STEPPING STONE
SCHOOL (HIGH)

CLASS :IX

Subject: Chemistry **Date:30/06/2020**

Topic: Hydrogen **Time Limit:40 min.**

Worksheet No.13

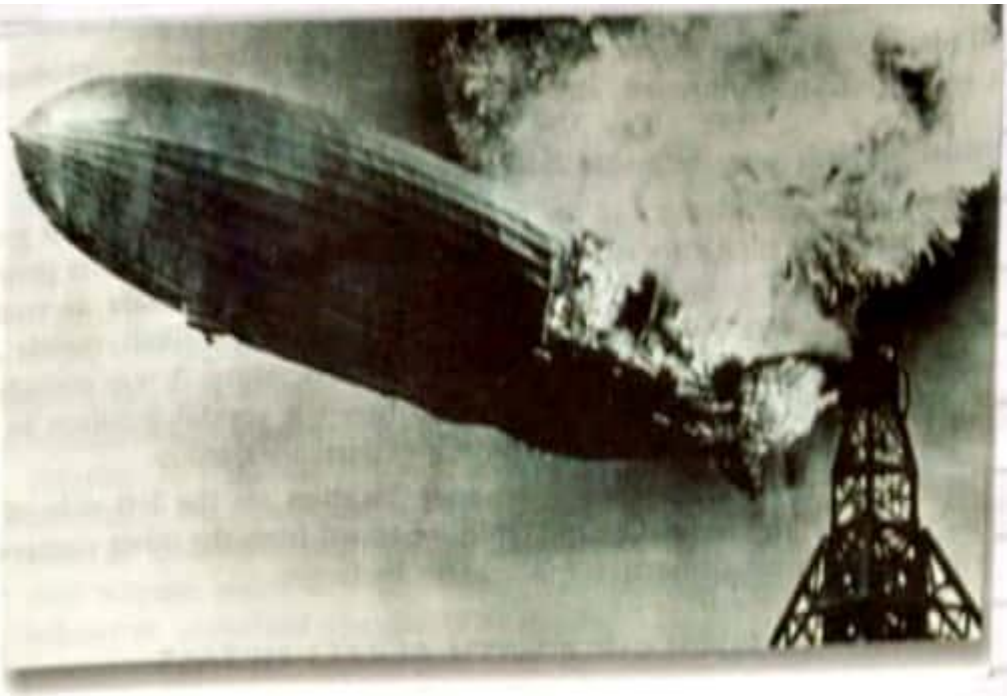
IMPORTANT INSTRUCTIONS

- Please read the chapter from your text book and the attached notes.
- Then work out the exercises neatly in your notebooks henceforth.
- Do not write above the red line of the notebook pages.
- Use notebook with 68 pages and write with black ink.
- Each page of your notebook should be marked with the page number.
- Make a contents page first with columns under the heads as given below:

CONTENTS

DATE	WORKSHEET NO.	CHAPTER NO. & NAME	PAGE NOs.	TEACHER'S SIGNATURE

- Every new chapter (topic) should be started on a new page.
- Ensure neat and tidy work.



HYDROGEN

Atomic symbol	H	Atomic number	1
Electronic configuration	$^{1}_{1}$	Atomic mass	1.008 u
Valency	+1, −1	Atomic radius	37 pm
Molecular formula	H_2	Molecular mass	2.016 u
Density	0.0899 g/mL	Molar mass	2.016 g mol^{-1}

Hydrogen in the gaseous state exists as a diatomic species H_2. The diatomic H_2 molecule is also termed as **dihydrogen** to distinguish it from the hydrogen atom.

DISCOVERY OF HYDROGEN

In the beginning of the 16th century, a German chemist, **Paracelsus** obtained a highly inflammable gas when iron was added to sulphuric acid. **Robert Boyle** (in 1672) studied the combustibility of this gas.

Henry Cavendish (1766) obtained this gas by the reaction between zinc and dilute sulphuric acid. He also showed that hydrogen when burnt gives water as the only product.

Antoine Lavoisier named this gas as **hydrogen** because it produced water when burnt (Greek: *hydro* = water, *gennas* = producer).

Occurrence of hydrogen

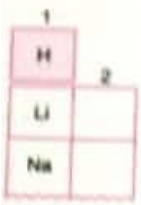
Hydrogen constitutes 0.9% (by mass) of the earth's crust and is the ninth element in the order of abundance.

Hydrogen occurs free in the earth's atmosphere in traces. In combined state, it occurs as water, acids, organic materials, such as hydrocarbons and many minerals.

Hydrogen occurs in abundance on the Sun and other bright stars. The Jupiter and Saturn consist mainly of hydrogen. The source of the Sun's energy is the fusion of hydrogen into helium.

All plants and animal tissues contain compounds of hydrogen in combination with carbon, oxygen, nitrogen, etc.

Position of hydrogen in periodic table



Hydrogen is the first element of the periodic table. It was assigned first group and first period of the periodic table. This position of hydrogen in the periodic table was disputed because it resembles both, the **alkali metals** as well as **halogens**. Moreover, although hydrogen resembles both alkali metals and halogens, it differs from both in certain respects. Therefore, it was considered more appropriate and justified to allot hydrogen a special position in the periodic table and not to associate it with any particular group.

Hence, hydrogen is assigned a **separate location** on the left side of the periodic table on top of the Group IA, but separated from the other elements of Group IA to indicate distinctive character of hydrogen.

RESEMBLANCE WITH ALKALI METALS

How does hydrogen resemble with alkali metals

Hydrogen resembles alkali metals in the following respects.

- **Electronic configuration.** The hydrogen atom has only one electron in its outermost shell, like the alkali metals.

Element	H	Li	Na
Atomic no.	1	3	11
Electronic configuration	1	2, 1	2, 8, 1

- **Cation formation.** Hydrogen, like alkali metals, forms singly charged cation by losing its outermost electron.

$$H \rightarrow H^+ + e^-$$
$$Na \rightarrow Na^+ + e^-$$

- **Affinity for nonmetals.** Both hydrogen and alkali metals combine with halogens to form halides, with oxygen to give oxides and with sulphur to give sulphides. For example,

HCl	H_2O	H_2S
NaCl	Na_2O	Na_2S

- **Electropositive nature.** Hydrogen is displaced from acids by active metals. In this reaction, hydrogen behaves as an electropositive element. For example,

$$Zn(s) + \text{dil. } H_2SO_4 \rightarrow ZnSO_4(aq) + H_2(g)$$

It is further supported by the fact that when an aqueous solution of hydrogen chloride or a molten alkali metal halide is electrolysed, both

hydrogen and alkali metals are liberated at the cathode.

$HCl(aq) \rightarrow H^+ + Cl^-$	$NaCl\ (molten) \rightarrow Na^+ + Cl^-$
$2H^+ + 2e^- \rightarrow H_2(g)$	$Na^+ + e^- \rightarrow Na$
liberated at cathode	liberated at cathode

- **Reducing character.** Hydrogen, like alkali metals, acts as a strong reducing agent.

$$\underset{\text{copper(I) oxide}}{CuO(s)} + \underset{\text{hydrogen}}{H_2(g)} \xrightarrow{\Delta} \underset{\text{copper}}{Cu} + H_2O$$

$$\underset{\text{boron trioxide}}{B_2O_3} + \underset{\text{potassium (an alkali metal)}}{6K} \rightarrow \underset{\text{boron}}{2B} + 3K_2O$$

RESEMBLANCE WITH HALOGENS

How does hydrogen resemble with halogens

Hydrogen resembles halogens in the following aspects.

- **Nonmetallic nature and atomicity.** Hydrogen is a gas, like fluorine and chlorine. Its molecule H_2 is diatomic like F_2, Cl_2, Br_2 and I_2.
- **Electronic configuration.** Both hydrogen and halogens are **one electron short of saturation in their outermost shell.** After gaining one electron, they acquire stable configuration of the nearest noble gas. Thus, both behave as **univalent nonmetals** as shown below.

$$\underset{(1)}{H} + e^- \rightarrow \underset{(2)}{H^-} \qquad \underset{(2)}{He}$$

$$\underset{(2,8,7)}{Cl} + e^- \rightarrow \underset{(2,8,8)}{Cl^-} \qquad \underset{(2,8,8)}{Ar}$$

$$\underset{(2,8,18,7)}{Br} + e^- \rightarrow \underset{(2,8,18,8)}{Br^-} \qquad \underset{(2,8,18,8)}{Kr}$$

- **Hydrides and halides.** Hydrogen combines with alkali and alkaline earth metals to form hydrides similar to halides.

$$\underset{\text{hydrogen}}{H_2} + \underset{\text{sodium}}{2Na} \rightarrow \underset{\text{sodium hydride}}{2NaH} \qquad \underset{\text{chlorine}}{Cl_2} + \underset{\text{sodium}}{2Na} \rightarrow \underset{\text{sodium chloride}}{2NaCl}$$

$$\underset{\text{hydrogen}}{H_2} + \underset{\text{calcium}}{Ca} \rightarrow \underset{\text{calcium hydride}}{CaH_2} \qquad \underset{\text{chlorine}}{Cl_2} + \underset{\text{calcium}}{Ca} \rightarrow \underset{\text{calcium chloride}}{CaCl_2}$$

The molten hydrides on electrolysis produce hydrogen at **anode**, like chlorine from molten chlorides.

$$\underset{\text{hydride ion}}{H^-} \xrightarrow{\text{electrolysis}} \underset{\text{(at anode)}}{\tfrac{1}{2}H_2(g)} + e^- \qquad \underset{\text{chloride ion}}{Cl^-} \xrightarrow{\text{electrolysis}} \underset{\text{(at anode)}}{\tfrac{1}{2}Cl_2(g)} + e^-$$

- **Substitution of hydrogen by halogens.** Halogens easily replace hydrogen from compounds such as hydrocarbons. For example, in methane

$$\underset{\text{methane}}{CH_4(g)} + \underset{\text{chlorine}}{Cl_2(g)} \rightarrow \underset{\text{chloromethane}}{CH_3Cl(g)} + HCl(g)$$

$$CH_3Cl(g) + Cl_2(g) \rightarrow \underset{\text{dichloromethane}}{CH_2Cl_2(g)} + HCl(g)$$

and so on.

PROPERTIES OF HYDROGEN NOT COMMON TO BOTH THE ALKALI METALS AND HALOGENS

Hydrogen has some properties which neither resemble alkali metals nor halogens. For example,

- **Nature of oxide.** The oxide of hydrogen, H_2O is **neutral**, while the oxides of halogens, *e.g.*, Cl_2O, ClO_2, Cl_2O_7, etc. are **acidic** and the oxides of alkali metals, *e.g.* Na_2O, K_2O, etc. are **basic.**
- **Electronic configuration.** Hydrogen atom has no inner electrons and no unshared electrons.

ISOTOPES OF HYDROGEN

What are the isotopes of hydrogen

There are three isotopes of hydrogen. These are — protium, deuterium and tritium. These three isotopes of hydrogen are shown in Fig. 9.1.

	Hydrogen (^1_1H)	Deuterium (^2_1H or D)	Tritium (^3_1H or T)
Mass number	1	2	3
Nuclear composition :			
Protons	1	1	1
Neutrons	Nil	1	2
Relative abundance :	1	1.56×10^{-2}	1×10^{-17}
	Nonradioactive	Nonradioactive	Radioactive

Fig. 9.1 Three isotopes of hydrogen

PREPARATION OF HYDROGEN

Hydrogen can be prepared by various methods.

- From water
- From acids
- From alkalis

Preparation of hydrogen from water

Water contains about 11% (by mass) of hydrogen. Water is the most abundant and the cheapest source of hydrogen. Following are some of the methods used for preparing hydrogen from water.

By electrolysis of water

This process is suitable for places where **cheap electric** supply is available. Pure water is a poor conductor of electricity. It is made a good conductor of electricity by adding a small quantity of sulphuric acid or sodium hydroxide to it. Hydrogen obtained by this method is 99.9% pure.

$$\underset{\text{sulphuric acid}}{H_2SO_4(aq)} \rightarrow \underset{\text{hydrogen ion}}{2H^+(aq)} + \underset{\text{sulphate ion}}{SO_4^{2-}(aq)}$$

The SO_4^{2-} does not get involved in the electrode reaction. The ion which gets oxidised at the anode in preference to SO_4^{2-} is OH^- (coming from the ionisation of water).

At anode:

$H_2O \rightarrow OH^- + H^+] \times 4$

$OH^- \rightarrow OH + e^-] \times 4$

$2OH \rightarrow H_2O + O] \times 2$

$O + O \rightarrow O_2(g)$

Net reaction at anode: $2H_2O \rightarrow 4H^+ + O_2(g) + 4e^-$

At cathode: $H^+ + e^- \rightarrow \frac{1}{2}H_2(g)] \times 4$

Net overall reaction: $\underset{\text{acidulated water}}{2H_2O(l)} \xrightarrow{\text{electricity}} \underset{\text{hydrogen (at cathode)}}{2H_2(g)} + \underset{\text{oxygen (at anode)}}{O_2(g)}$

During electrolysis of water, hydrogen and oxygen gases are evolved in the volume ratio of 2 : 1.

By the action of metals on water

Metals above hydrogen in the electrochemical series displace hydrogen from water under conditions depending upon their reactivity.

Action of metals on cold water

Elements like sodium, potassium, calcium, etc. displace hydrogen from water at room temperature. With alkali metals the reaction is explosive.

$\underset{\text{sodium}}{2Na(s)} + \underset{\text{water (cold)}}{2H_2O(l)} \rightarrow \underset{\text{sodium hydroxide}}{2NaOH(aq)} + \underset{\text{hydrogen}}{H_2(g)}$

$\underset{\text{potassium}}{2K(s)} + \underset{\text{water (cold)}}{2H_2O(l)} \rightarrow \underset{\text{potassium hydroxide}}{2KOH(aq)} + \underset{\text{hydrogen}}{H_2(g)}$

$\underset{\text{calcium}}{Ca(s)} + \underset{\text{water (cold)}}{2H_2O(l)} \rightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{hydrogen}}{H_2(g)}$

Action of metals on boiling water

Metals like magnesium and aluminium in powder form decompose boiling water, giving hydrogen gas.

$\underset{\text{magnesium}}{Mg(s)} + \underset{\text{(boiling)}}{H_2O(l)} \rightarrow \underset{\text{magnesium oxide}}{MgO(s)} + \underset{\text{hydrogen}}{H_2(g)}$

$\underset{\text{aluminium}}{2Al(s)} + \underset{\text{(boiling)}}{3H_2O(l)} \rightarrow \underset{\text{aluminium oxide}}{Al_2O_3(s)} + \underset{\text{hydrogen}}{3H_2(g)}$

By passing steam over heated metals

When steam is passed over some heated metals, such as zinc, magnesium and iron, hydrogen gas is obtained.

Hydrogen so evolved is collected over water.

$\underset{\text{red hot iron}}{3Fe(s)} + \underset{\text{(steam)}}{4H_2O} \rightleftharpoons \underset{\text{ferrosoferric oxide}}{Fe_3O_4(s)} + \underset{\text{hydrogen}}{4H_2(g)}$

By the action of water on metal hydrides

Hydrides of alkali and alkaline earth metals react readily with water producing hydrogen.

$\underset{\text{calcium hydride}}{CaH_2(s)} + \underset{\text{water (cold)}}{2H_2O(l)} \rightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{hydrogen gas}}{H_2(g)}$

Preparation of hydrogen from acids

Acids contain replaceable hydrogen. Electropositive metals, such as sodium, potassium, zinc, iron, aluminium, magnesium, etc. which appear above hydrogen in the electrochemical series displace hydrogen from acids. For example,

Nitric acid makes the metals passive by forming a layer of oxide on their surfaces. So, it is not used in such **hydrogen displacement reactions**.

$$\underset{\text{zinc}}{Zn} + H_2SO_4(aq) \rightarrow \underset{\text{zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{hydrogen}}{H_2(g)}$$

$$\underset{\text{magnesium}}{Mg} + H_2SO_4(aq) \rightarrow \underset{\text{magnesium sulphate}}{MgSO_4(aq)} + \underset{\text{hydrogen}}{H_2(g)}$$

Preparation of hydrogen from alkalis

Metals like zinc, aluminium, tin, etc. or a nonmetal like silicon when boiled with concentrated solution of sodium hydroxide (or caustic soda) or potassium hydroxide (or caustic potash) produce hydrogen.

$$\underset{\text{zinc (powder)}}{Zn(s)} + \underset{\text{sodium hydroxide}}{2NaOH(aq)} \xrightarrow{\text{boiling}} \underset{\text{sodium zincate}}{NaZnO_2(aq)} + \underset{\text{hydrogen}}{H_2(g)}$$

$$\underset{\text{aluminium (powder)}}{2Al(s)} + 2NaOH(aq) + 2H_2O(l) \xrightarrow{\text{boiling}} \underset{\text{sodium aluminate}}{2NaAlO_2(aq)} + \underset{\text{hydrogen}}{3H_2(g)}$$

$$\underset{\text{tin}}{Sn(s)} + 2NaOH(aq) + H_2O(l) \xrightarrow{\text{boiling}} \underset{\text{sodium stannate}}{Na_2SnO_3(aq)} + \underset{\text{hydrogen}}{2H_2(g)}$$

$$\underset{\text{silicon}}{Si(s)} + 2NaOH(aq) + H_2O(l) \xrightarrow{\text{boiling}} \underset{\text{sodium silicate}}{Na_2SiO_3} + \underset{\text{hydrogen}}{2H_2(g)}$$

LABORATORY PREPARATION OF HYDROGEN

How is hydrogen prepared in the laboratory

In laboratory, hydrogen gas is generally prepared by the action of dilute H_2SO_4 on zinc metal (in the form of small granules).

Reaction:

$$\underset{\text{zinc}}{Zn(s)} + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + \underset{\text{hydrogen}}{H_2(g)}$$

The experimental set-up used for the preparation of hydrogen gas in the laboratory is shown in Fig. 9.2.

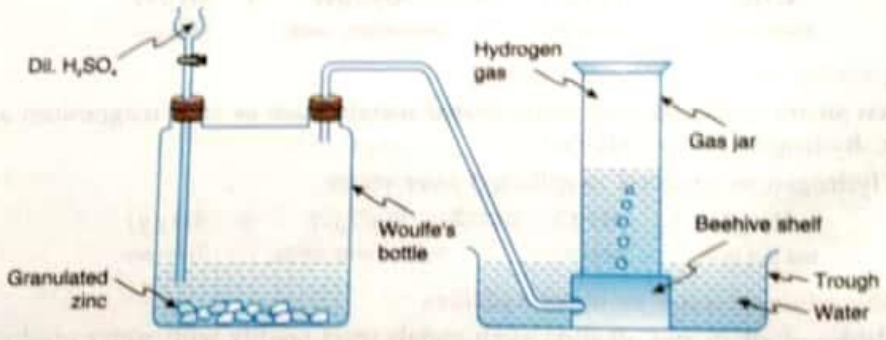


Fig. 9.2 Laboratory preparation of hydrogen gas

Procedure. Proceed through the following steps:

- **Setting up the apparatus.** A few pieces of granulated zinc are placed in a Woulfe's bottle. Pour some water through the thistle funnel. Add dilute sulphuric acid solution through thistle funnel. The reaction starts immediately. Being exothermic reaction, the bottle gets warm.
- **Collection of gas.** Hydrogen gas produced, passes through the delivery tube and is collected by the **downward displacement** of water.

- When the jar is filled with hydrogen gas, it is lifted and a glass cover (or lid) is placed over the mouth of the jar. The covered jar is kept in inverted position to prevent the escape of hydrogen out of jar.
- Hydrogen gas is collected over water because it is **almost insoluble** in water.
- Hydrogen gas is **lighter than air**. So, it could be collected by the downward displacement of air. But it is not done so. This is because hydrogen forms explosive mixture with air.

ANSWER THE QUESTIONS.

1) State the position of hydrogen in the periodic table.

2) What are the similarities between hydrogen and the halogens?

3) Why hydrogen is said to have a dual nature?

4) State the resemblance of hydrogen with alkali metals.

5) Name the isotopes of hydrogen.

6) Why Nitric acid is ~~used~~ not used in the preparation of hydrogen by reacting with metals?

7) In laboratory preparation of hydrogen why granulated Zinc is used?

8) Complete the reactions

(i) $Sn + NaOH \rightarrow$.

(ii) $CaH_2(s) + H_2O(l) \rightarrow$.

(iii) $Mg + H_2O \rightarrow$.

(iv) $Zn + KOH \rightarrow$.

(v) $Fe + H_2O \rightarrow$.

SUGGESTED LINK:
https://youtu.be/xuKXYPDDnes