A LEVEL CHEMISTRY

TOPIC 11 – HOW FAR HOW FAST II

TEST

Answer all questions

Max 50 marks

Name ……..
Mark ……../50 ……....% Grade ……

SECTION A

1. The rate of hydrolysis of an ester **X** ($HCOOCH_2CH_2CH_3$) was studied in alkaline conditions at a given temperature. The rate was found to be first order with respect to the ester and first order with respect to hydroxide ions.

(a) (i) Name ester **X**.

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(1)

(ii) Using **X** to represent the ester, write a rate equation for this hydrolysis reaction.

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(1)

(iii) When the initial concentration of **X** was 0.024 mol dm^{-3} and the initial concentration of hydroxide ions was 0.035 mol dm^{-3}, the initial rate of the reaction was 8.5×10^{-5} mol dm^{-3} s^{-1}.
Calculate a value for the rate constant at this temperature and give its units.

Calculation .....

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Units .....

(3)

(iv) In a second experiment at the same temperature, water was added to the original reaction mixture so that the total volume was doubled.
Calculate the initial rate of reaction in this second experiment.

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(1)

(v) In a third experiment at the same temperature, the concentration of **X** was half that used in the experiment in part (a) (iii) and the concentration of hydroxide ions was three times the original value.
Calculate the initial rate of reaction in this third experiment.

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(1)

(vi) State the effect, if any, on the value of the rate constant *k* when the temperature is lowered but all other conditions are kept constant. Explain your answer.

Effect .....

Explanation .....

(2)

(b) Compound **A** reacts with compound **B** as shown by the overall equation

$$A + 3B \rightarrow AB_3$$

The rate equation for the reaction is

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

A suggested mechanism for the reaction is

Step **1** $A + B \rightarrow AB$

Step **2** $AB + B \rightarrow AB_2$

Step **3** $AB_2 + B \rightarrow AB_3$

Deduce which one of the three steps is the rate-determining step.

Explain your answer.

Rate-determining step .....

Explanation .....

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(2)

(Total 11 marks)

2. (a) The initial rate of the reaction between compounds **A** and **B** was measured in a series of experiments at a fixed temperature. The following rate equation was deduced.

rate = k[**A**][**B**]^2

(i) Complete the table of data below for the reaction between **A** and **B**.

Expt	Initial [**A**] /mol dm^{-3}	Initial [**B**] /mol dm^{-3}	Initial rate /mol dm^{-3} s^{-1}
1	4.80×10^{-2}	6.60×10^{-2}	10.4×10^{-3}
2	4.80×10^{-2}	3.30×10^{-2}	
3		13.2×10^{-2}	5.20×10^{-3}
4	1.60×10^{-2}		10.4×10^{-3}

(ii) Using the data for experiment 1, calculate a value for the rate constant, k, and state its units.

Calculation .....

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Units .....

(6)

(b) State how the value of the rate constant, k, would change, if at all, if the concentration of **A** were increased in a series of experiments.

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(1)

(Total 7 marks)

3. (a) The following data were obtained in a series of experiments on the rate of the reaction between compounds **A** and **B** at a constant temperature.

Experiment	Initial concentration of **A**/mol dm^{-3}	Initial concentration of **B**/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
1	0.12	0.15	0.32×10^{-3}
2	0.36	0.15	2.88×10^{-3}
3	0.72	0.30	11.52×10^{-3}

(i) Deduce the order of reaction with respect to **A**.

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(ii) Deduce the order of reaction with respect to **B**.

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(2)

(b) The following data were obtained in a series of experiments on the rate of the reaction between NO and O_2 at a constant temperature.

Experiment	Initial concentration of NO/mol dm^{-3}	Initial concentration of O_2/mol dm^{-3}	Initial rate/mol dm^{-3} s^{-1}
4	5.0×10^{-2}	2.0×10^{-2}	6.5×10^{-4}
5	6.5×10^{-2}	3.4×10^{-2}	To be calculated

The rate equation for this reaction is

$rate = k[NO]^2[O_2]$

(i) Use the data from experiment 4 to calculate a value for the rate constant, *k*, at this temperature, and state its units.

Value of k .....

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Units of k .....

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(ii) Calculate a value for the initial rate in experiment 5.

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(4)
(Total 6 marks)

4. Propanone and iodine react in acidic conditions according to the following equation.

$$CH_3COCH_3 + I_2 \rightarrow ICH_2COCH_3 + HI$$

A student studied the kinetics of this reaction using hydrochloric acid and a solution containing propanone and iodine. From the results the following rate equation was deduced.

$$\text{rate} = k[CH_3COCH_3][H^+]$$

(a) Give the overall order for this reaction.

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(1)

(b) When the initial concentrations of the reactants were as shown in the table below, the initial rate of reaction was found to be 1.24×10^{-4} mol dm^{-3} s^{-1}.

	initial concentration / mol dm^{-3}
CH_3COCH_3	4.40
I_2	5.00×10^{-3}
H^+	0.820

Use these data to calculate a value for the rate constant, *k*, for the reaction and give its units.

Calculation .....

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Units .....

(3)

(c) Deduce how the initial rate of reaction changes when the concentration of iodine is doubled but the concentrations of propanone and of hydrochloric acid are unchanged.

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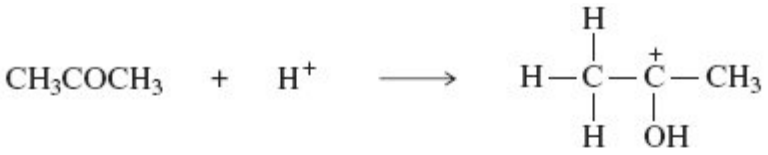
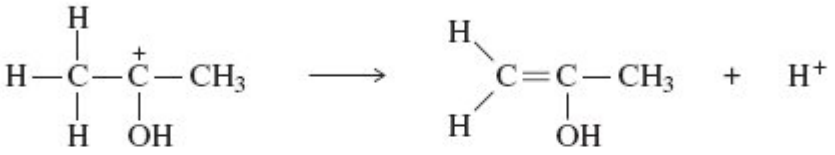
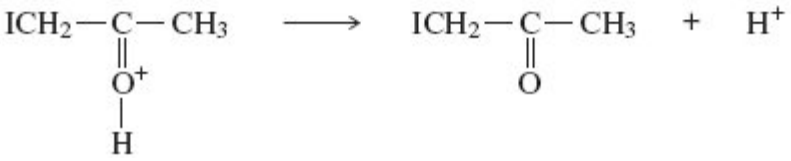
(1)

(d) The following mechanism for the overall reaction has been proposed.

Step 1 

Step 2 

Step 3 

Step 4 

Use the rate equation to suggest which of the four steps could be the rate-determining step. Explain your answer.

Rate-determining step .....

Explanation .....

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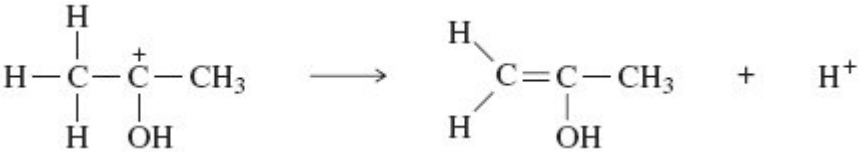
(2)

(e) Use your understanding of reaction mechanisms to predict a mechanism for Step **2** by adding one or more curly arrows as necessary to the structure of the carbocation below.

Step 2 

(1)

(Total 8 marks)

5. At high temperatures, SO_2Cl_2 dissociates according to the following equation.

$$SO_2Cl_2(g) \rightleftharpoons SO_2(g) + Cl_2(g) \qquad \Delta H^{\ominus} = +93 \text{ kJ mol}^{-1}$$

When 1.00 mol of SO_2Cl_2 dissociates, the equilibrium mixture contains 0.75 mol of Cl_2 at 673 K and a total pressure of 125 kPa.

(a) Write an expression for the equilibrium constant, K_p, for this reaction.

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(1)

(b) Calculate the total number of moles of gas present in the equilibrium mixture.

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(2)

(c) (i) Write a general expression for the partial pressure of a gas in a mixture of gases in terms of the total pressure.

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(ii) Calculate the partial pressure of SO_2Cl_2 and the partial pressure of Cl_2 in the equilibrium mixture.

Partial pressure of SO_2Cl_2 .....

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Partial pressure of Cl_2 .....

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(5)

(d) Calculate a value for the equilibrium constant, K_p, for this reaction and give its units.

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(3)

(e) State the effect, if any, of an increase in temperature on the value of K_p for this reaction. Explain your answer.

Effect on K_p .....

Explanation .....

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(2)

(f) State the effect, if any, of an increase in the total pressure on the value of K_p for this reaction.

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(1)

(Total 14 marks)

SECTION B

This question relates to the equilibrium gas-phase synthesis of sulphur trioxide:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

Thermodynamic data for the components of this equilibrium are:

This equilibrium, at a temperature of 585 K and a total pressure of 540 kPa, occurs in a vessel of volume 1.80 dm^3. At equilibrium, the vessel contains 0.0500 mol of $SO_2(g)$, 0.0800 mol of $O_2(g)$ and 0.0700 mol of $SO_3(g)$.

6. The mole fraction of SO_3 in the equilibrium mixture is

A 0.250

B 0.350

C 0.440

D 0.700

(Total 1 mark)

7. With pressures expressed in MPa units, the value of the equilibrium constant, K_p, is

A 4.90

B 6.48

C 9.07

D 16.8

(Total 1 mark)

8. Possible units for the equilibrium constant K_p include

A no units

B kPa

C Mpa^{-1}

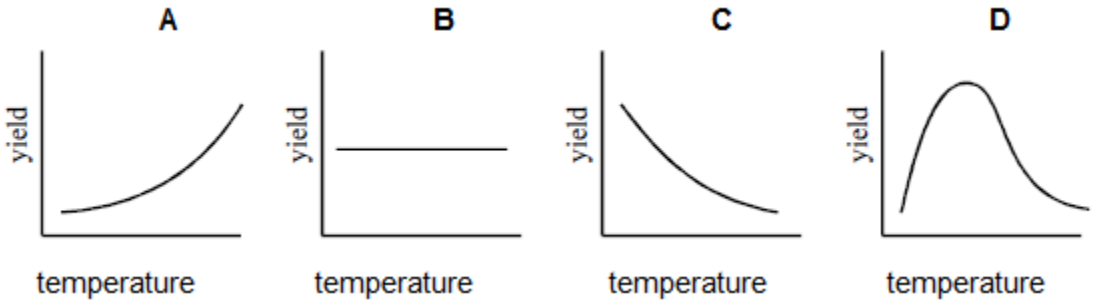
D kPa^{-2}

(Total 1 mark)

9. Normal water and heavy water react together to form isotopically mixed water according to the equation

$$H_2O(l) + D_2O(l) \rightleftharpoons 2HDO(l)$$

The standard enthalpy of formation of $H_2O(l)$ is −286 kJ mol^{-1}, that of $D_2O(l)$ is −294 kJ mol^{-1}, and that of HDO(l) is −290 kJ mol^{-1}. Which one of the following best represents the variation with temperature of the yield of HDO at equilibrium?



(Total 1 mark)