ST PAUL'S SCHOOL
JUNIOR SCHOLARSHIP EXAMINATION

MAY 2016

CHEMISTRY

Answer the questions in the spaces provided.

Name...

Question 1

A space scientist was analysing an unknown sample of rock and the sample was found to contain four metallic elements which the scientist labelled as **metals A**, **B**, **C** and **D**.

Mass spectrometry analysis showed that the four metals present were **magnesium, copper, zinc and iron** (in no particular order).

A series of experiments was conducted on the four metals in order to rank them in terms of reactivity and determine their identity. The results of these experiments are outlined below:

- Reaction 1:
  Four test tubes half-full of **dilute nitric acid** were measured out.
  Metals B, **C** and **D** all reacted with the **dilute nitric acid** and fizzing was seen. **Metal A** did not.
- Reaction 2:
  The **oxides** of **metals B** and **C** were ***reduced*** when ***roasted with carbon*** but the **oxide** of **metal D** was unaffected.
- Reaction 3:
  Metal C was heated up with the **oxide** of **metal B** but no reaction was observed.

(a) What can be deduced about the reactivity order of the metals following **Reaction 1**?

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[1 mark]

(b) What can be deduced about the reactivity order of the metals following **Reaction 2**?

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[1 mark]

(c) Given that **Reaction 3** shows **metal B** to be more reactive than **metal C**, complete the table below in order to rank the metals in order of their reactivity and match them to the correct element (magnesium, copper, zinc or iron) based on your knowledge of the reactivity series.

	Letter of Metal	**Name of Metal**
Most Reactive		
Least Reactive		

[2 marks]

(d) Using your answer in the table of part (c) write a ***word equation*** for the reaction of **metal D** in **Reaction 1**.

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[1 mark]

(e) Using your answer in the table of part (c) write a ***word equation*** for the reaction of the **oxide of metal B** in **Reaction 2**.

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[1 mark]

(f) **Reaction 2** is an example of a ***redox reaction***. Define the term redox reaction.

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[1 mark]

TURN OVER

(g) **Reaction 2** could also be carried out with **methane gas** being passed over the heated metal oxides instead of roasting with carbon but this only works well for the **oxide of metal A**.
Methane gas is a hydrocarbon molecule containing only the elements carbon and hydrogen.
This is also a redox process.
Write a ***word equation*** for the reaction of **methane gas** with the **oxide of metal A** in **Reaction 2**.

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[1 mark]

Many of the metals that we use every day are obtained from metal ores, usually in the form of metal oxides and metal carbonates. If we wish to obtain the metal itself then a process of extracting the metal from its ore needs to take place. Generally we consider a metal ore to be an abundance of rock that contains enough of a particular metal to make extraction commercially viable.

The metallic elements of gold and silver can be found ‘native’. This means that they are not found combined with other elements: they exist in their elemental form rather than in compounds.

(h) Given that there is no need for extraction from a metal ore since these metals are found ‘native’, explain why the cost of gold and silver often far exceeds that of other metals.

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[1 mark]

[Total for Question 1: 9 marks]

Question 2

A simple definition of a salt is a substance in which the hydrogen atoms of an acid are replaced by either metal atoms or an ammonium group.

Most commonly salts are made using the reactions of acids with either bases or alkalis (soluble bases).

The salt sodium chloride may be made by the reaction of the alkali sodium hydroxide with an acid.

(a) Write a ***word equation*** for the formation of sodium chloride as described above. You will need to identify the correct acid that is required for this reaction.

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[2 marks]

Crystals of the salt copper (II) sulfate may be prepared by reaction of sulfuric acid with an appropriate copper-containing base such as *insoluble* copper (II) carbonate.

(b) Write a ***word equation*** for the reaction described above.

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[1 mark]

(c) Suggest the identity of an alternative *insoluble* copper-containing base that could be used to prepare the copper (II) sulfate crystals.

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[1 mark]

TURN OVER

When *insoluble* copper (II) carbonate is used to prepare the copper (II) sulfate crystals the following outline method was given to a student to follow:

1. *Place 100cm^3 of sulfuric acid into a large beaker and warm gently*
2. *Add an excess of insoluble copper (II) carbonate (the base) to the acid with gentle stirring*
3. *Separate the product copper (II) sulfate solution from the excess base*
4. *Transfer the copper (II) sulfate solution to an evaporating basin*
5. *Heat the basin to reduce the volume of the solution by half*
6. *Leave the remaining solution to crystallise forming hydrated copper (II) sulfate crystals*

(d) Suggest why the acid was warmed up in the first step.

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[1 mark]

(e) Suggest why an ***excess*** of the base was added in step 2.

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[1 mark]

(f) What ***physical method*** would be used to achieve step 3?

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[1 mark]

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In the final step, the concentrated solution of copper (II) sulfate is left to slowly crystallise.

During this process much of the water evaporates to the surroundings but some water molecules become incorporated within the crystalline structure of the salt thus making it a *hydrated salt*. These water molecules are called the *water of crystallisation*.

When hydrated copper (II) sulfate crystals are gently heated the water of crystallisation is removed leaving an anhydrous salt. The word equation for this process is shown below:

Hydrated copper (II) sulfate → anhydrous copper (II) sulfate + water

As water is lost from the salt its mass decreases. In a series of experiments the mass of hydrated crystals was varied and the final mass was measured following a period of heating. In each experiment all of the water is lost from the hydrated salt leaving only the anhydrous crystals of copper (II) sulfate. The mass of water lost can also be calculated and the results are shown below:

Experiment	Starting mass of hydrated copper (II) sulfate crystals / g	Mass of anhydrous copper (II) sulfate crystals after heating / g	Mass of water lost / g
1	0.250	0.160	0.090
2	0.450	0.288	0.162
3	0.600	0.384	0.216
4	0.740	**x**	Not recorded
5	**y**	0.610	Not recorded
6	1.150	0.736	0.414

Note: the mass of water lost in both experiments 4 and 5 has deliberately not been recorded.

(g) Given that all the water is removed from the hydrated salts in each of the experiments deduce the values of **x** and **y** in **experiments 4** and **5**.
You will need to use the data from other experiments. Show your workings.

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x = ……………………………g **y =** …..……..………………g

[3 marks]

In a seventh experiment the student decided to heat the hydrated salt on a **roaring blue Bunsen flame**. The student was told that this experiment must be conducted in a fume cupboard since elevated temperatures lead to the decomposition of anhydrous copper (II) sulfate, which releases fumes of toxic *sulfur trioxide gas* and leaves black copper (II) oxide. The copper (II) oxide undergoes no further decomposition. The results of this experiment are shown below:

Experiment	Starting mass of hydrated copper (II) sulfate crystals before heating / g	Final mass of ***boiling tube contents*** after heating on a roaring Bunsen flame / g	Mass of water lost / g
7	2.000	**z** = 1.160	0.720

(h) Explain why the value shown above for **z -** the final mass of the boiling tube contents after heating on a roaring Bunsen flame, is lower than the student had calculated based upon the previous experiments.

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[1 mark]

TURN OVER

A safer way of conducting **experiment 7** away from the fume cupboard would be to allow any gases produced to bubble into a beaker of water. This method was followed and the beaker of water was then tested following prolonged heating on a roaring Bunsen flame.

(i) Universal indicator was added to the beaker. Given that the sulphur trioxide reacts fully with the water predict and explain the colour you would expect to see in the beaker following the addition of the universal indicator.

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[2 marks]

(j) A small lump of calcium (a reactive metal) was added to the same beaker. Initially fizzing was observed but then the fizzing subsided a short time later and appeared to completely stop. Identify which gas was responsible for the initial fizzing in this reaction.

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[1 mark]

(k) The reaction soon stopped fizzing despite the calcium lump still being present within the beaker. Given that calcium metal would also react rapidly with water in a reaction that also produces fizzing, suggest a sensible reason why the reaction appeared to stop.
(**Hint** – you should consider the calcium-containing product of the reaction in part (j)).

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[2 marks]

[Total for Question 2: 16 marks]

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