Unit - 13 – Hydrogen

Abundance: Hydrogen is the third most abundant element on earth surface

Position in periodic table	Atomic number	Atomic mass	Oxidation state
Period 1	1	1	+1(Most Stable)
Group : Middle of first period			-1 (Hydrides)

Serial No.	Property	Similarity with alkali metals	
		Hydrogen	Alkali Metals
1.	Electronic configuration	$1s^1$	ns^1
2.	Oxidation state	+1	+1
3.	Reducing Agent	Good	Good
4.	Reaction with halogens and oxygen	Stable Halide and oxides	Stable Halide and oxides
		Differences with alkali metals	
1.	Ionisation enthalpy	$1312KJmol^{-1}$	Δ_iH of Li =520
2.	Physical state	Diatomic Gas	Solid
3.	Bonding in halides	Covalent	Ionic

Serial No.	Property	Similarity with Halogens	
		Hydrogen	Halogens
1.	Electronic configuration	$1s^1$(Short of one electron for stable noble gas configuration)	ns^2np^5 (Short of one electron for stable noble gas configuration)
2.	Oxidation state		-1
3.	Atomicity	-1 (Hydrides)	2
4.	Δ_iH	2	Δ_iH of F = 1681
		$1312KJmol^{-1}$	(Decreases down the group)
5.	Reaction with metals	Hydrogen eg. NaH	Halides eg.NaCl
		Differences with Halogens	
1.	Colour	Colorless	Colored
2.	Oxidising agent	Poor	Strong
3.	Nature of oxide	Neutral (H_2O)	Acidic (Cl_2O_7)

Therefore hydrogen is placed in middle of first period.

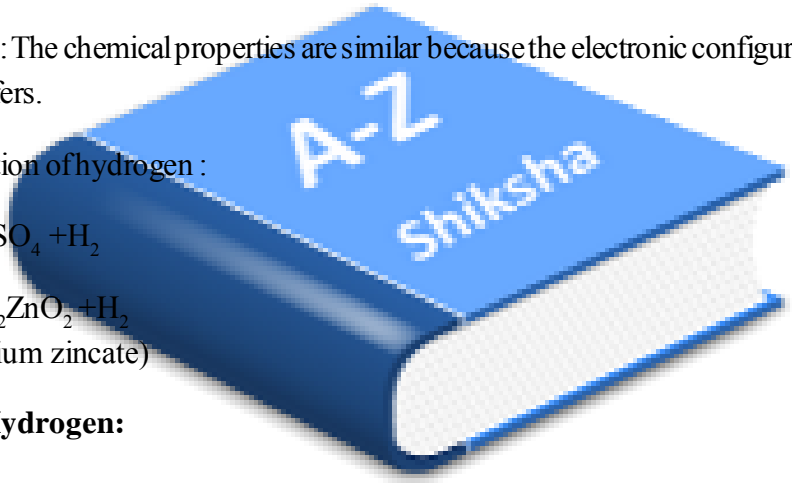
Isotopes of hydrogen

Sl:No:	Name &symbol	Atomic number	Atomic mass	No: of protons	No: of neutrons	occurrence	Nuclear stability&$t_{1/2}$
1	Protium $_1^1H$	1	1	1	0	Highest 99.9850%	Stable
2	Deuterium or $_1^2H$	1	2	1	1	0.015%	Stable
3	Tritium or $_1^3H$	1	3	1	2	T: $_1^1H$ 1:10	12.33yrs Radioactive $_1^3H \rightarrow {}_2^3He + {}_{-1}^0e$

Physical properties

Physical properties of isotopes are slightly higher than hydrogen because the mass of isotopes are higher.

Chemical properties: The chemical properties are similar because the electronic configuration is same. The rate of reactions differs.



Laboratory preparation of hydrogen :

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

$Zn + NaOH \rightarrow Na_2ZnO_2 + H_2$
(Sodium zincate)

Manufacture of Hydrogen:

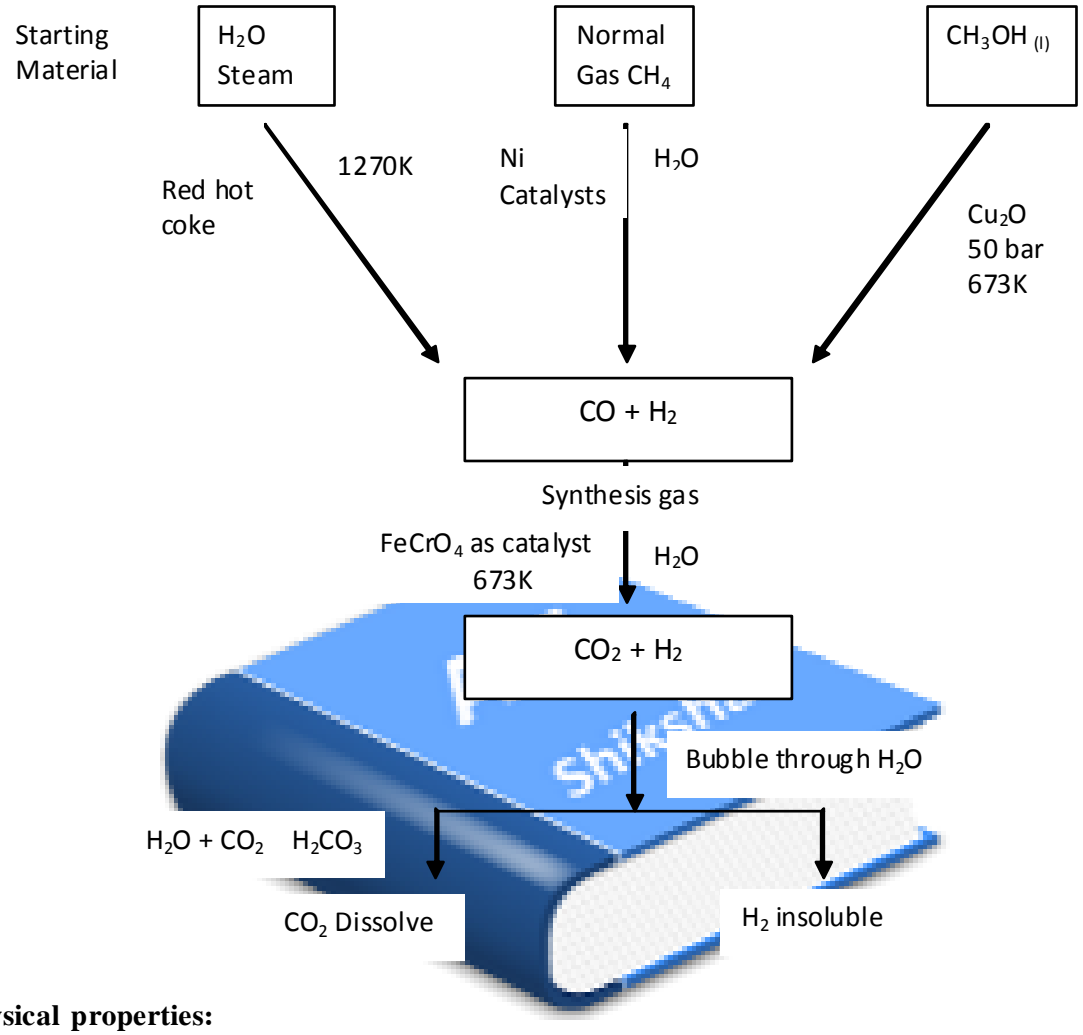
Industrial Preparation:

Electrolysis:

	Electrolyte	Electrodes
a)	Acidified water	Pt
b)	Aqueous $Ba(OH)_2$	Ni

Hydrogen is liberated at the cathode.

Manufacture of Hydrogen



Physical properties:

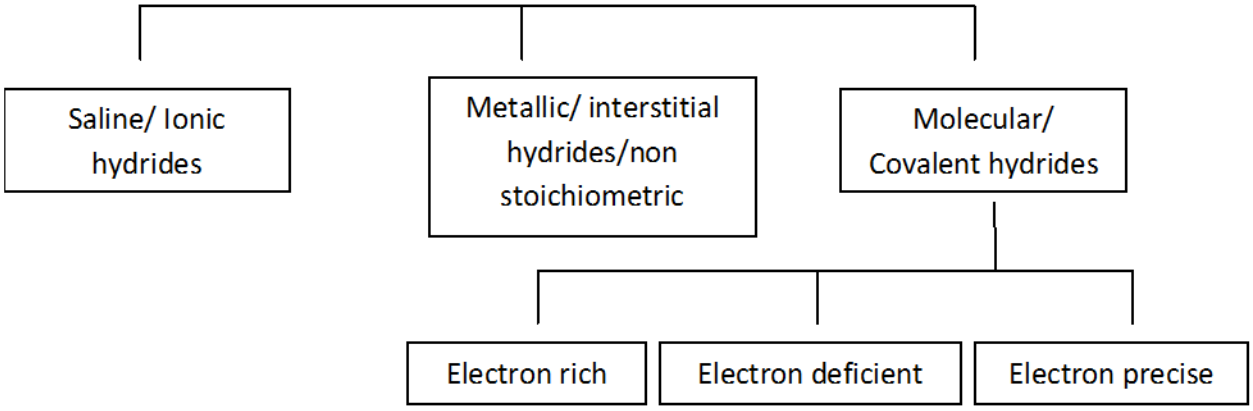
1. Colourless, tasteless & odourless
2. It is diatomic gas, insoluble in water.
3. It is the lightest element & diamagnetic.

⇒ **Chemical properties of Dihydrogen:**

$H_{2(g)}$

- $\xrightarrow{X_{2(g)}} 2HX_{(g)}\ (X = F, Cl, Br, I)$
- $\xrightarrow[\text{Catalyst or } \Delta]{O_{2(g)}} H_2O_{(l)} \quad \Delta H = -285.9\ KJ/mol$
- $\xrightarrow[200\ bar\ Fe]{N_{2(g)}\ 673K} NH_{3(g)} \quad \Delta H = -92.6\ KJ/mol$
- $\xrightarrow{2M_{(S)}} 2MH_{(S)} \quad M = \text{Alkali metal}$
- $\xrightarrow{Pd^{2+}_{(aq)}} Pd_{(S)} + 2H^{+}_{(aq)}$
- $\xrightarrow{MxOy_{(S)}} XM_{(S)} + YH_2O_{(r)}$
- $\xrightarrow[Ni,390K]{CH_2=CH_2} CH_3 - CH_3$ Ethane
- $\xrightarrow[\text{Raney Ni},390\,K]{CH\equiv CH} CH_3 - CH_3$ Ethane
- $\xrightarrow[50\ bar,\ Cu_2O]{CO_{(g)}\ 573K} CH_3OH_{(l)}$

Hydrogen forms hydrides of the type MH_x & M_mH_n with most metals



Sr. No.	Type of hydride	Type of element	Type of bonds	Properties	Uses
1	Saline	s-Block Group 1- MH Group2- MH_2	Ionic	I. Crystaline, non volatile and non conductance solid state II. In molten state it conducts electricity. Hydrogen is liberated at anode III. BeH_2 & MgH_2 are polymeric IV. $MH + H_2O \rightarrow MOH + H_2$ + Heat	LiH is used in preparation of $LiAlH_4$ & $LiBH_4$ which are used as in versatile reducing agent s in organic chemistry
2	Metallic	d-Block or p-Block elements		Non stoicheometric because H_2 is absorbed in the interstitial spaces.	Catalysts
3	Molecular	Metals non-metals of p-Block eg. CH_4, PH_3, SbH_3	Covalent	I. Exists as gas or liquid II. Stable	

Water: Most important compound for living beings

i) ***Structure:***

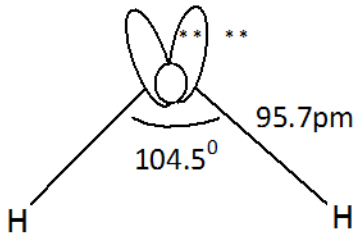
Type of hybridisation – sp^3

Bond angle = 104.5

Bond Length = 95.7pm

Bond angle is less then $109^0 28'$

Because of presence of two lone pairs of electron



ii) ***Ice:***

3-d structure due to H-bond format Ice is lighter than water

Reason: Due to H-bond the volume increases for the same mass of water.

Physical properties :

a Colourless, tasteless, odourless

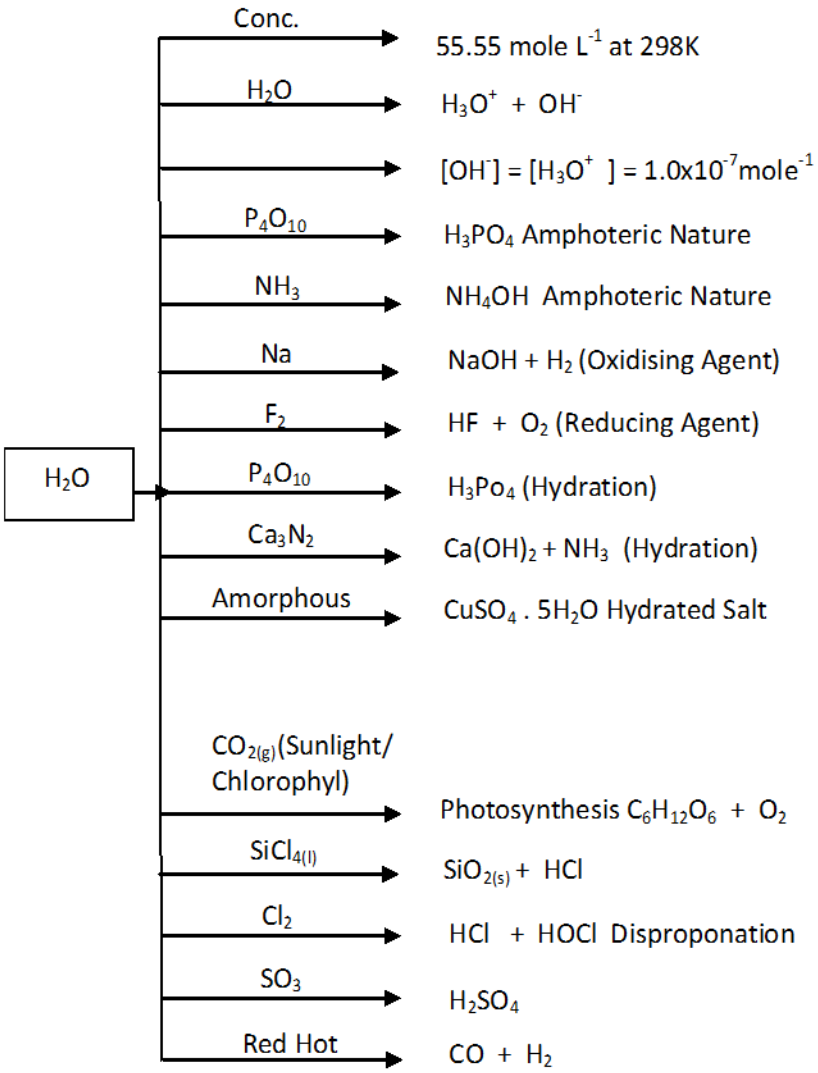
b Melting point= 273K Boiling point = 373K

c Density at 298K = $1.00 g/cm^{-3}$

d Polar

e Special Property: anomalous explosion between 273K & 277K

Chemical properties of H_2O



Hardness of water

Temporary

Due to presence of bicarbonates salts of calcium &magnesium

Methods of removal

- Boiling
  $M(HCO_3)_2 \rightarrow MCO_3 + CO_2$
- Clarks method
  Addition of lime
  $M(HCO_3)_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$
  M= Ca^{2+} or Mg^{2+}

Permanent

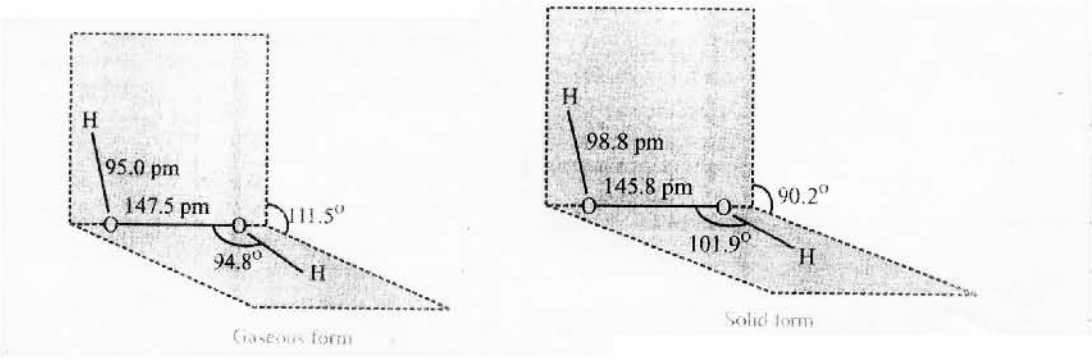
Due to presence of soluble salts of Soluble chlorides &sulphates of Ca & Mg

Methods of removal

1. Chemical methods :
   (a) Addition of washing soda
   $MCl_2 + Na_2CO_3 \rightarrow MCO_3 + 2NaCl$
   M = Ca^{2+}/ Mg^{+2}
   (b) Ca^{2+}&Mg^{2+} ions are made ineffective by addition of calgon Sodium hexa Meta phosphate
   $Na_6P_6O_{18} \rightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$
   $M^{2+} + Na_4P_6O_{18}^{2-} \rightarrow 2Na^+ +$
   $[Na2MP_6O_{18}^{2-}]$
   (c) Ion exchange method :
   Zeolite is used .Zeolite is sodium aluminosilicate
   ($Na_2AlSi_4O_{12}$) .The shape is like honey comb. In the voids sodium ions are replaced calcium& magnesium ions.
   $2NaZ + Ca \rightarrow Ca^{2+}(Z)_2 + 2Na^+$
2. Synthetic Resin method :
   Cation or Anion exchange resin is used.
   $2RNa + M^{2+} \rightarrow R_2M + 2Na^+$

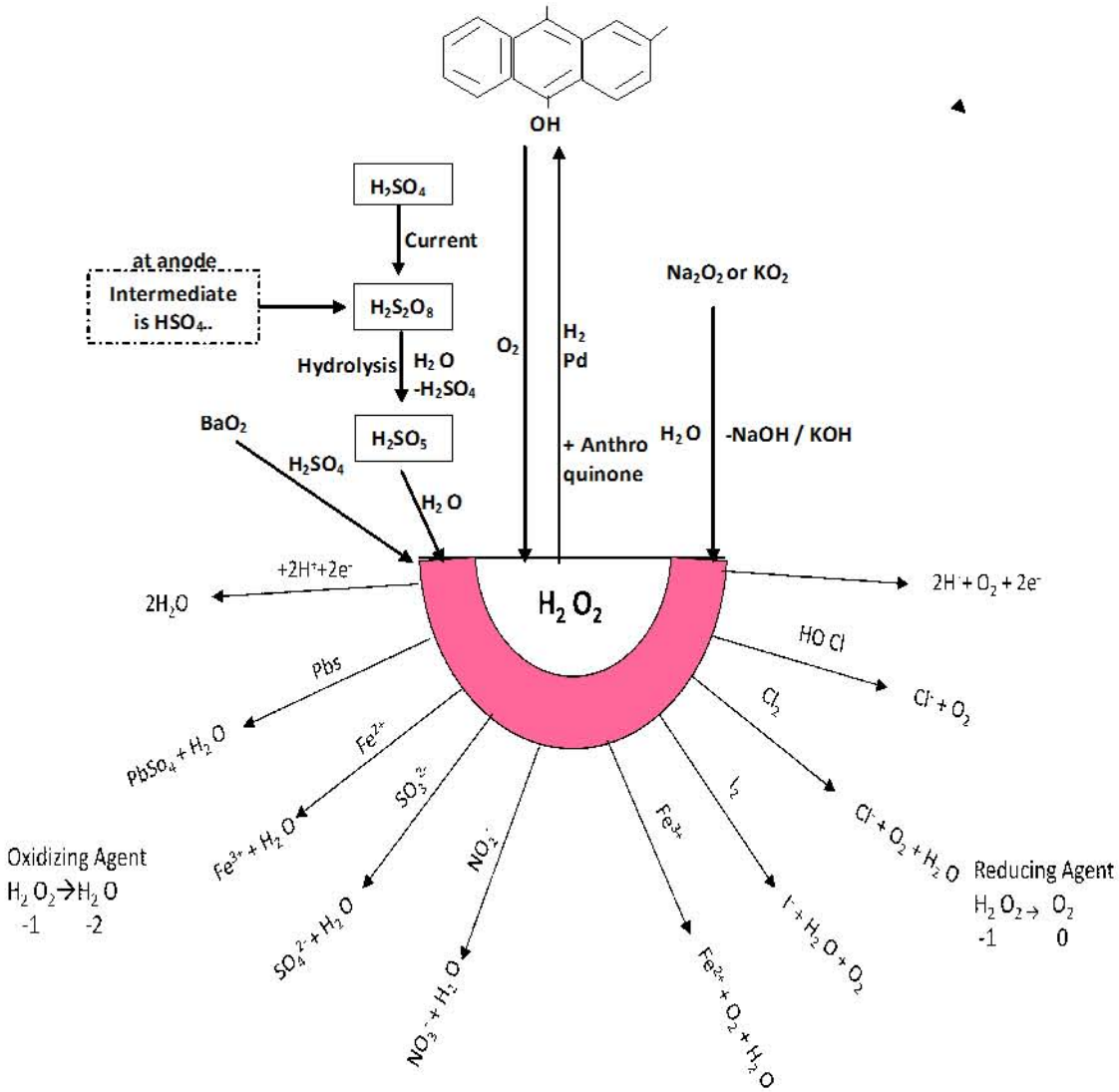
HYDROGEN PEROXIDE:

Structure of Hydrogen Peroxide :



Preparation and properties of Hydrogen peroxide :

It was first prepared by J.L. Thenard



Heavy Water

Dicovery

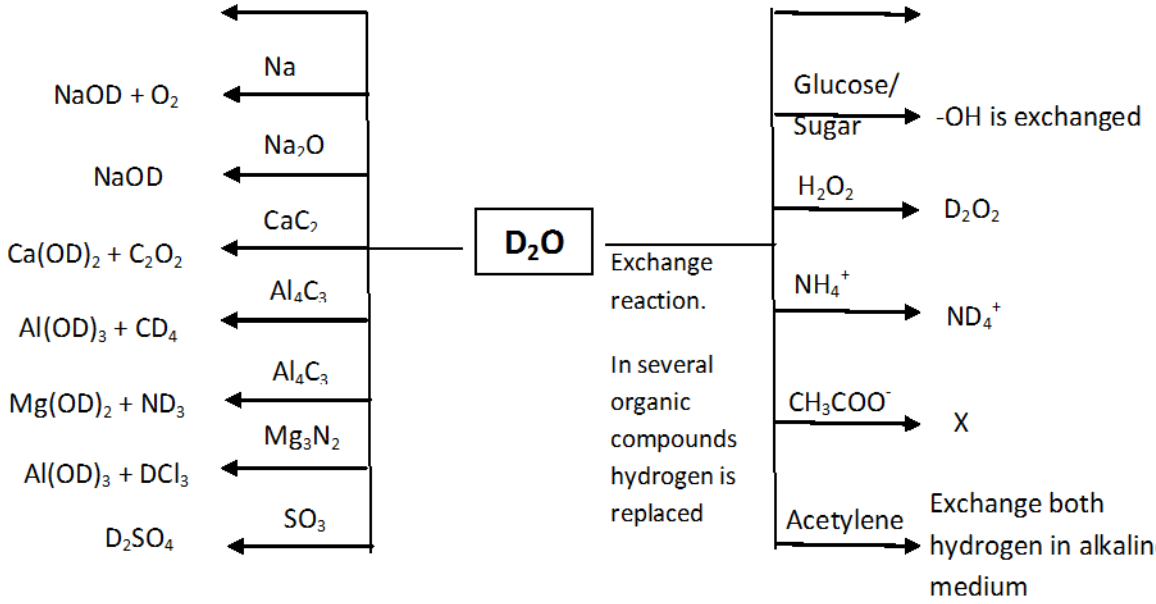
1. Urey → Discovery of heavy water
2. Lewis & Donald → Prepared few cm^3 of D_2O
3. Taylor, ryeing & Frost → Electrolytic procedure

Physical properties:

Almost all physical properties like Melting Point & Boiling point, Density is higher than H_2O because mass of Deuterium is greater than hydrogen. It is injurious to living organisms.

Chemical Properties :

Chemical properties are very similar to H_2O however rate of reaction is slower.



Hydrogen Economy: (Use of hydrogen as fuel)

Hydrogen could replace coal & oil as major source of energy. The hydrogen fuel is environment friendly.

The problems to overcome are

i. Production of H_2 at low cost. Solar energy can be used but it depends on development of catalyst

ii. Strong & transportation

⇒ FORMULA :

(1) $M = \frac{W}{M^1 \times V}$ M = Molarity

W = Weight of solute

M = Molecular mass

V = Volume

(2) $N = \frac{W}{E \times V}$ N = Normality

W = Weight of solute

E = Equivalent mass

V = Volume

(3) $gL^{-1} = N \times E$

(4) Equivalent weight for $H_2O_2 = 17$

(5) For H_2O_2, $N = 2M$

(6) % w/v = The mass of H_2O_2 in 100 ml solution

(7) Volume = % w/v × 3.294

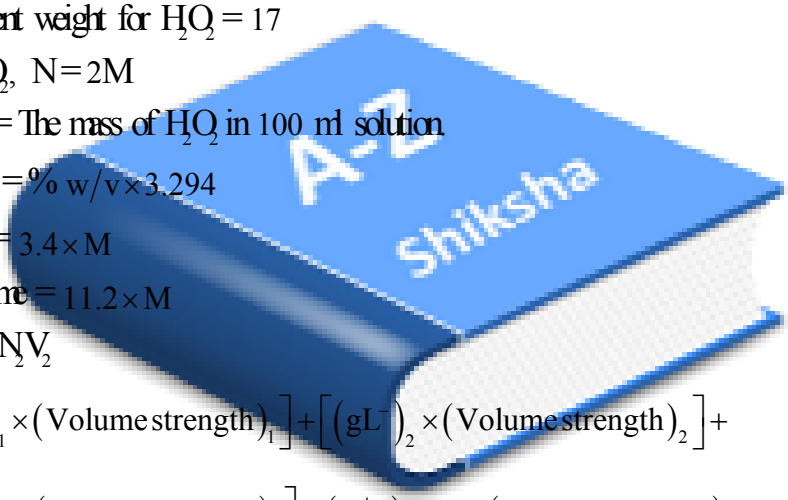
(8) % w/v = $3.4 \times M$

(9) % Volume = $11.2 \times M$

(10) $N_1V_1 = N_2V_2$

(11) $\left[\left(gL^-\right)_1 \times \left(\text{Volume strength}\right)_1\right] + \left[\left(gL^-\right)_2 \times \left(\text{Volume strength}\right)_2\right] +$

$\left[\left(gL^-\right)_3 \times \left(\text{Volume strength}\right)_2\right] = \left(g/L\right)_{\text{mixture}} \times \left(\text{Volume strength}\right)_{\text{mix}}$



M.C.Q.

1. The element which is the biggest source of energy in future is
   (a) Monoatomic gas (b) Gaseous non-metal
   (c) Liquid nonmetal (d) lightest element
2. Dihydrogen is liberated at the anode by electrolysis of :
   (a) Molten sodium hydride (b) Acidified water
   (c) Molten sodium chloride (d) Water with $Ba_{(OH)2}$
3. The conversion of atomic hydrogen to dihydrogen is :
   (a) endothermic change (b) Photochemical change
   (c) exothermic change (d) Nuclear change
4. The isotope of hydrogen with half-life of 12.33 year is :
   (a) Protium (b) Deuterium (c) Tritium (d) b & c
5. Zinc on reaction with ..... liberates a combustible gas.
   (a) dil HCl (b) dil KOH (c) H_2SO_4 (d) a, b, & c
6. Hydrogen gas can be produced from
   (a) Water gas (b) producer gas (c) coal gas (d) air
7. When Zn pieces are dropped in NaOH solution $H_{2(g)}$ is obtained and soluble ..... is obtained
   (a) Na_2ZnO_3 (b) $NaZnO_2$ (c) Na_4ZnO_3 (d) Na_3ZnO_2
8. $CO_{(g)} + H_2O_{(g)} \xrightarrow[[x]]{673k} CO_{2(g)} + H_{2(g)}$. x is .....
   (a) Fe (b) Pd (c) $FeCrO_4$ (d) V_2O_5
9. H_2 can be obtained from mixture of CO_2 & H_2 by bubbling the mixture through
   (a) Water (b) Alkaline Ca_2Cl_2
   (c) Conc H_2SO_4 (d) Hot Nacl solution
10. $H_2 + A \xrightarrow[[Fe]]{673k\ 200bar} \text{Alkaline gas}$. A is
    (a) Cl_2 (b) O_2 (c) N_2 (d) Na
11. The decay product of tritium is :
    (a) ${}_2^4He$ (b) ${}_1^1H$ (c) ${}_1^2H$ (d) ${}_2^3He$
12. The metal Zn, Al, Mg & Be are placed in different Test tubes. If NaOH is added, the metal which libaate Hydrogen gas are
    (a) Zn, Al, Mg & Be (b) Zn & Al (c) Mg & Be (d) Zn, Al & Mg

13. The gas used in welding & cutting of metal is a strong .....

(a) Reducing agent (b) Oxidising agent

(c) Reducing & oxidising agent (d) Dehydrating agent

14. Hydrogen closely resembles halogens becouse

(a) Strong reducing agent (b) diatomic gas

(c) it is a colourless gas (d) its is reduction potential is 0.00 V

15. $K_w = 1.0 \times 10^{-14}$ at 298k because

(a) $\left[OH^-\right] = \left[H_3O^+\right] = \left(1.0 \times 10^{-14}\right) M$

(b) $\left[OH^-\right] = \left(1.0 \times 10^{-8}\right) M$ & $\left[H_3O^+\right] = \left(1.0 \times 10^{-6}\right) M$

(c) $\left[OH^-\right] = \left[H_3O^+\right] = \left(1.0 \times 10^{-7}\right) M$

(d) $\left[OH^-\right] = \left(1.0 \times 10^{-6}\right) M$, $\left[H_3O^+\right] = \left(1.0 \times 10^{-8}\right) M$

16. The type of hybridisation of O in H_2O & $H_2H_{2(s)}$ is

(a) sp^3, sp^3 (b) sp^2, sp^3 (c) sp^3, sp^2 (d) sp^3, sp

17. The shape of water moleale is bent and not linear because

(a) Bond angle is < 180 (b) sp^3 hybridisation

(c) Presence of one lone pair of electron (d) sp^2 hybridisation

18. $BH + H_2O \rightleftharpoons BH_2^+ + OH^-$, H_2O acts as

(a) Base (b) Reducing

(c) acid (d) a & c

19. A metal M belongs to period 3 & group 2 reacts with nitrogen to give compound B. If B is added to water the products are :

(a) $Mg(OH)_2$ & NH_3 (b) $Be(OH)_2$ & NH_3

(c) LiOH & NH_3 (d) $Ca(OH)_2$ & NH_3

20. The Only compound whose density in solid state is less if than liguid is

(a) Water (b) Sodium hydrocide

(c) Nitric acid (d) phosphoras penta chloride

21. Fishes survive in frozen lakes because

(a) Ice floats on water (b) Ice acts as an insulator

(c) The Solubility of CO_2 in water increaze (d) a & b

22. Water is most important solvent because it is

(a) polar (b) Non polar

(c) forms H- bond (d) a & c

23. Ice is lighter than water because

(a) Density of ice is greater than water

(b) The volume of ice is more for given mass of water due to H - bonding

(c) Anomalous expansion

(d) Oxygen is electronegative & size is large

24. $SiCl_4 + H_2O \rightarrow A + HCl$ A is _____.

(a) $Si(OH)_4$ (b) SiO_2 (c) SiO (d) $SiCl_4 \cdot 2H_2O$

25. $MH + H_2O \rightarrow MOH + H_2 \cdot M$ belongs to

(a) p - block (b) d - block (c) s - block (d) p - block & d - block

26. The hydrogen which are used in catalytic reaction are :

(a) hydrides of p-block (b) hydrides of d-block

(c) interstial hydrides (d) b & c

27. Alkali metal do not form interstial hydrides because

(a) alkali metals loose electron readily. (b) The packing in alkali metals in vay close

(c) Absence of interstitial voids (d) size is large

28. The position of the element which forms deficient hydrides.

(a) Period 2 group 14 (b) Period 2 group 15

(c) Period 2 group 13 (d) Period 6 group 13

29. An element forms electron rich hydride. The electonic configuration of the element is

(a) $[He]2s^2 2p^2$ (b) $[He]2s^2 2p^1$

(c) $[Ne]2s^2 2p^2$ (d) $[He]2s^2 2p^5$

30. The set if quantum number for valence electron of an element which from election precise of water is

(a) $n = 4 \quad \ell = 2$ (b) $n = 2 \quad \ell = 1$

(c) $n = 3 \quad \ell = 0$ (d) $n = 2 \quad \ell = 0$

31. The method which can be used for removal of temporary & permanent hardness of water is

(a) Decantation (b) Distillation

(c) Boiling (d) Filteration

32. Which of the following reacts easily with H_2O to form hydrogen

(a) HCl (b)KH (c) NH_3 (d) B_2H_6

33. It is not advisable to use hard water for washing clothes beacause

(a) Precipitate of sodium salt of fatty acid is formed

(b) Precipitate of sodium salt of sulphonic acid is formed

(c) Precipitate of Magnesium salt of sulphonic acid is formed

(d) Precipitate of Magnesium salt of fatty acid is formed

34. Calgon softens hard water by

(a) Precipation of Ca^{2+} & Mg^{2+} ions (b) Coagulation of solts

(c) Complexing Ca^{2+} & Mg^{2+} ions (d) a & c

35. clark's method is used to remove

(a) Temporary hardenes (b) permanent

(c) Hardnes due to soluble SO_4^{-2} of Ca^{+2}, MG^{+2} (d) Temporary & permanent

36. $Na + D_2O \rightarrow A + B$, A & B are _____ & _____ respecitively.

(a) NaOH & H_2O (b) NaOD & D_2

(c) NaOD & D_2O (d) Na_2D & D_2

37. The % (mass) of deuterium in heavy water is

(a) 18.0 (b) Cannot be predicted

(c) 11.1 (d) 20.0

38. H_2O_2 is not used as

(a) Oxidising agent (b) Redusing agent

(c) Catalyst (d) Bleaching

⇒ **True - False Type**

39. 1. H_2O_2 acts as bleaching agent because of if its oxidising property

2. It is dangerous to used H_2O_2 is maintenance of environment

3. H_2O_2 is used is properation of good quality detergents

4. Perhydral is used as a disuifectant

(a) TFTT (b) FTTT (c) TTFF (d) FFTF

40. 1. A paper with stain of black Pbs, dipped in H_2O_2 solution turns white

2. The colour of acidified $KMnO_4$ does not diappear when H_2O_2 is added

3. A basic solution containinig Fe^{3+} ion turn blue on addition of H_2O_2

(a) FFF (b) FTF (c) TFF (d) TTT

41. 1. Tritium can be obtaned from natural source.

2. In ionic hydrides the oxidation state of hydrogen is +1

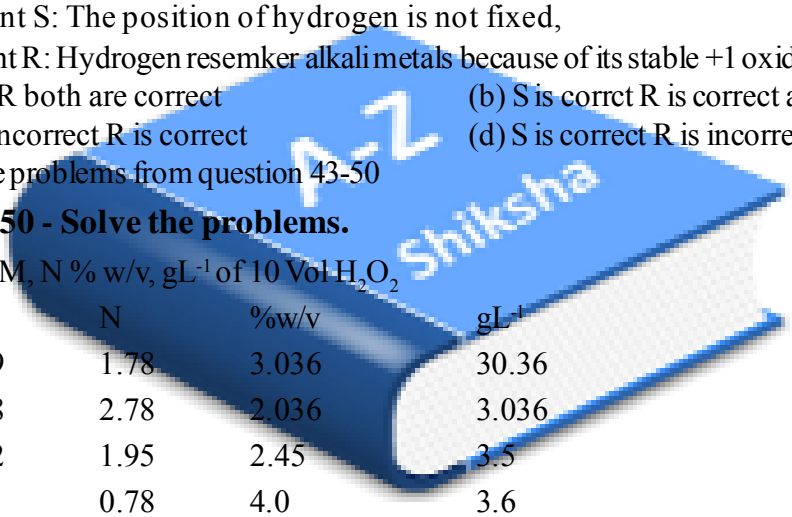
3. The four atom of oxygen in H_2O_2 are in the same plane

4. Na_2CO_3 removes temporary & permannent hardenes

(a) TFTT (b) FFFT (c) TFFT (d) TTTF

42. Statement S: The position of hydrogen is not fixed,
Statement R: Hydrogen resemker alkali metals because of its stable +1 oxidation state.
(a) S & R both are correct (b) S is corrct R is correct and explains S.
(c) S is incorrect R is correct (d) S is correct R is incorrect

Solve the problems from question 43-50



Questions 43-50 - Solve the problems.

43. Calculate M, N % w/v, gL^{-1} of 10 Vol H_2O_2

	M	N	%w/v	gL^{-1}
(a)	0.89	1.78	3.036	30.36
(b)	0.78	2.78	2.036	3.036
(c)	0.92	1.95	2.45	3.5
(d)	0.1	0.78	4.0	3.6

44. 30 ml of acidified solution of H_2O_2 required 30 ml of 0.1N$KMnO_4$ Calculate strength Volume strength & molarity.

	M	gL^{-1}	Volume
(a)	0.06	0.7	0.8
(b)	0.12	0.9	0.6
(c)	0.05	1.7	0.56
(d)	0.1	1.0	0.90

45. 374 g of H_2O_2 is present in 15 lit solution calculate M, N, % w/v & volume strength.

	M	N	%w/v	Volume	gL^{-1}
(a)	0.89	1.2	1.49	6.8	22.0
(b)	1.6	1.3	3.49	7.9	23.1
(c)	1.9	1.7	0.49	9.0	22.2
(d)	0.733	1.466	2.49	8.2	24.9

46. 2.72 g of H_2O_2 is present in 50ml solution Calculate M, N, Strength gL^{-1} Volume strength H_2O_2

(a) M = 10, N = 2.9, g/l = 53.0, Vol = 17.0

(b) M = 1.6, N = 3.2, g/l = 54.4, Vol = 17.92

(c) M = 0.89, N = 1.8, g/l = 52.9, Vol = 18.1

(d) M = 0.90, N = 1.0, g/l = 5.44, Vol = 16.0

47. Calculate % w/v, Volume Strength, M & N of a mixture contaning 800 ml of 2.5% w/v, 700 ml of 4.2 w/v & 500 ml 5.3w/v of H_2O_2 Solution

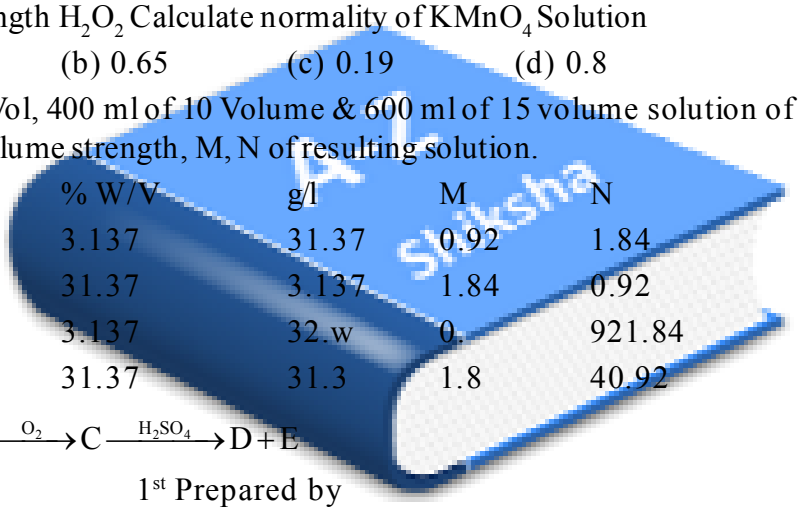
	% W/V	g/L	M	N
(a)	3.795	37.95	3.4	2.23
(b)	3.02	3.795	1.116	1.92
(c)	3.795	37.95	1.116	2.23
(d)	2.92	02.89	3.4	1.92

48. 10ml of $KMnO_4$ Solution is required ti completely oxidise acidic solution of 30ml of 1.5 Volume strength H_2O_2 Calculate normality of $KMnO_4$ Solution

(a) 0.4 (b) 0.65 (c) 0.19 (d) 0.8

49. 500 ml of 5Vol, 400 ml of 10 Volume & 600 ml of 15 volume solution of H_2O_2 is mixed Calculate volume strength, M, N of resulting solution.

	Vol	% W/V	g/l	M	N
(a)	10.33	3.137	31.37	0.92	1.84
(b)	10.33	31.37	3.137	1.84	0.92
(c)	9.95	3.137	32.w	0.	921.84
(d)	9.95	31.37	31.3	1.8	40.92



50. $A \xrightarrow{O_2} B \xrightarrow{O_2} C \xrightarrow{H_2SO_4} D + E$

gives green Colour flame

1st Prepared by J.L Thenard

A, B, C, D & E are

(a) Ba, BaO, BaO_2, $BaSO_4$, H_2O_2 (b) Na, Na_2O, Na_2O_2, Na_2SO_4, H_2O

(c) Ba, Ba_2O_2, BaO_2, $BaSO_4$, H_2O_2 (d) Ca, CaO, CaO_2, $CaSO_4$, H_2O_2

HINTS

43. Volume = 11.2× M N = 2M %W / V = 3.4×M

10 = 11.2× M = 2×0.89 = 3.4×0.89

M = 0.89 N = 1.78 gL^{-1} = 3.036

gm/L = 30.36

44. $H_2O_2 = kMnO_4$ gm/L = N×E V=11.2×M

$N_1V_1 = N_2V_2$ gm/L = 0.1 × 17 =11.2×0.05

$N_1 \times 30 = 0.1 \times 30$ gm/L = 1.7 =0.56

$N_1 = 0.1$

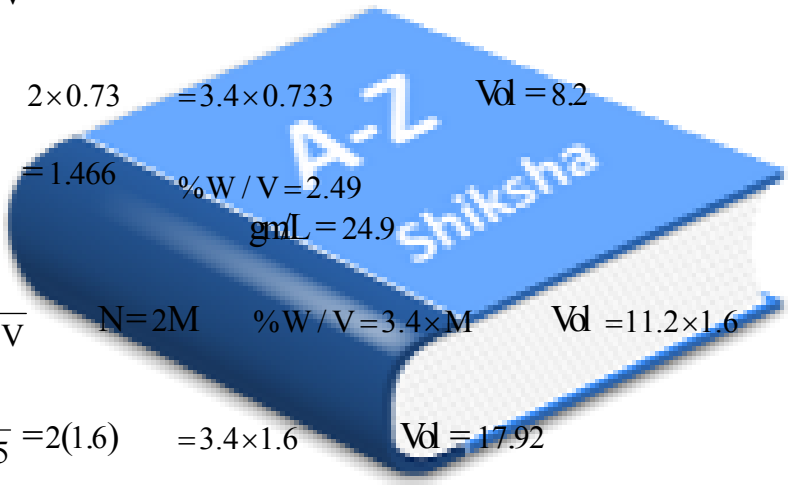
Molarity of H_2O_2 Sol. = 0.05

45. $M = \frac{W}{M^1 \times V}$ N=2M %W / V = 3.4 ×M Vol =11.2×0.733

$= \frac{374}{34 \times 15}$ 2×0.73 =3.4×0.733 Vol = 8.2

M=0.733 = 1.466 %W / V = 2.49

gm/L = 24.9



46. $M = \frac{W}{M^1 \times V}$ N=2M %W / V = 3.4×M Vol =11.2×1.6

$= \frac{2.72}{34 \times 0.05}$ =2(1.6) =3.4×1.6 Vol = 17.92

M=1.6 =3.2 =5.44

gm/L = 54.4

47. 2.5×800 + 700×4.2 + 500×5.3 = 2000×% W / V

%WV = 3.795

gm/L = 37.95

%WV = 3.4×M

3.795 = 3.4×M

M=1.116

N=2.232

48. H_2O_2 $kMnO_4$ Volume $= 11.2 \times M$

$1.5 \times 30 =$ Strength $\times 10$ $M = 0.40$

$V = 4.5$

$N = 2M = 2 \times 0.4$

$N = 0.8$

49. $500 \times 5 + 400 \times 10 + 600 \times 15 = \text{Volume} \times 1500$

Volume $= 10.33$

$\%W/V = {}^{\cdot 1}/3.294$

%WV $= 3.137$

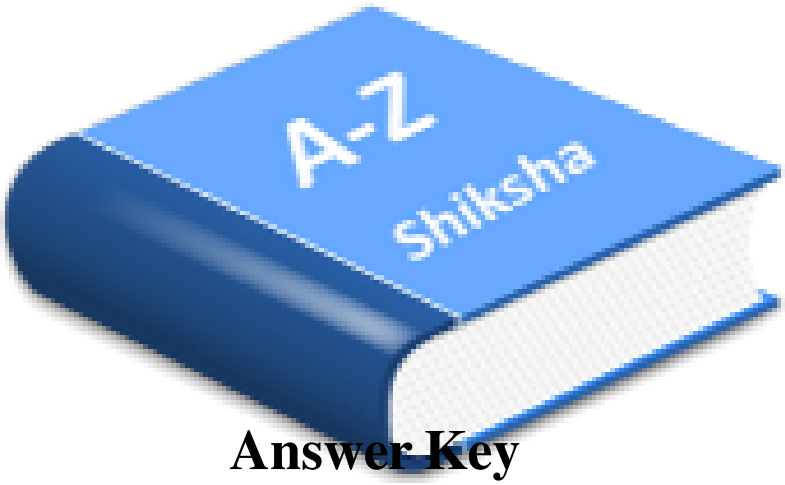
gm/L $= 31.37$

Volume $= 11.2 \times M$

$M = 0.92$

$N = 2M$

$N = 1.84$



Answer Key

1	d	11	d	21	d	31	b	41	b
2	a	12	b	22	d	32	b	42	a
3	c	13	a	23	b	33	d	43	a
4	c	14	b	24	b	34	c	44	c
5	d	15	c	25	c	35	a	45	d
6	a	16	a	26	d	36	b	46	b
7	b	17	b	27	a	37	d	47	c
8	c	18	c	28	c	38	c	48	d
9	a	19	a	29	d	39	a	49	a
10	c	20	a	30	b	40	c	50	a