• *Учебни опити и демонстрации* •
• *Teaching Chemical Experiment* •

EXOTHERMIC PROCESSES: QUITE OXIDATION OF NO BY OXYGEN – A LECTURE DEMONSTRATION

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Summary. Processes of vigorous oxidation are well known to be exothermic, as evidenced by common experience. It could be proved that processes of quite oxidation (rusting of iron and breathing are only two of the many examples) are also exothermic. In the offered demonstration, oxidation of nitric oxide (NO) with pure oxygen is monitored via thermocouple thermometer in a reaction chamber. Temperature increases by more than 15 °C, thus proving that this is another example of quite (yet instantaneous) oxidation.

Introduction

With respect to the energy balance during the reaction, chemical reactions (processes) may be endo- or exoenergetic. Exoenergetic processes are, of course, those that are accompanied by a decrease of the system enthalpy. A special class of exoenergetic processes are those in which the enthalpy decrease results from a release of heat, i.e. the exothermic processes.

There are quite a number of demonstrations of exothermic processes [1—4], although the key point in the demonstration is often shifted to other interesting side effects of the experiment and not to the energy release. Among the above there are, naturally, many demonstrations where the exothermic effect is a consequence of an oxidation (as a rule, a vigorous one).

Apart from processes of vigorous oxidation, there are many phenomena that are based on so-called quite oxidation. By quite oxidation we mean oxidation that proceeds without flame, glow or any other similar/spectacular side effect. Typical examples are breathing and rusting of iron. The first phenomenon does not need any special prove, for it is obvious that the temperature of a living organism is (practically always) higher than the temperature of the surrounding. It is also possible to demonstrate that rusting is exothermic, especially if the process is speeded up in an appropriate way [5]. In the course of the above, we offer an interesting (and a very attractive) demonstration of oxidation of NO with oxygen. The demonstration shows (visually very clear) that oxidation occurs, and also that it is exothermic. Let us mention in passing that NO is really an amazing compound, because it contains an odd number of electrons and may thus be treated as the simplest stable free radical. We have already published two other papers dealing with experiments where 'in the center of the events' is again NO and some of its unique properties [6, 7]. {*Remark*: Being a spectroscopist for a quarter of a century, one of us (VMP) finds it appropriate to mention another curiosity about NO: it is the only stable diatomic gas that exhibits P, Q and R branches in the rotovibrational spectrum! For all other diatomics, the Q branch is missing. The peculiar behavior of NO comes out as a consequence of the non-zero orbital electronic angular momentum, which arises from the presence of an impaired electron in the $p(2p)^*$ orbital [8]}.

Materials & Equipment

Gas reservoir filled with NO, steel container with oxygen, rubber balloon with a stopcock, reaction chamber (a large test-tube) of a volume of » 100 mL, a thermocouple thermometer with a digital display, thermocouple protection glass tube, a stand with a screw and a clamp, two-holed rubber stopper to match the reaction chamber.

An easy way for generation of high purity NO is described elsewhere [6].

Experimental Setup

The reaction chamber (the large test-tube) is previously filled with NO from the gas reservoir, it is stoppered with the two-holed stopper and is finally clamped (bottom down). The thermocouple protection glass (with the thermocouple in it) passes through one of the holes and the outlet tube from the stopcock (bind to the balloon) passes through the other. The details are given in Figure 1.

Results and Discussion

In the very start of the demonstration, the reaction chamber is full of NO and hence is colorless, while the temperature equals the room temperature of the lab (cf. Figure 2). Once students are familiar with the above facts, the in-

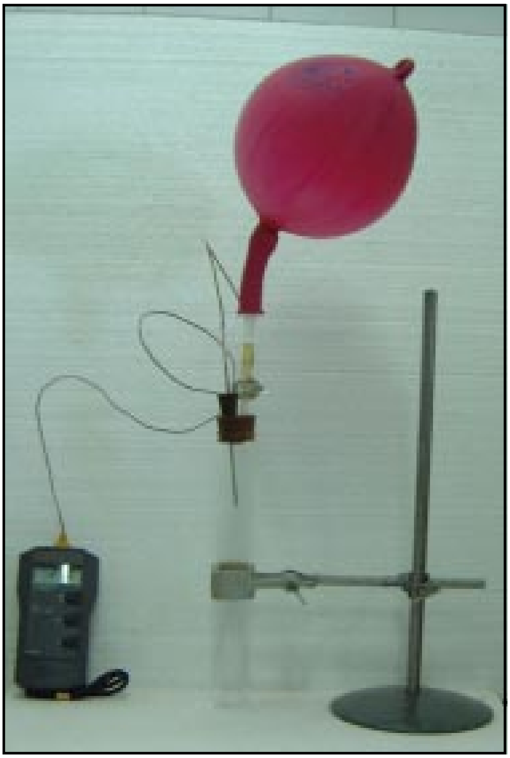

Figure 1: Experimental setup for the demonstration.

Figure 2: Start of the demonstration: one can read the room temperature on the display of the thermometer.

structor carefully opens the stopcock thus letting slow stream of oxygen gas to enter the reaction chamber.

After opening the stopcock, the color of the gas in the reaction chamber instantaneously turns brown. Few seconds after this, the temperature increases significantly (in our case by some 17—18 °C, cf. Figure 3). Both changes are result of a chemical reaction of nitric oxide oxidation. The product is gaseous NO_2 with an intense brown color. One should perhaps add, for clarity, that NO_2 (brown) is in equilibrium with its dimer N_2O_4 (colorless). At room temperature the mole ratio of the monomer and dimer is close to 1.

$$\begin{gathered}\mathrm{NO(g,\ colorless)}\ + \\ +\ \tfrac{1}{2}\mathrm{O_2(g,\ colorless)}\ = \\ =\ \mathrm{NO_2(g,\ brown)} \\ \Delta H = -56.5\ \mathrm{kJ}\end{gathered}$$

As some might already expect it *a priori*, the above chemical reaction is exothermic as evidenced by the temperature increase. Indeed, it is not an example of vigorous oxidation, but still temperature increase can easily be demonstrated in the above way (at least in small lecture rooms, with 10—20 students). For large classes (like 100 students in a large lecture room) we have developed an alternative, where the temperature changes are shown graphically on a computer screen.

Figure 3: End of demonstration: the temperature is by more than 15 °C higher.

Conclusion

This is a fast, efficient and attractive demonstration. It may be used to demonstrate processes of quite oxidation (as proposed), but also to complement existing demonstrations on the chemistry of nitrogen and its oxides (like the color of NO_2, the reactivity of NO, etc.).

Safety Tips

Nitrous oxide and nitrogen dioxide are poisonous gases! Gas generation and filling the reservoir should, for reasons of safety, preferably be done in a hood. All important details concerning generation and handling of NO gas are given elsewhere [6].

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ЕКЗОТЕРМИЧНИ ПРОЦЕСИ – ПЪЛНО ОКИСЛЕНИЕ НА NO С КИСЛОРОД (ЛЕКЦИОННА ДЕМОНСТРАЦИЯ)

Резюме. Окислението на NO с чист кислород може да се проследи в реакционна камера чрез промяна на температурата на реакционната смес, която се отчита с термометър с термодвойка. Температурата се покачва с повече от 15 °C, което е указание за пълно (мигновено) окисление. Тази реакция е предложена като лекционен демонстрационен опит.

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