BEST STEPS GCSE:

Student Transitions to Enable Progress in Science

Chemistry

- *Fractional distillation of crude oil*
- *Structure and properties of matter*
- *Understanding chemical equations*
- *Energy changes*
- *Rates of reaction*
- *Bonding*
- *Periodic Table*
- *Atmospheric pollutants*

By Helen Harden

The Association for Science Education
Promoting Excellence in Science Teaching and Learning

BEST
Best Evidence Science Teaching

Welcome to BEST STEPS...

How to use the BEST STEPS GCSE resource:

BEST STEPS (Student Transitions to Enable Progress in Science) GCSE consists of a set of teaching progressions for biology, chemistry and physics. These use diagnostic questions from the Best Evidence Science Teaching (BEST) Project and GCSE examination questions to check student understanding of some key scientific concepts.

BEST STEPS GCSE facilitates an individualised approach by using formative assessment to identify the educational needs of students. This enables support to be provided to some students to address gaps in their understanding. Extension material may be offered to those students identified as having secure understanding, to ensure that they are not held back. Appropriate extension material could involve the application of understanding of a key concept to an unfamiliar context.

All GCSE subject content in this resource has been taken from the Department for Education subject guidelines (upon which all specifications in England are based), meaning that this resource is suitable for all GCSE specifications. The topics selected are studied by all students regardless of tier and are required for both combined science and triple science specifications. However, the science concepts developed are universal, so the resource can also be used to support students studying for equivalent qualifications in other countries.

Introducing the Best Evidence Science Teaching (BEST) resources:

Best Evidence Science Teaching (BEST) is a collection of free research evidence-informed resources for effective teaching of difficult ideas, embedded formative assessment and adaptive lesson planning. It is initially focused on science at ages 11-14, although new materials are now being written to extend BEST to support students aged 11-16.

Research evidence-informed progression toolkits for key concepts in science are available free to download from the BEST website.

Each progression toolkit includes:

- appropriately-sequenced learning steps;
- diagnostic questions that provide evidence of learning and of common misunderstandings; and
- response activities that promote purposeful practical work, metacognition and conceptual progression.

If you are unfamiliar with the BEST resources, a short introduction may be downloaded from the BEST website here. You may also find it helpful to watch an introductory webinar on the project - "Introduction to Best Evidence Science Teaching (BEST)" - which can be found in the "Secondary (11-19) science education" section here on the ASE website.

Welcome to BEST STEPS...

How to use the BEST STEPS GCSE resource:

The eight topics may be used in any order so use the topics in the order that works best for your students. The resource provides a sequence of three questions for each topic, which together develop conceptual understanding of a key concept. Give your students the introductory question to start with. If students are successful give them the next question. If students have not grasped the introductory level idea, provide additional material or teaching that will develop their understanding, before continuing to the next question in the progression. Use the final GCSE question to check that your students can apply their conceptual understanding at GCSE level.

How to navigate the Best Evidence Science Teaching (BEST) resources

For your convenience, the BEST diagnostic questions used in these progressions are hyperlinked from each topic page - just click on the question image.

The BEST resources are categorised into "big ideas", with the "big ideas" in chemistry being:

- *Substances and properties (CSU)*
- *Particles and structure (CPS)*
- *Chemical reactions (CCR)*
- *Earth chemistry (EEA)*

Use the three letter codes to help you navigate the full set of resources on the BEST website. Here you will find response activities for each diagnostic question used in BEST STEPS GCSE 11-14 subject maps and much more.

Using the GCSE questions

Clicking on the image of each GCSE question will bring up a word version of the question, guidance on how this can help to identify gaps in your students' understanding and the official mark scheme.

Acknowledgements

All BEST resources are free to download thanks to the support of the Salters' Institute and a partnership with STEM Learning. ASE is grateful to OCR for permission to use its questions in this resource.

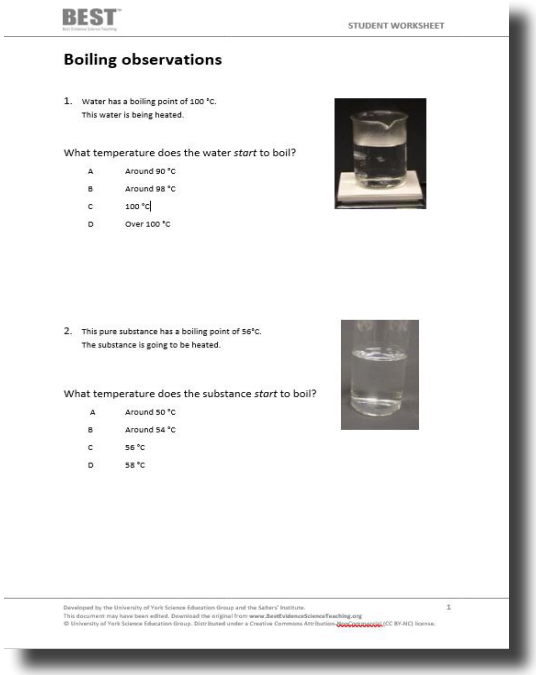
Fractional distillation of crude oil

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept CSU1.1:
Substance

A chemical substance has a characteristic melting point and boiling point and can exist in different states.



BEST

STUDENT WORKSHEET

Boiling observations

1. Water has a boiling point of 100 °C.
This water is being heated.

What temperature does the water *start* to boil?

A Around 90 °C
B Around 98 °C
C 100 °C
D Over 100 °C

2. This pure substance has a boiling point of 56°C.
The substance is going to be heated.

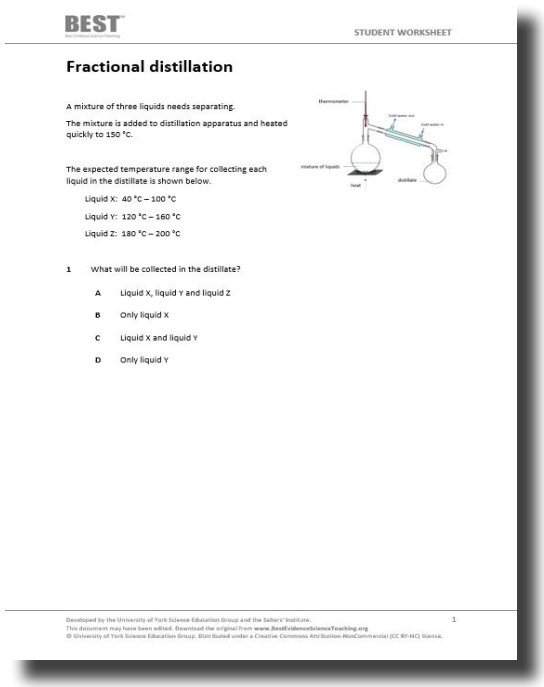
What temperature does the substance *start* to boil?

A Around 50 °C
B Around 54 °C
C 56 °C
D 58 °C

Consolidating...

BEST Key concept CSU1.3:
Separating solutions

Change of state may be used to separate solutions.



BEST

STUDENT WORKSHEET

Fractional distillation

A mixture of three liquids needs separating.

The mixture is added to distillation apparatus and heated quickly to 150 °C.

The expected temperature range for collecting each liquid in the distillate is shown below.

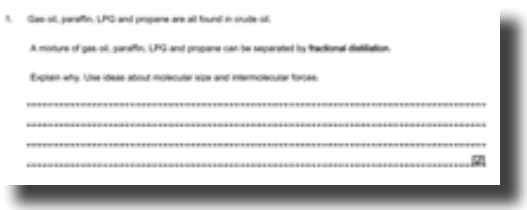
Liquid X: 40 °C – 100 °C
Liquid Y: 120 °C – 160 °C
Liquid Z: 180 °C – 200 °C

1 What will be collected in the distillate?

A Liquid X, liquid Y and liquid Z
B Only liquid X
C Liquid X and liquid Y
D Only liquid Y

Securing...

GCSE Subject content:
Fractional distillation of crude oil



1. Gas oil, paraffin, LPG and propane are all found in crude oil.

A mixture of gas oil, paraffin, LPG and propane can be separated by **fractional distillation**.

Explain why. Use ideas about molecular size and intermolecular forces.

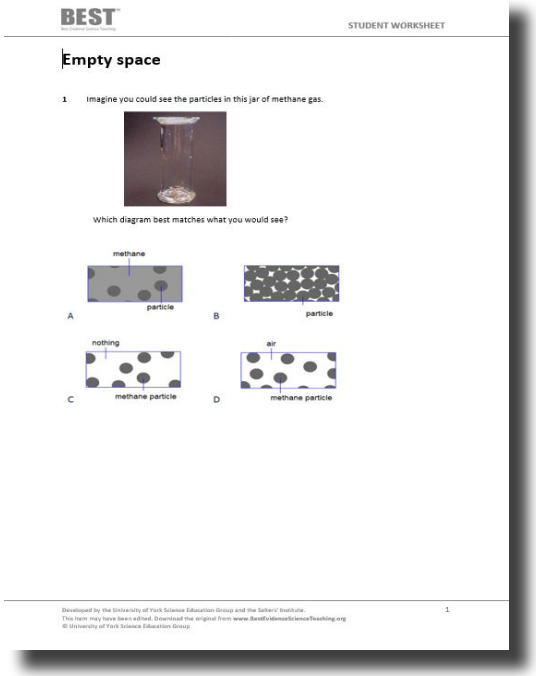
Structure and properties of matter

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept CPS1.1:
Particle model for the solid, liquid and gas state

The particle model of matter can explain the properties of substances in the solid, liquid and gas states.


BEST
STUDENT WORKSHEET

Empty space

1 Imagine you could see the particles in this jar of methane gas.

Which diagram best matches what you would see?

methane particle
A
B particle
nothing
C methane particle
air
D methane particle

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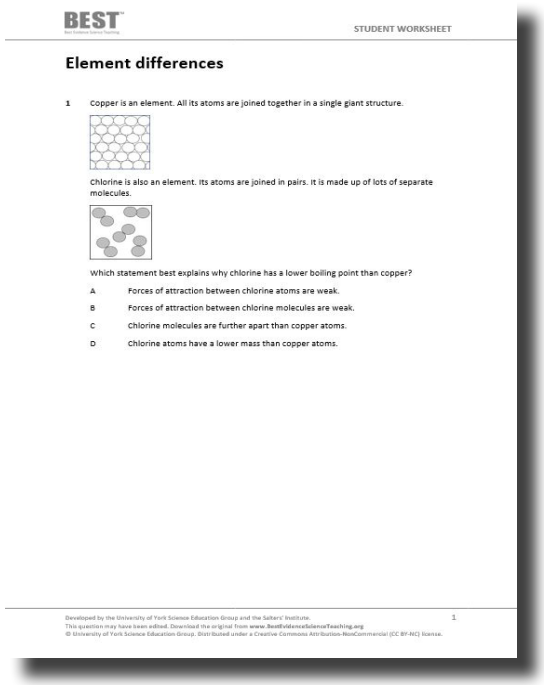
Consolidating...

BEST Key concept CPS2.1:
Atoms and molecules

The properties of elements and compounds arise from the structural arrangement of their constituent atoms.


BEST
STUDENT WORKSHEET

Element differences

1 Copper is an element. All its atoms are joined together in a single giant structure.

Chlorine is also an element. Its atoms are joined in pairs. It is made up of lots of separate molecules.

Which statement best explains why chlorine has a lower boiling point than copper?

A Forces of attraction between chlorine atoms are weak.
B Forces of attraction between chlorine molecules are weak.
C Chlorine molecules are further apart than copper atoms.
D Chlorine atoms have a lower mass than copper atoms.

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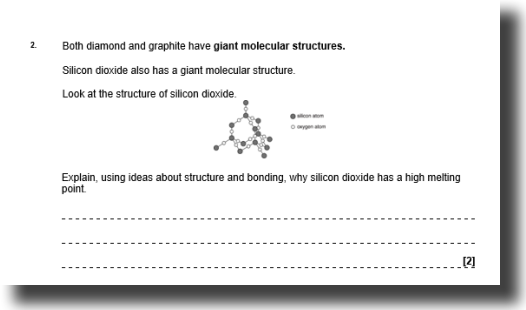
Securing...

GCSE Subject content:
Structure and properties of matter

The structure of a substance and the relative strength of chemical bonds and intermolecular forces explain the different temperatures at which changes of state occur.


2. Both diamond and graphite have **giant molecular structures.**

Silicon dioxide also has a giant molecular structure.

Look at the structure of silicon dioxide.

silicon atom
oxygen atom

Explain, using ideas about structure and bonding, why silicon dioxide has a high melting point.

[2]

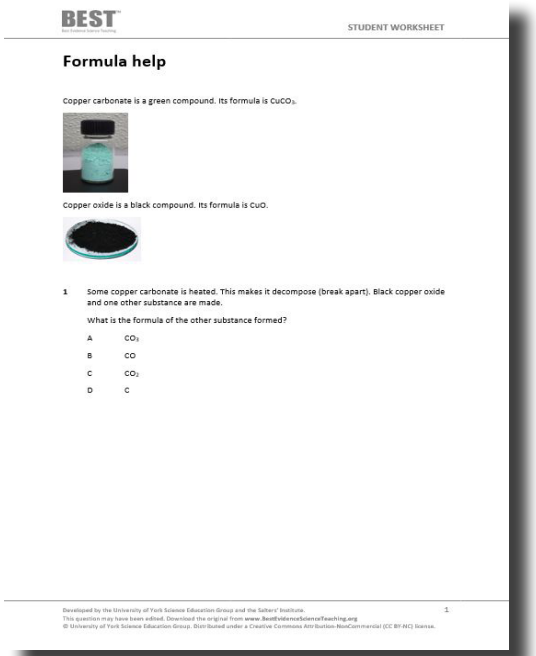
Understanding chemical equations

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept CPS3.1: Rearrangement of atoms

During a chemical reaction, atoms are rearranged and a new substance (or substances) are formed with different properties.



BEST STUDENT WORKSHEET

Formula help

Copper carbonate is a green compound. Its formula is $CuCO_3$.

Copper oxide is a black compound. Its formula is CuO.

1 Some copper carbonate is heated. This makes it decompose (break apart). Black copper oxide and one other substance are made.

What is the formula of the other substance formed?

A CO_3
B CO
C CO_2
D C

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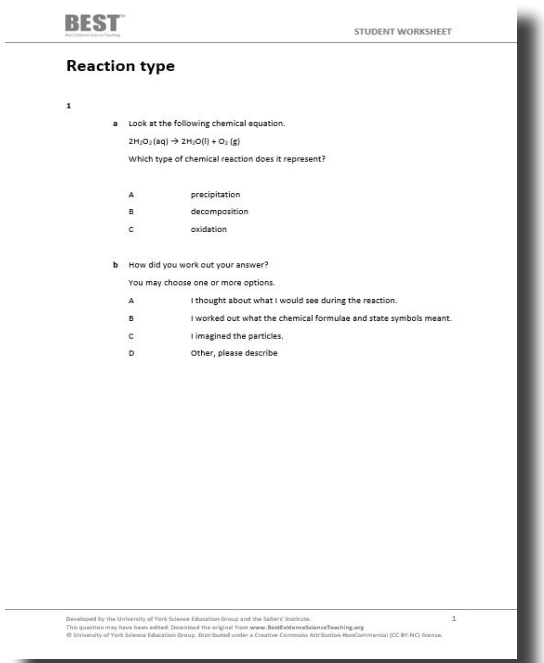
Consolidating...

BEST Key concept CPS4.1: Representing reactions

A chemical reaction may be summarised by a chemical equation.



BEST STUDENT WORKSHEET

Reaction type

1

a Look at the following chemical equation.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

Which type of chemical reaction does it represent?

A precipitation
B decomposition
C oxidation

b How did you work out your answer?

You may choose one or more options.

A I thought about what I would see during the reaction.
B I worked out what the chemical formulae and state symbols meant.
C I imagined the particles.
D Other, please describe

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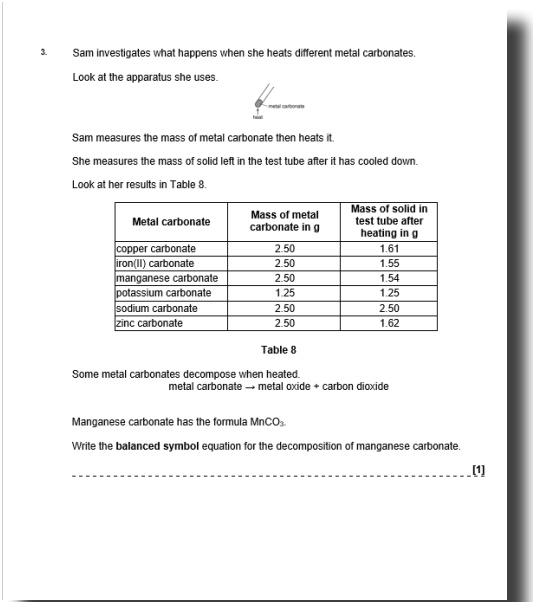
Securing...

GCSE Subject content: Understanding chemical equations

The names and symbols of common elements and compounds and the principle of conservation of mass may be used to write formulae and balanced chemical equations.



3. Sam investigates what happens when she heats different metal carbonates.

Look at the apparatus she uses.

Sam measures the mass of metal carbonate then heats it.

She measures the mass of solid left in the test tube after it has cooled down.

Look at her results in Table 8.

Metal carbonate	Mass of metal carbonate in g	Mass of solid in test tube after heating in g
copper carbonate	2.50	1.61
iron(II) carbonate	2.50	1.55
manganese carbonate	2.50	1.54
potassium carbonate	1.25	1.25
sodium carbonate	2.50	2.50
zinc carbonate	2.50	1.62

Table 8

Some metal carbonates decompose when heated.

metal carbonate → metal oxide + carbon dioxide

Manganese carbonate has the formula $MnCO_3$.

Write the **balanced symbol** equation for the decomposition of manganese carbonate.

[1]

Energy changes

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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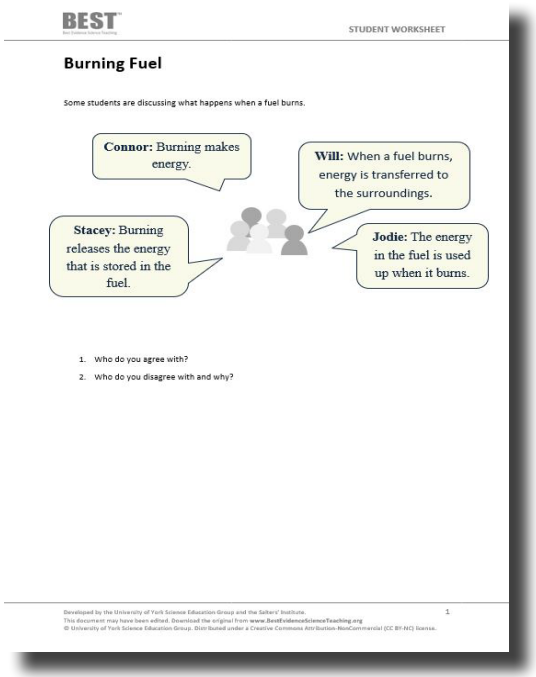
Introducing...

BEST Key concept CCR3.1:
Exothermic and endothermic reactions

Energy cannot be created or destroyed.



BEST STUDENT WORKSHEET

Burning Fuel

Some students are discussing what happens when a fuel burns.

Connor: Burning makes energy.

Will: When a fuel burns, energy is transferred to the surroundings.

Stacey: Burning releases the energy that is stored in the fuel.

Jodie: The energy in the fuel is used up when it burns.

1. Who do you agree with?
2. Who do you disagree with and why?

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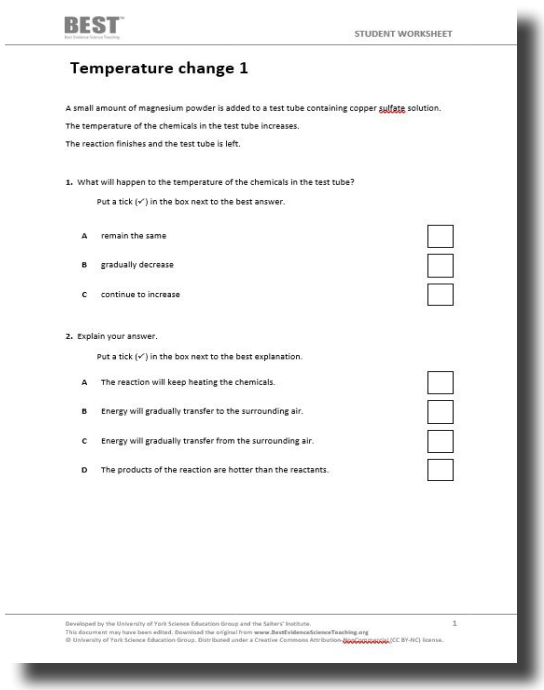
Consolidating...

BEST Key concept CCR3.1:
Exothermic and endothermic reactions

During a chemical reaction energy may be transferred to or from the surroundings.



BEST STUDENT WORKSHEET

Temperature change 1

A small amount of magnesium powder is added to a test tube containing copper sulfate solution.
The temperature of the chemicals in the test tube increases.
The reaction finishes and the test tube is left.

1. What will happen to the temperature of the chemicals in the test tube?
Put a tick (✓) in the box next to the best answer.

A remain the same ☐
B gradually decrease ☐
C continue to increase ☐

2. Explain your answer.
Put a tick (✓) in the box next to the best explanation.

A The reaction will keep heating the chemicals. ☐
B Energy will gradually transfer to the surrounding air. ☐
C Energy will gradually transfer from the surrounding air. ☐
D The products of the reaction are hotter than the reactants. ☐

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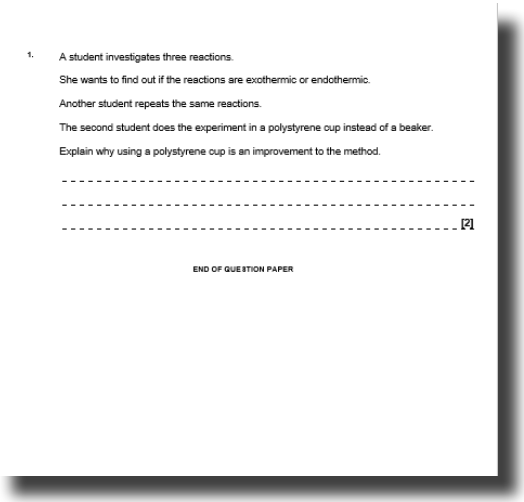
Securing...

GCSE Subject content:
Energy changes



1. A student investigates three reactions.
She wants to find out if the reactions are exothermic or endothermic.
Another student repeats the same reactions.
The second student does the experiment in a polystyrene cup instead of a beaker.
Explain why using a polystyrene cup is an improvement to the method.

.....
.....
..... [2]

END OF QUESTION PAPER

Rates of reaction

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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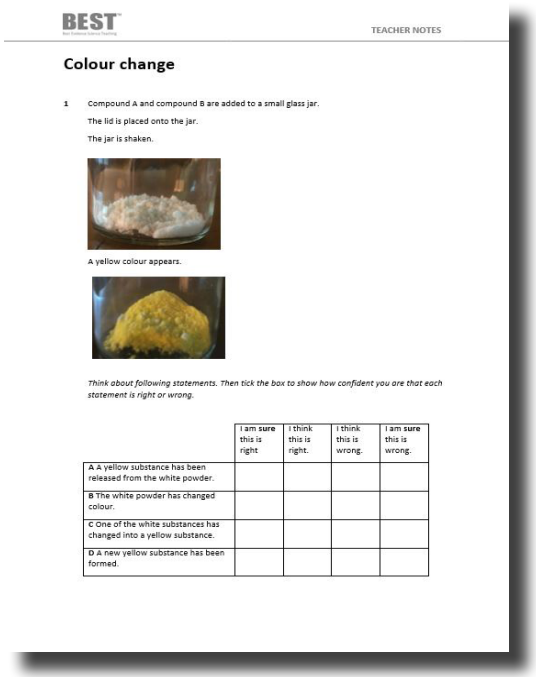
Introducing...

BEST Key concept CCR1.1: Formation of new substance

During a chemical reaction, a new substance (or substances) are formed with different properties.



BEST — TEACHER NOTES

Colour change

1 Compound A and compound B are added to a small glass jar.

The lid is placed onto the jar.

The jar is shaken.

A yellow colour appears.

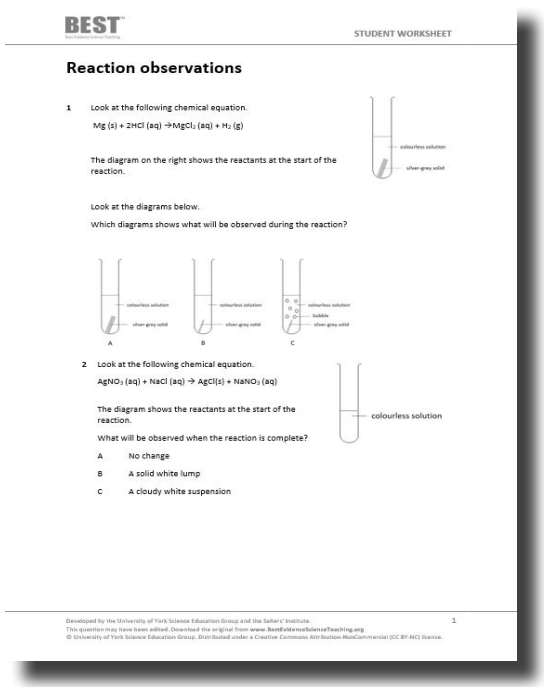
Think about following statements. Then tick the box to show how confident you are that each statement is right or wrong.

	I am **sure** this is right	I think this is right.	I think this is wrong.	I am **sure** this is wrong.
A A yellow substance has been released from the white powder.				
B The white powder has changed colour.				
C One of the white substances has changed into a yellow substance.				
D A new yellow substance has been formed.				

Consolidating...

BEST Key concept CPS4.1: Representing reactions

A chemical reaction is summarised by a chemical equation.



BEST — STUDENT WORKSHEET

Reaction observations

1 Look at the following chemical equation.

$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

The diagram on the right shows the reactants at the start of the reaction.

Look at the diagrams below.

Which diagrams shows what will be observed during the reaction?

2 Look at the following chemical equation.

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

The diagram shows the reactants at the start of the reaction.

What will be observed when the reaction is complete?

A No change

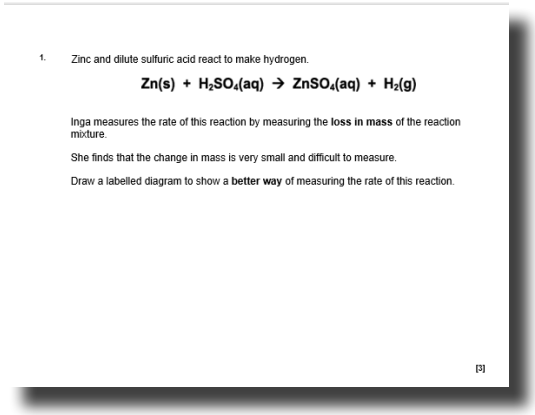
B A solid white lump

C A cloudy white suspension

Securing...

GCSE Subject content: Rates of reaction

Rate of reaction is a measure of the amount of product formed in a unit of time (or the amount of reactant lost).



1. Zinc and dilute sulfuric acid react to make hydrogen.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Inga measures the rate of this reaction by measuring the **loss in mass** of the reaction mixture.

She finds that the change in mass is very small and difficult to measure.

Draw a labelled diagram to show a **better way** of measuring the rate of this reaction.

[3]

Bonding

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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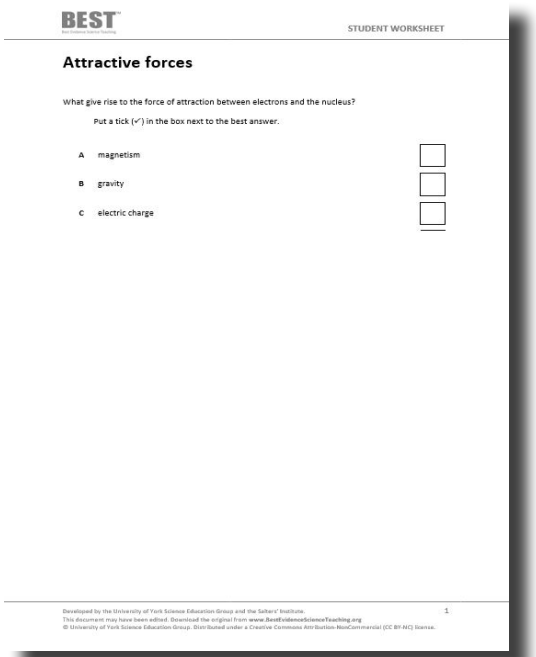
Introducing...

BEST Key concept CPS6.1:
Atomic model

The force of attraction between the nucleus and electrons is an electrostatic force.


BEST
STUDENT WORKSHEET

Attractive forces

What give rise to the force of attraction between electrons and the nucleus?

Put a tick (✓) in the box next to the best answer.

A magnetism ☐
B gravity ☐
C electric charge ☐

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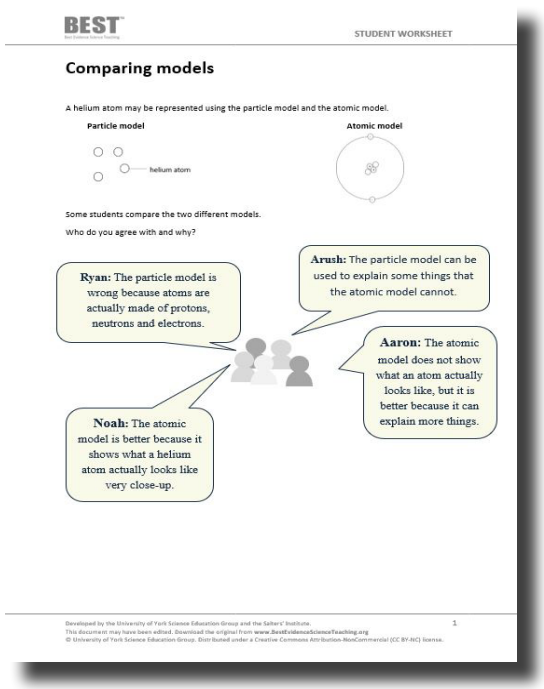
Consolidating...

BEST Key concept CPS6.1:
Atomic model

The structure of an atom may be represented by an atomic model.


BEST
STUDENT WORKSHEET

Comparing models

A helium atom may be represented using the particle model and the atomic model.

Particle model — helium atom
Atomic model

Some students compare the two different models.

Who do you agree with and why?

Ryan: The particle model is wrong because atoms are actually made of protons, neutrons and electrons.

Arush: The particle model can be used to explain some things that the atomic model cannot.

Aaron: The atomic model does not show what an atom actually looks like, but it is better because it can explain more things.

Noah: The atomic model is better because it shows what a helium atom actually looks like very close-up.

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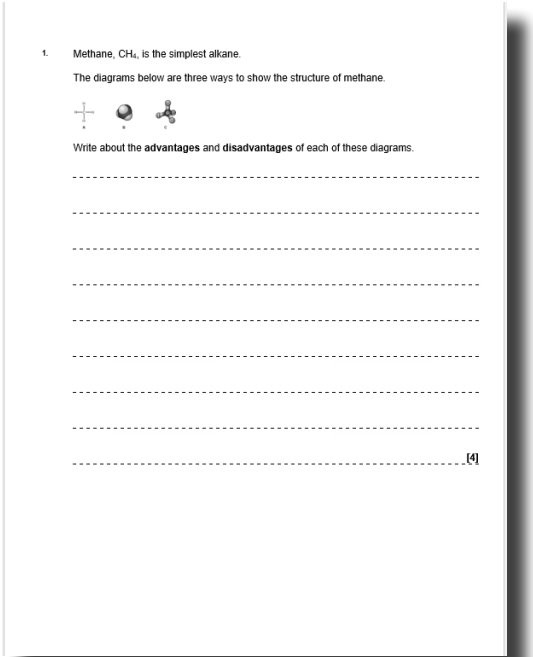
Securing...

GCSE Subject content:
Bonding

Chemical bonding may be explained in terms of electrostatic forces. Chemical bonds may be modelled using a variety of representations.


1. Methane, CH_4, is the simplest alkane.

The diagrams below are three ways to show the structure of methane.

Write about the **advantages** and **disadvantages** of each of these diagrams.

[4]

Periodic Table

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
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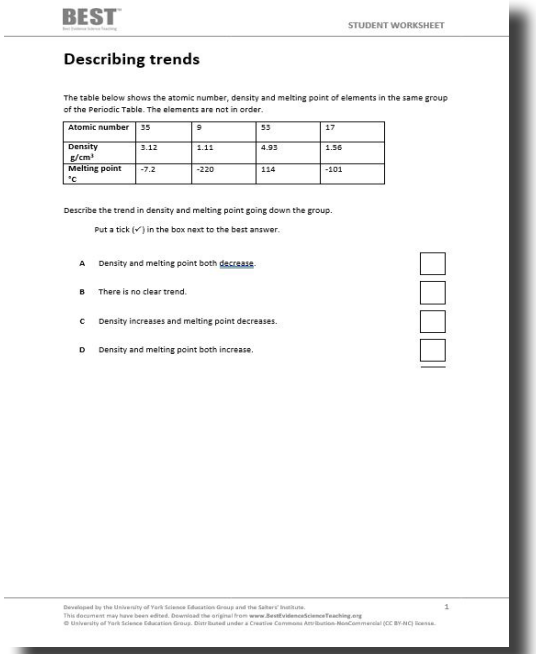
Introducing...

BEST Key concept CSU4.1: Trends in physical properties

Trends in physical properties of the elements can be used to predict properties of unfamiliar elements.



BEST

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Describing trends

The table below shows the atomic number, density and melting point of elements in the same group of the Periodic Table. The elements are not in order.

Atomic number	35	9	53	17
Density g/cm³	3.12	1.11	4.93	1.56
Melting point °C	-7.2	-220	114	-101

Describe the trend in density and melting point going down the group.

Put a tick (✓) in the box next to the best answer.

A Density and melting point both decrease. ☐

B There is no clear trend. ☐

C Density increases and melting point decreases. ☐

D Density and melting point both increase. ☐

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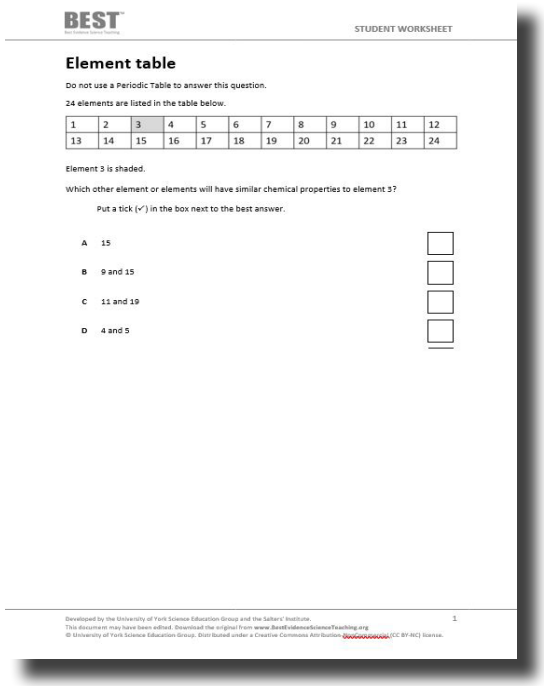
Consolidating...

BEST Key concept CCR5.1: Periodic patterns

When sequenced by atomic number, elements with similar chemical properties recur at periodic intervals.



BEST

STUDENT WORKSHEET

Element table

Do not use a Periodic Table to answer this question.

24 elements are listed in the table below.

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

Element 3 is shaded.

Which other element or elements will have similar chemical properties to element 3?

Put a tick (✓) in the box next to the best answer.

A 15 ☐

B 9 and 15 ☐

C 11 and 19 ☐

D 4 and 5 ☐

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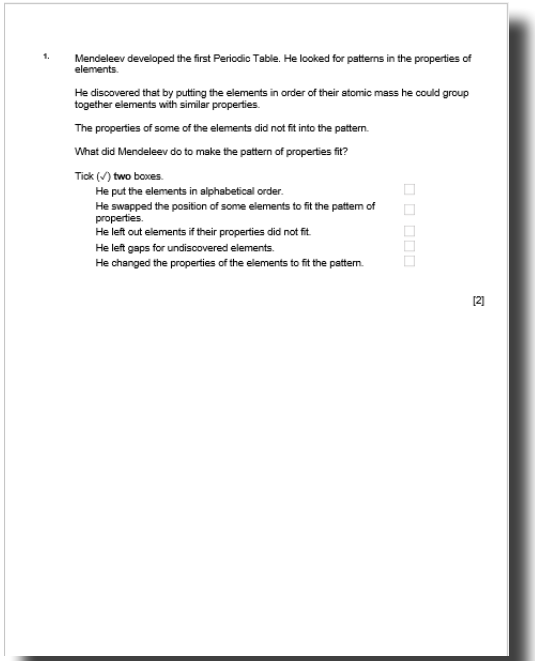
Securing...

GCSE Subject content: Periodic Table



1. Mendeleev developed the first Periodic Table. He looked for patterns in the properties of elements.

He discovered that by putting the elements in order of their atomic mass he could group together elements with similar properties.

The properties of some of the elements did not fit into the pattern.

What did Mendeleev do to make the pattern of properties fit?

Tick (✓) **two** boxes.

He put the elements in alphabetical order. ☐

He swapped the position of some elements to fit the pattern of properties. ☐

He left out elements if their properties did not fit. ☐

He left gaps for undiscovered elements. ☐

He changed the properties of the elements to fit the pattern. ☐

[2]

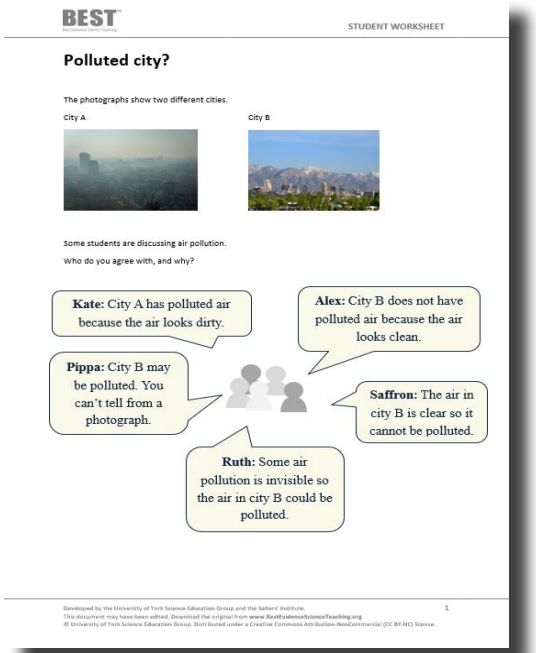
Atmospheric pollutants

Guidance on each key concept, research summaries, more diagnostic questions and accompanying response activities may be downloaded from:
https://www.stem.org.uk/best-evidence-science-teaching

Introducing...

BEST Key concept EEC1.1: Air quality

Additional substances (pollutants) may be added to the air, which can affect air quality both locally and at a distance.



BEST

STUDENT WORKSHEET

Polluted city?

The photographs show two different cities.

City A

City B

Some students are discussing air pollution.

Who do you agree with, and why?

Kate: City A has polluted air because the air looks dirty.

Alex: City B does not have polluted air because the air looks clean.

Pippa: City B may be polluted. You can't tell from a photograph.

Saffron: The air in city B is clear so it cannot be polluted.

Ruth: Some air pollution is invisible so the air in city B could be polluted.

Developed by the University of York Science Education Group and the Salters' Institute. 1
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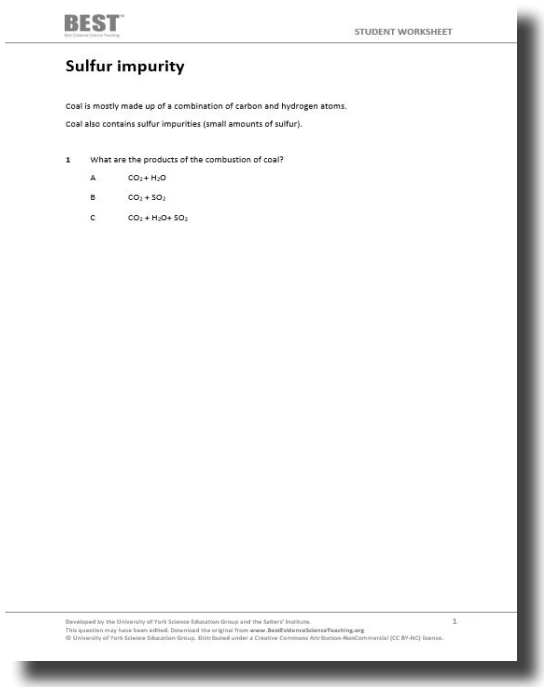
Consolidating...

BEST Key concept CCR2.2: Combustion

During combustion, new products are formed from the combination of oxygen with the fuel.



BEST

STUDENT WORKSHEET

Sulfur impurity

Coal is mostly made up of a combination of carbon and hydrogen atoms.

Coal also contains sulfur impurities (small amounts of sulfur).

1 What are the products of the combination of coal?

A $CO_2 + H_2O$

B $CO_2 + SO_2$

C $CO_2 + H_2O + SO_2$

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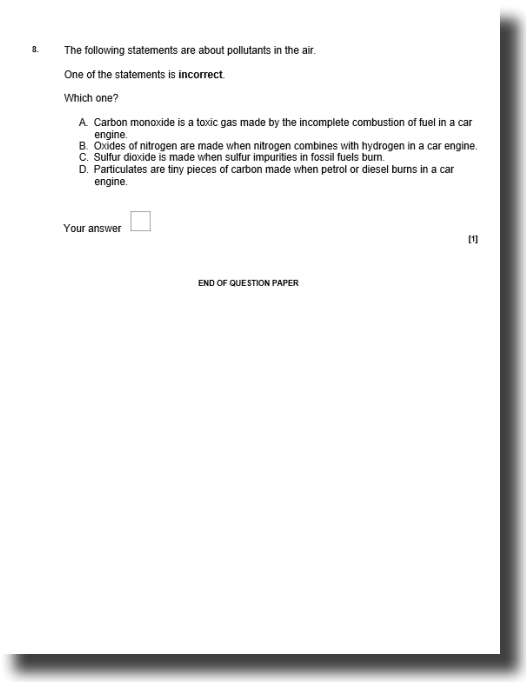
Securing...

GCSE Subject content: Atmospheric pollutants

Atmospheric pollutants include sulfur dioxide and oxides of nitrogen. These are produced as a result of burning fossil fuels.



8. The following statements are about pollutants in the air.

One of the statements is **incorrect**.

Which one?

A. Carbon monoxide is a toxic gas made by the incomplete combustion of fuel in a car engine.
B. Oxides of nitrogen are made when nitrogen combines with hydrogen in a car engine.
C. Sulfur dioxide is made when sulfur impurities in fossil fuels burn.
D. Particulates are tiny pieces of carbon made when petrol or diesel burns in a car engine.

Your answer ☐

[1]

END OF QUESTION PAPER

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