Mark schemes

Q1.

(a) 2,8,8,1

1

(b) they have the same number of outer shell electrons

1

(c) metallic

1

(d) any two from:

- bubbles (very) quickly
- melts (into a ball)
- floats
- moves (very) quickly

allow flame

2

(e) (reactivity) increases (down the group)

1

(f) any two from:

- increasing speed of movement
- increasing rate of bubble production
- doesn't melt → melts
- no flame → flame
  or
  flame → explosion

2

(g) hydrogen

1

(h) sodium ion structure 2,8

1

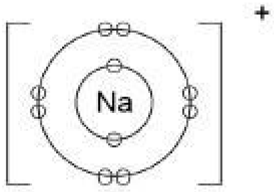
fluoride ion structure 2,8

allow any combination of circles, dots, crosses or e(–)

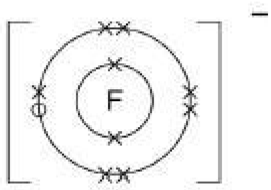
1

+ charge on sodium ion and
– charge on fluoride ion

an answer of



sodium ion



fluoride ion

scores 3 marks

1

[12]

Q2.

(a) $\frac{54 + 50 + 55}{3}$

1

= 53 (°C)

if no other mark awarded allow 1 mark for

$\frac{54 + 50 + 37 + 55}{4}$ *= 49 (°C)*

1

(b) (most reactive) magnesium zinc
(least reactive) cobalt

allow ecf from question (a)

1

(c) (18 ±) 2 (°C)

1

(d) control

1

(e) use the same mass of metal / powder

1

(f) (A) progress of reaction

1

(B) activation energy

1

(C) products

1

[9]

Q3.

(a) (3 × *Mr* H_2O = 3 × (2 + 16) =) 54

(*Ar* R = 150 – 54 =) 96

ignore units

1

alternative approach
(M_r RO_3 = 150 – 6 =) 144 (1)

(A_r R = 144 – (3 × 16) =) 96 (1)

ignore units

1

(b) (R =) molybdenum / Mo

allow ecf from question (a)

1

(c) (total M_r of reactants) = 163

1

(% atom economy =) $\frac{119}{163}$ (×100)

allow correct use of an incorrectly calculated value of total Mr

1

= 73 (%)

allow 73.00613 (%) correctly rounded to at least 2 significant figures

1

(d) Level 2: Some logically linked reasons are given. There may also be a simple judgement.

3–4

Level 1: Relevant points are made. They are not logically linked.

1–2

No relevant content

0

Indicative content

- carbon and iron are the cheapest reactants
- hydrogen is the most expensive reactant
- separating solid products is expensive
- separating solid products is time consuming
- in method 1, tungsten needs to be separated from tungsten carbide
- in method 1, some tungsten is lost as tungsten carbide
- in method 1, the carbon dioxide produced will escape
- in method 2, the water vapour produced will escape
- in method 2, no separation of solids is needed
- in method 3, tungsten needs to be separated from iron oxide

[10]

Q4.

(a) any two from:

- (potassium) floats
- (potassium) melts
- (potassium) moves around
- potassium becomes smaller

    allow potassium disappears
- (lilac) flame
- effervescence

    allow fizzing

2

(b) $2K + 2H2O \rightarrow 2KOH + H2$

allow multiples

allow 1 mark for KOH and H2

2

(c) reactivity increases (going down the group)

1

(because) the outer electron / shell is further from the nucleus

allow (because) there are more shells

allow (because) the atoms get larger

1

(so) there is less attraction between the nucleus and the outer electron / shell

allow (so) there is more shielding from the nucleus

do not accept incorrect attractions

1

(so) the atom loses an electron more easily

1

(d) (dot and cross diagram to show) sodium atom and oxygen atom

allow use of outer shells only

1

two sodium atoms to one oxygen atom

allow two sodium ions to one oxide ion

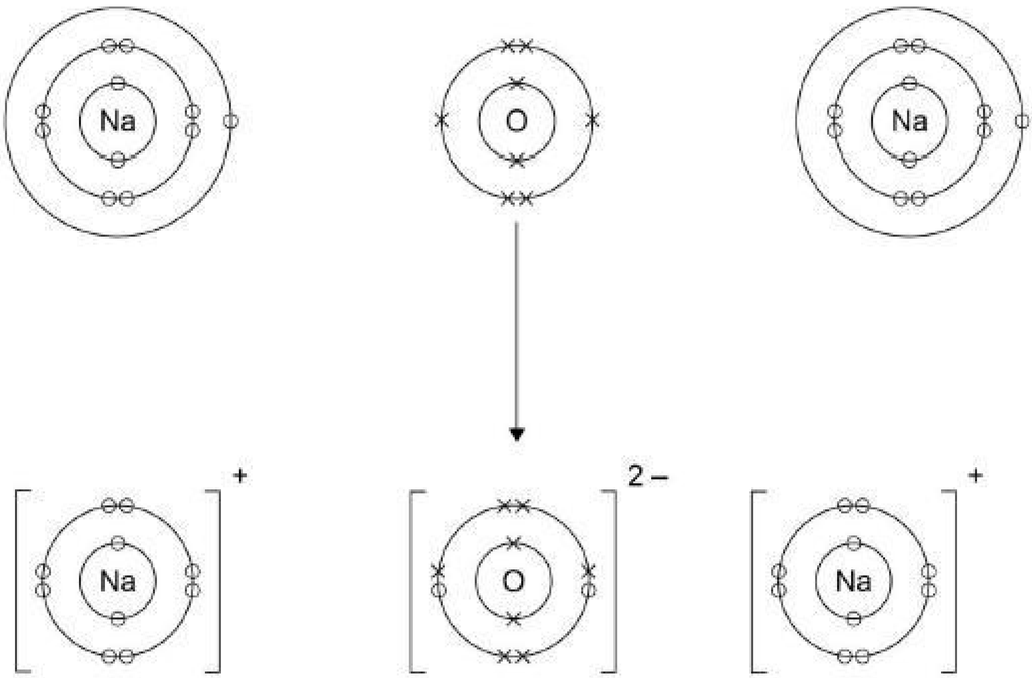
1

(to produce) sodium ion with a + charge

1

(to produce) oxide ion with a 2– charge

1



scores 4 marks

(e) (oxygen) gains electrons

1

(f) giant structure

allow (giant ionic) lattice

1

(with) strong (electrostatic) forces of attraction between (oppositely charged) ions

1

(so) large amounts of energy are needed to break the bonds / forces

allow (so) large amounts of energy are needed to separate the ions

1

[16]

Q5.

(a) C

1

(b) (in an alloy) the atoms are of different sizes

1

(so) the layers (of atoms in an alloy) are distorted

1

(so in an alloy) the layers slide over each other less easily (than in a pure metal)

1

(c) measure temperature change

allow measure the temperature before and after the reaction

1

when each metal is added to silver nitrate solution

1

same concentration / volume of solution
or
same mass / moles of metal

allow same initial temperature (of silver nitrate solution)

1

the greater the temperature change the more reactive

1

[8]

Q6.

(a) they form ions with different charges

1

they have high melting points

1

(b) the (grey) crystals are silver

1

the copper ions (produced) are blue

allow the copper nitrate / compound (produced) is blue

1

(because) copper displaces silver

1

(c) Level 2: The method would lead to the production of a valid outcome. The key steps are identified and logically sequenced.

3–4

Level 1: The method would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.

1–2

No relevant content

0

Indicative content

Key steps

- add the metals to (dilute) hydrochloric acid
- measure temperature change

  or

compare rate of bubbling
or
compare colour of resulting solution

for copper:

- no reaction
- shown by no temperature change
  or
  shown by no bubbles

for magnesium and iron:

- magnesium increases in temperature more than iron
  or
  magnesium bubbles faster than iron
  or
  magnesium forms a colourless solution and iron forms a coloured solution

Control variables

- same concentration / volume of hydrochloric acid
- same mass / moles of metal
- same particle size of metal
- same temperature (of acid if comparing rate of bubbling)

(d)

$$\frac{(203 \times 30) + (205 \times 70)}{100}$$

or

$$\frac{6090 + 14\,350}{100}$$

1

= 204.4

ignore units

1

[11]

Q7.

(a) the (minimum) energy needed for particles to react
or
the (minimum) energy needed for a reaction to occur

allow the (minimum) energy needed to start a reaction

1

(b) (*M*r of Fe2O3 =) 160

1

(moles Fe2O3 = $\frac{3000}{160}$ =)

18.75 (mol)

allow correct use of incorrectly calculated Mr

1

(moles Al = $\frac{1000}{27}$ =) 37.0 (mol)

allow 37.037037 (mol) correctly rounded to at least 2 significant figures

if both MP2 and MP3 are not awarded allow 1 mark for 0.01875 mol Fe2O3 and 0.037 mol Al

1

(aluminium is limiting because)
37.0 mol is less than the (2 x 18.75 =) 37.5 mol (aluminium needed)
or
iron oxide is in excess because 18.75 mol is more than the ($\frac{37.0}{2}$ =) 18.5 mol (iron oxide needed)

allow correct use of incorrect number of moles from steps 2 and/or 3

alternative approaches:

approach 1:

(finding required mass of aluminium by moles method)

(*M*r of Fe2O3 =) 160 (1)

(moles Fe2O3 = $\frac{3000}{160}$ =)
18.75 (mol) (1)

allow correct use of incorrectly calculated Mr

(moles Al needed =18.75 × 2 =) 37.5 (mol)
and

(mass Al needed = 37.5 × 27 =) 1012.5 (g) or 1.0125 kg (1)

allow correct use of incorrectly calculated moles of iron oxide

allow correct use of incorrectly calculated moles of aluminium needed

(so) 1.00 kg of aluminium is not enough (1)

dependent on calculated mass of aluminium needed being greater than 1.00 (kg)

approach 2:
(finding required mass of aluminium by proportion method)

(*M*r of Fe_2O_3 =) 160 (1)

(3.00 kg Fe_2O_3 needs)
$\frac{3.00}{160}$ × 2 × 27 (kg Al) (1)

allow correct use of incorrectly calculated Mr

(=) 1.0125 (kg) (1)

(so) 1.00 kg of aluminium is not enough (1)

dependent on calculated mass of aluminium needed being greater than 1.00 (kg)

alternative approaches:

approach 3:
(finding required mass of iron oxide by moles method)

*M*r of Fe_2O_3 =) 160 (1)

(moles Al = $\frac{1000}{27}$ =) 37.0 (mol) (1)

allow 37.037037 (mol) correctly rounded to at least 2 significant figures

(moles Fe_2O_3 needed) = $\frac{37.0}{2}$) = 18.5 (mol)
and
(mass Fe_2O_3 needed = 18.5 × 160 =) 2960 (g) or 2.96 (kg) (1)

allow correct use of incorrectly calculated moles of aluminium

allow correct use of incorrectly calculated moles of iron oxide needed
allow correct use of incorrectly calculated Mr

(so) 3.00 kg of iron oxide is an excess (1)

dependent on calculated mass of iron oxide needed being less than 3.00 (kg)

approach 4:
(finding required mass of iron oxide by proportion method)

(*M*r of Fe_2O_3 =) 160 (1)

(1.00 kg Al needs) $\frac{1.00}{2 \times 27}$ (kg Fe_2O_3) (1)

allow correct use of incorrectly calculated Mr

(=) 2.96 (kg) (1)

(so) 3.00 kg of iron oxide is an excess (1)

dependent on calculated mass of iron oxide needed being less than 3.00 (kg)

1

(c) Mg(s) + Zn2+(aq) → Mg2+(aq) + Zn(s)

allow multiples

allow 1 mark for Mg2+ + Zn with missing or incorrect state symbols

2

(d) magnesium (atoms) are oxidised because they lose electrons

1

(and) zinc (ions) are reduced because they gain electrons

if no other marks awarded allow 1 mark for magnesium (atoms) lose electrons and zinc (ions) gain electrons 1

1

[9]

Q8.

(a)

an answer of 77 (%) scores 2 marks
an answer of 78.63247863 (%) correctly rounded to at least 2 significant figures scores 1 mark

$$\frac{184}{(232 + 6)} \times 100$$

1

= 77 (%)

allow 77.31092437 (%) correctly rounded to at least 2 significant figures

1

(b)

an answer of 15 (kg) scores 2 marks

$$\frac{38}{100} \times 40$$

1

= 15 (kg)

allow 15.2 (kg)

1

(c)

an answer of 102 scores 2 marks

(2 x 27) + (3 x 16)

1

= 102

ignore units

1

(d)

an answer of 89.3 (%) scores 3 marks

$\frac{28.4}{31.8} \times 100$

1

= 89.3081761 (%)

allow 89.3081761(%) correctly rounded to at least 2 significant figures

1

= 89.3 (%)

allow an answer correctly rounded to 3 significant figures from an incorrect calculation which uses the masses in the question

1

(e) aluminium is more reactive than carbon

allow aluminium is above carbon in the reactivity series

1

(so) carbon cannot displace aluminium

allow (so) carbon cannot replace aluminium

or

(so) carbon cannot reduce aluminium oxide

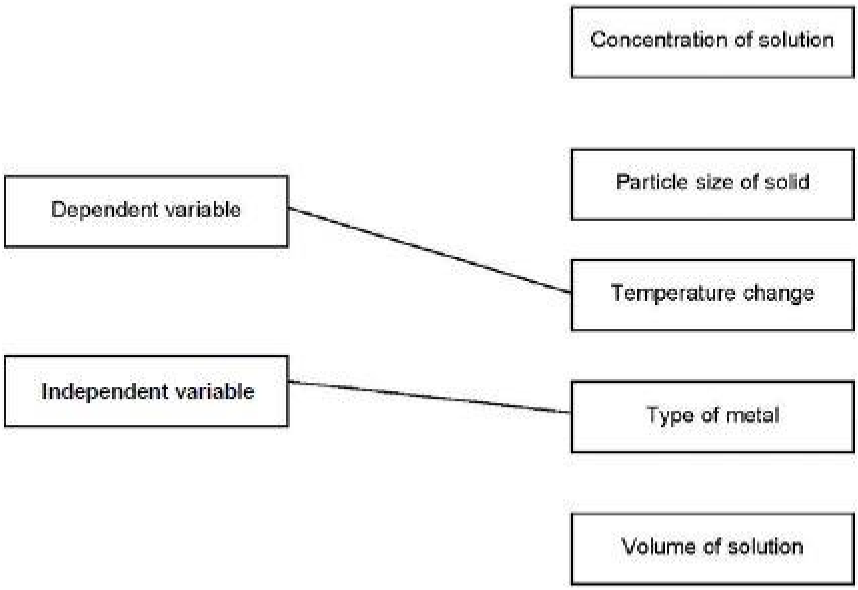
allow (so) carbon cannot remove oxygen from aluminium oxide
allow (so) carbon will not react with aluminium oxide

1

[11]

Q9.

(a)



allow one mark if answers are reversed

1
1

(b) polystyrene is a better insulator

1

(c) both bars labelled

1

both bars correctly plotted

allow tolerance of ±½ small square

ignore width and spacing of bars

if no other mark scored, allow 1 mark for any one bar correctly plotted and labelled

1

(d) temperature increases

allow (because) energy / 'heat' is transferred to the surroundings

or

temperature does not decrease

energy / 'heat' is not taken in from the surroundings

allow the energy of the products is less than the energy of the reactants

1

(e) (most reactive)

magnesium

(zinc)

nickel

this order only

1

(f) suitable method described

1

the observations / measurements required to place in order

1

an indication of how results would be used to place the unknown metal in the reactivity series

1

approaches that could be used:

approach 1:

add the unknown metal to copper sulfate solution (1)

measure temperature change (1)

place the metals in order of temperature change (1)

approach 2:

add the metal to salt solutions of the other metals

or

heat the metal with oxides of the other metals (1)

measure temperature change (only if salt solutions used)

or

observe whether a chemical change occurs (1)

compare temperature change or whether there is a reaction to place in correct order (1)

approach 3:

add all of the metals to an acid (1)

measure temperature change or means of comparing rate of reaction (1)

place the metals in order of temperature change or rate of reaction (1)

approach 4:

set up electrochemical cells with the unknown metal as one electrode and each of the other metals as the other electrode (1)

measure the voltage of the cell (1)

place the metals in order of voltage (1)

(g) D

1

(h) C

1

[12]

Q10.

(a) FeS_2

do not accept equations

1

(b) 26

1

30

1

26

1

must be this order

(c) any two from:

- iron has a high(er) melting / boiling point
- iron is dense(r)
- iron is hard(er)

allow iron is less malleable / ductile

- iron is strong(er)
- iron is less reactive

allow specific reactions showing difference in reactivity

- iron has ions with different charges
- iron forms coloured compounds
- iron can be a catalyst

allow iron is magnetic

allow the converse statements for sodium

allow transition metal for iron

allow Group 1 metal for sodium

ignore references to atomic structure

ignore iron rusts

2

(d) carbon is more reactive (than nickel)

allow converse

1

(so) carbon will displace / replace nickel (from nickel oxide)

allow (so) nickel ions gain electrons

or

(so) carbon will remove oxygen (from nickel oxide)

allow (so) carbon transfers electrons to nickel (ions)

1

(e) (total *M*r of reactants =) 87

1

(percentage atom economy)

$= \frac{59}{87} \times 100$

allow (percentage atom economy)

$= \frac{59}{\text{incorrectly calculated } M_r} \times 100$

1

= 67.8 (%)

allow an answer from an incorrect calculation to 3 sig figs

1

an answer of 67.8 (%) scores 3 marks

an answer of 67.8160919 (%) or correctly rounded answer to 2, 4 or more sig figs scores 2 marks

an incorrect answer for one step does not prevent allocation of marks for subsequent steps

[11]

Q11.

(a) all 4 metals labelled and suitable scale on *y*-axis

magnesium value must be at least half the height of the grid

1

all bars correctly plotted

allow a tolerance of ±½ a small square

ignore width and spacing of bars

allow 1 mark if copper not included and other 3 bars plotted correctly

1

(b) temperature increases

allow (because) energy / 'heat' is transferred to the surroundings
allow energy / 'heat' is given out

or

temperature does not decrease

allow energy / 'heat' is not taken in (from the surroundings)
allow the energy of the products is less than the energy of the reactants

1

ignore because it is exothermic
ignore references to copper

(c) suitable method described

1

the observations / measurements required to place in order

dependent on a suitable method

1

an indication of how results would be used to place the unknown metal in the reactivity series

1

a control variable to give a valid result

1

approaches that could be used

approach 1:
add the unknown metal to copper sulfate solution (1)

measure temperature change (1)

place the metals in order of temperature change (1)

any one from (1):

- same volume of solution
- same concentration of solution
- same mass / moles of metal
- same state of division of metal

approach 2:
add the metal to salt solutions of the other metals

or

heat the metal with oxides of the other metals (1)

measure temperature change (only if salt solutions used)
or
observe whether a chemical change occurs (1)

place the metals in order of temperature change or

compare whether there is a reaction to place in correct order (1)

any one from (1):

- same volume of salt solutions
- same concentration of salt solutions
- same (initial) temperature of salt solutions
- same mass / moles of metal or metal oxide
- same state of division of metal or metal oxide

approach 3:
add all of the metals to an acid (1)

measure temperature change or means of comparing rate of reaction (1) place the metals in order of temperature change or rate of reaction (1)

any one from (1):

- same volume of acid
- same concentration of acid
- same (initial) temperature of acid
- same mass / moles of metal
- same state of division of metal

approach 4:
set up electrochemical cells with the unknown metal as one electrode and each of the other metals as the other electrode (1)

measure the voltage of the cell (1)

place the metals in order of voltage (1)

any one from (1):

- same electrolyte
- same concentration of electrolyte
- same (initial) temperature of acid
- same temperature of electrolyte

(d) correct shape for exothermic reaction

the reactant and product lines needed not be labelled

do not accept incorrectly labelled reactant and product lines

1

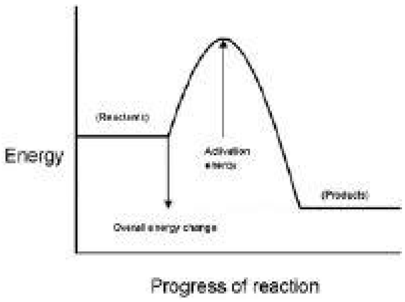
labelled activation energy

1

labelled (overall) energy change

1

ignore arrow heads
an answer of:



scores 3 marks

[10]

Q12.

(a) chlorine is toxic

allow carbon monoxide is toxic

allow poisonous for toxic
ignore harmful / deadly / dangerous
allow a poisonous gas is used / produced
allow titanium chloride is corrosive

1

(b) any one from:

- very exothermic reaction

  allow explosive
  allow violent reaction
  ignore vigorous reaction
  ignore sodium is very reactive

- produces a corrosive solution

  allow caustic for corrosive
  ignore alkaline

- produces hydrogen, which is explosive / flammable

  allow flames produced
  ignore sodium burns

1

(c) argon is unreactive / inert

allow argon will not react (with reactants / products / elements)

1

oxygen (from air) would react with sodium / titanium
or
water vapour (from air) would react with sodium / titanium

allow elements / reactants / products for sodium / titanium

1

(d) metal chlorides are usually ionic

allow titanium chloride is ionic

1

(so)(metal chlorides) are solid at room temperature
or
(so)(metal chlorides) have high melting points

allow titanium chloride for metal chlorides

1

(because) they have strong (electrostatic) forces between the ions

ignore strong ionic bonds

or
(but) must be a small molecule or covalent

allow molecular

1

allow alternative approach:

titanium chloride must be covalent or has small molecules (1)

with weak forces between molecules do not accept bonds unless intermolecular bonds(1)

(but) metal chlorides are usually ionic (1)

(e) sodium (atoms) lose electrons

do not accept references to oxygen

1

(f) Na → Na+ + e−

do not accept e for e−

1

(g) (*M*r of TiCl4 =) 190

$$(\text{moles Na} = \frac{20\,000}{23} =)\ 870\ (\text{mol})\ *$$

1

$$(\text{moles } TiCl_4 = \frac{40\,000}{190} =)\ 211\ (\text{mol})\ *$$

1

**allow 1 mark for 0.870 mol Na and 0.211 mol TiCl4*

allow use of incorrectly calculated Mr from step 1

either
(sodium is in excess because) 870 mol Na is more than the 844 mol needed
or
(because) 211 mol TiCl4 is less than the 217.5 mol needed

the mark is for correct application of the factor of 4

other correct reasoning showing, with values of moles or mass, an excess of sodium or insufficient TiCl4 is acceptable

allow use of incorrect number of moles from steps 2 and / or 3

1

alternative approaches:

approach 1:

(Mr of TiCl4 =) 190(1)

(40 kg TiClr needs)

$$\frac{40}{190} \times 4 \times 23\ (\text{kg Na})\ (1)$$

(=) 19.4 (kg) (1)
so 20 kg is an excess (1)
approach 2:
(Mr of TiCl4 =) 190(1)
(20 kg Na needs)

$$\frac{20}{4 \times 23} \times 190 \text{ (kg } TiCl_4\text{) (1)}$$

(=) 41.3 (kg) (1)
so 40 kg is not enough (1)

(h) $(\text{actual mass} =) \frac{92.3}{100} \times 13.5$
or
(actual mass =) 0.923 × 13.5

1

= 12.5 (kg)

allow 12 / 12.46 / 12.461 / 12.4605 (kg)

1

an answer 12.5 (kg) scores 2 marks

[15]

Q13.

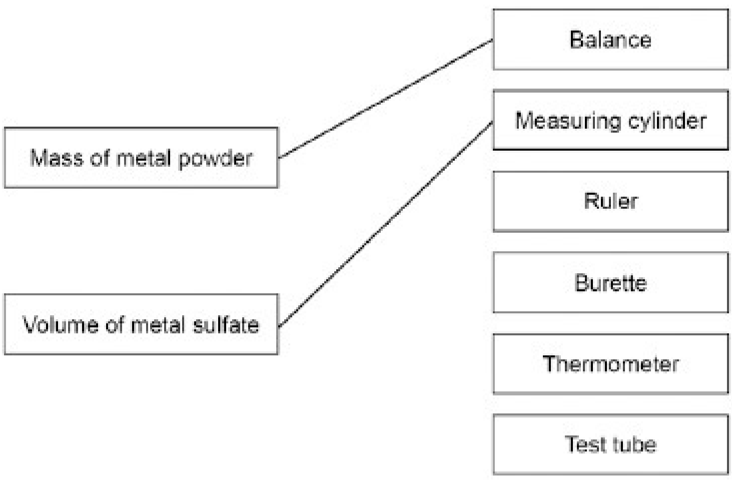
(a) Whether there was a reaction or not

1

(b) brown / orange / dark deposit on zinc
or
blue solution turns colourless / paler

1

(c) Variable — Measuring instrument



more than one line drawn from a variable negates the mark

2

(d) (Most reactive) Magnesium
Zinc
(Least reactive) Copper

must all be correct

1

(e) would not be safe or

too reactive

allow too dangerous

1

(f) Gold

1

(g) $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$

allow multiples

1

(h) carbon

1

(i) Loss of oxygen

1

[10]