

Deeper Insight into the Pyrolysis of Acetylsalicylic Acid by Means of Thermogravimetric Measurements in Various Gas Atmospheres, Part 3

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Introduction

In pharmacy, there is hardly any active ingredient about which more has been written than acetylsalicylic acid (or ASA for short; in English-speaking countries even the brand name Aspirin™ is often used as a synonym). Its success story began at the end of the 19th century when Dr. Felix Hoffmann synthesized the substance at the BAYER laboratories for the first time without impurities. Nowadays, it is still one of the most popular pharmaceuticals used across a broad therapeutic range. It belongs to the group of non-steroidal anti-inflammatory drugs (NSAIDs) and is indicated for the treatment of pain, fever and inflammation. In addition, it is used to prevent recurrence of heart attack or stroke in high-risk patients. In 1977, ASA was added as an analgesic to the “essential drug list” of the WHO (World Health Organization). [1]

This is one of four application notes that examine in more detail the thermal behavior of acetylsalicylic acid: decomposition in different gas atmospheres, decomposition kinetics, and the resulting gas species.

Experimental

The sample material, acetylsalicylic acid (CAS: 50-78-2), was acquired from Sigma Aldrich with a purity of > 99%. It is a white, crystalline powder which exists in three crystal modifications [2]. Form I, with a melting point of about 137°C [4], is the most stable one at ambient temperature and above [3].

Pyrolysis experiments are usually carried out in a nitrogen atmosphere due to its availability and comparatively low price. This is also reflected in several publications, for example [5] and [6]. To answer the question as to whether the results obtained under nitrogen can also be generalized to other atmospheres, an experimental series was performed for studying the thermal behavior of acetylsalicylic acid as a function of the purge gas nature. Besides nitrogen, other inert gas atmospheres used were helium and argon. The corresponding measurement parameters are summarized in table 1.

For characterization of the thermal behavior, a NETZSCH TG 209 **F1** instrument was employed.

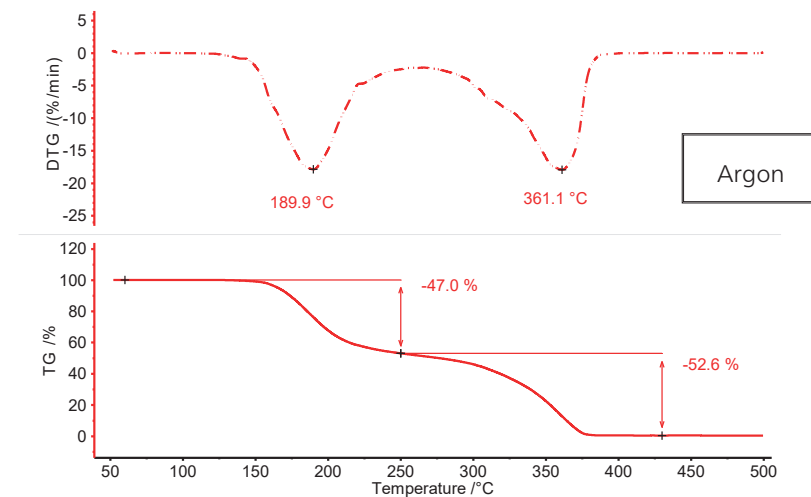
Table 1. Measurement parameters

Parameter	Acetylsalicylic Acid
Sample mass	Approx. 5 mg
Atmosphere	Argon, nitrogen and helium
Crucible	Al ₂ O ₃ , 85 µl, open
Temperature program	RT to 600°C
Flow rate	40 ml/min
Sample holder	TGA, Type P

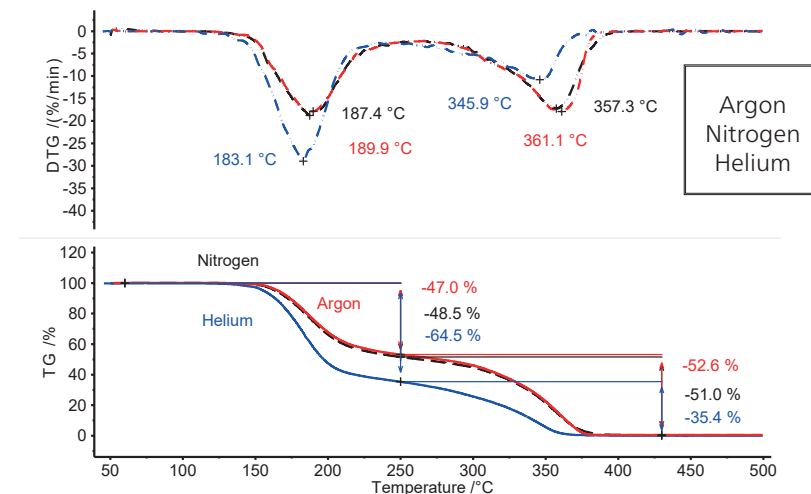
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Figure 1 depicts the typical two-step decomposition profile of acetylsalicylic acid, resulting from heating the substance in a flowing argon atmosphere. The first step, with a DTG peak temperature of about 190°C, exhibits a mass loss of 47%; the second step, at 361°C (again DTG peak temperature), exhibits almost 53%. However, no real plateau occurs between the two mass-loss steps. The first one merges, more or less, into the second. This indicates that maybe more than two decomposition steps are involved. The possibility that a more complex mechanism such as this would be the case here is additionally supported by the fact that the second DTG peak has a clearly visible shoulder at approx. 320°C in the descending slope.

Comparing the situation in an argon atmosphere with experiments performed at identical heating rates in both nitrogen and helium atmospheres (figure 2), the behavior under nitrogen conditions is about the same as in argon, whereas it changes significantly under a flowing helium atmosphere. An increase in the first mass-loss step of about 18 percentage points (from 47% to almost 65%) and consequently, a decrease in the second mass-loss step of the same amount (from 53% to 35%) is observed. In addition, both mass-loss steps are shifted to somewhat lower temperatures, indicated by the decrease in the particular DTG peak temperatures (4 K to 7 K for the first DTG peak and 11 K to 15 K for the second one). This suggests that something different is going on in a helium atmosphere than in argon and nitrogen atmospheres.



1 Temperature-dependent mass loss (TGA) and mass-loss rate (DTG) of acetylsalicylic acid in an argon atmosphere; sample mass: 5.02 mg; open Al_2O_3 crucible



2 Temperature-dependent mass loss (TGA) and mass-loss rate (DTG) of acetylsalicylic acid in an argon (red, solid line), nitrogen (black, dashed line) and helium atmosphere (blue, solid line); open Al_2O_3 crucible

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In literature, a two-step mechanism with simultaneous evaporation of intermediates is proposed as the pyrolysis mechanism of acetylsalicylic acid [7]. Measurements conducted by NETZSCH in a nitrogen as well as in a helium atmosphere using hyphenated techniques, more precisely, TGA/STA in combination with FT-IR [6] and GC-MS [8], support this hypothesis. This indicates that the nature of the decomposition products is independent of the gas atmosphere.

The major difference between all these experiments is the density of the purge gas used (see table 2). It differs maximally by a factor of 10.

This suggests that a higher density of the purge gas creates a higher back pressure, which results in a reduced transfer of the volatile sample components into the gas atmosphere. This effect is particularly visible when using helium, which has a much lower density than nitrogen or argon. Since true decomposition reactions are independent of the surrounding inert gas atmosphere [10], it is perhaps the parallel evaporation that is mostly affected.

The fact that the decomposition takes place at slightly lower temperatures in helium (e.g., DTG peak at 183°C compared to 187°C in nitrogen and approx. 190°C in argon) is due to the higher thermal conductivity of this gas (see table 3). In the temperature range where thermal radiation plays only a minor role, the sample reaches the reaction temperature in a purge gas with higher thermal conductivity somewhat earlier.

Conclusion

The present example shows that the selected gas atmosphere may have a strong impact on the thermogravimetric measurement results, even if the purge gas does not act as a reaction partner. A greatly varying gas density can have an effect on the transfer of gaseous compounds from the sample surface into the surrounding gas atmosphere – especially if evaporation is involved.

Table 2. Density values at 0°C and normal pressure of various purge gases

Gas	Density / (g/cm ³) [9]
Helium	0.178
Nitrogen	1.251
Argon	1.784

Table 3. Thermal conductivity values under standard conditions of the various purge gases

Gas	Thermal Conductivity (W/m·K) [11]
Helium	0.1567
Nitrogen	0.0260
Argon	0.0179

References

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