Metals

Student Notes

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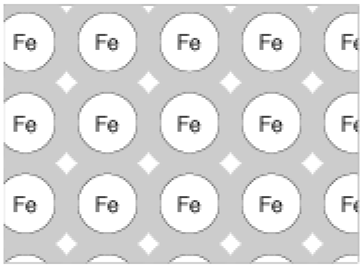
Activity 2: Iron as a Metal

Iron – true or false?

The statements below refer to the diagram of the structure of iron. The diagram shows part of a slice through the three dimensional structure.



Please read each statement carefully, and decide whether it is correct or not.

1. Iron has a type of bonding called metallic bonding.

2. Iron atoms do not have a full outer shell of electrons, and this makes iron very reactive.

3. An iron atom is a silver-grey colour, and so iron metal is a silver-grey colour.

4. Iron can conduct electricity because some of the iron atoms can slip over their neighbours, and move through the solid.

5. Iron can be reshaped, without changing the shape of iron atoms.

6. The reason iron rusts is that iron atoms will rust if exposed to damp air.

7. In iron metal each atom is bonded to each of the other iron atoms surrounding it.

8. Iron conducts electricity because iron atoms are electrical conductors.

9. Iron is a solid because that is the natural state for metals.

10. A metal such as iron consists of positive metal ions, and negative electrons which move around the solid between the ions.

11. An iron atom will reflect light, and so freshly polished iron shines.

12. The reason that iron becomes a liquid when heated is because the bonds melt.

13. Iron conducts electricity because it contains a 'sea' of electrons.

14. The atoms in a metal such as iron are held together by ionic bonds.

15. The reason iron conducts heat is because there is room between the atoms for hot air to move through the metal.

16. The reason that iron is hard is because iron atoms are hard.

17. In iron there are molecules held together by magnetism.

18. If a metal such as iron is heated to a very high temperature it would become a gas.

19. Metals such as iron expand when heated because the atoms get bigger.

20. Chemical bonds are needed to hold the atoms together in a metal such as iron, even though all of the atoms are of the same type.

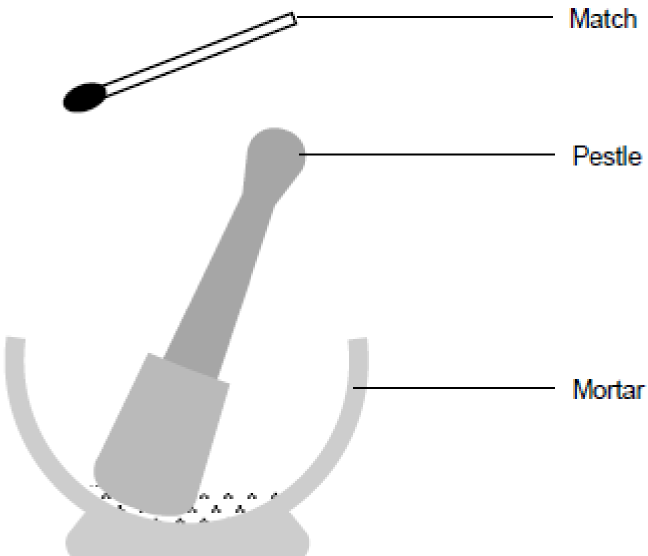
True or false? – response sheet

1.	True	Do not know	False	1.
2.	True	Do not know	False	2.
3.	True	Do not know	False	3.
4.	True	Do not know	False	4.
5.	True	Do not know	False	5.
6.	True	Do not know	False	6.
7.	True	Do not know	False	7.
8.	True	Do not know	False	8.
9.	True	Do not know	False	9.
10.	True	Do not know	False	10.
11.	True	Do not know	False	11.
12.	True	Do not know	False	12.
13.	True	Do not know	False	13.
14.	True	Do not know	False	14.
15.	True	Do not know	False	15.
16.	True	Do not know	False	16.
17.	True	Do not know	False	17.
18.	True	Do not know	False	18.
19.	True	Do not know	False	19.
20.	True	Do not know	False	20.

The reduction of iron oxide by carbon

Introduction

Metals high in the reactivity series will reduce the oxides of those lower in the series. The oxides of metals between zinc and copper in the reactivity series can be reduced by carbon. In this experiment, sodium carbonate is used to fuse the reactants in intimate contact.



What to do

1. Char the point of a used match, moisten it with a drop of water and rub on some sodium carbonate crystals.

2. Rub the point in some powdered iron(III) oxide (Fe_2O_3) and heat in a blue Bunsen burner flame until the point glows strongly.

3. Allow to cool.

4. Crush the charred head in a mortar and pestle then run a magnet through the pieces.

Health & Safety

Wear eye protection.

Questions

1. What does 'reduction' mean?

2. Carbon does not reduce aluminium oxide. Where would carbon be placed in this reactivity series?

Potassium
Sodium
Calcium
Magnesium
Aluminium
Zinc
Iron
Lead
Copper
What other information would you need to determine carbon's exact place?

3. Explain why calcium oxide cannot be reduced using carbon.

Activity 4: Displacement reactions between metals and their salts

Some metals are more reactive than others. In this experiment, a strip of metal is added to a solution of a compound of another metal. A more reactive metal displaces (pushes out) a less reactive metal from its compound.

Apparatus and chemicals

Eye protection

Each student or pair of students will require:

Spotting tile, with at least 16 depressions (or two smaller tiles)
Dropping (teat) pipette
Beaker (100 cm^3)
Felt tip pen or other means of labelling

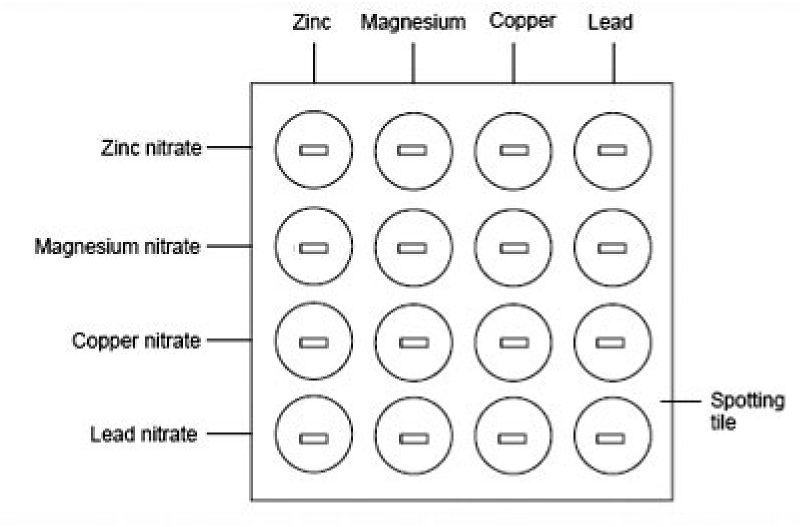
Access to about 5 cm^3 each of the following 0.1 mol dm^{-3} metal salt solutions:

Zinc sulfate (**Low Hazard** at this concentration),
Magnesium sulfate (**Low hazard**)
Copper(II) sulfate (**Low Hazard** at this concentration)
Lead(II) nitrate (**Toxic**, **Dangerous for the environment**)

Five samples, approximately 1 cm lengths or squares, of the following metals. The metals, except lead, present are low hazard as used here.
Zinc foil
Magnesium ribbon
Copper foil
Lead foil (**Toxic**, **Dangerous for environment**)

Procedure

a Using a dropping pipette, put a little of the zinc nitrate solution in four of the depressions in the spotting tile, using the following illustration as a guide. Label this row with the name of the solution. Rinse the pipette well with water afterwards.



b Do this for each solution in turn , rinsing the pipette when you change solution.

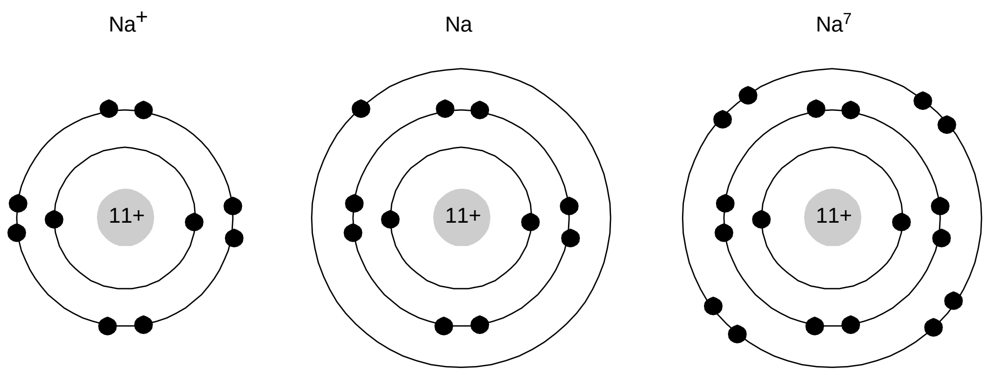
c Put a piece of each metal in each of the solutions, using the illustration as a guide.

d Over the next few minutes observe which mixtures have reacted and which have not.

Activity 6: Reactivity

Chemical stability (1)

The diagrams below represent three chemical species:-



Sodium ion with electronic configuration of 2.8

Sodium atom with electronic configuration of 2.8.1

Sodium ion with electronic configuration of 2.8.8

1. Tick ✓ one of the four statements:

☐ Na^{+} is more stable than Na

☐ Na^{+} and Na are equally stable

☐ Na^{+} is less stable than Na

☐ I do not know

Why did you think this was the answer?

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2. Tick ✓ one of the four statements:

☐ Na is more stable than Na^{7-}

☐ Na and Na^{7-} are equally stable

☐ Na is less stable than Na^{7-}

☐ I do not know

Why did you think this was the answer?

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3. Tick ✓ one of the four statements:

☐ Na^{7-} is more stable than Na^{+}

☐ Na^{7-} and Na^{+} are equally stable

☐ Na^{7-} is less stable than Na^{+}

☐ I do not know

Why did you think this was the answer?

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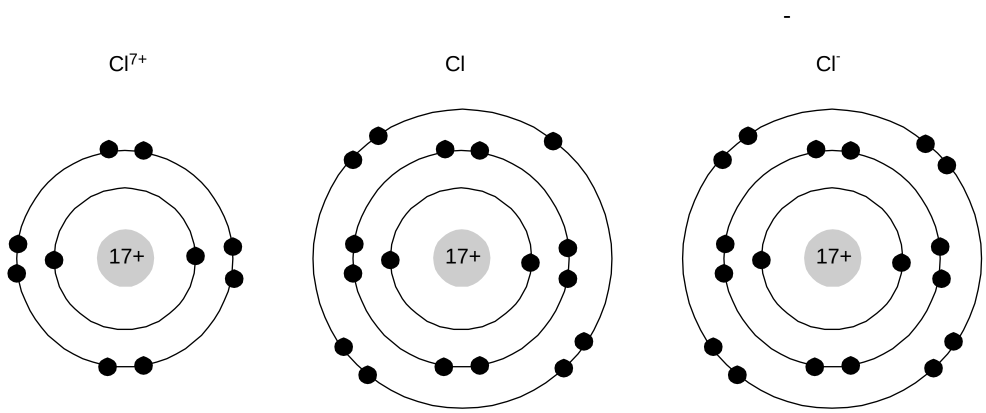
Chemical stability (2)

The diagrams below represent three chemical species:



Chloride ion with electronic configuration of 2.8	Chlorine atom with electronic configuration of 2.8.7	Chloride ion with electronic configuration of 2.8.8

4. Tick ✓ one of the four statements:

- ☐ Cl^{7+} is more stable than Cl
- ☐ Cl^{7+} is more stable than Cl
- ☐ Cl^{7+} is less stable than Cl
- ☐ I do not know

Why did you think this was the answer?

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5. Tick ✓ one of the four statements:

- ☐ Cl is more stable than Cl^{-}
- ☐ Cl and Cl^{-} are equally stable
- ☐ Cl is less stable than Cl^{-}
- ☐ I do not know

Why did you think this was the answer?

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6. Tick ✓ one of the four statements:

- ☐ Cl^{-} is more stable than Cl^{7+}
- ☐ Cl^{-} and Cl^{7+} are equally stable
- ☐ Cl^{-} is less stable than Cl^{7+}
- ☐ I do not know

Why did you think this was the answer?

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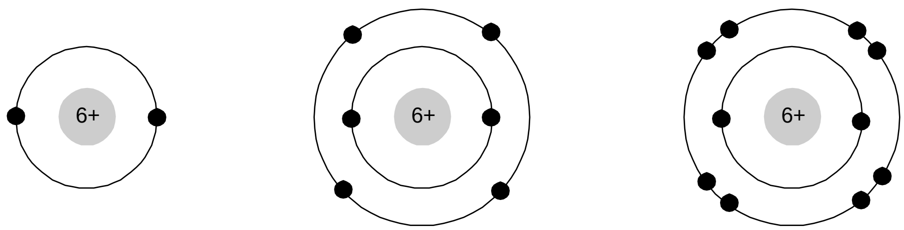
Chemical stability (3)

The diagrams below represent three chemical species:-

C^{4+} | C | C^{4-}



Carbon ion with electronic configuration of 2 | Carbon atom with electronic configuration of 2.4 | Carbon ion with electronic configuration of 2.8

7. Tick ✓ one of the four statements:

☐ C^{4+} is more stable than C

☐ C^{4+} and C are equally stable

☐ C^{4+} is less stable than C

☐ I do not know

Why did you think this was the answer?

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8. Tick ✓ one of the four statements:

☐ C is more stable than C^{4-}

☐ C and C^{4-} are equally stable

☐ C is less stable than C^{4-}

☐ I do not know

Why did you think this was the answer?

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9. Tick ✓ one of the four statements:

☐ C^{4-} is more stable than C^{4+}

☐ C^{4-} and C^{4+} are equally stable

☐ C^{4-} is less stable than C^{4+}

☐ I do not know

Why did you think this was the answer?

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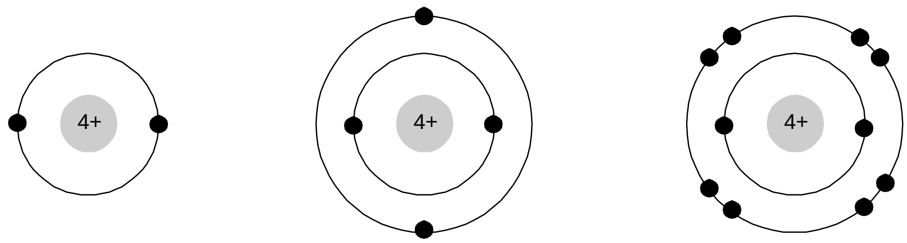
Chemical stability (4)

The diagrams below represent three chemical species:-

Be^{2+} Be Be^{6-}



Beryllium ion with electronic configuration of 2

Beryllium atom electronic configuration of 2.2

Beryllium ion with configuration of 2.8

10. Tick ✓ one of the four statements:

☐ Be^{2+} is more stable than Be

☐ Be^{2+} and Be are equally stable

☐ Be^{2+} is less stable than Be

☐ I do not know

Why did you think this was the answer?

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11. Tick ✓ one of the four statements:

☐ Be is more stable than Be^{6-}

☐ Be and Be^{6-} are equally stable

☐ Be is less stable than Be^{6-}

☐ I do not know

Why did you think this was the answer?

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12. Tick ✓ one of the four statements:

q Be^{6-} is more stable than Be^{2+}

q Be^{6-} and Be^{2+} are equally stable

q Be^{6-} is less stable than Be^{2+}

q I do not know

Why did you think this was the answer?

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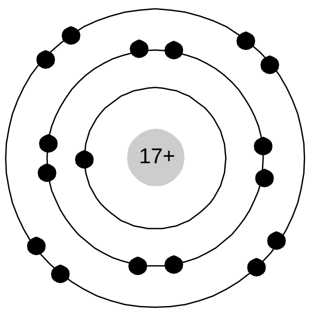
Chemical stability (5)

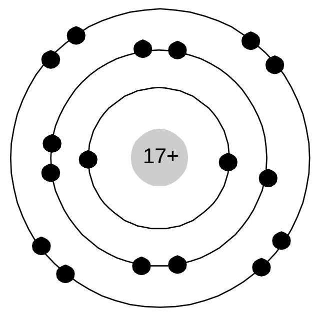
The diagrams below represent three chemical species:-

1.8.8



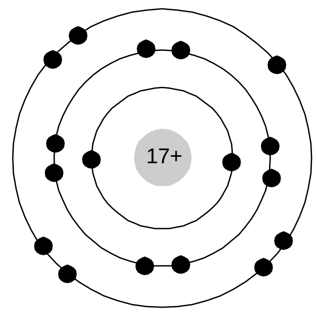
Chlorine atom with electronic configuration of 1.8.8

2.7.8



Chlorine atom with electronic configuration of 2.7.8

2.8.7



Chlorine atom with electronic configuration of 2.8.7

13. Tick ✓ one of the four statements:

☐ 1.8.8 is more stable than 2.7.8

☐ 1.8.8 and 2.7.8 are equally stable

☐ 1.8.8 is less stable than 2.7.8

☐ I do not know

Why did you think this was the answer?

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14. Tick ✓ one of the four statements:

☐ 2.7.8 is more stable than 2.8.7

☐ 2.7.8 and 2.8.7 are equally stable

☐ 2.7.8 is less stable than 2.8.7

☐ I do not know

Why did you think this was the answer?

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15. Tick ✓ one of the four statements:

☐ 2.8.7 is more stable than 1.8.8

☐ 2.8.7 and 1.8.8 are equally stable

☐ 2.8.7 is less stable than 1.8.8

☐ I do not know

Why did you think this was the answer?

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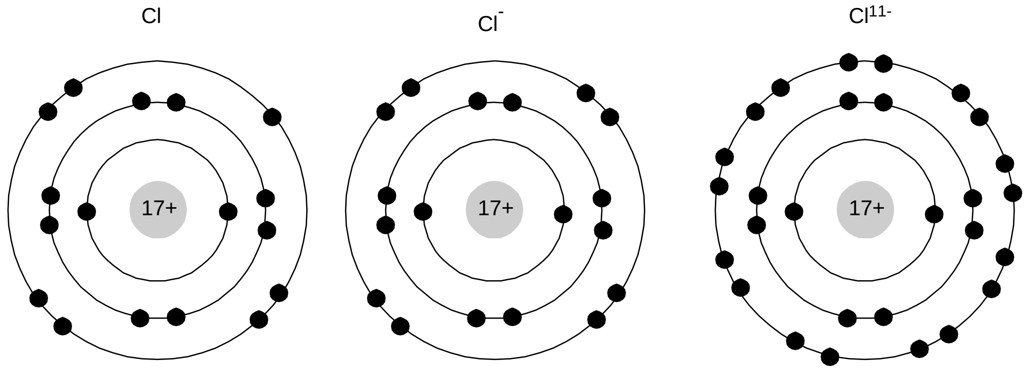
Chemical stability (6)

The diagrams below represent three chemical species:



Chlorine atom with configuration of 2.8.7

Chloride ion with electronic configuration of 2.8.8

Chloride ion with electronic configuration of 2.8.18

16. Tick ✓ one of the four statements:

- ☐ Cl is more stable than Cl^-
- ☐ Cl and Cl^- are equally stable
- ☐ Cl is less stable than Cl^-
- ☐ I do not know

Why did you think this was the answer?

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17. Tick ✓ one of the four statements:

- ☐ Cl^- is more stable than Cl^{11-}
- ☐ Cl^- and Cl^{11-} are equally stable
- ☐ Cl^- is less stable than Cl^{11-}
- ☐ I do not know

Why did you think this was the answer?

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18. Tick ✓ one of the four statements:

- ☐ Cl^{11-} is more stable than Cl
- ☐ Cl^{11-} and Cl are equally stable
- ☐ Cl^{11-} is less stable than Cl
- ☐ I do not know

Why did you think this was the answer?

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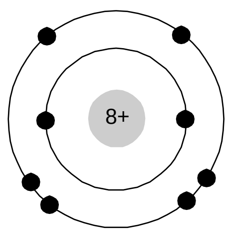
Chemical stability (7)

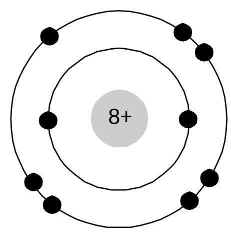
The diagrams below represent three chemical species:

O



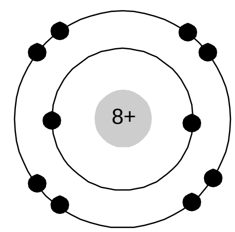
Oxygen atom with electronic configuration of 2.6

O^{-}



Oxygen ion with electronic configuration of 2.7

O^{2-}



Oxide ion with configuration of 2.8

19. Tick ✓ one of the four statements:

- ☐ O is more stable than O^{-}
- ☐ O and O^{-} are equally stable
- ☐ O is less stable than O^{-}
- ☐ I do not know

Why did you think this was the answer?

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20. Tick ✓ one of the four statements:

- ☐ O^{-} is more stable than O^{2-}
- ☐ O^{-} and O^{2-} are equally stable
- ☐ O^{-} is less stable than O^{2-}
- ☐ I do not know

Why did you think this was the answer?

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21. Tick ✓ one of the four statements:

- ☐ O^{2-} is more stable than O
- ☐ O^{2-} and O are equally stable
- ☐ O^{2-} is less stable than O
- ☐ I do not know

Why did you think this was the answer?

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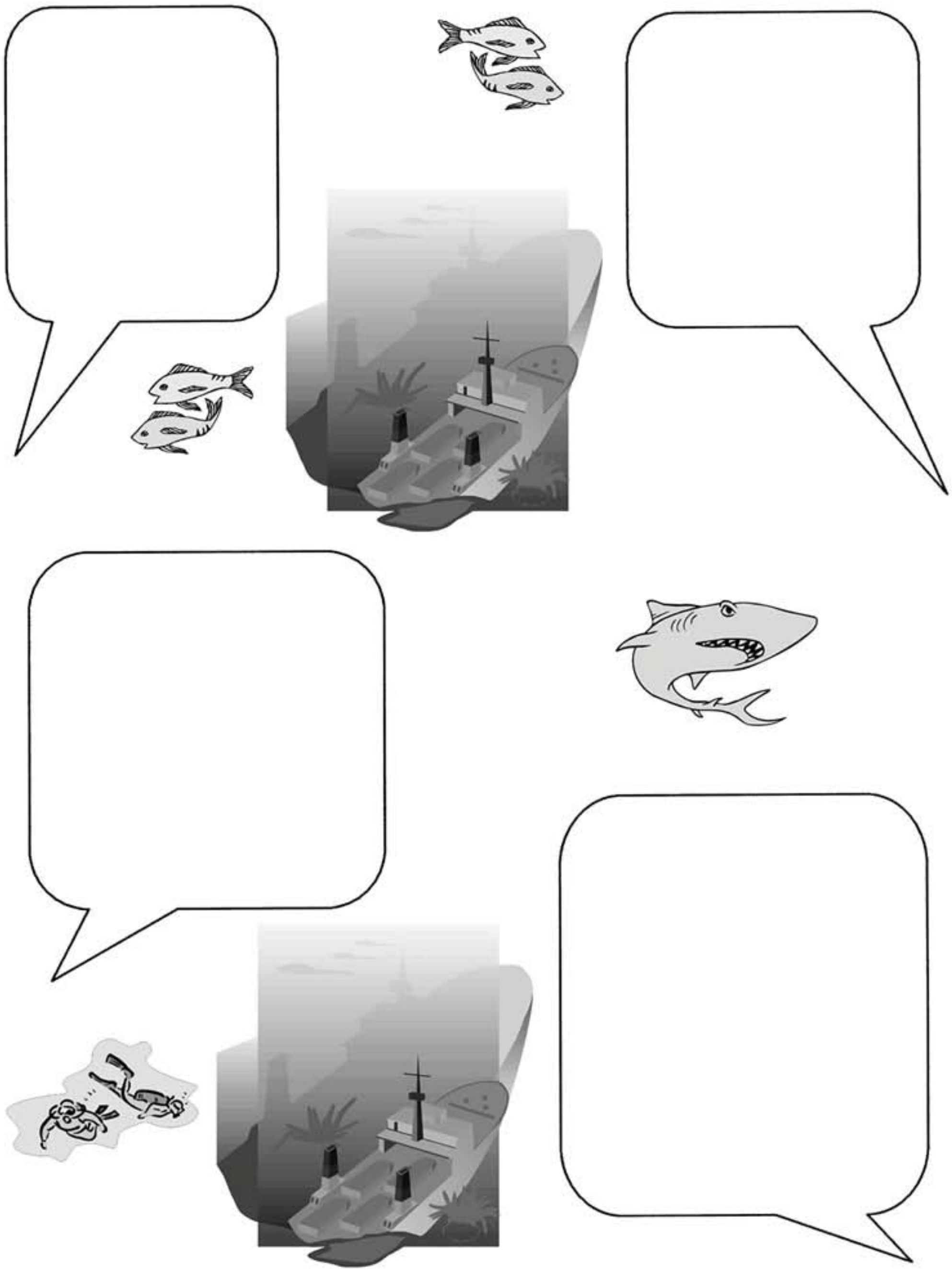
Rusting



Chemistry for the gifted and talented

Further thinking

Here are some suggested answers, but you may have thought of other and better ones.

The best explanations take the reasoning further and explain why...

...the shallow water might be warmer.

- Water above 4 °C expands on heating so it rises upwards through colder, denser water. The sun heats the surface of the water. Less sunlight gets down to the deeper water which is therefore warmed less.

...the shallow water might have more oxygen in it.

- The shallow water is closer to the surface and therefore nearer the source of oxygen (assuming it is dissolving from the air).
- More sunlight reaches the shallower water, encouraging more photosynthesis and therefore more production of oxygen.

...the shallow water might get stirred up more.

- The water nearer the surface is likely to be disturbed by the waves more.
- More sealife occupies shallow water and will stir the water more.

...the shallow water might have a higher concentration of salt.

- Evaporation at the surface might produce a higher salt concentration as might freezing of seawater (when seawater freezes it leaves a proportion of its salt in the surrounding water). However, water which has a greater salt concentration is denser than water with less salt and so it tends to sink to deeper water.

Applications in real life

Who might be very interested in how the rate of rusting changes with depth at sea?

- Salvage companies who may want to predict the extent of corrosion in sunken ships.
- Ship owners who want to predict the working life of their vessels.
- Oil rig companies who want the iron legs of the rigs to remain strong enough to support the rig.
- Naval historians that want to date artefacts or shipwrecks.

Planning

The details of each plan will vary but here are some general points to consider.

- The mass balance has a limited precision. It probably gives readings to the nearest 0.1 g or 0.01 g. Therefore data are unreliable if you are measuring too small a difference in mass (so if there is only a small amount of rust a mass balance will not measure it accurately).
- To obtain more rust you might consider using more than one nail and leaving them for quite a while to rust.

- You need to do the same experiment more than once to find out how reliable the data is. If the data from the repeat experiment are very different from the other data then your experiment is unreliable.

Activity 8: Diagnostic test

Part 1

1 Which is more reactive, potassium or magnesium, and why? (7)

2 Which is more reactive, sulfur or fluorine, and why? (7)

3 Why might you expect sulfur and bromine to have similar reactivities? (7)

4 Why can aluminium not be extracted from its oxide ore using coke as a reducing agent? (3)

5 Why does copper not react with dilute hydrochloric acid? (3)

Part 2

1 Complete the following word equations by either writing the names of the products, or 'no reaction' if you think there will be no reaction:

a) Magnesium + copper sulfate →

b) Lead + zinc nitrate →

c) Sodium hydroxide + sodium nitrate →

d) Potassium hydroxide + zinc sulfate →

e) Aluminium + iron oxide →

f) Zinc + sulfuric acid →

g) Copper + hydrochloric acid →

h) Sodium hydroxide + nitric acid →

i) Calcium carbonate + hydrochloric acid →

j) Magnesium + water →

Glossary

Below are some of the terms used within this document:

Term	Definition
Corrosion	Corrosion is the disintegration of a material into its constituent components
Displacement	A more reactive substance displaces a less reactive one from a compound
Electron	Stable elementary particle with a negative charge
Element	Containing one type of atom
Ion	An atom that has either lost or gained an electron forming a charged particle
oxidation	The is the loss of electrons
Reduction	The gain of electrons
Thermal dissociation	A reaction that can be reversed by altering the temperature.

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