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Rate & Extent of Chemical Reactions	Rates of reaction	1. 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 = $\frac{\text{quantity of reactant used}}{\text{Time taken}}$ ● Mean rate of reaction = $\frac{\text{quantity of product formed}}{\text{Time taken}}$ 2. The quantity of reactant or product can be measured by the mass (grams) or by volume (cm^3) 3. The units of rate of reaction are g/s or cm^3/s. 4. *The quantity of reactions can also be given in terms of moles and the units for rate of reaction in mol/s.* 5. Factors which affect the rate of chemical reactions include – ● Concentration of reactant ● Pressure of reacting gases ● Surface area of solid reactants ● Temperature ● Presence of a catalyst.
	Collision theory & activation energy	6. Collision theory states that chemical reactions can only occur when particles collide with each other with enough energy. 7. The minimum amount of energy that particles must have to react is called the activation energy. 8. 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. 9. Increasing the temperature increases the frequency of collisions and makes the collisions more energetic and so increases the rate of reaction.
	Catalysts	10. Catalysts change the rate of chemical reactions but are not changed or used up during the reaction. 11. Different reactions need different catalysts. 12. Enzymes are catalysts in biological systems. 13. Catalysts increase the rate of reaction by providing a different pathway for the reaction that has a lower activation energy.

	Reversible reactions	14. In some chemical reactions, the products of the reaction can react to produce the original reactants. These reactions are called reversible reactions. A + B $\rightleftharpoons$ C + D 15. The direction of the reversible reactions can be changed by changing the conditions, for example heating or cooling the reaction. Ammonium chloride $\underset{\text{heat}}{\overset{\text{cool}}{\rightleftharpoons}}$ ammonia + hydrogen chloride
	Energy Changes reversible reactions	16. If a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction. 17. The same amount of energy is transferred in each direction. 18. For example – Hydrated copper sulfate (blue) $\underset{\text{endothermic}}{\overset{\text{exothermic}}{\rightleftharpoons}}$ anhydrous copper sulfate (white) + water
	Equilibrium	19. When a reversible reaction, equilibrium is reached when the forward and reverse reactions occur at exactly the same rate. 20. Equilibrium can only be achieved in a closed system where no materials can escape. This is a sealed container for gases but a beaker for liquids is good enough.

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	Effect of Changing conditions on equilibrium (Higher Tier Only)	21. *If a system is at equilibrium and a change is made to any of the conditions, then the system responds to counteract the change.* 22. *The effects of changing conditions on a system at equilibrium can be predicted using Le Chatelier's Principal.* 23. *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.* 24. *If the concentration of one of the reactants is increased, more products will be formed until equilibrium is reached again.* 25. *If the concentration of a product is decreased, more reactants will react until equilibrium is reached again.* 26. *If the temperature of a system at equilibrium is increased, the endothermic reaction is favoured in an attempt to cool the system.* *27. If the temperature of a system at equilibrium is decreased, the exothermic reaction is favoured in an attempt to heat the system.* 28. *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 equations 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 equations for that reaction.*

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Carbon compounds as fuels.	Crude oil, hydrocarbons and alkanes	29. Crude oil is the remains of ancient biomass consisting mainly of plankton that was once buried in mud; it is a finite resource found in rocks. 30. Crude oil is a mixture of hydrocarbon compounds. 31. Hydrocarbon compounds are molecules made only of carbon and hydrogen atoms. 32. Most of the hydrocarbons in crude oil are alkanes. 33. Alkanes are a homologous series with the formula C_nH_{2n+2} *34.* Alkane molecules are saturated; they have single bonds between the carbon atoms. *35.* The first 4 members of the alkane series are methane, ethane, propane and butane. *36.* The combustion of hydrocarbons releases energy and produces carbon dioxide and water as the carbon and hydrogen atoms in the molecules are oxidised. *37.* As hydrocarbon molecules get larger, they become more viscous, less flammable and have higher boiling points.

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Carbon compounds as fuels and feedstock	Fractional distillation	38. Fractional distillation is the method used to separate the molecules in crude oil into fractions, each of which contains molecules with a similar number of carbon atoms. 39. Many fuels such as petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases (LPG) are produced from crude oil. 40. Many useful materials are produced using the fractions from crude oil by the petrochemical industry such as solvents, lubricants, polymers and detergents. 41. During fractional distillation the molecules in crude oil are heated to evaporate them. 42. Smaller hydrocarbons have lower boiling points and rise higher in the fractional distillation column before condensing. 43. Larger molecules have higher boiling points and condense lower down the column where the temperature is hotter.
	Cracking and the alkenes.	44. Fractions containing larger hydrocarbon molecules are in less demand than those containing smaller hydrocarbon molecules. 45. Large hydrocarbon molecules can be broken down (cracked) using steam or catalytic cracking. 46. The conditions for steam cracking are mix vapour with steam and heat to very high temperature. 47. The conditions for catalytic cracking are to heat to 500^0C and pass over hot catalyst. 48. The products of cracking are smaller hydrocarbons and another types of hydrocarbon called alkenes. 49. Alkenes are hydrocarbons that contain a carbon – carbon double bond. 50. When bromine water reacts with an alkene it turns from orange/ brown to colourless. 51. Bromine water remains orange / brown when added to an alkane. 52. Alkenes are used to produce polymers. **53. The general formula for the homologous series of alkenes is C_nH_{2n}** **54. Alkene molecules are unsaturated.** **55. The first 4 alkenes in the series are called ethane, propene, butane and pentene.** **56. The functional group in an alkene is C=C** **57. Alkenes react with oxygen but tend to burn with smoky flames due t incomplete combustion.** **58. Alkenes react with water to produce alcohols.** **59. Alkenes react with halogens; the halogen attaches to both carbons that formed the double bond.** **60. Bromine water can be used to test for an alkene; the bromine water will change from orange / brown to colourless when added to an alkene.**

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Organic chemistry	**Alcohols**	**61. Alcohols contain the functional group –OH.** **62. Methanol, ethanol, propanol and butanol are the first 4 members of the homologous series of alcohols.** **63. Alcohols react with sodium; it displaces the hydrogen on the functional group.** **64. Alcohols form carbon dioxide and water when the burn in air.** **65. Alcohols dissolve when added to water to form a neutral solution.** **66. Alcohols react with oxidising agents to form carboxylic acids. Eg ethanol oxidises to form ethanoic acid.** **67. Aqueous solutions of ethanol are produced when sugar solutions are fermented using yeast.** **68. The conditions used for fermentation of sugar using yeast are warm temperature and no oxygen.**
	Carboxylic acids	**69. Carboxylic acids have the functional group –COOH.** **70. The first 4 members of the homologous series are methanoic acid, ethanoic acid, propanoic acid and butanoic acid.** **71. Carboxylic acids react with metal carbonates to form a salt (eg sodium ethanoate), carbon dioxide and water.** **72. Carboxylic acids dissolve in water** **73. Carboxylic acids react with alcohols to form esters eg ethyl ethanoate.**

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Synthetic and naturally occurring polymers	**Addition polymerisation**	**74. Alkenes can be used to make polymers such as polyethene and polypropene.** **75. In addition polymerisation reactions, many small molecules (called monomers) join together to make very large molecules called polymers.** **76. In addition polymerisation, no other product is formed; each repeating unit in the polymer has the same atoms as the monomer.** 77. **Monomers contain double bonds which break during the reaction.**
	Condensation polymerisation	***78. Condensation polymerisation involves monomers with 2 functional groups.*** ***79. In condensation polymerisation, the monomers lose a small molecule such as water.*** ***80. A diol has 2 alcohol functional groups; one at each end*** ***81. A dioic acid has 2 carboxylic functional groups; one at each end.*** ***82. A diol and a dioic acid form a polyester and water when they react.***
	Amino acids	***83. Amino acids have 2 different functional groups in a molecule.*** ***84. Amino acids react by condensation polymerisation to form polypeptides.*** ***85. Glycine (H_2NCH_2COOH) is an amino acid that forms the polypeptide ($(HNCH_2COO)_n$) and water.***
	DNA	**86. DNA (deoxyribonucleic acid) molecules are 2 polymer chains made from 4 different monomers called nucleotides, in the form of a double helix.** **87. DNA encodes genetic instructions for the development and functioning of living organisms.** **88. Proteins are naturally occurring polymers made from monomers called amino acids.** **89. Starch is a naturally occurring polymers made from monomers called glucose.** ***90.* Cellulose is a naturally occurring polymers made from monomers called glucose.**

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Chemical analysis	Purity, formulations and chromatography	91. A pure substance is a single element or compound not mixed with any other substance. 92. Pure substances have specific melting and boiling pints that helps us identify them. 93. A formulation is a mixture that has been designed as a useful product, eg panits, medicines and foods. 94. Chromatography can be used to separate substances using a stationary and a mobile phase. 95. $R_f \text{ value} = \frac{\text{distance moved by the substance}}{\text{distance moved by the solvent}}$ 96. Different compounds have different R_f values is different solvents which can be used to help identify the compounds. 97. The compounds in a mixture will be separated into different spots depending on the solvent. 98. A pure compound will only produce a single spot. 99. In paper chromatography, the starting line should be drawn in pencil as it is insoluble and will not be dissolved by the solvent and interfere with the results.
Chemical analysis	Identifying gases.	100. The test for hydrogen uses a burning splint held over the end of the tube of gas. The result is a pop sound. 101. The test for oxygen uses a glowing splint inserted into the gas. The splint relights in oxygen. 102. The test for carbon dioxide uses limewater (calcium hydroxide solution). Carbon dioxide makes limewater turn cloudy when bubbles through it. 103. The test for chlorine uses damp litmus paper. The paper bleaches and turns white.

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	Identification of ions by chemical and spectroscopic means	**104. Flame tests can be used to identify some metal ions (cations).** **105. Lithium compounds result in a crimson flame.** **106. Sodium compounds result in a yellow flame.** **107. Potassium compounds result in a lilac flame.** **108. Calcium compounds result in an orange-red flame.** **109. Copper compounds result in a green flame.** **110. If a sample containing a mixture is used, some colours will mask other colours.** **111. Sodium hydroxide solution can be used to identify some metal ions (cations).** **112. Solutions of aluminium,calcium and magnesium ions form white hydroxide precipitates when added to sodium hydroxide.** **113. Aluminium hydroxide dissolves in excess sodium hydroxide but magnesium and calcium do not.** **114. Copper (II) ions form a blue hydroxide precipitate when sodium hydroxide is added.** **115. Iron (II) ions form a green hydroxide precipitate when sodium hydroxide is added.** **116. Iron (III) ions form a brown hydroxide precipitate when sodium hydroxide is added.** **117. Carbonates react with dilute acids to form carbon dioxide gas. Carbon dioxide gas can be identified using limewater.** **118. Silver nitrate (in the presence of nitric acid) is used to test for the presence of halide ions in solution.** **119. Chloride ions form a white precipitate of silver chloride when silver nitrate is added.** **120. Bromide ions form a cream precipitate of silver bromide when silver nitrate is added.** **121. Iodide ions form a yellow precipitate of silver iodide when silver nitrate is added.** **122. Sulfate ions produce a white precipitate of barium sulfate when barium chloride solution is added in the presence of hydrochloric acid.**

	Instrumental methods; flame emission spectroscopy	**123. Elements and compounds can be detected and identified using instrumental methods. These are accurate, sensitive and rapid.** **124. Flame emission spectroscopy is an instrumental method used to analyse metal ions in solution.** **125. The sample is put into a flame and the light given out is passed through a spectroscope.** **126. The output is a line spectrum that can identify the metal ion and measure the concentration in the solution.** **127. The line spectrum produced is compared to a reference set of data.** **128. The advantages of instrumental methods are it is sensitive (so very small amounts can be detected), accurate and rapid.**

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Chemistry of the atmosphere	Gases in the atmosphere	129. For 200 million years the percentages of the gases in the atmosphere have been much as the same as today. 130. About 4/5ths of todays atmosphere is (80%) is nitrogen (N_2) 131. About 1/5th is oxygen (O_2) 132. There are small proportions of others gases including carbon dioxide, water vapour and noble gases (group 0)
	The early atmosphere of the Earth	133. Evidence for the Earth's early atmosphere is limited because of the time scale of 4.6 billion years. 134. One theory suggests volcanic activity released carbon dioxide, water vapour and other gases that formed the first atmosphere. 135. The water vapour condensed to form oceans. 136. Carbon dioxide dissolved in the water and carbonates were precipitated forming sediments, reducing the amount of carbon dioxide in the atmosphere. 137. Algae began photosynthesising about 2.7 billion years ago, which created oxygen in the atmosphere. 138. Plants then evolved over the next billion years and the percentage of oxygen increased. 139. Photosynthesis by algae and plants also decreased the percentage of carbon dioxide in the atmosphere. 140. Carbon dioxide was also decreased by the formation of sedimentary rocks and fossil fuels that contain carbon.
Greenhouse gases	Greenhouse gases	141. Greenhouse gases in the atmosphere maintain temperatures on Earth high enough to support life. 142. Water vapour, carbon dioxide and methane are greenhouse gases. 143. Greenhouse gases let short wave radiation from the sun through to Earth. 144. Greenhouse gases absorb the infra-red radiation emitted by the Earth, trapping the energy. 145. The burning of fossil fuels to make electricity, heat homes and run cars (human activities) has increased the amount of carbon dioxide in the atmosphere. 146. Swamps and rice fields produce methane as does the growing number of grazing cattle and their decomposing waste. 147. Based on peer- reviewed evidence, many scientists believe that human activities will cause the temperature of the Earth's surface to increase and will result in global climate change. 148. It is difficult to model such complex systems so we cannot predict with certainty the effects of increased levels of greenhouse gases.

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	Global climate change	149. Global warming is a major cause of climate change. 150. Consequences of global climate change include; - rising sea levels as a result of melting ice caps - an increased number of extreme weather events, - changes in temperature and rainfall which could impact on food production, - changes to the distribution of wildlife species with some becoming extinct.
	Carbon footprint	151. The carbon footprint is the total amount of carbon dioxide and other greenhouse gases emitted over the full life cycle of a product, service or event. 152. The carbon footprint could be reduced by reducing emissions of carbon dioxide and methane. 153. Carbon dioxide emissions could be reduced by carbon capture; pumping the carbon dioxide produced underground into porous rocks. 154. Plant based diets would reduce demand for beef and reduce methane emissions. 155. Biofuels use carbon dioxide when they grow but create carbon dioxide when they are burnt so are classed as carbon neutral. 156. Reducing emissions will have cost implications in all manufacturing and transport industries.
Atmospheric pollutants	Atmospheric pollutants from fuels	157. Most fuels, including coal, contains carbon and /or hydrogen and may also contain some sulfur. 158. Carbon dioxide, sulfur dioxide, carbon monoxide, water vapour and oxides of nitrogen are all produced by the burning of various fuels. 159. The complete combustion of a hydrocarbon fuel produces carbon dioxide and water vapour. 160. The incomplete combustion of a hydrocarbon fuel produces carbon monoxide and water vapour (when less oxygen is available). 161. Particulates of carbon (soot) can also be produced during incomplete combustion. These cause global dimming and health problems. 162. Carbon monoxide is poisonous (toxic). 163. Carbon monoxide is colourless and odourless so is not easily detected. 164. Sulfur impurities in fuels form sulfur dioxide when burnt. 165. At high temperatures (eg in engines) nitrogen from the atmosphere reacts with oxygen to form oxides of nitrogen. 166. Sulfur dioxide and oxides of nitrogen cause acid rain and breathing problems.

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Using the Earth's resources	Earth's resources	167. Finite natural resources from the Earth. Oceans and atmosphere are processed to provide energy and materials. 168. Some of these finite resources will run put if we continue to exploit them e.g. fossil fuels. 169. Renewable resources can be replaced as we use them e.g. crops for biofuels. 170. Chemistry helps improve agriculture and industrial processes to provide new products and in sustainable development.
	Potable water	171. Water that is safe to drink is called potable water. 172. Potable water is not pure as it may contain dissolved substances. 173. In the UK rain water provides ground water which is settled then filtered and sterilised to produce potable water. 174. Sterilising agents include chlorine, ozone or UV light. These kill microbes. 175. If supplies of fresh water are limited salty water (sea water) is desalinated. 176. Desalination can be done by distillation or reverse osmosis. Both use large amounts of energy. 177. Pure water has a pH of 7 and a boiling point of 100^0C
	Waste water	178. Waste water from homes and industry needs treating before being released into the environment. 179. Sewage and agricultural waste needs organic matter and harmful microbes removing. 180. Sewage treatment includes: screening to remove large solids and grit sedimentation to produce sewage sludge and effluent the sewage sludge is broken down by anaerobic digestion and dried aerobic biological treatment of effluent which is returned into the environment.

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	Alternative methods of extracting metals	181. *Copper ores (and other metal ores) are becoming scarce.* 182. *Phytomining and bioleaching are used to extract copper from low grade ore.* 183. *Phytomining uses plants to absorb metal compounds. The plants are then burnt to produce ash and the metals extracted from the ash.* 184. *Bioleaching uses bacteria to produce leachate solutions that contain metal compounds.* 185. *The copper can be obtained from the solutions by displacement using scrap iron or by electrolysis.*

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Life cycle assessments and recycling	Life cycle assessment.	186. Life cycle assessments (LCAs) are carried out to assess the environmental impact of a product. 187. LCAs assess the following stages: - extracting and processing raw materials - manufacturing and packaging - use and operation during its lifetime - disposal at the end of its useful lifetime, including transport at each stage 188. Use of water, materials, energy and the production of some waste can be measured and quantified. 189. It is difficult to quantify other things eg pollutants released into the atmosphere so value judgements have to be used. 190. LCAs are not purely objective. Some values are subjective. 191. LCAs could be biased and be misused for advertising.
	Reducing use of resources	192. There are 2 ways we can reduce the use of resources: reduce how much we use, reuse items and recycle materials. 193. Reducing the use of resources also saves energy, waste and cuts down environmental impacts. 194. Metals, glass, building materials, clay ceramics and most plastics are produced from limited resources.
Using materials	**Corrosion and its prevention**	**195. Corrosion is the destruction of materials by chemical reactions with substances in the atmosphere eg the oxidation of metals.** **196. Rusting is an example of corrosion. Rusting is the oxidation of iron (rust is iron oxide).** **197. Both air (oxygen) and water are necessary for iron to rust.** **198. Corrosion can be prevented by applying a coating that acts as a barrier, eg grease, paint or electroplating.** **199. Aluminium has an oxide coating that is non- porous and protects the metal from further corrosion.** **200. Galvanised iron is coated in zinc. Zinc is more reactive so any water or oxygen would react with the zinc rather than the iron.** 201. **Using zinc this way is an example of sacrificial protection.**

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Using materials	**Alloys as useful materials**	**202. Most metals in everyday use are alloys; mixtures of metals.** **203. Bronze is an alloy of copper and tin.** **204. Brass is an alloy of copper and zinc** **205. Gold used in jewellery is usually an alloy with silver, copper and zinc.** **206. The proportion of gold in the alloy is measured in carats. Pure gold is 24 carats, 75% gold is 18 carats.** **207. Steels are alloys of iron that contain carbon and / or other metals.** **208. High carbon steel is strong but brittle** **209. Low carbon steel is softer and more easily shaped.** **210. Stainless steels contain nickel and chromium and are hard and resistant to corrosion.**
	Ceramics, polymers and composites	**211. Most glass is soda lime glass, made by heating a mixture of sand, sodium carbonate and limestone.** **212. Borosilicate glass has a higher melting point and is made from sand and boron trioxide.** **213. Clay ceramics (pottery and bricks) are made by heating clay in a furnace.** **214. The properties of polymers depend on the monomer used and the condition it is made in.** **215. High density poly(ethene) is made using a catalyst at 50°C with a slightly raised pressure.** **216. Low density polyethene is made using very high pressure and a trace of oxygen.** **217. High density polyethene contains straighter polymer chains which pack together more closely and it is stronger than low density polyethene.** **218. Thermosoftening polymers will soften or melt easily when heated because their intermolecular forces are weak.** **219. Thermosetting polymers will not soften as cross links between polymer chains makes them rigid and heat resistant.** **220. Most composites are made of 2 materials; a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement.**

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The Haber process and the use of NPK fertilisers.	**The Haber process**	**221. The Haber process is used to manufacture ammonia, which is used to produce nitrogen based fertilisers.** **222. Nitrogen and hydrogen are the raw materials for making ammonia.** **223. Nitrogen comes from the air.** **224. Hydrogen comes from natural gas.** **225. The conditions for the Haber process are a high temperature of about 450°C, a high pressure of 200 atmospheres and an iron catalyst.** **226. The reaction is reversible so some of the ammonia breaks down into nitrogen and hydrogen.** **227. As the products are cooled the ammonia liquefies and is removed. The remaining hydrogen and nitrogen are recycled.**
	Fertilisers	**228. Compounds of nitrogen (N), phosphorus (P) and potassium (K) are used as fertilisers.** **229. NPK fertilisers are formulations of various salts containing appropriate percentages of the elements.** **230. Ammonia can be used to manufacture ammonium salts and nitric acid.** **231. Potassium chloride, potassium sulfate and phosphate rock are obtained from mining.** **232. Phosphate rock needs treating with nitric or sulfuric acid to produce soluble salts that can be used as fertilisers.** **233. When phosphate rock is reacted with nitric acid it produces calcium nitrate.** **234. When phosphate rock is reacted with sulphuric acid it produces single superphosphate (calcium phosphate + calcium phosphate)** **235. When phosphate rock is reacted with phosphoric acid it produces triple superphosphate (Calcium phosphate)**