Unit 8

Answers: Chemical Reaction

Quick checks

1 c Melting is a change of state: the water that comes off the ice is the same substance as the ice. The black on the spoon is silver sulphide, curd sets because bacteria turn milk sugar into lactic acid, and a candle's wax turns into carbon dioxide and water: new substances every time.

2 c Barium nitrate and sodium sulphate swap partners to give barium sulphate, which doesn't dissolve: $Ba(NO_3)_2 + Na_2SO_4 \rightarrow BaSO_4\downarrow + 2NaNO_3$. In the other pairs, every possible new pair is a sodium, potassium or ammonium salt, or a nitrate, or an ordinary chloride, all of which dissolve.

3 c Sodium ethanoate comes from a weak acid (ethanoic acid) and a strong base (sodium hydroxide); its hydrolysis leaves OH^- ions in excess. Potassium nitrate and sodium sulphate are salts of a strong acid and a strong base (neutral); ammonium chloride is acidic.

4 c A catalyst changes only how fast the product forms, never how much: the amount is fixed by the reactants and the equation. That is the point of the potassium chlorate example above.

5 b Silver nitrate, like silver chloride and hydrogen peroxide, decomposes in light: $2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$. Brown glass absorbs the violet and ultraviolet light that drives the reaction.

6 c An electrolytic reaction is driven by an electric current. The others are driven by a catalyst, by light and by heat: all four are decompositions, but only one is electrolysis.

7 b Zinc gives two electrons to the copper ion ($Zn \rightarrow Zn^{2+} + 2e^-$), so zinc reduces it: zinc is the reducing agent, and it is itself oxidized. The copper ion takes the electrons: it is the oxidizing agent, and it is reduced.

8 c In a neutralization, H^+ and OH^- ions join to make water, and the sodium and chloride ions stay as they were: no electrons change hands. The other three move oxygen or electrons from one substance to another.

9 b Giving off a small molecule at every link is what condensation means. Addition polymerization needs a C=C and gives off nothing. Hydrolysis is the reverse: it takes water in and splits a polymer.

10 b Cellulose is made by plants; rayon is cellulose chemically dissolved and spun into new fibers, so it is semi-synthetic. Nylon and PVC are both synthetic; glucose is a monomer, not a polymer; polythene is synthetic and natural rubber natural.

11 c Both are insulators, but a switch can get hot, and polythene, a thermoplastic, softens. Bakelite is a thermosetting plastic: its cross-linked network stays hard and doesn't soften when heated.

1 a. **c** Lead nitrate and potassium iodide give lead(II) iodide, bright yellow. The others give white silver chloride, pale blue copper hydroxide and white barium sulphate.

1 b. **c** Sodium carbonate comes from weak carbonic acid and strong sodium hydroxide. Its hydrolysis leaves more OH^- than H^+ ions in the water.

1 c. **b** A photochemical reaction is driven by light. Silver bromide decomposing in light is the reaction of photographic film.

1 d. **a** Copper oxide gives its oxygen to hydrogen, so it oxidizes the hydrogen; copper oxide itself is reduced. Hydrogen is the reducing agent.

1 e. **c** PVC is polyvinyl chloride: n $CH_2{=}CHCl \rightarrow [{-}CH_2{-}CHCl{-}]_n$. Ethene gives polythene, propene polypropylene, tetrafluoroethene PTFE.

1 f. **d** Nylon is made from a diamine and a dicarboxylic acid, giving off water at each link. The other three are addition polymers of monomers with C=C.

1 g. **b** Cellulose is made by plants from glucose units. Bakelite, PTFE and polyester are synthetic.

1 h. **b** The repeating unit, C_2H_4, is 28 g/mol: $n = 42{,}000 \div 28 = 1{,}500$.

2 a. Ammonium chloride is the salt of a strong acid (hydrochloric acid) and a weak base (ammonium hydroxide). In water it hydrolyzes: $NH_4Cl + H_2O \rightleftharpoons NH_4OH + HCl$. The hydrochloric acid formed is fully ionized, while the weak ammonium hydroxide stays mostly un-ionized, so the solution has more H^+ ions than OH^- ions. It is acidic, and turns blue litmus red.

2 b. A catalyst only changes the rate of the reaction; it is not used up, and it is left at the end with the same mass and chemical composition as at the start. Since it isn't turned into products, it is not a reactant, so it is written over the arrow as a condition of the reaction.

2 c. Silver bromide is decomposed by light, a photochemical reaction: $2AgBr \rightarrow 2Ag + Br_2$. Where light falls on the film, tiny dark grains of silver form, more where the light is brighter. So the pattern of light from the scene is recorded as a pattern of silver on the film, which is developed into the picture.

2 d. Electrons can't be destroyed or left loose. When one substance loses electrons (is oxidized), another must take them (is reduced); when one substance gains oxygen, it takes it from another, which loses it. So a reaction can't have oxidation without reduction: both happen at once, which is why such reactions are called redox reactions.

2 e. Raw rubber becomes soft and sticky when hot and hard and brittle when cold, and it wears quickly. Heating it with sulphur (vulcanization) forms sulphur bridges between its long chains, so they can't slide past one another. Vulcanized rubber stays elastic over a wide range of temperatures, is much stronger and tougher, and lasts far longer on the road.

2 f. The handle gets hot. Polythene is a thermoplastic: it would soften and lose its shape. Bakelite is a thermosetting plastic, whose chains are cross-linked into a rigid network, so it stays hard when heated; it is also a poor conductor of heat and electricity, so the handle stays safe to hold.

3 i.

Oxidation	Reduction
Addition of oxygen to a substance.	Removal of oxygen from a substance.
Removal of hydrogen from a substance.	Addition of hydrogen to a substance.
Loss of electrons: $Na \rightarrow Na^+ + e^-$.	Gain of electrons: $Cl_2 + 2e^- \rightarrow 2Cl^-$.
Happens to the reducing agent.	Happens to the oxidizing agent.
Takes place at the anode in electrolysis.	Takes place at the cathode in electrolysis.

3 ii.

Precipitation reaction	Hydrolysis reaction
Two substances in solution react to form an insoluble solid.	A substance reacts with water, which is split into H and OH.
A precipitate is always formed.	Usually no precipitate; the solution may become acidic or basic.
Water is only the solvent.	Water is a reactant.
Example: $AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$	Example: $NH_4Cl + H_2O \rightleftharpoons NH_4OH + HCl$

3 iii.

Addition polymerization	Condensation polymerization
Monomers have a double bond (C=C).	Monomers have two reactive functional groups.
No by-product is formed.	A small molecule such as water is given off at each link.
The repeating unit has the same formula as the monomer.	The repeating unit has fewer atoms than the monomers.
Examples: polythene, PVC, PTFE, natural rubber.	Examples: nylon, polyester, Bakelite, proteins, starch.

3 iv.

Natural polymers	Synthetic polymers
Made by living things.	Made by people in factories, mostly from oil and natural gas.
Examples: starch, cellulose, proteins, natural rubber, DNA.	Examples: polythene, PVC, nylon, polyester, Bakelite.
Most are broken down by microbes (biodegradable).	Most are not biodegradable and last for centuries.

3 v.

Thermoplastic	Thermosetting plastic
Softens on heating and hardens on cooling, again and again.	Sets hard once; doesn't soften on heating again, but chars.
Its chains are separate (linear or branched).	Its chains are cross-linked into a network.
Can be remolded and recycled.	Can't be remolded or recycled by melting.
Examples: polythene, PVC, nylon.	Examples: Bakelite, melamine.

4 a. A **precipitation reaction** is a reaction in which two solutions react to form an insoluble solid, the precipitate.

- $AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$: silver chloride, a **white** precipitate.
- $Pb(NO_3)_2 + 2KI \rightarrow PbI_2\downarrow + 2KNO_3$: lead(II) iodide, a **yellow** precipitate.

(Also: $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4\downarrow + 2NaCl$, white; $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2\downarrow + Na_2SO_4$, blue.)

4 b. **Hydrolysis** is a reaction in which a substance reacts with water, the water molecule being split into H and OH, which join the parts of the substance.
Sodium ethanoate is the salt of a weak acid (ethanoic acid) and a strong base (sodium hydroxide):

$$_3 + _2 \rightleftharpoons _3 +$$

Sodium hydroxide is fully ionized, giving OH^- ions, while ethanoic acid stays mostly un-ionized; OH^- ions are in excess, so the solution is basic.
Sodium chloride is the salt of a strong acid and a strong base. Any HCl and NaOH formed would be fully ionized back into Na^+, Cl^-, H^+ and OH^-, with H^+ and OH^- in equal numbers, so there is no net hydrolysis and the solution is neutral.

4 c. A **catalyst** is a substance that changes the rate of a chemical reaction without itself undergoing any permanent chemical change.
Characteristics (any four):

- It is left unchanged in mass and chemical composition at the end of the reaction.
- A very small amount is enough.
- It doesn't start a reaction that can't take place; it only changes the rate.
- It doesn't change the amount of product formed.
- It is specific: each works for one reaction or a few.
- It works best at a particular temperature.
- It can be poisoned by some substances and helped by promoters.

4 d. Add 2 mL of silver nitrate solution (0.1 mol/L) to 2 mL of common salt solution in a test tube, in the shade: a white precipitate of silver chloride forms, $AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$. Filter it, open the filter paper, lay a coin on part of the precipitate, and put it in bright sunlight for 10–15 minutes. The exposed silver chloride turns violet, then gray-black, while the part under the coin stays white. Light has decomposed the silver chloride into finely divided silver:

$$2 \longrightarrow 2 + {}_2$$

Silver chloride kept in the dark stays white, showing that light causes the change. (Wear gloves: silver nitrate stains skin.)

4 e. **Oxidation:** addition of oxygen, removal of hydrogen, or loss of electrons.

Reduction: removal of oxygen, addition of hydrogen, or gain of electrons.

In $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$, iron(III) oxide loses its oxygen: it is **reduced** (to iron). Carbon monoxide gains oxygen: it is **oxidized** (to carbon dioxide). So CO is the reducing agent and Fe_2O_3 the oxidizing agent.

4 f. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$, or as ions, $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$ (the sulphate ions take no part).

- $Zn \rightarrow Zn^{2+} + 2e^-$: zinc loses electrons, so it is **oxidized**.
- $Cu^{2+} + 2e^- \rightarrow Cu$: copper ions gain electrons, so they are **reduced**.

The electrons lost by zinc are gained by the copper ions, so oxidation and reduction happen together: it is a redox reaction. Zinc is the reducing agent and Cu^{2+} the oxidizing agent.

4 g. An **electrolytic reaction** is a chemical reaction brought about by passing an electric current through an electrolyte (molten or in solution); electrical energy is converted into chemical energy.

- Electrolysis of acidified water: $2H_2O \rightarrow 2H_2 + O_2$.
- Electrolysis of molten sodium chloride: $2NaCl \rightarrow 2Na + Cl_2$.

(Also brine: $2NaCl + 2H_2O \rightarrow 2NaOH + H_2 + Cl_2$.)

4 h. A **monomer** is a small molecule that can join with others into a long chain. A **polymer** is a macromolecule made of many monomer units joined by covalent bonds. **Polymerization** is the reaction in which monomers join to form a polymer.

$$n\,C_2H_4 \longrightarrow [C_2H_4]_n$$

Ethene is the monomer and polythene the polymer, formed by addition polymerization.

4 i. Any four, for example:

- **Polythene:** carry bags, milk pouches, water tanks.
- **PVC:** water pipes, electric wire coating, raincoats.
- **Nylon:** ropes, fishing nets, toothbrush bristles, clothes.
- **Polyester:** clothes, soft-drink bottles.
- **PTFE (Teflon):** non-stick coating on pans.
- **Bakelite:** electric switches, handles of cookers and pans.
- **Vulcanized rubber:** tyres, chappals.

4 j. Starch (rice) and cellulose (cotton) are both condensation polymers of glucose, but their links are turned differently. Digesting either means hydrolyzing those links back to glucose, and each kind of link needs its own enzyme, because enzymes are specific. Your saliva and gut make amylase, which fits starch's links, but no enzyme for cellulose's links. A cow's stomach holds microbes that make cellulase, the enzyme that hydrolyzes cellulose, so a cow can live on grass. The same water, the same glucose, and still two very different foods: what decides is whether the right catalyst is there.

5 a. $M(\text{CaCO}_3) = 63.5 + 32 + 64 = 159.5$ g/mol, so $n = \frac{3.19}{159.5} = 0.02$ mol.

a. $M(\text{Cu(OH)}_2) = 63.5 + 2 \times 17 = 97.5$ g/mol. 0.02 mol Cu(OH)_2: $0.02 \times 97.5 = \mathbf{1.95\ g}$.

b. NaOH needed: $2 \times 0.02 = 0.04$ mol; $M(\text{NaOH}) = 40$ g/mol: $0.04 \times 40 = \mathbf{1.6\ g}$.

5 b. $n(_{22}) = \frac{6.8}{34} = 0.2$ mol.

a. 2 mol H_2O_2 give 1 mol O_2, so 0.1 mol O_2: $0.1 \times 22.4 =$ **2.24 L at STP**.

b. 2 mol H_2O_2 give 2 mol H_2O, so 0.2 mol H_2O: $0.2 \times 18 =$ **3.6 g**.

c. **1 g**: a catalyst is not used up. (Check: 6.8 g of H_2O_2 gave 3.6 g of water and $0.1 \times 32 = 3.2$ g of oxygen, 6.8 g in all.)

5 c. $n(_2) = \frac{3.36}{22.4} = 0.15$ mol.
2 mol $KClO_3$ give 3 mol O_2, so $n(_3) = 0.15 \times \frac{2}{3} = 0.1$ mol.
$M(_3) = 122.5$ g/mol: $0.1 \times 122.5 =$ **12.25 g**.

5 d. Molar mass of the repeating unit, $C_2H_3Cl = 2 \times 12 + 3 \times 1 + 35.5 = 62.5$ g/mol.
Molar mass of PVC $= 1{,}600 \times 62.5 =$ **100,000 g/mol**.

5 e. Molar mass of $C_6H_{10}O_5 = 72 + 10 + 80 = 162$ g/mol, so 16.2 g holds $\frac{16.2}{162} = 0.1$ mol of units.
Each unit takes 1 mol of water: $0.1 \times 18 =$ **1.8 g of water**.
Each unit gives 1 mol of glucose ($C_6H_{12}O_6$, 180 g/mol): $0.1 \times 180 =$ **18 g of glucose**.
Check: $16.2 + 1.8 = 18$ g. The glucose is heavier than the starch by exactly the water it took in.

5 f. Molar mass of the repeating unit $= 12 \times 12 + 22 \times 1 + 2 \times 14 + 2 \times 16 = 144 + 22 + 28 + 32 = 226$ g/mol.
n $= 22{,}600 \div 226 =$ **100 repeating units**.
Each repeating unit is one diamine and one diacid, so the chain is 200 monomers in a row, with 199 links; each link gave off one water molecule: **199 water molecules**, about 2 for every repeating unit.