The reaction between zinc powder and sulfur

Teach with flair and enthusiasm with the help of this collection of experiments and demonstrations specially designed for non-specialists: rsc.li/4aPubnl

Learning objectives

1. Recall the definitions of elements, mixtures and compounds
2. Describe the changes during the chemical reaction
3. Write chemical equations for the reactions
4. Use energy changes to decide if a reaction is exothermic or endothermic

The PowerPoint has slides to recap definitions of elements and compounds (LO1). The practical demonstration allows learners to observe the changes that take place during a chemical reaction (LO2). Slide 6 offers ways for learners to record their observations. Completion of the follow-up questions will allow learners to succeed in LO3 and LO4.

Scaffolding

There are two versions of the learner worksheet: scaffolded (✪) and unscaffolded (✪✪). The scaffolded sheet offers more support to allow learners to access the questions. For example, on the scaffolded sheet, learners are supported by gap-filing activities, sentence starters and hints.

Technician notes

Read our standard health and safety guidance (rsc.li/3zyJLkx) and carry out a risk assessment before running any live practical.

Equipment

- Safety glasses
- Access to a fume cupboard
- Test tube Pyrex (or boiling tube)
- Test tube holder
- Metal test tube holder
- Bunsen burner
- Weighing boat
- Spatula (2)
- Top pan balance (1 dp)

Chemicals

- 0.1 g zinc powder (Highly flammable)
- 0.1 g sulfur powder (Irritant – skin)
- 10 g mineral wool

Disposal

Put the remnants from the reaction into a beaker of 500 cm^3 of dilute hydrochloric acid (0.1 molar) and leave for an hour or so (stirring from time to time). This will dissolve any remaining metal (and the oxide). Then neutralise the acid and wash to waste with plenty of running water.

Safety and hazards

- Wear safety glasses throughout the and demonstrate the reaction in a fume cupboard.
- Do not be tempted to increase the scale of this reaction – to do so would be in breach of the Explosives Regulations 2014. The reaction between magnesium or aluminium powder and sulfur can be explosive and should not be attempted. For further information see CLEAPSS PS081, refer to SSERC or refer to your local safety advisory body.
- Zinc – see CLEAPSS Hazcard HC107, refer to SSERC or refer to your local safety advisory body. Zinc powder or dust is very reactive and highly flammable – it must be stored and disposed of safely. It may be supplied in different states of fineness, and it may have become oxidised and be mainly zinc oxide. For that reason, the reactivity seen from any given sample can be very different.


- Sulfur – see CLEAPSS Hazcard HC096a, refer to SSERC or refer to your local safety advisory body. Sulfur may be supplied as crushed roll sulfur, flowers of sulfur, precipitated sulfur or resublimed sulfur. All are suitable, but resublimed sulfur seems to react more vigorously.

- When heating the mixed powders, direct the mouth of the tube towards the inner corner of the fume cupboard, until the reaction occurs.

Demonstration method

1. Measure out 0.1 g of zinc powder into a weighing boat.
2. Measure out 0.1 g sulfur powder into the weighing boat.
3. Mix the two powders to form a uniform mix.
4. Put the powder into a Pyrex test tube.
5. Fit a mineral wool plug to the top of the test tube.
6. Light the Bunsen burner and adjust to a blue working flame.
7. Holding the tube with the test tube holders, heat the mixed powders and direct the mouth of the tube towards the inner corner of the fume cupboard, until the reaction occurs.

Teaching notes

This demonstration is a great extension of the iron and sulfur experiment at 11–14 (rsc.li/3LVXGeC), which you may wish to use to activate prior knowledge. This demonstration pulls together lots of key areas of the specification, so could also be used as a revision activity.

Background information

The products of this reaction bear little resemblance to the starting elements, pale blue zinc and bright yellow sulfur. Learners can see that a new compound has been formed. The pale yellow residue is a mixture of zinc oxide and zinc sulfide. Reducing this residue (by electrical or chemical means) back to zinc demonstrates the chemical differences between mixtures and compounds. A drop of hydrochloric acid on the residue can be a fitting conclusion to the reaction, if done in a fume cupboard. The reaction produces the pungent, foul-smelling gas hydrogen sulfide which learners often associate with stink bombs – once smelled never forgotten.

The chemical reactions that are occurring in the reaction are:

$$\mathrm{Zn(s)} + \mathrm{S(s)} \rightarrow \mathrm{ZnS(s)}\ \Delta H^{\ominus}{}_{f} = -206.0\ \mathrm{kJ\ mol^{-1}}$$

$$\mathrm{Zn(s)} + \tfrac{1}{2}\mathrm{O_2(g)} \rightarrow \mathrm{ZnO(s)}\ \Delta H^{\ominus}{}_{f} = -348.3\ \mathrm{kJ\ mol^{-1}}$$

$$\mathrm{S(s)} + \mathrm{O_2(g)} \rightarrow \mathrm{SO_2(g)}\ \Delta H^{\ominus}{}_{f} = -297.0\ \mathrm{kJ\ mol^{-1}}$$

The overall reaction needs heat to get started, but the heat it produces is enough to sustain the reaction thereafter.

Zinc can be obtained by electrolysis of zinc sulfate or by smelting in a process similar to the production of iron from the blast furnace. First, the zinc ore is roasted in air, converting it to zinc oxide:

$$\mathrm{2ZnS(s)} + \mathrm{3O_2(g)} \rightarrow \mathrm{2ZnO(s)} + \mathrm{2SO_2(g)}$$

Coke and the roasted ore are fed into the top of the furnace, and air is blasted in at the bottom. The most important reaction taking place is:

$$\mathrm{ZnO(s)} + \mathrm{CO(g)} \rightarrow \mathrm{Zn(g)} + \mathrm{CO_2(g)}$$

Unlike the production of iron (mp = 1535°C; bp = 2750°C), zinc (mp = 420°C; bp = 907°C) is produced as a vapour. Cooling the zinc vapour to produce a liquid results in the re-oxidation of the metal. This problem was solved in the 1950s by Imperial Smelting of Bristol. The zinc vapour is sprayed with molten lead. This chills and dissolves the zinc so rapidly that re-oxidation is minimal. Molten lead and zinc are only partially miscible in each other and so, by cooling the solution, zinc separates as a liquid of nearly 99% purity. Vacuum distillation can further refine the liquid to 99.99% purity. This method has the advantage that the charge composition is not critical, and mixed $\mathrm{Zn/Pb}$ sulfide ores (often found together) will produce both metals simultaneously, with the lead being tapped from the bottom of the furnace.

When using this demonstration, it is worth mentioning that zinc is applied in thin layers to iron and steel products to stop them rusting. This process is called galvanising. More than half of the zinc consumed each year is used for galvanising. About 7.7 kg of zinc is used to protect the average car from rust.

Answers

1. Observations during heating: observed a bright light; saw sparks; heard hisses/pops. Observations at the end: a pale yellow solid substances was left; replacing the pale blue and bright yellow solid mixture.

2. zinc + sulfur → zinc sulphide
   $Zn(s) + S(s) \rightarrow ZnS(s)$

3. (a) observed a bright light; observed sparks; heard hisses/pops.

   (b) At the start of the reaction **energy** was needed to **break** the bonds in the reactants.

   The **atoms** rearranged and **energy** was given out as the new bonds **formed**.

   During the reaction **heat** and sound **energy** were given out to the surroundings. Therefore the reaction was exothermic

   (c) To get the reaction started.

4. (a) A product formed during the reaction that is not wanted.

   (b) Zinc sulfide. Zinc oxide

   (c) zinc + oxygen → zinc oxide $2Zn(s) + O_2(g) \rightarrow 2ZnO(s)$

   sulfur + oxygen → sulfur dioxide $S(s) + O_2(g) \rightarrow SO_2(g)$

   (d) For zinc oxide – reactants are zinc and oxygen; zinc came from the zinc / sulfur mixture, oxygen came from the air.

   For sulfur dioxide – reactants are sulfur and oxygen; zinc came from the zinc / sulfur mixture, oxygen came from the air.

5. By-products are formed during the reaction / Some sulfur dioxide is formed during the reaction / Some zinc oxide is formed during the reaction / Not all the zinc and sulfur atoms end up in the final zinc sulfide product. Therefore, the yield is less than100%.

6. (a) Zinc sulphide is a compound. The atoms are held together by strong covalent bonds and a lot of energy is required to break them.

   (b) zinc sulfide + oxygen → zinc oxide + sulfur dioxide

   $2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$

   (c) zinc oxide + carbon monoxide → zinc + carbon monoxide

   $ZnO(s) + CO(g) \rightarrow Zn(g) + CO_2(g)$

   (d) The zinc forms a mixture with lead. The components of a mixture can be easily separated by physical processes as there are no strong chemical bonds to break.