Gateways School

**Kinetics & Equilibria**

**Revision PPQ**

50 marks

**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_**

**Q1.**

(a)     The table shows the results of three experiments to investigate the rate of reaction between compounds **A** and **B** dissolved in a given solvent.
All three experiments were carried out at the same temperature.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Experiment 1** | **Experiment 2** | **Experiment 3** |
| **Initial concentration of A / mol dm–3** | 1.60 × 10–2 | 2.40 × 10–2 | 3.60 × 10–2 |
| **Initial concentration of B / mol dm–3** | 4.20 × 10–2 | 6.30 × 10–2 | 6.30 × 10–2 |
| **Initial rate /mol dm–3 s–1** | 8.00 × 10–5 | 1.80 × 10–4 | 4.05 × 10–4 |

(i)      Deduce the order of reaction with respect to **A**.
Tick (✓) **one** box.

|  |  |
| --- | --- |
| **Order of reactionwith respect to A** | **Tick (✓)** |
| 0 |   |
| 1 |   |
| 2 |   |

**(1)**

(ii)     Deduce the order of reaction with respect to **B**.
Tick (✓) **one** box.

|  |  |
| --- | --- |
| **Order of reactionwith respect to B** | **Tick(✓)** |
| 0 |   |
| 1 |   |
| 2 |   |

**(1)**

(b)     The reaction between two different compounds, **C** and **D**, is studied at a given temperature.
The rate equation for the reaction is found to be

rate = *k*[**C**][**D**]2

(i)      When the initial concentration of **C** is 4.55 × 10–2 mol dm–3 and the initial concentration of **D** is 1.70 × 10–2 mol dm–3, the initial rate of reaction is
6.64 × 10–5 mol dm–3 s–1.

Calculate the value of the rate constant at this temperature and deduce its units.

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Units of rate constant \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(3)**

(ii)     The experiment in part (i) is repeated at the same temperature but after the addition of extra solvent so that the total volume of the mixture is doubled.

Deduce the new initial rate of reaction.

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**(1)**

**(Total 6 marks)**

**Q2.**

(a)     The diagram below shows the effect of temperature and pressure on the equilibrium yield of the product in a gaseous equilibrium.



(i)      Use the diagram to deduce whether the forward reaction involves an increase or a decrease in the number of moles of gas. Explain your answer.

*Change in number of moles* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Explanation* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(ii)     Use the diagram to deduce whether the forward reaction is exothermic or endothermic.
Explain your answer.

*The forward reaction is* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Explanation* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(6)**

(b)     When a 0.218 mol sample of hydrogen iodide was heated in a flask of volume V dm3, the following equilibrium was established at 700 K.

2HI(g)   H2(g) + I2(g)

The equilibrium mixture was found to contain 0.023 mol of hydrogen.

(i)      Calculate the number of moles of iodine and the number of moles of hydrogen iodide in the equilibrium mixture.

*Number of moles of iodine* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*Number of moles of hydrogen iodide* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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(ii)     Write an expression for *K*c for the equilibrium.

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(iii)     State why the volume of the flask need not be known when calculating a value for *K*c.

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(iv)    Calculate the value of *K*c at 700 K.

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(v)     Calculate the value of *K*c at 700 K for the equilibrium

H2(g) + I2(g)  2HI(g)

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**(7)**

**(Total 13 marks)**

**Q3.**

When iodine molecules are dissolved in aqueous solutions containing iodide ions, they react to form triiodide ions (I3–).

I2   +   I–       I3–

The rate of the oxidation of iodide ions to iodine by peroxodisulfate(VI) ions (S2O82–) was studied by measuring the concentration of the l3– ions at different times, starting at time = 0, when the reactants were mixed together. The concentration of the l3– ions was determined by measuring the absorption of light using a spectrometer.

The table below shows the results.

|  |  |
| --- | --- |
| **Time / s** | **Concentration of l3– / mol dm–3** |
| 10 | 0.23 |
| 20 | 0.34 |
| 30 | 0.39 |
| 40 | 0.42 |
| 50 | 0.47 |
| 60 | 0.44 |
| 70 | 0.45 |

(a)     Plot the values of the concentration of I3– (*y*-axis) against time on the grid below.



**(2)**

(b)     A graph of these results should include an additional point. On the grid, draw a ring around this additional point.

**(1)**

(c)     Draw a best-fit curve on the grid, **including the extra point from part (b)**.

**(2)**

(d)     Draw a tangent to your curve at time = 30 seconds. Calculate the slope (gradient) of this tangent and hence the rate of reaction at 30 seconds. Include units with your final answer.
Show your working.

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**(4)**

**(Total 9 marks)**

**Q4.**

(a)     In an experiment, at a fixed temperature, an equilibrium mixture contained the following amounts, in moles, of each component.

|  |  |  |  |
| --- | --- | --- | --- |
| CH3CH2COOH | CH3CH2OH | CH3CH2COOCH2CH3 | H2O |
| 0.0424 | 0.0525 | 0.0745 | 0.0813 |

Use the data in the table above to calculate a value for the equilibrium constant, *K*c, at this fixed temperature.
Record your answer to the appropriate precision.

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**(2)**

(b)     If the mixture is uncovered during the time it is left to reach equilibrium, some of the ester formed will evaporate.
Explain why a smaller volume of sodium hydroxide would then be required in the titration compared with the volume for the covered mixture.

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**(2)**

**(Total 4 marks)**

**Q5.**

The manufacture of methanol can be achieved in two stages.

(a)     In the first stage, methane and steam react according to the following equation.

CH4(g) + H2O(g)  CO(g) + 3H2(g)                           ∆*H*ο= +210 kJ mol–1

Discuss, with reasons, the effects of increasing separately the temperature and the pressure on the yield of the products and on the rate of this reaction.

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**(6)**

(b)     In the second stage, carbon monoxide and hydrogen react according to the following equation.

CO(g) + 2H2(g)  CH3OH(g)

A 62.8 mol sample of carbon monoxide was added to 146 mol of hydrogen. When equilibrium was reached at a given temperature, the mixture contained 26.2 mol of methanol at a total pressure of 9.50 MPa.

Write an expression for the equilibrium constant, *K*p, for this reaction. Calculate a value for *K*p at this temperature and give its units.

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**(8)**

**(Total 14 marks)**

**Q6.**

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

CO(g) + 2H2(g)  CH3OH(g)

At equilibrium, when the temperature is 68 °C, the total pressure is 1.70 MPa.
The number of moles of CO, H2 and CH3OH present are 0.160, 0.320 and 0.180, respectively.

Thermodynamic data are given below.

|  |  |  |
| --- | --- | --- |
| **Substance** | **Δ*H* / kJ mol−1** | ***S* / J K-1 mol-1** |
| CO(g) | −110 | 198 |
| H2(g) | 0 | 131 |
| CH3OH(g) | −201 | 240 |

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)**

**Q7.**

Methanol is synthesised from carbon monoxide and hydrogen according to the equation below.

CO(g) + 2H2(g)⇌ CH3OH(g)           ∆H = −91 kJ mol−1

Which one of the following changes would **not** affect the value of the equilibrium constant and would **not** increase the yield of methanol?

**A**       increase in temperature

**B**       decrease in temperature

**C**       increase in pressure

**D**       decrease in pressure

**(Total 1 mark)**

**Q8.**

The equation for the combustion of butane in oxygen is

C4H10 + 6 O2 → 4CO2 + 5H2O

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

**C**       0.200

**(Total 1 mark)**