10.3 Extraction of metals

01. 0620_w21_qp_41 Q: 1

Some elements are shown in the order they appear in the reactivity series. The most reactive element is at the top.

sodium
calcium
magnesium
aluminium
zinc
iron
hydrogen
copper

(a) Answer the questions using the list of elements. Each element may be used once, more than once or not at all.

Identify:

(i) a non-metal

..... [1]

(ii) a metal which is stored under oil

..... [1]

(iii) the main component of steel

..... [1]

(iv) a metal with three electrons in the outer shell of its atoms

..... [1]

(v) a metal found in brass

..... [1]

(vi) a metal that forms chlorides of the type XCl_2 and XCl_3.

..... [1]

(b) Name the main ores of:

(i) zinc ..... [1]

(ii) aluminium. ..... [1]

(c) In an experiment, a sample of aluminium appeared less reactive than expected.

Explain why.

.....

..... [1]

(d) Name **two** metals from the list which are extracted by reduction of their ores using carbon.

1 .....

2 .....
[2]

(e) When zinc granules are added to aqueous copper(II) sulfate, a reaction occurs. During the reaction, a red-pink solid is formed and the solution becomes colourless.

(i) Name the red-pink solid.

..... [1]

(ii) Name the colourless solution.

..... [1]

(iii) Explain, in terms of particles, why the rate of this reaction increases when the temperature is increased.

.....

.....

.....

.....

.....

..... [3]

(iv) Suggest two **other** ways of increasing the rate of this reaction.

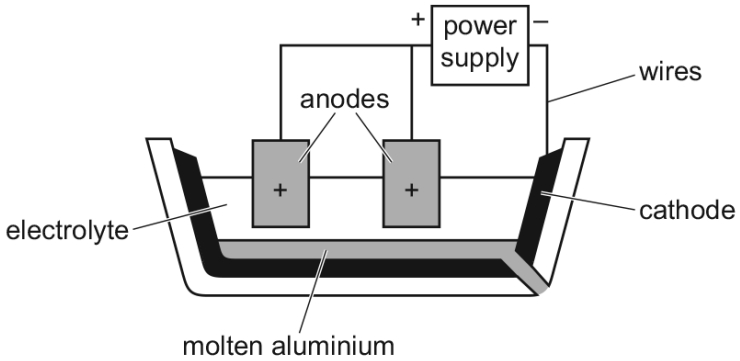
1 .....

2 .....
[2]

[Total: 18]

02. 0620_m20_qp_42 Q: 2

Aluminium is extracted from its ore. The ore is converted into pure aluminium oxide, which then undergoes electrolysis as shown.



(a) (i) Name an ore of aluminium.

..... [1]

(ii) What is meant by the term *electrolysis*?

.....

..... [2]

(b) Aluminium oxide has a melting point of about 2000 °C, but the electrolysis process operates at about 900 °C.

(i) Name the compound added to aluminium oxide to reduce the operating temperature.

..... [1]

(ii) Suggest **one** benefit to the environment of reducing the operating temperature.

.....

..... [1]

(iii) Write the ionic half-equation for the reaction taking place at:

the negative electrode (cathode) .....

the positive electrode (anode) .....

[4]

(iv) Explain why the anodes need frequent replacement.

.....

..... [2]

(c) Aluminium oxide reacts with acids and with alkalis.

(i) What term is used to describe an oxide that reacts with acids and with alkalis?

..... [1]

(ii) Aluminium oxide reacts with dilute sulfuric acid to form a salt.

State the name and write the formula of the salt formed.

name .....

formula .....
[2]

(iii) Aluminium oxide reacts with dilute sodium hydroxide to form a salt and one other product.

Name the other product.

..... [1]

(iv) Aluminium hydroxide, $Al(OH)_3$, decomposes when heated to form aluminium oxide and water.

Write the chemical equation for this reaction.

..... [2]

(v) Suggest the names of **two** other aluminium compounds that decompose when heated to form aluminium oxide.

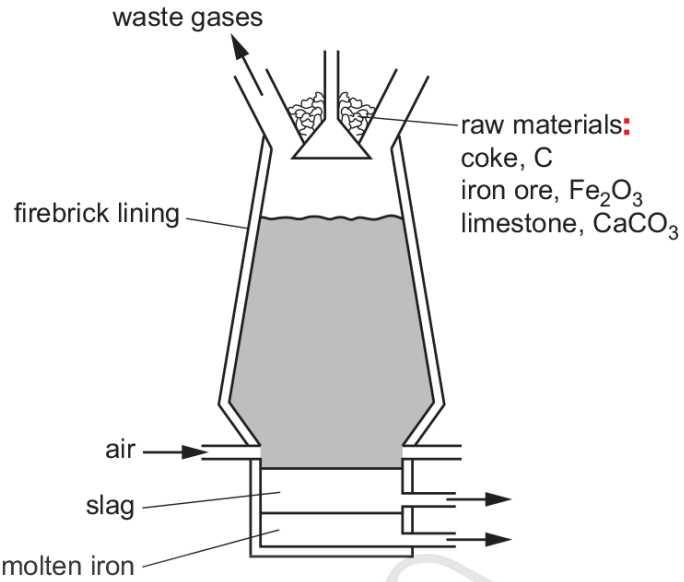
.....

..... [2]

[Total: 19]

03. 0620_p20_qp_40 Q: 5

Iron is extracted from its ore, hematite, in the blast furnace.



Describe the reactions involved in this extraction.

Include one equation for a redox reaction and one for an acid/base reaction.

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [5]

[Total: 5]

04. 0620_w20_qp_43 Q: 4

Zinc is manufactured from zinc blende. Zinc blende is an ore which consists mainly of zinc sulfide, ZnS.

(a) Zinc blende is roasted in air. One of the products is zinc oxide.

Name the **other** product formed in this reaction.

..... [1]

(b) Zinc oxide is then converted into zinc.

Zinc oxide and coke, a source of carbon, are heated in a furnace. Hot air is blown into the furnace.

(i) Give **two** reasons why coke is needed.

1 .....

2 .....
[2]

(ii) Write a chemical equation for the formation of zinc in the furnace.

..... [1]

(iii) Zinc has a melting point of 420 °C and a boiling point of 907 °C. The temperature inside the furnace is 1200 °C.

Explain how this information shows that the zinc produced inside the furnace is a gas.

..... [1]

(iv) The gaseous zinc is converted to molten zinc.

Name this change of state.

..... [1]

(c) Zinc reacts with dilute sulfuric acid to produce aqueous zinc sulfate.

$$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$$

Hydrated zinc sulfate crystals are made from aqueous zinc sulfate.

Step 1 Solid zinc is added to dilute sulfuric acid until zinc is in excess.

Step 2 Excess zinc is separated from aqueous zinc sulfate by filtration.

Step 3 Aqueous zinc sulfate is heated until the solution is saturated.

Step 4 The saturated solution is allowed to cool and crystallise.

Step 5 The crystals are removed and dried.

(i) Name the residue in **step 2**.

..... [1]

(ii) In **step 3**, a saturated solution is produced.

Describe what a saturated solution is.

.....

.....

..... [2]

(iii) Name **two** compounds each of which react with dilute sulfuric acid to produce aqueous zinc sulfate.

1 .....

2 .....

[2]

(d) When hydrated magnesium sulfate crystals, $MgSO_4 \cdot xH_2O$, are heated they give off water.

$$MgSO_4 \cdot xH_2O(s) \rightarrow MgSO_4(s) + xH_2O(g)$$

A student carries out an experiment to determine the value of x in $MgSO_4 \cdot xH_2O$.

Step 1 Hydrated magnesium sulfate crystals were weighed.

Step 2 Hydrated magnesium sulfate crystals were heated.

Step 3 The remaining solid was weighed.

(i) Describe how the student can ensure that all the water is given off.

.....

.....

..... [2]

(ii) In an experiment, all the water was removed from 1.23 g of $MgSO_4 \cdot xH_2O$. The mass of $MgSO_4$ remaining was 0.60 g.

M_r: $MgSO_4$ = 120; M_r: H_2O = 18

Determine the value of x using the following steps.

- Calculate the number of moles of $MgSO_4$ remaining.

moles of $MgSO_4$ = ...

- Calculate the mass of H_2O given off.

mass of H_2O = ... g

- Calculate the moles of H_2O given off.

moles of H_2O = ...

- Determine the value of x.

x = ...
[4]

[Total: 17]

05. 0620_w19_qp_41 Q: 3

This question is about metals and metal oxides.

(a) Most metals have a high melting point.

State **one** other physical property that all metals have.

..... [1]

(b) Iron often rusts.

Name the **two** substances, other than iron, that must be present for iron to rust.

1 .....

2 .....

[1]

(c) Iron can be obtained by heating iron(III) oxide with zinc powder.

$$Fe_2O_3 + 3Zn \rightarrow 2Fe + 3ZnO$$

(i) What can be deduced about the reactivity of zinc from this reaction?

..... [1]

(ii) The ionic equation for this reaction is shown.

$$2Fe^{3+} + 3Zn \rightarrow 2Fe + 3Zn^{2+}$$

Identify the oxidising agent in this reaction. Explain your answer in terms of electron transfer.

oxidising agent .....

explanation .....

.....

[2]

(d) Zinc oxide is amphoteric.

Describe **two** simple experiments to show that zinc oxide is amphoteric.
Name the reagents you would use and describe the observations you would make.

reagent 1 .....

observation .....

reagent 2 .....

observation .....

[3]

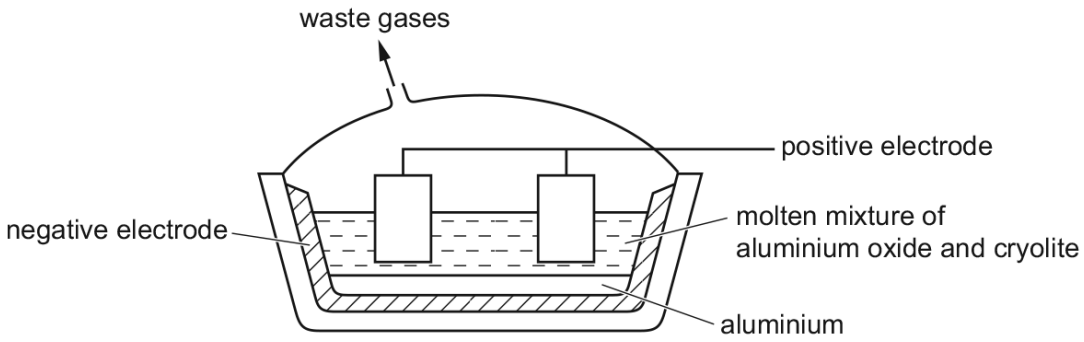
[Total: 8]

06. 0620_w19_qp_43 Q: 3

(a) Name the ore of aluminium which mainly consists of aluminium oxide.

..... [1]

(b) Aluminium is produced by the electrolysis of aluminium oxide dissolved in molten cryolite.



(i) Give **two** reasons why the electrolysis is done using a molten mixture of aluminium oxide and cryolite instead of molten aluminium oxide only.

1 .....

2 .....

[2]

(ii) Write ionic half-equations for the reactions occurring at the electrodes.

positive electrode .....

negative electrode .....

[2]

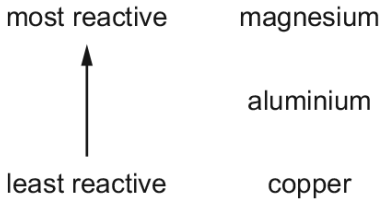
(iii) The anodes are made of carbon and have to be replaced regularly.

Explain why the carbon anodes have to be replaced regularly.

.....

..... [2]

(c) The positions of some common metals in the reactivity series are shown.



(i) When magnesium is placed in aqueous copper(II) sulfate a displacement reaction occurs immediately.

Write an ionic equation for the reaction. Include state symbols.

..... [2]

(ii) State **two** observations you would make when magnesium is placed in aqueous copper(II) sulfate.

1 .....

2 .....
[2]

(iii) When aluminium foil is added to aqueous copper(II) sulfate no immediate reaction takes place.

Explain why.

..... [1]

(d) Aluminium powder reacts with iron(III) oxide to produce aluminium oxide and iron.

Write a chemical equation for this reaction.

..... [2]

[Total: 14]

07. 0620_s18_qp_43 Q: 2

(a) ^{29}Al is a radioactive isotope of aluminium. The only non-radioactive isotope of aluminium is ^{27}Al.

(i) Describe, in terms of protons, neutrons and electrons, how the isotopes ^{29}Al and ^{27}Al are similar and how they are different.

how they are similar .....

how they are different .....

[2]

(ii) Complete the table to show the number of nucleons, neutrons and electrons in an $^{27}_{13}Al^{3+}$ ion.

	number in $^{27}_{13}Al^{3+}$
nucleons	
neutrons	
electrons	

[3]

(b) Aluminium is extracted from its ore by electrolysis.

(i) Name the main ore of aluminium.

..... [1]

(ii) Why is aluminium **not** extracted from its ore by reduction with carbon?

..... [1]

(iii) The main ore of aluminium contains aluminium oxide. Aluminium oxide is dissolved in molten cryolite before it is electrolysed.

Give **two** reasons, other than cost, why cryolite is used.

1 .....

2 .....

[2]

(iv) The reaction at the anode during the extraction of aluminium by electrolysis is shown.

$$2O^{2-} \rightarrow O_2 + 4e^-$$

Is this process oxidation or reduction?
Give a reason for your answer.

..... [1]

(v) During the extraction of aluminium by electrolysis, carbon dioxide is formed at the anode.

Explain how carbon dioxide is formed at the anode.

.....

..... [2]

(c) When a piece of zinc metal is added to copper(II) sulfate solution there is an immediate reaction.

$$Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$$

When a piece of aluminium metal is added to copper(II) sulfate solution the initial reaction is very slow.

(i) Explain why zinc metal reacts with copper(II) sulfate.

..... [1]

(ii) What type of reaction is this?

..... [1]

(iii) Explain why the initial reaction between aluminium metal and copper(II) sulfate is very slow.

..... [1]

[Total: 15]

08. 0620_s17_qp_41 Q: 4

Zinc is a very important metal.

(a) Zinc is extracted from its ore, zinc blende. Zinc blende contains zinc sulfide, ZnS.

Zinc sulfide is converted to zinc oxide in an industrial process.

(i) Describe how zinc sulfide is converted to zinc oxide in this industrial process.

.....

..... [1]

(ii) Write the chemical equation for this reaction.

..... [2]

(b) Zinc oxide is then reduced in a furnace.

(i) Name the substance added to the furnace to reduce the zinc oxide.

..... [1]

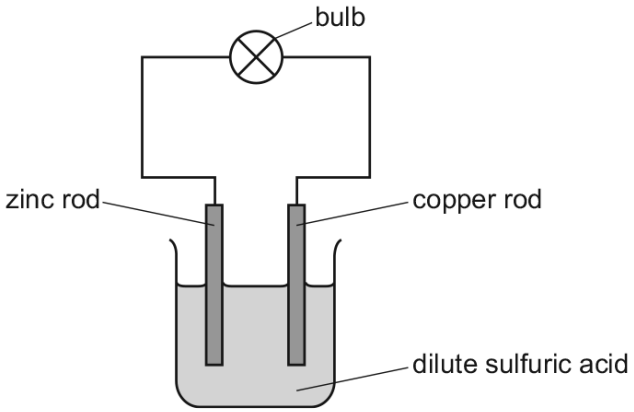
(ii) Describe how the pure zinc is removed from the furnace and collected.

.....

.....

..... [2]

(c) When rods of zinc and copper are placed into dilute sulfuric acid as shown, electricity is generated.



(i) Write the ionic half-equation for the reaction occurring at the zinc rod.

..... [2]

(ii) Write the ionic half-equation for the reaction occurring at the copper rod.

..... [2]

(iii) The copper rod was replaced by an iron rod.

Suggest the change, if any, in the intensity of the light emitted from the bulb and give a reason for your answer.

change .....

reason .....

.....
[2]

[Total: 12]

09. 0620_w17_qp_41 Q: 6

Aluminium is extracted from aluminium oxide by electrolysis.

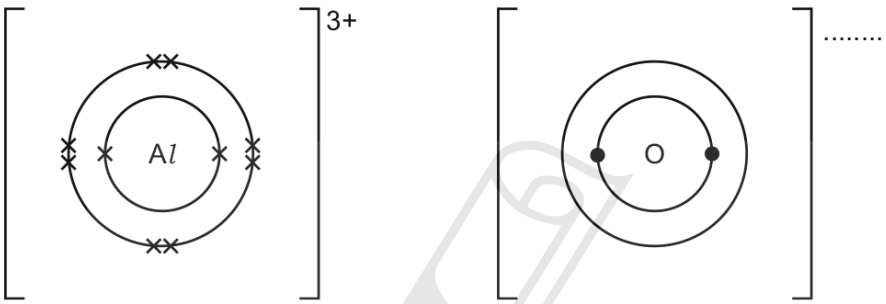
(a) Why is aluminium **not** extracted by heating aluminium oxide with carbon?

.....

..... [1]

(b) Aluminium oxide is an ionic compound with a high melting point.

(i) Complete the dot-and-cross diagram to show the electron arrangement in **one** of the oxide ions present in aluminium oxide. Include the charge on the oxide ion.
One of the aluminium ions is shown.



.....

[2]

(ii) The melting point of aluminium oxide is above 2000 °C.

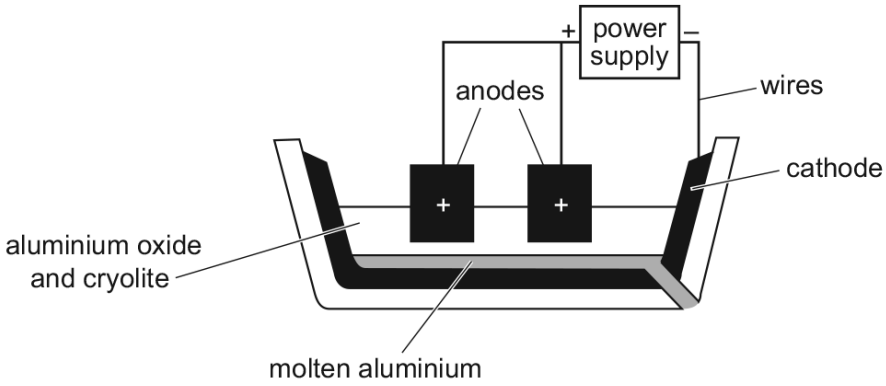
Explain why aluminium oxide has a high melting point.

.....

.....

..... [2]

(c) Aluminium can be extracted by electrolysis using the apparatus shown.



(i) Name the type of particle responsible for the transfer of charge in

the wires, ...

the electrolyte. .....

[2]

(ii) Give **two** reasons why cryolite is used.

1 .....

2 .....

[2]

(iii) Write the ionic half-equation for the formation of aluminium during the electrolysis.

..... [1]

(iv) Explain how carbon dioxide gas is formed at the anodes.

.....

.....

..... [3]

(d) When a piece of aluminium is placed in dilute hydrochloric acid, there is no immediate visible reaction.
If the aluminium is left in the dilute hydrochloric acid for several hours, bubbles start to form.

Explain why aluminium does **not** react immediately with dilute hydrochloric acid.

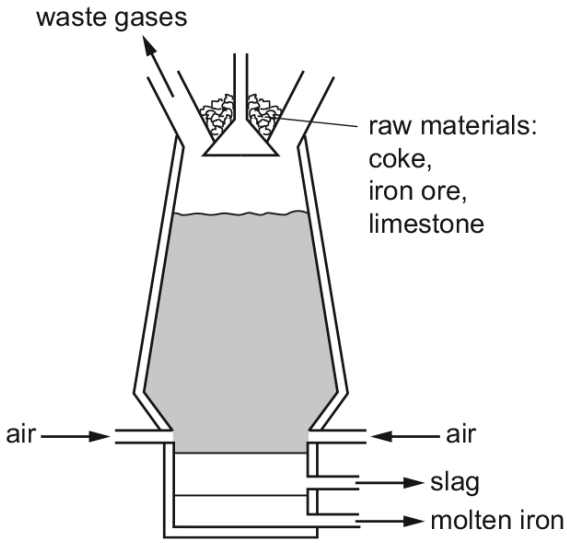
.....

..... [1]

[Total: 14]

10. 0620_w17_qp_43 Q: 3

Iron is extracted from its ore using coke in a blast furnace.



(a) Name the ore of iron which is mainly iron(III) oxide.

..... [1]

(b) Describe the reactions occurring in the blast furnace.

In your answer, include

- **two** reasons for using coke in the blast furnace,
- a chemical equation for the reduction of iron(III) oxide,
- an explanation for using limestone in the blast furnace.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [6]

(c) (i) Describe the bonding in iron. Include a diagram in your answer.

.....

..... [3]

(ii) Use your diagram in **(c)(i)** to explain why iron is malleable.

.....

..... [2]

(iii) Iron containing a small amount of carbon is known as steel.

Explain why steel is less malleable than iron.

.....

..... [2]

(d) (i) When iron is added to dilute sulfuric acid, an aqueous solution of iron(II) sulfate is formed as one of the products.

Write a chemical equation for the reaction.

..... [1]

(ii) When iron(III) oxide is added to dilute sulfuric acid, an aqueous solution of iron(III) sulfate is formed as one of the products.

Write a chemical equation for the reaction.

..... [3]

(e) Aqueous sodium hydroxide, aqueous potassium iodide and aqueous acidified potassium manganate(VII) are added to aqueous solutions of iron(II) sulfate and iron(III) sulfate.

- Iron(II) ions, Fe^{2+}, are reducing agents in aqueous solution.
- Iron(III) ions, Fe^{3+}, are oxidising agents in aqueous solution.

Complete the table.

reagent	observations with aqueous iron(II) sulfate	observations with aqueous iron(III) sulfate
aqueous sodium hydroxide	green precipitate	
aqueous potassium iodide		
aqueous acidified potassium manganate(VII)		no change

[4]

[Total: 22]

11. 0620_s16_qp_42 Q: 6

Zinc is extracted from an ore called zinc blende, which consists mainly of zinc sulfide, ZnS.

(a) (i) The zinc sulfide in the ore is first converted into zinc oxide.

Describe how zinc oxide is made from zinc sulfide.

.....

..... [1]

(ii) Write a chemical equation for the reaction in **(a)(i)**.

..... [2]

(b) Zinc oxide is converted into zinc. Zinc oxide and coke are fed into a furnace. Hot air is blown into the bottom of the furnace.

Zinc has a melting point of 420 °C and a boiling point of 907 °C. The temperature inside the furnace is over 1000 °C.

(i) Explain how zinc oxide is converted into zinc. Your answer should include details of how the heat is produced and equations for all the reactions you describe.

.....

.....

.....

.....

..... [3]

(ii) Explain why the zinc produced inside the furnace is a gas.

..... [1]

(iii) State the name of the physical change for conversion of gaseous zinc into molten zinc.

..... [1]

(c) Rusting of steel can be prevented by coating the steel with a layer of zinc.

Explain, in terms of electron transfer, why steel does **not** rust even if the layer of zinc is scratched so that the steel is exposed to air and water.

.....

.....

.....

.....

..... [4]

(d) When a sample of steel is added to dilute hydrochloric acid, an aqueous solution of iron(II) chloride, $FeCl_2$, is formed.

When a sample of rust is added to dilute hydrochloric acid, an aqueous solution of iron(III) chloride, $FeCl_3$, is formed.

(i) Aqueous sodium hydroxide is added to the solutions of iron(II) chloride and iron(III) chloride.

Complete the table below, showing the observations you would expect to make.

	iron(II) chloride solution	iron(III) chloride solution
aqueous sodium hydroxide		

[2]

Solutions of iron(II) chloride and iron(III) chloride were added to solutions of potassium iodide and acidified potassium manganate(VII). The results are shown in the table.

	iron(II) chloride solution	iron(III) chloride solution
potassium iodide solution	no change	solution turns from colourless to brown
acidified potassium manganate(VII) solution	solution turns from purple to colourless	no change

(ii) What **types** of substance cause potassium iodide solution to turn from colourless to brown?

..... [1]

(iii) What **types** of substance cause acidified potassium manganate(VII) solution to turn from purple to colourless?

..... [1]

(iv) Which **ion** in iron(III) chloride solution causes potassium iodide solution to turn from colourless to brown?

..... [1]

(v) Which **ion** in iron(II) chloride solution causes acidified potassium manganate(VII) solution to turn from purple to colourless?

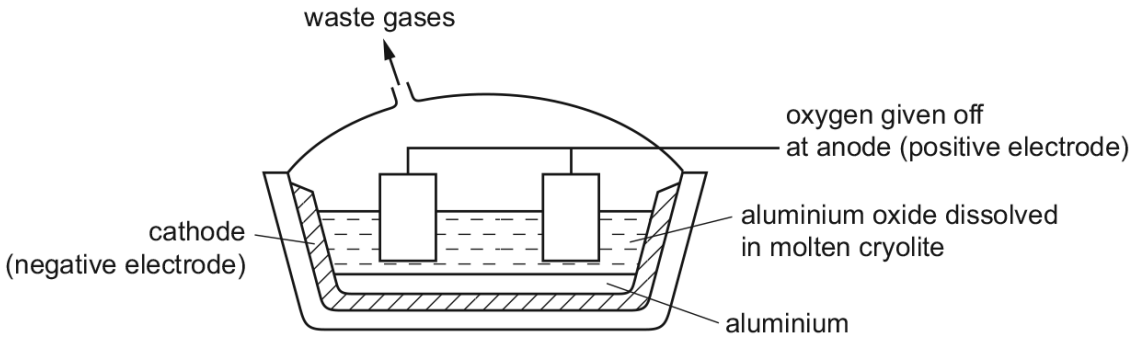
..... [1]

[Total: 18]

12. 0620_m15_qp_32 Q: 5

Aluminium and iron are extracted from their ores by different methods.

Aluminium is extracted from its purified oxide ore by electrolysis.



(a) What is the name of the ore of aluminium which consists mainly of aluminium oxide?

..... [1]

(b) The electrodes are both made of the same substance.

Name this substance.

..... [1]

(c) Aluminium oxide is dissolved in molten cryolite before it is electrolysed.

Give **two** reasons why aluminium oxide dissolved in molten cryolite is electrolysed rather than molten aluminium oxide alone.

.....

..... [2]

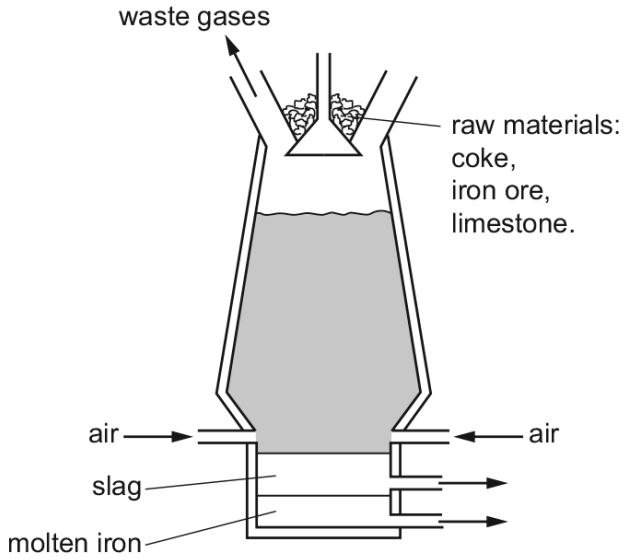
(d) Write the **ionic** equations for the reactions at the electrodes in this electrolysis.

anode (positive electrode) .....

cathode (negative electrode) .....

[2]

(e) Iron is extracted from its oxide ore by reduction using carbon in a blast furnace.



(i) Place the elements aluminium, carbon and iron in order of reactivity with the **least** reactive element first.

..... [1]

(ii) Use your answer to **(e)(i)** to explain why iron is extracted by reduction using carbon but aluminium is not.

.....

..... [1]

(f) What is the name of the ore of iron which consists mainly of iron(III) oxide?

..... [1]

(g) Write balanced equations for the reactions occurring in the blast furnace which involve

(i) the complete combustion of coke (carbon),

..... [1]

(ii) the production of carbon monoxide from carbon dioxide,

..... [1]

(iii) the reduction of iron(III) oxide,

..... [1]

(iv) the formation of slag.

..... [1]

[Total: 13]

13. 0620_w15_qp_32 Q: 3

Two of the main uses of zinc are for galvanising and for making alloys.

One of the main ores of zinc is zinc blende, ZnS. There are two stages in the extraction of zinc from this ore.

(a) Stage 1 Zinc oxide is made from zinc blende.

Describe how this is done and write a word equation for the reaction.

.....

.....

..... [2]

(b) Stage 2 Zinc oxide is reduced to zinc.

Write a word equation for the reduction of zinc oxide by coke.

..... [1]

(c) The zinc produced by this process is impure. It can be purified by electrolysis using a method which is similar to the purification of copper. Under the conditions used in the process, zinc is the product at the negative electrode (cathode).

Complete the following description of this purification.

The electrolyte is aqueous ..... . [1]

The negative electrode (cathode) is made of ..... . [1]

The positive electrode (anode) is impure zinc.

The equation for the reaction at the cathode is ..... . [1]

The equation for the reaction at the anode is ..... . [1]

Explain why the concentration of the electrolyte does **not** change.

.....

..... [2]

(d) Brass is an alloy which contains zinc.

(i) Name the other metal in brass.

..... [1]

(ii) Suggest **two** reasons why an alloy such as brass is preferred to either of its constituent metals.

.....

..... [2]

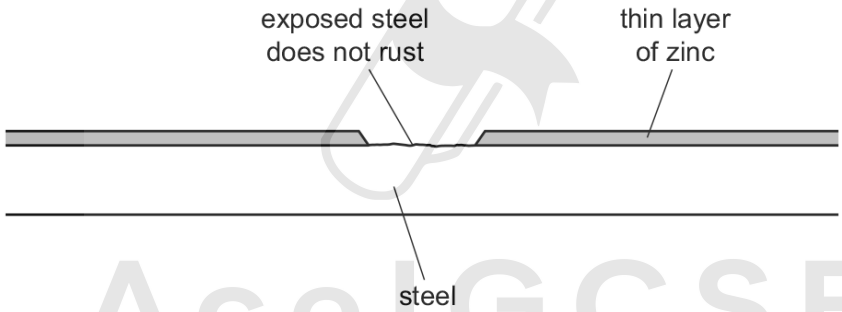
(e) In an experiment to investigate the rate of rusting of steel, three pieces of steel were used. One piece of steel was completely coated with copper, one piece completely coated with zinc and the third piece was left uncoated. All three pieces were left exposed to the atmosphere.

(i) Explain why the uncoated piece started to rust.

.....

..... [1]

(ii) The coating on both of the other two pieces was scratched, exposing the steel.



The piece of steel coated with zinc still did not rust but the copper-coated piece of steel rusted very rapidly.

Explain these observations in terms of the formation of ions and the transfer of electrons.

.....

.....

.....

.....

..... [4]

[Total: 17]

14. 0620_w15_qp_32 Q: 5

Iron is extracted from its ore, hematite, in a blast furnace.

Substances added to the furnace are:

- iron ore, hematite, containing impurities such as silica, SiO_2
- air
- coke, C
- limestone, $CaCO_3$

Substances formed in the blast furnace are:

- molten iron
- molten slag
- waste gases such as carbon dioxide

(a) State the **two** functions of the coke used in the blast furnace.

.....

..... [2]

(b) Write an equation for the conversion of hematite, Fe_2O_3, to iron.

..... [2]

(c) Explain how the silica impurity is removed and separated from the molten iron.

.....

.....

.....

..... [3]

(d) The molten iron from the furnace is impure.
It contains impurities which include the element carbon.

Explain how the carbon is removed. Include an equation in your answer.

.....

.....

..... [3]

[Total: 10]

---

01. 0620_w21_ms_41 Q: 1

Question	Answer	Marks
(a)(i)	hydrogen	1
(a)(ii)	sodium	1
(a)(iii)	iron	1
(a)(iv)	aluminium	1
(a)(v)	zinc or copper	1
(a)(vi)	iron	1
(b)(i)	zinc blende	1
(b)(ii)	bauxite	1
(c)	protective oxide layer	1
(d)	Any 2 from 3 • zinc • iron • copper	2
(e)(i)	copper	1
(e)(ii)	zinc sulfate	1
(e)(iii)	**M1** particles have more energy **M2** More collisions (between particles) occur per second / per unit time **M3** A greater percentage / proportion / fraction of collisions (of particles) are successful / have energy above activation energy / have energy equal to activation energy	3

Question	Answer	Marks
(e)(iv)	Any 2 from 3: • use a catalyst • use smaller granules • increase concentration	2

02. 0620_m20_ms_42 Q: 2

(a)(i)	bauxite	1
(a)(ii)	**breakdown** by (the passage of) **electricity** (1) of an **ionic compound** in **molten / aqueous** (state) (1)	2
(b)(i)	cryolite	1
(b)(ii)	less CO_2 emission	1

(b)(iii)	$Al^{3+} + 3e^- \rightarrow Al$ any positive Al species gaining electron(s) (1) correct species and balance (1) $2O^{2-} \rightarrow O_2 + 4e^-$ any negative O species losing electron(s) (1) correct species and balance (1)	4
(b)(iv)	anodes **or** carbon / graphite react with oxygen / O_2 (1) (form) carbon dioxide (1)	2
(c)(i)	amphoteric	1
(c)(ii)	aluminium sulfate (1) $Al_2(SO_4)_3$ (1)	2
(c)(iii)	water	1
(c)(iv)	$2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$ species (1) balance (1)	2
(c)(v)	aluminium carbonate (1) aluminium nitrate (1)	2

03. 0620_p20_ms_40 Q: 5

one redox equation from: [1]
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$
$Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$
$C + O_2 \rightarrow CO_2$
$CO_2 + C \rightarrow 2CO$

one acid/base equation: [1]
$CaO + SiO_2 \rightarrow CaSiO_3$
$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

Any three additional equations or comments from: [3]
carbon burns or reacts to form carbon dioxide;
this reaction is exothermic or produces heat;
carbon dioxide is reduced to carbon monoxide;
carbon monoxide reduces hematite to iron;
carbon reduces hematite to iron;
limestone removes silica to form slag;
limestone decomposes;

04. 0620_w20_ms_43 Q: 4

Question	Answer	Marks
(a)	sulfur dioxide	1
(b)(i)	**Any two from** (coke) • releases heat **or** releases energy(when it reacts with oxygen or burns in air) / (acts as a) fuel / increases temperature (in the furnace) / heats (the furnace) / source of energy (coke) • reduces zinc oxide / is a reducing agent / converts zinc oxide to zinc / removes oxygen from zinc oxide (coke) • (reacts with oxygen) to produce carbon monoxide / reacts with carbon dioxide to form carbon monoxide • carbon monoxide reduces zinc oxide / converts zinc oxide to zinc / removes oxygen from zinc oxide	2

Question	Answer	Marks
(b)(ii)	$ZnO + CO \rightarrow Zn + CO_2$ **OR** $2ZnO + C \rightarrow 2Zn + CO_2$ **OR** $ZnO + C \rightarrow Zn + CO$	1
(b)(iii)	temperature inside furnace is above / higher than 907 (°C) **OR** temperature is above / higher than the boiling point (of zinc) **ORA** **OR** 1200 (°C) is above / higher than the boiling point (of zinc) **ORA** **OR** 1200 (°C) is above / higher than 907 (°C) **ORA**	1
(b)(iv)	condensation / condensing	1
(c)(i)	zinc	1
(c)(ii)	(a solution containing the) **maximum** amount of solute **dissolved** / **no more** solute can **dissolve** (1) at a given temperature (1)	2
(c)(iii)	one mark for each of any two from: • zinc oxide • zinc hydroxide • zinc carbonate	2
(d)(i)	**heat** again and **weigh** again / repeat steps 2 and 3 (1) until **mass** is **constant** (1)	2

Question	Answer	Marks
(d)(ii)	(moles of $MgSO_4$ =) $0.005 / 5 \times 10^{-3}$ (1) mass of water = 0.63 g (1) moles of water = $0.63 \div 18 = 0.035 / 3.5 \times 10^{-2}$ (1) $(x = 0.035 \div 0.005) = 7$ (1)	4

05. 0620_w19_ms_41 Q: 3

(a)	malleable / conduct electricity / conduct heat	1
(b)	water and oxygen / air	1
(c)(i)	(zinc is) more reactive than iron	1
(c)(ii)	Fe^{3+} (1) accept / take / gain electrons (1)	2
(d)	(add a) named acid (1) (add a) named alkali (1) disappears / dissolves in both (1)	3

06. 0620_w19_ms_43 Q: 3

(a)	bauxite	1
(b)(i)	improves conductivity / better conductor (1) lower (operating) temperature (1)	2
(b)(ii)	positive: $2O^{2-} \rightarrow O_2 + 4e^-$ (1) negative: $Al^{3+} + 3e^- \rightarrow Al$ (1)	2
(b)(iii)	anodes **or** carbon react with oxygen (1) (form) carbon dioxide (1)	1
(c)(i)	$Mg(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Mg^{2+}(aq)$ ionic equation correct (1) state symbols (1)	2
(c)(ii)	any two from: □ solid dissolves / disappears □ blue colour of solution fades **OR** paler solution **OR** colour of solution disappears **OR** becomes colourless solution □ pink or orange or brown **AND** solid	2
(c)(iii)	unreactive coating of aluminium oxide	1
(d)	$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$ Fe_2O_3 and Al_2O_3 both correct (anywhere) (1) Equation completely correct (1)	2

07. 0620_s18_ms_43 Q: 2

(a)(i)	similarities: number of protons **and** electrons	1
	differences: number of neutrons	1
(a)(ii)	nucleons: 27	1
	neutrons: 14	1
	electrons: 10	1
(b)(i)	bauxite	1
(b)(ii)	aluminium is more reactive than carbon	1
(b)(iii)	to lower the operating temperature / the mixture has a lower melting point than aluminium oxide	1
	to increase the conductivity	1

(b)(iv)	oxidation (because) (the O^{2-} ion OR 'oxide ions') electrons are lost **OR** (the O^{2-} ion OR 'oxide ions') oxidation number increases	1
(b)(v)	electrodes/anodes are made from carbon/graphite	1
	oxygen (made) reacts with carbon/anode	1
(c)(i)	zinc is more reactive than copper	1
(c)(ii)	displacement / redox	1
(c)(iii)	(aluminium) has (inert) coating of aluminium oxide	1

08. 0620_s17_ms_41 Q: 4

(a)(i)	roast in air	1
(a)(ii)	$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ **M1** correct species **M2** correct balancing	2
(b)(i)	coke	1
(b)(ii)	zinc is vaporised / boiled	1
	and is condensed	1

(c)(i)	$Zn \rightarrow Zn^{2+} + 2e^-$ **M1** correct species **M2** correct balancing	2
(c)(ii)	$2H^+ + 2e^- \rightarrow H_2$ **M1** correct species **M2** correct balancing	2
(c)(iii)	change: (the intensity would) decrease	1
	reason: the difference in reactivity between zinc and iron is less than the difference in reactivity between zinc and copper	1

09. 0620_w17_ms_41 Q: 6

(a)	aluminium is more reactive than carbon	1
(b)(i)	oxide ion has an outer shell with six dots and two crosses	1
	oxide ion has a charge of 2^-	1

(b)(ii)	(electrostatic) forces of attraction between ions	1
	(are) strong **OR** require lots of energy to overcome	1
(c)(i)	*the wires:* electrons	1
	the electrolyte: ions	1
(c)(ii)	any 2 from: □ increases conductivity □ as a solvent □ lowers the operating temperature	2
(c)(iii)	$Al^{3+} + 3e^- \rightarrow Al$	1
(c)(iv)	oxygen is made at the anode	1
	the anodes are made of carbon	1
	oxygen (made) reacts with carbon	1
(d)	aluminium coated with layer of (unreactive) aluminium oxide	1

10. 0620_w17_ms_43 Q: 3

(a)	hematite	1
(b)	(coke reacts with oxygen / air) to produce heat / increase temperature / exothermically	1
	coke is reducing agent / produces reducing agent / produces carbon monoxide **OR** **coke reduces** Fe_2O_3 / (iron) ore / hematite (producing iron)	1
	$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ **OR** $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$ **OR** $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$ **M1** species correct **M2** balanced	2
	limestone (decomposes to calcium oxide which) reacts with / removes **acidic impurities** / SiO_2 / sand / silica / silicon(IV) oxide / silicon dioxide	1
	limestone / calcium oxide / lime is involved in the production of slag / calcium silicate	1
(c)(i)	positive ions / cations	1
	sea of electrons / mobile electrons / delocalised electrons / moving electrons / flowing electrons	1
	attraction between positive ions and electrons	1
(c)(ii)	layers / rows / sheets of ions	1
	slide / slip / shift (over each other or past each other)	1
(c)(iii)	particles have different sizes / radii	1
	layers cannot slide / slip / shift	1
(d)(i)	$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$	1
(d)(ii)	$Fe_2O_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2O$ **M1** formula of $Fe_2(SO_4)_3$ **M2** all formulae correct (no additional species) **M3** balanced	3
(e)		4

	observation with aqueous iron(II) sulfate	observation with aqueous iron(III) sulfate
aqueous sodium hydroxide		**M3** brown precipitate
aqueous potassium iodide	**M1** no change	**M4** brown solution / black solid
aqueous acidified potassium manganate(VII)	**M2** (pink / purple to) colourless / decolourised	

11. 0620_s16_ms_42 Q: 6

(a)(i)	roast/heat **and** in air/oxygen;	**1**
(a)(ii)	$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$; SO_2 on right of equation; all formulae and balancing correct;	**2**
(b)(i)	**M1** heat produced by carbon/coke (burning in) oxygen/air; **OR** $C + O_2 \rightarrow CO_2$ produces heat/exothermic; **OR** $2C + O_2 \rightarrow 2CO$ produces heat/exothermic (scores **M1** and **M2**); **M2** $C + CO_2 \rightarrow 2CO$; **OR** $2C + O_2 \rightarrow 2CO$; **M3** $ZnO + CO \rightarrow Zn + CO_2$; **OR** $ZnO + C \rightarrow Zn + CO$; **OR** $2ZnO + C \rightarrow 2Zn + CO_2$;	**3** 1 1 1
(b)(ii)	temperature (inside the furnace) is above 907 °C/temperature (inside the furnace) is above the boiling point (of zinc)/1000 °C is above the boiling point (of zinc);	**1**
(b)(iii)	condensation/condensing/condense;	**1**
(c)	**M1** zinc is more reactive than iron/zinc is higher in the reactivity series than iron ora; **M2** zinc loses electrons; **M3** iron/steel/oxygen/air/water gains electrons **OR** electrons move to iron/steel/oxygen/air/water; **M4** (therefore) iron does not lose electrons/get oxidised/form iron(II)/form iron(III);	**4** 1 1 1 1

(d)(i)	green precipitate; red-brown/brown/orange precipitate;	**2** 1 1
(d)(ii)	oxidising agent/oxidant;	**1**
(d)(iii)	reducing agent/reductant;	**1**
(d)(iv)	iron(III)/Fe^{3+};	**1**
(d)(v)	iron(II)/Fe^{2+};	**1**

12. 0620_m15_ms_32 Q: 5

(a) Bauxite [1]

(b) carbon / graphite [1]

(c) improves conductivity / better conductor [1]

Lower (operating) temperature / save energy / saves electricity / saves heat [1]

(d) anode: $2O^{2-} \rightarrow O_2 + 4e^-$ / $2O^{2-} - 4e^- \rightarrow O_2$ [1]

cathode: $Al^{3+} + 3e^- \rightarrow Al$ / $Al^{3+} \rightarrow Al - 3e^-$ [1]

(e) **(i)** Iron carbon aluminium / Fe, C, Al [1]

(ii) Aluminium oxide is not reduced by carbon but iron(III) oxide is [1]

(f) haematite / hematite [1]

(g) **Allow:** multiples in **(i)** to **(iv)**

(i) $C + O_2 \rightarrow CO_2$ [1]

(ii) $CO_2 + C \rightarrow 2CO$ [1]

(iii) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ / $Fe_2O_3 + 3C \rightarrow 2Fe + 3CO$ / $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$ [1]

(iv) $CaO + SiO_2 \rightarrow CaSiO_3$ / $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$ [1]

[Total:13]

13. 0620_w15_ms_32 Q: 3

(a)	zinc blende is burnt / roasted / heated in air; zinc sulfide + oxygen → zinc oxide + sulfur dioxide;	**2**
(b)	zinc oxide + carbon → zinc + carbon dioxide / monoxide;	**1**
(c)	zinc sulfate; pure zinc; $Zn^{2+} + 2e^- \rightarrow Zn$; $Zn \rightarrow Zn^{2+} + 2e^-$; zinc ions are removed (from solution) and replaced (into solution); at the same rate / speed;	**6**
(d)(i)	copper;	**1**
(d)(ii)	any two from: • hard(er) / less malleable; • strong(er); • (better) appearance; • (more) resistant to corrosion;	**2**
(e)(i)	steel (or iron) is exposed to oxygen **and** water;	**1**
(e)(ii)	Zn more reactive than Fe (allow steel); Zn loses / transfers electrons (more readily) **and** forms (+ve) ions (in preference to Fe); Fe (allow steel) is more reactive than Cu; Fe loses / transfers electrons (more readily) **and** forms (+ve) ions (in preference to Cu);	**4**

14. 0620_w15_ms_32 Q: 5

(a)	as a reducing agent; source of heat/energy;	**2**
(b)	$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ species; balancing;	**2**
(c)	silica reacts with limestone or calcium oxide; to form a slag or calcium silicate or $CaSiO_3$; (liquid) slag floats (above molten iron);	**3**
(d)	blow or pass oxygen through (molten) iron; $C + O_2 \rightarrow CO_2$; carbon dioxide escapes or carbon dioxide is a gas;	**3**