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Review

# Analytical techniques for the analysis of consumer fireworks

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ABSTRACT

This review provides an overview of common consumer fireworks, their usual chemical compositions, and some important classification and legal regulations in Western countries. We show the main analytical techniques and methodologies used to determine consumer fireworks. Most articles published to date focused on studying characteristics and properties of pyrotechnic reagents and explosive compositions by thermal techniques. However, a few research papers focused on the determination of chemical reagents from intact devices or their residues. In this review, we critically review colorimetric tests, and microscopy, spectroscopy, separation and potentiometric techniques. This information is useful for police laboratories in order to identify the consumer fireworks involved in certain incidents.



**Contents**



## 1. Introduction

Pyrotechnic compositions are usually based on organic or inorganic chemical oxidizers and fuels to produce visual, thermal, audible or mechanical terminal effects, such as smoke, light, loud noise, motion, and color [1–3]. In the industrial and military field, pyrotechnic mixtures are used to demolish, and they comprise ammunition or signaling and illuminating items [2]. In the civilian field, they are utilized to make fireworks for attractive displays for entertainment [1].

Fireworks are any composition or devices designed to produce visible and/or audible effects by combustion, while meeting the definitions of "professional or display fireworks" or "consumer fireworks" [4,5]. Professional or display fireworks are large items commonly used during festivals and celebrations. They are handled and ignited by qualified workers. Consumer fireworks are small fireworks designed to produce some effects, such as smoke, sparks, noise, color, and flames, by combustion. They have generally weaker explosive properties than professional items. Consumer fireworks are available on sale to the general public and are used in marriages, parties or other celebration events.

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Fig. 1 shows some examples of consumer fireworks – a wide variety of devices with numerous effects. Firecrackers (European bangers), bottle rockets, sparklers, fountains and smoke bombs are some widely-used consumer fireworks.

For analytical chemists, it is important to analyze consumer fireworks in order to know their composition for quality control. Furthermore, there is a high forensic interest in the analysis of post-blast residues (PBRs) and pre-blast devices from incidents where consumer fireworks have been used in acts of vandalism, street riots, or illegal trade. It is tremendously important that some improvised explosive devices (IEDs) could contain pyrotechnic mixtures as explosive charges, obtained by breaking down consumer fireworks or purchasing legally the reagents used in fireworks reactions [6,7]. Other important and quite common cases that require forensic attention in Western countries are occupational accidents, suicides, injuries, fires or arsons [8,9]. Lots of such cases are related to misuse, devices being altered or fireworks being made by non-professional users using legal handbooks in a home laboratory [4,7,10–12]. For example, in USA, during 2001–12, over 100,000 firework-related injuries were treated by emergency departments [10,11]. Sparklers, reloadable shells, and firecrackers are the types of firework devices with higher percentages of incidents. In Spain, 80% of the annual workload at the explosive area of the Criminalistics Service of Guardia Civil (SECRIM) relates to pyrotechnic devices or incendiary improvised devices (IIDs) [13,14]. In The Netherlands, more than half the explosives casework at the Netherlands Forensic Institute (NFI) relates to fireworks [7].

Most countries have strict laws, continually under revision, trying to control their citizens' handling of all kind of explosive devices, including firework devices [15–18]. These laws relate to manufacture, supply, possession, transport, storage and use of fireworks. Explosives and fireworks are classified using procedures established by the United Nations (UN) within the framework of international transport [19]. The UN proposed UN numbers that exactly identify hazardous substances and articles. Regarding fireworks, UN0336 identifies consumer fireworks, while UN0035 covers display fireworks. In USA, the Code of Federal Regulations (CFR) establishes the fireworks regulations [20]. CFR, in titles 16 (parts 1500 and 1507) and 27 (part 555), includes some definitions of explosives and consumer product safety [5,21]. In addition, the Department of Transportation (DOT) lists and classifies fireworks [22]. This classification comprises a class number indicating the shipping hazard class, and a compatibility group suffix describing the type of material in general. Display fireworks, which are more hazardous than consumer fireworks because they may contain certain chemicals or larger amounts of powder, are included in the 1.3G class whereas consumer fireworks are classified as 1.4G class. Table 1 shows this information and some characteristics. These transportation codes, as well as the UN numbers, must be marked on the item's container or package. In the European Union (EU), Directive 2007/23/EC of the European Parliament and of the Council states that groups of pyrotechnic articles that are similar in design, function or behavior should be assessed by the notified bodies as product families [17]. In the EU, consumer fireworks are categorized in three categories (Table 1). This depends on their hazard, which affects directly the public limits on age of purchase and use. The fourth category corresponds to display fireworks, restricted to professional operators. Table 1 also shows other characteristics influencing this classification. The EU Directive provides a wide framework in which the European countries may

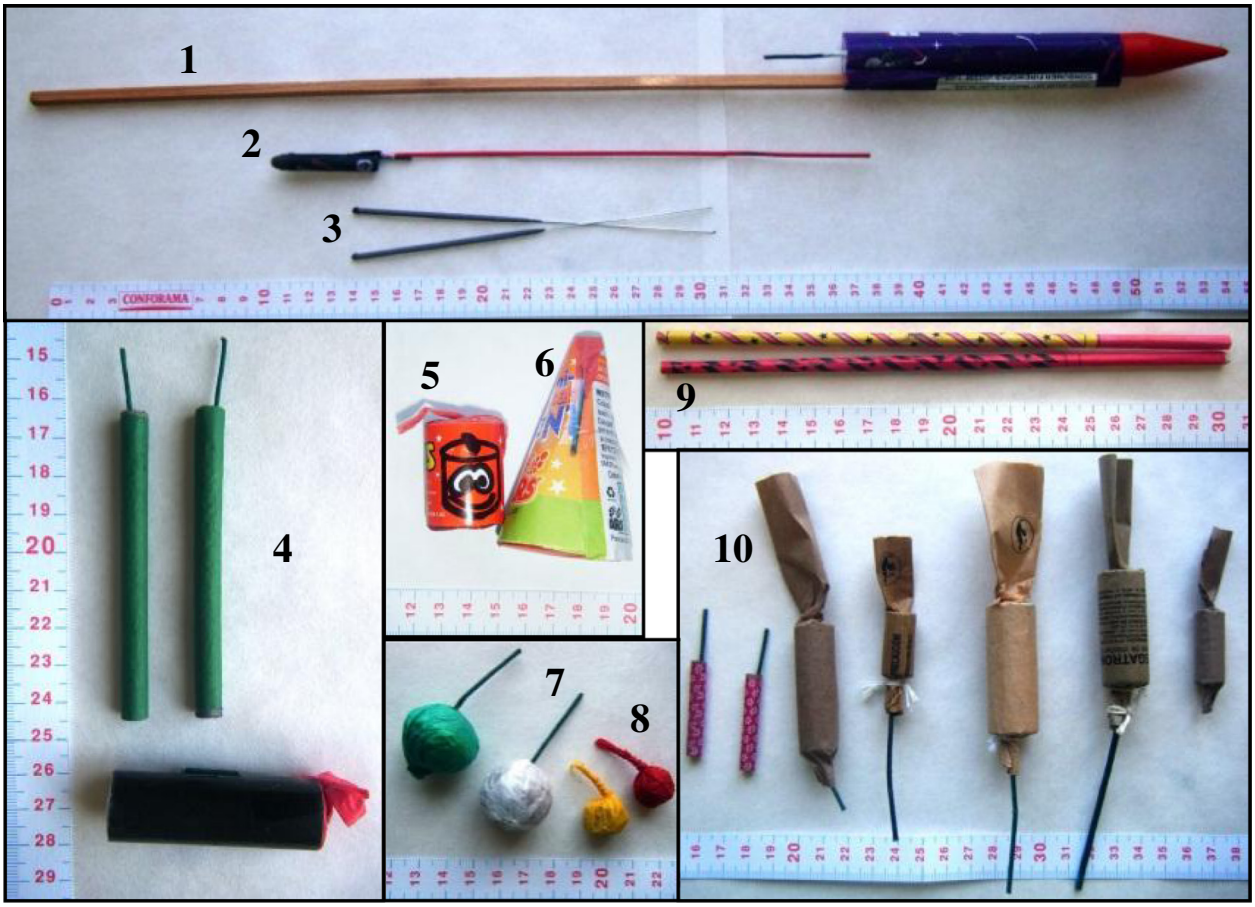


**Fig. 1.** Multi-picture showing some consumer fireworks. **1**. Rocket, **2**. Mini-whistle rocket, **3**. Two units of sparkler flares, **4**. Two kind of multi-effect firecracker, **5**. Mini-fountain, **6**. Cone-fountain, **7**. Smoke bombs, **8**. Thunder snaps or trick noisemakers, **9**. Multi-color flares, **10**. Firecrackers (different sizes and categories).