AS Chemistry

Reaction Rates

Contents

[Measuring Reaction Rate 4](#_Toc424028540)

[Calculating Reaction Rates 6](#_Toc424028541)

[Catalysis 10](#_Toc424028542)

[Catalysts & the Environment 12](#_Toc424028543)

[Rates & Boltzmann 14](#_Toc424028544)

[Dynamic Equilibria 16](#_Toc424028545)

[Le Chatelier’s Principle 18](#_Toc424028546)

[The Equilibrium Constant, Kc 20](#_Toc424028547)

[Exam Style Questions 22](#_Toc424028548)

Measuring Reaction Rate

Chemists are very interested in studying and understanding the rate of reactions. Knowing a reaction’s rate can inform the best route to make a certain product and influence decisions taken by industrial manufacturers of products such as pharmaceuticals.

1. How can changes in the following quantities be used to measure the rate of a reaction?
2. Concentration of reactant;
3. Volume of gas produced;
4. Concentration of product;
5. Explain briefly what is meant by ‘rate of reaction.’

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Briefly outline collision theory and use it to explain how surface area, pressure and temperature affect the rate of a reaction.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

Calculating Reaction Rates

We usually define reaction rate as:

*‘’the change in a quantity per unit time.’’*

This can also be written as:

*Rate of reaction = change in quantity/time elapsed.*

As the quantity that we investigate will be different depending on the reaction this often means units must be derived for each reaction rate individually.

1. State the equation used to deduce the rate of a reaction.
2. Plot the following data onto the axes on the next page and then answer the questions.

|  |  |
| --- | --- |
| Time /s | Mass /g |
| 0 | 280.0 |
| 30 | 279.3 |
| 60 | 278.7 |
| 90 | 278.2 |
| 120 | 278.0 |
| 150 | 277.9 |
| 180 | 277.8 |
| 210 | 277.7 |
| 240 | 277.7 |
| 270 | 277.7 |



1. At what time does the reaction stop? How can you tell?

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………….

1. Draw a line of best fit on your graph.
2. Using dy/dx find the rate of reaction at 120s.
3. Describe what happens to the rate of reaction between 0s and 270s.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Outline how collecting a gas evolved during a reaction could be used to deduce the rate of reaction. You should mention any relevant equipment and how you would process the results.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

Catalysis

Catalysts are important in many areas of chemistry, from the lab to items we use every day. They are often used when it would be difficult or costly to change other factors that would affect the rate of a reaction.

1. What is a catalyst?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Explain how a catalyst speeds up the rate of reaction.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. What is meant by the terms heterogeneous and homogeneous?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Sketch an enthalpy profile diagram for the exothermic reaction to produce product X. Add the enthalpy profile for the catalysed version of this reaction to the same axes.

Catalysts & the Environment

1. What are some of the environmental benefits of using catalysts in the industrial production of chemicals?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. All vehicles in the UK are fitted with a catalytic converter. State their composition and why they are used. Your answer should involve the equation for the reaction they catalyse.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Research the use of a catalyst in either the Born-Haber process or the production of ibuprofen. What benefits does the catalyst provide? Why is it used? Include equations for the catalysed reactions and an overview of the process.

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

Rates & Boltzmann

A useful way to visualise what is happening in a reaction at a molecular level is by the use of Boltzmann distributions. These can help us visualise how altering conditions will affect the quantities of molecules that are able to react.

1. Sketch two Boltzmann distributions on the axes below, one for a reaction at 25oC and one for a reaction at 45oC. Add labels for the activation energy.
2. On the axes below draw and label a Boltzmann distribution for a catalysed and uncatalysed reaction. Include labels for activation energy, Ea.

Dynamic Equilibria

We usually think of a chemical reaction as happening in a single direction, with reactants being used up to form products. In reality this is not the case for many reactions. If a reaction can run in either direction then we call this a *reversible reaction.*

1. Describe what is happening in a reaction at equilibrium in terms of macroscopic and microscopic quantities.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Equilibria can only be reached in a closed system.
2. What is meant by the term ‘closed system’?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Why can’t a reaction reach equilibrium in an open system?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. The reaction below is reversible.

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

1. Write both the forward and backwards reactions from this equation.

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

Le Chatelier’s Principle

1. State Le Chatelier’s principle.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Ethanol is produced industrially in the reaction:

**C2H4 (g) + H2O (g) C2H5OH(g) Δ*H =* -46 kj mol-1**

Explain what would happen to the equilibrium position if:

1. The pressure was increased.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. The temperature was decreased.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. A catalyst was used.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. An industrial process uses the following reversible reaction:

**A(g) + 2B(g) C(g) + D(g) Δ*H =* + 189 kj mol-1**

Explain the effect on equilibrium position of:

1. Increasing the concentration of A.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Increasing the pressure.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Increasing the temperature.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Briefly outline the best reaction conditions to maximise the production of product D.

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

The Equilibrium Constant, Kc

An equilibrium constant is a numerical value that can be calculated for any reaction at equilibrium. It provides a useful means to estimate which side of the reaction is favoured.

1. Write an expression to deduce Kc for the reaction:

**aA + bB dD + eE**

1. Explain what the square brackets [] represent in the expression for Kc.

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. Why is Kc given for a stated temperature?

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

1. The following equilibrium exists under certain conditions.

**C2H4 + H2O C2H5OH**

Write out the expression for the equilibrium constant, Kc, for this reaction.

1. The following equilibrium exists under certain conditions.

**2SO2 + O2 2SO3**

1. Write out the expression for Kc for this reaction.
2. At a certain temperature the equilibrium concentrations for the three reagents were found to be:

**SO2**= 0.250 mol dm-3 **O2**  = 0.180 mol dm-3 **SO3** = 0.360 mol dm-3

 Calculate Kc  for this equilibrium.

1. In what position does the equilibrium lie in the above reaction for the calculated Kc?

Exam Style Questions

1. Methanol can be manufactured by the reaction of carbon dioxide with hydrogen.

**3H2(g) + CO2(g) CH3OH(g) + H2O(g)** *equation 4.1*

In this reaction 49.0 kj of energy are released when 3 moles of H2 react completely. This enthalpy change is called the enthalpy change of reaction Δ*H*r­.

1. Calculate the energy released when 1000dm3 of hydrogen, measured at room temperature and pressure, react completely with carbon dioxide.

Give your answer to **three** significant figures.

Energy released = ………………………………….. kj **[3]**

1. Complete the enthalpy profile diagram for the forward reaction.

Label the activation energy, Ea, and the enthalpy change Δ*H*r.

 3H2(g) + CO2(g)

Enthalpy

 Progress of reaction

 **[3]**

1. The temperature of the equilibrium mixture in **equation 4.1** is **increased**.

Describe and explain what happens to the position of the equilibrium.

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………**[2]**

1. The total pressure of the equilibrium mixture in **equation 4.1** is **decreased**.

Describe and explain what happens to the position of the equilibrium.

…………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………**[2]**

1. The reaction uses a solid catalyst. The catalyst functions in a similar way to the catalyst used in catalytic converters.

Outline the stages that allow H2 to react with CO2 in the presence of a solid catalyst.

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………..……**[3]**

**[Total:13]**

1. Propenenitrile is manufactured from propene as shown in the equation.

**C3H6(g) + NH3(g) + 1½ O2(g) CH2CHCN(g) + 3H2O(g)**

**Δ*H* = -540kj mol-1**

The conditions used are 450oC and 2.5 atmospheres in the presence of a catalyst.

Describe and explain, using le Chatelier’s principle, the effect on the equilibrium of the following changes:

* A temperature above 450oC
* A pressure above 2.5 atmospheres
* The absence of a catalyst.

*In your answer you should link the effects you describe with your explanations.*

……………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………**[5]**

 *Reaction Rates Homework Booklet by Stephen J.P. Harding, (2016), of* [*English Martyrs Catholic School*](http://www.englishmartyrs.org) *This resource is shared under a* [*Creative Commons Attribution 4.0 International License*](http://creativecommons.org/licenses/by/4.0/)*.*