# A Safe Way of Performing Some Dangerous Experiments. I. Construction of a Safety Spoon

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**Abstract:** The demonstrations of many remarkable experiments include a high safety risk (e.g. the reaction of large pieces of sodium/potassium with water; the reaction of potassium with liquid bromine; the reaction of sodium with concentrated sulfuric acid, etc.). Chemistry teachers and instructors are usually reluctant to perform experiments that include a hazard. As a result, a number of fascinating experiments remain unknown to the public. Using homemade devices (in this case a safety spoon) one can perform all the above experiments with complete safety, both for the audience and the demonstrator. Details for performing some of these dangerous experiments are given in this paper. In addition, the construction of a simple remote-controlled (RC) safety spoon is explained in detail. Video clips of two demonstrations are offered as an aid for inexperienced instructors.

## Introduction

The reaction of sodium with water has been a well-known demonstration for many decades [1–4]. It can be performed in a trough [1, 2], in a Petrie dish placed on an overhead [3], in a test tube [4], or with a number of other variations. All of these methods, however, have one point in common: the piece of sodium used must be very small (about the size of a rice grain). It is often cautioned that it is hazardous to use large pieces of sodium, the exact hazard is not always discussed. “Why don’t we try a large piece?” is also a common question asked by students. This question is fairly logical because, after all, the demonstration performed with a small piece appears completely safe.

The reaction of sodium with water is a very vigorous one (that of potassium is even more vigorous: the potassium and generated hydrogen gas burst into flame when even a small piece of potassium is put in a trough with water.) The quantity of heat evolved is large enough to melt the metal. Thus, a sphere of molten sodium runs upon the water surface. If the motion of the sodium piece is localized (e.g. by placing it over a piece of filter paper floating on the surface of the water) the sodium ignites. One could imagine that large pieces of either sodium or potassium can give spectacular results (accounting for the possible side reactions, once the metal ignites), but **it is very dangerous to perform these demonstrations without special precautions**. If the demonstration could be performed in a hood with the window closed, it would remove the hazard, but under these circumstances it is not possible to add the metal to the water!

A couple of other demonstrations are also very impressive and exciting, but they include a high risk of accident when performed as advised in the literature. For instance, the reaction of potassium and liquid bromine [5] is so vigorous that a loud explosion occurs immediately when the piece of potassium comes into contact with the bromine. There is even a theoretical explanation for the high rate of this reaction (based on the so-called “harpoon mechanism” [6]). Also, the reactions of lithium and sodium with concentrated sulfuric acid (and probably with concentrated nitric and hydrochloric acids) are also known to be very remarkable demonstrations [7], but the latter also involves a high risk.

These risks often preclude the use of these experiments as lecture demonstrations. This is understandable, but at the same time it means that the students will never see a large number of fascinating experiments. To overcome this obstacle, we have constructed a RC device called a safety spoon.

## Construction of the Safety Spoon

To reduce the risks involved, a safety spoon can be constructed. This spoon can then be used in all cases where the possibility of explosion exists upon addition of a solid to a reaction system (as is the case with the sodium and water demonstration). Figure 1 helps to under its design (actually two variants of this spoon are possible).

For constructing the spoon, some basic knowledge of electronics is desirable. The spoon consists of an electric motor (a) connected via plastic or rubber tube (b) to a glass spoon (c). In a simple version of the spoon, the remote control (d) is connected to the electric motor via a long wire (e). The rotation of the glass spoon was restricted to 180° with a side brake (f), which, after half a cycle is completed, hits a piece of rubber or sponge (g) that hinders the rotation. The electric motor, the piece of rubber (or sponge) and the glass spoon are built in a housing (h) made of some suitable plastic. The electric motor and the wires we used were obtained from a car toy (~ $3 cost). The departments’ glassblower made the glass spoon.

A more sophisticated version (with true radio control) of the safety spoon is shown in Figure 2. Again, the simplest way to assemble this spoon is to buy a radio-controlled toy car (there are models available for ~ $10). The emitter is the original one (a). The motor is placed in a plastic box (b) and connected to the glass spoon exactly in the same way as described above. The connection to the receiver (c) may be accomplished via flexible wire (d) and suitable connectors (e).

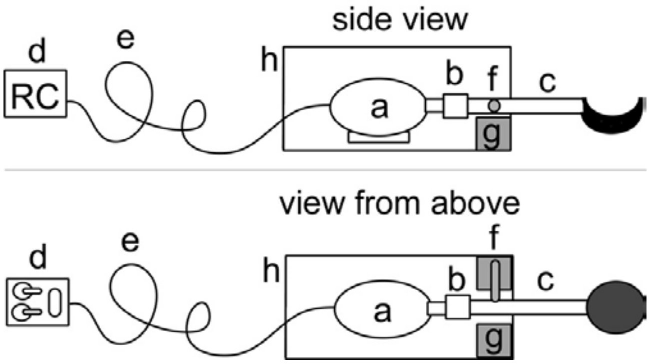


**Figure 1.** The RC safety spoon (variant 1). Legend: (a) electric motor, (b) plastic or rubber tube, (c) glass spoon, (d) remote control, (e) electric cable, (f) side brake , (g) rubber or sponge, (h) plastic housing.

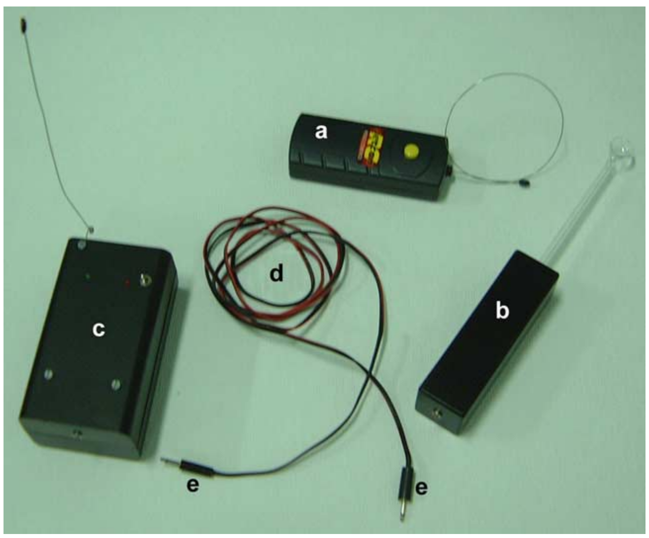


**Figure 2.** A photograph of the RC safety spoon (variant 2). Legend: (a) emitter, (b) electric motor and glass spoon, (c) receiver, (d) flexible wire, (e) connectors.

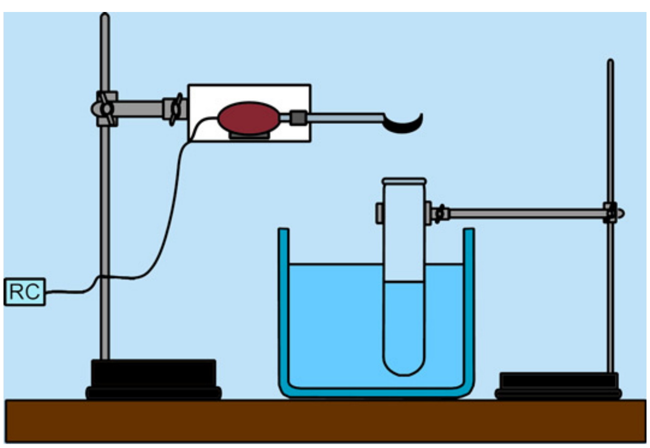


**Figure 3.** Setup for demonstration of the reaction of large piece of sodium with water (RC = remote control).

**Demonstrations**

All of the experiments mentioned above can be performed using the safety spoon. We shall describe here in detail only the reaction of sodium with water. The reaction of potassium with water and of sodium with concentrated sulfuric acid may be performed using the exact same method (in the latter case, one should take about 20 mL of acid and about 50 mg of sodium metal), while the reaction of potassium with bromine may be performed with a minor modification (using a crucible, jar, and glass tube, see below).

The equipment used is schematically presented in Figure 3. A large test tube is filled with water to about one quarter of its height, clamped on a stand, and put in a trough full of water (as a safety precaution). The safety spoon is clamped onto another stand, some 5 to 10 cm above the test-tube mouth. Its position is adjusted in such a way that after the activation (half-cycle hindered rotation) the piece of sodium falls in the test tube (with large test tubes this is not a problem).

A large piece of sodium (~ 0.5 to 1 g) is cut from a sodium lump, quickly wiped with a dry filter paper and placed on the spoon (see Safety Tips and Hazards). After this is finished, the window of the hood is closed. The instructor calls for attention and triggers the spoon. Once in the water, the sodium reacts vigorously, with audible puffing and blasting. Some sparking can occasionally be seen at the contact surface. It can not be predicted exactly what will happen or when it will happen, but in about 10 s the sodium usually explodes with a tremendous bang and quantities of white smoke (mainly sodium peroxide and sodium oxide—products of the burning sodium). Very often intense yellow sparks can be seen escaping from the test-tube mouth (these are pieces of ignited sodium). Sometimes, prior to the explosion, the hydrogen ignites at the test-tube mouth and burns with a light-yellow flame (colored by traces of sodium). On two occasions the bang was so intense that the test tube fractured and cracked (usually near its bottom). Most of the phenomena described above can be seen on the video clip (NaMovie, supporting material).

By the end of the lecture the instructor should discuss and explain as thouroughly as possible everything observed in the demonstration. It is important to conclude with the statement that this experiment shows quite well why is it dangerous to use large pieces of sodium for this type of demonstration.

Related demonstrations may be found on the World Wide Web [8, 9]. These demonstrations as described on the Web (the way they are performed) are very dangerous and we do not recommend that they be attempted as such.

**Related Demonstrations**

The same experiment using large pieces of potassium can be performed in exactly the same way. Although potassium is more reactive, the result of the experiment never appears to be as spectacular as that with sodium (the probable reason is the instantaneous ignition of the potassium when it touches the water surface, part of it being immediately oxidized).

The reaction of sodium with concentrated sulfuric acid, as mentioned earlier, may be performed by exactly the same method, but the quantities must be smaller, ~ 20 mL of concentrated $H_2SO_4$ and 50 to 100 mg of sodium metal.

The reaction of potassium with liquid bromine may be performed in a crucible placed in a deep jar (as a substitution for the test tube in a trough). A glass tube (of diameter ~5 cm and length ~30 to 50 cm) should be used to guide the piece of potassium from the spoon to the crucible. ~ 1 mL of bromine and ~ 50 mg of potassium give really dramatic results (K&BrMovie, supporting material).

**Important.** We have performed the demonstrations described many times and they have always worked safely, successfully, and impressively; however, we are neither recommending nor advising that instructors perform these experiments unless they know exactly what happens. These demonstrations are not trivial and the demonstrator must be aware of all hazards. We are only trying to offer a safer way for the demonstrator to perform the demonstrations, providing that he or she also takes all safety precautions and performs the demonstration exactly as explained above. We are always willing to advice, discuss, or help in any way a reader who would like to try these experiments.

## Conclusion

These demonstrations are fascinating and unforgettable. They show some very frightening possibilities that can occur when mixing sodium and water. They also point out to students what should not be attempted and give answers to many chemical questions. The authors offer instructors a safe way of performing these demonstrations, providing no modifications to the procedures are made. For those that are still reluctant to perform this kind of demonstration, the available video clip is surely an absolutely safe alternative. The video clip is educational and also serves as a warning to students and others.

## Safety Tips and Hazards

**Sodium is highly reactive metal and care should be taken when it is used in any experiment!** In the presence of water it may spontaneously ignite or even explode. Always wear gloves and face shield during the preparation of this demonstration. Sodium oxide, sodium peroxide, and sodium hydroxide (the first two are products of burning sodium in air; the third one is formed in the reaction of sodium with water) are caustic, and skin and eye irritants.

If several demonstrations are planned, this must be the final demonstration. Because some pieces of ignited sodium often escape from the test-tube mouth and end up on the walls (or the window) of the hood, wait 24 h before cleaning the hood (during this period any sodium still present in metallic form will be oxidized by the oxygen/moisture in the air and will be partly converted to sodium carbonate, in reaction with the $CO_2$ present). Needless to say, during hood cleaning, gloves and face shield must be worn.

**Supporting Material.** A 41 s video clip (http://dx.doi.org/10.1007/s00897000546b), showing the reaction of a large piece of sodium with water and a 14 s video clip of the reaction between potassium metal and liquid bromine (http://dx.doi.org/10.1007/s00897000546c), are available as a supporting materials. A SONY camera (CCD-TR 620E PAL ) coupled to ATI RAGE FURY PRO-vivo graphic card, was used for recording and digitalization.

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## References and Notes

1. Fowles, G. F. *Lecture Experiments in Chemistry;* Bell & Sons Ltd.: London, 1959; pp 40–42.
2. Brady, J. D. *General Chemistry. Principles and Structure;* John Wiley & Sons: New York, 1990; p 23.
3. DoChem 046. Sodium in Water. http://dwb.unl.edu/Chemistry/DoChem/DoChem046.html (accessed March 2002).
4. Verhovskii, V. N. *Techniques and Methods of Performing Chemistry Experiments in a College,* Volume 2; Zavod za izdavanje udžbenika SR Srbije: Beograd, 1965; pp 598–601 (translation from Russian into Serbian).
5. Herak, J. *General and Inorganic Chemistry. Experiments;* Školska knjiga: Zagreb, 1968; p 262 (in Croatian).
6. Atkins, P. W. *Physical Chemistry*, 3rd ed.; Oxford University Press: Oxford, 1986; p 740.
7. Verhovskii, V. N. *Techniques and Methods of Performing Chemistry Experiments in a College,* Volume 2; Zavod za izdavanje udžbenika SR Srbije: Beograd, 1965; pp 602–603 (translation from Russian into Serbian).
8. About the Sodium Movies. http://www.allatoms.com/aboutsodium.htm (accessed March 2002).
9. 4.4.1.1 Sodium and Water. http://www.pc.chemie.uni-siegen.de/pci/versuche/english/v44-1-1.html (accessed March 2002.)