C6 The rate and extent of chemical change

What's the science story?

Chemical reactions can occur at vastly different rates. Whilst the reactivity of chemicals is a significant factor in how fast chemical reactions proceed, there are many variables that can be manipulated in order to speed them up or slow them down. Chemical reactions may also be reversible and therefore the effect of different variables needs to be established in order to identify how to maximise the yield of desired product. Understanding energy changes that accompany chemical reactions is important for this process. In industry, chemists and chemical engineers determine the effect of different variables on reaction rate and yield of product. Whilst there may be compromises to be made, they carry out optimisation processes to ensure that enough product is produced within a sufficient time, and in an energy-efficient way.

Previous knowledge:	Next steps…
Check KS3 – waiting for new 3 year curriculum plan KS4 topics – c2 bonding c3 quantitative chemistry c4 chemical changes c5 energy changes	C7 organic chemistry

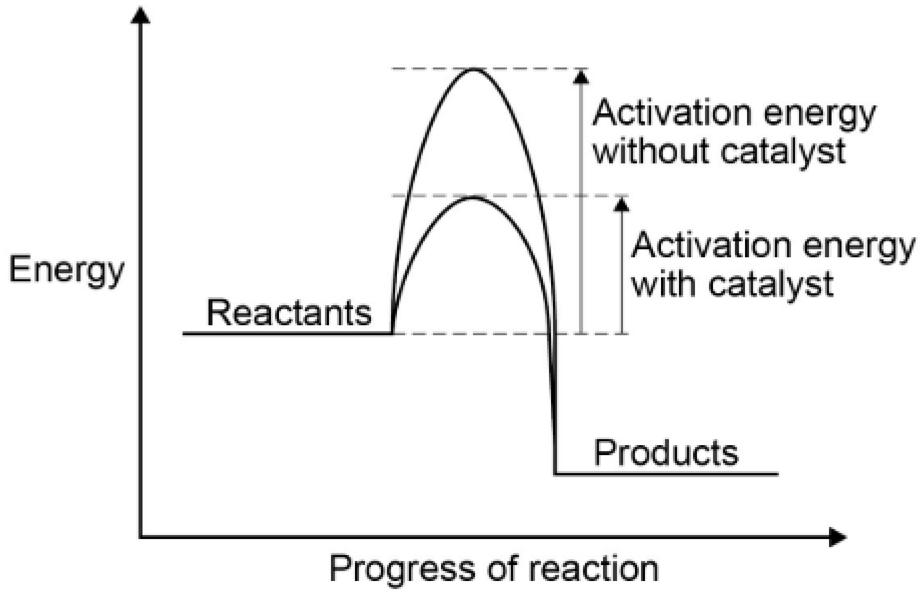
Keywords	factor	Catalyst	Reaction	conditions	
rate	concentration	Rate	Rate	Le Chatelier's Principle	
reactants	pressure	Reaction	Particles	amount	
products	surface area	Reactants	Collide	symbol equation	
units	temperature	Products	Frequency		
mass	catalyst	Activation energy	Energy		
volume	collision	Enzymes	turbidity		
graph	particles	Reversible	gas syringe		
tangent	activation energy	Reaction	dependent		
gradient		Reactant	independent		
		Product	control		
		Direction	volume		
		Exothermic			
		Endothermic			
		Equilibrium			
		rate			

Working scientifically skills:		Assessments:
WS2	Draw/Interpret diagrams	End of unit test (summative) Exit tickets x 2/3 (formative) Exit ticket 11 – rates of reaction
WS3	Make predictions	
WS7	Hypothesis	
WS8	Method	
WS9	Variables	
WS10	Selecting equipment	
WS11	Hazards	
WS12	Errors	
WS13	Constructing tables	
WS14	Graphs	
WS15	Data	
WS16	Using equations	
WS17	Make conclusions	

Lesson No. and Title	Learning objectives	AQA Specification	Practical equipment
1. Rate of reaction	4 – To describe the different changes that can occur during a reaction (AO1). 5 – To explore a range of methods to investigate rates of reaction (AO3). 6 – To interpret graphs to explain what is	5.6.1.1 Calculating rates of reactions	Demo: HCl, marble chips, conical flask, cotton wool, balance, 100 ml beaker, limewater, Mg ribbon, sulfuric acid

	happening during reactions (AO3).	The rate of a chemical reaction can be found by measuring the quantity of a reactant used or the quantity of product formed over time: $$mean\ rate\ of\ reaction = \frac{quantity\ of\ reactant\ used}{time\ taken}$$ $$mean\ rate\ of\ reaction = \frac{quantity\ of\ product\ formed}{time\ taken}$$ The quantity of reactant or product can be measured by the mass in grams or by a volume in cm^3. The units of rate of reaction may be given as g/s or cm^3/s. For the Higher Tier, students are also required to use quantity of reactants in terms of moles and units for rate of reaction in mol/s. Students should be able to: • calculate the mean rate of a reaction from given information about the quantity of a reactant used or the quantity of a product formed and the time taken • draw, and interpret, graphs showing the quantity of product formed or quantity of reactant used up against time • draw tangents to the curves on these graphs and use the slope of the tangent as a measure of the rate of reaction • (HT only) calculate the gradient of a tangent to the curve on these graphs as a measure of rate of reaction at a specific time.	Class practical: balance, water trough, 100 cm3 measuring cylinder, stopwatch, conical flask, delivery tube and bung, 5 concentrations of dilute HCl (4,3.2,2.4,1.6,0,8 g/dm3) small and large marble chips

2. Factors affecting reaction rates	4 – To state what has to happen for reactions to take place (AO1). 5 – To describe ways of speeding up or slowing down chemical reactions (AO2). 6 – To explain why changes in the frequency of collisions between particles affect the rate of reaction (AO2).	**5.6.1.2 Factors which affect the rates of chemical reactions** Factors which affect the rates of chemical reactions include: the concentrations of reactants in solution, the pressure of reacting gases, the surface area of solid reactants, the temperature and the presence of catalysts. Students should be able to recall how changing these factors affects the rate of chemical reactions. **5.6.1.3 Collision theory and activation energy** Collision theory explains how various factors affect rates of reactions. According to this theory, chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy. Increasing the concentration of reactants in solution, the pressure of reacting gases, and the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction. Increasing the temperature increases the frequency of collisions and makes the collisions more energetic, and so increases the rate of reaction. Students should be able to : • predict and explain using collision theory the effects of changing conditions of concentration, pressure and temperature on the rate of a reaction • predict and explain the effects of changes in the size of pieces of a reacting solid in terms of surface area to volume ratio • use simple ideas about proportionality when using collision theory to explain the effect of a factor on the rate of a reaction.	Demo: tray of marbles, whoosh bottle Class practical: 250cm3 conical flask 10cm3 measuring cylinder 50cm3 measuring cylinder stopwatch water bath sodium thiosulfate soln dil HCl

3.Catalysts and activation energy	4 – To describe what a catalyst does and how they useful (AO1). 5 – To explain what the activation energy of a reaction is (AO2). 6 – To explain in detail how catalysts speed up chemical reactions (AO2).	Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts. Enzymes act as catalysts in biological systems. Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy. A reaction profile for a catalysed reaction can be drawn in the following form:  Students should be able to identify catalysts in reactions from their effect on the rate of reaction and because they are not included in the chemical equation for the reaction. Students should be able to explain catalytic action in terms of activation energy. Students do not need to know the names of catalysts other than those specified in the subject content.	Demo: hydrogen peroxide, conical flask, manganese oxide, raw liver, potassium sodium tartrate soln, cobalt chloride soln, 2 beakers Class prac: gas syringe, delivery tube, stopwatch, conical flask, hydrogen peroxide, manganese dioxide, copper oxide, iron filings, spatula

4. reversible reactions and dynamic equilibrium	4 – To describe reversible reactions (AO1). 5 – To explain what happens during a reversible reaction in terms of energy (AO2). 6 – To construct word equations to explain a range of reversible reactions (AO2).	**5.6.2 Reversible reactions and dynamic equilibrium** **5.6.2.1 Reversible reactions** **Content** In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented: $A + B \rightleftharpoons C + D$ The direction of reversible reactions can be changed by changing the conditions. For example: ammonium chloride $\underset{\text{cool}}{\overset{\text{heat}}{\rightleftharpoons}}$ ammonia + hydrogen chloride **5.6.2.2 Energy changes and reversible reactions** **Content** If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. The same amount of energy is transferred in each case. For example: hydrated copper sulfate (blue) $\underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water **5.6.2.3 Equilibrium** **Content** When a reversible reaction occurs in apparatus which prevents the escape of reactants and products, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate.	test tube, copper sulfate, spatula

5. RP 11 Effect of changing concentration on rate of reaction (measuring volume of gas method)	4 – To explore the effect of concentration on the rate of reaction. 6 – To construct an accurate method.	**Required practical activity 11:** investigate how changes in concentration affect the rates of reactions by a method involving measuring the volume of a gas produced and a method involving a change in colour or turbidity. This should be an investigation involving developing a hypothesis.	conical flask sodium thiosulfate hydrochloric acid 10 cm3 measuring cylinders 50 cm3 measuring cylinder 2 x pipettes
6. RP 11 Effect of changing concentration on rate of reaction (changing colour/turbidity method)	4 – To explore the effect of concentration on the rate of reaction. 6 – To construct an accurate method.	**Required practical activity 11:** investigate how changes in concentration affect the rates of reactions by a method involving measuring the volume of a gas produced and a method involving a change in colour or turbidity. This should be an investigation involving developing a hypothesis.	conical flask, delivery tube, trough, measuring cylinder, gas syringe, marble chips, hydrochloric acid, distilled water
7. The effect of changing conditions on equilibrium (HT)	4 – To define 'equilibrium' 6 To explain the effects of changing the pressure, concentration and temperature of a reaction.	5.6.2.4 The effect of changing conditions on equilibrium (HT **Content** The relative amounts of all the reactants and products at equilibrium depend on the conditions of the reaction. If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change. The effects of changing conditions on a system at equilibrium can be predicted using Le Chatelier's Principle. Students should be able to make qualitative predictions about the effect of changes on systems at equilibrium when given appropriate information. 5.6.2.5 The effect of changing concentration (HT only) **Content** If the concentration of one of the reactants or products is changed, the system is no longer at equilibrium and the concentrations of all the substances will change until equilibrium is reached again. If the concentration of a reactant is increased, more products will be formed until equilibrium is reached again. If the concentration of a product is decreased, more reactants will react until equilibrium is reached again. Students should be able to interpret appropriate given data to predict the effect of a change in concentration of a reactant or product on given reactions at equilibrium.	

		5.6.2.6 The effect of temperature changes on equilibrium (HT only) **Content** | **Key o skills** If the temperature of a system at equilibrium is increased: • the relative amount of products at equilibrium increases for an endothermic reaction • the relative amount of products at equilibrium decreases for an exothermic reaction. If the temperature of a system at equilibrium is decreased: • the relative amount of products at equilibrium decreases for an endothermic reaction • the relative amount of products at equilibrium increases for an exothermic reaction. Students should be able to interpret appropriate given data to predict the effect of a change in temperature on given reactions at equilibrium. 5.6.2.7 The effect of pressure changes on equilibrium (HT only) **Content** | **Key ski** For gaseous reactions at equilibrium: • an increase in pressure causes the equilibrium position to shift towards the side with the smaller number of molecules as shown by the symbol equation for that reaction • a decrease in pressure causes the equilibrium position to shift towards the side with the larger number of molecules as shown by the symbol equation for that reaction. Students should be able to interpret appropriate given data to predict the effect of pressure changes on given reactions at equilibrium.	