

GCSE / IGCSE Chemistry – Rates, Equilibrium and Organic

GCSE/IGCSE (Edexcel/Cambridge style, Higher tier) · Total marks: 43 · Answers on the last page

This worksheet covers collision theory and rates of reaction, reversible reactions and equilibrium, and organic chemistry (crude oil, alkanes, alkenes and polymers). A calculator is allowed. Allow about 40 minutes.

Section A – Collision theory and rates of reaction

- State what is meant by the term 'rate of reaction'.
 - In an experiment, magnesium reacts with excess dilute hydrochloric acid and 48 cm^3 of hydrogen gas is collected in the first 60 seconds. Calculate the mean rate of reaction over this time in cm^3s^{-1} .
[3]
- Using collision theory, explain why increasing the temperature of a reaction mixture increases the rate of reaction.
[3]
- A student investigates the reaction between calcium carbonate and hydrochloric acid using (i) large marble chips and (ii) the same mass of powdered calcium carbonate, with the same concentration and volume of acid.
 - Predict which mixture reacts faster, and explain your answer using collision theory.
 - State one variable that should be controlled for this to be a fair test.
[4]
- Explain, in terms of activation energy, how a catalyst increases the rate of a reaction without being used up.
[3]

Section B – Reversible reactions and equilibrium

- Ammonium chloride decomposes on heating: $\text{NH}_4\text{Cl(s)} \rightleftharpoons \text{NH}_3\text{(g)} + \text{HCl(g)}$.
 - State what the $\rightleftharpoons$ symbol indicates about this reaction.
 - Describe what would happen to solid ammonium chloride heated in a closed, sealed tube, in terms of the forward and reverse reactions.
[3]
- The industrial production of ammonia uses the reversible reaction $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$, which is exothermic in the forward direction.
 - State and explain the effect of increasing the pressure on the position of equilibrium.
 - State and explain the effect of increasing the temperature on the position of equilibrium.
[4]
- Explain what is meant by a 'dynamic equilibrium', and state the two conditions needed for it to be established.
[3]
- State Le Chatelier's principle and use it to predict the effect of adding more hydrogen gas to the equilibrium mixture in $\text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)}$.
[3]

Section C – Crude oil, alkanes, alkenes and polymers (Exam-style)

- Crude oil is separated into fractions by fractional distillation.
 - Describe how fractional distillation separates crude oil into fractions, in terms of boiling points and hydrocarbon chain length.

- (b) State one use of a fraction with short-chain hydrocarbons, and one use of a fraction with long-chain hydrocarbons. [4]
10. (a) Give the general formula for the alkanes.
(b) Draw-by-description the structure of propane, C_3H_8 , stating the number of C-C and C-H bonds.
(c) Alkanes are described as 'saturated hydrocarbons'. Explain this term. [4]
11. Long-chain alkanes can be broken down into smaller, more useful molecules by cracking, e.g. $\text{C}_{10}\text{H}_{22} \rightarrow \text{C}_8\text{H}_{18} + \text{X}$.
(a) Identify molecule X and state the type of hydrocarbon it belongs to.
(b) Describe one industrial method used to crack hydrocarbons, and explain why cracking is carried out.
(c) Describe a simple chemical test to distinguish an alkane from an alkene, including the observation for each. [5]
12. Poly(ethene) is made from ethene, $\text{CH}_2=\text{CH}_2$, by addition polymerisation.
(a) Draw-by-description the repeating unit of poly(ethene), including how it links to neighbouring units.
(b) Explain why addition polymers such as poly(ethene) are generally not biodegradable, and state one environmental problem this causes. [4]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- (a) Rate of reaction is the change in amount of reactant or product per unit time.
(b) $\text{Rate} = \frac{48}{60} = 0.80 \text{ cm}^3\text{s}^{-1}$
- Increasing temperature gives particles more kinetic energy, so they move faster and collide more frequently; more importantly, a greater proportion of collisions have energy greater than or equal to the activation energy, so a greater proportion of collisions are successful, increasing the rate.
- (a) The powdered calcium carbonate reacts faster because it has a much greater surface area to volume ratio than the marble chips, so more particles are exposed at the surface. This increases the frequency of collisions between acid particles and calcium carbonate particles per unit time, increasing the rate.
(b) Any one of: temperature of the acid, concentration/volume of the acid, mass of calcium carbonate used.
- A catalyst provides an alternative reaction pathway with a lower activation energy. This means a greater proportion of particle collisions have enough energy to react successfully, increasing the rate. The catalyst is not chemically changed by the reaction and can be reused.
- (a) The symbol shows the reaction is reversible: it can proceed in both the forward and reverse directions.
(b) On heating, the forward (decomposition) reaction occurs, producing ammonia and hydrogen chloride gases. Because the tube is sealed, these gases cannot escape and can recombine (reverse reaction) to re-form ammonium chloride; a dynamic equilibrium can be reached where the forward and reverse reactions occur at the same rate.
- (a) Increasing pressure shifts the equilibrium to the right (towards the products), because there are fewer moles of gas on the product side (2 mol) than the reactant side (4 mol), and the system responds to the increase in pressure by favouring the side with fewer gas molecules, reducing the pressure.
(b) Increasing temperature shifts the equilibrium to the left (towards the reactants), because the forward reaction is exothermic; the system opposes the increase in temperature by favouring the endothermic (reverse) reaction, which absorbs heat.
- A dynamic equilibrium is reached in a reversible reaction when the forward and reverse reactions occur at exactly the same rate, so the concentrations of reactants and products remain constant (though both reactions continue to happen). It can only be established in a closed system, at constant temperature.
- Le Chatelier's principle states that if a system at equilibrium is subjected to a change, the position of equilibrium shifts to oppose that change. Adding more hydrogen increases the concentration of a reactant, so the equilibrium shifts to the right (towards ammonia) to use up some of the extra hydrogen, increasing the yield of ammonia.
- (a) Crude oil is heated and vaporised, and the vapour rises up a fractionating column which is hotter at the bottom and cooler at the top. Hydrocarbons with shorter chains have lower boiling points, so they remain gaseous and rise further before condensing near the top; hydrocarbons with longer chains have higher boiling points and condense lower down. Fractions of similar chain length/boiling point are collected at different heights.
(b) Short-chain fraction (e.g. gases/petrol): used as fuel for cars or for cooking/heating (LPG).

Long-chain fraction (e.g. bitumen/fuel oil): used for surfacing roads or as fuel for ships/power stations.

10. (a) C_nH_{2n+2}
(b) Propane has a chain of three carbon atoms joined by single bonds ($CH_3 - CH_2 - CH_3$): 2 C-C single bonds and 8 C-H single bonds, with each carbon having four single bonds in total.
(c) 'Saturated' means the molecule contains only single covalent bonds between carbon atoms, with no carbon-carbon double bonds; it is a hydrocarbon (contains only hydrogen and carbon).
11. (a) $X = C_2H_4$ (ethene), an alkene, since carbon and hydrogen atoms must balance ($10 = 8 + 2$, $22 = 18 + 4$).
(b) Catalytic cracking passes vaporised hydrocarbons over a hot catalyst (e.g. silica or alumina) at high temperature; steam cracking uses very high temperatures without a catalyst. Cracking is carried out because there is greater demand for shorter-chain hydrocarbons (e.g. petrol) than is naturally present in crude oil, and it also produces alkenes, which are used to make polymers and other chemicals.
(c) Add a few drops of orange/brown bromine water to each hydrocarbon and shake. With an alkene, the bromine water is decolourised (turns from orange to colourless) because the alkene's C=C double bond reacts with bromine by addition. With an alkane, the bromine water stays orange/brown as no reaction occurs (no C=C double bond present).
12. (a) The repeating unit is $-CH_2 - CH_2-$, drawn with a bond extending from each end (shown in brackets with n outside) to show that it links to identical units on both sides, formed by the C=C double bond of ethene opening up to form single bonds between repeating units.
(b) Addition polymers have a strong, unreactive carbon-carbon backbone made only of single covalent bonds with no easily broken groups, so microorganisms cannot easily break them down; this means they persist for a very long time in the environment, contributing to problems such as landfill waste build-up or plastic pollution in oceans/harm to wildlife.

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