## Storyline: answers to assignments

- **1 a** The concentrations of the Group 2 elements, calcium and magnesium, are much higher, relative to sodium, in Dead Sea water.
  - **b** The proportion of bromide ions is particularly high in Dead Sea water: about 75 times higher than in ocean water.
- 2 a 14000 tonnes b 64%
- 3 An advantage of the Anglesey process compared to the Dead Sea process is that it is not necessary to evaporate any of the sea water.

An advantage of the Dead Sea process is that one displacement with chlorine is sufficient. The Anglesey process requires two treatments with chlorine, for after the first displacement, the concentration of bromine is too low to allow for effective separation. The bromine is reduced by reacting it with sulphur dioxide and water which converts it to hydrogen bromide. Bromine is then displaced from the hydrogen bromide by a second treatment with chlorine.

- **4** Some of many suggestions are:
  - dangerous chemicals could be transported at times when roads are less busy
  - routes should avoid centres of population
  - hazards, emergency telephone numbers and emergency treatment should be clearly labelled on the vehicle
  - drivers should carry documents containing useful information
  - vehicles should be specially designed to avoid turning over and other ways of causing damage to the cargo.
- 5 a i  $Br^- \rightarrow Br + e^-$

b

- **ii**  $Ag^+ + e^- \rightarrow Ag$
- iii Process i is oxidation, ii is reduction.
- i The developer is a reducing agent.
- **ii**  $Ag^+$  are reduced.
- **iii** Br<sup>-</sup> ions are not oxidised during development.
- 6 **a**  $2Cu_3(OH)_2(CO_3)_2 + 3C \rightarrow 6Cu + 7CO_2 + 2H_2O$ **b** The oxidation state changes which occur are

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Cu from +2 \rightarrow 0
C from 0 \rightarrow +4
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**c** 1 mol of azurite has a mass of 346 g and produces 192 g of copper

1 kg of azurite will produce  $\frac{192}{346}$  kg = 0.55 kg of copper

- a Mining: noise, dust, smoke, rock and solid waste. Concentrating: noise, rock and solid waste, contamination of water.
   Smelting: noise, dust and smoke, dangerous gases, solid waste.
  - **b** Mining operations could be sited well away from people's homes. Dust and smoke would be filtered out of the air. Dangerous gases could be removed (eg SO<sub>2</sub> reacting with CaCO<sub>3</sub>). Solid waste could be used to fill old open-pit workings. Mounds could be landscaped and re-vegetated or screened with trees. Contaminants could be filtered out of water, eg by growing certain species of plants.
- **8 a** 80 000 m<sup>3</sup>
  - **b** Since 99% of the mined rock is waste, approximately  $80\,000\,\text{m}^3$  of waste is disposed of each day.
  - **c** Mining and concentration contribute about equally; smelting produces relatively little waste.
  - **d** Volume of office block =  $60\,000\,\text{m}^3$ . The mine produces more than this volume of waste each day.
- **9 a** % Cu by mass = 100 × 64/184 ≈ 35%
  - **b** % chalcopyrite = 28 × 100/35 = 80%
  - **c** Froth flotation produces material which is mainly chalcopyrite from a very low-grade material. It is very effective.

10	a	Smelting:	Cu(+2)	$\rightarrow Cu(0)$	reduced
			O(0)	→ O(-2)	reduced
			Fe(+2)	$\rightarrow$ Fe(+3)	oxidised
			S(-2)	$\rightarrow$ S(+4)	oxidised
		Bacterial leaching:	Fe(+2)	$\rightarrow$ Fe(+3)	oxidised
			S(-2)	$\rightarrow$ S(+6)	oxidised
			O(0)	→ O(-2)	reduced
	b	The negative ions i	n sulphic	de minerals o	can be oxidi

**b** The negative ions in sulphide minerals can be oxidised by combination with oxygen to form  $SO_2$  or  $SO_4^{2^-}$ . In carbonate and oxide minerals, the negative ions cannot combine further with oxygen and so the elements are already fully oxidised.

## Activities: notes and answers to questions\_

## M1.1 Solutions of ions

**AS LEVEL** 

*Safety note* Information about hazardous chemicals is given on the activity sheet.

This activity helps students to develop and consolidate their understanding of the nature of solutions of ionic compounds. Students should become confident about their 'picture' of what happens when an ionic compound dissolves in water, when solutions of ionic compounds are diluted or mixed with other solutions, and when reactions occur between solutions of ionic compounds. Students should be encouraged to discuss with each other their observations, answers to questions and in particular the explanations they think should be written into Table 1. A *brief* summary of the table is shown on page 33. Encourage your students to think about the ions and molecules present in solution, and the ions present in the solids, and to fill in their tables in more detail.

- **a** 1 mol dm<sup>-3</sup>
- **b** 1 mol dm<sup>-3</sup>
- **c** Concentration of Cu<sup>2+</sup>(aq) is 1 mol dm<sup>-3</sup> Concentration of Cl<sup>-</sup>(aq) is 2 mol dm<sup>-3</sup>
- **d** A white precipitate
- e In both examples, the same reaction is occurring

 $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ 

and in both examples the concentrations of  $H^+(aq)$  and of  $OH^-(aq)$  are identical, therefore the enthalpy changes will be identical.



	Reagents	Observations	Explanation	Equations
i	$1 \text{ cm}^3 \text{ CuSO}_4(\text{aq}) + 5 \text{ cm}^3 \text{ H}_2\text{O}$	Pale blue solution	Mixing/diluting	
ii	5 drops CuSO <sub>4</sub> (aq) + 5 cm <sup>3</sup> H <sub>2</sub> O	Very pale blue solution	Mixing/diluting	—
iii	$1 \text{ cm}^3 \text{ CuSO}_4(\text{aq}) + 5 \text{ cm}^3 \text{ NaNO}_3(\text{aq})$	Pale blue solution	Mixing/diluting	—
iv	5 drops $CuSO_4(aq) + 5 cm^3 NaNO_3(aq)$	Very pale blue solution	Mixing/diluting	—
v	$1 \text{ cm}^3 \text{ CuSO}_4(\text{aq}) + 1 \text{ cm}^3 \text{ Na}_2 \text{CO}_3(\text{aq})$	Blue/green ppt	Precipitation, insoluble salt	$Cu^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CuCO_3(s)$
vi	$1 \text{ cm}^3 \text{ CuSO}_4(\text{aq}) + 1 \text{ cm}^3 \text{ NaOH}(\text{aq})$	Blue ppt	Precipitation, insoluble salt	$Cu^{2+}(aq) + 2OH^{-}(aq) \rightarrow Cu(OH)_{2}(s)$
vii	$1 \text{ cm}^3 \text{ CuSO}_4(\text{aq}) + 1 \text{ cm}^3 \text{Pb(NO}_3)_2(\text{aq})$	White ppt, blue solution	Precipitation, insoluble salt	$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$
viii	$1 \text{ cm}^3 \text{ Pb(NO}_3)_2(\text{aq}) + 1 \text{ cm}^3 \text{ KI(aq)}^2$	Yellow ppt	Precipitation, insoluble salt	$Pb^{2+}(aq) + 2l^{-}(aq) \rightarrow PbI_{2}(s)$
ix	$1 \text{ cm}^3 \text{ Pb}(\text{NO}_3)_2^2(\text{aq}) + 1 \text{ cm}^3 \text{ HCl}(\text{aq})$	White ppt	Precipitation, insoluble salt	$Pb^{2+}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_{2}(s)$
x	$1 \text{ cm}^3 \text{ Na}_2 \text{CO}_3(\text{aq}) + 2 \text{ cm}^3 \text{ HCl(aq)}$	Bubbles colourless gas	Acid–base, soluble salt	$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(I) + CO_2(g)$
xi	$1 \text{ cm}^3 \text{ NaOH(aq)} + 1 \text{ cm}^3 \text{ HCl(aq)}$	Colourless solution	Acid–base, soluble salt	$H^+(aq) + OH^-(aq) \rightarrow H_2O(I)$
xii	$\frac{1}{2}$ spatula CuCO <sub>3</sub> (s) + 2 cm <sup>3</sup> H <sub>2</sub> SO <sub>4</sub> (aq)	Bubbles colourless gas, blue solution	Acid–base, soluble salt (dissolving)	$2H^{+}(aq) + CO_{3}^{2-}(aq) \rightarrow H_{2}O(I) + CO_{2}(g)$

## M1.2 Bromine production

**a i**  $Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(g) + 2Cl^-(aq)$ Br<sup>-</sup> is oxidised by  $Cl_2$ **ii**  $Br_2(aq) + SO_2(g) + 2H_2O(l) \rightarrow$ 

 $2HBr(aq) + H_2SO_4(aq)$ 

- SO<sub>2</sub> is oxidised by Br<sub>2</sub>
- iii  $Cl_2(g) + 2HBr(aq) \rightarrow Br_2(g) + 2HCl(aq)$  or as in i HBr (or Br<sup>-</sup>) is oxidised by  $Cl_2$
- **b** Volatility. Almost insoluble in water.
- **c**  $Br_2(g)$ , steam and HCl(g)
- $\begin{array}{c} \mathbf{d} \quad \mathbf{X} \operatorname{HCl}(aq) \\ \mathbf{Y} \operatorname{H}_2 \operatorname{SO}_4(aq) \end{array}$
- e i Steam for steaming out towerii Condensing vapour from steaming out tower

## M1.3 Halogens and their compounds

*Safety note* Information about hazardous chemicals is given on the activity sheet.

If possible also have available samples of chlorine gas, bromine liquid and solid iodine for observation. **Take great care** for chlorine and bromine are severe irritants and are harmful. Iodine is harmful.

This activity provides a good opportunity for students to practise and develop their skills in implementing practical instructions, making observations, analysing their observations and drawing conclusions. It can also be used for *assessment* of experimental skills (see **OCR Teacher Support: Coursework Guidance for Chemistry (Salters)**).

- **a** The halogens used are all coloured, volatile substances. They are less soluble in water than in organic solvents. Fluorine should be a pale coloured gas, astatine should be a black solid. Neither would be particularly soluble in water.
- **b** The alkali metal halides are very soluble in water but insoluble in cyclohexane. The same should be true for KF and KAt.

**AS LEVEL** 

- ii There is electron transfer in both processes, for example:
   2Br<sup>-</sup> → Br<sub>2</sub>+ 2e<sup>-</sup>
   Cl<sub>2</sub> + 2e<sup>-</sup> → 2Cl<sup>-</sup>
- **d i** The decreasing order is  $Cl_2 > Br_2 > I_2$ 
  - **ii** Fluorine would come before chlorine and astatine after iodine.
  - iii Oxidising power decreases down Group 7.
- e The depth of 'yellowness' increases from AgCl to AgI.
- **f i** AgCl appears to be more sensitive than AgBr, with AgI unaffected, when precipitates are used.
  - ii Ag<sup>+</sup> ions are reduced to Ag. Br<sup>-</sup> ions are oxidised to  $Br_2$
- g i AgCl should be most sensitive in low levels of light.ii AgI should be best for high energy radiation.
- **h i** S(+2) in S<sub>2</sub>O<sub>3</sub><sup>2-</sup>; S(+2<sup>1</sup>/<sub>2</sub>) in S<sub>4</sub>O<sub>6</sub><sup>2-</sup> **ii** I<sub>2</sub> + 2S<sub>2</sub>O<sub>3</sub><sup>2-</sup> → 2I<sup>-</sup> + S<sub>4</sub>O<sub>6</sub><sup>2-</sup> **iii** Sulphur is oxidised from +2 to +2<sup>1</sup>/<sub>2</sub>; iodine is reduced from oxidation state 0 to −1.

### M1.4 This liquid is dangerous

- a i Glass does not react with bromine and inspection can be carried out safely from outside.ii Glass is too brittle for use in tankers.
- **b** Safety rules: evacuate the area; emergency staff should wear full protective clothing, including breathing apparatus; add sodium thiosulphate to reduce the bromine; wash away with plenty of water, retaining the waste.
- c The red/brown colour should disappear.
- **d** Packing provides a much greater surface for gas/liquid contact. Bromine is dense and could sink downwards, so the packing extends below the entry point.
- e The products of the reaction with sodium hydroxide are very soluble in water. Sodium hydroxide reacts with bromine:

 $2NaOH + Br_2 \rightarrow NaBr + NaOBr + H_2O$ 

**f** The absorbing solution must be strongly alkaline. If the pH falls, the solution is becoming spent and must be replaced.

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### M1.5 Manufacturing chlorine

- a i At the positive electrode, oxidation At the negative electrode, reductionii Sodium chloride
- **b i** 25000 moles
  - **ii** 0.5
  - **iii**  $12\,500 \text{ moles} = 0.89 \text{ tonnes}$
- **d i** Na<sup>+</sup> ions must be able to diffuse to prevent process stopping.
  - Cl<sup>-</sup> ions would contaminate product if they were able to diffuse into the compartment containing the negative electrode. OH<sup>-</sup> ions must remain in the compartment containing the negative electrode to form product.
- **e** Ca<sup>2+</sup> and Mg<sup>2+</sup> would bind strongly to the negatively charged groups in the membrane and prevent passage of Na<sup>+</sup>.
- **f** It appears to meet all the criteria listed.
- g i Purer products, fewer environmental dangers (eg Hg in effluent). Low maintenance costs.ii Capital costs of replacement.
- **h** Water must not be present. Use molten sodium chloride, or hydrogen will be discharged, rather than sodium, at the negative electrode.

## M2.1 Mineral spotting

For supplies of unroasted ore and mineral samples for inspection, see the **Salters Advanced Chemistry Web Site**.

- **a** Students should be able to see evidence for all the minerals listed in the Data Table.
- **b** Liberation only sets free grains down to a certain *minimum* size. There will still be some very small grains of mineral which are attached to host rock.
- **c** The grain sizes will vary, an average value will be around 0.1 mm.

### M2.2 Getting at the minerals

*Safety not*e Information about hazardous chemicals is given on the activity sheet.

Earlier versions of this activity and **Activity M2.3** required you to roast a sample of ore. It is now recommended that you buy artificial 'roasted ore' along with the unroasted ore required for **Activity M2.1**. (See **Salters Advanced Chemistry Web Site** for supplier.)

- **a** The contents of the beaker containing acid fizz violently. Most of the acid reacts with the calcium carbonate. The ammonia leach reacts without effervescence to produce a deep blue solution containing extracted copper compounds.
- **b** Reagent is not wasted by reaction with the host rock and the process is much easier to control if the ammonia leach is used.

### M2.3 Extracting copper

*Safety note* Information about hazardous chemicals is given on the activity sheet. It is important to use a fume cupboard for this activity.

It is recommended that you use the artificial 'roasted ore' for this activity. This has been made by mixing 4% copper(II) oxide and 96% crushed limestone by mass.

#### Leaching the ore

Satisfactory results can be obtained with leaching times of 10 minutes. This stage can be done in a double period (70 – 80 minutes), along with **Activity M2.1** or **M2.2**.

- **a** Leaching is a slow process. A long time is needed even when the process is speeded up by warming.
- **b** The mining company will wish to maximise the quantity of copper produced *per day*.

# Vacuum filtration and neutralising leached solution

This can be done in another double period. Take care with the filtration, as any fine particulate ore which comes through gives a green hue to the solution and this can be confusing when students try to dissolve the precipitate later.

- i The filtrates become progressively paler blue.ii The third filtrate is still quite blue. A fourth washing would still remove some copper compounds.
  - iii The process would go on for ever, washing out progressively smaller and smaller amounts of copper.iv By distillation.
- **d i** Carbon dioxide. Lime water turns milky.
  - ii Pale blue copper(II) hydroxide (some basic carbonates also likely to be present). The green hue mentioned earlier is a problem here, as it persists and gives a slightly cloudy appearance to the solution. The final solution can look anything from pale blue to pale green. Normal filtration at this stage, with fluted filter paper, gives a blue solution but it takes time.
  - $\begin{array}{rcl} \textbf{iii} & \operatorname{CuCO}_3 + \operatorname{H}_2 \mathrm{SO}_4 & \rightarrow & \operatorname{CuSO}_4 + \operatorname{CO}_2 + \operatorname{H}_2 \mathrm{O} \\ & \operatorname{Cu}(\mathrm{OH})_2 + \operatorname{H}_2 \mathrm{SO}_4 & \rightarrow & \operatorname{CuSO}_4 + 2\operatorname{H}_2 \mathrm{O} \\ & 2\mathrm{NH}_3 + \operatorname{H}_2 \mathrm{SO}_4 & \rightarrow & (\mathrm{NH}_4)_2 \mathrm{SO}_4 \end{array}$

# Finding the concentration of $Cu^{2+}(aq)$ ions in solution (optional extension)

This provides instructions for finding the concentration of  $Cu^{2+}(aq)$  in the filtrate from step **9**, by using the copper ions to oxidise iodide ions to iodine and then titrating the iodine with a standard solution of sodium thiosulphate.

Redox titrations are not covered until **The Steel Story** so the activity gives students the mole ratio of sodium thiosulphate to  $Cu^{2+}(aq)$ , but with some students you may wish to justify this by giving the equations:

 $Cu^{2+}(aq) + 2I^{-}(aq) \rightarrow CuI(s) + 0.5I_{2}(aq)$   $I_{2}(aq) + 2S_{2}O_{3}^{2-}(aq) \rightarrow S_{4}O_{6}^{2-}(aq) + 2I^{-}(aq)$ moles of S<sub>2</sub>O<sub>3</sub><sup>2-</sup>(aq) = moles of Cu<sup>2+</sup>(aq)

There may be some problems with getting the correct pH to ensure precipitation of CuI, so it is important to look for the brown colour of iodine in solution when the KI is added.

# AS LEVEL

If students do the titration, the unused contents of the volumetric flask (see step **E9**) are then used for the gravimetric determination beginning at step **10**.

## Producing and weighing the copper

This can be done in a double period, although the sample of copper may need to be left overnight to dry if an oven is not used.

# Evaluation of your results and procedures (optional extension)

**g** Typical results in **f** obtained by students give the percentage of copper extracted from the roasted ore as 2.5%–3.0%. The 'roasted ore' is made up of 4.0% CuO and 96% limestone and so contains 3.2% by mass of copper. The titration results indicate that 80%–90% of the copper is extracted.

Most students find that the mass of copper extracted by displacement is slightly higher. This is likely to be an anomalous result due to lack of thorough drying.

The titration method is likely to be the more accurate as there are more obvious potential sources of error associated with the procedure used in the displacement method.

**h** Unleached copper mineral will be the biggest source of lost copper.

# M2.4 Finding out bow much acid there is in a solution

*Safety note* Information about hazardous materials is given on the activity sheet.

This activity provides a further opportunity for students to practise and develop their skills in evaluating their evidence and procedures.

It can also be used for *assessment* of experimental skills (see **OCR Teacher Support: Coursework Guidance for Chemistry (Salters)**).

- a c This is an opportunity to discuss how uncertainties in readings should affect the number of significant figures used in final answers (see Appendix 2 in the Individual Investigation: notes for students (Activities and Assessment Pack, page 361)).
- **d i** 2
  - ii Both have masses of 64 giii 2 tonnes of SO<sub>2</sub>
- **e i** 2000 tonnes of SO<sub>2</sub> **ii** 5479 km<sup>3</sup> of air

## M2.5 The philosopher's microbe?

- **a** The gold was deposited during hydrothermal precipitation in cracks in the host rock.
- **b** It is often difficult to keep the leach mixture cool enough for the bacteria to work effectively.
- **c** Acid, oxygen and carbon dioxide.
- **d** The bacteria can only survive on sulphide minerals. These are not present in any life form.
- e Bacterial leaching can be economically carried out on old spoil-heaps which cannot be processed economically using current methods.

## M2.6 Molecules and networks

- a i Carbon monoxide simple molecular
  ii Silica giant covalent (network)
  iii Hexane simple molecular.
- **b** In a solid, the atoms are held in fixed positions. (The only movement possible is vibration.) When a solid melts, the rigid structure breaks down and the particles move around.

To melt a giant covalent (network) structure it is necessary to overcome the covalent bonds between the atoms. When a simple molecular structure melts the molecules remain intact and it is only necessary to overcome the weak intermolecular forces between the molecules, which requires less energy than that needed to overcome covalent bonds.

c A carbon dioxide molecule is made up of one carbon atom covalently bonded to two oxygen atoms. Solid carbon dioxide consists of CO<sub>2</sub> molecules held together by weak intermolecular forces. When solid carbon dioxide is cut it is relatively easy to force the knife between the layers of molecules because the forces holding them together are weak. Silica consists of a giant covalent (network) structure in which each silicon atom is covalently bonded to four oxygen atoms and each oxygen to two silicon atoms. To cut silica it would be necessary to force a knife between layers of atoms held together by covalent bonds. This is not possible as the bonding forces are too strong.

