PHYSOC MONTHLY

MAY 2022 EDITION

ENERGY

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FOREWORD

Dear readers,

A warm welcome from the Physoc Academics team! We can't wait for you to read our next few article issues on the theme of energy production, an area of physics that we haven't ventured upon so far. So, without further ado, let's begin our journey into the field of energy development and while we take you through some cutting edge technologies that have been discovered (but yet to be implemented in full swing), we will also explore the physics underlying these processes.

In this issue, we will explore an upcoming technology to produce renewable energy: how organic waste can be turned into renewable biofuel additives using radiation! This radiation would be derived from nuclear waste. The discovery of a new production pathway for these additives can help to cut down carbon dioxide emissions and tackle climate change.

Warm Regards,
The Physics Society 2021-22

BIOFUELS - TURNING ORGANIC WASTE INTO RENEWABLE BIOFUEL ADDITIVES USING RADIATION

Many of you must have heard of nuclear power plants and the process of nuclear fission. Today, nuclear energy is being used in more than 30 countries around the world and it even powers the rovers to Mars! But what exactly happens in a nuclear fission? We can guess that nuclear fusion involves the combination of something. Well, fission is just the exact opposite of that. It refers to splitting apart. During a nuclear fission reaction, a neutron collides with a uranium atom and splits it. This releases a large amount of heat energy and radiation. Now the fascinating aspect of this process lies in the fact that the process is actually a chain reaction. When the neutrons collide with more and more uranium atoms, the process repeats itself again and again. Under the controlled conditions of a nuclear power plant reactor, this process can yield the desired amount of heat.

When a fission chain is stopped suddenly due to the emergency shutdown of a nuclear reactor (called a reactor scram), energy will be produced by the fission products left within the fuel rods.The energy that is produced is called the residual energy or the decay heat. This residual energy from the exhausted nuclear fuel can be used to make a short-lived, radiation-induced catalyst. The catalyst in turn facilitates a reaction that converts glycerol (an organic waste material) to valuable chemicals such as acetol and solketal. Catalytic conversion can get quite complicated because of the high temperature and pressure requirements. However, scientists have found that because this process is radiation-initiated, it forgoes the requirement for costly and energy-intensive steps. Moreover, the ongoing radiation processing costs are insignificant once this has been fully set up.

Solketal is a fuel additive (a substance added to something in small amounts to improve its quality) that can be used to increase the octane rating of fuel in vehicles. The octane rating is simply a measure of a fuel's ability to avoid knock, which is when fuel burns unevenly in your engine's cylinders. With an enhanced octane fuel count, the fuel would be more stable and not produce a grinding noise or create potential damage to your engine's cylinder walls and pistons. Furthermore, solketal also brings down gum formation; which are insoluble deposits formed by the slow oxidation of some unstable compounds during gasoline storage that can have adverse effects on engine performance, efficiency and durability. Acetol on the other hand can be used to make useful substances like propylene glycol (commonly used to absorb extra water and maintain moisture in certain medicines and food products) by combining different chemicals, or serve as a dyeing agent for textile manufacturing.

It has also been predicted that by 2030, the renewable percentage of commercial petroleum blend is set to increase from 5-20% volume concentration, with E10 petrol (containing 10% renewable ethanol) to be accepted as a standard grade in countries like the United Kingdom. The large scale on which this process is carried out in nuclear facilities in Europe has also seen researchers estimate an annual production of 10000 tonnes of solketal, which would equal to a considerable volume of usable fuel blend per year.

In conclusion, we can see how these 'chemical gems' derived from biomass through nuclear energy can help cut carbon dioxide emissions associated with petrol vehicles and tackle climate change, using this green technology to pave the pathway to use waste as a resource to produce the valuable "propylene glycol".

THE STORY OF HYDROGEN: THE HIGH-LIGHT OF ENERGY

A Cosmic (Baby) Boom

After the Big Bang, out from the core of the universe was born a particular species of element. Making its mark as the oldest but the baby of the periodic table (ironic, innit?), it flooded the universe as the most abundant element ever found (talk about the results of a cosmic baby boom ☺). Its tiny little being consisted of a single proton being orbited by a single electron. To get the love and belonging it so desperately wanted, it stuck around in pairs of two - scientists thought this was awfully cute and affectionately named the product of its clingy behaviour a ✨diatomic molecule✨. More specifically, we call this iconic duo 'hydrogen gas', the apple of every scientist's eye.

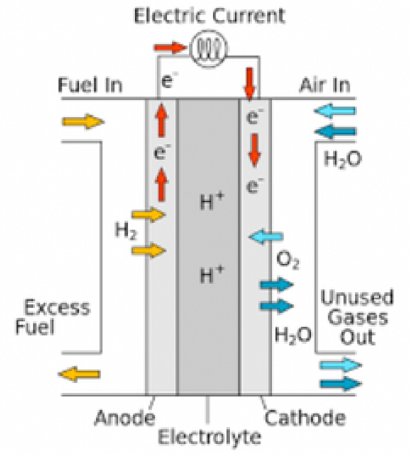
21st Century Scientists say, "May the Hydrogen be with you."

As the menacing heat of global warming loomed over the earth, a new, even hotter hero was required to save it (talk about double standards in society). This is when our little baby rose to the challenge - it not only grew up but also glew up. Owing to its fiery combustible nature, it scorched through the scientific community as 'the clean energy of the future' (it's safe to say that people were unable to take its heat).

Now how is it actually used as clean energy, you may ask? It all boils down (literally) to this miraculous chemical equation, another fan-favourite of the scientists - the formation of water.

$$2H_2 + O_2 \rightarrow H_2O$$

Unlike the other (quite mediocre) forms of fuel which release an army of greenhouse gases, hydrogen is considered clean because the only by-product of its combustion is water. The energy-giving powers of hydrogen are unlocked in special cells called 'hydrogen fuel cells' (talk about the lack of creativity). Hydrogen fuel cells work by converting chemical energy into electrical energy.



A hydrogen fuel cell.
Source: Wikimedia Commons

In a hydrogen fuel cell, entering hydrogen is subject to a chemical reaction that causes it to convert from diatomic gas into hydrogen ions, releasing electrons in the process. At the same time, entering oxygen from the opposite side is also subject to a similar chemical reaction. However, as it turns from gas to ions, it takes electrons. This giving and taking of electrons in the cell drives electric current, resulting in converting chemical energy into electrical energy. Water is formed as a by-product when the positive hydrogen ions react with the negative oxygen ions.

Future Prospects

So what lies ahead for our hero? Current projections indicate that hydrogen would become even more popular among the community. Its demand will grow more than threefold, and companies will continue to invest in hydrogen technologies and the sectors they target. The use of hydrogen fuel cells will spread to the transportation sector, as shipping and aviation require low-carbon fuel options, presenting an excellent hydrogen opportunity. Hydrogen is also projected to be a leading option for power generation in the future.

So, now you know the story of how hydrogen, the great hero, reached its full potential. We hope that you will also, someday, realise your potential and soar up the sky like Hydrogen (and continue reading PhySoc Monthly to fuel your intellectual needs).

NUCLEAR ENERGY

Before we go any further, we'd like to declare our support for Ukraine. This article was written prior to the invasion of Ukraine by Russia, and was not meant to offend anyone involved.

Nuclear energy has a poor reputation. Everyone knows of the numerous disasters that have occurred over the course of history, but as with all fields of science, with time, developments have been made. Nuclear energy is now widely used, and with a growing concern for global warming and reducing our carbon footprint, energy sources like nuclear energy are growing in popularity, along with renewable sources of energy, such as solar and wind. This is not to say, however, that nuclear energy is without problems, because it isn't.

Nuclear energy production is performed in several ways, and we will be detailing the current obstacles as well as different kinds of reactors. We hope you learn something from this article, and that you enjoy reading it!

THE PROBLEMS WITH NUCLEAR ENERGY

There is, however, one major threat when it comes to nuclear power- nuclear waste. While the volume is minimal (only 400 000 tonnes after decades of use), the problem lies in the nature of the waste- it lasts for an extremely long time and remains toxic hundreds of thousands of years, making it extremely difficult to store. The current way of dealing with it is just to place it in short term storage(around a century) and hope that future generations solve the problem in an economical and safe manner. However, leaving an expensive and dangerous problem for future generations is unethical.To combat the long term storage problem one of two things can be done - create permanent storage facilities or convert the material into something easier to store/use. This brings us to the second part of our article, the existing and theoretical methods to deal with our nuclear waste.

What is being done?

Skipping over the unfeasible methods like launching it into the sun we shall dig into the more interesting potential solutions to make nuclear power truly sustainable.

Talking about digging in we come to our first option - burying the nuclear fuel deep into the earth.The Onkalo spent nuclear fuel repository in finland does exactly this, it is a series of underground tunnels 500m below the surface. Here fuel will be encased in cast iron and copper canisters for an estimated 100,000 years. These are placed in the tunnel and surrounded by bentonite clay to block off the tunnel.

The general idea is to place the waste in storage that cannot leak, Finland is ideal for this as there are no earthquakes to damage the casings. The clay is used not only to block of the tunnel but also as a raincoat of sorts to prevent water from seeping into the facility and getting contaminated.

While this facility can safely store around 100 years of finland's nuclear waste, ideal conditions like this are extremely rare and as of now no other country has immediate plans to construct such a facility. So what else can we do?

HOW CURRENT REACTORS WORK

You probably already know what nuclear fission is, but let's go through it again! Current reactors use nuclear fission, which is the splitting of atoms. We haven't yet found a safe way to perform nuclear fusion(the process that powers the stars!) such that it benefits us with ample energy, so we're stuck with fission- although there has been a recent breakthrough with nuclear fusion, click the link in further reading to learn more!

In nuclear fission, a neutron is fired at an atom, splitting it into two atoms (plus a few neutrons), releasing a large amount of energy as heat. Some of the neutrons hit other atoms, and the process that ensues is called a chain reaction- nuclear reactors are built and meant to contain such violent chain reactions, and the heat is usually removed by a coolant. Water is often used due to its high specific heat capacity- this means that water can absorb a lot of heat energy without undergoing a large temperature change. This heat is used to turn water to steam, which then turns turbines to produce electrical energy.

Nuclear fission reactors commonly use fuels such as Uranium-235, Plutonium and Thorium, which are all well known for their use.

FUTURE OF NUCLEAR REACTORS: BREEDER REACTORS

Breeder reactors are a type of nuclear reactor that produce 30% more fission energy than they use, making nuclear fuels much more sustainable (but not renewable!) These reactors use not only Uranium 235 but Uranium 238 too, which is the naturally occurring isotope (and therefore much more abundant than Uranium 235). Breeder reactors also use Thorium to breed more unstable isotopes of Thorium that are then used in fission reactions. Plutonium 239 is also commonly bred. However, there are certain things to note about breeder reactors: namely, how are they better than our current (or more widely used) reactors? What are the downsides to using them?

Breeder reactors have a number of advantages over the reactors we use more in nuclear energy- key among them being that they produce 30% more fuel than they consume, and so much more than the energy coal plants produce, making them a very viable alternative. Breeder reactors are also a way to get rid of nuclear waste, such as uranium waste from processing, or spent fuel from other reactors- maybe even the depleted uranium from nuclear weapons. Moreover, as we mentioned before- breeder reactors use a lot more Uranium-238 rather than the 235 isotope as it is much more abundant in that form- they also reuse fuel, so altogether these pros keep the costs of breeder reactors minimised. There's also minimal waste produced, and no pollution, with the exception of mining.

Breeder reactors aren't all sunshine and rainbows though, they do have several disadvantages. For example, the plutonium that it breeds is extremely toxic, and has a half life of 24000 years. Additionally, the operation and construction costs are extremely high- construction costs alone are 4 to 8 billion, with a B. And breeder reactors don't use water as a coolant like other reactors- they use liquid sodium and potassium instead, and both are super reactive in comparison to water. Breeder reactors are also very complex to operate, hard to repair and accident prone as well- so we must weigh our options carefully.

So to conclude, dear reader, Nuclear energy has a lot in its future, and its power is being widely harnessed. We hope you learnt something from this article, and that you enjoyed reading it as much as we did writing. See you in the next issue!

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