



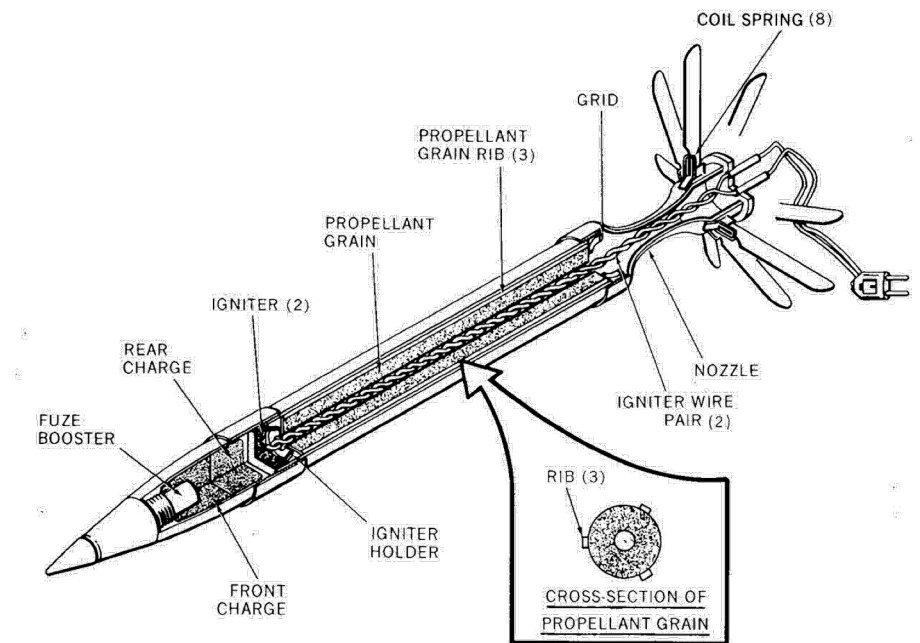
Influence of Humidity on the Life of Double Base Rocket Propellants

Mr. Alonso Romero Jabalquinto

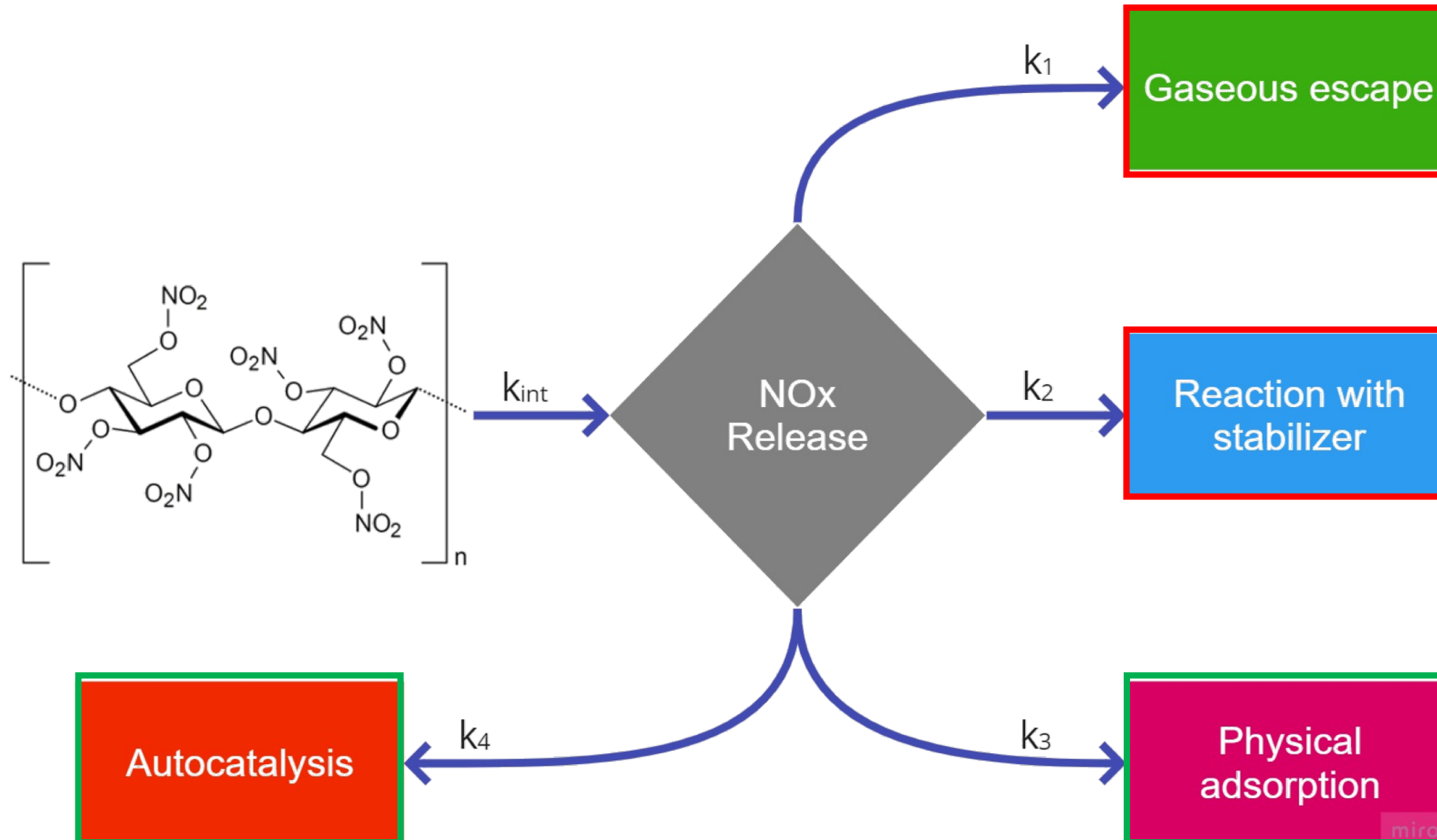
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- Methodology
- Heat flow curve
- Results
 - Stabiliser depletion
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- Decomposition kinetics using HFC data
 - Results
- Conclusion



Introduction: Double base propellant chemical decomposition



Introduction

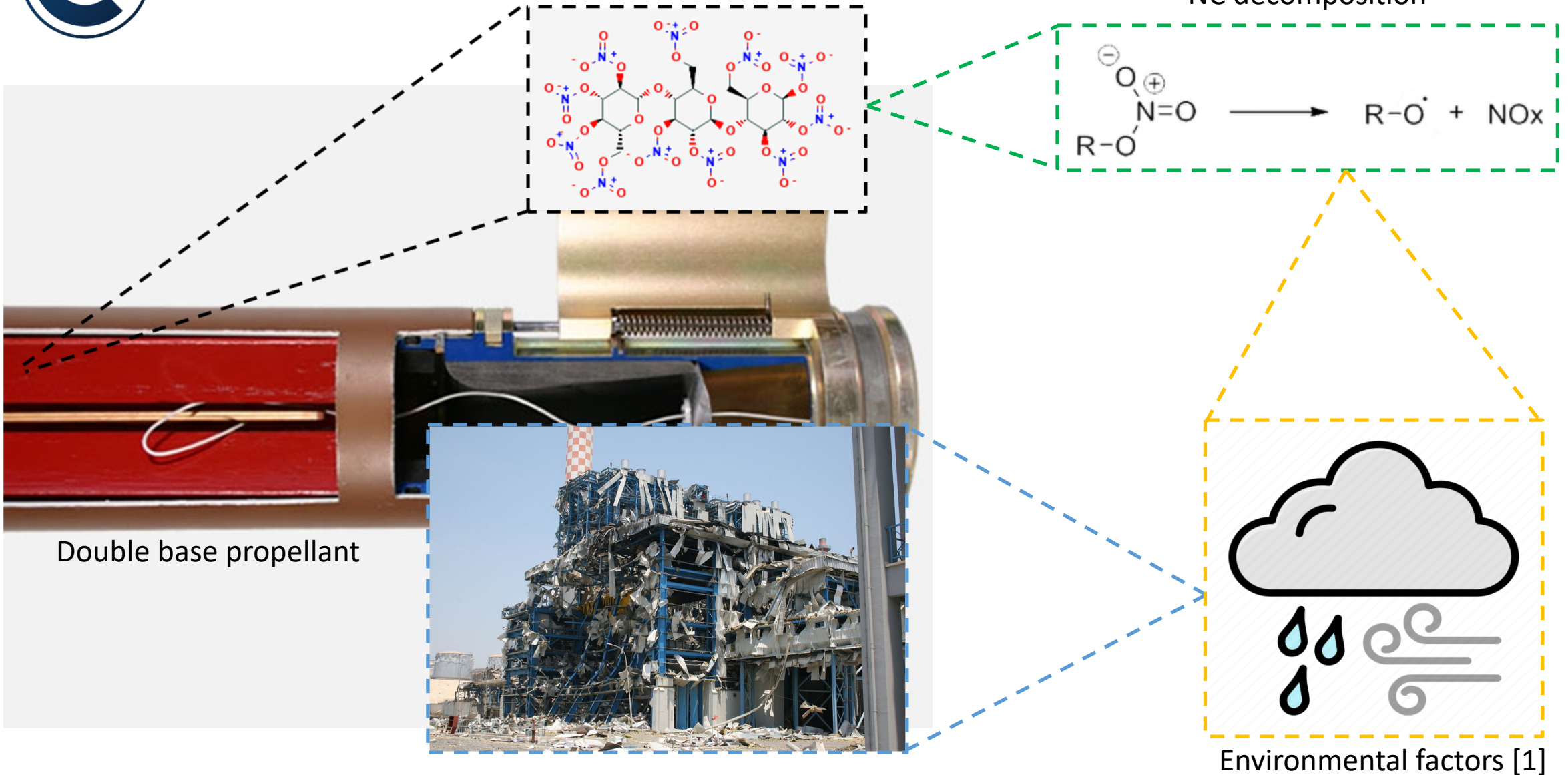
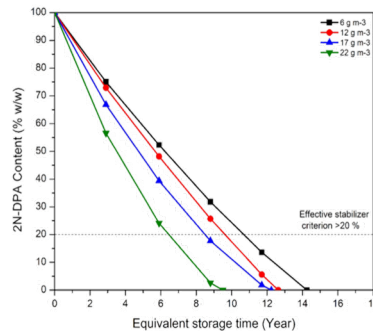
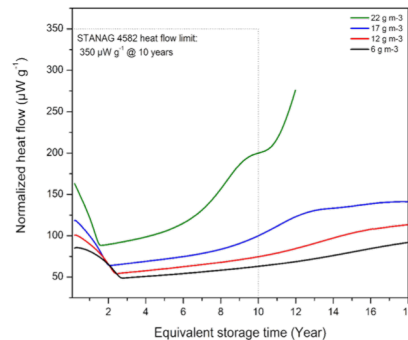
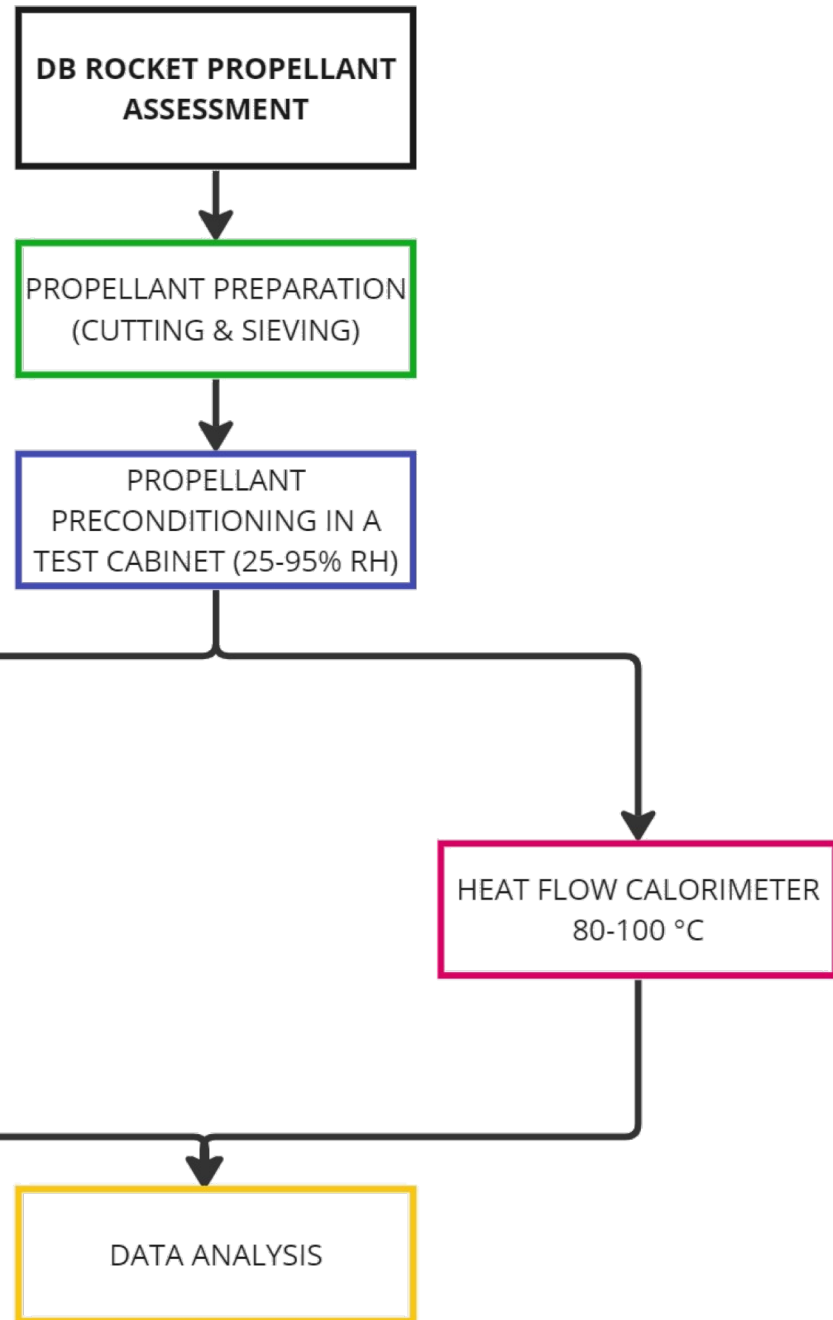
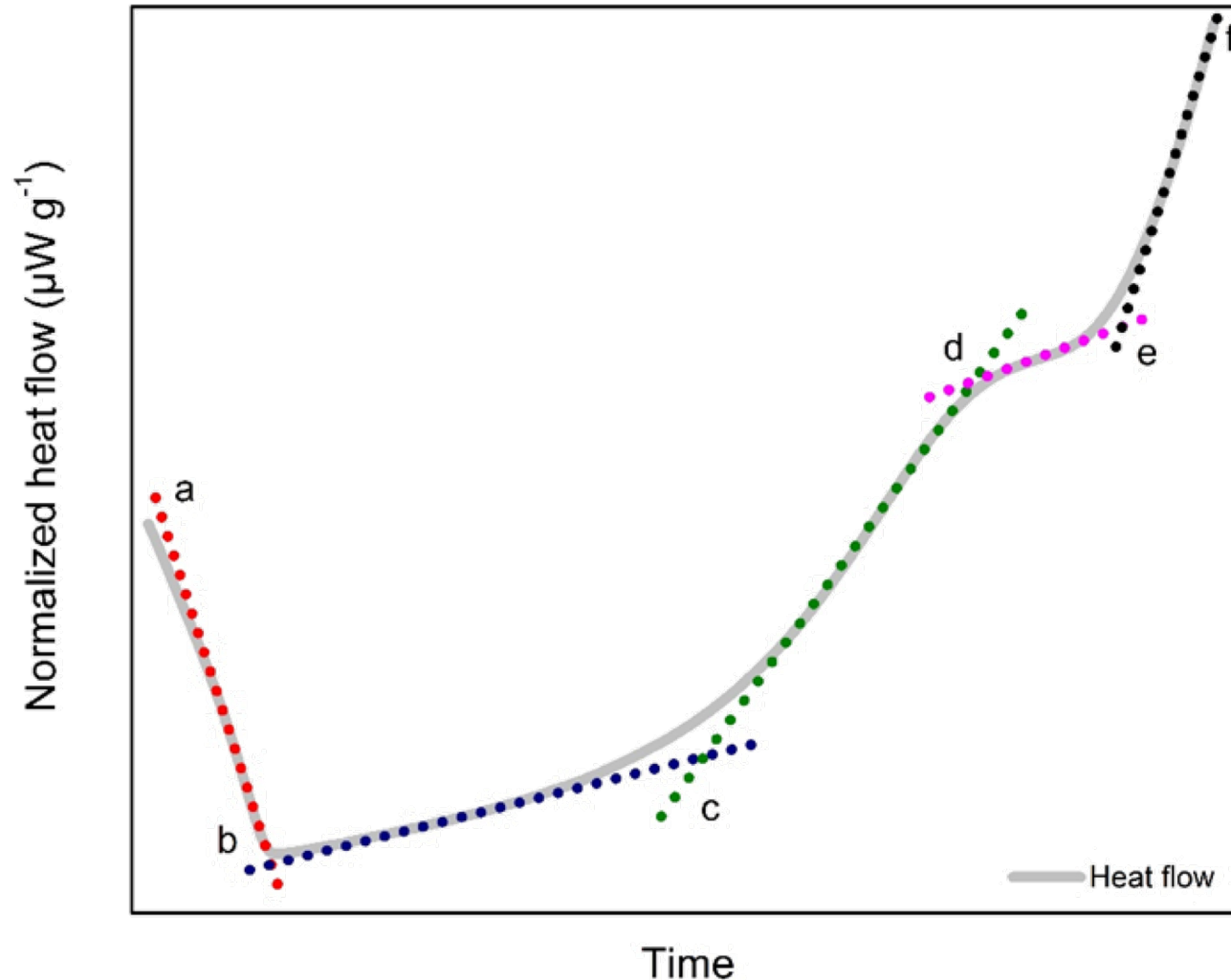


Table 1. DB propellant chemical composition.

Ingredient	Content (w/w %)	Ingredient	Content (w/w %)
Nitrocellulose (NC)	5-57	2-N-Diphenyl amine	1-8
Nitroglycerine (NG)	19-46	Copper Oxide	0-3



Heat flow curve



Different stages of a DB rocket propellant linearized decomposition [2-3]

a-b Stage where the remaining oxygen in the vial interacts with the propellant

b-c Region where propellant decomposition is accompanied by the depletion of the main stabiliser

c-d Stage where the heat flow increases due to the depletion of the main stabiliser

d-e Zone where propellant decomposition is followed by the consumption of secondary stabilisers

e-f Stage of a considerable increase in decomposition (autocatalysis)

2. Guillaume, Pierre, et al. "Heat flow calorimetry of propellants—Effects of sample preparation and measuring conditions." *Propellants, Explosives, Pyrotechnics* 26.2 (2001): 51-57.

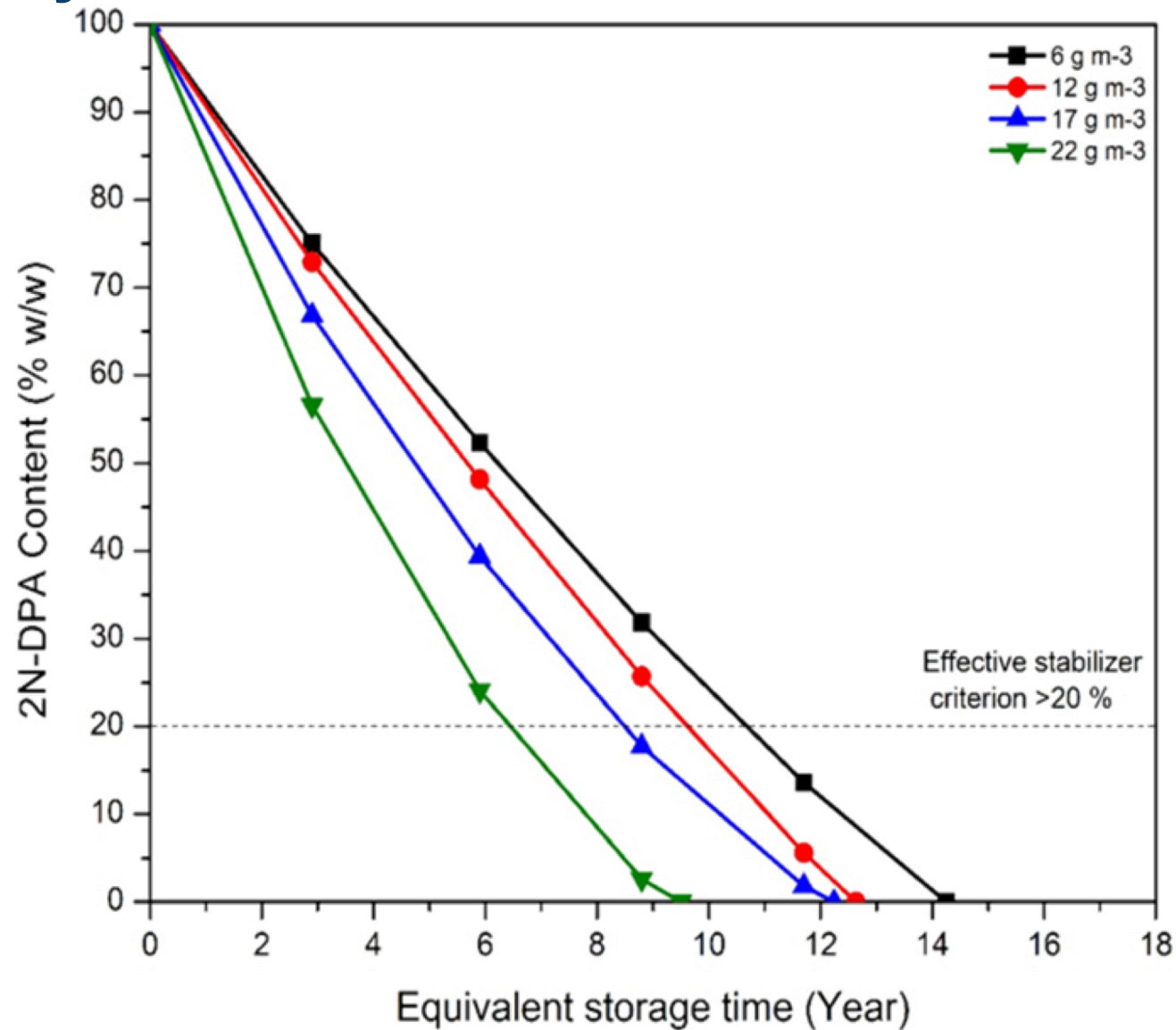
3. Guillaume, P. & Wilker, S. "International Round Robin Test to Determine the Stability of DB Ball Propellants by Heat Flow Calorimetry." *Proceedings of the Workshop on the Microcalorimetry of Energetic Materials Held in Leeds* (1999): T1–T13.



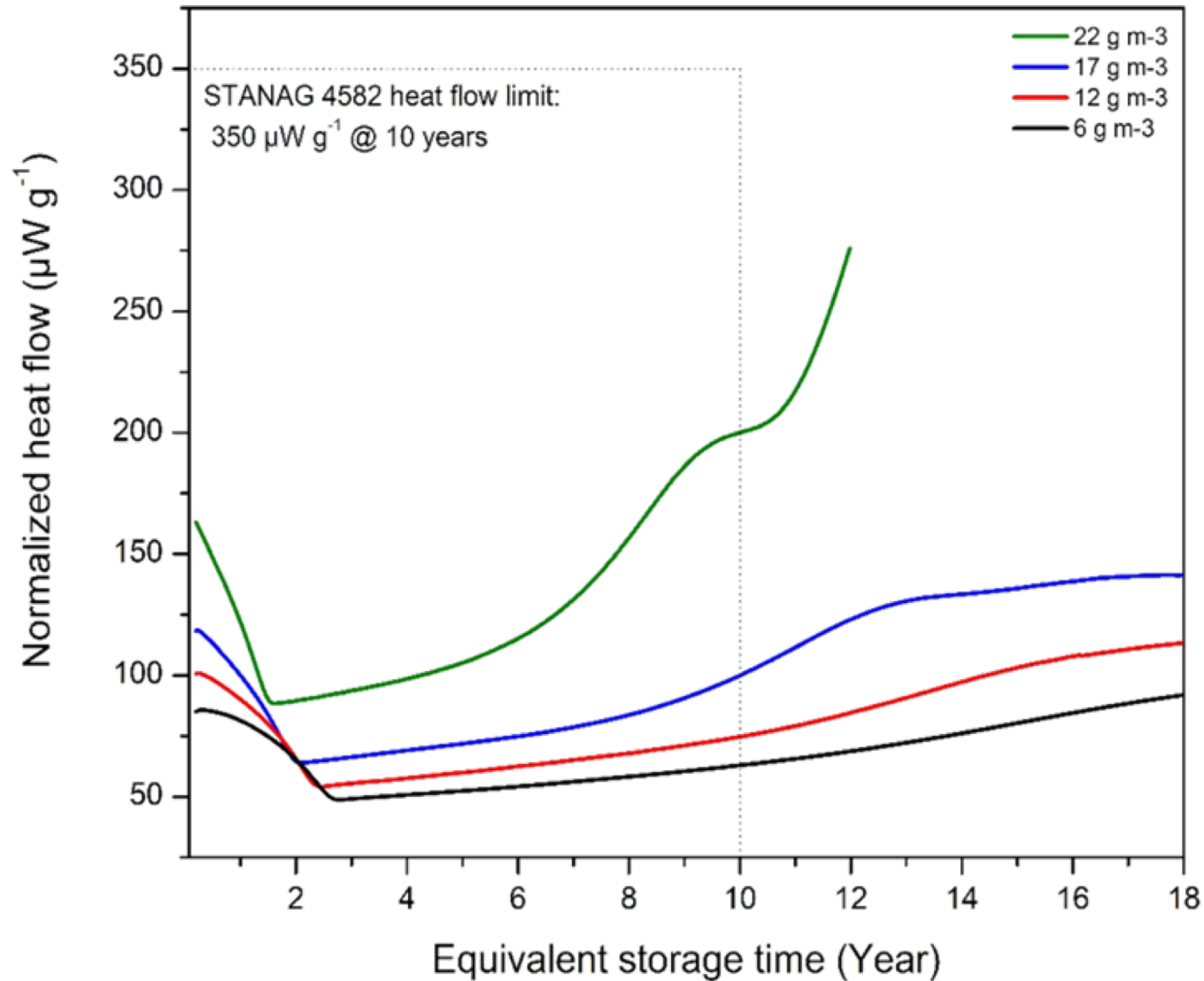
Results: Stabiliser depletion @ 90 °C as a function of humidity

Sample (% RH)	Time to reach 20 % w/w effective stabilizer content (Day)	Equivalent time to reach 20 % w/w effective stabilizer content (Year)	Pass/Fail
25 (6 g/m ³)	3.68	10.8	Pass
50 (12 g m/3)	3.2	9.4	Fail
75 (17 g m/3)	2.85	8.4	Fail
95 (22 g m/3)	2.2	6.5	Fail

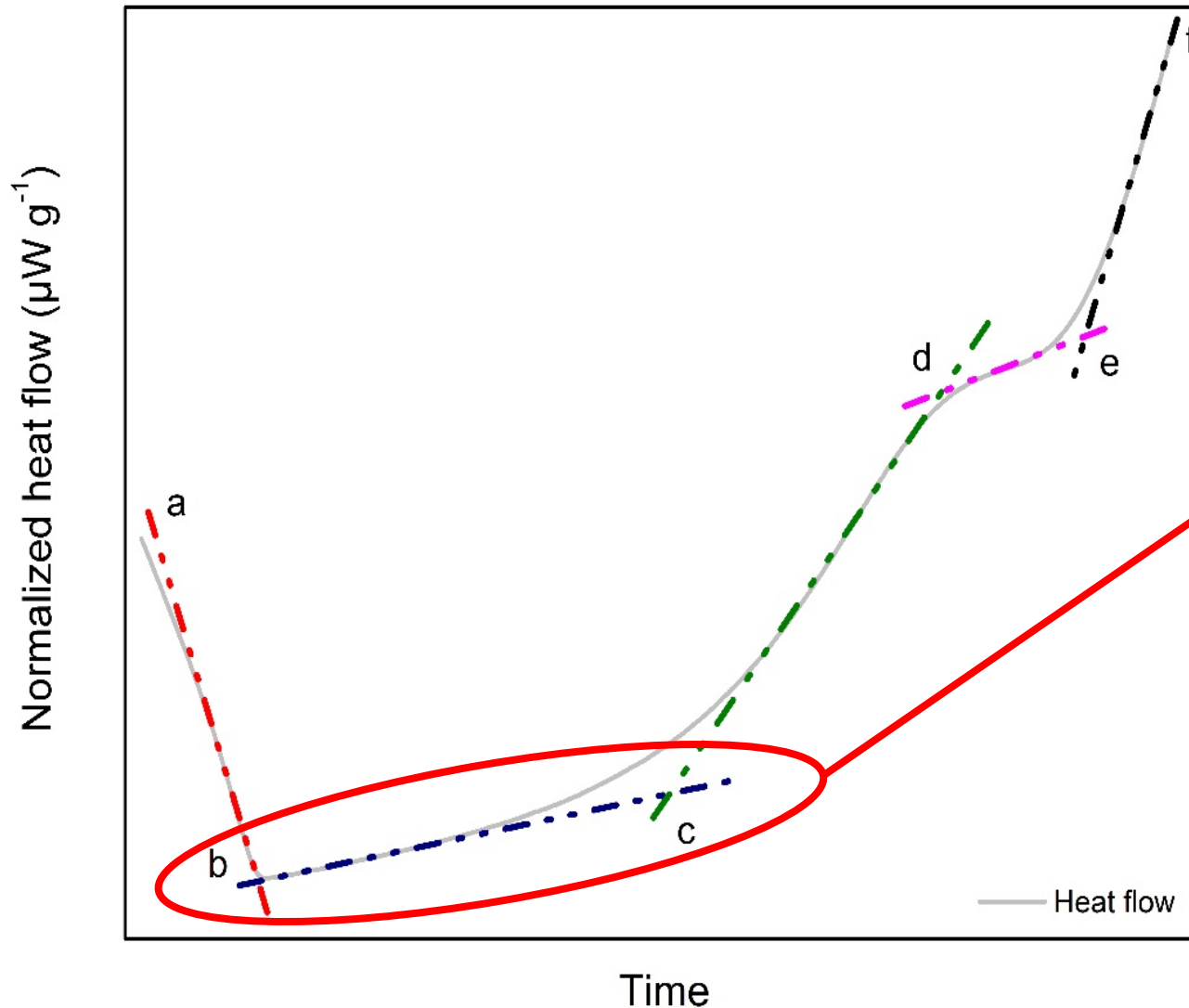
Results: Stabiliser depletion @ 90 °C as a function of humidity



Results: Heat flow @ 90 °C as a function of humidity



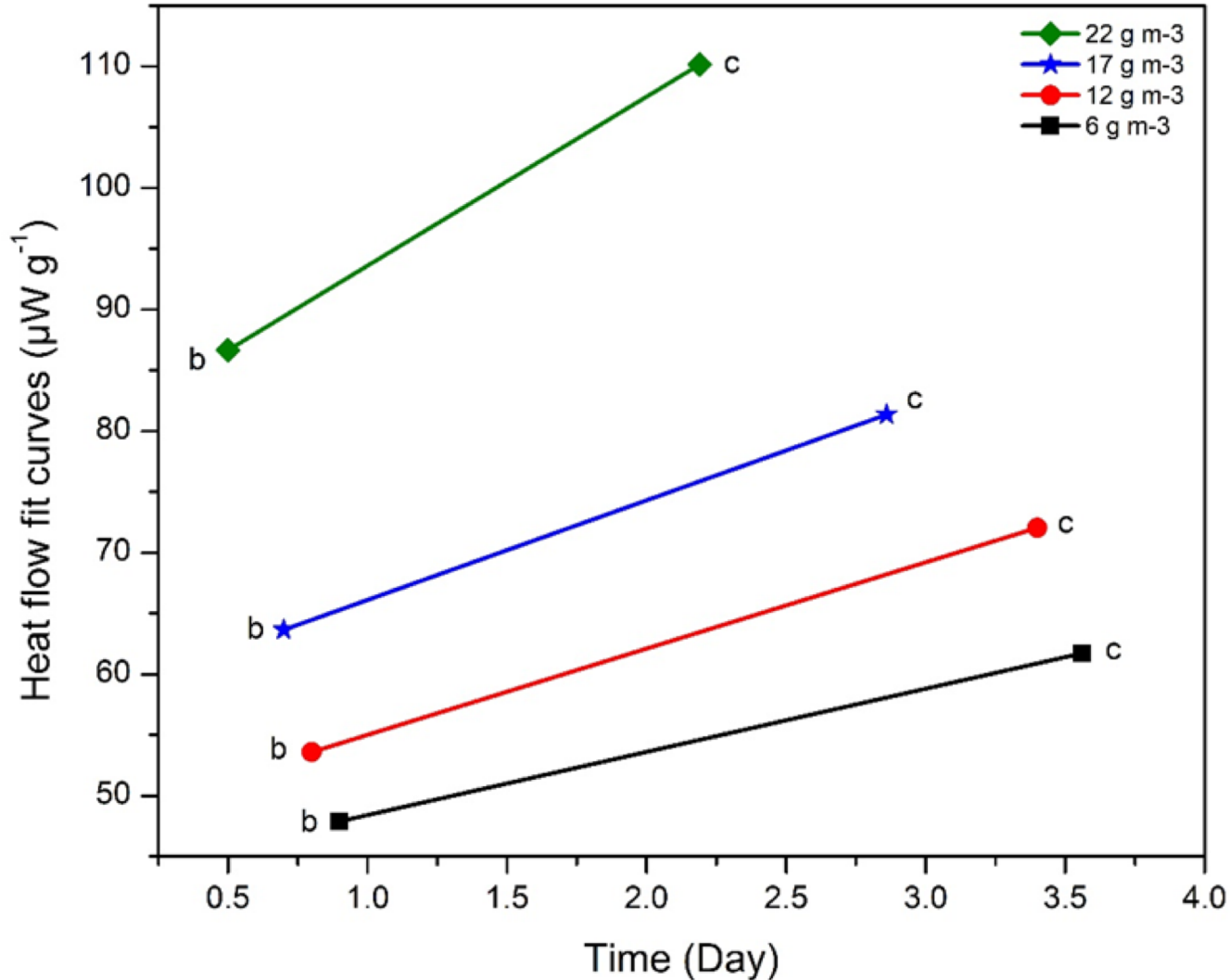
Decomposition kinetics using HFC data



First order stabiliser depletion decomposition process [1-3]

1. Guillaume, Pierre, et al. "Heat flow calorimetry of propellants—Effects of sample preparation and measuring conditions." *Propellants, Explosives, Pyrotechnics* 26.2 (2001): 51-57.
2. Guillaume, P. & Wilker, S. "International Round Robin Test to Determine the Stability of DB Ball Propellants by Heat Flow Calorimetry." *Proceedings of the Workshop on the Microcalorimetry of Energetic Materials Held in Leeds (1999)*: S1–S20.
3. Zhao, Xin, et al. "A Novel Method for Prediction of Propellant Shelf-Life Based on Arrhenius Equation." *Propellants, Explosives, Pyrotechnics* 43.4 (2018): 348-354.

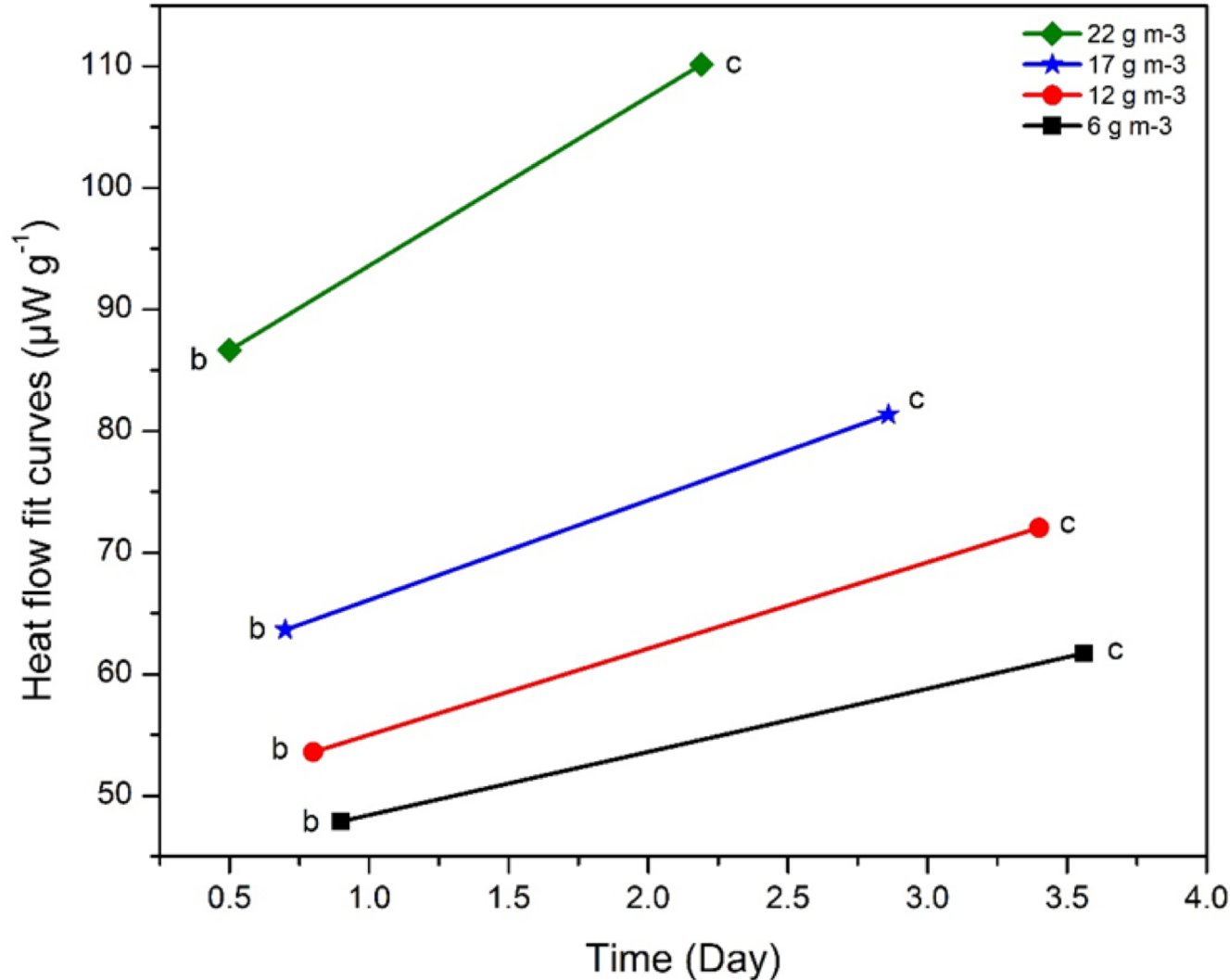
Decomposition kinetics using HFC data: Results (90 °C)



- Decomposition of DB rocket propellants can be described as a first-order kinetic process:

$$\ln|\Delta HF| = -k \cdot t$$

Decomposition kinetics using HFC data: Results (90 °C)



- Decomposition of DB rocket propellants can be described as a first-order kinetic process:

$$\ln|\Delta HF| = -k \cdot t$$

- General model for the combined effect of temperature and water content on propellant decomposition [4-6]:

$$\ln|k| = -\frac{E_a}{RT} + \ln|A| + [C \cdot WC]$$

4.K.C. Waterman, R.C. Adami, Accelerated aging: Prediction of chemical stability of pharmaceuticals, Int. J. Pharm. 293 (2005) 101–125. <https://doi.org/10.1016/j.ijpharm.2004.12.013>.

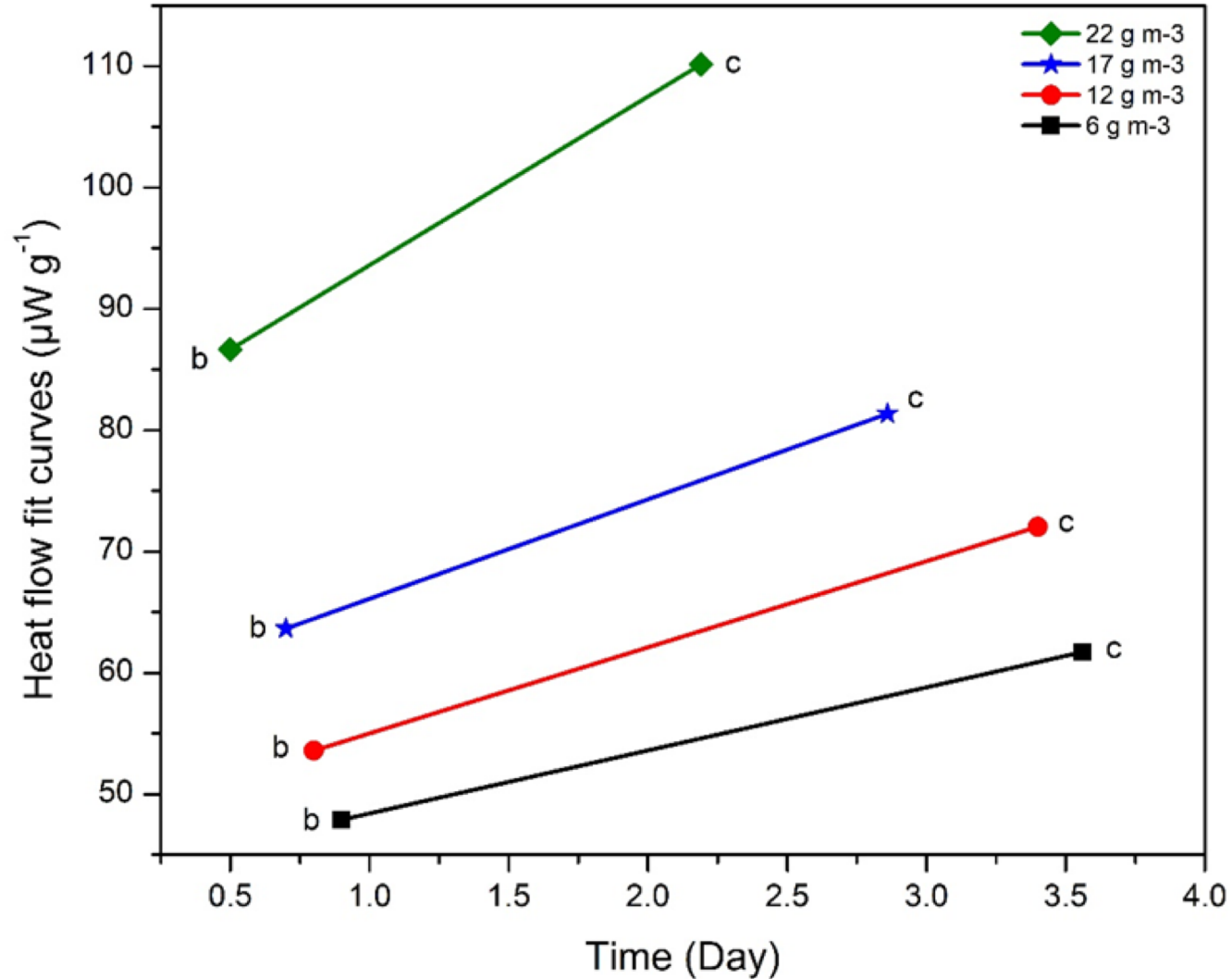
5.N. Li, L.S. Taylor, L.J. Mauer, Degradation kinetics of catechins in green tea powder: Effects of temperature and relative humidity,

J. Agric. Food Chem. 59 (2011) 6082–6090. <https://doi.org/10.1021/jf200203n>.

6. X. Zhao, X. Rui, Y. Wang, C. Li, W. Liu, Propellant shelf-life prediction under temperature and relative humidity conditions based on DPA kinetics,

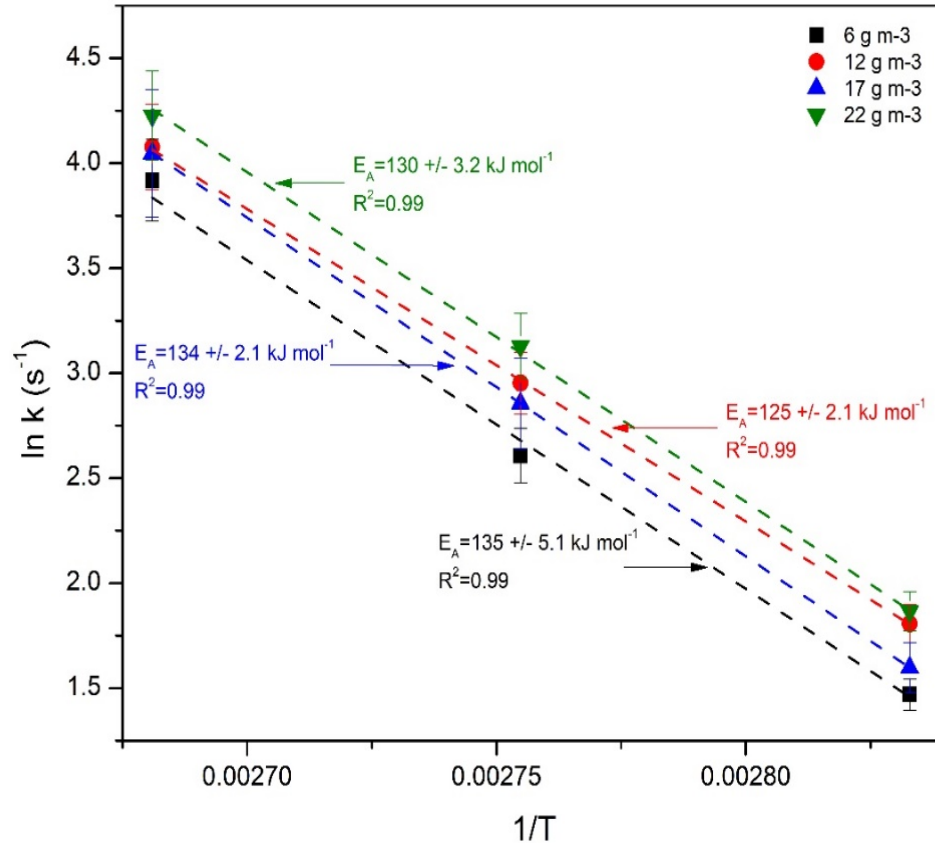
J. Energ. Mater. 37 (2019) 407–419. <https://doi.org/10.1080/07370652.2019.1630027>.

Decomposition kinetics using HFC data: Results

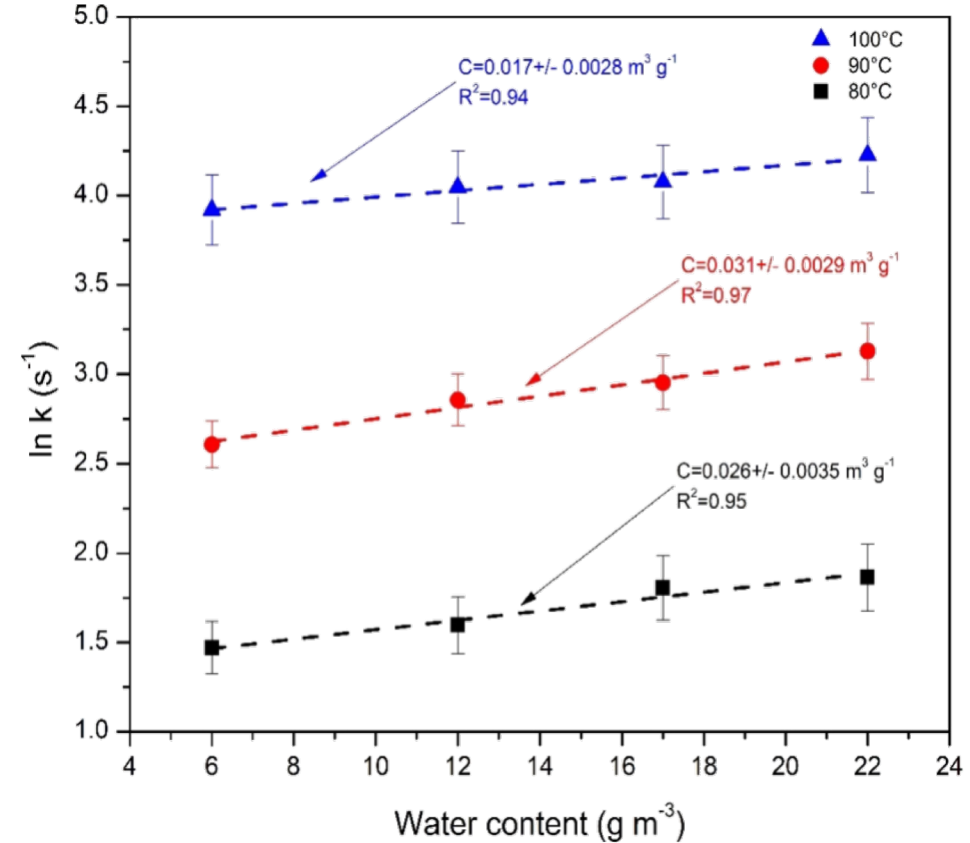


T	Water content	Δ Normalized heat flow
°C	g m ⁻³	$\mu\text{W g}^{-1}$
80	6	4.3
	12	6.1
	17	4.9
	22	6.4
90	6	13.6
	12	19.1
	17	17.4
	22	22.8
100	6	50.4
	12	59
	17	57.3
	22	68.5

Decomposition kinetics using HFC data: Results



Influence of absolute humidity on Arrhenius curves of HFC region b-c

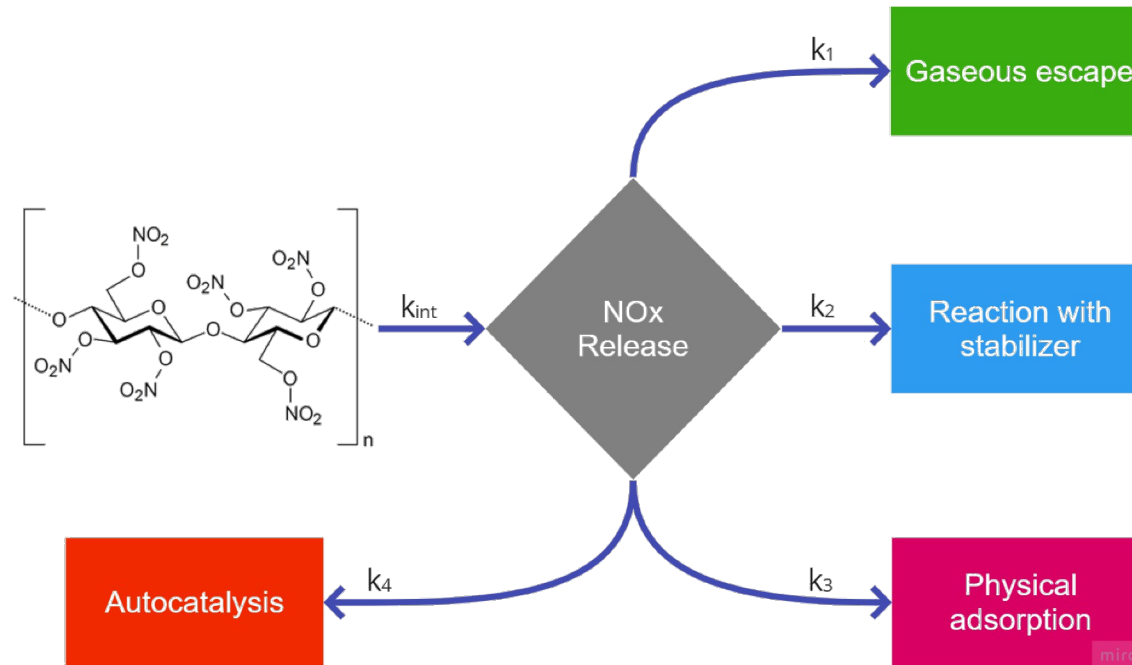


Relationship between reaction rate constant and water content at different temperatures

Kinetic model:
$$\ln|k| = -\frac{131 \text{ kJ mol}^{-1}}{RT} + \ln|A| + [(0.025 \text{ m}^3 \text{ g}^{-1}) \cdot WC]$$

Conclusions

- Humidity/water significantly reduces the life of DB propellant
- Discrepancy between the failure criteria established for stabiliser depletion and HFC (AOP-48 ed2 and STANAG 4582).





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- Discrepancy between the failure criteria established for stabiliser depletion and HFC (AOP-48 ed2 and STANAG 4582).
- Dominant mechanism in the decomposition of DB rocket propellant is thermolysis, but water drives the autocatalysis reaction.



Conclusions

- Humidity/water significantly reduces the life of DB propellant
- Discrepancy between the failure criteria established for stabiliser depletion and HFC (AOP-48 ed2 and STANAG 4582).
- Dominant mechanism in the decomposition of DB rocket propellant is thermolysis, but water drives the autocatalysis reaction.
- Environmental parameters such as water/humidity should be addressed in addition to temperature.

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For your attention, Thank you!



Q & A Time



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