Solid/gas displacement reactions

This section builds on Microscale activity 2.5 on page 22 of the book, and Chapter 4.

Concepts being developed: The chemical reaction

How should students know that a chemical change has occurred? In the early stages of teaching, they should recognise that new chemical substances with different physical and chemical with have formed. They may see:

- colour changes,
- sudden ability to be a conductor of electricity or to be attracted to a magnet,
- changes of physical state such as the formation of gases, liquids, or formation of solids in liquids (suspensions).

In this reaction, black copper(II) oxide gradually turns reddish, sometimes forming shiny mirrors, and water vapour condenses further down the tube. The new solid is a conductor of electricity, whereas copper oxide is a non-conductor.

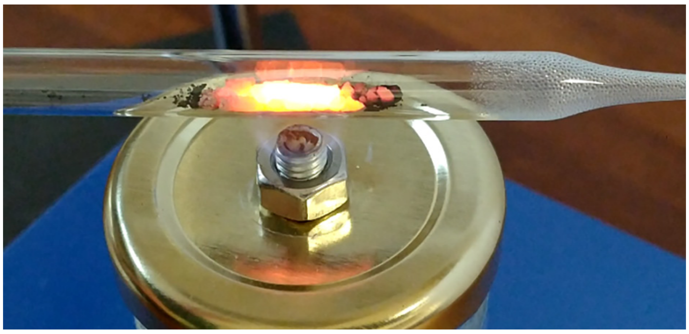


Figure 1 The reaction between copper(II) oxide and hydrogen showing water condensing and the exothermic nature of the reaction.

In the activity that follows, hydrogen is passed over hot copper(II) oxide more rapidly. The reaction suddenly glows white hot with temperatures exceeding 1000°C. When chemicals react, the energy stored in existing bonds is released. In this case, the new bonds made store less energy. (See page 42 of the book). Further evidence that a chemical reaction is occurring is shown through:

- Changes in energy
  - seen as temperature changes with a thermometer placed in the surrounding air or solvent molecules or
  - "sensing" electromagnetic radiation through colour of flames/solids or feeling temperature changes on our skin from a safe distance.

This begs the question concerning the existence of spontaneous endothermic reactions such as the citric acid/sodium carbonate reaction. Explanation of this remarkable effect, (akin to a ball spontaneous rolling uphill,) will need special treatment as it introduces the concept of entropy.

Concepts being developed: The Redox reaction

Oxidation was originally described (Lavoisier) as the addition of oxygen to a metal. The removal of oxygen was accompanied by observing a loss (**reduction**) in mass (see Figure 2).

The word "reduction" has many other meanings to students, which causes difficulties in understanding. Using words that have one meaning in everyday usage and a different scientific meaning (often specific) is a common issue

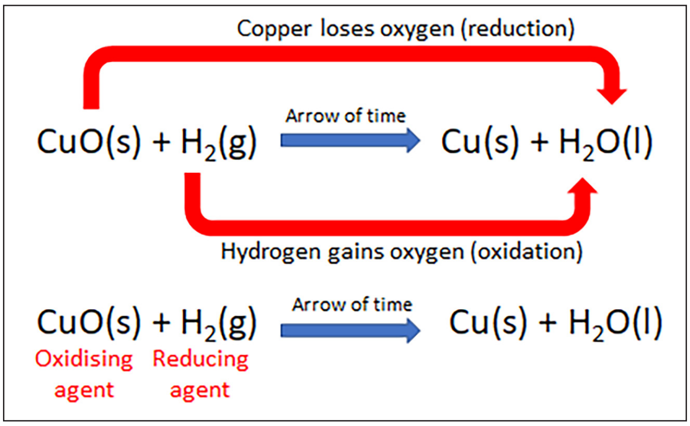


Figure 2 Showing how redox ideas connect with the copper(II) oxide hydrogen reaction.

which, teachers need to be aware of. Michael Faraday invented a new name, "ions", for electrically-charged particles, but even using a new name has not helped with the understanding of the term by students.

Starting with the basic idea that the oxidation state of an atom, with equal numbers of protons and electrons is zero, there are further definitions of "redox reactions".

- Oxidation involves an increase in the value of the oxidation state.
- Reduction involves a decrease in value of the oxidation state.

In this reaction, both the copper and hydrogen have changed their oxidation states. Copper in copper(II) oxide is +2, reducing to zero in the element. Hydrogen is zero in the element, increasing to +1 in water. There are 2 hydrogen atoms involved, so the overall increase is +2. The overall decrease in the oxidation number in reduction is always the same as the overall increase in the oxidation number in oxidation.

Electrons are negatively charged and so this makes the next definition even more confusing for the learner.

- Oxidation involves the loss (reduction in the number) of electrons.
- Reduction involves an increase (in the number) of electrons.

This is another example of overloading students with too much information in one session. It needs to be introduced a small step at a time. It is yet another reason to spiral topics through a scheme of work. Combining a microscale approach with a traditional approach will add variety to the repetition.

Microscale activity: An alternative method of reducing copper(II) oxide to copper with hydrogen

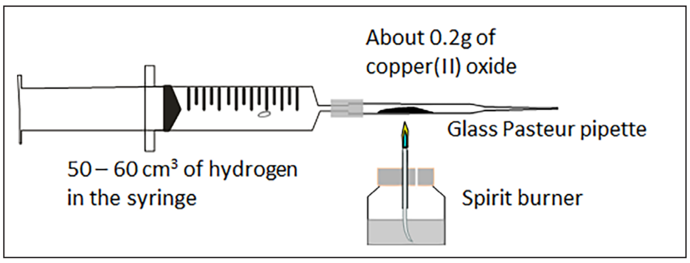
Ensure that full planning and risk assessment is carried out before attempting this activity.

Outline requirements

- Plastic 50 cm^3 syringe of hydrogen fitted with a cap
- Glass Pasteur pipette containing 0.2 g of copper(II) oxide
- Spirit burner containing ethanol
- Retort stand and clamp
- Copper(II) oxide is hygroscopic so water will condense out on cooler areas of the glass
- To move the plunger steadily, hold the stem of the plunger and move it along about 5-10 cm^3 a time

Outline method (see Figure 3)

1. Fill the syringe with hydrogen and insert a cap on the nozzle.
2. Add about 0.2 g of copper(II) oxide to the glass Pasteur pipette.
3. Connect the syringe to the Pasteur pipette with a piece of tubing.
4. Place the ethanol spirit burner under the Pasteur pipette and ignite the alcohol on the wick.
5. After about 30 to 60 s, slowly push the hydrogen over the hot copper oxide in 5 to 10 cm^3 bursts.
6. Let the glass cool, tip out the copper metal and test it for electrical conductivity.
7. The glass should be placed in the "sharps" bin.



Teacher activities

Using iron oxide

Iron(III) oxide is a very complicated substance, existing in different forms. When heated in the Pasteur pipette it changes colour from red to black, but it does not appear to be magnetic. After hydrogen is passed over the iron(III) oxide, some water is produced, but not as much as with copper(II) oxide. The solid product is magnetic but does not conduct an electric current. It is most likely that the mixed oxide, Fe_3O_4 is formed.

$$3Fe_2O_3(s) + H_2(g) \rightarrow 2Fe_3O_4(s) + H_2O(l)$$

Using copper(II) carbonate

Copper(II) carbonate is a mixture of copper carbonate and copper hydroxide $CuCO_3.Cu(OH)_2$. Use about 0.4 g of copper(II) carbonate in the horizontal Pasteur pipette and heat with the spirit burner to drive off the water and carbon dioxide to form black copper(II) oxide. Then attach the syringe, heat the oxide and pass the gas over (as above).

Nickel and cobalt carbonates

There is further interest in applying these procedures to the oxides of nickel and cobalt, because both metals are magnetic and both of the metals conduct an electric current. Unfortunately, the compounds of these metals are known to cause skin allergies and, if taken internally (breathing aerosols and dust), they can cause cancers. In schools, the risk is extremely small, and teachers should refer to their countries' guidelines.

More reactions for teachers to think about

The following table shows some basic rules about oxidation states. They are best regarded in identifying which elements are being oxidised and reduced and as a book-keeping method to balance equations. They do not have to be whole numbers.

Oxidation number	Explanation
Always zero	• The sum of all the oxidation numbers in a compound • An element not combined with anything else
-1	• Flourine in compounds • Any monatomic ions with a -1 charge
+1	• Hydrogen* • Group 1 metals in compounds** • Any monatomic ions with a +1 charge
-2	• Oxygen in compounds*** • Any monatomic ions with a -2 charge
+2	• Group 2 metals in compounds • Any monatomic ions with a +2 charge

***In hydrides it is -1.**
****Chemists "enjoy" finding elements with uncommon oxidisation numbers in compounds.**
*****In peroxides, each oxygen is -1, on potassium superoxide, KO_2, it has to be 0.5!**

Examine the redox issues with these reactions:

1. Copper oxide + carbon produces carbon dioxide and copper
2. Copper oxide + carbon monoxide produces carbon dioxide and copper
3. Copper oxide + zinc produces zinc oxide and copper
4. Copper oxide + ammonia produces nitrogen, water and copper
5. Copper oxide + methanol produces methanal and copper