			Name: ()
5 5	A CONTRACTOR	Chem!stry	Class:
SCHOOL OF SCIENCE AND TECHNOLOGY, SINGAPORE	appeo .		Date: / /

Toyota's New Hydrogen Car

Toyota Unveils a New Hydrogen Sedan Car, Mirai, Which Means "Future" in Japanese

On 15th December, Toyota released the Mirai, a hydrogen car, in Japan. Other car firms such as Honda, Audi, Hyundai, General Motors and Mercedes-Benz are also planning to release their own versions. Hydrogen cars can either burn the gas in an engine or use it in fuel cells to drive an electric motor, producing water as a by-product.

Hydrogen is one of the most abundant elements on Earth and is one of the building elements of the water molecule. In its gaseous form, it was famously used during the early part of the 20th century for the transatlantic Zeppelins that used to ferry passengers until the Hindenburg burst into flames in 1937 in Lakehurst, New Jersey.

But modern standards of handling hydrogen have improved greatly in terms of safety and efficiency. Several articles said Toyota even went to the extent of testing its hydrogen fuel tank to withstand gunshot bullets and extreme crash tests. The Mirai fuel tank uses triple-layered carbon fibre, one of the strongest materials available.

Several experts have said hydrogen has got a bum rap from the Hindenburg disaster, but is actually safer than petrol, even if it leaks.

Hydrogen is often made from methane or from thermally gasifying, in a low oxygen environment, fossil fuels such as coal, which releases the hydrogen in gaseous form, but does not release the carbon into the atmosphere. It can also be made from waste-to-energy processes. There are also other methods, including electrolysis, but these are expensive.

Because the by-product of a fuel cell is water and not greenhouse gases, hydrogen is a very environmentally friendly gas. In fact, the United States National Aeronautics and Space Administration (NASA) has been using hydrogen fuel cells to produce electricity and water for its space missions. But special materials that can withstand hydrogen's very reactive properties have to be used.

Critics abound such as Mr. Elon Musk, chief executive officer of Tesla, whose latest version of its electric car can now go over 640 km on a single charge, and Dr. Joseph Romm, a former US Department of Energy official, who argue that the environmentally friendly nature of using hydrogen at the vehicle-end should factor in the energy required to produce it.

1

Challenges to Go Hydrogen

Make no mistake, Toyota's effort at a hydrogen car will be fraught with challenges, both technological and economic. These include the high cost of the vehicles, the challenges of producing hydrogen at low cost and the lack of a fuelling infrastructure. Although there are still technological hurdles, a lot of it is now shifting to the economic side. The fuel cell itself is still expensive, especially due to the use of platinum as a catalyst, although research continues to try to find ways to drop its price. Media reports estimate the Mirai to retail in Japan initially for US\$ 58,000 (S\$ 76,700).

Take for example a potential Singaporean buyer of a hydrogen car. To be practical, Singapore has to be dotted with a few hydrogen-charging stations, allowing the user to operate the vehicle for a few days, including possibly crossing over to Malaysia for a trip, although the range on a full tank of hydrogen can go up to 480 km. Such considerations need to be factored in. Early buyers would most probably be environmentally-conscious early adopters, who want to make a statement and who do not mind paying the high price tag to be different from their peers.

Unfortunately, unlike the turn of the 20th Century, which saw the development of early vehicles such as the Ford Model T going hand-in-hand with the development of the petroleum industry, there are now other alternatives. So hydrogen vehicles have to contend with fragmented efforts, unlike when the petrol / diesel car was developed; it was mostly for all intents and purposes the only game in town. Now there are other technologies out there such as the electric car.

The hydrogen car does have one advantage. It can be filled-up quickly in a few minutes and can run up to 480 km on a tankful. Contrast this with the 20 minutes it takes for a Tesla to charge its battery halfway – and that is already state-of-the-art for electric vehicle fast-charging.

In building a hydrogen car and releasing it to the market, Toyota has thrown its multi-billion dollar muscle into a new market as it had done with the Prius hybrid, which has been a success for the company.

Whether to go hydrogen or not is an issue that will occupy the automotive community for some time with endless debate and discussion. Whether the ecosystem responds remains to be seen, but at least we can say that Toyota has made the first move.

Dennis Posadas, *Today*, Wednesday 31st December 2015, page 20, MediaCorp Press Ltd.

2

Questions:

 a) Write a balanced chemical equation, including state symbols, for the reaction between hydrogen and oxygen in the fuel cell.

.....

- b) i) Petrol has the formula C₈H₁₈. Write a balanced chemical equation, including state symbols, for the complete combustion of petrol to form carbon dioxide and water.
 - ii) In addition to carbon dioxide and water, what other chemicals can be produced when petrol is burned in an internal combustion engine?
- c) The waste products from vehicles with internal combustion engines cause more harm to human health than those from vehicles with fuel cells. Explain why this statement is true.
- Some people think that the hydrogen fuel cell is a completely non-polluting source of energy. Mr. Elon Musk and Dr. Joseph Romm disagree with this point of view. Explain why Mr. Musk and Dr. Romm are right to disagree.

.....

- 3. The article states that the hydrogen fuel cell uses a platinum catalyst.
 - a) Explain why a catalyst used in the hydrogen fuel cell.
 -
 - **b)** Briefly explain how a catalyst works.
 - c) Do you expect the catalyst in the hydrogen fuel cell will need to be frequently replaced?
 Explain your answer.

.....

4. Using ideas about bond breaking and bond formation, explain why the reaction between hydrogen and oxygen in the fuel cell is *exothermic*.

.....

5. The article mentions that hydrogen can be obtained by *gasification*. Gasification is a process that converts fossil fuels into carbon dioxide, carbon monoxide and hydrogen. This is achieved by reacting the fossil fuel at a high temperature (>700 °C), without combustion, with a controlled amount of oxygen and / or steam. The resulting mixture is called syngas (from "synthesis gas" or "synthetic gas") and can be used as a fuel.

In one reaction, methane and steam react together to form carbon monoxide and hydrogen.

- a) Write the balanced chemical equation, including state symbols, for this reaction.
- b) Calculate the total volume, in dm³, of methane and steam that are required to produce 72.0 g of hydrogen gas.

6. The table below provides information about hydrogen and petrol which may both be used as fuels in cars.

Fuel	Formula	Physical State at r.t.p.	Relative Molecular Mass	Enthalpy Change of Combustion kJ/mol
Hydrogen	H ₂	Gas	2	-286
Petrol	C_8H_{18}	Liquid	114	-5529

a) Show by calculation that hydrogen produces more energy per gram than petrol.

b) Give one advantage that petrol has over hydrogen as a fuel for cars.

.....

7. The article mentions that hydrogen for the hydrogen fuel cell can be obtained from the electrolysis of water, although this process is relatively expensive.

The balanced chemical equation for the electrolysis of water is given below.

 $2H_2O(I) \ \rightarrow \ 2H_2(g) \ + \ O_2(g) \ \Delta H = +474 \ kJ$

Sketch the energy profile diagram for the electrolysis of water on the axes given below. Your diagram should include:

- a) The enthalpy change for the reaction, labelled ΔH .
- **b)** The activation energy for the reaction, labelled E_{a} .
- c) The effect of a catalyst on the energy profile of the reaction, labelled E_a (catalyst).

