10.1 Properties of metals

01. 0620_w21_qp_41 Q: 2

This question is about copper and its compounds.

(a) Copper has two different naturally occurring atoms, ^{63}Cu and ^{65}Cu.

(i) State the term used for atoms of the same element with different nucleon numbers.

..... [1]

(ii) The atomic number of copper is 29.

Complete the table to show the number of protons, neutrons and electrons in the particles of copper shown.

	^{63}Cu	$^{65}Cu^{2+}$
protons		
neutrons		
electrons		

[3]

(iii) Relative atomic mass is the average mass of naturally occurring atoms of an element.

The percentage of the naturally occurring atoms in a sample of copper is shown.

^{63}Cu	^{65}Cu
70%	30%

Deduce the relative atomic mass of copper in this sample.

Give your answer to **one** decimal place.

relative atomic mass = ... [2]

(b) Anhydrous copper(II) sulfate is used to test for the presence of water. When this test is positive, hydrated copper(II) sulfate is formed.

(i) State the colour change seen during this test.

from ..... to ..... [2]

(ii) Complete the chemical equation to show the reaction that takes place.

$CuSO_4$ + ... $\rightleftharpoons$ $CuSO_4 \cdot 5H_2O$ [1]

(iii) State how hydrated copper(II) sulfate can be turned back into anhydrous copper(II) sulfate.

..... [1]

(iv) Describe a test for pure water.

.....

..... [2]

(c) Aqueous copper(II) sulfate contains $Cu^{2+}(aq)$ ions.

(i) Describe what is seen when aqueous copper(II) sulfate is added to aqueous sodium hydroxide, NaOH(aq).

..... [1]

(ii) Write the ionic equation for the reaction between aqueous copper(II) sulfate and aqueous sodium hydroxide.

Include state symbols.

..... [3]

(d) When solid copper(II) nitrate is heated copper(II) oxide, nitrogen dioxide and oxygen are formed.

$$2Cu(NO_3)_2 \rightarrow 2CuO + 4NO_2 + O_2$$

Calculate the volume of nitrogen dioxide formed at room temperature and pressure when 4.7 g of $Cu(NO_3)_2$ is heated.

Use the following steps:

- calculate the mass of one mole of $Cu(NO_3)_2$

..... g

- calculate the number of moles of $Cu(NO_3)_2$ used

..... moles

- determine the number of moles of nitrogen dioxide formed

..... moles

- calculate the volume of nitrogen dioxide formed at room temperature and pressure.

..... dm^3

[4]

(e) Write the chemical equation to show the action of heat on sodium nitrate, $NaNO_3$.

..... [2]

[Total: 22]

02. 0620_s18_qp_43 Q: 3

Cobalt is a transition element. Potassium is in Group I of the Periodic Table.

(a) State **one** physical property that is similar for cobalt and potassium.

..... [1]

(b) (i) State **one** physical property that is different for cobalt and potassium.

..... [1]

(ii) Describe how the physical property given in **(b)(i)** is different for cobalt compared to potassium.

..... [1]

(c) When a small piece of potassium is added to cold water, the potassium floats and disappears as it reacts.

Give **two** other observations that would be made when a small piece of potassium is added to cold water.

1 .....

2 .....
[2]

(d) Cobalt reacts with dilute hydrochloric acid to make the salt cobalt(II) chloride. Bubbles of hydrogen gas are produced.

(i) Describe a test for hydrogen.

test .....

result .....
[2]

(ii) The rate of reaction of cobalt with dilute hydrochloric acid can be made faster by heating the acid or by increasing its concentration.

State **one** other way to make the rate of reaction faster.

..... [1]

(iii) Use collision theory to explain how heating the dilute hydrochloric acid makes the rate of reaction faster.

.....

.....

.....

.....

..... [3]

(e) When cobalt(II) chloride is added to water an equilibrium is established.

$$\underset{\text{blue}}{[CoCl_4]^{2-}} + 6H_2O \rightleftharpoons \underset{\text{pink}}{[Co(H_2O)_6]^{2+}} + 4Cl^-$$

(i) A student adds water to a blue solution containing $[CoCl_4]^{2-}$ ions.

Describe what the student observes. Give a reason for your answer in terms of the position of the equilibrium.

.....

.....

..... [2]

(ii) Another student cools a blue solution containing $[CoCl_4]^{2-}$. The blue solution turns pink.

What does this information indicate about the forward reaction?

.....

..... [1]

(f) Another compound of cobalt is $Co(OH)_3$.

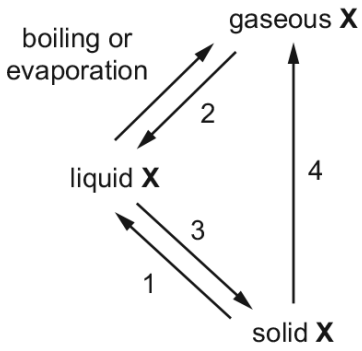
Deduce the charge on the cobalt ion in $Co(OH)_3$.

..... [1]

[Total: 15]

03. 0620_w18_qp_42 Q: 1

Element **X** can undergo the following physical changes.



(a) (i) Give the scientific name for each of the numbered physical changes.

1 .....

2 .....

3 .....

4 .....

[4]

(ii) Explain why the changes shown are physical changes.

.....

..... [1]

(iii) One difference between boiling and evaporation is the rate at which the processes occur.

State **one** other difference between boiling and evaporation.

.....

..... [1]

(b) Describe the separation, arrangement and motion of particles of element **X** in the solid state.

separation .....

arrangement .....

motion .....

[3]

(c) Element **X** is a Group I metal. It burns in air to form an oxide X_2O.

Write a chemical equation for this reaction.

..... [2]

[Total: 11]

04. 0620_s17_qp_43 Q: 3

Magnesium is a metal.

(a) Describe the structure and bonding in magnesium.

.....

.....

.....

..... [3]

(b) Why can magnesium conduct electricity when solid?

.....

.....

.....

..... [2]

(c) Why is magnesium malleable?

.....

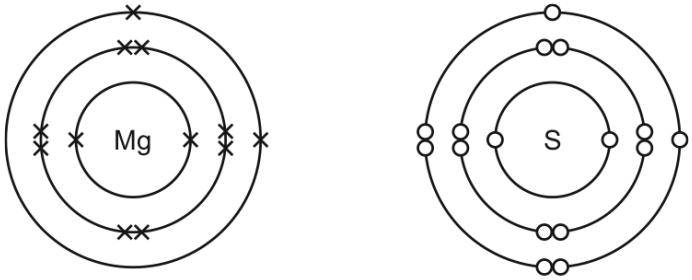
.....

.....

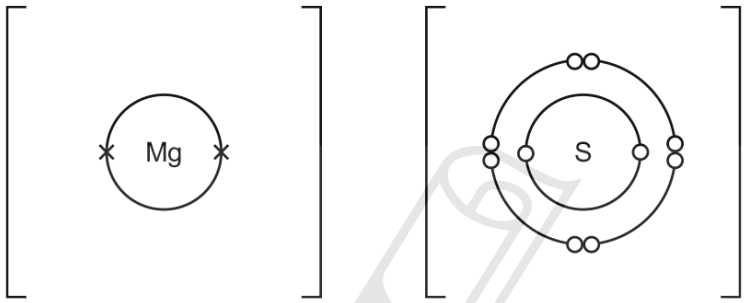
..... [2]

(d) Magnesium reacts with sulfur to form the ionic compound magnesium sulfide, MgS.

The diagrams show the electronic structures of atoms of magnesium and sulfur.



(i) Complete the diagrams to show the electronic structures of the ions in magnesium sulfide. Show the charges on the ions.



[3]

(ii) Ionic compounds, such as magnesium sulfide, do **not** conduct electricity when solid.
Magnesium sulfide does **not** dissolve in water.
Magnesium sulfide **does** conduct electricity under certain conditions.

State the conditions needed for magnesium sulfide to conduct electricity. Explain why magnesium sulfide conducts electricity under these conditions.

.....

.....

.....

..... [2]

[Total: 12]

05. 0620_w17_qp_41 Q: 3

(a) When magnesium is added to aqueous copper(II) sulfate a reaction occurs.
The ionic equation for the reaction is shown.

$$Mg + Cu^{2+} \rightarrow Mg^{2+} + Cu$$

(i) Give **one** change you would observe during this reaction.

..... [1]

(ii) Explain why this is a redox reaction.

.....

..... [1]

(iii) Identify the oxidising agent in this reaction. Give a reason for your answer.

.....

..... [2]

(iv) A redox reaction occurs when magnesium is heated with iron(III) oxide.

Write a chemical equation for the reaction between magnesium and iron(III) oxide.

..... [2]

(b) The metal iron and the alloy steel are commonly used materials. A problem with them is that they rust.

(i) How does painting iron and steel prevent rusting?

.....

..... [1]

(ii) Magnesium blocks can be attached to the bottom of steel boats.

Explain how the magnesium blocks prevent the whole of the bottom of the boat from rusting.

.....

.....

.....

..... [2]

(iii) Replacing the magnesium blocks with copper blocks does not prevent rusting.

Explain why the copper blocks do **not** prevent rusting.

.....

..... [1]

[Total: 10]

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06. 0620_s16_qp_42 Q: 3

Gallium is a metallic element in Group III. It has similar properties to aluminium.

(a) (i) Describe the structure and bonding in a metallic element.
You should include a labelled diagram in your answer.

.....

..... [3]

(ii) Explain why metallic elements such as gallium are good conductors of electricity.

..... [1]

(b) Give the formula of

gallium(III) chloride, ...

gallium(III) sulfate. .....
[2]

(c) Gallium(III) oxide, Ga_2O_3, is amphoteric.

(i) Write the chemical equation for the reaction between gallium(III) oxide and dilute nitric acid to form a salt and water only.

..... [2]

(ii) The reaction between gallium(III) oxide and sodium hydroxide solution forms only water and a salt containing the negative ion $Ga_2O_4^{2-}$.

Write the chemical equation for this reaction.

..... [2]

(d) Alloys of gallium and other elements are often more useful than the metallic element itself.

Suggest **two** reasons why alloys of gallium are more useful than the metallic element.

.....

..... [2]

[Total: 12]

07. 0620_w16_qp_42 Q: 4

Dilute nitric acid behaves as a typical acid in some reactions but **not** in other reactions.

(a) Dilute nitric acid behaves as a typical acid when reacted with copper(II) oxide and with copper(II) carbonate.

Describe what you would **see** if excess dilute nitric acid is added separately to solid samples of copper(II) carbonate and copper(II) oxide followed by warming the mixtures.

copper(II) carbonate

.....

.....

copper(II) oxide

.....

.....

[4]

(b) When dilute nitric acid is added to pieces of copper and heated, a reaction takes place and copper(II) nitrate is formed.

(i) Part of the chemical equation for the reaction between copper and dilute nitric acid is shown.

Complete the chemical equation by inserting the formula of copper(II) nitrate and balancing the equation.

.....$Cu(s) + 8HNO_3(aq) \rightarrow$ .....$(aq) + 4H_2O(l) + 2NO(g)$

[2]

(ii) How is the reaction of dilute nitric acid with copper different from that of a typical metal with a typical acid?

.....

..... [1]

[Total: 7]

08. 0620_w14_qp_32 Q: 4

Zinc is an important metal. Its uses include making alloys and the construction of dry cells (batteries).

(a) Name an alloy which contains zinc. What is the other metal in this alloy?

name of alloy .....

other metal in alloy .....
[2]

(b) The main ore of zinc is zinc blende, ZnS.

(i) The ore is heated in the presence of air to form zinc oxide and sulfur dioxide.
Write the equation for this reaction.

..... [2]

(ii) Give a major use of sulfur dioxide.

..... [1]

(c) Zinc can be obtained from zinc oxide in a two step process. Aqueous zinc sulfate is made from zinc oxide and then this solution is electrolysed with inert electrodes. The electrolysis is similar to that of copper(II) sulfate with inert electrodes.

(i) Name the reagent which will react with zinc oxide to form zinc sulfate.

..... [1]

(ii) Complete the following for the electrolysis of aqueous zinc sulfate.

Write the equation for the reaction at the negative electrode.

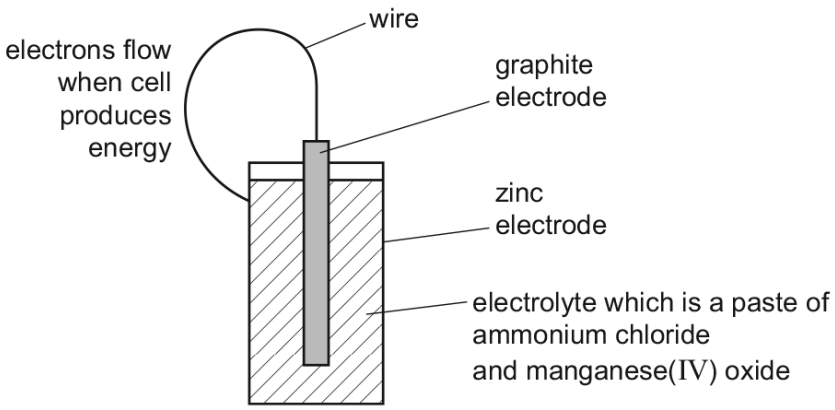
.....

Name the product at the positive electrode.

.....

The electrolyte changes from zinc sulfate to ..... .
[3]

(d) A dry cell (battery) has a central rod, usually made of graphite. This is the positive electrode which is surrounded by the electrolyte, typically a paste of ammonium chloride and manganese(IV) oxide, all of which are in a zinc container which is the negative electrode.



(i) Draw an arrow on the diagram to indicate the direction of electron flow. [1]

(ii) Suggest why the electrolyte is a paste.

..... [1]

(iii) The following changes occur in a dry cell.
For each change, decide if it is oxidation or reduction and give a reason for your choice.

Zn to Zn^{2+}

.....

manganese(IV) oxide to manganese(III) oxide

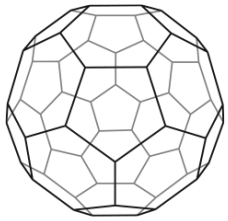
.....

[2]

[Total: 13]

09. 0620_w14_qp_33 Q: 3

In 1985 the fullerenes were discovered. They are solid forms of the element carbon. The structure of the C_{60} fullerene is given below.



(a) (i) In the C_{60} fullerene, how many other carbon atoms is each carbon atom bonded to?

..... [1]

(ii) Another fullerene has a relative molecular mass of 840.
How many carbon atoms are there in one molecule of this fullerene?

..... [1]

(b) Fullerenes are soluble in liquid hydrocarbons such as octane. The other solid forms of carbon are insoluble.
Describe how you could obtain crystals of fullerenes from soot which is a mixture of fullerenes and other solid forms of carbon.

.....

.....

.....

..... [3]

(c) A mixture of a fullerene and potassium is an excellent conductor of electricity.

(i) Which other form of solid carbon is a good conductor of electricity?

..... [1]

(ii) Explain why metals, such as potassium, are good conductors of electricity.

.....

..... [2]

(iii) The mixture of fullerene and potassium has to be stored out of contact with air. There are substances in unpolluted air which will react with potassium.
Name **two** potassium compounds which could be formed when potassium is exposed to air.

..... [2]

[Total: 10]

10. 0620_w12_qp_33 Q: 1

For each of the following, select an element from Period 4, potassium to krypton, which matches the description.

(a) A metal that reacts rapidly with cold water to form a compound of the type $M(OH)_2$ and hydrogen.

..... [1]

(b) Its only oxidation state is 0. ..... [1]

(c) It has a macromolecular oxide, XO_2, which has similar physical properties to those of diamond.

..... [1]

(d) This is one of the metals alloyed with iron in stainless steel. ..... [1]

(e) It can be reduced to an ion of the type X^-. ..... [1]

(f) It can form a covalent hydride having the formula H_2X. ..... [1]

(g) Its soluble salts are blue and its oxide is black. ..... [1]

(h) It is a liquid at room temperature. ..... [1]

[Total: 8]

01. 0620_w21_ms_41 Q: 2

Question	Answer	Marks
(a)(i)	isotopes	1
(a)(ii)	1 mark for each correct row ^{63}Cu / $^{65}Cu^{2+}$ p: 29 / 29 n: 34 / 36 e: 29 / 27	3
(a)(iii)	**M1** = (70 × 63) + (30 × 65) or [(4410) + (1950)] or 6360 (1) **M2** = M1 / 100 = 63.6 (1) OR **M1**= (0.7(0) × 63) + (0.3(0) × 65) or [(44.1(0)) + (19.5(0))] (1) **M2** = 63.6 (1)	2

Question	Answer	Marks
(b)(i)	**M1** white (1) **M2** to (light) blue (1)	2
(b)(ii)	$5H_2O$	1
(b)(iii)	heating	1
(b)(iv)	**M1** boiling point (1) **M2** is 100 °C OR **M1** freezing point (1) **M2** is 0 °C (1)	2
(c)(i)	blue precipitate	1
(c)(ii)	Alternative suggestion: **M1** $Cu(OH)_2$ (as only product) (1) **M2** Cu^{2+} and $2OH^-$ (as reactants) (1) **M3** state symbols (1)	3
(d)	**M1** 188 **M2** 4.7 / 188 = 0.025(0) **M3** 0.025(0) × 2 = 0.05(0) **M4** 0.05(0) × 24.0 = 1.2	4
(e)	$2NaNO_3 \rightarrow 2NaNO_2 + O_2$ $NaNO_2$ (1) rest of equation (1)	2

02. 0620_s18_ms_43 Q: 3

(a)	any **one** from: conduct electricity conduct heat malleable ductile shiny	**1**
(b)(i)	any **one** from: melting point hardness strength density	**1**
(b)(ii)	(cobalt) high(er) / (cobalt) strong(er)	**1**

(c)	any **two** from: potassium melts / potassium forms a ball fizzes / bubbles potassium moves (lilac) flame	**2**
(d)(i)	test: lighted splint / flame result: (squeaky) pop	**2**
(d)(ii)	any **one** from: increase surface area (of cobalt) powder the metal add a catalyst	**1**
(d)(iii)	(particles) have more energy / (particles) move faster	**1**
	more collisions per second / greater collision rate	**1**
	more of the colliding molecules have sufficient energy (activation energy) to react	**1**
(e)(i)	becomes pink / becomes purple	**1**
	equilibrium moves right	**1**
(e)(ii)	(forward reaction is) exothermic	**1**
(f)	3+	**1**

03. 0620_w18_ms_42 Q: 1

(a)(i)	M1 Melting M2 Condensing M3 Freezing M4 Sublimation	**4**
(a)(ii)	No new substances are made **or** The change can be reversed (by a physical process)	**1**
(a)(iii)	Boiling happens at a specific temperature **or** Evaporation happens over a range of temperatures	**1**
(b)	M1 Separation: Touching M2 Arrangement: Regular M3 Movement: Vibrate	**3**
(c)	$4X + O_2 \rightarrow 2X_2O$ M1 Species M2 Balance	**2**

04. 0620_s17_ms_43 Q: 3

(a)	regular arrangement / lattice of positive ions / magnesium ions / Mg^{2+} ions	1
	sea of electrons **OR** delocalised electrons	1
	attraction between (positive) ions and (delocalised / sea of) electrons	1
(b)	electrons	1
	move / flow (throughout / through the structure)	1
(c)	layers (of atoms or ions)	1
	layers / atoms / ions can slide / slip / glide (over each other) (without breaking the metallic bonds)	1
(d)(i)	magnesium shown as (2, 8) using crosses	1
	sulfide shown as (2, 8, 8), with the two gained electrons in the outer shell of sulfur shown as crosses and all other electrons on sulfur shown as dots	1
	magnesium ion charge as 2^+ **AND** sulfide charge as 2^-	1
(d)(ii)	melt / fused	1
	ions can move **OR** are mobile	1

05. 0620_w17_ms_41 Q: 3

(a)(i)	brown / orange solid (forms / is made) **OR** solution becomes paler / colourless	1
(a)(ii)	magnesium is oxidised **AND** copper ions are reduced **OR** magnesium loses electrons **AND** copper ions gain electrons **OR** magnesium increases in oxidation number **AND** copper decreases in oxidation number	1
(a)(iii)	Cu^{2+} **OR** copper(II) ions **OR** copper ions	1
	gains electrons	1
(a)(iv)	$3Mg + Fe_2O_3 \rightarrow 3MgO + 2Fe$ **M1** Fe_2O_3 **AND** MgO **M2** fully correct	2
(b)(i)	prevents air / oxygen **AND** water from reaching the steel	1
(b)(ii)	magnesium is more reactive than iron / steel	1
	the magnesium corrodes (before the iron / steel) **OR** the magnesium corrodes preferentially	1
(b)(iii)	copper is less reactive than iron / steel	1

06. 0620_s16_ms_42 Q: 3

(a)(i)	**M1** positive ions / cations (labelled or named in text); **M2** electrons (labelled or named in text); **M3** attraction between positive and negative;	3 1 1 1
(a)(ii)	(conduction due to) movement of electrons / mobile electrons;	1
(b)	$GaCl_3$; $Ga_2(SO_4)_3$;	2 1 1
(c)(i)	$Ga_2O_3 + 6HNO_3 \rightarrow 2Ga(NO_3)_3 + 3H_2O$ formula of $Ga(NO_3)_3$; all formulae and balancing correct;	2
(c)(ii)	$Ga_2O_3 + 2NaOH \rightarrow Na_2Ga_2O_4 + H_2O$; formula of $Na_2Ga_2O_4$; all formulae and balancing correct;	2

(d)	any 2 from: • (do not) corrode; • strong; • hard; • (improved) appearance;	2

07. 0620_w16_ms_42 Q: 4

(a)	*copper(II) carbonate* fizzes / bubbles / effervescence dissolves / disappears *copper(II) oxide* dissolves / disappears blue (solution formed)	**2** **2**
(b)(i)	 $Cu(NO_3)_2$ 3Cu **AND** $3Cu(NO_3)_2$	**2**
(b)(ii)	hydrogen (gas) is not produced (when copper reacts with nitric acid)	**1**

08. 0620_w14_ms_32 Q: 4

(a) M1 brass [1]

M2 copper **COND** on M1 [1]

(b) (i) $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ [2]
species (1) balancing (1)

(ii) Manufacture of sulfuric acid
or bleach or making wood pulp or making paper
or food or fruit juice or wine preservative
or fumigant or sterilising [1]

(c) (i) sulfuric acid [1]

(c) (ii) $Zn^{2+} + 2e \rightarrow Zn$ [1]

oxygen or water Allow O_2 and H_2O if no name seen [1]

sulfuric acid [1]
Allow: H_2SO_4 if no name seen

(d) (i) from zinc to carbon
(clockwise direction on or near the wire) [1]

(ii) to allow ions to flow [1]

(iii) oxidation
and loss of electron(s) or increase in oxidation number/state [1]

reduction
and decrease in oxidation number/state or gain of electron(s) [1]

[Total: 13]

09. 0620_w14_ms_33 Q: 3

(a) (i) 3 [1]

(ii) 70 [1]

(b) Add octane (or other liquid hydrocarbon) (to soot) [1]

COND(on addition of **any** solvent) filter (to remove insoluble forms of carbon) [1]

(allow to) evaporate **or** heat **or** warm **or** leave in sun(to get crystals of fullerene) [1]

(c) (i) graphite [1]

(ii) delocalised electrons/free electrons/sea of electrons [1]

COND (on electrons) move/mobile/electrons flow [1]

(iii) Any **two** from: [2]
potassium oxide
potassium hydroxide
potassium carbonate
potassium hydrogencarbonate (bicarbonate)

[Total: 10]

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10. 0620_w12_ms_33 Q: 1

(a) Ca / calcium; [1]

(b) Kr / krypton; [1]

(c) Ge / germanium; [1]

(d) Ni / nickel **or** Cr / chromium; [1]

(e) Br / bromine / Br_2; [1]

(f) Se / selenium; [1]

(g) Cu / copper; [1]

(h) Br / bromine / Br_2; [1]

[Total: 8]
