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# Formation Rules of Harmful Gas Products of Flame Colour Agents of Fireworks

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The influence of fireworks bring to the environment can't be neglected. By calculating and simulation experiment with the principle of free energy minimum, this study reports the formation rules of harmful by products of colouring flame of fireworks with the results as follows: the major harmful gas in the combustion by product of colouring flame is carbon monoxide. After analyzing, oxygen negative balance in the composition of colouring agent is found to be the main reason for the formation of carbon monoxide and raise the oxygen balance in the composition could reduce the formation of carbon monoxide.

**Key Words: Fireworks, Harmful gas products, Carbon monoxide.**

## INTRODUCTION

China is the origin of fireworks and the tradition of setting off fireworks has continued for over 1,000 years. Nowadays, firework displaying an important part during praying, celebration and other big events. Fireworks displaying bring laughter, however, they also pose threaten to public sanitation and human health and bring great pressure to ecologic environment. Among all respects, firework-caused air pollution is a major factor.

During the combustion of fireworks, a string of chemical reactions would occur, producing harmful gas products like carbon monoxide, nitrogen oxide and sulfide[1]. These products pollute the air environment and effect human health in adversely. They can even suffocate people when getting dense to certain extent. In Taiyuan, capital of Shanxi province, during the holiday of Chinese Lunar New Year and Lantern Festival of 2003, the deafening sound of fireworks drag the air quality of the city to five degree. Thus testing the harmful gas is of great meaning for the controlling of the pernicious gas formation and protecting human health and the environment.

Flame colour agents are the most common materials used in fireworks producing for special effect. This article takes a typical fireworks flame colour agent as research target. Firstly, evaluate the harmful gas products of flame colour agents through theoretical calculation. Secondly, based on the result of the former calculation, test the harmful gas products, which are simulatively produced with gas analyzer and then discuss the forming rules of the harmful gas products produced by the combustion of flame colour agents.

## EXPERIMENTAL

**Theoretical calculation:** Based on the principle of free energy minimum[2,3], this research would theoretically estimate the formation of harmful gas products from flame colour agents of red, green, blue, yellow which is commonly used in the producing of typical fireworks for export. Formula of flame colour agents for research is shown in Table-1.

TABLE-1
FORMULA OF FLAME COLOUR AGENTS FOR RESEARCH

| Ingredients | Colour | | | |
|---|---|---|---|---|
| | Red | Green | Blue | Yellow |
| $KClO_4$ | 45 | 23 | 45 | 45 |
| $Ba(NO_3)_2$ | | 39 | | |
| $Sr(CO_3)_2$ | 18 | | | |
| Cryolite | | | | 15 |
| CuO | | | 27 | |
| MgAl | 22 | 22 | | 23 |
| Bakelite | 6 | 6 | 6 | 7 |
| S | | | 15 | |
| PVC | 5 | 6 | 6 | 6 |
| Shellac | 4 | 4 | | 4 |

**Gas analyzer:** KANE KM9106 portable integrated gas analyzer made in Britain which can measure CO, $SO_2$, NO at one time, which is shown in the Fig. 1.

**Closed combustion lab:** A combustion box with the dimensions 1 m × 1 m × 1 m, made of metal frame and sealed with aerial Plexiglas, with air circulating and exhausting device, self made, which is shown in the Fig. 2.


Fig. 1. KANE KM9106 portable integrated gas analyzer

Fig. 2. Closed combustion laboratory

**Samples preparation:** Choose the colour agents of red, green, blue and yellow which is made with the formula that has mentioned in Table-1 as samples for experiments and researches respectively.

**Experimental method:** Take 1 g of experiment sample and put it in the middle of the combustion lab. After igniting the agent, circulate the air and make the gas get even in the box quickly. At the same time, turn on the gas analyzer. When the time is enough for sample preparation, turn off the analyzer and exhaust the combustion gas in the box with exhausting system.

## RESULTS AND DISCUSSION

**Theoretical calculated results:** Based on the formula listed in Table-1, with 1 g of flame colour agent and suppose the combustion space is of the same dimensions with the experiment combustion box, that is 1 m × 1 m × 1 m and then we can theoretically estimate the combustion products under normal pressure and analyze the harmful gas composition of the products. Main harmful combustion gas products from the 4 flame colour agents are listed in Table-2. Table-2 indicates that there are a lot of carbon monoxide in the product of the 4 kinds of agent. Meanwhile, there is also some $SO_2$ in the combustion product of the blue colour agent.

TABLE-2
CALCULATED RESULTS OF MAJOR HARMFUL COMBUSTION GAS PRODUCTS OF THE FLAME COLOR AGENTS

| Item no | Kind of agents | Concentration of products (ppm) | |
|---|---|---|---|
| | | CO | $SO_2$ |
| 1 | Red | 246.6 | - |
| 2 | Green | 170.5 | - |
| 3 | Blue | 198.6 | 17.9 |
| 4 | Yellow | 101.2 | - |

**Analysis on the experimental result of harmful gas products:** According to the theoretically calculated results, main harmful gas products from the flame colour agents which are indicated in Table-1 are CO and $SO_2$. These two kinds of gases are all in the testing scope of the analyzer. Therefore, we can choose gas analyzer to analyze the combustion products during the process of experiment.

Ignite 1 g doze of agent in the closed combustion box and then analyze the combustion products by gas analyzer. The combustion products analysis results of the 4 kinds of flame agent listed in Table-1 are as shown in Table-3.

TABLE-3
ANALYSIS RESULTS OF THE COMBUSTION PRODUCTS OF FLAME COLOR AGENTS

| Item No. | Kind of agents | Concentration (ppm) | |
|---|---|---|---|
| | | CO | $SO_2$ |
| 1 | Red | 225.6 | - |
| 2 | Green | 195.8 | - |
| 3 | Blue | 200.6 | 12.6 |
| 4 | Yellow | 145.6 | - |

Among in four formula,carbon monoxide production curve of the red flame pharmaceutical is shown in Fig. 3.

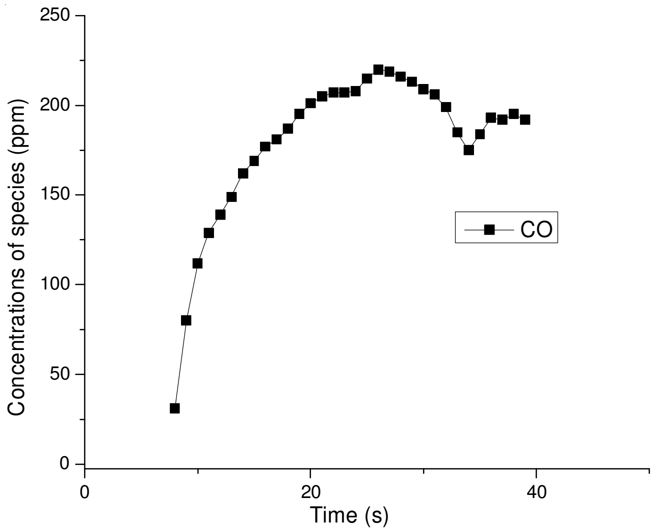


Fig. 3. Carbon monoxide production curve of the red flame pharmaceutical

The analysis results in Table-3 indicates that carbon monoxide is the major composition of harmful gas products, with the release quality of each 4 colour agent are 225.6, 195.8, 200.6 and 145.6 ppm respectively. Meanwhile, there is also 12.6 ppm of $SO_2$ in the combustion product of the blue colour agent. These results are in accordance with the former theoretical calculated results. Further more, if we take the systematic deviation caused by the experiment condition out of consideration, the products concentration produced in the experiment and the theoretically calculated concentration of CO and $SO_2$ are basically complies with each other. From the above, it is concluded that with the flame colour agent formula that we choose, main harmful gas product of the flame colour agents is CO and there is also certain concentration of $SO_2$ in the combustion products of blue colour agent. Thus we can confirm that there are indeed some harmful gas products as the result of the combustion of flame colour agents, which would pollute the air environment.

**Analysis on the formation rules of harmful gas products of flame colour agents:** It is proved by the theoretical estimation and practical experimental research that main harmful gas product from the flame colour agents chosen by us is CO. When analyzing the composition of the 4 kinds of flame colour agent that is listed in Table-1, it is obvious that, besides metal element, major nonmetal elements include C, H and O. For these nonmetal elements, if oxygen element is sufficient enough, after complete combustion, the products would be $CO_2$ and $HO_2$. However, if the O element is insufficient, CO would come into being as a harmful gas product. Reflecting on the formula of the agents, it is the degree of formula oxygen balance that makes the difference. When using oxygen-balanced formula or formula with high oxygen balance, there is no CO formed in the complete combustion gas products. Whereas when the oxygen balance is negative, CO would then be formed as the result of the combustion. According to the formula of Table-1, the oxygen balance of red, green, blue and yellow agents are -35.05, -21.26, -23.84 and -16.50 % respectively. All the oxygen balance are negative, thus there are CO in the combustion gas products. This phenomenon indicates that, during the process of developing a formula of flame colour agents, oxygen balance should be taken into consideration. Under the precondition the performance of agents, we should choose a higher degree oxygen balanced formula to avoid the forming of harmful gas products.

## Conclusion

There is a lot of CO formed during the combustion process of flame colour agent and it would pollute the air environment. Raise the oxygen balance in the formula of flame colour agents can effectively reduce the forming of carbon monoxide and other harmful gas products. Under the condition of guaranteeing the performance of agents, we should choose a higher degree oxygen balanced formula to minimize the pollution to the environment.

## REFERENCES

1. G.P. Pan and S. Yang, Pyrotechnics, Beijing Institute of Technology Press, Beijing, pp. 234-240 (1997).
2. R.E. Williford and T.R. Armstrong, *J. Solid State Chem.*, **149**, 320 (2000).
3. B. Cheynet, M. Dall'Aglio, A. Garavelli, M.F. Grasso and F. Vurro, *J. Volcanol. Geothermal Res.*, **95**, 273 (2000).