Chapter – 4

Hydrogen

I. Choose the best Answer:

Question 1.
Which of the following statements about hydrogen is incorrect ? (NEET – 2016)
(a) Hydrogen ion, H_3O^+ exists freely in solution.
(b) Dihydrogen acts a,s a reducing agent.
(c) Hydrogen has three isotopes of which tritium is the most common.
(d) Hydrogen never acts as a cation in ionic salts.

Answer:
(c) Hydrogen has three isotopes of which tritium is the most common.
Hint:
Correct statement:
Hydrogen has three isotopes of which protium is the most common.

Question 2.
Water-gas is …….
(a) $H_2\,O_{(g)}$
(b) $CO + H_2O$
(C) $CO + H_2$
(d) $CO + N_2$

Answer:
(c) $CO + H_2$

Question 3.
Which one of the following statements is incorrect with regard to ortho and para dihydrogen?
(a) They are nuclear spin isomers
(b) Ortho isomer has zero nuclear spins whereas the para isomer has one nuclear spin
(c) The para isomer is favoured at low temperatures
(d) The thermal conductivity of the para isomer is 50% greater than that of

the ortho isomer.

Answer:

(b) Ortho isomer has zero nuclear spins whereas the para isomer has one nuclear spin

Hints:

Correct statement:

Ortho isomer – one nuclear spin Para isomer – zero nuclear spin

Question 4.

Ionic hydrides are formed by ……..

(a) halogens

(b) chalcogens

(c) inert gases

(d) group one elements

Answer:

(d) group one elements

e.g., Sodium hydride ($Na^+ H^-$)

Question 5.

Tritium nucleus is contains ……..

(a) 1p + 0n

(b) 2p + 1n

(c) 1p + 2n

(d) none of these

Answer:

(c) lp + 2n

$_1T^3$ (le^-, lp, 2n)

Question 6.

Non-stoichiometric hydrides are formed by……..

(a) palladium, vanadium

(b) carbon, nickel

(c) manganese, lithium

(d) nitrogen, chlorine

Answer:
(a) palladium, vanadium

Question 7.
Assertion: Permanent hardness of water is removed by treatment with washing soda.

Reason: Washing soda reacts with soluble calcium and magnesium chlorides and sulphates in hard water to form insoluble carbonates
(a) Both assertion and reason are true and the reason is the correct explanation of assertion.
(b) Both assertion and reason are true but the reason is not the correct explanation of assertion.
(c) Assertion is true but the reason is false
(d) Both assertion and reason are false

Answer:
(a) Both assertion and reason are true and the reason is the correct explanation of assertion.
$Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3\downarrow + 2Na^+$

Question 8.
If a body of a fish contains 1.2 g hydrogen in its total body mass, if all the hydrogen is replaced with deuterium then the increase in body weight of the fish will be ……
(a) 1.2 g
(b) 2.4 g
(c) 3.6 g
(d) $\sqrt{4.8}$ g

Answer:
(a) 1.2 g
Hints:
Mass of deuterium $= 2 \times$ mass of protium
If all the 1.2 g hydrogen is replaced with deuterium, the weight will become 2.4g. Hence the increase in body weight is $(2.4 - 1.2 = 1.2$ g).

Question 9.
The hardness of water can be determined by volumetrically using the reagent

……..
(a) sodium thiosulphate
(b) potassium permanganate
(c) hydrogen peroxide
(d) EDTA

Answer:
(d) EDTA

Question 10.
The cause of permanent hardness of water is due to ……..
(a) $Ca(HCO_3)_2$
(b) $Mg(HCO_{3k})_3$
(c) $CaCl_2$
(d) $MgCO_3$

Answer:
(c) $CaCl_2$
Hints:
The permanent hardness of water is due to the presence of the chlorides, nitrates and sulphates of Ca^{2+} and Mg^{2+} ions.

Question 11.
Zeolite used to soften hardness of water is, hydrated ……..
(a) Sodium aluminium silicate
(b) Calcium aluminium silicate
(c) Zinc aluminium borate
(d) Lithium aluminium hydride

Answer:
(a) Sodium aluminium silicate
Zeolite is sodium aluminium silicate.
($NaAlSi_2O_6 .H_2O$)

Question 12.
A commercial sample of hydrogen peroxide marked as 100 volume H_2O_2, it means that ……
(a) 1 ml of H_2O_2 will give 100 ml O_2 at STP
(b) 1 L of H_2O_2 will give 100 ml O_2 at STP

(c) 1 L of H_2O_2 will give 22.4 L O_2
(d) 1 ml of H_2O_2 will give 1 mole of O_2 at STP

Answer:
(a) 1 ml of H_2O_2 will give 100 ml O_2 at STP

Question 13.
When hydrogen peroxide is shaken with an acidified solution of potassium dichromate in presence of ether, the ethereal layer turns blue due to the formation of
(a) Cr_2O_3
(b) CrO_4^{2-}
(c) $CrO(O_2)_2$
(d) none of these

Answer:
(c) $CrO(O_2)_2$ $CrO(O_2)_2$
Hints:
$Cr_2O_7^{2-} + 2H^+ + 4H_2O_2 \rightarrow 2CrO(O_2)_2 + 5H_2O$

Question 14.
For decolorization of 1 mole of acidified $KMnO_4$, the moles of H_2O_2 required is ……..
(a) $\frac{1}{2}$
(b) $\frac{3}{2}$
(c) $\frac{5}{2}$
(d) $\frac{7}{2}$

Answer:
(c) 5/2
Hints:
$2MnO_4^- + 5H_2O_{2(aq)} + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$

Question 15.
Volume strength of 1.5 N H_2O_2 is ……..
(a) 1.5
(b) 4.5

(c) 16.8
(d) 8.4
Answer:
(d) 8.4

Hints:
Volume strength of hydrogen peroxide = Normality of hydrogen peroxide × 5.6 = 1.5 x 5.6 = 8.4

$$\underset{(2 \times 34g)}{2H_2O_2} \rightarrow \underset{}{2H_2O} + \underset{(22.4 \text{ litres})}{O_2} \uparrow$$

Volume strength of hydrogen peroxide $= \frac{\text{Normality} \times \text{Equivalent weight of } H_2O_2 \times 2.24}{68}$

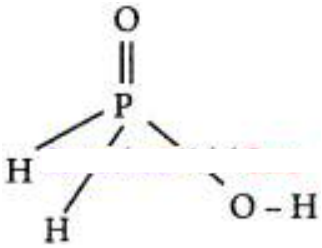
$= \text{Normality} \times \frac{17 \times 22.4}{68}$

Volume strength of hydrogen peroxide = Normality x 5.6

Question 16.
The hybridization of oxygen atom is H_2O and H_2O_2 are respectively
(a) sp and sp^3
(b) sp and sp
(c) sp and sp^2
(d) sp^3 and sp^3

Answer:
(d) sp^3 and sp^3

Question 17.
The reaction $H_3PO_2 + D_2O \rightarrow H_2DPO_2 + HDO$ indicates that hypo-phosphorus acid is ……
(a) tri basic acid
(b) di basic acid
(c) mono basic acid
(d) none of these



Answer:
(c) monobasic acid

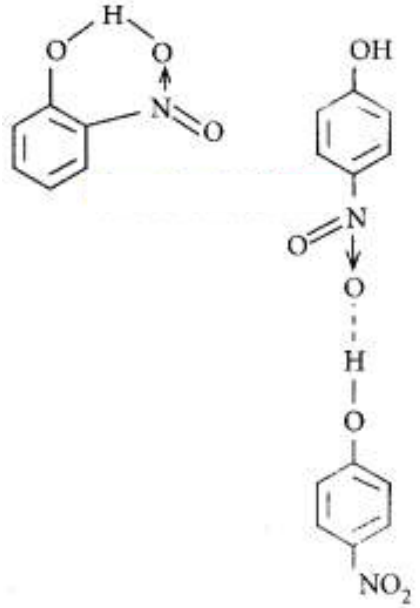
Hints:
Hypophosphorous acid on reaction with D_2O, only one hydrogen is replaced P by deuterium and hence it is monobasic.

Question 18.
In solid ice, the oxygen atom is surrounded
(a) tetrahedrally by 4 hydrogen atoms
(b) octahedrally by 2 oxygen and 4 hydrogen atoms
(c) tetrahedrally by 2 hydrogen and 2 oxygen atoms
(d) octahedrally by 6 hydrogen atoms

Answer:
(a) tetrahedrally by 4 hydrogen atoms

Question 19.
The type of H-bonding present in ortho nitrophenol and p-nitrophenol is respectively ……
(a) intermolecular H-bonding and intramolecular H-bonding
(b) intramolecular H-bonding and intermolecular H-bonding
(c) intramolecular H – bonding and no H – bonding
(d) intramolecular H – bonding and intramolecular H – bonding

o-nitro phenol p - nitro phenol



Answer:
(A) intramolecular H-bonding and intermolecular H-bonding

Question 20.
Heavy water is used as ……
(a) modulator in nuclear reactions
(b) coolant in nuclear reactions
(c) both (a) and (b)
(d) none of these

Answer:
(c) both (a) and (A)
Hints:
Heavy water is used as a moderator as well as a coolant in nuclear reactions.

Question 21.
Water is a ……
(a) basic oxide
(b) acidic oxide
(c) amphoteric oxide
(d) none of these

Answer:
(c) amphoteric oxide

II. Write brief answer to the following questions

Question 22.
Explain why hydrogen is not placed with the halogen in the periodic table.

Answer:
The electron affinity of hydrogen is much less than that of halogen atoms. Hence, the tendency of hydrogen to form hydride ions is low compared to that of halide ions. In most of its compounds hydrogen exists in a +1 oxidation state. Therefore, it is reasonable to place the hydrogen in group -1 along with alkali metals and not placed with halogens.

Question 23.
Discuss the three types of Covalent hydrides.

Answer:
Covalent hydrides are the compound in which hydrogen is attached to another element by sharing electrons. The most common examples of covalent hydrides of non-metals are methane, ammonia, water, and hydrogen chloride. Covalent hydrides are further divided into three categories, viz., electron precise (CH_4 C_2H_6), electron-deficient (B_2H_6), and electron-rich hydrides (NH_3H_2 O). Since most of the covalent hydrides consist of discrete, small molecules that have relatively weak intermolecular forces, they are generally gases or volatile liquids.

Question 24.
Predict which of the following hydrides is gas on a solid (a) HCl (b) NaH. Give your reason.

Answer:

- At room temperature, HCl is a colourless gas, and the solution of HCl in water is called hydrochloric acid and it is in a liquid state.

- Sodium hydride NaH is an ionic compound and it is made of sodium cations (Na^+) and hydride (H^-) anions. It has an octahedral crystal structure. It is an alkali metal hydride.

Question 25.
Write the expected formulas for the hydrides of 4th-period elements. What is the trend in the formulas? In what way the first two numbers of the series different from the others?

Answer:
The expected formulas of the hydrides of 4th-period elements are MH or MH_2. However, except for the first two members, many of the elements form non-stoichiometric interstitial hydrides with variable composition. The first two members of the period alkali metal (Potassium) and alkali earth metal (Calcium) forms ionic hydrides.

Question 26.
Write the chemical equation for the following reactions.

1. the reaction of hydrogen with tungsten (VI) oxide NO_3 on heating.
2. hydrogen gas and chlorine gas.

Answer:

1. $3H_2 + WO_2 \rightarrow W + 3H_2O$
   Hydrogen reduces tungsten (VI) oxide. WO_3 to tungsten at high temperature.
2. $H_2 + Cl_2 \rightarrow 2HCl$ (Hydrogen Chloride)
   Hydrogen reacts with chlorine at room temperature under light to give hydrogen chloride.

Question 27.
Complete the following chemical reactions and classify them into (a) hydrolysis (b) redox (c) hydration reactions.
(i) $KMnO_4 + H_2O_2 \rightarrow$
(ii) $CrCl3 + H_4O \rightarrow$
(iii) $CaO + H_2O \rightarrow$

Answer:
(i) $KMnO_4 + H_2O_2 \rightarrow 2KMnO_2 + 2KOH + 2H_2O + 3O_2$
The reaction of potassium permanganate with hydrogen peroxide is a redox reaction.

(ii) $CrCl_3 + H_2O \rightarrow [Cr(H_2O)_6]Cl_3$
It is a hydration reaction. Many salts crystallized from aqueous solutions form hydrated crystals. The water in the hydrated salt may form co-ordinate bonds.

(iii) $CaO + H_2O \rightarrow Ca(OH)_2$
It is a hydrolysis reaction. Calcium oxide hydrolyses to calcium hydroxide.

Question 28.
Hydrogen peroxide can function as an oxidizing agent as well as a reducing agent. Substantiate this statement with suitable examples.

Answer:
Hydrogen peroxide can function as an oxidizing agent as well as a reducing agent.

- H_2O_2 acts as an oxidizing agent in an acidic medium. For example,
  $2FeSO_4 + H_2SO_4 + H_2O_2 \rightarrow Fe_2(SO_4)_3 + 2H_2O$
  Ferrous sulphate — Ferric sulphate
- H_2O_2 acts as a reducing agent in a basic medium. For example,
  $2KMnO_{4\,(aq)} + 3H_2O_{2\,(aq)} \rightarrow 2MnO_2 + 2KOH + 2H_2O + 3O_{2\,(g)}$
  Potassium permanganate — Manganese dioxide

Question 29.
Do you think that heavy water can be used for drinking purposes?

Answer:

- Heavy water (D_2O) contains a proton and a neutron. This makes deuterium about twice as heavy as protium, but it is not radioactive. So heavy water is not radioactive.
- If you drink heavy water, you don't need to worry about radiation poisoning. But it is not completely safe to drink, because the

biochemical reaction in our cells is affected by the difference in the mass of hydrogen atoms.
- If you drink an appreciable volume of heavy water, you might feel dizzy because of the density difference. It would change the density of the fluid in your inner ear. So it is unlikely to drink heavy water.

Question 30.
What is the water-gas shift reaction?

Answer:
The carbon monoxide of water gas can be converted to carbon dioxide by mixing the gas mixture with more steam at 400°C and passed over a shift converter containing iron/copper catalysts. This reaction is called the water-gas shift reaction.
$CO + H_2O \rightarrow CO_2 + H_2\uparrow$

Question 31.
Justify the position of hydrogen in the periodic table?

Answer:
The hydrogen has the electronic configuration of $1s^1$ which resembles with ns^1 general valence shell configuration of alkali metals and shows similarity with them as follows:

1. It forms unipositive ion (H^+) like alkali metals (Na^+, K^+, Cs^+)

2. It forms halides (HX), oxides, (H_2O), peroxides (H_2O_2), and sulphides (H_2S) like alkali metals (NaX, Na_2O, NaH_2OH_2, NaH_2S)

3. It also acts as a reducing agent.
However, unlike alkali metals which have ionization energy ranging from 377 to 520 kJ mol^{-1}, hydrogen has 1,314 kJ mol^{-1} which is much higher than alkali metals.

Like the formation of halides (X^-) from halogens, hydrogen also has a tendency to gain one electron to form a hydride ion (H^-) whose electronic configuration is similar to the noble gas, helium. However, the electron affinity of hydrogen is much less than that of halogen atoms. Hence, the tendency of

hydrogen to form hydride ion is low compared to that of halogens to form the halide ions as evident from the following reactions:

$\frac{1}{2} H_2 + e^- \rightarrow H^-$ $\quad \Delta H = +36\ kcalmol^{-1}$

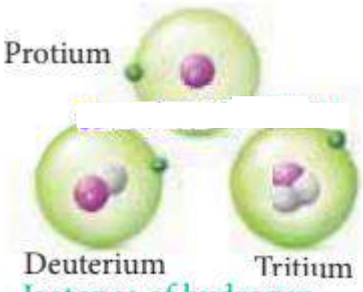
$\frac{1}{2} Br_2 + e^- \rightarrow Br^-$ $\quad \Delta H = -55\ kcalmol^{-1}$

Since hydrogen has similarities with alkali metals as well as halogens; it is difficult to find the right position in the periodic table. However, in most of its compounds hydrogen exists in a +1 oxidation state. Therefore, it is reasonable to place the hydrogen in group 1 along with alkali metals as shown in the latest periodic table published by IUPAC.

Question 32.
What are isotopes? Write the names of isotopes of hydrogen.

Answer:

1. Isotopes are atoms of the same element that have the same atomic number but having different mass numbers (or) Isotopes are atoms with the same number of protons and electrons but differ in a number of neutrons.
2. Hydrogen has three naturally occurring isotopes namely Protium ($_1H^1$), Deuterium ($_1H^2$), and Tritium ($_1H^3$).



Isotopes of hydrogen

Question 33.
Give the uses of heavy water.

Answer:
The uses of heavy water are as follows:

1. Heavy water is widely used as a moderator in nuclear reactors as it can lower the energies of fast neutrons
2. It is commonly used as a tracer to study organic reaction mechanisms and mechanism of metabolic reactions
3. It is also used as a coolant in nuclear reactors as it absorbs the heat generated.

Question 34.
Explain the exchange reactions of deuterium.

Answer:
Deuterium can replace reversibly hydrogen in compounds either partially or completely depending upon the reaction conditions. These reactions occur in the presence of deuterium.

$$\underset{\text{Methane}}{CH_4} + 2D_2 \rightarrow \underset{\text{Deutero methane}}{CD_4} + 2H_2$$

$$\underset{\text{Ammonia}}{2NH_3} + 3D_2 \rightarrow \underset{\text{Deutero ammonia}}{2ND_3} + 3H_2$$

Question 35.
How do you convert para-hydrogen into ortho hydrogen?

Answer:
At room temperature, normal hydrogen consists of about 75% ortho-form and 25% para-form. As the ortho-form is more stable than para-form, the conversion of one isomer into the other is a slow process. However, the equilibrium shifts in favour of para hydrogen when the temperature is lowered.

The para-form can be catalytically transformed into an I ortho-form using platinum or iron. Alternatively, it can also be converted by passing an electric j discharge, heating above 800°C, and mixing with paramagnetic molecules such as O_2, NO, NO_2, or with nascent/atomic hydrogen.

Question 36.
Mention the uses of deuterium.

Answer:

- Deuterium is used as a tracer element.
- Deuterium is used to study the movement of groundwater by isotopic effect.

Question 37.
Explain the preparation of hydrogen using electrolysis.

Answer:
High purity hydrogen (> 99.9 %) is obtained by the electrolysis of water containing traces of acid or alkali or the electrolysis of an aqueous solution of sodium hydroxide or potassium hydroxide using a nickel anode and iron cathode. However, this process is not economical for large-scale production.

At anode:

$$2OH^- \rightarrow H_2O + \frac{1}{2}O_2 + 2e^-$$

At cathode:

$$2H_2O + 2e^- \rightarrow 2OH^- + H_2$$

Overall reaction:

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2$$

Question 38.
A group metal (A) which is present in common salt reacts with (B) to give compound (C) in which hydrogen is present in a -1 oxidation state. (B) on reaction with a gas (C) to give universal solvent (D). The compound (D) reacts with (A) to give (B), a strong base. Identify A, B, C, D, and E. Explain the reactions.

Answer:
1. Group (1) metal (A) is present in common salt NaCl. So, (A) is sodium – Na.

2. Sodium reacts with hydrogen (B) to give sodium hydride – NaH (C) in which hydrogen is in a -1 oxidation state.

$$\underset{\text{Sodium (A)}}{2Na} + \underset{\text{Hydrogen (B)}}{H_2} \rightarrow \underset{\text{Sodium hydride (C)}}{2NaH}$$

3. Hydrogen on reaction with oxygen (O_2) gas which is (C) to give universal solvent water (D).

$$2H_2 + O_2 \rightarrow \underset{\text{Water}}{2H_2O}$$

4. Water (D) reacts with sodium metal (A) to give a strong base sodium hydroxide NaOH which is (E).

$$2Na + 2H_2O \rightarrow \underset{\text{Sodium hydroxide(E)}}{2NaOH} + H_2$$

A	Sodium	Na
B	Hydrogen	H_2
C	Oxygen	O_2
D	Water	H_2O
E	Sodium hydroxide	NaOH

Question 39.

An isotope of hydrogen (A) reacts with a diatomic molecule of the element which occupies group number 16 and period number 2 to give compound (B) is used as a modulator in a nuclear reaction. (A) adds on to a compound (C), which has the molecular formula C_3H_6 to give (D). Identify A, B, C, and D.

Answer:

1. An isotope of hydrogen Deuterium (A) reacts with a diatomic molecule of element belongs to group number 16 and period number 2 oxygen O_2 to give a compound (B) which is heavy water D_2O. D_2O is used as a moderator in a nuclear reaction.

$$\underset{\text{Deuterium (A)}}{2D_2} + O_2 \rightarrow \underset{\text{Heavy water (B)}}{2D_2O}$$

2. Deuterium reacts with C_3H_6 propane (C) to give Deutero propane C_2D_6 (D).

$$3D_2 + \underset{\text{Propane}}{C_3H_6} \rightarrow \underset{\text{Deutero propane}}{C_3D_6} + 3H_2$$

A	Deuterium	D_2
B	Heavy water	D_2O
C	Propane	C_3H_6
D	Deutero propane	C_3D_6

Question 40.
NH_3 has an exceptionally high melting point and boiling point as compared to those of the hydrides of the remaining element of group 15- Explain.

Answer:

1. NH_3 has an exceptionally high melting point and boiling point due to hydrogen bonding between NH_3 molecules.

2. Each molecule can form a maximum of 4 hydrogen bonds but on average 1 hydrogen bond per molecule as there is only one lone pair on NH_3 available for hydrogen bonding.

3. Hydrogen bonding is a strong intermolecular attraction as H on NH_3 acts as a proton due to partial positive on it the whole N has the partial negative charge. Thus when the very polarized H comes close to an N atom in another NH_3 molecule, a very strong hydrogen bond is formed.

4. Due to many strong intermolecular interactions compared to weaker permanent dipole-dipole interactions between other XH_3 molecules in group 15, a large amount of energy are required to overcome the forces, giving it the highest boiling point and highest melting point.

Question 41.
Why interstitial hydrides have a lower density than the parent metal.

Answer:
In interstitial hydrides, hydrogen occupies the interstitial sites. These hydrides show properties similar to parent metals. Most of these hydrides are non-stoichiometric with variable composition. Hence, interstitial hydrides have a lower density than the parent metal.

Question 42.
How do you expect the metallic hydrides to be useful for hydrogen storage?

Answer:

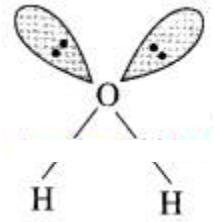
In metallic hydrides, hydrogen is adsorbed as H-atoms. Due to the adsorption of H atoms, the metal lattice expands and becomes unstable. Thus, when metallic hydride is heated, it decomposes to form hydrogen and finely divided metal. The hydrogen evolved can be used as fuel.

Question 43.
Arrange NH_3, H_2O, and HF in the order of increasing magnitude of hydrogen bonding and explain the basis for your arrangement.

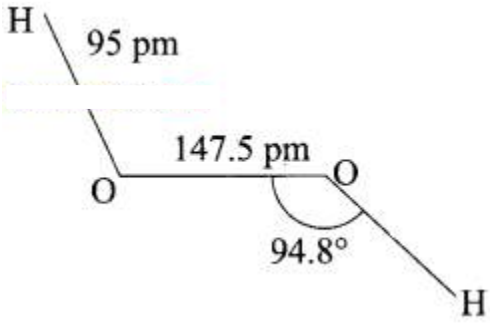
Answer:
When a hydrogen atom is covalently bonded to a highly electronegative atom such as nitrogen, the bond is polarized. Due to this effect, the polarized hydrogen atom is able to form a weak electrostatic interaction with another electronegative atom present in the vicinity. This interaction is called hydrogen bonding. The magnitude of hydrogen bonding increases with the increase in the electronegativity of the atom. Hence, the increasing magnitude of hydrogen bonding of NH_3, H_2O, and HF follows the order $NH_3 < H_2O < HF$.

Question 44.
Compare the structures of H_2O and H_2O_2.

Answer:
In water, O is sp^3 hybridized. Due to stronger lone pair-lone pair repulsions than bond pair-bond pair repulsions, the HOH bond angle decreases from 109.5° to 104.5°. Thus water molecule has a bent structure.



H_2O_2 has a non-planar structure. The 0 – H bonds are in different planes. Thus, the structure of H_2O_2 is like an open book.


H
95 pm
147.5 pm
O
O
94.8°
H