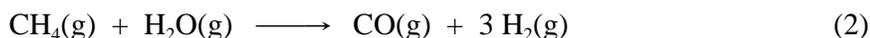


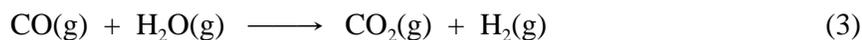
# Chemical of the Week

## HYDROGEN — H<sub>2</sub>

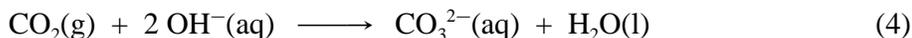
Hydrogen is an important commercial chemical. It is prepared industrially by two processes: the “water gas reaction” using coke and water (equation 1), and the steam reforming process using natural gas and water (equation 2). Both reactions require high temperatures.



The mixture of products from these two reactions is often called synthesis gas or syngas. The carbon monoxide in this gaseous mixture can be made to react with more water in the “water gas shift reaction” (equation 3) to produce hydrogen and CO<sub>2</sub>.



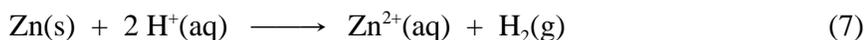
The CO<sub>2</sub> is then easily removed by passing this gas through a solution of sodium hydroxide. The carbon dioxide reacts and dissolves (equation 4), leaving pure hydrogen.



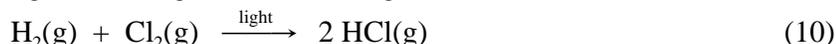
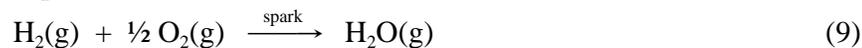
A subject of much current interest in chemistry is the conversion of synthesis gas (CO + H<sub>2</sub>) to other products such as methanol (equation 5) and liquid hydrocarbons (equation 6). These substances could be used as synthetic fuels, such as substitutes for gasoline.



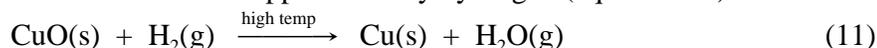
In the laboratory, hydrogen is easily prepared by the reaction of a reactive metal such as zinc or magnesium with an acid (equation 7). It can also be obtained by electrolysis of water (equation 8). These methods are too expensive for use in commercial production of H<sub>2</sub>.



Hydrogen is a colorless, odorless gas. It is the least dense gas, having a density of 0.089 g/liter at 0°C and 1 atmosphere (standard temperature and pressure, STP). It is not very soluble in water; only 1.9 mg dissolves in a liter of water at 0°C. It reacts vigorously with many elements including oxygen and halogens, as was demonstrated in lecture (equations 9 and 10).

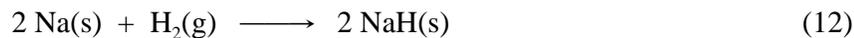


At high temperatures, H<sub>2</sub> reacts with metal oxides to form water vapor and metal. For example, as shown in lecture, hot copper oxide is reduced to copper metal by hydrogen (equation 11).



The copper oxide used in lecture was formed by heating copper in air.

Hydrogen also reacts with active metals such as sodium to give a group of compounds known as metal hydrides, which contain the hydride anion, H<sup>-</sup> (equation 12).



About 40% of the hydrogen produced industrially is used in the preparation of ammonia by the Haber process. Ammonia's primary use is as an agricultural fertilizer. A large portion of manufactured ammonia is also used in the production of nitric acid. Oxidation of  $\text{NH}_3$  gives  $\text{H}_2\text{O}$  and  $\text{NO}_2$ , and the latter can be converted to nitric acid,  $\text{HNO}_3$ .

#### REFERENCES

1. B. Z. Shakhshiri, *Chemical Demonstrations: A Handbook for Teachers of Chemistry*, Volume 1, pp.106, 121, University of Wisconsin Press (1983).
2. B. Z. Shakhshiri, *Chemical Demonstrations: A Handbook for Teachers of Chemistry*, Volume 2, p.131, University of Wisconsin Press (1985).
3. B. Z. Shakhshiri and R. Schreiner, *Instructors Guide to accompany Shakhshiri Chemical Demonstrations Videotapes*, p.16, Saunders College Publishing (1991).