15.15: Hydrogen for Energy Storage and Utilization

Hydrogen gas, H_2, can serve as a pollution-free means to store and utilize energy. Elemental hydrogen is the least polluting of fuels because it produces only water. Electricity that is generated on an intermittent basis from solar, wind, and even tidal flow processes can be used to electrolyze water,

$$2\,H_2O + \text{electrical energy} \rightarrow 2\,H_2(g) + O_2(g) \tag{15.15.1}$$

and the hydrogen piped some distance and combusted in an engine, used in a fuel cell (Figure 15.5(5)), or stored by pumping it underground. Although not yet practical, direct photochemical processes that can split water molecules to H_2 and O_2 are attractive from the viewpoint of sustainability.

Hydrogen is employed to a limited extent to power vehicles. Such vehicles using internal combustion engines fueled with hydrogen are especially well adapted to Iceland where abundant geothermal and hydroelectric power provide ample supplies of electrolytically generated hydrogen. Furthermore, in Iceland it is not possible to drive long distances so that one is unlikely to be stranded far from a refueling station. Honda has made a very limited number of fuel-cell-powered automobiles available for lease in southern California where the company has established hydrogen fueling stations.

The idea of a “hydrogen economy” in which H_2 gas is the predominant medium of energy transfer, storage, and utilization may be too optimistic because of factors such as hydrogen’s low heating value per unit volume and the wide range of explosive mixtures it forms with air. One of the greatest barriers to the widespread adoption of hydrogen-fueled vehicles has been their inability to carry sufficient hydrogen for an acceptable range. Several solutions to this problem are now being investigated. One possibility is the storage of hydrogen in high-strength containers at up to almost 700 times atmospheric pressure reputed to contain sufficient hydrogen to propel an automobile 300 miles. Solids with very high sorptive capacities for H_2 (“super activated carbons”)are being investigated for hydrogen storage. Liquid fuels including gasoline and methanol can be broken down catalytically to generate hydrogen, but in so doing release greenhouse gas carbon dioxide.

Unlike fossil fuels such as methane, elemental hydrogen is not a primary source of energy and must be produced from other energy sources. In addition to generation by the electrolysis of water, most hydrogen now is produced by steam reforming of methane from natural gas

$$CH_4 + H_2O \rightarrow 3\,H_2 + CO \tag{15.15.2}$$

The carbon monoxide product can be reacted with steam,

$$CO + H_2O \rightarrow CO_2 + H_2 \tag{15.15.3}$$

to produce additional H_2 and the CO_2. Such a process is counterproductive in providing fuel especially in that methane gas is easier to store and transport than elemental hydrogen and the modern internal combustion engine with associated emissions controls running on methane is virtually pollution-free. So the intermediate step to produce elemental hydrogen is not a very sustainable approach. Although production of elemental hydrogen by electrolysis of water using electricity from renewable sources as discussed above is essentially non-polluting, electrolysis is a relatively inefficient means of using electrical energy, which might more sustainably be used for example in charging batteries in plugin hybrid vehicles.