Unit Preparation Booklet

C4.2 Extraction of Metals

Teacher name:

Science Mastery

Ark Curriculum+

Science **Mastery**

Contents

Steps to Success

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Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

Scope and Sequence

Scope

This unit begins with prior knowledge review of the reactions of metals, and ions, ionic formulae and ionic bonding. From here, students will learn about the extraction of less reactive metals using displacement reactions. This will also include reference to prior learning, as students have already studied displacement reactions. Here, students will revisit the definitions of oxidation and reduction in terms of reaction with oxygen. At this point, students studying higher tier material will be introduced to ionic and half equations and redox equations, where we will define reduction and oxidation in terms of electrons for this first time. This will be aided by the recent review of ions and ionic formulae. Ionic and half equations are first taught outside the context of electrolysis and extraction of metals, so that students are confident in the notation and in interpreting these equations. From here, students will meet the process of electrolysis, building their knowledge of this process over a number of lessons, and completing the required practical in electrolysis. This topic gives students their first opportunity to apply ionic and half equations and to see how they are useful. Students will first encounter electrolysis in principle, then the electrolysis of simple molten ionic compounds, and then the electrolysis of ionic solutions where there are competing ions at each electrode. The end of the unit deals with metals more generally, looking at corrosion and its prevention, alternative methods of extraction and recycling metals. Each of these topics links back to previous learning at KS3, especially 'Using resources' topic in year 9 and rusting/reactions of metals. Having learned about the extraction of metals at this point, students can appreciate the energy required to do this, and the scarcity of some ores, and so realise the value of preventing corrosion of extracted metals, and recycling these where possible to preserve valuable resources.

Sequence

In C2.2 Changing Substances, pupils will have encountered different types of chemical reaction, including oxidation reactions and acid and metal reactions. Later, in C3.2 Introduction to Quantitative Chemistry, pupils will have learned about writing balanced symbol equations and how to make soluble salts. Students have more recently learned about how ions are formed and the details of ionic bonding (in C4.1 Structure and Bonding).

The knowledge within this unit has been sequenced so that there is recap of fundamental knowledge of chemical reactions and ions, before moving onto electrolysis. There are 6 lessons dedicated to learning about electrolysis of molten ionic compounds and ionic solution, giving time to practice and apply the tricky process of electrolysis. Then the knowledge of electrolysis is applied in real-life contexts such as electroplating and in obtaining raw materials.

Knowledge and skills from this unit will be practised further in the next chemistry unit C4.3 Quantitative Chemistry. The topic recycling and effects on the environment will be referred to in the future unit of C5.2 Our Atmosphere.

A full set of knowledge objectives for this unit can be found as **Appendix 3.**

1	2	3	4

Prior Knowledge Review: Reactions of Metals	Extracting Less Reactive Metals	Prior Knowledge Review: Ions, Ionic Bonding and Deducing Ionic Formulae	HT only: Ionic Equations and Displacement Reactions
5	**6**	**7**	**8**
HT only: Writing Half Equations	HT: Ionic Equations for the Reactions of Acids and Metals	Introduction to Electrolysis	Extracting Metals by Electrolysis
9	**10**	**11**	**12**
Electrolysis of Molten Ionic Compounds	Electrolysis in Solutions	Required Practical: The Electrolysis of Aqueous Solutions Part 1	Required Practical: The Electrolysis of Aqueous Solutions Part 2
13	**14**	**15**	**16**
Taking it Further: Corrosion and its Prevention	(HT) Obtaining Raw Materials	Recycling Metals	Feedback Lesson

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

TASK: Below is the pre-unit quiz available for your pupils. Complete yourself and set for your pupils ahead of starting the unit. There is space to record the key outcomes from marking the quiz for your class. **See Appendix 1 for the mark scheme.**

1. Choose the correct general word equation for the reaction of metals and acid.[1]

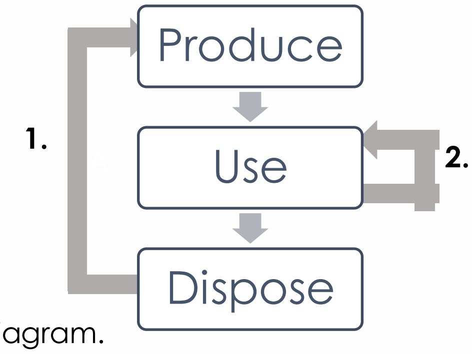
Tick (✓) **one** box.

A. Acid + metal → salt + water ☐

B. Acid + metal → salt + hydrogen ☐

C. Acid + metal → salt + carbon dioxide ☐

2. The diagram below shows ways to save the limited resources that are on Earth.



Complete the gaps in the diagram. [1]

Tick (✓) **one** box.

A. 1 = recycle 2 = reduce ☐

B. 1 = reduce 2 = recycle ☐

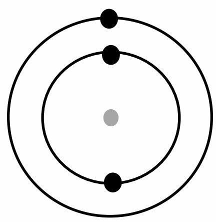
C. 1 = recycle 2 = reuse ☐

D. 1 = reuse 2 = recycle ☐

3. The atomic structure of metals relates to their position on the Periodic Table.

In which group of the Periodic Table would you find the element represented by this electronic configuration? [1]

Tick (✓) **one** box.



A. Group 2 ☐

B. Group 3 ☐

C. Group 1 ☐

4. A finite resource is a resource that… [1]

Tick (✓) **one** box.

A. is being used up more quickly than it is being made. ☐

B. is being made more quickly than it is being used up. ☐

C. is running out. ☐

5. Choose which describes a property of alkali metals. [1]

Tick (✓) **one** box.

A. Unreactive ☐

B. Very high melting point ☐

C. Soft ☐

6. Choose the product of the following chemical reaction.

Lithium + fluorine $\longrightarrow$ [1]

Tick (✓) **one** box.

A. Lithium fluorate ☐

B. Lithium fluoride ☐

C. Lithium fluorine ☐

7. Choose the correct electronic configuration of a sodium atom.

The atomic number of sodium is 11. [1]

Tick (✓) **one** box.

A. 2,8,1 ☐

B. 2,9 ☐

C. 4,7 ☐

8. Choose the best explanation for why distillation isn't often used to obtain drinking water from salt-water. [1]

Tick (✓) **one** box.

A. The boiling points of water and salt are very close so they are hard to separate accurately by distillation ☐

B. Only small volumes can be distilled ☐

C. It is very expensive due to the energy required ☐

9. This box shows the reactivity series.

Potassium
Sodium
Calcium
Aluminium
Carbon
Iron
Tin
Lead
Hydrogen
Silver
Gold
Platinum

Increasing reactivity

Choose a metal that would displace aluminium from aluminium oxide. [1]

Tick (✓) **one** box.

A. Iron ☐

B. Platinum ☐

C. Sodium ☐

10. Iron oxide is an iron ore found on Earth.

Choose which method would extract the iron from iron oxide. [1]

Tick (✓) **one** box.

A. React with a more reactive metal to displace the iron ☐

B. Filter the iron oxide to separate out the iron ☐

C. Add an acid to separate the iron and the oxygen ☐

Total = ___ /10

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

Section A

Reactivity series	
Potassium Sodium Calcium Aluminium Carbon Iron Tin Lead Hydrogen Silver Gold Platinum	↑ Increasing reactivity

1. Part of the reactivity series is shown in the box.

Choose the only correct statement about reactivity. [1]
Tick (✓) one box.

A. Potassium is the least reactive ☐

B. Platinum is the least reactive ☐

C. Tin is less reactive than lead ☐

2. Electrolysis is a process where ______________can be broken down into simpler substances using electricity.

Choose the correct term to complete the blank. [1]
Tick (✓) one box.

A. covalent substances ☐

B. ionic substances ☐

C. elements ☐

3. An example of an oxidation reaction is when a metal… [1]
Tick (✓) one box.

A. loses oxygen. ☐

B. reacts with oxygen. ☐

C. reacts with an oxide. ☐

4. An electrolyte is... [1]

Tick (✓) one box.

A. a liquid able to conduct electricity. ☐

B. a mixture used to extract a metal from its ore. ☐

C. a molten compound, such as molten sodium chloride. ☐

5. Choose one way that metals can be recycled. [1]

Tick (✓) one box.

A. Extracting metals using electrolysis

B. Melting and recasting

C. Separating iron using magnets

6. Choose which reaction is an example of the extraction of a metal using reduction with carbon. [1]

Tick (✓) one box.

A. Magnesium oxide + carbon ⟶ magnesium oxide + carbon

B. Sodium hydroxide + carbon dioxide ⟶ sodium carbonate + water

C. Copper oxide + carbon ⟶ copper + carbon dioxide

7. A good inert electrode… [1]

Tick (✓) one box.

A. conducts electricity and reacts with ions.

B. conducts electricity and is unreactive.

C. doesn't conduct electricity and reacts with ions.

D. doesn't conduct electricity and is unreactive.

8. The diagram below shows the equipment used for electrolysis.

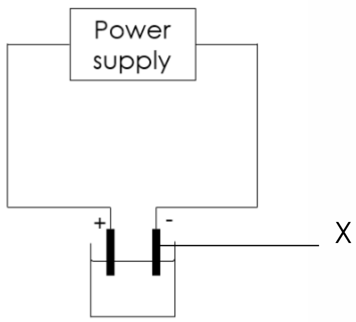
Choose the label for X. [1]

Tick (✓) one box.

A. Electrode

B. Circuit

C. Electricity



9. Using the reactivity series, choose what could be used to extract iron from iron oxide. [1]

Tick (✓) one box.

A. Carbon ☐

B. Oxygen ☐

C. Lead ☐

Potassium	↑
Sodium	
Calcium	
Aluminium	
Carbon	
Iron	Increasing reactivity
Tin	
Lead	
Hydrogen	
Silver	
Gold	
Platinum	

10. Electrolysis can be used to extract aluminium from a molten mixture of aluminum oxide and cryolite.
Choose one disadvantage of this extraction method. [1]

Tick (✓) one box.

A. Large amounts of energy are required ☐

B. The negative electrode needs to be continually replaced ☐

C. Cryolite makes it more difficult to melt aluminium oxide ☐

11. Choose what would happen if a mixture of molten pure iron and molten pure aluminium was electrolysed. [1]

Tick (✓) one box.

A. Both iron and aluminium would move to the negative electrode because metals form positive charges ☐

B. Nothing would happen because there must be ions present for electrolysis to take place ☐

C. Iron and aluminium would be separated because metals conduct electricity ☐

12. Choose which of the following is a chemical reaction. [1]
Tick (✓) one box.

A. Reduction of calcium oxide
B. Electrolysis of calcium oxide
C. Both A and B
D. Neither A or B

13. The table below shows whether a chemical reaction was observed between different metals and ionic solutions. A tick (✓) means there was a reaction and a cross (X) means there was no reaction.

	Zinc	Magnesium	Copper
Magnesium sulfate	X	X	X
Copper sulfate	✓	✓	X
Zinc sulfate	X	✓	X

Using the information in the table, choose the correct order of reactivity.

Start from the least reactive. [1]

Tick (✓) one box.

A. Zinc, magnesium, copper
B. Magnesium, zinc, copper
C. Copper, zinc, magnesium

14. Molten copper chloride can be electrolysed.

Choose the product formed at the negative electrode. [1]
Tick (✓) one box.

A. Cu
B. Cu^{2+}
C. Cl
D. Cl^{-}

15. A scientist wanted to extract sodium metal from sodium chloride solution using

electrolysis.

Choose the best explanation for why sodium metal could not be extracted. [1]
Tick (✓) one box.

A. Hydrogen is produced instead of sodium because sodium is more reactive than hydrogen
B. Only chlorine would be produced because chlorine is more reactive than sodium
C. Solid metals cannot be produced from electrolysis.

Questions 16 – 20 are suitable for higher tier only

16. The reactions of acids and metals… [1]
Tick (✓) one box.

A. are redox reactions.
B. happen in electrolysis.
C. are very reactive.

17. Choose the correct ionic equation for the reaction between magnesium and hydrochloric acid. [1]
Tick (✓) one box.

A. $Mg + 2\ HCl \longrightarrow 2MgCl_2 + H_2$
B. $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$
C. $Mg \longrightarrow Mg^{2+} + 2e^-$

18. Below shows two half equations.

$Ca \longrightarrow Ca^{2+} + 2e^-$
$2H^+ + 2e^- \longrightarrow H_2$

Choose which reaction these half equations represent. [1]
Tick (✓) one box.

A. Calcium reacts with sulfuric acid
B. Calcium reacts with hydrochloric acid
C. It could be either A or B

19. Choose why the equation below is not an ionic equation. [1]

$Zn(s) + 2Cl^-(aq) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + 2Cl^-(aq) + H_2(g)$

Tick (✓) one box.

A. Ions that appear on both sides of the equations should not be included ☐

B. State symbols are not needed ☐

C. It doesn't need to be balanced because it is the charge on the ions that is important ☐

20. Choose the method which is used to obtain copper metal from copper solutions. [1]

Tick (✓) one box.

A. Displacement using scrap iron ☐

B. Quarrying and mining ☐

C. Reacting the solution with silver ☐

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21. Choose what is required for iron to rust. [1]

Tick (✓) **one** box.

A. Air ☐

B. Water ☐

C. Both air and water ☐

22. Aluminium is more reactive than iron.

Choose why aluminium would be used as a coating for iron to prevent rusting. [1]

Tick (✓) **one** box.

A. For sacrificial protection ☐

B. For electroplating ☐

C. Both A and B ☐

Section B

1. State the charge on the ion formed from a group 2 metal. [1]

2. Describe what it means when a compound is 'reduced'. [1]

3. Explain why gold is found as pure metal in the Earth. [2]

4. Molten magnesium chloride was electrolysed.

   Explain how magnesium is produced by electrolysis. [4]

Questions 5-6 are suitable for higher tier only

5. Ores that contain a high percentage of copper are rare, so low-grade ores are used for copper extraction.

   Describe two methods used to extract copper from low-grade copper ore. [6]

6. Zinc reacts with hydrochloric acid.

   Write the two half equations for the reaction between zinc and hydrochloric acid. [2]

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7. Explain how metals can be corroded. [1]

Mastery quiz reflections

Which aspects of this unit are likely to be the most challenging to teach?

What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*
How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using Exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors and misconceptions

How would you tackle the following common mistakes, errors and misconceptions by pupils?

TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
A Na^+ ion loses an electron to become an atom.	When ions lose electrons they have an overall positive charge because there are more protons than electrons. Therefore, Na^+ would have to gain an electron to become and atom.	
Bioleaching uses plants to extract copper ores	Bioleaching uses bacteria and not plants in the process of extracting copper ore.	

Planning for the misconceptions

Misconception: Oxidation only happens when oxygen is a reactant
Oxidation is the loss of electrons in a reaction. This is not specific to reacting with only oxygen.
Supporting pupil understanding Students have previously been taught that when a metal becomes oxidised a metal oxide is produced BUT in this unit, students need to understand that oxidation is the loss of electrons. Recap the acronym OILRIG as prompt students to always recall OILRIG when thinking about oxidation (or reduction).

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that TBAT = to be able to

NOTE: All TKT statements can be found in Appendix 5 of this document

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior knowledge review – Reactions of Metals

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document* ******This lesson is a review of content from previously studied units relating to this big idea	
TBAT list metals in order of reactivity	Describe what the reactivity series shows. List the metals more reactive the hydrogen. List the metals less reactive than carbon.
TBAT describe the reactions of acids and metals	Write the general word equation for the reaction of a metal and acid. Write the word equation for the reaction between sodium and hydrochloric acid.
TBAT predict the salts formed in neutralisation reactions	State what salt is formed when potassium reacts with nitric acid. State what reactants are needed to produce calcium sulfate.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2: Extracting Less Reactive Metals

Intended outcome	Example questions

**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT list metals in order of reactivity	State what you would observe if metals of different reactivities were added to hydrochloric acid.
TBAT write equations for displacement reactions, and predict the products of these reactions	Write the word equation for the displacement reaction between copper oxide and carbon. State the products made when lead oxide reacts with carbon
TBAT identify substances which are oxidised and reduced in displacement reactions	Write definitions for oxidation and reduction. When zinc oxide reacts with carbon, state what has been oxidised. When metal oxides react with carbon in a displacement reaction, state what has been reduced.
What did the Exit ticket data tell me?	
What do I need to review in future lessons?	

Lesson 3: Prior Knowledge Review – Ions, Ionic Bonding and Deducing Ionic Formulae

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT describe how ions are formed	What is the difference between a sodium atom and a sodium ion? Describe how a chlorine atom can become a chlorine ion.
TBAT describe ionic bonding in terms of electrons	Define ionic bonding Compare ionic bonding and covalent bonding
TBAT relate the group number of an element to the charge on its ions	Describe the relationship between the group of the periodic table and the number of outer shell electrons. For metals, what is the relationship between the group number and the charge on the ion? For non-metals, what is the relationship between the group number and the charge on the ion?
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 4: (HT Only) Ionic Equations and Displacement Reactions

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT write chemical equations in terms of ions	List the ions that make up Na_2O
TBAT write ionic equations for displacement reactions	Write an ionic equation for the following reaction: $Zn_{(s)} + CuCl_{2(aq)} \rightarrow ZnCl_{2(aq)} + Cu_{(s)}$
TBAT identify oxidised and reduced species using ionic equations	Define 'redox reaction' Define oxidation in terms of electrons Define reduction in terms of electrons Identify what has been reduced and what has been oxidised in the following reaction: $Zn_{(s)} + CuCl_{2(aq)} \rightarrow ZnCl_{2(aq)} + Cu_{(s)}$
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

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Lesson 5: (HT Only) Writing Half Equations

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT split an ionic equation into two half equations	Use the following ionic equation to write two half equations. $Br_{2(s)} + 2Na^+_{(aq)} + 2I^-_{(aq)} \rightarrow 2Na^+_{(aq)} + 2Br^-_{(aq)} + I_{2(s)}$
TBAT identify the species which are oxidised and reduced.	Identify what has been reduced and what has been oxidised in the following reaction: $Zn_{(s)} + CuCl_{2(aq)} \rightarrow ZnCl_{2(aq)} + Cu_{(s)}$
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

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Lesson 6: (HT Only) Ionic Equations for the Reactions of Acids and Metals

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT describe the reactions of acids and metals with chemical equations	Write the balanced symbol equation for the reaction of iron and sulfuric acid Write the balanced symbol equation for the reaction of magnesium and hydrochloric acid
TBAT write ionic equations for the reactions of acids and metals	Write an ionic equation for the following reaction: $Fe_{(s)} + H_2SO_{4(aq)} \rightarrow FeSO_{4(aq)} + H_{2(g)}$
TBAT write half equations for the reactions of acids and metals	Write two half equations for the following reaction: $Fe_{(s)} + H_2SO_{4(aq)} \rightarrow FeSO_{4(aq)} + H_{2(g)}$
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 7: Introduction to Electrolysis

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT define electrolysis.	Write a definition for electrolysis. Describe what an electrolyte is
TBAT list the ions present in an electrolyte, and predict their movement when the current is switched on in electrolysis	List the ions present in molten sodium bromide. Predict the movement of ions in sodium bromide when the current is switched on in electrolysis
TBAT explain why electrolysis cannot be carried out with a solid ionic substance	Explain why solid sodium chloride cannot be electrolysed but molten sodium chloride can.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

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Lesson 8: Extracting Metals Using Electrolysis

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT recall that metals can be extracted from molten compounds by electrolysis	Describe a use of electrolysis. Explain why aluminium cannot be extracted from aluminium oxide using reduction with carbon.
TBAT describe a disadvantage of extraction of metals by electrolysis	Explain why electrolysis is relatively expensive to carry out.
TBAT describe how electrolysis is used to extract aluminium from its ore	Describe the function of cryolite in the electrolysis of aluminium oxide. State what is produced at each electrode during the electrolysis of aluminium oxide. *(HT only) Write half equations for what is produced at each electrode during the electrolysis of aluminium oxide.*
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 9: Electrolysis of Molten Ionic Compounds

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT recall that during electrolysis, ions are discharged at the electrodes forming elements	State what is produced when a positive ion is discharged at an electrode. When a negative ion is discharged at an electrode, a non-metal is produced
TBAT predict the ions discharged at each electrode	Describe what happens at the positive electrode when molten lithium fluoride is electrolysed. Describe what happens at the negative electrode when molten sodium chloride is electrolysed.
TBAT (HT) write half equations to describe the discharge of ions at each electrode	Write half equations what happens when molten lithium fluoride is electrolysed. Write half equations what happens when molten sodium chloride is electrolysed.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 10: Electrolysis in Solutions

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT list the ions present in the electrolytes of molten salts and salt solutions.	List the ions present in the electrolytes of molten lithium fluoride. List the ions present in the electrolytes of aqueous lithium fluoride solution.
TBAT explain which ions are discharged at the anode and cathode.	If the two positive ions in solution are K^+ and H^+, which positive ion would be discharged at the cathode? Explain your answer. If the two negative ions in solution are OH^- and SO_4^{2-}, which negative ion would be discharged at the anode? Explain your answer.
TBAT predict what will be observed at the anode and cathode.	During the electrolysis of aqueous lithium fluoride solution, predict what is formed at each electrode.
TBAT write half equations for the discharge of ions at each electrode.	Write half equations to show what happens at each electrode during the electrolysis of aqueous lithium fluoride solution.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 11-12: Required Practical – Electrolysis of Aqueous Solution

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT describe the apparatus used for electrolysis	Write an equipment list for the electrolysis of sodium chloride solution. Describe what each piece of equipment is used for.
TBAT safely carry out the electrolysis of a salt solution	State a hazard that must be considered when electrolysing sodium chloride solution. Describe the precautions you should take when electrolysing sodium chloride solution.
TBAT predict the products of electrolysis of a salt solution	During the electrolysis of aqueous sodium chloride solution, predict what is formed at each electrode.
TBAT test for gases produced in electrolysis	Describe how to test for hydrogen gas. Describe how to test for oxygen gas. Describe how to test for chlorine gas.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 13: Taking it Further – Corrosion and its Prevention

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT define corrosion	Define corrosion. Define rusting.
TBAT describe some methods used to prevent corrosion	Describe how sacrificial protection prevents corrosion. Describe how greasing and painting prevent corrosion.
TBAT explain how electroplating is carried out	Describe how to electroplate a metal spoon in silver. Explain which electrode the metal object to be electroplated must be attached to.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 14: (HT Only) Obtaining Raw Materials

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT list some disadvantages of mining and quarrying	Explain the environment effect of mining and quarrying.
TBAT define bioleaching and phytomining	Define bioleaching. Define phytomining. Explain why bioleaching and phytomining are required.
TBAT explain how bioleaching and phytomining are carried out	Write a numbered list to show the steps in bioleaching. Write a numbered list to show the steps in phytomining.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 15: Recycling Metals

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT describe how metals are recycled	Write out the steps involved in metal recycling. Define recasting.
TBAT describe the ethical, social, economic and environmental impacts of recycling metals	Describe the environmental benefits of metal recycling. Give an advantage and a disadvantage of the economic impact of metal recycling.
TBAT suggest how the public and businesses might be encouraged to recycle their waste metals	Write a paragraph that includes suggestions for a town council who need to increase the amount of metal recycling in their town.
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 13: Feedback lesson

Intended outcome	Example questions
Edit based upon your classe's performance in the Mastery Quiz	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

In A-level chemistry, students will learn that redox reactions take place in electrochemical cells where electrons are transferred via an external circuit. This leads to learning about electrode potentials to be able to predict the direction of redox reactions. Students will then apply this knowledge when they learn about the commercial applications of electrochemical cells.

Several topics in physical chemistry and inorganic chemistry require a strong foundational knowledge of how redox reactions, formation of ions and ionic bonding. For instance, students will need to be able to predict charges on ions and use that information to construct formulas for ionic compounds. Additionally, the foundations of writing half equations to show redox reactions will be further developed at A-Level where oxidation states will be introduced.

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS5?
What content from this unit is fundamental to student understanding at KS5?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Anode	The positively charged electrode used in electrolysis. *Negatively charged ions such as fluoride ions are attracted to the **anode**.*
Bioleaching *(HT only)*	A process that uses bacteria to produce leachate solutions that contain metal compounds. *Bacteria carry out **bioleaching** to extract copper ions from ores.*
Cathode	The negatively charged electrode used in electrolysis. *Positively charged ions such as sodium ions are attracted to the **cathode**.*
Corrosion	The destruction of materials by chemical reactions with substances in the environment. *Rusting is an example of **corrosion**.*
Cryolite	A compound that reduces the melting point of aluminium oxide, ***Cryolite** is used for the electrolysis of molten aluminium oxide.*
Discharged	When ions gain or lose electrons to form neutral atoms or molecules. *Sodium ions are **discharged** at the cathode during electrolysis.*
Displacement reaction	A reaction where a more reactive element replaces a less reactive element in a compound. *A **displacement reaction** takes place when carbon reacts with iron oxide.*
Electrode	A conductor through which electricity can flow. *Anodes and cathodes are **conductors** and can be made of graphite.*
Electrolysis	The process of passing an electric current through a substance, to split it up into its ions. ***Electrolysis** requires an electrolyte, electrodes and a power source.*
Electrolyte	A liquid containing ions that current is passed through during electrolysis. *An aqueous solution of sodium chloride is an example of an **electrolyte**.*
Electron	A negatively charged subatomic particle that orbits the nucleus of an atom. *In ionic bonding **electrons** are transferred from one atom to another.*
Electroplating	Adding a thin layer of metal to an object using electrolysis. *A metal spoon can be **electroplated** with silver.*
Empirical formula	The simplest ratio of atoms of each element in a compound. ***The empirical formula** of calcium hydroxide is $Ca(OH)_2$.*

Extracted	To take something out *Aluminium can be extracted from its ore, aluminium oxide, using electrolysis.*
Galvanise (SS only)	Zinc is used as a sacrificial metal to prevent the corrosion of iron. *Iron pipes can be **galvanised** to prevent corrosion.*
Half equation *(HT only)*	A rock that contains enough metal compound to extract the metal. *Haematite is a common iron oxide **ore**.*
Ion	A charged particle or group of particles. *A sodium **ion** has a positive charge.*
Ionic bonding	Ionic bonding occurs in compounds formed from metals combined with non-metals. Electrons are lost or gained to form a stable electronic configuration. ***Ionic bonding** occurs in sodium fluoride because sodium is a metal and fluorine is a non-metal. As sodium fluoride forms, an electron is transferred from a sodium atom to a fluorine atom, forming Na^+ and F^- ions.*
Ionic equation *(HT only)*	A balances symbol equation that shows the reacting ions in a chemical reaction. ***Ionic equations** allow us to see more easily what has been oxidised and what has been reduced in a reaction..*
Low-grade ore	An ore that contains a very low percentage of the metal or compound to be extracted. *Most nickel ores are **low-grade ores**.*
Mining	The digging and moving of rock from the Earth. ***Mining** is needed to obtain metal ores but it can be destructive to wildlife.*
Molten	When a substance has been heated so it is a liquid. ***Molten** aluminium oxide can be electrolysed.*
Ore	A rock that contains enough metal compound to extract the metal. *Haematite is a common iron oxide **ore**.*
Oxidation	When electrons are lost. *When a magnesium atom is **oxidised,** it loses two electrons and becomes a Mg^{2+} ion.*
Phytomining *(HT only)*	An extraction process that uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains metal compounds. ***Phytomining** is used to extract copper from copper ores.*

Pure	A substance that is made from only one type of particle. ***Pure**, molten aluminium oxide only contains aluminium ions and oxide ions.*
Recasting/ reforming	When molten, recycled metal is used to form something new. *During the recycling process, molten aluminium can be **recast** to form cans.*
Recycling	When a substance is collected and processed to form a usable material. *Metals can be **recycled** by melting and recasting or reforming into different products.*
Redox	A reaction in which oxidation and reduction take place at the same time *When a metal and oxygen react, a **redox** reaction occurs.*
Reduction	When electrons are gained. *When a chlorine atom is **reduced,** it gains two electrons and becomes a Cl^{2-} ion.*
Rusting	The corrosion of iron. *Iron **rusts** when it reacts with oxygen.*
Sacrificial protection (SS only)	When a metal contains a coating of a more reactive metal so that it is protected from corrosion. *Magnesium can be used to coat iron as **sacrificial protection** which prevents iron from being oxidised and therefore rusting.*
Spectator ions	Ions that are the same in the reactants and the products. ***Spectator ions** are excluded when we write ionic equations.*
Sustainable	Recycling and reusing materials when there is a limited amount of the material on Earth. *Recycling metals ensures the **sustainable** use of metals.*
Valence electron(s)	Electrons in the outer shell of an atom or ion. *A fluorine atom has 7 **valence electrons**.*

Appendices

Appendix 1: Mark scheme for pre-unit quiz

C4.2 Pre-Unit Quiz: Extraction of Metals

Mark Scheme

Qu	Answer	Marks	Supporting information for fix-it tasks
1	B	1	Answering A or C suggests a gap in knowledge about the general word equation for reaction of metals and acids. *To fix it, ask students to copy the correct general equation out and then give practice questions of the reactants and ask students to write out the products.*
2	C	1	Answering incorrectly suggests a gap in knowledge about reusing and recycling resources. *To fix it, ask students to describe how they would reuse and recycle a glass jar.*
3	C	1	Answering A suggests that the student might associate the number of shells with the group number, instead of the period number. Answering B suggests that the student might associate the number of electrons with the group number. *To fix it, give students some electronic configuration diagrams and ask them to identify the element in the Periodic Table, and then to write down the period and group number of that element.*
4	A	1	Answering B suggests a gap in knowledge because the opposite of this statement is true. *To fix it, ask students to explain why fossil fuels are an example of a finite resource using the definition in part A.* Answering C suggests the common misconception that all finite resources are currently running out, however a more accurate description must include the rate of use vs. the rate of production. *To fix it ask students to compare a finite resource and an infinite resource, using examples.*
5	C	1	Answering A suggests a gap in knowledge about alkali metals being very reactive. *To fix it, remind students about the alkali metals in water demo (and/or show a video clip) and then ask them to list properties of alkali metals.* Answering B suggests a misconception that because group 1 elements are metals, they must have very high melting points, however these elements have relatively low melting and boiling points. *To fix it, give students mp and bp data on alkali metals vs transition metals and ask them to describe what the data shows.*
6	B	1	Answering A suggests or C suggests a gap in knowledge about metals + halogens → metal halide. *To fix it, students should write down the general equation and then use the periodic table to write out lots of example reactions.*
7	A	1	Answering B suggests a gap in knowledge about how many electrons are in the 2^{nd} electron shell.

			Answering C suggests a gap in knowledge about how many electrons are in the 1st electron shell. *To fix it, reteach the rules of writing out electronic configuration and then give many practise questions.*
8	C	1	Answering A suggests a misconception that salt and water have similar boiling points. However it does show some understanding of the method of distillation. *To fix it, ask students to explain how a mixture of ethanol and water can be separated when the boiling point of ethanol is 78℃.* Answering B suggests a gap in knowledge because the volume capability of distillation is not relevant here. *To fix it, ask students to explain how evaporation takes place during distillation and why this is expensive.*
9	C	1	Answering A or B suggests a gap in being able to interpret the reactivity of metals using the reactivity series. *To fix it, ask students to copy out some of the reactivity series and then ask them to label on there the most and least reactive metals.*
10	A	1	Answering B suggests a misconception that filtration can separate elements in a compound. *To fix it, ask students to explain the difference between a chemical reaction and a physical change. Then recap that separation techniques do not involve chemical reactions.* Answering C suggests a misconception that reacting with an acid will separate the elements in a compound. *To fix it, ask students to explain what happens in a displacement reaction.*

Appendix 2: Mark scheme for mastery quiz

C4.2 CS Mastery Quiz: Extraction of Metals
Mark Scheme

Section A

Qu	Answer	Marks	Supporting information for fix-it tasks
1	B	1	Answering A suggests a misconception that the substance at the top of the reactivity series is the least reactive. *To fix it, model how to annotate this reactivity series by labelling the top as 'most reactive' and the bottom as 'least reactive'. Then ask students to describe how the substances in the reactivity series are organised.* Answering C suggests a misconception that a substance higher up in the series is less reactive. *To fix it, reteach how the reactivity series is arranged and model how to compare reactivities of two substances. Then ask students to write sentences to compare the reactivities of different substances.*
2	B	1	Answering A suggests the misconception that covalent compounds can be electrolysed. *To fix it, recap a comparison the types of boding for covalent and ionic and then ask students to explain why only ionic compounds can be electrolysed.* Answering C suggests the misconception that electrolysis can break down elements. *To fix it, reteach that elements are not charged so cannot conduct electricity when molten. Also recap that electrolysis is for breaking down ionic compounds and that subatomic particles cannot be broken down using electrolysis. Then ask students to describe why only ionic compounds can be broken down using electrolysis.*
3	B	1	Answering A suggests a confusion between oxidation and reduction. *To fix it, ask students to compare oxidation and reduction using the key terms: gain, loss, oxygen, electrons.* Answering C suggests the misconception that 'oxide' is a substance that metals react with. *To fix it, ask students to write out the word equations for the reaction of iron and oxygen, magnesium and oxygen and calcium and oxygen.*
4	A	1	Answering B suggests the misconception that electrolysis has the sole function of extracting metals from their ores. *To fix it, ask students to write a definition of electrolysis.* Answering C suggests the misconception that electrolysis only happens for molten ionic compounds. *To fix it, reteach that both aqueous solutions of ionic compounds and molten ionic compounds can be electrolytes. Then ask students to explain why an ionic compound must be in solution or molten to be electrolysed.*
5	B	1	Answering A or C suggests a gap in knowledge that melting and recasting is a possible method to recycle metals. *To fix it, ask students to explain why melting and recasting recycled steel is useful.*
6	C	1	Answering A suggests the misconception that a reaction has taken place, even is the products and reactants are identical. *To fix it, reteach that if the products and reactants are the same then no reaction has taken place and that this the case in A because magnesium is more reactive than carbon. Then ask students to write out the general word equation for the reduction of a metal oxide with carbon and then write example reactions as word equations.* Answering B suggests the misconception that carbon dioxide is

			used to reduce a metal oxide. *To fix it, ask students to write out the general word equation for the reduction of a metal oxide with carbon and then write example reactions as word equations.*
7	B	1	Answering A suggests a misconception that an inert electrode needs to be reactive to react with ions. *To fix it, recap the definition of the word inert (refer to noble gases and unreactive metals like gold and platinum). Then ask students to explain why an inert electrode is useful for an electrolysis experiment.* Answering C or D suggests a fundamental gap in knowledge that electrodes have to conduct electricity to function. *To fix it, reteach the function of electrodes, using platinum electrodes as an example. Then ask students to state what properties platinum has that makes it a good inert electrode, and explain why.*
8	A	1	Answering B or C suggests a gap in knowledge of how an electrode is represented in a diagram of electrolysis equipment. *To fix it, reteach each part of the equipment shown and what the functions are. Then ask students to sketch this diagram into books and label every part with annotations of functions.*
9	A	1	Answering B suggests a misconception that oxygen is added to a metal oxide for extracting the metal. *To fix it, discuss with student what the key word 'extraction' means and then ask students to explain why iron is extracted from iron oxide.* Answering C suggests an inability to apply the reactivity series in this example. *To fix it, ask students to state which is the most and which is the least reactive substance on this reactivity series. Then ask students to explain why carbon can be used to reduce iron oxide but lead cannot.*
10	A	1	Answering B suggests the misconception that it is the negative electrode that wears away during the electrolysis of molten aluminium oxide. *To fix it, reteach that the positive (not negative) electrode is made from carbon and reacts with oxygen to form carbon dioxide so it gradually wears away. Then ask students to sketch diagram of the electrolysis of molten aluminium oxide, labelling all the parts, including an equation for the reaction of the formation of carbon dioxide at the positive electrode.* Answering C suggests the misconception that cryolite makes it more difficult to melt aluminium oxide. *To fix it, reteach that cryolite is added to lower the melting point so that aluminium oxide becomes liquid more easily. Then ask students to explain why cryolite is added to reduce the cost of extracting aluminium from aluminium oxide.*
11	B	1	Answering A suggests the misconception that pure, elemental metal has a charge. *To fix it, ask students to compare elements, ions and ionic compounds.* Answering C suggests misconception that electrolysis causes the separation of different metal atoms. *To fix it, reteach how the process of electrolysis of molten ionic compounds works. Then ask students to explain why iron and aluminium would not be separated in this example.*

12	C	1	Answering A suggests the common misconception that electrolysis not a chemical reaction. *To fix it, reteach that chemical reactions cause the formation of new products from reactants. Then ask students to explain why electrolysis can be considered a chemical change/reaction.* Answering B suggests the misconception that the reduction of a compound is not a chemical reaction. *To fix it, ask students to write out the word equation of the reduction of calcium oxide using sodium and then to explain why this shows a chemical reaction and not a physical change.* Answering D suggests a fundamental gap in knowledge about the definition of chemical reactions/changes. *To fix it, reteach that chemical reactions cause the formation of new products from reactants. Then students should write example word equations from their notes that represent reduction reactions and electrolysis ionic equations.*
13	C	1	Answering A or B suggests an inability to link reactivity data to comparing reactivities of metals. *To fix it, model how to analyse these results (e.g. looking for which column has the most ticks to show the most reactions),. Then ask students to use evidence from the table to explain why copper is the least reactive metal here.*
14	A	1	Answering B suggests the common misconception that it is the ion that is formed at the electrode. *To fix it, reteach how Cu is formed in this example by using a diagram of electrolysis.. Then ask students to predict what would be formed at the positive electrode and explain why using the term 'electron(s)'..* Answering C or D suggests the misconception that negatively charged ions are attracted the negative electrode. *To fix it, ask students to write out whether positively or negatively charged ions are attracted to the positive electrode and the negative electrode..*
15	A	1	Answering B suggests a misconception that halogens are formed at the positive electrode because they are more reactive than the metal ion in solution. *To fix it, reteach that at the negative electrode, hydrogen is produced if the metal is more reactive than hydrogen. Then ask students to explain whether silver could be extracted from a solution of silver chloride using electrolysis..* Answering C suggests a fundamental gap in knowledge about the products formed in electrolysis. *To fix it, reteach what happens at the positive and negative electrodes when the ionic compound is in solution. Then ask students to describe what happens at the negative electrode during the electrolysis of sodium chloride solution.*
16 (HT)	A	1	Answering B or C suggests a gap in knowledge that reduction and oxidation happen when acids and metal react. *To fix it, ask students to define a redox reaction, giving an example.*
17 (HT)	B	1	Answering A suggests a confusion of the symbol equation for the reaction and the ionic equation. *To fix it, ask students to describe the difference between a chemical/symbol equation and an ionic equation.* Answering C suggests a confusion of an ionic equation and a

			half equation. *To fix it, ask students to describe the difference between a half equation and an ionic equation.*
18 (HT)	C	1	Answering A or B suggests a misconception that only some acids contribute a H^+ ion to a half equation. *To fix it, model this thinking by writing out the ionic equations to remind students that acids always have a* H^+ *ion. Then ask students to write out the half equations for the reaction of sodium and hydrochloric acid (HINT – think about which group Na is in)*
19 (HT)	A	1	Answering B suggests the misconception that state symbols are not required for ionic equations. *To fix it, recap the importance of state symbols. Then ask students to explain why we include state symbols in ionic equations.* Answering C suggests the misconception that balancing is not needed for ionic equations. *To fix it, recap why balancing an ionic equation is so important. Then ask students to explain why the half equations written from an unbalanced ionic equation would be incorrect.*
20 (HT)	A	1	Answering B suggests a gap in knowledge about the uses of quarrying and mining. *To fix it, recap when quarrying and mining are used and then ask students to explain why quarrying and mining is carried out.* Answering C suggests the misconception that a less reactive metal can displace a more reactive metal. *To fix it, ask students to look at the reactivity series and explain why silver could not displace copper in this example.*
21 (Chemistry only)	C	1	Answering A suggests the misconception that only air, and not water, is needed for rusting. *To fix it, ask students to briefly plan an investigation to find out whether air and water are needed for an iron nail to rust.* Answering B suggests the misconception that only water, and not air/oxygen is needed for rusting. *To fix it, ask students to briefly plan an investigation to find out whether air and water are needed for an iron nail to rust.*
22 (Chemistry only)	C	1	Answering A or B suggests a gap in knowledge that a more reactive metal is used for both electroplating and sacrificial protection. *To fix it, ask students to explain what might happen if electroplating and* sacrificial protection was carried out using a metal less reactive than iron.

Section B

Qu	Answer	Marks	Supporting information ***Suggestions for fix-it tasks***
1	2+	1	A common error is to simply state positive or +, rather than 2+. *To fix it, ask students to state what the charge on the ion would be if: (a) 1 electron is gained (b) 2 electrons are lost (c) 2 electrons are gained etc.*
2	(It has) gained electrons	1	A common error when answering questions about oxidation and reduction is to limit answers to the gain or loss of oxygen. *To fix*

	Allow it has lost oxygen		*it, reteach that it can mean the gain or loss of oxygen, but a more complete and relevant definition is the loss of electrons or the gain of electrons, respectively. Recap OILRIG as an acronym. Then ask students to compare oxidation and reduction of a compound.*
3	(It/gold is very) unreactive (so it found as pure metal in the Earth because it will) not easily react with other substances.	1 1	A common error in this type of explain question is to not include terms such as 'because' or 'this means that'. *To fix it, ask students to rewrite their answer ensuring that they include* 'because' or 'this means that'.
4	Magnesium <u>ions</u> (in the molten magnesium chloride) are attracted to the <u>negative electrode/cathode</u> (because they are positively charged). (At the negative electrode,) magnesium ions <u>gain electrons</u> Or are reduced 2 electrons are gained *(HT only) Allow 3 marks for the correct half equation* $Mg^{2+} + 2e^{-} \rightarrow Mg$ *(HT only)*	1 1 1 1	A common error in this type of explain question is to not link the initial scientific statement back to the information in the question. *To fix it, ask students to re write their answer using a scientific statement at the start and then link their explanation to information in the question. Underline key information in the question to support this.* Another common error with answering questions about explaining the formation of products in electrolysis, is confusion of the many key terms. *To fix it, look at the glossary or give definitions of: positive electrode, negative electrode, electron, element, ion, electrolysis. And then ask students to explain how zinc is produced from the electrolysis of molten zinc chloride.*
5	<u>Phytomining</u> uses plants to absorb metal compounds (The plants are harvested and) then burned to produce ash that contains metal compounds <u>Bioleaching</u> uses bacteria to produce leachate solutions (that contain metal compounds).	1 1 1 1 1 1	A common error here is to be able to state the names of these two methods but there could be an absence of, or lack of detail, in the description. *To fix it, reteach these two processes and then ask students to write their own descriptions again using key words: plants, absorb, burned, bacteria, leachate.*
6	$Zn \rightarrow Zn^{2+} + 2e^{-}$	1	A common error when writing half equations is to not balance them. *To fix it, model, in sequence, how to write out the symbol*

	$2H^+ \rightarrow 2e^- \rightarrow H_2$	1	*equation, then the ionic equation and then the half equations.*
7	By reacting with substances in the environment.	1	Students may struggle to explain this and may instead attempt to further describe what corrosion is, perhaps linked to the corrosive hazard symbol. *To fix it, ask students to rewrite their answer but specifically refer to rusting as an example of corrosion.*

Appendix 3: Core knowledge statements

Prior Knowledge Review: Reactions of Metals

• Metals can be arranged in order of their reactivity in a reactivity series.
• Metals react with oxygen to produce metal oxides.
• The reactions are oxidation reactions because the metals gain oxygen.
• A reactivity series is a list of metals in order of most reactive (at the top) to least reactive (at the bottom)
• The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids.
• Some metals are unreactive. This means they do not easily take part in chemical reactions
• Some metals are reactive. This means they readily take part in chemical reactions
• The chemical formula for hydrochloric acid is HCl
• The chemical formula for nitric acid is HNO_3
• The chemical formula for sulphuric acid is H_2SO_4

• Acids react with some metals to produce salts and hydrogen gas
• Acids are neutralised by alkalis (e.g. soluble metal hydroxides) and bases (e.g. insoluble metal hydroxides and metal oxides) to produce salts and water, and by metal carbonates to produce salts, water and carbon dioxide
• All alkalis release hydroxide ions, OH-, into solutions
• Alkalis and bases can be metal oxides or metal hydroxides

Extracting Less Reactive Metals

• Unreactive metals such as gold are found in the Earth as the metal itself
• Most metals are found as compounds that require chemical reactions to extract the metal.
• Metals less reactive than carbon can be extracted from their oxides by reduction with carbon.
• Reduction involves the loss of oxygen.
• The non-metals hydrogen and carbon are often included in the reactivity series.
• A more reactive metal can displace a less reactive metal from a compound.
• We can use chemical equations to identify substances which are oxidised or reduced in a chemical reaction

Prior Knowledge Review: Ions, Ionic Bonding and Deducing Ionic Formulae

• When a metal atom reacts with a non-metal atom electrons in the outer shell of the metal atom are transferred.
• Metal atoms lose electrons to become positively charged ions.
• Non-metal atoms gain electrons to become negatively charged ions.
• The ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 have the electronic structure of a noble gas (Group 0).
• The electron transfer during the formation of an ionic compound can be represented by a dot and cross diagram.
• The charge on the ions produced by metals in Groups 1 and 2 and by non-metals in Groups 6 and 7 relates to the group number of the element in the periodic table.

HT only: Ionic Equations and Displacement Reactions

• Oxidation is the loss of electrons and reduction is the gain of electrons.
• When metals react with other substances the metal atoms form positive ions.
• The reactivity of a metal is related to its tendency to form positive ions
• A balanced equation for a displacement reaction can be written in terms of the ions involved
• Ions that appear on both sides of the equation do not take part in the reaction, and so the equation can be written without them.

HT: Writing Half Equations

• A balanced ionic equation can be split into two half equations
• A redox reaction is one in which oxidation and reduction happen at the same time"

HT: Ionic Equations for the Reactions of Acids and Metals

• The reactions of acids with metals are redox reactions
• (see the common ions handout sheet for a list of chemical equations, ionic equation and half equation examples)

Introduction to Electrolysis

• When an ionic compound is melted or dissolved in water, the ions are free to move about within the liquid or solution.
• These liquids and solutions are able to conduct electricity and are called electrolytes.
• Passing an electric current through electrolytes causes the ions to move to the electrodes.
• Electricity is the flow of electrons or ions
• Positively charged ions move to the negative electrode (the cathode), where they receive electrons and are reduced.
• Negatively charged ions move to the positive electrode (the anode), where they lose

electrons and are oxidised.
• For electrolysis to work, the compound must contain ions
• The ions must be free to move, which is possible when an ionic substance is dissolved in water or melted.
• Electrolysis is the process by which ionic substances are decomposed into simpler substances when an electric current is passed through them

Extracting Metals by Electrolysis

• Metals can be extracted from molten compounds using electrolysis.
• Electrolysis is used if the metal is too reactive to be extracted by reduction with carbon or if the metal reacts with carbon.
• Large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current.
• Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite using carbon as the positive electrode (anode).
• To prepare for electrolysis, the aluminium ore is dissolved in molten cryolite instead of being melted.
• Cryolite has a much lower melting point than aluminium oxide
• This is because melting aluminium ore would be too expensive a process, due to the high costs of energy to heat to the high temperature that would be required.

Electrolysis of Molten Ionic Compounds

• Ions are discharged at the electrodes producing elements.
• Half equations can be written for the reactions at each electrode in electrolysis
• When a simple ionic compound (eg lead bromide) is electrolysed in the molten state using inert electrodes, the metal (lead) is produced at the cathode and the non-metal (bromine) is produced at the anode.

Electrolysis in Solutions

• The ions discharged when an aqueous solution is electrolysed using inert electrodes depend on the relative reactivity of the elements involved.
• At the negative electrode (cathode), hydrogen is produced if the metal is more reactive than hydrogen.
• At the positive electrode (anode), oxygen is produced unless the solution contains halide ions when the halogen is produced.
• This happens because in the aqueous solution water molecules break down producing hydrogen ions and hydroxide ions that are discharged.
• Reactions at electrodes can be represented by half equations, for example: $2H^+ + 2e^- \rightarrow H_2$

Taking it Further: Corrosion and its Prevention

• Corrosion is the destruction of materials by chemical reactions with substances in the environment.
• Rusting is an example of corrosion.
• Both oxygen and water are necessary for iron to rust.
• Corrosion can be prevented by applying a coating that acts as a barrier, such as greasing, painting or electroplating.
• Aluminium has an oxide coating that protects the metal from further corrosion.
• Some coatings are reactive and contain a more reactive metal to provide sacrificial protection, eg zinc is used to galvanise iron."

(HT) Obtaining Raw Materials

• The Earth's resources of metal ores are limited.
• Copper ores are becoming scarce and new ways of extracting copper from low-grade ores include phytomining, and bioleaching.
• These methods avoid traditional mining methods of digging, moving and disposing of large

amounts of rock.
- Mining destroys wildlife habitats
- Phytomining uses plants to absorb metal compounds. The plants are harvested and then burned to produce ash that contains metal compounds.
- Phytomining conserves supplies of ores
- Bioleaching uses bacteria to produce leachate solutions that contain metal compounds.
- The metal compounds can be processed to obtain the metal.
- For example, copper can be obtained from solutions of copper compounds by displacement using scrap iron or by electrolysis.
- Obtaining raw materials from the Earth by quarrying and mining causes environmental impacts.

Recycling Metals
- Metals can be recycled by melting and recasting or reforming into different products.
- The amount of separation required for recycling depends on the material and the properties required of the final product. For example, some scrap steel can be added to iron from a blast furnace to reduce the amount of iron that needs to be extracted from iron ore."

Practical Skills

20. Describe, suggest or select the technique, instrument, apparatus or material that should be used for a particular purpose, and explain why

43. Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis

13a. Suggest a hypothesis to explain given observations or data.
b. Explain why a certain hypothesis was chosen, with reference to scientific theories and explanations

42. Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds

43. Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis

20. Describe, suggest or select the technique, instrument, apparatus or material that should be used for a particular purpose, and explain why

7. b. Describe and evaluate, with the help of data, methods that can be used to tackle problems caused by human impacts on the environment.