

Enjoying fireworks from chemical and educational point of view

Yukiko TAKEGAWA*

ABSTRACT

In fireworks, there are many chemical reactions, such as combustion, explosion, flame reaction, and black body radiation, to produce its beauty. So, to enjoy fireworks from chemical viewpoint is to lead to better understanding on combustion. Fireworks can be a very good subject of chemical education. I have been practicing the science education program named "Chemistry of Fireworks" in the Osaka Science Museum since 2000, which contains the demonstration of experiments, special exhibitions, lectures, workshops, and publishing a booklet. I here report some program on the Chemistry of Fireworks and educational effect on the visitors and participants.

1. INTRODUCTION

Because many chemical reactions occur in fireworks, such as combustion, explosion, flame reaction, and black body radiation, I had come up with the idea that fireworks could be a very good material for education of chemistry. And I have been practicing the educational activities named "Chemistry of Fireworks" in the Osaka Science Museum since 2000. This "Chemistry of Fireworks" contains the demonstration of experiments, special exhibitions, lectures, workshops, and publishing a booklet.

In the following section, I will introduce the demonstration of experiments with the theme of fireworks, the special exhibitions (§ 3), lectures (§ 4), and the booklet (§ 5). In the final section, I summarize the educational effect on the visitors and participants of the "Chemistry of Fireworks".

2. THE SCIENCE SHOW

We are demonstrating some scientific experiments everyday with various themes at the Osaka Science Museum. We call these demonstrations as "Science Show". Each science show has about 30 minutes

duration and about 100 audiences, and is demonstrated 4 times a day.

In 2000, I had planned and produced the science show with the theme of "Chemistry of Fireworks" for the first time (Figure 1).

The contents of the Science Show are shown in Table 1. This program has two objectives, to understand the combustion condition and to know the secret of the color and light emission of fireworks.





Figure 1 - Science Show, demonstrated by myself (2016)


* Osaka Science Museum, Japan
takegawa@sci-museum.jp

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Table 1 - The contents of the “Chemistry of Fireworks” show

Experiment	Contents
(1) Introduction	
Demonstration of fireworks	Presentation: Why do fireworks burn well? What does make fireworks so bright and so colorful?
Black powder formulation	Mixing potassium nitrate, sulfur and carbon to make the standard black powder 
Combustion of black powder	Observe how it burns violently
Requirements of burning	Combustion needs “Oxygen”, “Heat” and “Fuel”. Classify the ingredient of black powder as these three elements
(2) OXYGEN	
Nature of oxygen	Oxygen is contained in the air at only 21%, but when black powder burns, it produces much oxygen by its ingredient; potassium nitrate.
Burn incense in pure oxygen	Oxygen is essential for combustion. Combustion is exactly to bind matter with oxygen. In pure oxygen, even incense burns so violently. 
Fireworks in the water	Can fireworks burn in the water where there is neither air nor oxygen? This experiment shows the evidence that the fireworks (black powder) produces

	enough oxygen by itself.
(3) The lights of fireworks	
Sprinkle some carbon powder on flame	You will see orange - colored light. In the old days fireworks had only orange color. This is blackbody radiation caused by burning charcoal powder. Blackbody radiation is the main component of the light of fireworks.
How to make fireworks more beautiful	Put an iron bolt into the flame, but it does not burn, of course. Next, if you put a steel wool into the flame, it burns gently. Then, when you sprinkle some iron powder on flame, you will see beautiful white  color!
Black powder + iron powder	Mix some black powder and some iron powder, and you can make simple but beautiful fireworks.
(4) Various colors of fireworks	
Put copper powder into the flame	When putting copper powder into the flame, you will see green color light. This is caused by “flame reaction” of copper. With flame reaction, you can make various colored fireworks.
Flame reaction	By spraying some mixture of solution of metal with alcohol into the flame, various colors will appear; copper -green or blue,

	sodium -orange, potassium -purple, and strontium -red. Fireworks makers are trying out various combinations to develop more beautiful color fireworks.
(5) Ending	"The reason of burns well of fireworks" is oxygen. "The reason of lights and colors of fireworks" are "black-body radiation" and "flame reaction".

3. SPECIAL EXHIBITION

I have been collecting valuable items related to fireworks including some models of fireworks shells and their half section ones (**Figure 2**).

In 2010, I met Mr. Akihiro Koga, a fireworks manufacturer of KATSURAGI Fire Bland Co., Ltd. in the TV program (**Figure 3**) and Mr. Koga and I clicked with each other as soon as we talked about my activities of chemistry of fireworks. He has been helping me since this meeting.

In 2011, I produced the first special exhibition "chemistry of fireworks" in collaboration with Mr. Koga. Since then, I continued to produce 5 special exhibitions including the exhibition at Osaka Municipal Library that was held as the first satellite exhibition for us (**Table 2**).

Those special exhibitions could only be realized with the cooperation of Mr. Koga, Osaka Municipal Library (2016), *Tenmangu* shrine (2016).

I think exhibitions are also good method to educate chemistry of fireworks, because the exhibition can be seen whenever visitors want and exhibition goods cannot be seen usually.

I believe that the education for chemistry of fireworks can only be success using both demonstration and exhibition.

Table 2 – Special exhibitions

Year	Theme (Term)
2011	Chemistry of Fireworks (Jun. 18 th . – Aug. 31 st .)
2012	Chemistry of Fireworks (Jun. 23 rd . – Aug. 31 st .)
2015	Color and Light of Fireworks (Figure 5) (Jul. 1 st . – Aug. 30 th .)
2016	Osaka and Chemistry of Fireworks (Figure 6) (Jun. 3 rd . – Aug. 28 th .)
2016	Fireworks from Chemical view point (Jun.17 th . – Aug. 17 th .)



Figure 2 – Model of fireworks shell (left) and its half section one (right).



Figure 3– The TV program when Mr. Koga and I met for the first time (the 4th person from left is Mr. Koga and the person on the far right is myself).



Figure 4 – The special exhibition “Color and Light of Fireworks” (2015)



Figure 5 – The special exhibition “Osaka and Chemistry of Fireworks” (2016)

4. HISTORY OF FIREWORKS AS EDUCATIONAL MATERIAL

I believe that human history is the history of chemistry, and the history of fireworks is part of it. Fireworks used black powder for ornamental purposes; black powder was introduced to Japan in 1543. *Date Masamune* (1567–1636, first Lord of *Sendai Domain*) and *Ieyasu Tokugawa* (1543–1616, the founder and first shogun of the *Tokugawa shogunate*) are recorded as the first Japanese who appreciate fireworks. The origin of fireworks of Japan is very interesting but it is still unknown.

The history of fireworks may inspire us to study fireworks and also chemistry of fireworks. In our science show, the origin of a black powder and history of fireworks are explained while mixing black powder or burning iron powder.

In the special exhibition “Osaka and Chemistry of Fireworks” (2016), the “*Tenjin matsuri Festival*”, that is one of the most famous festival in Japan because of its more than 1000 year’s history with fireworks, was introduced. Historical goods in the special exhibition “Osaka and Chemistry of Fireworks” are shown in Table 3. These goods attracted the local people who know “*Tenjin matsuri*

Festival” well.

The history of fireworks may be useful theme to understand chemistry of fireworks, and I recommend to progress with chemistry and history side by side.

Table 3 – Historical goods in the special exhibition “Osaka and Chemistry of Fireworks” (2016)

1	Name	<i>Naniwa Tenma Matsuri Festival 1</i>
	Year, Author	<i>Ansei 3 (1859)</i> By <i>Gountei Sadahide</i> (<i>Utagawa Sadahide</i>)
	Sponsor	<i>Osaka Tenmangu Shrine</i> [replica]
	This Woodcut was drawn the <i>Tenjin Matsuri</i> festival. We can see the fireworks display of 160 years ago.	
2	Name	<i>Settu-meisho-zue</i> (Diagrams and pictures of famous places in <i>Settu</i> region)
	Year, Author	By <i>Takehara Shunchousai</i> (Painting) <i>Kansei 8-10, (1798-1798)</i>
	Sponsor	OSAKA Municipal Library
	<i>Settu-meisho-zue</i> was travel guidebooks of Edo period. Fireworks display of <i>Tenjin Matsuri</i> festival is not known when it was started. This picture shows us that the fireworks display of <i>Tenjin Matsuri</i> festival has been held from more than 220 years ago.	
3	Name	<i>Osaka meisyo</i> (Pictures of Osaka’s landscapes) The Yammer Festival of <i>Tenmangu</i> , and the excursion Boats
	Year, Author	By <i>Nagano Risuke</i> <i>Meiji 33 (1900)</i>
	Sponsor	OSAKA Municipal Library
	The Fireworks of <i>Tenjin Matsuri</i> festival was drawn at the upper right of the picture.	
4	Name	<i>Hanabi seizou-hou</i> (Fireworks Manufacturing methods)
	Year, Author	Release/ Date: known
	Sponsor	National Diet Library [replica]
	This is a book that was written about manufacturing methods of fireworks. We can see the words, “Potassium nitrate”, “Charcoal”, “Sulfur”, and “Iron”.	

5. LECTURES

For further understanding for the chemistry of fireworks, we started to give a lecture in 2011 (Figure 6). The lecturers were Mr. Koga and I. The seating capacity was 120 people, but more than 500 people from children to the elderly applied. In the lecture, Mr. Koga showed them how to manufacture fireworks and how to operate fireworks display, and I explained some chemistry of fireworks. This first lecture in 2011 went very well.

Then another lecture was produced with Mr. Kishimoto, *Negi* (Shinto priest) of *Osaka Tenmangu Shrine*, for the history of fireworks festivals of *Osaka Tenmangu Shrine*.

In this way, lecture with professional stories based on real experience addition to the experimental demonstrations and the exhibition could deepen their understanding of fireworks.

I also gave lectures at the Special Exhibitions (Figure 7) and there I experimented about exhibition goods and experimented "Flame reaction". Many visitors gathered every time.



Figure 6 – The first lecture (2011)



Figure 7 – Gallery talk at the special exhibition of "Color and Light of Fireworks" (2015)

6. PUBLISHING A BOOKLET "CHEMISTRY OF FIREWORKS"

I published the booklet "Chemistry of Fireworks" in 2015 in order to utilize it for helping our visitors and audiences to study and enjoy chemistry of fireworks after getting home (Figure 8). This 12 pages booklet could be bought for 100 JPY at our museum shop and contents are shown in Table 4. 1,588(16.6% of sales number) copies were sold for 3 months (2016.June–Aug.) and this indicated that many audiences were interested in chemistry of fireworks. I am happy that I guess many people have a lively conversation about chemistry of fireworks.

Table 4 – contents of a booklet "chemistry of fireworks"

page 2	Introduction
page 3	FAQ
page 4	History of fireworks
page 6	Chemistry of fireworks- oxygen-
page 8	Chemistry of fireworks- color and light-
page 10	Launch fireworks

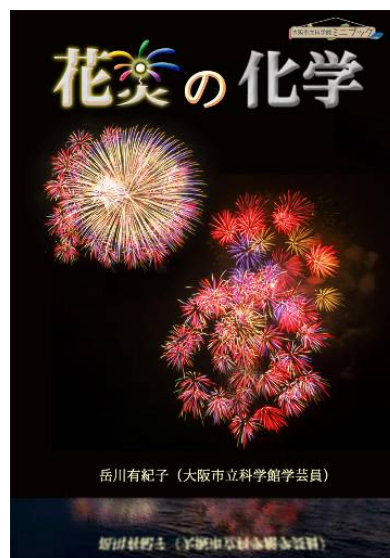


Figure 8 – A booklet "Chemistry of Fireworks"



Figure 9 – Audiences who bought a booklet “Chemistry of Fireworks” after “Science Show”

7. RESULTS

We got more than 100 thousand audiences of the “Chemistry of Fireworks” (Table 5).

Table 5 – The term and number of audiences for “Chemistry of Fireworks”.

Year	Term	Times	Audiences
2000	Jun. 2 nd . – Aug. 31 st .	319	19,339
2004	Jun. 1 st . – Aug. 31 st .	318	27,164
2010	Jun. 4 th . –Aug. 31 st .	281	27,576
2016	Jun. 3 rd . –Aug. 28 st .	297	25,926
Total		1,215	100,005

Osaka science museum has more than 700 thousand visitors in a year. And the science shows should be enjoyed by all the generations since the half of visitors are adults.

Japanese likes fireworks and the summer is the season of fireworks for Japanese, thus many visitors come to Science Show when they hear the title call. During the show, many audiences enjoy experiments or nod their heads or say “I see!” And they look happy to know the chemistry of fireworks. After the show, many audiences come and talk to me, “I understudied the fireworks is chemistry”, “I will change how to enjoy fireworks”, “I had a nice time!” From those reactions, I think the “Science Show” named “chemistry of fireworks” is the best tool to enjoy and study of the chemistry of fireworks for everyone.

And add other events, like special exhibitions, lectures, and so on are good way to understand and enjoy of fireworks.

8. CONCLUSIONS

I have created various lectures and exhibitions focusing on chemistry of fireworks for 16 years, based on my belief that the knowledge about chemistry of fireworks makes you enjoy fireworks 2 times more than without it.

Many audiences of my lectures and exhibitions have been enjoying and studying fireworks from chemical point of view. Thus, “Enjoying Fireworks from Chemical and Educational Point of View” is exploited many schools or museums to teach chemistry of fireworks.

These teaching materials are to be believed new additional values and culture in Japan.

I am sure fireworks are more enjoyable if you know chemistry, and the knowledge of “chemistry of fireworks” makes you enjoy studying chemistry more. “To create new culture of enjoying fireworks” is my policy and goal.

REFERENCE

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