could you measure the reaction rate after 800 s directly from the graph alone?

....

....[1]

[Total : 12]

For Examiner's Use

2 The reaction between hydrogen, H_2, and nitrogen monoxide, NO, has the following rate equation.

$$\text{rate} = k[H_2(g)][NO(g)]^2$$

(a) Using 6.0×10^{-3} mol dm^{-3} $H_2(g)$ and 3.0×10^{-3} mol dm^{-3} NO(g), the initial rate of this reaction was 4.5×10^{-3} mol dm^{-3} s^{-1}.

Calculate the rate constant, *k*, for this reaction and state its units.

[3]

(b) Predict what would happen to the reaction rate after the following changes in concentrations. Show your reasoning.

(i) The concentration of $H_2(g)$ is doubled.

effect on rate ....

reason ....

.... [2]

(ii) The concentration of NO(g) is halved.

effect on rate ....

reason ....

.... [2]

(iii) The concentrations of $H_2(g)$ and NO(g) are both tripled.

effect on rate .... [1]

(c) The overall equation for the reaction between hydrogen and nitrogen monoxide is shown below.

$$2H_2(g) + 2NO(g) \longrightarrow N_2(g) + 2H_2O(l)$$

This reaction takes place by a two step mechanism with the rate-determining step taking place first.

(i) Explain the term *rate-determining step.*

....

.... [1]

(ii) Suggest the two steps for this reaction and write their equations below. The equation for the rate-determining step (RDS) has been partly completed.

step 1 (RDS) .... + 2.............. $\longrightarrow$ .... + $H_2O(l)$

step 2 .... + ... $\longrightarrow$ $N_2(g) + H_2O(l)$

[2]

(d) Each year in the UK, 700 000 tonnes of nitric acid, HNO_3, are manufactured for the production of fertilisers, dyes, explosives, etc. Nitrogen monoxide, NO, is prepared as an intermediate in the production of nitric acid from ammonia, NH_3.

$$\boxed{NH_3(g)} \xrightarrow{O_2(g)} \boxed{NO(g) + H_2O(l)} \longrightarrow \boxed{HNO_3(l)}$$

(i) What is the oxidation state of nitrogen in the following?

NH_3 ....

NO ....

HNO_3 .... [3]

(ii) Construct a balanced equation for the formation of NO(g) from $NH_3(g)$.

.... [2]

(iii) Assuming that 1 mol NH_3 produces 1 mol HNO_3, calculate the mass of NH_3 that is required to meet the annual demand for HNO_3 in the UK.

[2]

[Total : 18]

2 Nitrous oxide, N_2O, is a colourless gas with a mild, pleasing odour and sweet taste. It is widely used as a propellant in aerosol cans of whipped cream.

(a) Nitrous oxide is formed when ammonium nitrate, NH_4NO_3, is gently heated.

$$NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(l)$$

(i) What mass of N_2O is formed by heating 100 g of NH_4NO_3?

[3]

(ii) What happens to the oxidation number of each nitrogen from NH_4NO_3 in this reaction?

....

....

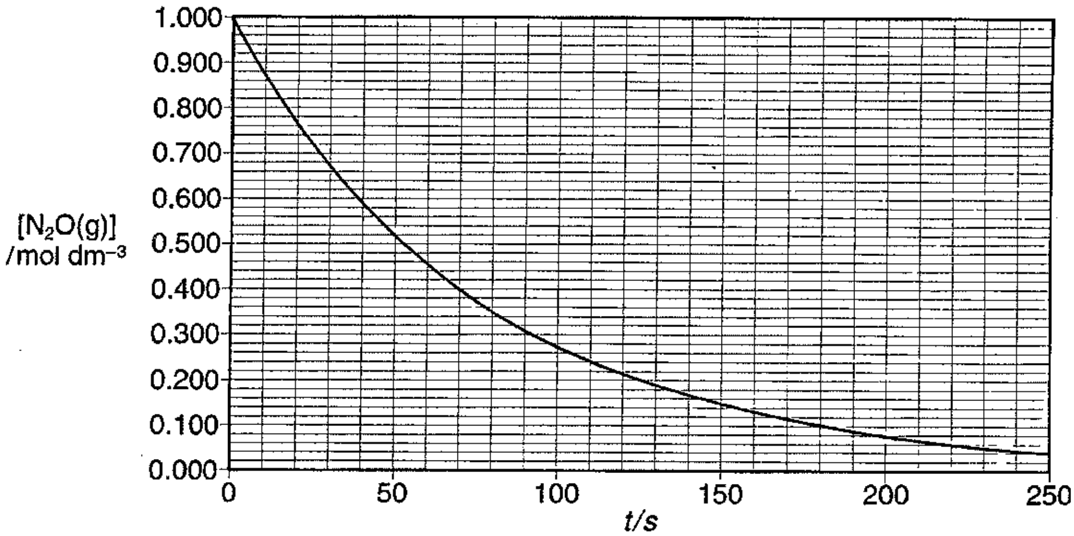
....[2]

(b) When heated strongly, nitrous oxide decomposes into its elements.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

This reaction is first order with respect to N_2O.

The graph below shows how nitrous oxide decomposes with time at constant temperature.



(i) Explain how the graph confirms that this reaction is first order with respect to N_2O.

....

....

....

....[3]

(ii) Write the expression for the rate equation of this reaction.

[1]

(iii) Use the graph to work out the rate of reaction, in $mol\,dm^{-3}s^{-1}$, at 70 seconds. Show clearly your working on the graph.

rate = ...$mol\,dm^{-3}s^{-1}$ [2]

(iv) Calculate the rate constant for this reaction. State the units.

k = ... units .... [2]

(v) What evidence is there that the mechanism of this reaction takes place in more than a single step?

....

....

....[2]

(c) N_2O is occasionally injected into the engines of racing cars to give more power and exceptional acceleration. The N_2O decomposes exothermically to N_2 and O_2.

Suggest **two** reasons why this reaction provides an extra boost to the engine.

....

....

....[2]

[Total: 17]

Answer **all** the questions.

1 Bromine can be formed by the oxidation of bromide ions. This question compares the rates of two reactions that produce bromine.

(a) Bromine is formed by the oxidation of bromide ions with acidified bromate(V) ions.

$$5Br^-(aq) + 6H^+(aq) + BrO_3^-(aq) \longrightarrow 3Br_2(aq) + 3H_2O(l)$$

This reaction was carried out several times using different concentrations of the three reactants. The initial rate of each experimental run was calculated and the results are shown below. In each case, initial concentrations are shown.

experiment	$[Br^-(aq)]$ /mol dm^{-3}	$[H^+(aq)]$ /mol dm^{-3}	$[BrO_3^-(aq)]$ /mol dm^{-3}	initial rate /10^{-3} mol dm^{-3} s^{-1}
1	0.10	0.10	0.10	1.2
2	0.10	0.10	0.20	2.4
3	0.30	0.10	0.10	3.6
4	0.10	0.20	0.20	9.6

(i) For each reactant, deduce the order of reaction. Show your reasoning.

$Br^-(aq)$ ....

....

....

$H^+(aq)$ ....

....

....

$BrO_3^-(aq)$ ....

....

....[6]

(ii) Deduce the rate equation.

....[1]

For Examiner's Use

(iii) Calculate the rate constant, k, for this reaction. State the units for k.

rate constant, k .... units ....[3]

(b) Bromine can **also** be formed by the oxidation of hydrogen bromide with oxygen.

The following mechanism has been suggested for this multi-step reaction.

step 1	$HBr + O_2 \longrightarrow HBrO_2$
step 2	$HBrO_2 + HBr \longrightarrow 2HBrO$
step 3	$HBrO + HBr \longrightarrow Br_2 + H_2O$
step 4	$HBrO + HBr \longrightarrow Br_2 + H_2O$ (a repeat of step 3)

(i) Explain the term *rate-determining step.*

....

....[1]

(ii) The rate equation for this reaction is: rate = $k[HBr][O_2]$.

Explain which of the four steps above is the **rate-determining step** for this reaction.

....

....

....[2]

(iii) Determine the **overall** equation for this reaction.

....[1]

[Total: 14]