14–16 years

The composition and formula of water

ROYAL SOCIETY OF CHEMISTRY

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Water, an essential compound

Water is an essential compound. Without water, life on Earth could not exist. Both plants and animals depend on water to keep them alive.

In this teacher demonstration we will investigate the composition of water.

You will observe the reaction between copper(II) oxide and hydrogen and use the results to determine the formula of water.

Learning objectives

- Describe how water is formed during the redox reaction of copper oxide with hydrogen.
- Accurately record experimental observations and data.
- Determine the formula of water from the experimental data.

Questions

1. Write the word equation for the reaction.
2. Select the correct words to complete the sentences.

In a redox reaction, oxidation and reduction occur at the same time.

Reduction occurs when a substance **loses/gains** oxygen. Oxidation occurs when a substance **loses/gains** oxygen.

In this experiment, the copper oxide is **oxidised/reduced** and the hydrogen is **oxidised/reduced.**

Scaffolded questions

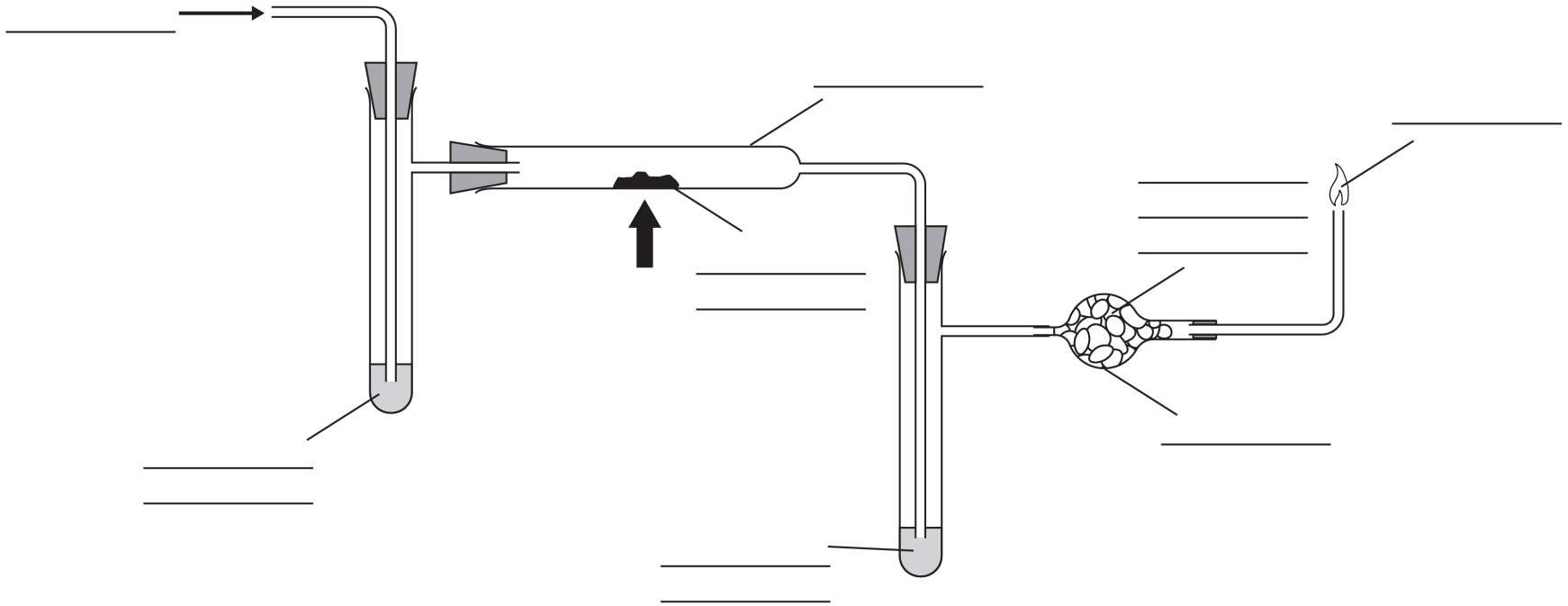
Questions

3. Label the diagram using the following words:

concentrated sulfuric acid **heat** **drying tube**

combustion tube **copper oxide** **hydrogen in**

exhaust fumes **anhydrous copper chloride**



Questions

4. State why concentrated sulfuric acid was added to the side arms.

Hint: Concentrated sulfuric acid is a drying agent.

It was added to the left-hand arm to dry _____

It was added to the right-hand arm to _____

5. List two safety precautions taken during the reaction.

6. Record the masses in the table.

	Mass before heating / g	Mass after heating / g
Mass of combustion tube and contents		
Mass of combustion tube, side arm and contents		

Scaffolded questions

Questions

7. Note your observations in a table.

Use the final column to explain your observation.

	Observations	Explanations
Before heating		
During heating		
After heating		

Scaffolded questions

Questions

8. Use the data recorded in your table to calculate:

a) The mass of oxygen lost from the copper oxide (M5) = M1 – M2 = _____ g

b) The mass of water formed during the reaction (M6) = M4 – M3 = _____ g

c) The mass of hydrogen in the water formed (M7) = M6 − M5 = _____ g

9. The relative atomic mass of oxygen is 16 and the relative atomic mass of hydrogen is 1.

Calculate:

a) The number of moles of oxygen in the water = M5/16 = _____ mol

b) The number of moles of hydrogen in the water = M7/1 = _____ mol

c) The mole ratio of H:O in the water = _____

Scaffolded questions

Questions

10. Write the formula of water and describe its composition.

The formula of water is _____.

A molecule of water is made up of two _____ atoms bonded to one _____ atom.

11. Complete the balanced symbol equation for the reaction

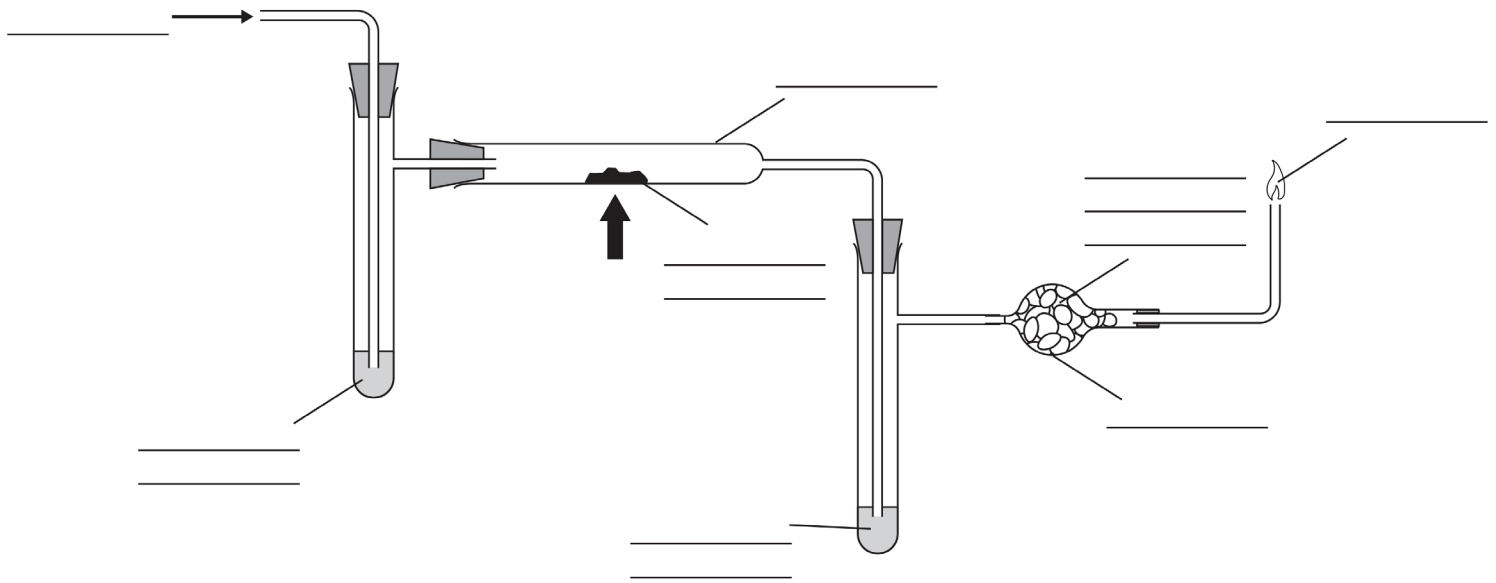
$\mathrm{CuO(s)} + \mathrm{H_2(g)} \rightarrow$ _____

Scaffolded questions

Questions

During the demonstration, listen to your teacher and answer the following questions.

1. Write the word equation for the reaction.
2. Describe what happens during a redox reaction. Include what is oxidised and what is reduced.
3. Label the diagram.



Unscaffolded questions

Questions

4. State why was concentrated sulfuric acid added to the side arm.
5. List two safety precautions that should be taken during the reaction.
6. Record the masses in the table

	Mass before heating / g	Mass after heating / g
Mass of combustion tube and contents		
Mass of combustion tube, side arm and contents		

Unscaffolded questions

Questions

7. Note down your observations in the table.

Use the final column to explain your observation.

	Observations	Explanations
Before heating		
During heating		
After heating		

Unscaffolded questions

Questions

8. Use the data recorded in your table to calculate:

a) The mass of oxygen lost from the copper oxide (M5) = M1 – M2 = _____ g

b) The mass of water formed during the reaction (M6) = M4 – M3 = _____ g

c) The mass of hydrogen in the water formed (M7) = M6 − M5 = _____ g

9. The relative atomic mass of oxygen is 16 and the relative atomic mass of hydrogen is 1.

Calculate:

a) The number of moles of oxygen in the water = M5/16 = _____ mol

b) The number of moles of hydrogen in the water = M7/1 = _____ mol

c) The mole ratio of H:O in the water = _____

Unscaffolded questions

Questions

10. Write the formula of water and describe its composition.
11. Write the balanced symbol equation for the reaction.

Unscaffolded questions

Answers

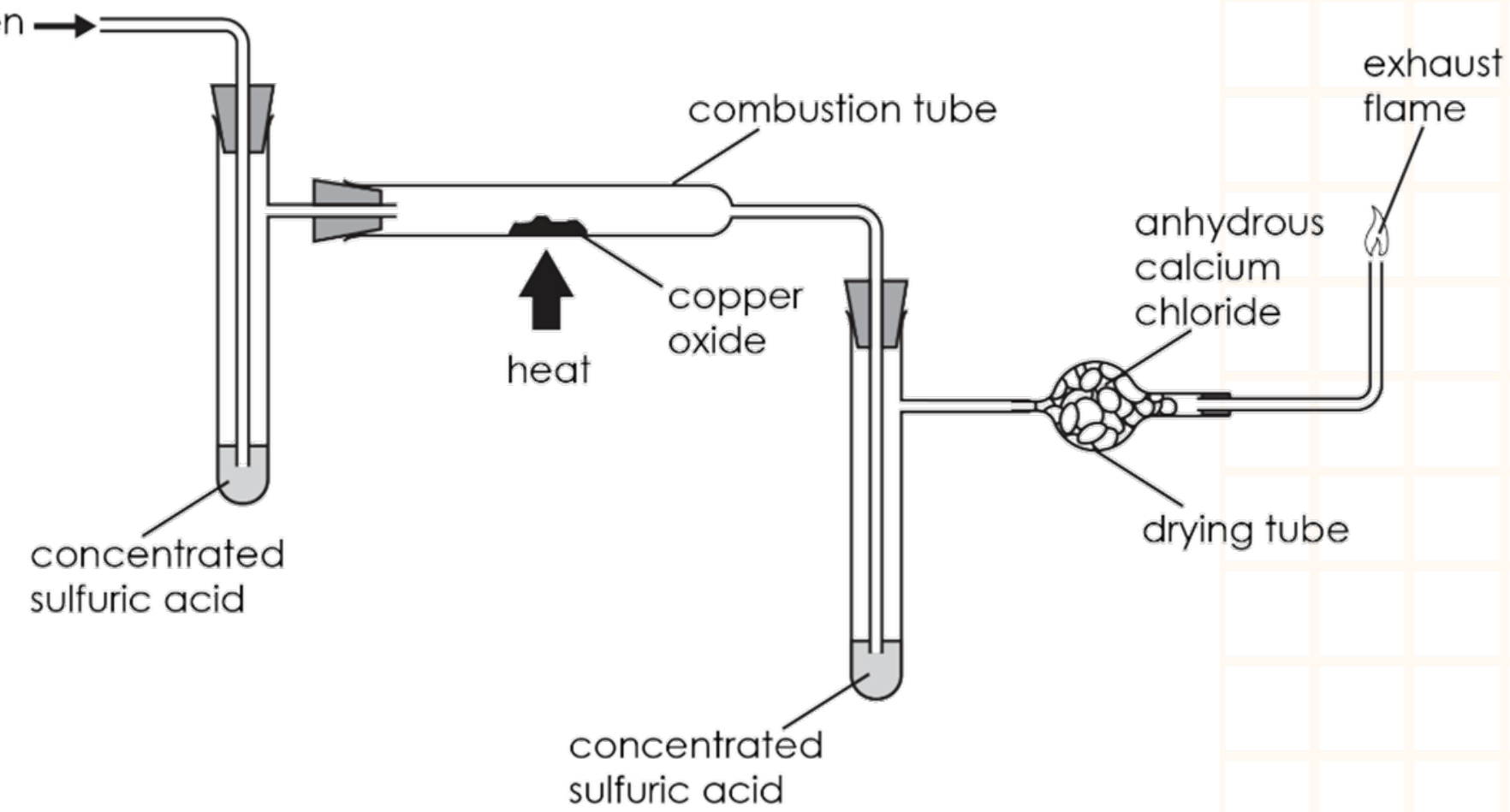
1. copper oxide + hydrogen → copper + water
2. In a redox reaction, oxidation and reduction occur at the same time.

Reduction occurs when a substance **loses** oxygen. Oxidation occurs when a substance **gains** oxygen.

In this experiment, the copper oxide is **reduced** and the hydrogen is **oxidised.**

Answers

3.


hydrogen gas
combustion tube
exhaust flame
anhydrous calcium chloride
copper oxide
heat
concentrated sulfuric acid
drying tube
concentrated sulfuric acid

Answers

4. Concentrated sulfuric acid was added to the left-hand arm to dry the hydrogen gas.

It was added to the right-hand arm to collect the water produced during the reaction.

5. Any two of:

- Wear safety goggles
- Light the exhaust gas to stop flammable hydrogen gas going into the room
- Wear gloves when handling concentrated sulfuric acid

6. Use experimental data to complete the table.

Answers

7.

	Observations	Explanations
Before heating	The solid in the combustion tube was black	Copper oxide was present
During heating	A colourless liquid was seen on the side of the combustion tube	Water formed during the reaction. It then turned into water vapour when it got hot and exaporated
After heating	The solid in the combustion tube was a pink colour	Copper metal was present

Answers

8. Use experimental data to calculate. See the teacher notes.
9. Use experimental data to calculate. In part (c), the mole ratio of H to O should be close to 2:1. See the teacher notes.
10. $\mathrm{H_2O}$

A molecule of water is made up of two atoms of hydrogen chemically bonded to one atom of oxygen.

11. $\mathrm{CuO(s) + H_2(g) \rightarrow Cu(s) + H_2O(l)}$

Mole calculations

Remember a mole (mol) is the relative atomic mass (A_r) of an element or relative formula mass (M_r)of a compound in grams.

$$\text{moles} = \frac{\text{mass (g)}}{\text{relative atomic (or formula) mass}}$$

The A_r of oxygen is 16

The A_r of hydrogen is 1

So, the number of moles in 5.2 g of oxygen = $\frac{5.2}{16} = 0.325$

Calculate:

a) The number of moles of oxygen in the water

b) The number of moles of hydrogen in the water

c) The mole ratio of $\mathrm{H}:\mathrm{O}$ in the water

Hint: to work out a mole ratio, divide the larger number by the smaller number.

Write down the formula of water and describe its composition.