MEGA LECTURE

A LEVEL CHEMISTRY

TOPIC 11 – HOW FAR HOW FAST II
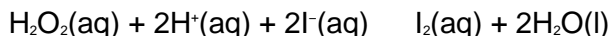
ASSESSED HOMEWORK

Answer all questions

Max 80 marks

Name	....
Mark	......../80 ….....…% Grade ………

1. Hydrogen peroxide is a powerful oxidising agent. Acidified hydrogen peroxide reacts with iodide ions to form iodine according to the following equation.

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

The **initial rate** of this reaction is investigated by measuring the time taken to produce sufficient iodine to give a blue colour with starch solution.

A series of experiments was carried out, in which the concentration of iodide ions was varied, while keeping the concentrations of all of the other reagents the same. In each experiment the time taken (t) for the reaction mixture to turn blue was recorded.

The initial rate of the reaction can be represented as ($\frac{1}{t}$), and the initial concentration of iodide ions can be represented by the volume of potassium iodide solution used.

A graph of $\log_{10}$ ($\frac{1}{t}$) on the y-axis against $\log_{10}$ (volume of KI(aq)) is a straight line. The gradient of this straight line is equal to the order of the reaction with respect to iodide ions.

The results obtained are given in the table below. The time taken for each mixture to turn blue was recorded on a stopclock graduated in seconds.

Expt.	Volume of KI(aq) / cm³	$\log_{10}$ (volume of KI(aq))	Time / s	$\log_{10}$ ($\frac{1}{t}$)
1	5	0.70	71	−1.85
2	8	0.90	46	−1.66
3	10	1.00	37	−1.57
4	15	1.18	25	−1.40
5	20	1.30	19	−1.28
6	25	1.40	14	−1.15

(a)   Use the results given in the table to plot a graph of $\log_{10}$ ($\frac{1}{t}$) on the y-axis against $\log_{10}$ (volume of KI(aq)).

Draw a straight line of best fit on the graph, ignoring any anomalous points.
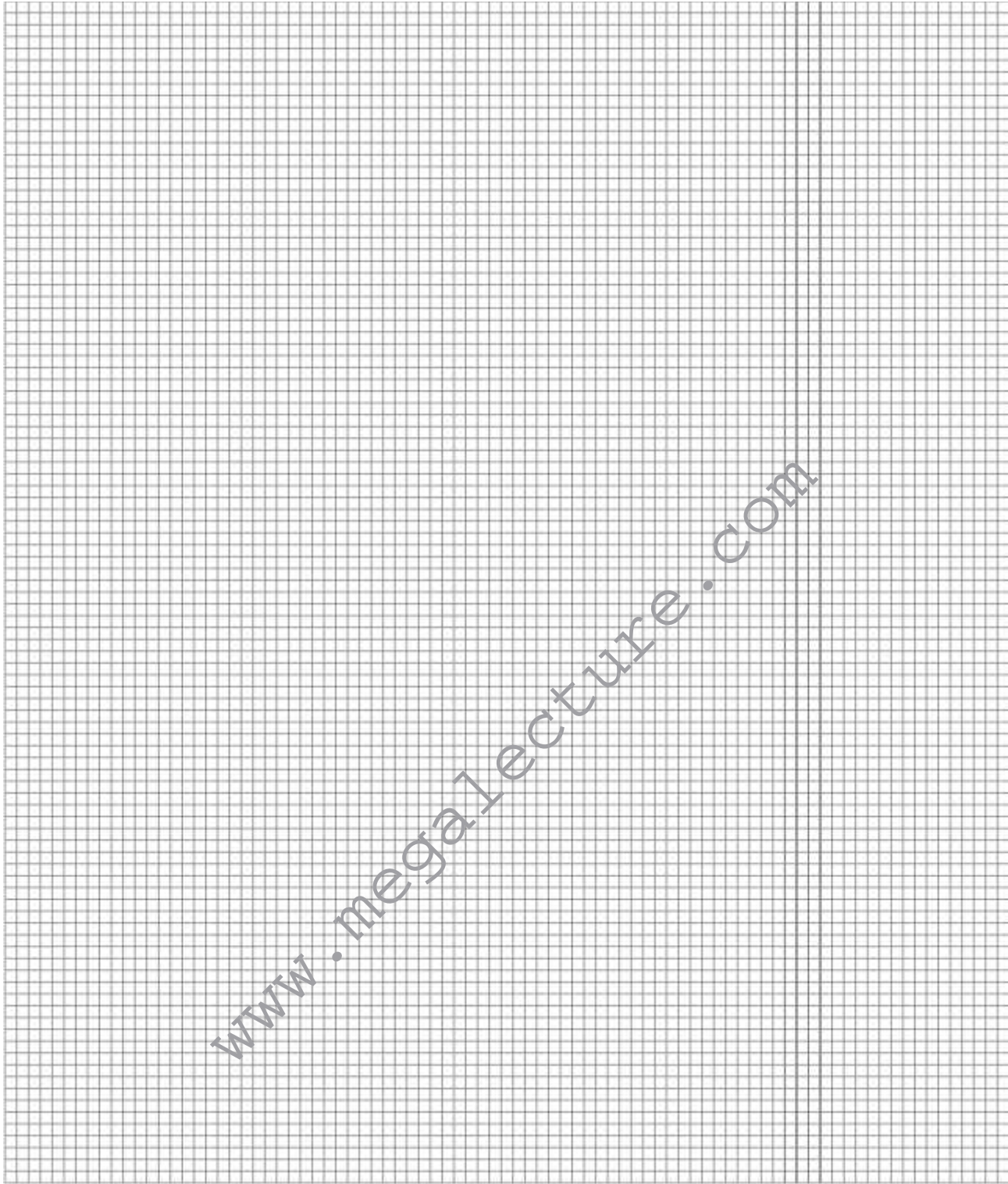
(5)

(b)   Determine the gradient of the line you have drawn. Give your answer to two decimal
places. Show your working.

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(3)

(c) Deduce the order of reaction with respect to iodide ions.

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(1)

(d) A student carried out the experiment using a flask on the laboratory bench. The student recorded the time taken for the reaction mixture to turn blue. State **one** way this method could be improved, other than by repeating the experiment or by improving the precision of time or volume measurements. Explain why the accuracy of the experiment would be improved.

Improvement ....

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Explanation ....

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(2)
(Total 11 marks)

2. (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	0.15	0.24	0.45×10^{-5}
2	0.30	0.24	0.90×10^{-5}
3	0.60	0.48	7.20×10^{-5}

(i) Show how the data in the table can be used to deduce that the reaction is first-order with respect to **A**.

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

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(2)

(b)   The following data were obtained in a second series of experiments on the rate of the reaction between compounds **C** and **D** 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
4	0.75	1.50	9.30×10^{-5}
5	0.20	0.10	To be calculated

The rate equation for this reaction is

rate = $k[\mathbf{C}]^2[\mathbf{D}]$

(i)   Use the data from Experiment 4 to calculate a value for the rate constant, k, at this temperature. State the units of k.

Value for k ....

....

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Units of k ....

(ii)   Calculate the value of the initial rate in Experiment 5.

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(4)
(Total 6 marks)

3. (a) The initial rate of the reaction between substances **P** and **Q** was measured in a series of experiments and the following rate equation was deduced.

$$\text{rate} = k[\mathbf{P}]^2[\mathbf{Q}]$$

(i) Complete the table of data below for the reaction between **P** and **Q**.

Experiment	Initial [**P**] / mol dm^{-3}	Initial [**Q**] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.20	0.30	4.8×10^{-3}
2	0.10	0.10	
3	0.40		9.6×10^{-3}
4		0.60	19.2×10^{-3}

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

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(6)

(b) What change in the reaction conditions would cause the value of the rate constant to change?

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(1)
(Total 7 marks)

4. The rate of the reaction between substance **A** and substance **B** was studied in a series of experiments carried out at the same temperature. In each experiment the initial rate was measured using different concentrations of **A** and **B**. These results were used to deduce the order of reaction with respect to **A** and the order of reaction with respect to **B**.

(a) What is meant by the term *order of reaction* with respect to **A**?

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(1)

(b) When the concentrations of **A** and **B** were both doubled, the initial rate increased by a factor of 4. Deduce the **overall** order of the reaction.

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(1)

(c) In another experiment, the concentration of **A** was increased by a factor of three and the concentration of **B** was halved. This caused the initial rate to increase by a factor of nine.

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

*Order with respect to **A*** ....

*Order with respect to **B*** ....

(ii) Using your answers from part (c)(i), write a rate equation for the reaction and suggest suitable units for the rate constant.

Rate equation ....

Units for the rate constant ....

....

(4)
(Total 6 marks)

5. (a) The following table shows the results of three experiments carried out at the same temperature to investigate the rate of the reaction between compounds **P** and **Q**.

	Experiment 1	Experiment 2	Experiment 3
Initial concentration of **P**/mol dm^{-3}	0.50	0.25	0.25
Initial concentration of **Q**/mol dm^{-3}	0.36	0.36	0.72
Initial rate/mol dm^{-3}s^{-1}	7.6×10^{-3}	1.9×10^{-3}	3.8×10^{-3}

Use the data in the table to deduce the order with respect to **P** and the order with respect to **Q**.

Order with respect to P ....

Order with respect to Q ....

(2)

(b) In a reaction between **R** and **S**, the order of reaction with respect to **R** is one, the order of reaction with respect to **S** is two and the rate constant at temperature T_1 has a value of 4.2 $\times 10^{-4}$ mol^{-2} dm^6 s^{-1}.

(i) Write a rate equation for the reaction. Calculate a value for the initial rate of reaction when the initial concentration of **R** is 0.16 mol dm^{-3} and that of **S** is 0.84 mol dm^{-3}.

Rate equation ....…...

Calculation ....

(ii) In a second experiment performed at a different temperature, T_2, the initial rate of reaction is 8.1×10^{-5} mol dm^{-3}s^{-1} when the initial concentration of **R** is 0.76 mol dm^{-3} and that of **S** is 0.98 mol dm^{-3}. Calculate the value of the rate constant at temperature T_2.

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(iii) Deduce which of T_1 and T_2 is the higher temperature.

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(6)
(Total 8 marks)

6. Kinetic studies enable chemists to suggest mechanisms for reactions.

(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

$$\text{rate} = k[NO]^2[O_2]$$

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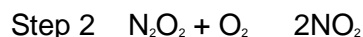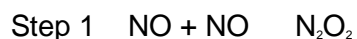
Value of k ....

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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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(iii)   Using the rate equation, a scientist suggested a mechanism for the reaction which consisted of the two steps shown below.
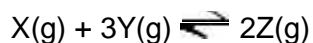
Step 1   NO + NO N_2O_2

Step 2 $N_2O_2 + O_2$ $2NO_2$

Which did the scientist suggest was the rate–determining step?

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(5)
(Total 7 marks)

7. A sealed flask containing gases **X** and **Y** in the mole ratio 1:3 was maintained at 600 K until the following equilibrium was established.

$$X(g) + 3Y(g) \rightleftharpoons 2Z(g)$$

The partial pressure of **Z** in the equilibrium mixture was 6.0 MPa when the total pressure was 22.0 MPa.

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

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....

(ii) Calculate the partial pressure of **X** and the partial pressure of **Y** in the equilibrium mixture.

Partial pressure of **X** ....

....

Partial pressure of **Y** ....

(iii) Calculate the value of K_p for this reaction under these conditions and state its units.

Value of K_p ....

....

....

Units of K_p ....

(6)

(b) When this reaction is carried out at 300 K and a high pressure of 100 MPa, rather than at 600 K and 22.0 MPa, a higher equilibrium yield of gas **Z** is obtained.

Give two reasons why an industrialist is unlikely to choose these reaction conditions.
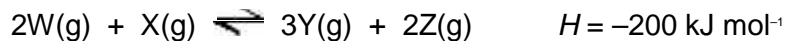
Reason 1 ....

Reason 2 ....

(2)
(Total 8 marks)

8. The gaseous reactants **W** and **X** were sealed in a flask and the mixture left until the following equilibrium had been established.

$$2W(g) + X(g) \rightleftharpoons 3Y(g) + 2Z(g) \qquad H = -200 \text{ kJ mol}^{-1}$$

Write an expression for the equilibrium constant, K_p, for this reaction.
State one change in the conditions which would both increase the rate of reaction and decrease the value of K_p. Explain your answers.
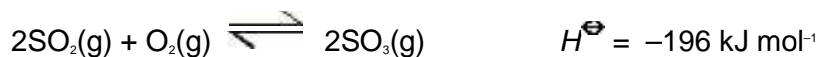
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(7)
(Total 7 marks)

9. Sulphur dioxide and oxygen were mixed in a 2:1 mol ratio and sealed in a flask with a catalyst.

The following equilibrium was established at temperature T_1

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad H^{\ominus} = -196 \text{ kJ mol}^{-1}$$

The partial pressure of sulphur dioxide in the equilibrium mixture was 24 kPa and the total pressure in the flask was 104 kPa.

(a) Deduce the partial pressure of oxygen and hence calculate the mole fraction of oxygen in the equilibrium mixture.

Partial pressure of oxygen ....

Mole fraction of oxygen ....

....

....

(3)

(b) Calculate the partial pressure of sulphur trioxide in the equilibrium mixture.

....

(1)

(c) Write an expression for the equilibrium constant, K_p, for this reaction. Use this expression to calculate the value of K_p at temperature T_1 and state its units.

Expression for K_p ....

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Calculation ....

....

....

Units ....

(4)

(d) When equilibrium was established at a different temperature, T_2, the value of K_p was found to have increased. State which of T_1 and T_2 is the lower temperature and explain your answer.

Lower temperature...

Explanation ....

....

(3)

(e) In a further experiment, the amounts of sulphur dioxide and oxygen used, the catalyst and the temperature, T_1, were all unchanged, but a flask of smaller volume was used.

Deduce the effect of this change on the yield of sulphur trioxide and on the value of K_p.

Effect on yield of SO_3 ....

Effect on K_p ....

....

(2)
(Total 13 marks)

10. Rate = k $[A]^2$ [B]

Correct units for the rate constant in the rate equation above are

A $mol\ dm^{-3}s^{-1}$

B $mol^{-1}\ dm^{-3}s^{-1}$

C $mol^2\ dm^{-6}s^{-1}$

D $mol^{-2}\ dm^6s^{-1}$

(Total 1 mark)

11. This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.

$$CH_3COCH_3 + HOCH_2CH_2OH \rightleftharpoons (CH_3)_2 C \overset{O-CH_2}{\underset{O-CH_2}{\Big\langle}} \Big| \quad + H_2O$$

Y
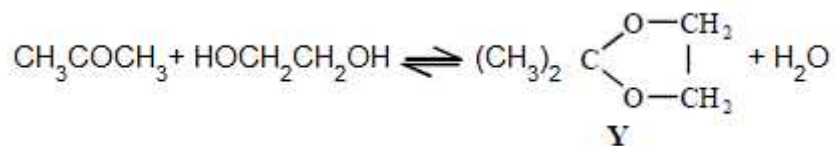
In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

When the concentration of benzenesulphonic acid is doubled, the rate of the reaction doubles. It can be deduced that

A the reaction is first order overall.

B the reaction is third order overall.

C the reaction is acid-catalysed.

D units for the rate constant, k, are $mol^{-2}\ dm^6\ s^{-1}$.

(Total 1 mark)

12. The equation for the combustion of butane in oxygen is
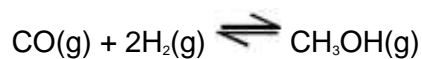
$$C_4H_{10} + 6\tfrac{1}{2}O_2 \quad 4CO_2 + 5H_2O$$
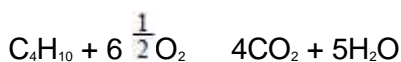
The mole fraction of butane in a mixture of butane and oxygen with the minimum amount of oxygen required for complete combustion is

A 0.133

B 0.153

C 0.167

D 0.200

(Total 1 mark)

The following information concerns the equilibrium gas-phase synthesis of methanol.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
The number of moles of CO, H_2 and CH_3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

Substance	$H_f^{\ominus}$ / kJ mol^{-1}
CO(g)	−110
H_2(g)	0
CH_3OH(g)	−201

13. Possible units for the equilibrium constant, K_p, for this reaction are

A no units

B kPa

C MPa^{-1}

D kPa^{-2}

(Total 1 mark)

14. The mole fraction of hydrogen in the equilibrium mixture is

A 0.242

B 0.485

C 0.653

D 0.970

(Total 1 mark)

15. With pressures expressed in MPa units, the value of the equilibrium constant, K_p, under these conditions is

A 1.37

B 1.66

C 2.82

D 4.80

(Total 1 mark)

16.   Which one of the following statements applies to this equilibrium?

A   The value of K_p increases if the temperature is raised.

B   The value of K_p increases if the pressure is raised.

C   The yield of methanol decreases if the temperature is lowered.

D   The yield of methanol decreases if the pressure is lowered.

(Total 1 mark)