SC17a Group 1

Student Book

1 Because they have similar reactions/chemical properties/same number of electrons in their outer shell.

2 They have relatively low melting points and are soft/easily cut.

3 a sodium + oxygen → sodium oxide

b sodium + water → sodium hydroxide + hydrogen

4 The caesium explodes.

5 The sodium ion has two shells with two dots (crosses) in the first shell and eight dots (crosses) in the second shell. The oxide ion has two shells with two crosses (dots) in the first shell and eight crosses (dots) in the second.

6 Alkali metals form an ion with a 1^+ charge because they have one electron in their outer shell and this is lost when they form an ion. Having lost one electron, this leaves one extra proton with a 1^+ charge.

7 a to stop them reacting with oxygen (and water) in the air

b Rubidium will be more reactive than sodium but less reactive than caesium.

8 When alkali metals react they lose their outer electrons. Potassium is more reactive than sodium as its atoms are larger and the outer electrons are further away from the nucleus. Thus it is easier to remove the electrons from potassium atoms so it reacts more easily.

9 **H** $4K + O_2 \rightarrow 2(K^+)2O^{2-}$

S1 Lithium, sodium and potassium are three examples of alkali metals.

All alkali metals are malleable, conduct electricity, have relatively low melting points, are soft and easily cut and react quickly with oxygen (forming metal oxides) and water (forming metal hydroxides and hydrogen).

E1 a Caesium is more reactive than rubidium because its atoms are larger and the outer electrons are further away from the nucleus. Thus it is easier to remove the electrons from caesium atoms so it reacts more easily.

b **H** $2Rb + 2H_2O \rightarrow 2Rb^+OH^- + H_2$

$2Cs + 2H_2O \rightarrow 2Cs^+OH^- + H_2$

Exam-style question

a $2K + 2H_2O$ (1) → $2KOH + H_2$ (1)

b Because caesium is too reactive and dangerous. (1)

Activity and Assessment Pack

SC17a.1 The alkali metals

1 Students' own tables

2 Compared to common metals such as iron and copper, the alkali metals are generally softer, and have lower melting points, boiling points and densities. Both are good conductors of electricity.

3 a lithium + oxygen → lithium oxide

$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

sodium + oxygen → sodium oxide

$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

potassium + oxygen → potassium oxide

$4K(s) + O_2\ (g) \rightarrow 2K_2O(s)$

b lithium + water → lithium hydroxide + hydrogen

$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$

sodium + water → sodium hydroxide + hydrogen

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

potassium + water → potassium hydroxide + hydrogen

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

4 lithium < sodium < potassium

5 Reactivity increases down the group in the periodic table.

6 The larger the atoms (the further from the nucleus the outer electrons) the more reactive the alkali metal.

7 The melting points, boiling points and hardness of elements decreases down the alkali metal group.

SC17a.2 The alkali metals Strengthen

1 a soft

b low

c float

2 The lithium drawing should show a solid piece of metal forming bubbles of gas on the surface of the water.

bubbles; melt; flames

3 sodium hydroxide; Na; 2: H_2

4 The least reactive of these metals is – lithium.

After cutting, these metals become dull – as they react with oxygen.

When alkali metals react – their atoms lose one electron.

The most reactive alkali metals – have the largest atoms.

The metals with the largest atoms – lose electrons more easily.

Of these, the metal with the largest atoms is – potassium.

SC17a.3 Chemical equations – Extend

1 When alkali metals react they lose their outer electron; this is easier the further away the outer electron is from the nucleus. Therefore, the reactivity will increase as the size of the atoms increases going down the group of alkali metals.

2 a i lithium + water → lithium hydroxide + hydrogen

ii rubidium + oxygen → rubidium oxide

b i $2Cs + 2H_2O \rightarrow 2CsOH + H_2$

ii $4K + O_2 \rightarrow 2K_2O$

c i $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

ii $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

d i $2Rb + 2H_2O \rightarrow 2Rb^+ + 2OH^- + H_2$
or $2Rb(s) + 2H_2O(l)$
$\rightarrow 2Rb^+(aq) + 2OH^-(aq) + H_2(g)$

ii $2Li + 2H_2O \rightarrow 2Li^+ + 2OH^- + H_2$
or $2Li(s) + 2H_2O(l)$
$\rightarrow 2Li^+(aq) + 2OH^-(aq) + H_2(g)$

3 a Compared to iron, sodium will have lower melting and boiling points.

b Compared to iron, sodium will have a lower density.

c Iron and sodium will have similar conductivity properties.

d Compared to iron, sodium will be softer.

SC17a.4 Group 1 – Homework 1

1 The names of the groups are: group 1 – alkali metals, group 7 – halogens and group 0 – noble gases. The symbols for the group 1 elements are, in order: Li, Na, K.

2 a Y

b potassium

c lithium

d sodium + water → sodium hydroxide + hydrogen

$2Na + 2H_2O \rightarrow 2NaOH + H_2$

3 Q is the alkali metal because it has the lowest melting and boiling points and is soft, compared to the other three metals.

SC17a.5 Group 1 – Homework 2

1 Rubidium would vigorously burst into flames/rubidium would explode.

2 $2Rb(s) + 2H_2O(l) \rightarrow 2RbOH(aq) + H_2(g)$

$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$

3 a The sodium reacts with the oxygen in the air OR the sodium oxidises OR sodium oxide is formed.

b The metal would be above sodium in the periodic table as it is less reactive than sodium.

4 a lithium + oxygen → lithium oxide

b $4K(s) + O_2(g) \rightarrow 2K_2O(s)$

5 a Missing information (from top left) is: 3; 2.1; 2; 11; 2.8.1; 3; 2.8.8.1; 4.

b Because they contain more occupied electron shells.

c When alkali metals react they lose their outer electron; this is easier the further away the outer electron is from the nucleus. Therefore, the reactivity will increase as the number of occupied electron shells increases.

6 Y is the alkali metal as all alkali metals are relatively soft, low melting point metals.

7 40 °C ± 5 °C

as melting points are decreasing down the group, with the gap between them getting smaller as we go down the group

8 $2Cs + 2H_2O \rightarrow 2Cs^+ + 2OH^- + H_2$

OR

$2Cs(s) + 2H_2O(l) \rightarrow 2Cs^+(aq) + 2OH^-(aq) + H_2(g)$

SC17b Group 7

Student Book

6th 1 The colour gets darker/deeper.

7th 2 All halogens (any two from): exist as two-atom molecules; are non-metals; are poor conductors of heat and electricity; react with metals and non-metals; are toxic/corrosive.

3 a pale yellow gas

b melting point about −200 ± 80 °C
boiling point about −130 ± 80 °C
density less than 0.003 g/cm^3

4 Na^+ and F^-

5 a calcium fluoride

b $F_2(g) + Ca(s) \rightarrow CaF_2(s)$

6 a Chlorine is used as bleach and a disinfectant.

b Care is needed not to breathe in chlorine fumes.

c The test for chlorine is that it turns damp blue litmus paper red at first, and then bleaches it white.

7 a chlorine would be a liquid; bromine and iodine would be solids

b chlorine and bromine would be gases; iodine would be a liquid

8 a lithium + chlorine → lithium chloride

b hydrogen + fluorine → hydrogen fluoride

9 When hydrogen fluoride dissolves it splits into H^+ and F^- ions. The H^+ ions make it an acid called hydrofluoric acid.

10 a $2Na + I_2 \rightarrow 2NaI$

b $H_2 + Br_2 \rightarrow 2HBr$

S1 The halogens chlorine, bromine and iodine are all: non-metallic elements; two-atom molecules (held together by covalent bonds); reactive with metals; toxic and corrosive.

The trends down the group of halogens are: melting/boiling points increase; density increases; colour gets darker.

E1 a react bromine with sodium metal:
$Br_2(g) + 2Na(s) \rightarrow 2NaBr(s)$

b (i) react hydrogen gas and bromine:
$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$

(ii) dissolve hydrogen bromide in water to form hydrobromic acid:
$HBr(g) + (aq) \rightarrow H^+Br^-(aq)$ or
$HBr(g) \rightarrow H^+Br^-(aq)$ (other answers are acceptable)

Exam-style question

Astatine should be a black solid (1) as it is at the bottom of the halogen group and the elements get darker and melting points increase down the group (1) (iodine, just above it, is a purple/black solid).

Activity and Assessment Pack

SC17b.1 Properties of halogens

1 Other answers are possible for sources and uses.

	Formula	Appearance	Sources	Uses
chlorine	Cl_2	pale green gas; smells choking, like swimming pools	chloride in sea salt	bleaches, disinfectants and water treatment
bromine	Br_2	brown liquid	bromide in sea salt	disinfectants and pesticide
iodine	I_2	purple/black solid	iodide in sea salt	disinfectants other medicines

2

Atomic number	Atomic size (pm)*	Bonding and structure	Melting point (°C)	Boiling point (°C)	Density (g dm^{-3})
17	99	covalent molecular	–101	–35	3.2
35	114	covalent molecular	–7	59	3120
53	133	covalent molecular	114	184	4930

* covalent radius, other values possible

3 They are all covalent molecular with two atoms in each molecule (formula X_2).

4 Both increase.

5 melting point = 250°C ± 80 °C

boiling point = 350 °C ± 80 °C

6 Fluorine is a pale coloured gas and astatine is a black solid.

7 Increasing atomic number means increasing numbers of electrons/electron shells, which account for most of the volume of an atom, so atomic size increases with atomic number.

8 Place moist blue litmus paper in chlorine and it first goes red then bleaches white.

SC17b.2 Equations for the reactions of halogens

1 a hydrogen + chlorine → **hydrogen chloride**

b **sodium + bromine** → sodium bromide

2 a Br_2(l) + 2Na(s) → 2NaBr(s)

b H_2(g) + F_2(g) → 2HF(g)

3 a Br_2(l) + H_2(g) → 2HBr(g)

b F_2(g) + Fe(s) → FeF_2(s)

4 a iodine + magnesium → magnesium iodide

I_2(s) + Mg(s) → MgI_2(s)

b chlorine + potassium → potassium chloride

Cl_2(l) + 2K(s) → 2KCl(s)

c chlorine + hydrogen → hydrogen chloride

Cl_2(l) + H_2(g) → 2HCl(g)

5 a $3F_2$(l) + 2Al(s) → $2AlF_3$(s)

b $2Br_2$(l) + Pb(s) → $PbBr_4$(s)

c 2Li(s) + F_2(g) → 2LiF(s)

d $5Cl_2$(g) + 2P(s) → $2PCl_5$(s)

SC17b.3 Group 7 – Strengthen

1

Halogen	Symbol	Formula	Colour	State
chlorine	Cl	**Cl_2**	pale green	**gas**
bromine	**Br**	Br_2	**brown**	**liquid**
iodine	I	I_2	**purple/black**	solid

missing text: halogens; molecular; two; covalent

2 a increase

b 300 °C

3 a hydrogen + iodine → **hydrogen iodide**

b **copper + chlorine** → copper chloride

c hydrogen chloride + **water** → hydrochloric acid

4 a iodine < bromine < chlorine

b Both fluorine and astatine would react with metals, forming metal halides, and with hydrogen, forming hydrogen halides (which are acidic). Fluorine would be the most reactive and astatine the least reactive.

SC17b.4 Group 7 – Homework 1

1 Across: 4 iodide, 5 fluoride, 7 covalent, 8 two, 9 brown, 10 chlorine

Down: 1 acid, 2 hydrochloric, 3 lead, 5 fluorine, 6 bromine

2 a increasing

b gas; –200 °C ± 50 °C

3 sodium + iodine → sodium iodide

4 H_2(g) + F_2(g) → 2HF(g)

5 There would be a slow change in colour (on heating). It would be less reactive than the other three halogens as the trend is to become less reactive down the group.

The product formed would be called zinc astatide.

6 Place moist blue litmus paper in chlorine and it first goes red then bleaches white.

SC17b.5 Group 7 – Homework 2

1 a Chlorine is a pale green gas, bromine is a brown liquid and iodine is a purple/black solid.

b Astatine is predicted to be a dark/black solid.

2 covalent bonding

3 a Scatter graph with axes correctly labelled, scales chosen to include all data (including the atomic number of astatine: 85) and to fit graph.

b Best fit line giving a prediction of relative atomic mass of 210 ± 5.

4 **a** Scatter graph with axes correctly labelled, scales chosen to include all data (including the atomic number of astatine: 85) and to fit graph.

b Best fit line giving predicted melting point of about 300 °C ± 80 °C.

5 **a** $Cl_2(g) + 2Ag(s) \rightarrow 2AgCl(s)$

b $3Br_2(l) + 2Al(s) \rightarrow 2AlBr_3(s)$

6 Place moist blue litmus paper in chlorine and it first goes red then bleaches white.

7 **a** **i** $F_2(g) + H_2(g) \rightarrow 2HF(g)$

ii $F_2(g) + Zn(s) \rightarrow ZnF_2(s)$

b The reaction of fluorine with zinc foil would be very violent/the zinc would burn violently in fluorine.

c **i** hydrofluoric acid

ii H^+ and F^-

d The pH value will be about 3.0 (± 0.5). Explanation: As we go down the group the decrease in pH value gets smaller so the decrease between fluorine and chlorine will be slightly greater (1.0) than the difference between chlorine and bromine (0.8).

8 **a** Scatter graph with axes correctly labelled, and scales chosen to include all data, the period number of astatine (6) and to fit graph paper.

b Scatter graph with axes correctly labelled, and scales chosen to include all data, the atomic number of astatine (85) and to fit graph paper.

9 The predicted value using period number will be slightly lower than that using atomic number.

SC17c Halogen reactivity

Student Book

1 **a** iron + astatine → iron(III) astatide

b Much slower as reactivity decreases down the group (and astatine is at the bottom).

2 $Mg + I_2 \rightarrow MgI_2$

3 Br_2 + LiCl as the bromine is less reactive than chlorine (and cannot displace it from its salts).

4 $Cl_2(g) + 2NaI(aq) \rightarrow I_2(aq) + 2NaCl(aq)$

5 A brown/black colour will appear.

6 Fluorine is the most reactive halogen; as it has the smallest atoms; which attract incoming electrons most strongly; and therefore forms ions most readily. Astatine is the least reactive halogen; as it has the largest atoms; which have the least attraction for incoming electrons; and therefore form ions least readily.

7 **a** H loss and gain of electrons

b H The Na(s) is oxidised and the $Br_2(g)$ is reduced. As the metal/sodium atom (with one electron in its outer shell) loses one electron to form a positive ion and the non-metal/bromine atom (with seven electrons in its outer shell) gains one electron to form a negative ion.

8 H $Br_2(g) + 2K^+I^-(aq) \rightarrow I_2(aq) + 2K^+Br^-(aq)$ (could have $I_2(s)$ or $I_2(g)$)

S1 Any clear, appropriate way of displaying the trends through the group. An example is given below.

	Trend in reactivity	Explanation of trend		
fluorine	reactivity increases ↑	size of atoms decreases ↑	increasing attraction for electrons ↑	increasing ease of forming ions ↑
chlorine				
bromine				
iodine				

(Other answers are possible.)

E1 H A displacement reaction such as:

$F_2(g) + 2K^+Br^-(aq) \rightarrow Br_2(aq) + 2K^+F^-(aq)$

This is a redox reaction as the $F_2(g)$ gains electrons – reduction (and becomes $2F^-$) – and the $Br^-(aq)$ loses electrons – oxidation (and becomes Br_2).

Exam-style question

The trends down the groups are:

- group 1: melting point decreases and reactivity increases (1)
- group 7: melting point increases and reactivity decreases (1).

These groups show opposite trends (1).

Activity and Assessment Pack

SC17c.1 Displacement reactions

Page 1

1

Halogen	Potassium chloride solution	Potassium bromide solution	Potassium iodide solution	**Extra challenge** effect on blue litmus paper
chlorine water	✗	✓	✓	quickly turns blue litmus red then bleaches
bromine water	✗	✗	✓	turns blue litmus red and bleaches very slowly or not at all
iodine water	✗	✗	✗	no change in blue litmus paper

2 chlorine > bromine > iodine

The more reactive halogens will take part in more (displacement) reactions.

3 Fluorine will be the most reactive and astatine will be the least reactive, as reactivity decreases down the group.

4 Sample answer (other answers possible).

When chlorine reacts with potassium bromide

$Cl_2(aq) + 2KBr(aq) \rightarrow 2KCl(aq) + Br_2(aq)$

the chlorine atoms form potassium chloride/chloride ions/lose electrons.

The bromide ions form the element bromine/bromine molecules/gain electrons.

5 The trend in reactivity was that the halogens are more reactive near the top of the group. This fits with the displacement reactions, as the halogens near the top of the group can displace halogen/halide ions from solutions of those further down the group, and are therefore more reactive.

Page 2

1

Halogen	Potassium chloride solution	Potassium bromide solution	Potassium iodide solution	**Extra challenge** effect on blue litmus paper
chlorine water	✗	✓	✓	quickly turns blue litmus red then bleaches
bromine water	✗	✗	✓	turns blue litmus red and bleaches very slowly or not at all
iodine water	✗	✗	✗	no change in blue litmus paper

2 chlorine > bromine > iodine

3 The reactivity decreases down the group.

4 Only halogens higher up the group can displace halogen (halide) ions further down the group.

5 It will be the most reactive, as reactivity decreases down the group.

6 It will be the least reactive as reactivity decreases down the group.

7 Because mixing some solutions makes the colour paler as the solution is diluted.

8 React the three halogens with something else (e.g. a metal) and note the difference in reactivity.

SC17c.2 Thinking about halogens

1 a sodium bromide + chlorine → **sodium chloride** + **bromine**

$\mathbf{2NaBr}(aq) + Cl_2(g) \rightarrow 2NaCl(aq) + \mathbf{Br_2}(aq)$

b missing words: displacement, displacing, compound

2 a iodine then bromine then chlorine

b The greater the number of electron shells, the less reactive the halogen, as the incoming electron is less attracted to the nucleus that is further away.

3 Chlorine + sodium iodide will react as chlorine is more reactive than iodine and will displace it from a compound.

H 4 a $F_2(g) + 2NaCl(aq) \rightarrow 2NaF(aq) + Cl_2(aq)$

$F_2(aq) + 2Cl^-(aq) \rightarrow 2F^-(aq) + Cl_2(aq)$

b The sodium ion/Na^+ ion. It can be missed out of the ionic equation as it doesn't change during the reaction.

c This is a redox reaction because electrons are transferred. Fluorine gains electrons so is reduced and sodium chloride loses electrons and so is oxidised.

SC17c.3 Halogen reactivity Strengthen

1 The missing information from the table, from left to right is: bromine; 53; 7; 7; 3; de(creasing); burns quickly/brightly.

The missing words from the sentences are: seven/7; gain; ion; electron; more; decreases; extra.

2 Only chlorine and sodium bromide react as only in this pair is the halogen more reactive/ higher up the group than the halide ion in the compound.

3 a potassium bromide + chlorine → **potassium chloride + bromine**

b **lithium iodide + chlorine** → lithium chloride + iodine

c $\mathbf{2KBr}(aq) + Cl_2(aq) \rightarrow 2KCl(aq) + Br_2(aq)$

d $2NaCl(aq) + F_2(g) \rightarrow \mathbf{2NaF}(aq) + \mathbf{Cl_2}(aq)$

SC17c.4 Halogen reactivity Homework 1

1 a false

b true

c false

d true

2 a The order of increasing reactivity of group 7 elements is $I_2 < Br_2 < Cl_2 < F_2$.

c Fluorine will displace iodine from lithium iodide solution.

3 The halogen fluorine is the … most reactive in the group.

When fluorine reacts it forms … fluoride ions by gaining electrons.

Fluorine atoms have fewer … occupied electron shells than other halogens.

The fluorine atoms gain … electrons more easily than other halogens.

4 a Astatine is less reactive than other halogens as it is at the bottom of group 7 and reactivity decreases down the group.

b Astatine has more electron shells than other halogens so the nucleus has less attraction for outer electrons and will react less easily.

c i sodium + astatine → **sodium astatide**

ii $Br_2(aq) + 2KAt(aq) \rightarrow \mathbf{At_2}(aq) + \mathbf{2KBr}(aq)$

SC17c.5 Halogen reactivity Homework 2

1 iodine < bromine < chlorine < fluorine as the trend is that the reactivity decreases down the group of halogens.

2 Fluorine is more reactive than chlorine because it has fewer electron shells and so has a greater attraction for the electron being added.

3 a More reactive element takes the place of a less reactive element in a compound.

b $Br_2(aq) + 2KI(aq) \rightarrow 2KBr(aq) + I_2(aq)$

4 Chlorine reacts with sodium bromide (bromine does not react with potassium chloride) as only a more reactive halogen, one higher up the group, will react with / displace a less reactive halide ion, one lower down the group, from its compounds.

H 5 a Oxidation is the loss of electrons (by an atom, molecule or ion) and reduction is the gain of electrons (by an atom, molecule or ion); OIL RIG.

b Halogens are usually reduced as they have seven electrons in their outer shell. They will gain one electron to attain a stable outer electron shell, like a noble gas.

H 6 a The chlorine is reduced as it gains electrons.

b $Ca \rightarrow Ca^{2+} + 2e^-$

H 7 a The fluorine molecules are reduced and the bromide ions are oxidised.

b reduction: $F_2(g) + 2e^- \rightarrow 2F^-(aq)$

oxidation: $2Br^-(aq) \rightarrow Br_2(aq) + 2e^-$

8 a An ion that doesn't take part in the reaction or is not changed by the reaction.

b $Br_2(aq) + 2I^-(aq) \rightarrow 2Br^-(aq) + I_2(aq)$

c $Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$ reduction

$2I^-(aq) \rightarrow I_2(aq) + 2e^-$ oxidation

SC17d Group 0

Student Book

1 **a** Density increases down the group.

b Melting point −117 ± 20 °C and boiling point −113 ± 20 °C. Note the boiling point should be 3–5 degrees higher than the melting point (actual melting point −111.9 °C and boiling point −108.1 °C).

c Calculated the increase in melting and boiling point between noble gases as you went down the group. The average was about 40 °C. Added average rise to melting and boiling points of krypton to get values for xenon.

2 **a** Neither reacts with anything easily.

b Nitrogen is made up of molecules containing two atoms. Argon is made up of single atoms.

3 Helium and neon will float as they are less dense than air.

4 Because they were not discovered at that time.

5 **a** xenon < krypton < helium < neon < argon

b Because oxygen gases could be detected reacting with other substances but argon gas doesn't react easily.

6 **a** Helium has a low density so it floats; and it is unreactive so it won't burst into flames or explode.

b Argon will put out the flame as it is unreactive (it is also more dense than air so it will not rise up).

7 Argon electron configuration 2.8.8 has a complete outer shell, so it doesn't need to lose or gain electrons to get a stable electron configuration. Potassium electron configuration 2.8.8.1 has one electron in its outer shell and can lose this one outer electron when it reacts to become an ion with a complete outer shell of electrons.

S1 When the atoms of elements react they can gain, lose or share electrons to get a complete outer shell of electrons. This electron configuration is stable and makes the compounds formed more stable than the elements. Noble gases all have electron configurations that already have a complete outer shell. They are therefore already stable and don't need to gain, lose or share electrons to get a stable electron configuration.

E1 Radon will be: a colourless gas; inert (not react easily); have a low melting point and boiling point (melting point about −117 ± 20 °C and boiling point about −113 ± 20 °C); a poor conductor of heat and electricity; a density above 4.0 g/dm^3 (actual 9.3 g/dm^3).

Exam-style question

a Inert means it does not react easily with anything (1).

b Because it doesn't form bonds (react) easily, (1) so it doesn't bond (join together with) other atoms (1).

Activity and Assessment Pack

SC17d.1 Properties of group 0

2 The order of increasing atomic size, relative atomic mass, boiling point and density is He < Ne < Ar < Kr < Xe.

The atomic size, relative atomic mass, boiling point and density of noble gases increase down the group.

3 The graph should be drawn with labelled axes. Crosses representing boiling points of the noble gases helium to krypton should be shown. The predicted value for xenon's boiling point is −90 ± 50 °C.

4 The graph should be drawn with labelled axes, with either atomic radius (pm) or relative atomic mass or density (g cm^{-3}) on the vertical axis. Crosses representing atomic radius or relative atomic mass or density of the noble gases helium to krypton should be shown.

The predicted values for xenon from the graphs are: atomic radius 120 ± 20 pm; relative atomic mass 127 ± 5 and density 0.0057 ± 0.0005 g cm^{-3}.

5 The most accurate prediction would be the one made using the graph where the scatter points lie closest to the line of best fit.

6 The actual values for xenon are: atomic radius 108 pm; relative atomic mass 131.3; boiling point −106.6 °C and density 0.0059 g cm^{-3}.

The predicted values for relative atomic mass and density are the most accurate.

SC17d.2 Putting out fires

1 Because the water would damage computers/ electronic equipment.

2 inert / unreactive / don't support combustion

3 These gases can produce dizziness / can form toxic substances so people need to leave before the gas is released into the room.

4 Halon gases put the fire out because of chemical reactions between the halons and the gases from the fire. Nitrogen/argon systems work by replacing some of the air in the room so that the fire does not have enough oxygen to continue burning.

5 a The gases have to be in the right concentration in the air in the room. The amount of gas needed to provide this concentration will depend on the volume of the room into which the gas is being released.

b More gas is needed to produce the correct concentration in a larger room. If they used a value that was too large, the concentration in the room would be too high. If this was a nitrogen/argon system, this might reduce the oxygen concentration and suffocate people in the room.

c Too little gas will be released, so the concentration of gas will be too low and it may not be enough to suppress a fire.

6 Because carbon dioxide can suffocate people.

7 Halons: advantages – do not suffocate people; disadvantages – can cause dizziness/produce toxic products, destroy ozone layer.

Carbon dioxide: advantages – cheap; disadvantages – can suffocate people.

Nitrogen/argon: advantages – does not suffocate people or cause giddiness; disadvantages – none given in the article.

8 The gases can be obtained from the atmosphere, but the fact that they have no ill effects on people when in the atmosphere does not necessarily mean that they will have no harmful effects at the higher concentrations used in fire suppression systems.

SC17d.3 Special gases – Strengthen

1 Missing information: **helium:** 2, and drawing of 2 electrons in single shell; **lithium:** drawing of 2 electrons in inner shell and 1 electron in outer shell; **fluorine:** 2.7, and drawing of 2 electrons in inner shell and 7 electrons in outer shell; **neon:** 2.8, and drawing of 2 electrons in inner shell and 8 electrons in outer shell.

2 All group 0 elements have an electronic configuration with a complete/full outer shell.

3 a The lithium electron arrangement changes from 2.1 to 2 and the fluorine electron arrangement changes from 2.7 to 2.8, so both attain an arrangement of electrons like a noble gas.

b The noble gas atoms already have a complete outer shell, which is very stable, and means they are unreactive.

4 low density and unreactive/non-flammable

5 On the graph supplied, crosses representing melting points of the noble gases helium, neon, argon and xenon should be shown. A best fit straight line should be drawn, using the points on the graph.

Predicted melting point of krypton is −160 ± 10 °C (actual melting point = −157 °C).

SC17d.4 Group 0 – Homework 1

1 Missing information:

a **helium:** 2, and drawing of 2 electrons in single shell; **neon:** 2.8, and drawing of 2 electrons in inner shell and 8 electrons in outer shell; **argon:** 2.8.8, and drawing of 2 electrons in inner shell, 8 electrons in middle shell and 8 electrons in outer shell.

b complete

c noble, 8 and 2

d inert, react

2 Argon is used in welding to stop the hot metal reacting with oxygen in the air; linked to: non-flammable and relatively inert.

Helium is used in airships and party balloons; linked to: low density gas, relatively inert and non-flammable.

Argon is used to put out fires in computer rooms; linked to: non-flammable, high density gas and relatively inert.

Argon is used inside filament lamps to stop the hot filament reacting with oxygen; linked to: relatively inert.

3 On the graph supplied, crosses representing boiling points of the noble gases helium, argon, krypton and xenon should be shown. A best fit straight line should be drawn, using the points on the graph.

Predicted boiling point −245 ± 10 °C (actual boiling point = −246 °C).

SC17d.5 Group 0 – Homework 2

1 a D, A, E, H, G, B, C, F

b i A, D and E

ii G and H

iii B

iv C and F

2 **a** neon – 2.8 and argon – 2.8.8

b The electronic configuration of noble gas elements includes a complete outer shell (if another electron is added it goes into a new shell) and this is a stable arrangement that makes them inert.

c The graph should be drawn with labelled axes, and crosses representing densities of the noble gases helium, neon, krypton and xenon. A best fit straight line should be drawn, using the points on the graph. Estimated density for argon
$= 1.8 \pm 0.1$ g dm^{-3}
(actual density = 1.8 g dm^{-3}).

d Because a best fit line can be drawn and an estimate read, using the graph scale.

3 Because xenon has larger atoms than the other noble gases so there is less attraction between the nucleus and its outer electrons and this may make it easier to lose electrons/form bonds.

4 The discovery of helium disagreed with Mendeleev's periodic table because there was no space for it to fit into any of the existing groups. The discovery of other noble gases confirmed the periodic table as they formed a whole new group of elements with similar properties to each other.

SC18a Rates of reaction

Student Book

1 Any sensible suggestion, but those taken from photo A are: faster reaction is burning wood/gas; slower reaction is cooking pizza/bread.

2 The concentration of reactants decreases and the concentration of products increases.

3 Because the concentration of reactants decreases as the reaction proceeds.

4 **a** a gas syringe or a measuring cylinder

b In a reaction that produces a gas, measuring the amount of gas produced relates to the amount of product formed and so it can be used to measure how far the reaction has gone in a certain time interval.

5 The gradient for the graph for the granules is steeper at the start than the graph for the ribbon (and levels off, is finished, faster)

6 **a** the (hydrochloric) acid

b when the gas stops being formed

c The line on the graph starts high on the vertical axis (mass of flask) and goes down rapidly at first, gradually levelling off until the line is parallel to the horizontal axis (time).

7 Because it would be difficult to measure the amount of reactants used up or products formed (because the reaction happens so slowly).

S1 **a** the loss in mass of the reactants (and flask)

b The concentration decreases.

c the volume of gas produced

E1 Diagram of a flask containing magnesium and hydrochloric acid with tubing from a one-hole stopper leading to a gas syringe (as in diagram C). Description to include: measure temperature of acid; add magnesium and stopper; measure volumes of gas in syringe at regular time intervals (or stated time interval); record the results; repeat after warming acid to a higher temperature.

Exam-style question

The electronic balance could be used to measure the change in mass (1) of the reactants (and flask/beaker) as the reaction proceeds. The faster the loss in mass, the faster the reaction (1).

Activity and Assessment Pack

SC18a.1 Investigating rates of reaction

Page 1

1 results of experiment

2 Task 1: If results are good, the graph should show two curves rising steadily and levelling off at about the same point. The curve for the small chips should rise and level off more quickly.

Task 2: If results are good, the graph should show a straight line rising steadily as the concentration increases.

3 Task 1: The graph for larger surface area (to volume ratio), i.e. the smaller chips, rises more quickly at the start and levels off more quickly. Therefore the larger the surface area/smaller the chips, the faster the reaction.

Task 2: The graph for volume of gas produced in one minute against concentration rises steadily. Therefore the higher the concentration, the faster the reaction.

4 Possible sources of error are: measuring the volume of gas (which is difficult because of the bubbles in the measuring cylinder), and making sure the marble chips are all the same size. (Other answers are possible.)

The reliability of the results could be improved in task 1 by measuring the volume of gas more frequently, and in task 2 by measuring the volume of gas produced for a longer period. (Other answers are possible.)

Page 2

1 results of experiment for task 1

2 If results for task 1 are good, the graph should show two curves rising steadily and levelling off at about the same point. The curve for the small chips should rise and level off more quickly.

3 The reactions had finished when the graphs levelled off.

4 For a fixed mass of chips, the smaller the chips the larger the surface area (to volume ratio).

5 The larger the surface area (to volume ratio), the faster the reaction.

6 The graph for larger surface area to volume ratio (smaller chips) rises more quickly at the start and levels off more quickly. Therefore the larger the surface area, the faster the reaction.

7 Possible sources of error are: measuring the volume of gas (which is difficult because of the bubbles in the measuring cylinder) and making sure the marble chips are all the same size. (Other answers are possible.)

8 Measure the volume of gas produced for a longer time, or measure larger volumes of gas. (Other answers are possible.)

9 results of experiment for task 2

10 If results for task 2 are good, the graph should show a straight line rising steadily as the concentration increases.

11 The higher the concentration of the acid, the faster the reaction.

12 The graph for volume of gas produced in one minute against concentration rises steadily. Therefore the higher the concentration, the faster the reaction.

13 Possible sources of error are: measuring the volume of gas (which is difficult because of the bubbles in the measuring cylinder) and making sure the marble chips are all the same size. (Other answers are possible.)

14 Measure the volume of gas produced for a longer time or measure larger volumes of gas. (Other answers are possible.)

SC18a.2 Data analysis on rates

1 a the concentration of the acid

b Three of: the temperature of the solution, the form of the magnesium, the mass of magnesium used and the volume of the acid used.

c The rate of the reaction increases as the concentration increases (the rate of the reaction is directly proportional to the concentration).

2 a the temperature

b Three of: the form of the calcium carbonate, the mass of calcium carbonate, the concentration of the acid and the volume of the acid.

c As the temperature increases, the rate of reaction increases. (A 10 °C rise roughly doubles the reaction rate.)

3 a the surface area (size of solid lumps)

b Three of: the mass of rhubarb, the concentration of potassium manganate(VII), the volume of potassium manganate(VII) and the temperature.

c As the surface area increases (size of pieces decreases), the rate of reaction increases.

4 Graph 1: a straight line rising steadily as the concentration increases

Graph 2: a curve bending upwards as temperature increases

Graph 3: a straight line falling steadily as the surface area increases

5 Graph 1 shows that the rate is directly proportional to the concentration. Double the concentration, and the rate doubles.

Graph 2 shows that the rate greatly increases with increases in temperature. (A 10 degree rise roughly doubles the reaction rate.)

Graph 3 shows that if you double the surface area then the time taken for the solution to go colourless roughly halves. (The rate is directly proportional to the surface area. Double the surface area, and the rate roughly doubles.)

SC18a.3 Rates of reaction Strengthen

1 a concentration, temperature, surface area

b The missing information is: mass, carbon dioxide, flask, reactants, volume, decrease.

2 a temperature

b Three of: the form/surface area/size of the chips of calcium carbonate, the mass of calcium carbonate, the concentration of the acid and the volume of the acid.

c As the temperature increases the time to produce the set loss in mass decreases quickly, so increasing temperature greatly increases the rate of the reaction.

SC18a.4 Rates of reaction Homework 1

1 a graph A

b Graph A shows the fastest reaction, as the line rises more steeply (levels off more quickly), so this must be the higher temperature.

2 nickel chloride, water

3 The labelled diagram should show a stoppered flask containing nickel carbonate and hydrochloric acid, with a delivery tube leading to a measuring cylinder upside down in a beaker of water. The flask should be in a water bath.

4 volume of gas produced (in a set time), temperature

5 concentration (or volume), nickel carbonate

6 The lines become less steep as the reactions slow down, because the concentration of the acid decreases. The graphs level off when (one of) the reactants has been used up.

SC18a.5 Rates of reaction Homework 2

1 the mass of calcium carbonate chips and the volume of hydrochloric acid

2 The shorter the time (to produce 0.5 g of gas), the faster the rate of the reaction.

3 a Increasing concentration increases the rate of the reaction, and doubling the concentration doubles the rate.

b Experiments 1, 2 and 3 show that as the concentration of the acid is doubled (and all other variables are kept constant) the time roughly halves, which means the rate must be twice as fast.

4 a the powder

b Increasing the surface area (to volume ratio) increases the rate of the reaction.

c Experiments 2, 4 and 5 (with all other variables constant) show that the larger surface area (powder) reacts faster. The time taken to produce the set loss in mass is smallest with powder and greatest with large chips.

5 a The graph should be drawn using experiments 1, 6, 7 and 8, and should show a downward curve, as time decreases as temperature increases.

b The graph shows that the rate of reaction increases (greatly) as the temperature increases.

c The rate almost doubles with every 10 degrees rise in temperature.

6 So that the reaction is completed in a reasonable time. The powder reaction would be over too quickly at higher temperatures.

7 Because the reactions would be too quick and the hot acid would be very dangerous (corrosive).

8 $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

9 5 moles of calcium chloride, 5 moles of water and 5 moles of carbon dioxide

SC18b Factors affecting reaction rates

Student Book

8th 1 The molecules must collide and have enough energy (the activation energy).

9th 2 Because the molecules don't have enough energy (the activation energy).

8th 3 The activation energy is the minimum amount of energy needed by the reactant particles to react on collision.

10th 4 Reducing the energy of the molecules and reducing the number of collisions would make the reaction slower.

7th 5 a wood dust

8th b The wood dust is the form that contains the smallest pieces of wood that have the largest surface area to volume ratio, so the most collisions occur.

8th c The wood would burn faster in pure oxygen as the concentration of oxygen is greater, and so more collisions occur.

9th 6 a $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

7th b Decreasing the gas pressure reduces the rate of reaction, as fewer collisions occur because the particles are further apart.

10th c Increasing the temperature increases the rate of reaction, as the particles have more energy and move about faster, so more collisions occur and more molecules have enough energy (the activation energy) to react on collision.

6th 7 Because the particles in gases are further apart so fewer collisions occur.

S1
- Increasing the concentration increases the rate of reaction, because more collisions occur.
- Decreasing the size of pieces of solid increases the rate of reaction, as the surface area to volume ratio is greater, and so more collisions occur.
- Increasing the temperature increases the rate of reaction, as more collisions occur and more reactant particles have enough energy to react when they collide.

E1 The rate of reaction between iron lumps and oxygen can be increased by:

1. increasing the concentration of oxygen (using pure oxygen) so more collisions occur
2. increasing the pressure, so oxygen molecules are closer together and more collisions occur
3. decreasing the size of the iron lumps, so the surface area to volume ratio increases and more collisions occur
4. increasing the temperature, so the particles have more energy, more collisions occur and more reactant particles have enough energy to react when they collide.

Exam-style question

The powdered chalk has a larger surface area to volume ratio than the lumps of chalk (1). This means more collisions occur between the acid particles and the chalk (1). More collisions mean that the reaction occurs more quickly (1).

SC18b Core practical – Investigating reaction rates

1 calcium carbonate + sulfuric acid (1)
→ calcium sulfate + water (1)

$CaCO_3(s) + H_2SO_4(aq)$ (1)
$\rightarrow CaSO_4(aq) + H_2O(l)$ (1)

2 **a** The dependent variable is the volume of carbon dioxide gas produced (with time) (1) and the independent variable is the size of the pieces of marble chips (or the surface area to volume ratio) (1).

b Two of: concentration; type of acid; temperature (2 × 1 mark).

3 **a** So that no gas is lost/so that we measure all the gas produced (1).

b electronic balance, measuring cylinder (1)

4 **a** It is finished in 5 (five) minutes (1), as at this point the graph levels off, which means no more gas is being formed (1).

b The graph for the smaller chips would have a similar shape to the graph for large chips but would rise faster (1) and level off at the same point, more quickly than the given large chips graph (1).

c the average rate = $\frac{40}{5}$ (1) = 8 cm^3/min (1)

d Find the point on the curve at 100 second, and draw the tangent line to the curve at the point. (1)

Choose two points on the tangent line where it is easy to read the time and volume, and calculate the change in volume that occurs for that change in time. (1)

Calculate the rate by dividing the change in the volume by the change in time. (1)

5 Add instruction between steps B and C: Measure and record the temperature of the acid (1). Change instruction step F: Repeat the experiment, using acid solutions at different temperatures (1).

6 the concentration of the acid (1)

7 to calculate the average temperature during the reaction (1), as the temperature will change during the reaction (1)

8 **a** The cross disappears because the precipitate (solid) settles at the bottom of the flask. (1)

b Vertical axis: 'Time for cross to disappear (s)' (1); horizontal axis: 'Average temperature (°C)' (1) sketch shows line starting high and curving downwards getting less steep as it gets closer to the horizontal axis (1).

c As the temperature increases the time taken decreases (1) so the reaction is getting quicker as less time is needed to get to the same point (1). (An approximate 10 °C rise in temperature halves the time taken, so doubles the reaction rate.)

d by repeating the experiment (at the same temperatures) and averaging the results (1)

Activity and Assessment Pack

SC18b.1 Temperature and reaction rates

1 Students' own tables of results

2 Graph should show a curve, with time decreasing quickly as temperature increases.

3 **a** The rate increases quickly as the temperature increases.

b The graph shows that, as the temperature rises, the time for the reaction decreases – which means the rate of reaction increases.

4 The time taken would halve.

5 **a** 10 degrees

b Students' own results. Students should choose any temperature on the graph and note the time taken for the cross to disappear. The temperature that caused the cross to disappear in half that time (double the rate) is about 10 °C.

6 Any two of the following measurements: temperature, time and volume of solutions.

7 Errors with recording temperature and time could be reduced by repeating the experiment more often. Errors with measuring volume of solution could be reduced by using burettes and/or pipettes. (Other answers are possible.)

SC18b.2 Explaining collisions Strengthen

1 If there are more particles, the reactant particles are closer together, therefore collisions occur more frequently.

2 Collisions occur more frequently.

More particles have enough energy to react when they collide.

3 Increasing the surface area (decreasing the lump size of the solid) while keeping the total volume/mass constant makes the reaction faster because there is more surface for collisions and so collisions occur more frequently.

SC18b.3 Factors affecting reaction rates – Extend

1 a New diagram drawn with more oxygen molecules in the same area.

Label similar to: molecules of oxygen closer together, so collisions occur more frequently and reaction is faster.

b New diagram drawn with iron atoms broken into two or more blocks.

Label similar to: more surface area for oxygen to get at iron, so collisions occur more frequently and reaction is faster.

c Increasing the temperature increases the rate of a reaction, because the reactant particles have more energy/speed, so more collisions occur and more particles have enough energy to react when they collide.

2 a As the pressure is increased, the molecules get closer together.

b As the molecules are closer together, collisions occur more frequently and the reaction is faster.

3 a $2HCl(aq) + CaCO_3(s)$
$\rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

b The graph curves upwards, getting less steep and finally levelling off at five minutes.

c At the start the reactant concentrations are greatest, so collisions occur more frequently and the reaction is fastest.

d As the reaction is finished (as one of the reactants is used up).

e The second graph would rise and level off more quickly, but would finish at the same level.

f 23.0 cm^3/min ± 2.0

g 11.2 cm^3/min ± 0.5

SC18b.4 Factors affecting reaction rates – Homework 1

1 a concentration

b temperature

c surface area

d gas pressure

2 a From left to right, the missing words are: chlorine, hydrogen chloride, energy.

b hydrogen, collide, energy, activation energy, increases, frequently, decreases, less, energy

3 a Mince is made up of smaller pieces with a larger surface area, so collisions occur more frequently and those that do take place are more likely to have enough energy.

b In the fridge, at lower temperature, particles have less energy, collisions occur less frequently and fewer particles have enough energy to react.

c At higher pressure, particles are closer together, so collisions occur more frequently and the reaction is faster (explosion).

SC18b.5 Factors affecting reaction rates – Homework 2

1 concentration, temperature, surface area, pressure

2 a A chemical reaction occurs when reactant particles collide with enough energy (activation energy).

b Smaller marble chips have a larger total surface area, so there is more space for collision. Therefore, collisions occur more frequently and the reaction is faster.

3 The diagram of low pressure contains a number of molecules of hydrogen and chlorine. The diagram of the higher pressure has the same number of each molecule in a smaller space.

Explanation: At the higher pressure the molecules are closer together, so collisions occur more frequently and the reaction is faster.

4 a The best-fit line curves downwards and levels off at 12 minutes.

b Because a gas (carbon dioxide) is produced and lost to the surroundings.

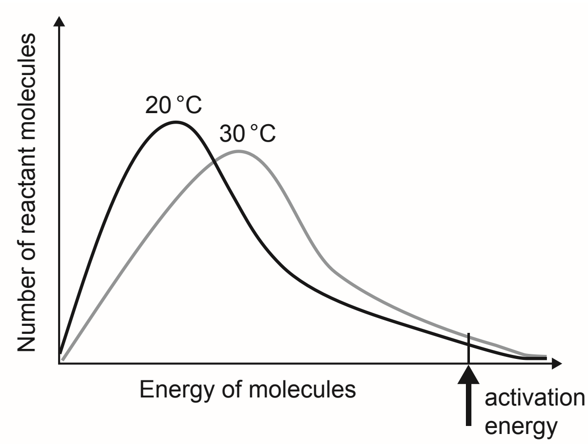
c At higher concentrations the graph would be steeper and the mass loss faster, because there would be more collisions and a faster reaction.

d 0.25 g/min ± 0.02

e 0.08 g/min ± 0.01

5 a Because there are very few molecules with energy at or above the activation energy.

b



c The graph for the higher temperature shows that more molecules have energy at or above the activation energy, so more molecules can react when they collide and the reaction is faster.

SC18c Catalysts and activation energy

Student Book

7th 1 By allowing reactions to occur at lower temperatures and pressures, the catalyst reduces the energy cost required to increase temperatures and pressures.

7th 2 Because the catalyst (platinum) is not used up and can be used again and again.

6th 3 By measuring the mass of manganese dioxide added at the start and comparing it to the mass of manganese dioxide collected (and dried) at the end.

9th 4 A reaction with a low activation energy will be faster as more of its reactant particles (molecules) will have enough energy to react on collision, so more successful collisions will occur.

6th 5 The overall energy change (from reactants to products) is the same.

7th 6 a So the catalyst has a large surface area.

8th b Because a catalyst is not used up (not permanently changed).

6th 7 a Zymase, which helps change glucose into ethanol (alcohol); or amylase, which helps change starch into simple sugars. (Other examples possible.)

9th b An enzyme works because its shape (active site) fits the reacting molecules (substrate) like a key in a lock. The enzyme won't fit in other reactant molecules so won't work in other reactions.

11th 8 Heating a catalysed reaction gives the reactant particles (molecules) more energy. They therefore move faster and collide more often and more of them have enough (activation) energy (more successful collisions occur).

Heating a reaction helped by an enzyme could denature the enzyme, changing its shape so it will no longer fit the reactants so the reaction won't take place.

S1 Catalysts and enzymes speed up chemical reactions by providing an alternative reaction route, with a lower activation energy so more of the reactant particles (molecules) have enough (activation) energy and more will react on collision.

Catalysts and enzymes are useful in industry as they make the product more quickly and save energy costs by allowing the reaction to take place at lower temperatures and pressures.

E1 Both speed up reactions by providing different reaction routes which need less (activation) energy.

Most chemical catalysts work at a range of temperatures and pressures (the reaction is faster the higher the temperature and pressure) while biological catalysts (enzymes) work best at specific temperatures and pHs, as changes in conditions alter the shape of the enzyme molecule so it no longer (fits) works.

Exam-style question

a A catalyst speeds up a reaction by lowering the activation energy (1), so more molecules have enough energy to react when they collide and more successful collisions (collisions with enough energy) occur (1).

b Increasing the temperature gives the reactant molecules more energy (1) (so they move faster and collide more often), so more of them have the required activation energy so more successful collisions (collisions with enough energy) occur (1).

Activity and Assessment Pack

SC18c.1 Investigating catalysts

1 Students' own table of results

2 From most effective catalyst to least effective: manganese(IV) oxide, copper(II) oxide, iron(III) oxide, zinc oxide, aluminium oxide.

3 The one that produced the most bubbles of oxygen was the best catalyst, and the one that produced the least bubbles was the worst catalyst.

4 **a** To make the test fair (because changing these variables could affect the amount of bubbles produced).

b The volume of hydrogen peroxide was accurate but the amount of catalyst was not very accurate.

c Measure the same mass of catalyst each time.

5 **a** not very sure

b Collect the gas in a gas syringe/measuring cylinder as it is produced and measure the volume of gas collected in a certain time.

SC18c.2 Catalytic converters

1 to reduce pollution/emission of poisonous gases

2 Two of: platinum, rhodium and palladium.

3 **a** carbon monoxide (CO), nitrous oxide or dinitrogen oxide (N_2O) and methane (CH_4)

b carbon dioxide (CO_2), nitrogen (N_2) and water (H_2O)

4 It is poisonous (blocks oxygen uptake by red blood cells).

5 **a** carbon monoxide + nitrogen oxide → carbon dioxide + nitrogen

$CO + N_2O \rightarrow CO_2 + N_2$

b $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

6 **a** Larger surface area, so more collisions with reactants occur.

b They are expensive.

c Increased temperatures increase reaction rates.

7 **a** Bar chart with data from the table for different cars, side by side, for each of the gases produced.

b The catalytic convertor reduces the amount of carbon monoxide, nitrogen oxides and unburnt hydrocarbons, but the amount of carbon dioxide stays the same.

c Diesel emissions contain less carbon monoxide and unburnt hydrocarbons but more oxides of nitrogen (and more carbon particles).

SC18c.3 Catalysts and activation energy – Strengthen

1 increases, used up, unchanged, living, catalyst

2 **a** Missing labels, left to right: reactants and activation

b Dotted line starting and finishing at the same points as the given graph, with a peak somewhere below the given graph.

c Arrow starting level with the energy level of the reactants, pointing up to a line which is level with the peak of the drawn catalysed reaction graph, labelled 'activation energy of the catalysed reaction'.

d The activation energy of the catalysed reaction is lower, so more molecules have enough energy and react on collision, and the reaction is faster.

3 active, substrate, key, energy, reused

SC18c.4 Catalysts and activation energy – Homework 1

1 Catalysts are used to ... speed up chemical reactions.

Catalysts allow chemical reactions to ... happen at lower temperatures.

Catalysts can be used again and again ... because they are not used up.

Catalysts work by lowering ... the activation energy.

Using a catalyst means more molecules ... have enough energy needed for reaction.

2 **a** Arrow starting level with the energy level of the reactants, going up to level with the peak of the catalysed reaction graph, labelled 'activation energy of the catalysed reaction'.

b Dotted line starting and finishing at the same points as the given graph, with a peak somewhere above the given graph.

c higher, fewer, energy, reaction, slower

3 **a** enzyme
b active site
c denatured
d substrate

SC18c.5 Catalysts and activation energy – Homework 2

1 **a** $4CO + 2NO_2 \rightarrow 4CO_2 + N_2$
b A catalyst speeds up a chemical reaction by providing a different reaction path that requires a lower activation energy. This speeds up the reaction, because more molecules have enough energy to react, and more collisions result in a reaction. The catalyst is not used up during the reaction and is left at the end, so it can be used again.

2 **a** scatter graph of data in table
b ZnO is less effective than CuO, which is less effective than MnO_2. Explanation: The most effective catalysts produce a larger volume of gas in a set time.
c Four of: volume of hydrogen peroxide, concentration of hydrogen peroxide, volume of metal oxide and form of metal oxide.
d Measure and use the same mass of metal oxide each time.

3 **a** Both enzymes and catalysts speed up chemical reactions by lowering the activation energy of the reaction. Catalysts work faster at higher temperatures and are unaffected by pH changes. Enzymes, which catalyse specific biological reactions, work best at particular temperatures and pH values.
b Dotted line starting and finishing at the same points as the given graph, with a peak somewhere above the given graph.
c Labelled activation energy of the reaction with an enzyme: arrow starting level with the energy level of the reactants, going up to level with the peak of the original enzyme reaction graph.

Labelled activation energy of the reaction without the enzyme: arrow starting level with the reactants, going up to level with the peak of the self-drawn graph of the reaction without enzyme.

Labelled overall energy change of both reactions: arrow starting level with the reactants going down to level with the products.
d The reaction is slower without the enzyme, because the activation energy is higher, so fewer molecules have enough energy, so fewer collisions result in a reaction.

4 **a** Inhibitors work by changing the reaction pathway to one with a higher activation energy, so the reaction is slower.
b Any suggestion where a slower reaction would be an advantage, e.g. preventing the discolouration of paint, the ageing of plastics or the oxidation of oils.

SC19a Exothermic and endothermic reactions Student Book

8th **1** They transfer energy to the surroundings; by heating; by light.

9th **2** The energy level of the reactants is higher than the products/the arrow points downwards in an exothermic reaction; the energy level of the reactants is lower than the products/the arrow points upwards in an endothermic reaction.

10th **3** diagram with upwards arrow labelled 'Energy' or 'Heat energy'; horizontal arrow labelled 'Progress of reaction'; lower line labelled 'citric acid + sodium hydrogen carbonate'; higher line labelled 'sodium citrate + water + carbon dioxide'; arrow pointing upwards between these two lines labelled 'energy taken in'

8th **4** These reduce energy transfers between the reaction mixture and the surroundings; insulators.

9th **5** The temperature should increase; because the reaction is used in the self-heating can; it is exothermic.

S1 Use a polystyrene cup; with a lid; steadied in a beaker; use a thermometer to measure the temperature; record the temperature before mixing the reactants; record the temperature after the reaction finishes/maximum or minimum temperature obtained; if the temperature goes up it is an exothermic reaction; if the temperature goes down it is an endothermic reaction.

E1 Volume of solution; concentration of solution; mass/amount of solid reactant used; these variables affect the amount of energy transferred; particle size of solid reactant; affects rate of energy transfer; starting temperature of solution; affects rate of energy transfer to or from the reaction container and so measured temperature change.

Exam-style question

Temperature decreases (1), so the reaction must be endothermic/energy is taken in from the surroundings (1).

Activity and Assessment Pack

SC19a.1 Investigating displacement reactions

1 Results recorded in a suitable table.

2 Temperature change for each metal powder calculated correctly.

3 No change in temperature, because there was no reaction/copper cannot displace itself.

The other reactions are exothermic because the temperature of the reaction mixture increased.

4 Metals placed in order of decreasing temperature change, e.g. Mg, Zn, Fe, Cu. (Zn might come first.)

Compared with reactivity series, Mg, Zn, Fe, Cu; differences identified, if any (e.g. Zn may be placed first if the magnesium powder has oxidised on storage).

5 Polystyrene is a poor conductor of heat/an insulator; air gap between the cup and beaker.

6 Improvement given with explanation, e.g. add a lid to reduce convection; wrap more insulation around the cup to reduce conduction; carry out the experiment in a vacuum flask to reduce conduction and radiation.

SC19a.2 Using exothermic and endothermic reactions

3 Organised pile for hand warmer:

a	iron + oxygen → iron(III) oxide
a	$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
b	The reaction is exothermic.
b	The reaction gives out heat energy to the surroundings.
b	The reaction mixture reaches 40 °C.
c	The reaction is started by opening an airtight container.
c	Sodium chloride and water are included to speed up rusting.
d	A hot powder similar to rusted iron is left at the end.

Organised pile for cold pack:

a	barium hydroxide + ammonium thiocyanate → barium thiocyanate + water + ammonia
a	$Ba(OH)_2(s) + 2NH_4SCN(s) \rightarrow Ba(SCN)_2(s) + 2H_2O(l) + 2NH_3(g)$
b	The reaction is endothermic.
b	The reaction takes in heat energy from the surroundings.
b	The reaction mixture reaches –25 °C.
c	The reaction is started by mixing the solids together.
d	A cold corrosive slush is left at the end.
d	Ammonia gas is toxic and causes skin burns.

4 The endothermic reaction might not be suitable for a cold pack because it gets very cold/too cold; a corrosive slush is left at the end; ammonia gas is produced, which is toxic and causes skin burns.

Both reactions allow only a single use, so the products and their packaging create waste.

SC19a.3 Exothermic and endothermic reactions – Strengthen

1 Table completed correctly:

	Exothermic	Endothermic
Heat energy is given out	✓	
Heat energy is taken in		✓
Temperature goes up	✓	
Temperature goes down		✓

2 a Heat energy is given out; and the temperature goes up/increases.
b Heat energy is taken in; and the temperature goes down/decreases.

3 a thermometer
b start temperature; end temperature
c Look at the difference between the two measurements; temperature should increase.

4 Ticks placed in all three boxes.

5 The temperature goes down/decreases.

SC19a.4 Investigating heat energy changes – Homework 1

1 D

2 a 24.6 Celsius degrees
b Exothermic; because the temperature went up/increased.
c To mix the reactants/make sure the reaction was complete; to obtain an accurate temperature reading/make sure the mixture was an even temperature.
d Add a lid/more insulation; to reduce heat losses/energy transfers from the reaction mixture.

3 precipitation

4 not enough sodium chloride dissolved/too much water/thermometer resolution too low

SC19a.5 Reactions and heat energy changes – Homework 2

1 a displacement/redox
b 24.6 Celsius degrees
c Exothermic; because the temperature went up/increased.
d To mix the reactants/make sure the reaction was complete; to obtain an accurate temperature reading/make sure the mixture was an even temperature.
e Add a lid/more insulation; to reduce heat losses/energy transfers from the reaction mixture.

2 not enough sodium chloride dissolved/too much water/thermometer resolution too low

3 a $Mg(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + MgCO_3(s)$
b i Endothermic, because heat energy is taken in from the surroundings.
ii (Some of) it is transferred to the reacting ions.
iii The temperature goes down/decreases; because energy is transferred from the surroundings.

4 a 0.100 kg
b 0.100 × 4180 × 5.5 = 2299 J
= 2.3 kJ to 2 significant figures
c heat losses/energy transfers from the reaction mixture; so the temperature rise is less than expected

SC19b Energy changes in reactions

Student Book

9th 1 The spark or flame provides the activation energy; the minimum energy needed to start the reaction.

9th 2 Activation energy is shown as a curved line/‘hump’; that goes higher than the reactants in an exothermic reaction/higher than the products in an endothermic reaction.

10th 3 Bond making gives out energy; bond breaking takes in energy; combustion is exothermic because more energy is given out (in bond making) than is taken in (for bond breaking); so energy is given out overall.

4 H energy in = (2 × 436) + 498
= 1370 kJ mol^{-1};
energy out = (4 × 464) = 1856 kJ mol^{-1};
overall energy change
= 1370 – 1856 = –486 kJ mol^{-1}

S1 Energy is taken in to break bonds; energy is given out when bonds are made. Bond breaking is endothermic; bond making is exothermic. In exothermic reactions more energy is given out in bond making than is taken in for bond breaking; in endothermic reactions more energy is taken in for bond breaking than is given out in bond making.

S2 Reaction profiles show (heat) energy on the vertical axis; progress of reaction on the horizontal axis; energy level of reactants; energy level of products; activation energy; overall energy change in the reaction; whether the reaction is exothermic or endothermic.

E1 energy in = (3 × (C–H)) + (C–O) + (O–H) + (1.5 × (O=O))
= (3 × 413) + 358 + 464 + (1.5 × 498)
= 1239 + 358 + 464 + 747
= 2808 kJ mol^{-1}

energy out = (2 × (C=O)) + (4 × (O–H))
= (2 × 805) + (4 × 464)
= 1610 + 1856
= 3466 kJ mol^{-1}

energy change = 2808 − 3466 = −658 kJ mol^{-1}

Exam-style question

The energy needed to break bonds in the reactants is greater (1) than the energy released when bonds are made in the products (1).

Activity and Assessment Pack

SC19b.1 Energy transfers and bonds

2

Reaction	a	b	c
1	864	679	endothermic
2	1895	1954	exothermic
3	2144	2354	exothermic
4	3508	3354	endothermic

3 If the C–H bond is 435 kJ mol^{-1}; the total energy in the reactants is 1983 kJ mol^{-1}; so answer **a** becomes greater than answer **b**; and the reaction is endothermic (not exothermic).

SC19b.2 Drawing reaction profiles

Students create the profile for each reaction.

SC19b.3 Energy changes in reactions Strengthen

1

	Reactants	Products
Bonds break	✓	
Bonds form		✓
Energy transferred to the substances	✓	
Energy transferred to the surroundings		✓

2 a Energy transferred to substances/ reactants; to break bonds.

b Energy transferred to surroundings; as bonds form in products.

3 a **less** crossed out

b In an endothermic reaction, less energy is given out than is taken in from the surroundings.

4 a Completed diagram will be the same as the left-hand diagram B in the Student Book, to show: ‘Progress of reaction’ on horizontal axis; ‘Heat energy’ on vertical axis; higher part of the line extended to the right with a dashed line and labelled ‘reactants’; lower part of the line extended to the left with a dashed line and labelled ‘products’; downwards arrow from the level of the reactants line to the level of the products line and labelled ‘overall energy change’; horizontal dashed line at the top of the hump; upwards arrow from the level of the reactants line to the top of the hump and labelled ‘activation energy’.

b Exothermic reaction; reactants line is higher than products line.

SC19b.4 Reactions and energy changes – Homework 1

1 a making of bonds

b breaking of bonds

2 The reactants contain more heat energy than the products; the difference in energy between them is given out.

3 minimum amount of energy needed by reacting particles for a reaction to happen

4 a Diagram (similar to right-hand diagram B in the Student Book) showing: ‘Progress of reaction’ on horizontal axis; ‘Heat energy’ on vertical axis; first horizontal line lower than last part of line; ‘N_2(g) + O_2(g)’ on