

UNIT-9

Hydrogen

SECTION-A: NCERT-Intext Questions with Answers

9.1. Justify the position of hydrogen in the periodic table on the basis of the electronic configuration.

Ans. Hydrogen electron configuration is $1s^1$. Hydrogen has one valence electron just like alkali metals. Therefore, hydrogen should be placed along with alkali metals in group 1. Like alkali metals, hydrogen also loses one electron to form H^+ ion but unlike alkali metal ions, H^+ ion does not exist freely. Also, to convert H into H^+ ion, ionization enthalpy is very high.

Hydrogen is also short of one electron to attain the nearest noble gas configuration. Hydrogen can also be placed along with halogens in group 17. Although hydrogen resembles alkali's metals and halogens but also differ from them also as well. Therefore, hydrogen has a unique position in the periodic table.

9.2. Write the names of isotopes of hydrogen. What is the mass ratio of these isotopes.

Ans. There are three isotopes of hydrogen.

(i) Protium, ${}^1_1\text{H}$

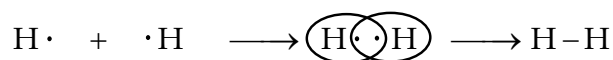
(ii) Deuterium, ${}^2_1\text{H}$

(iii) Tritium, ${}^3_1\text{H}$

The mass ratio of these isotopes is 1 : 2 : 3.

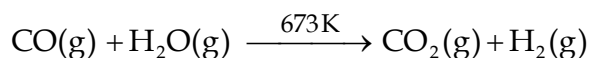
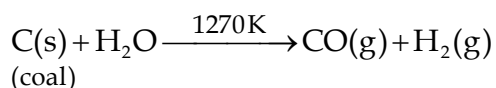
9.3. Why does hydrogen occur in a diatomic form rather than in an monatomic form under normal conditions?

Ans. Hydrogen atom has only one valence electron. In order to attain nearest noble gas configuration of helium, it share its one electron with itself and form a single covalent bond. Hence, hydrogen exist as a diatomic molecule rather than monoatomic



9.4. How can the production of dihydrogen, obtained from 'coal gasification', be increased?

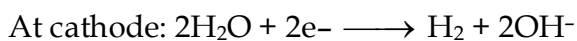
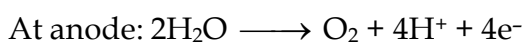
Ans. The production of hydrogen can be increased by absorbing the CO produced in H_2O (steam)



This is called **water gas shift reaction**.

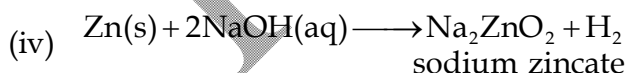
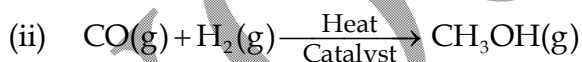
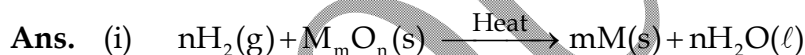
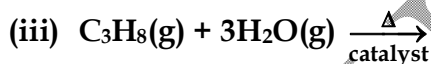
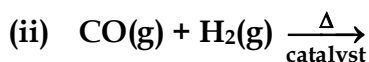
9.5. Describe the bulk preparation of dihydrogen by electrolytic method. What is the role of an electrolyte in this process?

Ans. Hydrogen is produced in bulk by the electrolysis of acidified water using platinum electrodes.



Electrolyte H_2SO_4 helps in the ionization of weak acid H_2O .

9.6. Complete the following reactions:



9.7. Discuss the consequences of high enthalpy of H - H bond in terms of chemical reactivity of dihydrogen.

Ans. The H-H bond dissociation enthalpy is the highest for a single bond between two atoms of any element. It is because of this factor that the dissociation of H_2 into its atoms is only 0.081% around 2000 K and increases to 95.5% at 5000 K. Because of this high bond dissociation enthalpy, H_2 is relatively inert at room temperature.

9.8. What do you understand by (i) electron-deficient, (ii) electron precise, and (iii) electron rich compounds of hydrogen? Provide justification with suitable examples.

Ans. (i) Electron-deficient hydrides

In these hydrides, the central atom has an incomplete octet, has too few electrons for writing its conventional Lewis structure.

These hydrides are electron pair acceptors and are called Lewis acids.

Examples: Diborane, Aluminium hydride.

(ii) Electron-precise hydrides

These hydrides have the required number of electrons to write their conventional Lewis structure.

All elements of group 14 form such compounds CH_4 , SiH_4 etc. All these are tetrahedral in shape.

(iii) Electron-rich hydrides

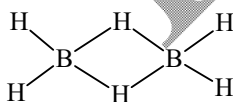
Electron -rich hydrides have excess electrons which are present as lone pairs. They all will behave as Lewis bases mean electron pair donor. Also the presence of electronegative atom N, O and F in hydrides results in hydrogen bond formation between the molecules and leads to the association of molecules.

Examples: :NH_3 (one lone pair) $\text{H}_2\ddot{\text{O}}$ (two lone pair) $\text{HF}\ddot{\text{F}}$ (three lone pair)

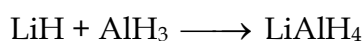
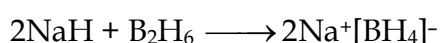
9.9. What characteristic do you expect from an electron-deficient hydride with respect to its structure and chemical reactions?

Ans. Electron deficient hydrides are all electron deficient, have an incomplete octet. All are Lewis acids. In order to complete the octet, all exists in the polymeric form.

Example is diborane, B_2H_6



They also react with alkali metal hydride to form mixed hydrides used as reducing agent.



9.10. Do you expect the carbon hydrides of the type (C_nH_{2n+2}) to act as 'Lewis' acid or base? Justify your answer.

Ans. Carbon hydrides of the type C_nH_{2n+2} are called alkanes. Alkanes are electron precise hydrides. So, they have no tendency to lose electron pair or gain electron pair. Hence, carbon hydrides of the type C_nH_{2n+2} are neither Lewis acids nor Lewis bases.

9.11. What do you understand by the term "non-stoichiometric hydrides"? Do you expect this type of the hydrides to be formed by alkali metals? Justify your answer.

Ans. Non-stoichiometric hydrides are deficient in hydrogen like $LaH_{2.87}$, $TiH_{1.5-1.8}$ etc. In these hydrides, the metal to hydrogen ratio is not a whole number ratio. These are mainly formed by many d-block and f-block elements. Alkali metals do not form non-stoichiometric hydrides. Their hydrides are always stoichiometric hydrides and the law of constant composition hold good.

9.12. How do you expect the metallic hydrides to be useful for hydrogen storage? Explain.

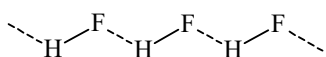
Ans. In metallic hydrides, the hydrogen is adsorbed as H-atom. Due to the inclusion of H atom, the metal lattice expands and thus becomes less stable. Therefore, when the metallic hydride is heated, it decompose to form hydrogen and very finely divided metal. The hydrogen thus evolved used as a fuel. Thus, transition metals or their alloys can be used to store and transport hydrogen to be used as fuel. This is called **hydrogen economy**.

9.13. How does the atomic hydrogen or oxy-hydrogen torch function for cutting and welding purposes? Explain.

Ans. Atomic hydrogen atoms are produced by dissociation of dihydrogen with the help of an electric arc. These hydrogen atoms are allowed to recombine on the surface to be welded to generate the temperature of 4000 K. Atomic hydrogen and oxy-hydrogen torches are used for cutting and welding purposes.

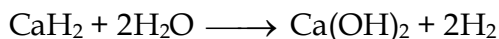
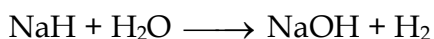
9.14. Among NH_3 , H_2O and HF , which would you, expect to have highest magnitude of hydrogen bonding and why?

Ans. All three hydrides NH_3 , H_2O and HF can undergo association via intermolecular hydrogen bonding. But due to highest electronegativity of F, H - F is the most polar and hydrogen has the most positive charge on it. Hence, the electrostatic attraction between the H of one HF and F of second H - F molecule is the strongest.

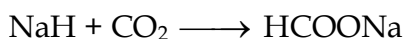


9.15. Saline hydrides are known to react with water violently producing fire. Can CO₂ a well known fire extinguisher, be used in this case? Explain.

Ans. Saline or ionic hydrides reacts vigorously with water to liberate H₂ gas



These reactions are highly exothermic and H₂ evolved catches fire. The fire so produced cannot be extinguish by CO₂ because CO₂ gets reduced by metal hydride to metal formate.



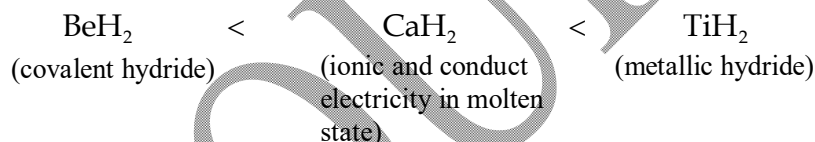
Hence, CO₂ cannot be used.

Instead, the sand is used as it is highly stable solid with high melting point.

9.16. Arrange the following:

- (i) CaH₂, BeH₂ and TiH₂ in order of increasing electrical conductance.
- (ii) LiH, NaH and CsH in order of increasing ionic character.
- (iii) H - H, D - D and F - F in order of increasing bond dissociation enthalpy.
- (iv) NaH, MgH₂ and H₂O in order of increasing reducing property.

Ans. (i)



(ii) LiH < NaH < CsH

Down the group, the electronegativity of metal decreases and the electronegativity difference increases. Hence ionic character increases.

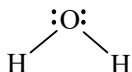
(iii) F - F < H - H < D - D

F - F bond is the weakest due to small size and strong repulsions between the lone pair and lone pair.

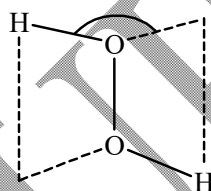
D - D bond is the strongest due to greater nuclear mass, the bond pair in D - D bond is attracted stronger by the nuclei.

(iv) H₂O < MgH₂ < NaH

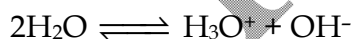
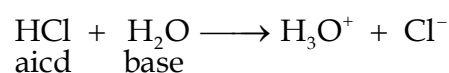
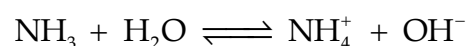
(ionic hydride and can release H₂ easily)

9.17. Compare the structures of H_2O and H_2O_2 .Ans. H_2O O \longrightarrow sp^3 hybridised H_2O is AX_2E_2 type molecule. H_2O has a tetrahedral geometry and is bent shapeThe bond angle is 104.6° and not 109° due to lone pair-lone pair repulsions. H_2O_2 H_2O_2 has a non-planar structure.

Two oxygen atoms are linked to each other by single covalent bond which is longer than expected due to lone pair-lone pair repulsions.

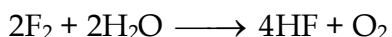
Each oxygen is single bonded to hydrogen. The two O - H bonds are in different planar. The H_2O_2 has a open book structure. H_2O_2 structure in gas phase.

9.18. What do you understand by the term 'auto-protolysis' of water? What is its significance?

Ans. Auto protolysis of water means self-ioniation of water to give both H^+ ion or H_3O^+ ion and OH^- ions.That's why H_2O is amphoteric in nature and shows both acidic and basic properties.And with NH_3 , H_2O act as an acid.

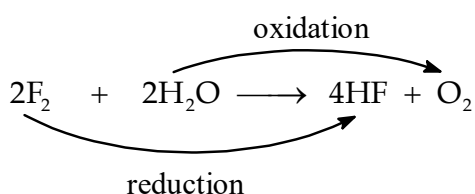
9.19. Consider the reaction of water with F_2 and suggest, in terms of oxidation and reduction, which species are oxidized/reduced.

Ans. F_2 is a very powerful oxidising agent and oxidizes H_2O to O_2 gas.



Oxidation state of fluorine is changing from zero in F_2 to -1 in HF . Fluorine is gaining electrons and hence F_2 is the oxidizing agent.

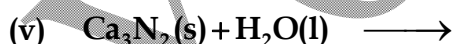
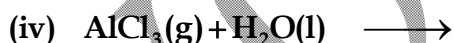
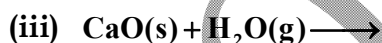
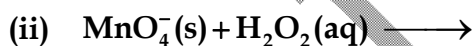
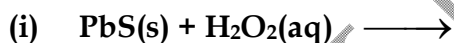
The oxidation state of oxygen is changing from -2 in H_2O to zero in O_2 . This reaction is called **oxidation** and hence H_2O is a **reducing agent**.



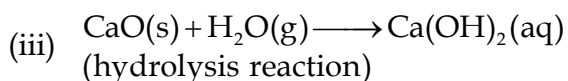
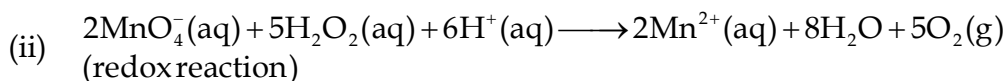
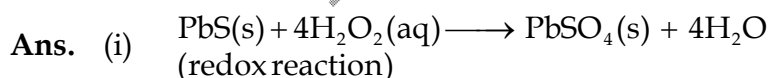
Substance oxidized : H_2O

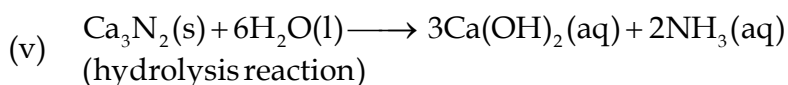
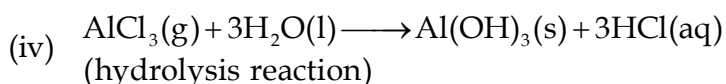
Substance reduced: F_2

9.20. Complete the following chemical reactions.



Classify the above into (a) hydrolysis (b) redox and (c) hydration reactions.





9.21. Describe the structure of the common form of ice.

Ans. Ice has a highly ordered three-dimensional hydrogen bonded structure. Each oxygen atom is sp^3 hybridised and is surrounded tetrahedrally by four oxygen atoms.

Hydrogen bonding gives ice a rather open type structure with wide holes.

9.22. What causes the temporary and permanent hardness of water?

- Ans.** (i) **Temporary hardness** is due to the presence of magnesium and calcium bicarbonates.
(ii) **Permanent hardness** is due to the presence of soluble salts of magnesium and calcium in the form of chlorides and sulphates in water.

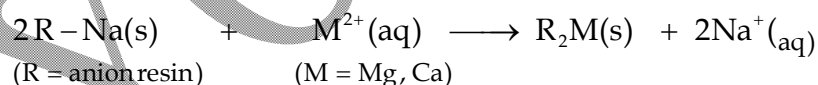
9.23. Discuss the principle and method of softening of hard water by synthetic ion exchange resins.

Ans. Synthetic ion-exchange resin method.

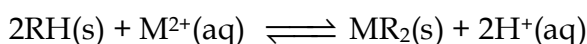
This method is more efficient to remove hardness of water. There are two types of ion-exchange resins

- (i) **Cation exchange resin** contain large molecule with $-\text{SO}_3\text{H}$ group and are water soluble.

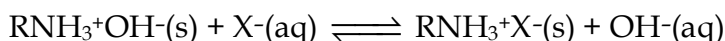
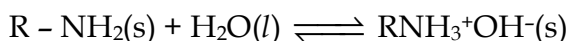
Ion-exchange resin (RSO_3H) is changed to RNa by treating with NaCl . The resin exchange Na^+ ions with Ca^{2+} and Mg^{2+} ions present in hard water to make the water soft.



Pure de-mineralised water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the form of H^+) and an anion-exchange (in the form of OH^-).

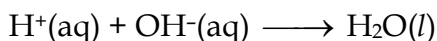


In this cation exchange process, H^+ exchanges for Na^+ , Ca^{2+} and Mg^{2+} in water. This process result in proton release and thus makes the water acidic.

Anion exchange process

OH^- exchanges for anions like Cl^- , HCO_3^- , SO_4^{2-} present in water.

OH^- ions, thus liberated neutralize the H^+ ions set free in the cation exchange.

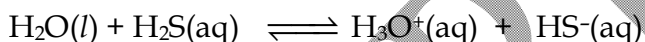
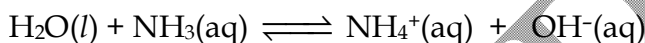


The exhausted cation and anion exchange resin beds are regenerated by treatment with dilute acid and alkali solutions respectively.

9.24. Write chemical reactions to show the amphoteric nature of water.

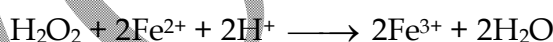
Ans. Water has the ability to act as an acid as well as base i.e., it behaves as an amphoteric substance.

In the Bronsted sense it acts as an acid with NH_3 and a base with HCl or H_2S .

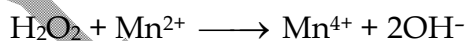
**9.25. Write chemical reactions to justify that hydrogen peroxide can function as an oxidizing as well as reducing agent.**

Ans. (a) H_2O_2 act as an oxidizing agent and oxidation state of oxygen changes from -1 to -2 in H_2O or OH^- .

(i) H_2O_2 oxidises Fe^{2+} to Fe^{3+} in acidic medium

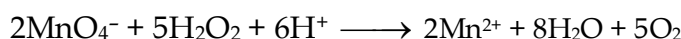


(ii) H_2O_2 oxidises Mn^{2+} to Mn^{4+} in alkaline medium



(b) H_2O_2 act as a reducing agent and oxidation state of oxygen changes from -1 to zero in O_2 .

(i) H_2O_2 reduced MnO_4^- to Mn^{2+} in acidic medium



(ii) H_2O_2 reduces MnO_4^- to MnO_2 in basic medium



9.26. What is meant by de-mineralised water and how can it be obtained?

Ans. De-mineralized water is a water which is free from all cations and anions.

Pure de-mineralised or de-ionised water free from all soluble mineral salts is obtained by passing water successively through a cation exchange (in the form of H^+) and an anion exchange (in the form of OH^-) resins.

9.27. Is de-mineralised or distilled water useful for drinking purposes? If not, how can it be made useful?

Ans. De-mineralised water or distilled water is not useful for drinking purposes as it does not contain any useful minerals. To make it useful for drinking purposes, useful minerals are added in proper amounts to make water tasteful and proper pH.

9.28. Describe the usefulness of water in biosphere and biological systems.

Ans. Water has a higher specific heat, thermal conductivity, surface tension, dipole moment and dielectric constant allow water to play a key role in the biosphere.

The high heat of vapourisation and heat capacity are responsible for moderation of the climate and body temperature of living beings.

It is an excellent solvent for transportation of ions and molecules required for plant and animal metabolism. Due to hydrogen bonding with polar molecules even covalent compounds like alcohol and carbohydrates dissolve in water.

9.29. What properties of water make it useful as a solvent? What types of compound can it (i) dissolve, and (ii) hydrolyse?

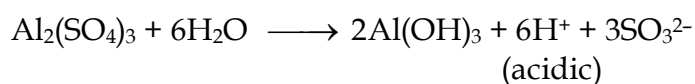
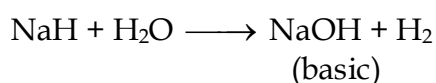
Ans. Water is a good universal solvent due to

(i) high dielectric constant

(ii) high dipole moment

(i) That's why ionic compound dissolve in water due to ion-dipole interaction (or hydration) and covalent compounds like alcohol, carboxylic acids, carbohydrates dissolves due to hydrogen bonding with water.

(ii) Water can also hydrolyse number of compounds like hydrides, carbides, salts to give either acidic or basic solutions.

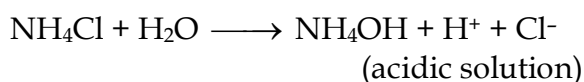
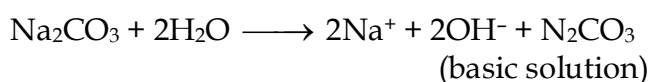


9.30. Knowing the properties of H_2O and D_2O , do you think that D_2O can be used for drinking purposes?

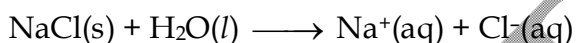
Ans. Heavy water cannot be used for drinking purposes. Heavy water slows down the rates of reaction in plants and in human beings. Hence, heavy water is injurious to plants, animals and human beings.

9.31. What is the difference between the terms 'hydrolysis' and 'hydration'?

Ans. Hydrolysis is the reaction of salt with water to form either acidic or basic solution.

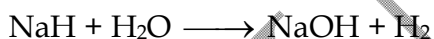


Hydration is the reaction of salt with water to form hydrated ions with no change in pH



9.32. How can saline hydrides remove traces of water from organic compounds?

Ans. Saline hydrides removes traces of water from organic compounds and hydrolyse to give metal hydroxides and libertes H_2 gas. Example



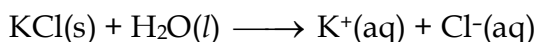
9.33. What do you expect the nature of hydrides is, if formed by elements of atomic numbers 15, 19, 23 and 44 with dihydrogen? Compare their behavior towards water.

Ans.

	Element	Hydride	Nature of hydride	Behaviour towards water
(i)	At. no. 15	PH_3	Covalent	No reaction
(ii)	At. no. 19	KH	Ionic	Gives basic solution
(iii)	At. no. 23	$\text{VH}_{0.56}$	Metallic interstitial	or No reaction
(iv)	At. no. 44	Ruthenium from group 8 does not form hydride	—	—

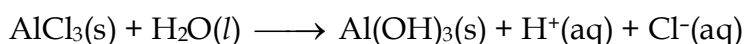
9.34. Do you expect different products in solution when aluminium (III) chloride and potassium chloride treated separately with (i) normal water (ii) acidified water and (iii) alkaline water? Write equations wherever necessary.

Ans. (i) KCl is a salt of strong base and strong acid. It does not undergo hydrolysis in normal water. It only undergo hydration.

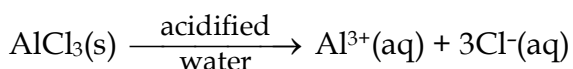


In acidified or alkaline water, the ions remains unaffected.

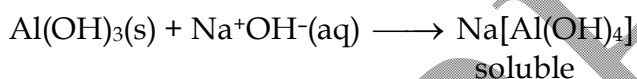
(ii) AlCl_3 is a salt of weak base and strong acid. It undergo hydrolysis in normal water



In acidified water, AlCl_3 exists as $\text{Al}^{3+} + \text{Cl}^-$

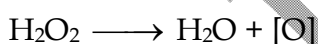


In alkaline water, $\text{Al}(\text{OH})_3$ dissolves to give soluble aluminate ion.



9.35. How does H_2O_2 behave as a bleaching agent?

Ans. The bleaching action of H_2O_2 is due to the nascent oxygen which it liberates on decomposition



This nascent oxygen combines with coloured matter and make them colourless.

9.36. What do you understand by the terms.

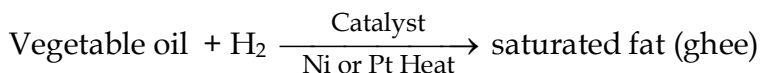
(i) hydrogen economy (ii) hydrogenation (iii) syngas (iv) water gas shift reaction (v) fuel-cell.

Ans. (i) **Hydrogen economy**

It deals with the production, storage and transportation of energy in the form of liquid acid gaseous hydrogen to be used as a fuel in motor vehicles, power plants, etc.

(ii) **Hydrogenation**

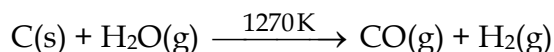
It is the addition of hydrogen to alkenes or alkynes in the presence of catalyst to form alkanes. This hydrogenation is used in the conversion of oil into fats.



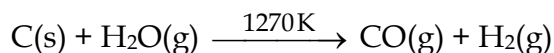
(iii) Syngas

The mixture of CO and H₂ is called **water gas**. As this mixture of CO and H₂ is used for the synthesis of methanol and a number of hydrocarbons, it is also called **synthesis gas** or **syn gas**.

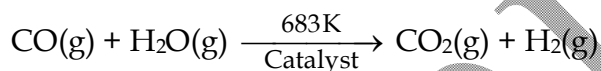
Nowadays, 'syngas' is produced from sewage, saw-dust, scrap wood, etc. The process of producing 'syngas' from coal is called **coal gasification**.

**(iv) Water-gas shift reactions**

The production of H₂ in the



can be increased by reacting CO of 'syngas' mixture with steam in the presence of iron chromate as a catalyst.



This is called **water gas shift reaction**.

(v) Fuel cell

Fuel cell converts the heat energy of the fuel directly into electrical energy.

Dihydrogen is used in fuel cells for generating electrical energy. It has many advantages over conventional fossil fuels and electric power. It does not produce any pollution and releases greater energy per unit mass of fuel in comparison to gasoline and other fuels. The net reaction in the H₂ - O₂ fuel cell is

