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# VCE Chemistry ½

## Metal Reactions & Recycling [0.3]

## Workshop

# Section A: Recap

## Learning Objective: [1.4.1] – 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

- Metals **[gain] / [lose]** electrons when reacting to gain a full outer shell.
- The general formula for metals reacting in the air is: Metal (s) + $O_2(g)$ → metal oxide
- Outside of metal turns into metal oxide, which is **[shiny] / [dull].**
- Inside **[has] / [has no]** contact with oxygen, and so remains as the pure, lustrous metal.
- When sliced, the metal on the inside is **[shiny] / [dull]**, as it is now exposed to oxygen, it converts to oxide form and becomes dull.
- The general formula for metals reacting in water is: Metal (s) + Water (l) → metal hydroxide ($OH^-$) + $H_2(g)$.
- This produces hydrogen gas, which is flammable and hence can cause an explosion.

## Learning Objective: [1.4.2] – Apply Trends in the Periodic Table to Metal Reactivity

- Metal reactivity is directly correlated with metallic character and first ionisation energy.
- Metal reactivity **[increases] / [decreases]** down a group, but **[increases] / [decreases]** across a period.
- Expensive metals are **[reactive] / [unreactive]** and exist in the usual shiny metallic form.
- To prevent reactive metals from reacting with oxygen in the air, they are usually stored in oil → Ar.

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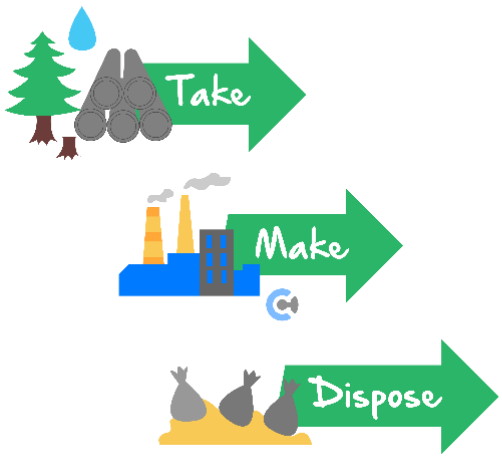
Learning Objective: [1.4.3] – Explain How Metals are Obtained and Recycled, and Their Associated Advantages and Disadvantages

- Metals are typically found in their stable, **[atomic] / [ionic]** form.
- After metal ore is extracted, the pure metal is obtained by heating at high temperatures with carbon, which is a process called smelting.
- The mining process uses land that needs to be cleared by deforestation which can lead to habitat destruction
- The smelting and electrolysis processes to extract the pure metal from the ground uses large amounts of energy.
- This use of energy is typically provided by [renewable] / [fossil] fuels which leads to more greenhouse gases emissions. (coal)
- Label the 2 types of economies below:

linear economy




circular economy


- The more reactive a metal, the **[more] / [less]** energy it requires to extract the metal and store it safely.
- Group 1 and Group 2 metals generally **[are] / [are not]** used to construct things, as they are too reactive and dangerous, thus are generally not recycled due to low use.
- Metal recycling uses scrap metal, which is first collected and shredded
- It is then classified into ferrous and non-ferrous groups, before being smelting, and finally, purification

## Section B: Warm Up (14 Marks)

INSTRUCTION: 14 Marks. 8 Minutes Writing.

**Question 1** (0.5 marks)

What is the main difference between a linear and circular economy?

The product life cycle of:

**A.** Both a linear and circular economy is an open cycle.

**B.** A linear economy is open, but a circular economy is a closed cycle.

**Question 2** (0.5 marks)

Sustainable development is characterised by a:

**A.** Linear economy product life cycle.

**B.** Circular economy product life cycle.

**Question 3** (0.5 marks)

Which of the following is an example of a sustainable product?

**A.** Glass milk bottle.

**B.** Single-use plastic bag.

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**Question 4** (0.5 marks)

Complete the word equation:

**Metal + Oxygen →** _____

**A.** Hydrogen

**B.** Metal hydroxide + hydrogen

**C.** Metal chloride + water

**D.** Metal oxide

**E.** Metal oxide + hydrogen

**Question 5** (3 marks)

$Mg^{2+}$ $O^{2-}$

Write the reaction which occurs when the following metals are exposed to oxygen in air.

**a.** Magnesium metal. (1 mark)

$Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

2 1 2

$Li^+$ $O^{2-}$

**b.** Lithium metal. (1 mark)

$2Li(s) + \frac{1}{2}O_2(g) \rightarrow Li_2O(s)$

**c.** Aluminium metal. (1 mark)

$Al(s) + O_2(g) \rightarrow Al_2O_3(s)$

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**Question 6** (2 marks)

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

**a.** Barium. (1 mark)

$Ba^{2+}$ $OH^-$

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

**b.** Aluminium. (1 mark)

$Al^{3+}$ $OH^-$

$Al(s) + 3H_2O(l) \rightarrow Al(OH)_3(aq) + \frac{3}{2}H_2(g)$

**Question 7** (7 marks)

Aluminium Recycling Process:

**a.** Steps: List the main steps in the recycling process of aluminium. (2 marks)

- collect scrap Al
- shred
- classify into non-ferrous
- smelt
- purify

**b.** Energy Savings: What percentage of energy is saved by recycling aluminium compared to its production from bauxite? (1 mark)

95%.

ore

**c.** Environmental Benefits: Name two environmental benefits of recycling aluminium. (2 marks)

- Energy efficient → less fossil fuel use → less green house gas emission
- less land clearance → bad for habitat loss

**d.** Circular Economy: Explain how aluminium recycling exemplifies a circular economy. (2 marks)

- Circular economy → use, reuse & recycle to minimum waste
- in Al recycle → reuse & recollect to prevent more mining.

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## Section C: Ramping Up (9 Marks)

**INSTRUCTION:** 9 Marks. 6.5 Minutes Writing.

**Question 8** (1 mark)

Which of these shows the **change** to the electronic configuration of potassium (K = 19 electrons: 2,8,8,1) as it reacts with oxygen?

**A.** K(2,8,8,1) → K(2,8,8,3)

**B.** K(2,8,8,1) → K(2,8,8,2)

**C.** K(2,8,8,1) → K(2,8,8,1)

**D.** K(2,8,8,1) → K(2,8,8)

**E.** K(2,8,8,1) → K(2,8,7)

**Question 9** (5 marks)

**a.** 2 Ba + 1 $O_2$ → 2 BaO. (0.5 marks)

**b.** _____Cu + 1/2 $O_2$ → _____CuO. (0.5 marks)

**c.** 2 Na + 1/2 $O_2$ → _____$Na_2O$. (0.5 marks)

**d.** 2 K + 1/2 $O_2$ → _____$K_2O$. (0.5 marks)

**e.** 2 Al + 3/2 $O_2$ → _____$Al_2O_3$. (0.5 marks)

**f.** 2 Fe + 3/2 $O_2$ → _____$Fe_2O_3$. (0.5 marks)

**g.** _____Ba + 2 $H_2O$ → _____$Ba(OH)_2$ + _____$H_2$. (0.5 marks)

**h.** _____Ni + 2 $H_2O$ → _____$Ni(OH)_2$ + _____$H_2$. (0.5 marks)

**i.** 1 Na + 1 $H_2O$ → 1 NaOH + 1/2 $H_2$. (0.5 marks)

**j.** 1 K + 1 $H_2O$ → 1 KOH + 1/2 $H_2$. (0.5 marks)

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**Question 10** (3 marks)

Explain which metal is most likely to react out of aluminium, zinc, and potassium.

- K → most reactive
- K has the lowest core charge (+1) → easiest to remove $e^-$
- K ↑ atomic radius → ↓ core charge ↑ further down the group ∴ electrons less attracted to nucleus → easier to remove.

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## Section D: Getting Trickier I (17 Marks)

INSTRUCTION: 17 Marks. 20 Minutes Writing.

**Question 11** (1 mark)

Which of these is the correct symbol equation for the reaction of group 2 element strontium with oxygen?

**A.** $2Sr + O_2 \rightarrow SrO$

**B.** $2Sr + O_2 \rightarrow 2SrO$

**C.** $Sr + 2O_2 \rightarrow SrO$

**D.** $2Sr + 2O_2 \rightarrow 2SrO$

**E.** $Sr + O_2 \rightarrow 2SrO$

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**Question 12** (8 marks)

**a.** Define metallic bonding and explain how it contributes to the lustre and electrical conductivity of metals. (2 marks)

• metallic bonding defines metals as cations in a sea of delocalised e⁻.

• this allows for conductivity → electrons free to move

• this allows for lustre → e⁻ reflect light

**b.** Danny decides to compare iron and copper. Describe how metallic bonding explains their high melting points and malleability. (3 marks)

• metals have a high melting point due to electrostatic forces [strong] → act between cations & e⁻ in lattice.

• they are also malleable as the delocalised e⁻ allow electrostatic forces to maintain even when cation shift.

**c.** Describe the ductility of metals ~~with~~ compared to ionic compounds (such as salt) in terms of bonding and structure. (3 marks)

• metals → have a S.O.D.E → this allows cations to shift

• salts → brittle → loses S.O.D.E → forces that can not be maintained

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**Question 13** (8 marks)

**a.** Raw Material Extraction: Name the three primary metals used in stainless steel and the key environmental impact of extracting each. (2 marks)

_____

_____

_____

_____

**b.** Manufacturing Impact: What is a major environmental concern associated with the manufacturing process of stainless steel products? (2 marks)

_____

_____

_____

_____

**c.** Usage Phase: Explain the environmental benefit of using a stainless steel water bottle compared to a single-use plastic bottle. (2 marks)

_____

_____

_____

_____

**d.** End-of-Life: Describe the recycling process for stainless steel and its significance in reducing environmental impact. (2 marks)

_____

_____

_____

_____

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## Section E: Getting Trickier II (10 Marks)

INSTRUCTION: 10 Marks. 11.5 Minutes Writing.

*The following information applies to the two questions that follow.*

The following image shows a crane sorting out metal at a recycling centre. Dealing in scrap metal is a big business as the value of scrap metal continues to rise.

**Question 14** (1 mark)

What property allows certain metals containing iron, nickel or cobalt to be separated out in this way?

**A.** Electric

**B.** Density

**C.** Magnetic

**D.** Electrostatic

**Question 15** (1 mark)

Why does the cost of some scrap metals keep rising?

**A.** Due to an increased amount of recycling.

**B.** Production of pure metal has decreased.

**C.** Because mining the ore has become more expensive.

**D.** Greater competition from other companies.

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**Question 16** (8 marks)

When you heat a square piece of copper metal in a blue Bunsen burner flame, the copper turns black.

**a.** What has the copper reacted with? (1 mark)

Oxygen

**b.**

**i.** How has the mass of the Copper changed? Circle your answer. (1 mark)

Decreased Stayed the Same Increased

**ii.** Explain your answer to **b.i.** (1 mark)

Cu layer will be deposited on the surface.

**c.** When you scrape the surface of the copper with a metal spatula, it removes the black solid and you can see the original shiny, copper underneath.

**i.** Have all of the copper atoms reacted? (1 mark)

No →

**ii.** Why? (2 marks)

– only the surface copper reacts to form CuO

– the inside remains as pure Cu(s)

**iii.** How would this reaction be different if you used powdered Copper instead? (1 mark)

increase rate of reaction → CuO will form faster.

**d.** Why do copper atoms react with oxygen? (1 mark)

Cu is a metal → lose its 2 valence e⁻ → to be stable

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## Section F: VCAA-Level Questions I (14 Marks)

INSTRUCTION: 14 Marks. 1 Minute Reading. 17.5 Minutes Writing.

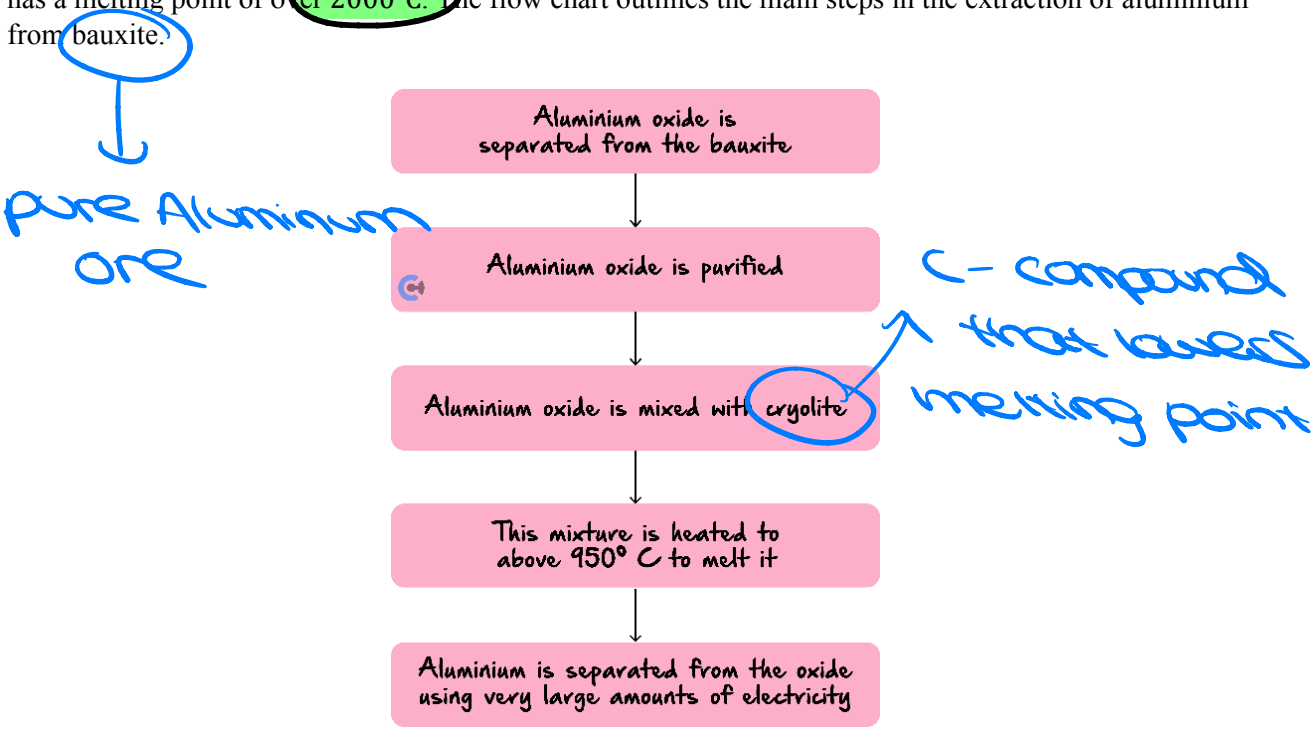
**Question 17** (14 marks)

Humans rely on metals to go about their everyday lives. Metals have different properties which determine how they are used in society.

**a.** Match up each of the metals listed with the relevant information in the table. (3 marks)

| | |
|---|---|
| **Copper** | Resistant to corrosion due to a strong oxide layer. |
| **Gold** | Most recycled element on Earth. |
| **Aluminium** | Reacts rapidly with water producing hydrogen gas. |
| **Iron** | Used in electrical wiring due to high conductance. |
| **Sodium** | Found in the Earth as a pure metal. |

**b.** Aluminium is extracted from an ore called bauxite which is impure aluminium oxide. Pure aluminium oxide has a melting point of over 2000°C. The flow chart outlines the main steps in the extraction of aluminium from bauxite.




Of the over 3 billion aluminium cans used annually in Australia around 55% are recycled.

When aluminium is recycled, the scrap aluminium melts at 700°C.

Using the information provided:

**i.** Suggest six reasons why most aluminium is recycled. Refer to three of your reasons for the extraction process and three reasons for the recycling process. (6 marks)

EXTRACTION (INC SMELTING)

- land degradation → land clearance
- high energy process → costly
- lots of greenhouse gas emission
- less safe, ↑ temp used

RECYCLING

- reduce waste → critical elements
- less energy (~75%)
- recycled Al is just as effective (retains value)

**ii.** Using the temperature values provided, explain how this process is designed for greater energy efficiency. (2 marks)

Recycling Al → done at 700°C

∴ we use less energy → less fossil

VS

Extracting Al → at 950°

↑ electricity → ↑ fossil fuels

**iii.** What additional steps could be taken to further improve the efficiency and sustainability of the processes making it more of a circular economy? (3 marks)

- make it products easier to recycle
→ use less paint → less plastic
- use renewable energy to facilitate recycle e.g (solar, hydro, wind)
- focus on developing a closed loop
→ incentive → make it easier

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## Section G: Multiple Choice Questions (13 Marks)

INSTRUCTION: 13 Marks. 13 Minutes Writing.

**Question 18** (1 mark)

When the group 1 metal **Lithium** is placed in a bowl of water it fizzes around and seems to "disappear". Why can't you see it after the reaction has happened?

**A.** It has disappeared.

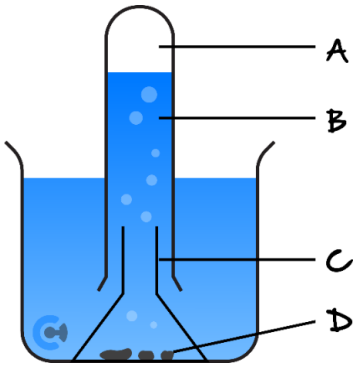
**B.** It has turned into a gas and mixed with air.

**C.** It has formed a soluble compound and dissolved.

**D.** It has become a clear liquid compound.

**Question 19** (1 mark)

Which label (A-D) shows where the gas collects as calcium reacts with water?




**A.** A

**B.** B

**C.** C

**D.** D

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**Question 20** (1 mark)

Which of the following materials should not be composed of metallic elements?

**A.** Gloves used by electricians to fix live wires.

**B.** Wires used in telephone communications.

**C.** Cooking pots.

**D.** Light bulb filaments.

**Question 21** (1 mark)

In a reaction between a strong acid and potassium metal, it is expected that we would:

**A.** Smell a fruity odour.

**B.** Observe bubbles.

**C.** Observe a change in the colour of the acid.

**D.** See no change.

**Question 22** (1 mark)

What type of economy is depicted by the image?


**A.** Linear

**B.** Financial

**C.** Circular

**D.** Chemical

**Question 23** (1 mark)

Which of the following metals is **least** likely to react with water at room temperature?

**A.** Magnesium

**B.** Rubidium

**C.** Copper

**D.** Beryllium

**Question 24** (1 mark)

Which of the following is not a possible mechanism for the formation of an alloy of two metals?

**A.** Atoms of one metal fit into the interstitial spaces between atoms of the other.

**B.** A new element is formed.

**C.** Atoms of one metal replace atoms of the other in the crystal lattice.

**D.** Separate crystals of one metal are dispersed throughout the other.

**Question 25** (1 mark)

Which element can be found in nature in elemental (uncombined) form?

**A.** K

**B.** Ca

**C.** Au

**D.** Al

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**Question 26** (1 mark)

Why does aluminium, a fairly reactive metal, not react with oxygen gas in the air?

**A.** It is protected by small amounts of its own impurities.

**B.** Its oxide forms a hard protective layer on the metal.

**C.** Nitrogen and carbon dioxide gas in the air prevent oxidation.

**D.** It forms a hard protective layer by a reaction with sulfur in the air.

**Question 27** (1 mark)

Why do iron rubbish bins coated with a complete layer of zinc, not rust?

**A.** The zinc acts as a sacrificial metal, reacting to prevent the iron from rusting.

**B.** Iron is a more reactive metal than zinc.

**C.** The zinc combines with the iron to form a new compound that does not rust.

**D.** Particles of rust are unable to stick to the zinc surface.

**Question 28** (1 mark)

Consider the following:

- Metal G slowly reacts with cold water.
- Metal H is generally shiny.
- Metal E readily reacts with oxygen.
- Metal F produces hydrogen when it reacts with acid.

What is their reactivity order, from the most to the least reactive?

**A.** H > G > F > E

**B.** H > E > F > G

**C.** F > H > G > E

**D.** E > G > F > H

**Question 29** (1 mark)

Which is formed by the reaction of zinc with hydrochloric acid?

**A.** Zinc hydroxide + Hydrogen

**B.** Zinc sulfate + Chlorine

**C.** Zinc chloride + Hydrogen

**D.** Zinc chloride + Water

**Question 30** (1 mark)

When a piece of sodium metal is carefully added to water, it reacts vigorously. What would a piece of caesium metal do?

**A.** React with about the same vigour.

**B.** React more vigorously.

**C.** React less vigorously.

**D.** Not react at all with the water.

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## Section H: VCAA-Level Questions II (9 Marks)

INSTRUCTION: 9 Marks. 9 Minutes Writing.

**Question 31** (9 marks)

Frank has been given three pieces of grey metal which look identical. He knows that one metal is magnesium, one metal is barium and one metal is beryllium. He wants to determine the identity of each metal based on its chemical reactions and properties.

**a.** Which metal would be expected to have the greatest reactivity? Justify your answer with reference to trends in the periodic table. (2 marks)

_____

_____

_____

_____

**b.** Write the equation of the chemical reaction that would occur between solid barium and water. If this reaction initially occurred in a sealed test tube, what would happen when a flame is placed inside the test tube after removing the seal? (2 marks)

_____

_____

_____

_____

**c.** Frank proposes that he could also determine the reactivity series by leaving the metals out in the open air. What would happen to the metal samples over time (include any relevant equations) and how could this be used to differentiate between them? (5 marks)

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## Section I: Summary

*What have we learnt today?*

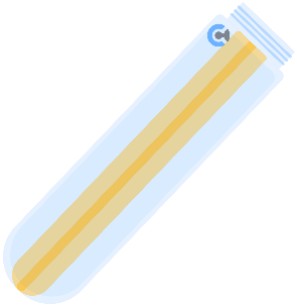
TIP:

Pitfalls

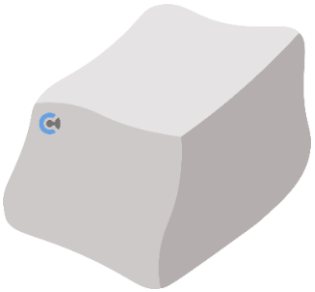
## Section J: Extension Questions (14 Marks)

**Question 32** (6 marks)

Fluorine gas and sodium metal are both very reactive elements that react vigorously with water.



Fluorine is a pale yellow, diatomic, highly corrosive, flammable gas, with a pungent odour.



Sodium is a silvery-white metal belonging to group 1 of the periodic table, which is the alkali metals group.

They react according to the following equations:

- Fluorine + water → Hydrogen fluoride + Oxygen gas

$$2F_2(g) + 2H_2O(l) \rightarrow 4HF(aq) + O_2(g)$$

- Sodium + water → Sodium hydroxide + Hydrogen gas

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

**a.** What type of chemical reaction does sodium undergo when it reacts with water? (1 mark)

_____

_____

**b.** How could you test for the presence of hydrogen gas in this reaction? (2 marks)

_____

_____

_____

_____

**c.** Why is fluorine gas referred to as a diatomic gas? (1 mark)

_____

_____

**d.** Explain why both fluorine gas and sodium metal react very vigorously with water. (2 marks)

_____

_____

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**Question 33** (8 marks) **Biological Role of Metals.**

**a.** Describe the importance of metals in biological systems. (2 marks)

_____

_____

**b.** Give an example of a metal ion that is crucial for human health and its role. (2 marks)

_____

_____

**c.** Why are some metals toxic to biological systems? (2 marks)

_____

_____

**d.** How do organisms protect themselves from metal toxicity? (2 marks)

_____

_____

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