PRELIMINARIES OF HYDROGEN ENERGY SYSTEMS

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Summary

Electric power, city-gas, and refined fossil fuel are presently the typical major energy carriers. The civilization of human beings has been supported by these carrier systems. However, the greenhouse effect of carbon dioxide resulting from fossil fuel utilization and the systematic safety problems of nuclear energy have led to concerns about increasing production of fossil fuels and a moratorium on nuclear generation. Conversion of energy systems must be, by all means, necessary as early as possible. We shall show, in this theme, that the most suitable system is to apply hydrogen as an energy medium, and the preliminaries of the systems are introduced in this Topic.

Hydrogen can be recycled via water, from which it is manufactured, and only water is produced when hydrogen burns. It is clean and powerful. Photosynthesis has the water-splitting process as its basis. Water-splitting technology by using renewable energy can be said to be the man-made photosynthesis.

In addition to the clean energy usages, the reversible and recycled usages of hydrogen should be noted, as innoxious heat mediums are needed today.

As the preliminaries of the hydrogen energy systems, the physical and chemical properties of hydrogen, the statistical data on hydrogen production and utilization, and the main international research programs are introduced in detail in this Topic.

1. Introduction: From Fossil Fuel to Hydrogen

Civilization has been greatly dependent on energy resources. These resources have changed from wood (charcoal) to coal, from coal to heavy oil, from heavy oil to light oil, and from light oil to fuel gas. By analyzing the changing tendency of fuel, we can find a rule.

Figure 1 shows a historical, but rough, tendency of the main fossil fuels. Fossil fuels are denoted by chemical notation as C_nH_m, where n and m are integers representing the number of carbon atoms and hydrogen atoms, respectively. For example, coal, methane, and hydrogen are expressed by C1H0 = C, CH4, and C0H2 = H2, respectively. On the vertical axis is the number (n) of carbon atoms and on the horizontal axis is the number ratio (m/n) of hydrogen to carbon. It can be seen that a clear trend exists in the direction of carbon, heavy oil, light oil, kerosene, naphtha, isooctane, gasoline, *N*-pentane, butane, propane, ethane, and methane. This indicates a trend from a fossil fuel with large n and small m/n to small n and large m/n, viz., from coal with n = 1 and m/n = zero to methane with n = 1 and m/n = 4. The author pointed out this trend in 1973.

On the vertical axis of the right hand side are indicated the boiling temperatures (in K) of each of the hydrocarbons. It is known that, at normal state, coal is a solid, heavy oil is highly viscous, gasoline is volatile, propane is gaseous, and methane is the lightest natural gas. Fossil fuels with small n and large m/n are in the gaseous state under normal conditions. These fuels are associated with oil production at oil fields, and are known by the name of LPG (liquefied petroleum gas, propane is the most popular). Total LPG production in the world was 81.76 million metric tons (Mt) in 1997, 58% of which was consumed in Japan. Most of the taxis in Japan are driven by LPG instead of gasoline. As shown in Figure 1.3, the boiling temperatures of these gases are relatively low, so that they can be readily liquefied by applying about 10 atmospheric pressure.

There are good reasons for this trend in hydrocarbon utilization:

1. Fossil fuels with high carbon content almost always contain high levels of sulfur and emit noxious gases on combustion.
2. The high-carbon hydrocarbons are heavy, highly viscous, and therefore difficult to handle.
3. CO_2 emissions are much greater than those of low-carbon hydrocarbons.

This trend will be more and more strengthened in the future. One must notice that the ultimate natural fuel (fossil fuel) is methane with m/n = 4. However, since methane is depletable, the truly ultimate fuel becomes hydrogen. It has m/n = infinite, is the lightest, and can be liquefied. Nevertheless, hydrogen fuel is not produced from underground (not a resource), but must be generated artificially from water using renewable energies.

According to this tendency, the twenty-first century will be at first the “methane age,” and then, the “hydrogen age.” One factor that supports this prediction is the existence of methane hydrate. Methane hydrate is a stable state of methane molecule, which is included in a cage of linked water molecules. There exist very large methane hydrate resources under the permanent frozen earth in Siberia and under the deep seas near Siberia and the Pacific side of the Japan Sea. Total methane hydrate resources are estimated to be 100 times the confirmed reserves of methane.

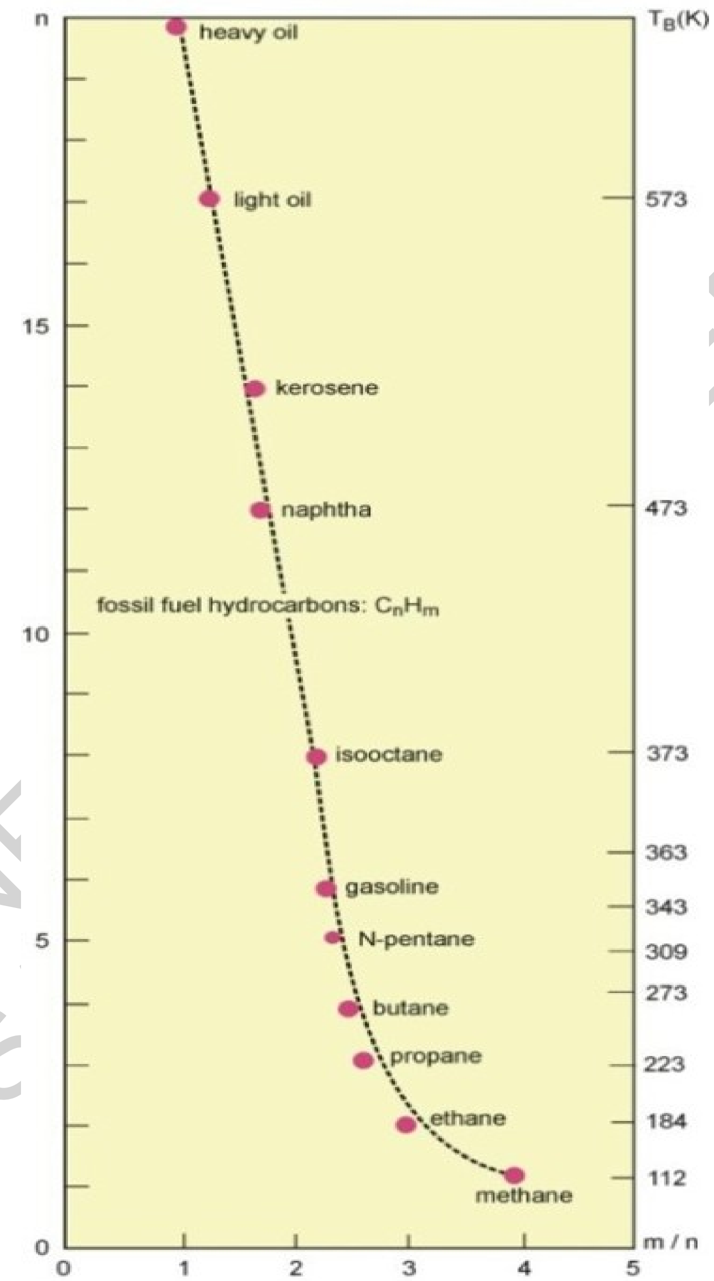

Figure 1. Tendency of used fossil fuel. The fuel with a larger value m/n ratio is emerging.

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Biographical Sketch

Tokio Ohta, born November 3, 1925, in Japan, received his education from the Department of Physics, University of Kyoto with a Ph.D. degree in Solid State Physics; he has taught at the University of Kyoto, Portland State University of Oregon, USA, and at the University of Tokyo, and served as the Dean of Faculty of Engineering, Yokohama National University (1985–1988), and President of Yokohama National University (1988–1994). Since 1999 he has been Superintendent of the International Network University; other appointments include the Committee Staff of Science and Technology to the Prime Minister (1974–1994) and the Committee Staff of the Minister of International Trade send Industry (1794–1999). He has published some 160 papers and 60 books on solid state physics and energy systems. He has been elected Vice President of the International Association for Hydrogen Energy, and is the Founding Past President of the Hydrogen Energy Systems Society of Japan.