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VCE Chemistry ½
Metal Reactions & Recycling [1.4]
Homework Solutions

Homework Outline:

Section A: Compulsory Questions (43 Marks)

Sub-Section: Write Balanced Equations for the Reactions Between a Metal and Oxygen and Between a Metal and Water, and Explain any Relevant Implications of These Reactions

Question 1 (4 marks)

For the following metals, write their reaction with oxygen in the air to form their respective metal oxides.

a. Ca. (1 mark)

$2Ca(s) + O_2(g) \rightarrow 2CaO(s)$

b. Na. (1 mark)

$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

c. Cu. (1 mark)

$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

d. Li. (1 mark)

$4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

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Question 2 (4 marks)

For the following metals, write their reactions with water.

a. Rubidium. (1 mark)

$2Rb(s) + H_2O(l) \rightarrow Rb_2O(s) + H_2(g)$

b. Zinc. (1 mark)

$Zn(s) + H_2O(l) \rightarrow ZnO(s) + H_2(g)$

c. Aluminium. (1 mark)

$2Al(s) + 3H_2O(l) \rightarrow Al_2O_3(s) + 3H_2(g)$

d. Iron(II). (1 mark)

$Fe(s) + H_2O(l) \rightarrow FeO(s) + H_2(g)$

Question 3 (4 marks)

Consider the metal of magnesium.

a. Write the reaction that happens when magnesium strips are exposed to oxygen in the air. (1 mark)

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

b. Now, write the reaction which occurs between magnesium and water. (1 mark)

$Mg(s) + H_2O(l) \rightarrow MgO + H_2(g)$

c. Explain a method to prevent magnesium strips from reacting spontaneously with oxygen in the air. (2 marks)

Submerging it in oil to prevent the magnesium strip from coming into contact with the air.

Sub-Section: Apply Trends in the Periodic Table to Metal Reactivity

Question 4 (2 marks)

Briefly state and explain what happens to the reactivity of metals down a group.

Metals become more reactive as the first ionisation energy of the element decreases, making it easier to lose its electrons and hence, react.

Question 5 (3 marks)

Explain which metal is most likely to react out of magnesium, calcium and sodium.

Calcium is the most likely to react since it has an extra electron shell compared to magnesium and sodium. Therefore, even though sodium has one valence electron, it still is less reactive than Calcium because Ca's first ionisation energy is lower than that of the other two, making it the easiest to lose an electron and hence, react.

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Question 6 (7 marks)

a. Explain whether potassium or lithium has a higher melting point. (2 marks)

Lithium will have a higher melting point because it has less electron shells than potassium as both contain a +1 charge. Therefore, the lithium will have stronger electrostatic attraction due to being closer to the delocalised electrons, hence it requires more thermal energy to weaken and hence, Lithium will have a higher melting point.

b. Explain whether potassium or lithium is more reactive as a metal. (2 marks)

As potassium is further from the valence electrons it is easier to remove electrons from itself and hence react, therefore, potassium is more reactive.

c. Hence, do you think the reactivity of metals is fundamentally the same as the boiling or melting point of a metal? Justify your answer. (3 marks)

Reactivity of metals is similar in terms of trends when compared to the melting point and boiling point, however, the more reactive a metal is, typically it has a lower MP/BP suggesting an inverse proportionality, but the justification for them involves similar properties such as strength of bonding.

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Sub-Section: Explain how Metals are Obtained and Recycled, and their associated Advantages and Disadvantages

Question 7 (2 marks)

State an environmental disadvantage with mining metal and how it affects the environment.

An environmental disadvantage would be the destruction of habitats, and it would cause damage to the wildlife and force them to be destroyed or relocated.

Question 8 (3 marks)

In a phone, is it possible to extract all amounts of metals from it while recycling it? Justify your answer.

No, it is not because phones have small electronic components made of many different metals, and thus, it is difficult to remove them and also separate them into each type of metal due to the miniscule amounts in which they exist inside phones.

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Question 9 (4 marks)

Metal recycling is an increasingly important aspect of the economy because the number of metals on Earth is finite.

a. Explain the difference between a linear and circular economy. (2 marks)

The main difference between them is that a linear economy does not consider the usage of existing materials via recycling, but a circular economy does.

b. Explain whether recycling iron or aluminium would save more energy. (2 marks)

Aluminium has a +3 charge where iron would have a +2 charge, this means that aluminium is more stable due to its higher charge and hence, stronger electrostatic attraction. Therefore, iron is more reactive than aluminium, and it will save more energy when recycling iron compared to aluminium.

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Sub-Section: Final Boss

Question 10 (10 marks)

You are part of a research team working for a sustainable engineering company. Your current project involves designing efficient, and eco-friendly materials for usage in shipbuilding and electronics recycling.

a. Ships are often constructed with steel, a material comprised of iron, aluminium among other metals. Write the most likely equation where iron reacts with water. (1 mark)

$Fe(s) + H_2O(l) \rightarrow FeO(s) + H_2(g)$

b. A common method of protecting ship hulls from rusting or reacting with oxygen is by 'sacrificing' another metal such as magnesium by connecting it to the iron hull or placing it on top of the iron hull instead. Explain why this works. (3 marks)

Magnesium is more reactive than iron due to its lower first ionisation energy. It will hence react with water first and form a layer around the iron that is already reacted, preventing the iron inside from reacting any further.

c. Suggest another method we can deploy to protect the ship's hull. (1 mark)

Coating it with water resistant paint.

d. Inside of the ship, certain materials are meant to be chosen as well.

i. Should magnesium or copper be used to make electrical wires? (2 marks)

Copper as it is less reactive as Mg is a group 2 metal. Hence, copper would last longer during its lifetime as a wire as well as handle the charge better as well because it has a lower risk of reacting even though both can ionise to 2 + and have similar charges (hence electrostatic attraction levels). Copper is also more durable than magnesium as group 2 metals are known to be softer than transition metals.

ii. For decorations and ornaments, the shipbuilder would like to recycle parts of old ships rather than ordering new blocks of metal. Explain whether this is a good decision. (3 marks)

This is a good decision as in this way the company will save a lot of energy and hence money because pure metals are required to be extracted from raw ore, which costs a lot of money due to high temperatures. Whereas, recycling old parts costs them nothing other than the cost of reshaping the old metals into the new desired shapes which occurs at a lower temperature than ore extraction anyway.

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Section B: Supplementary Questions (53 Marks)

Sub-Section: Write Balanced Equations for the Reactions Between a Metal and Oxygen and Between a Metal and Water, and Explain Any Relevant Implications of These Reactions

Question 11 (4 marks)

For the following metals, write their reaction with air.

a. Copper ionising with a 2 + charge. (1 mark)

$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$

b. Cobalt ionising with a 2 + charge. (1 mark)

$2Co(s) + O_2(g) \rightarrow 2CoO(s)$

c. Tin ionising with a 4 + charge. (1 mark)

$Sn(s) + O_2(g) \rightarrow SnO_2(s)$

d. Potassium. (1 mark)

$4K(s) + O_2(g) \rightarrow 2K_2O(g)$

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Question 12 (2 marks)

Write the equation for the reactions that occur when the following metals are dipped into a tub of water.

a. Barium. (1 mark)

$Ba(s) + 2H_2O(l) \rightarrow Ba(OH)_2(s) + H_2(g)$

b. Calcium. (1 mark)

$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g)$

Question 13 (4 marks)

a. Write the reaction that occurs when aluminium reacts with oxygen in air. (1 mark)

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

b. Now, write the reaction that takes place when aluminium reacts with water. (1 mark)

$2Al(s) + 6H_2O(l) \rightarrow 2Al(OH)_3 + 3H_2(g)$

c. Pure aluminium is often painted over with a plastic coating to help preserve the condition of the aluminium for longer. Explain this observation. (2 marks)

This is due to the plastic coating that will help the aluminium not be in contact with the oxygen in the air, preventing it from reacting and forming aluminium oxide.

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Question 14 (7 marks)

Shipbuilding is an important area where looking at preventing metals from reacting is really important.

a. Write the reaction that would occur between iron and water, assuming that the iron will form an ion with 3 + charge. (1 mark)

$2Fe(s) + 6H_2O(l) \rightarrow 2Fe(OH)_3(s) + 3H_2(g)$

b. Explain how forming a layer of iron oxide on the outside of a piece of iron would help it from reacting any further. (2 marks)

As the outside layer is now covered in iron oxide the inner layers won't be exposed to the oxygen in the air because it's a solid piece of metal, this means that the oxygen would only come into contact with the already-reacted surfaces of iron and not the inner parts.

c. What would happen if we took the piece of iron as observed in **part b.** and sliced it in half? (2 marks)

If we sliced the piece of iron in half, the pure parts would be seen and exposed in the air and hence, the pure parts will start to react with oxygen in the air to form iron oxide.

d. If the engine of a ship is situated near the bottom of a ship, would the iron hull of a ship face greater risk if it came into contact with oxygen in the air or water? Justify your answer. (2 marks)

It would be more dangerous to have the pure iron come into contact with water as a byproduct is hydrogen gas which is highly flammable and can explode due to its proximity to the engine which operates at high temperatures and contains fuel too.

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Sub-Section: Apply Trends in the Periodic Table to Metal Reactivity

Question 15 (4 marks)

For the following pairs of metals, state which is more reactive.

a. Sr and Be. (1 mark)

Sr

b. Li and Na. (1 mark)

Na

c. Al and Mg. (1 mark)

Mg

d. Ni and Fe. (1 mark)

Fe

Question 16 (3 marks)

Between sodium and lithium, which one requires more energy to extract?

As sodium is more reactive than lithium due to having an extra electron shell and hence lower first ionisation energy, this means that it is harder to separate the metal into its pure form because it does not form naturally and is hard to maintain in its pure form once attained.

Question 17 (5 marks)

Consider precious metals like gold and silver.

a. It's a common saying that you can shower with pure gold and silver jewellery on. Use your knowledge of chemistry to explain this phenomenon. (3 marks)

Gold and silver are most likely unreactive metals and as such they will not react to water as easily as other metals like iron.

b. Given the properties of expensive metals, what form do you suggest that they are found naturally as? (2 marks)

Gold and silver are most likely found in their pure form as they are unreactive and hence stable, they won't react easily to air or water.

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Question 18 (6 marks)

You are tasked with experimentally determining the reactivities of four metals: Mg, Cu, Zn, and K.

a. Predict the order of reactivity for the four metals based on their positions in the periodic table. (2 marks)

Most reactive: Potassium > Magnesium > Zinc > Copper (least reactive)

b. How would you go about experimenting to confirm the order that you have determined in **part a.**? (2 marks)

Place small pieces of each metal into separate test tubes and then pour equal amounts of water into them and observe which one reacts the fastest.

c. Hence, which metal would you recommend to a client that is looking to make something into a frying pan for use in a restaurant? (2 marks)

Copper because it is generally the most unreactive out of all the metals provided. As such it would last the longest out of them and not react with water as frying pans are subject to contact with hot air and water quite often, so looking for something that doesn't react is valuable. In addition, all metals are quite good heat conductors and copper also has that property.

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Sub-Section: Explain How Metals are Obtained and Recycled, and Their Associated Advantages and Disadvantages

Question 19 (2 marks)

Why are groups 1 & 2 metals not used in the industry?

These metals are too reactive and unstable due to having 1 or 2 valence electrons and thus, are not stable enough to be used as substances fit for recycling.

Question 20 (3 marks)

Not all metals are recycled in industry. For example, a lot of phones are disposed of rather than being recycled for their precious metals. Suggest a possible reason for this phenomenon.

Some wastage has small amounts of many different metals, and thus, it is difficult and uneconomic to recover all of these metals which are only present in small amounts.

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Question 21 (5 marks)

a. Explain why extracting metals from ores requires more energy compared to recycling metals instead. (3 marks)

Extracting metals from ores requires breaking strong chemical bonds in their natural forms as oxides, which demands high temperatures and large amounts of energy to maintain this state. Hence, it would use up a lot of energy especially for industrial amounts of metal. Recycling bypasses this process, as we are using metals that are already in their "pure" form, we spend energy trying to reshape them into the specific usages that we would like, which takes much less energy since that can be done at lower temperatures.

b. Discuss a disadvantage associated with metal recycling. (2 marks)

A disadvantage associated with metal recycling is that if something that is being recycled has many different parts to it with different metals and other non-metal materials like plastic, it can be energy intensive to sort them correctly and may not be economically feasible to do on a large scale. An example of this would be recycling smart phones for precious metals.

Question 22 (8 marks)

Obtaining metals from natural resources is a process that's important to obtain metals in their pure form.

a. Evaluate the energy usage involved in obtaining pure metals from its ore form. (2 marks)

A lot of energy is used because the metal ores need to be smelted in order for the pure form to be extracted, and this process operates at high temperatures which is energy intensive.

b. Consider an iron ore.

i. Explain why iron exists as an oxide form most of the time naturally as Fe_2O_3 for example. (2 marks)

This is because pure iron may not be stable on its own due to it losing electrons easily as it has a $4s^2$ subshell, and hence it reacts with something that is abundant in its surroundings such as oxygen in the air in order for it to fulfil the octet rule and become stable.

ii. Write the reaction that occurs with pure iron and oxygen in air, where the iron ionises to have a $2+$ charge. (1 mark)

$$2Fe(s) + O_2(g) \rightarrow 2FeO(s)$$

c. Consider iron and copper, where copper is known to be more reactive than iron. Explain which one will save more energy if we recycle that metal. (3 marks)

Since copper is more reactive, it will require more energy to extract to its pure form than iron would. Hence, it will save more energy if we recycled more copper since it doesn't require as much energy since we are just reshaping already existing pure copper rather than extracting copper ore from the ground and then extracting its pure form.

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