Demonstration of 1-Nitramino-2,3-dinitroxypropane as an Energetic Plasticiser Component in an HMX-based PBX

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Overview

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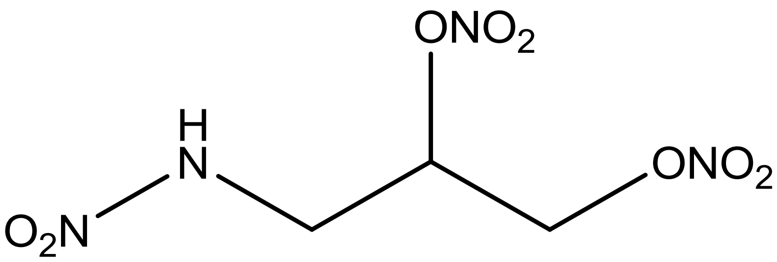
Background – 1-Nitramino-2,3-dinitroxypropane (NG-N1)

- Research into energetic binder systems for high powered PBXs
- Literature search revealed work on NG-N1*
- Stimulated interest in use as high energy plasticiser component
  - Physical properties
    - Crystalline solid – 1.799 g/cc, melting pt. 66°C
    - Readily forms waxy consistency when impure or when mixed
  - High performance
    - V of D. 8.8 km / s (calculated)
    - Energy 10.7 kJ/cc
  - Good hazard properties
    - BAM impact – 14 J. (NG 0.2 J, RDX 7 J)
    - BAM friction 96N (RDX 120)
    - OZM Spark 1.1 J (RDX 0.1-0.2 J)



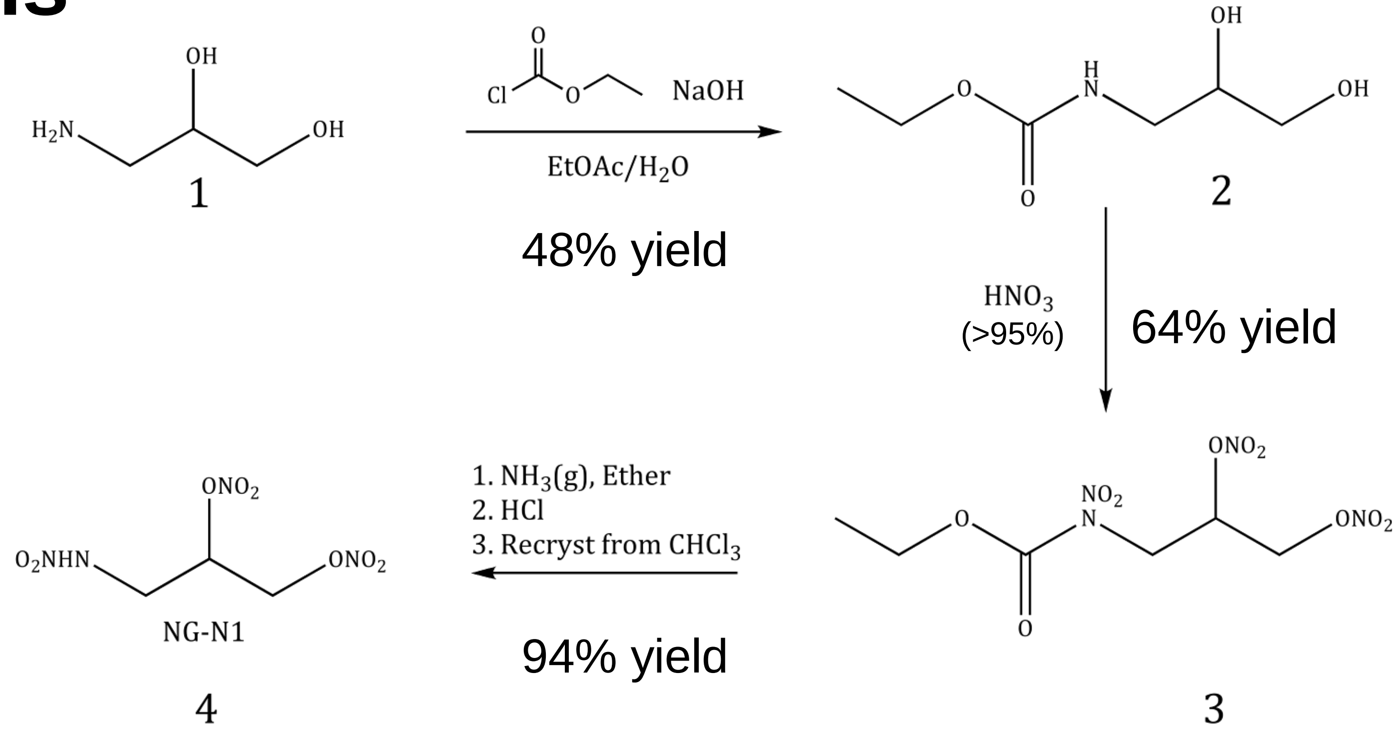
* Altenburg, Klapötke and Penger, *Central European Journal of Energetic Materials*, pp 255-275 (**2009**).

Aims of work

- Investigate feasibility of NG-N1 as a plasticiser ingredient – mix with a second component
  - Comparison with K10

    K10 is a mixture of di- and tri-nitro ethylbenzene (DNEB and TNEB)
- Produce an energetic binder system
  - Use plasticiser to form gel with nitrocellulose
- Formulate chosen binders with HMX
  - Hazard test and measure performance

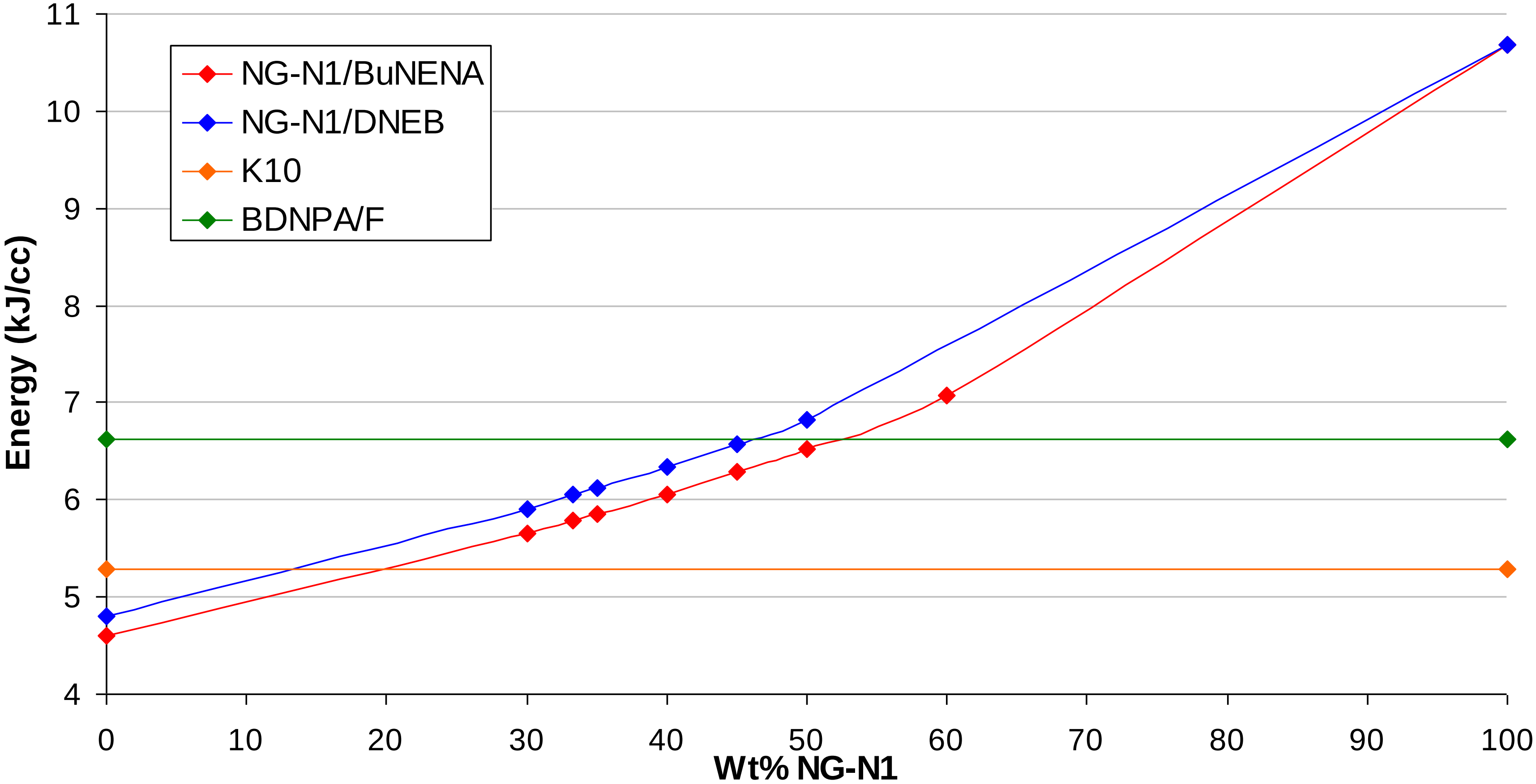
Synthesis



- Simple synthesis from affordable starting materials
- Recrystallisation from chloroform required to purify NG-N1 (**4**) from ethyl carbamate formed in the final step
- Yield dependent upon the efficiency of distillation in the synthesis of **2**
- Overall yield of 29 % obtained

Energy of plasticiser mixes

- Calculated energy of mixtures with DNEB or ButylNENA

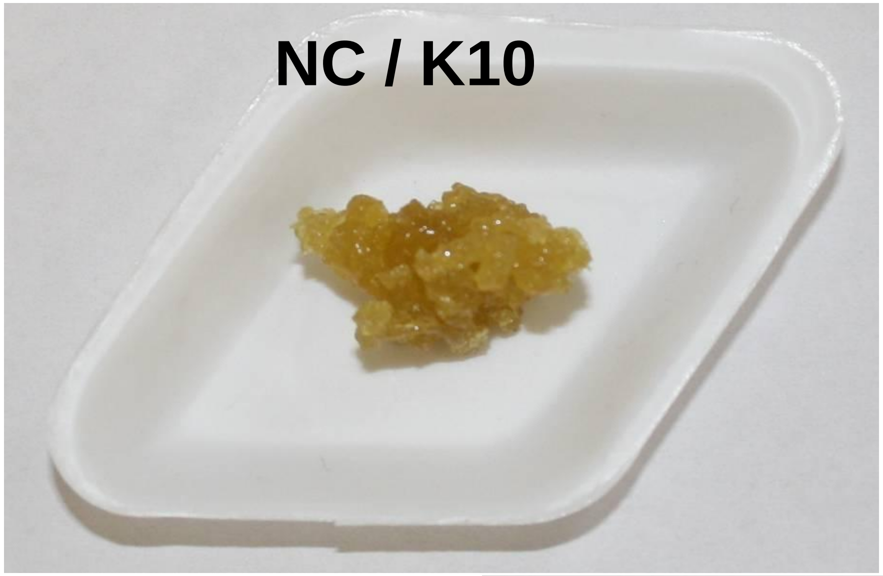


Binder Formulation

- Plasticisers: NG-N1 mixed (in solution) with either DNEB or Butyl NENA
- Experimentation carried out to investigate achievable loadings of NG-N1
- Solution of Nitrocellulose (~12% N) added to plasticisers at a ratio of 1:8 (NC : Plasticiser) - *found to produce gel consistency*
- Proportional amount of ethyl centralite stabiliser added

- Energy of Optimised Plasticiser mixes.
  - NG-N1/DNEB 33.3 / 66.6 wt% 6.05 kJ/cc
  - NG-N1/BuNENA 40 / 60 wt% 6.06 kJ/cc
  - NG-N1/BuNENA 50 / 50 wt% 6.5 kJ/cc

    (for comparison)
  - K10 (TNEB/DNEB) 35 / 65 wt% 5.3 kJ/cc
  - BDNPA/F 6.6 kJ/cc



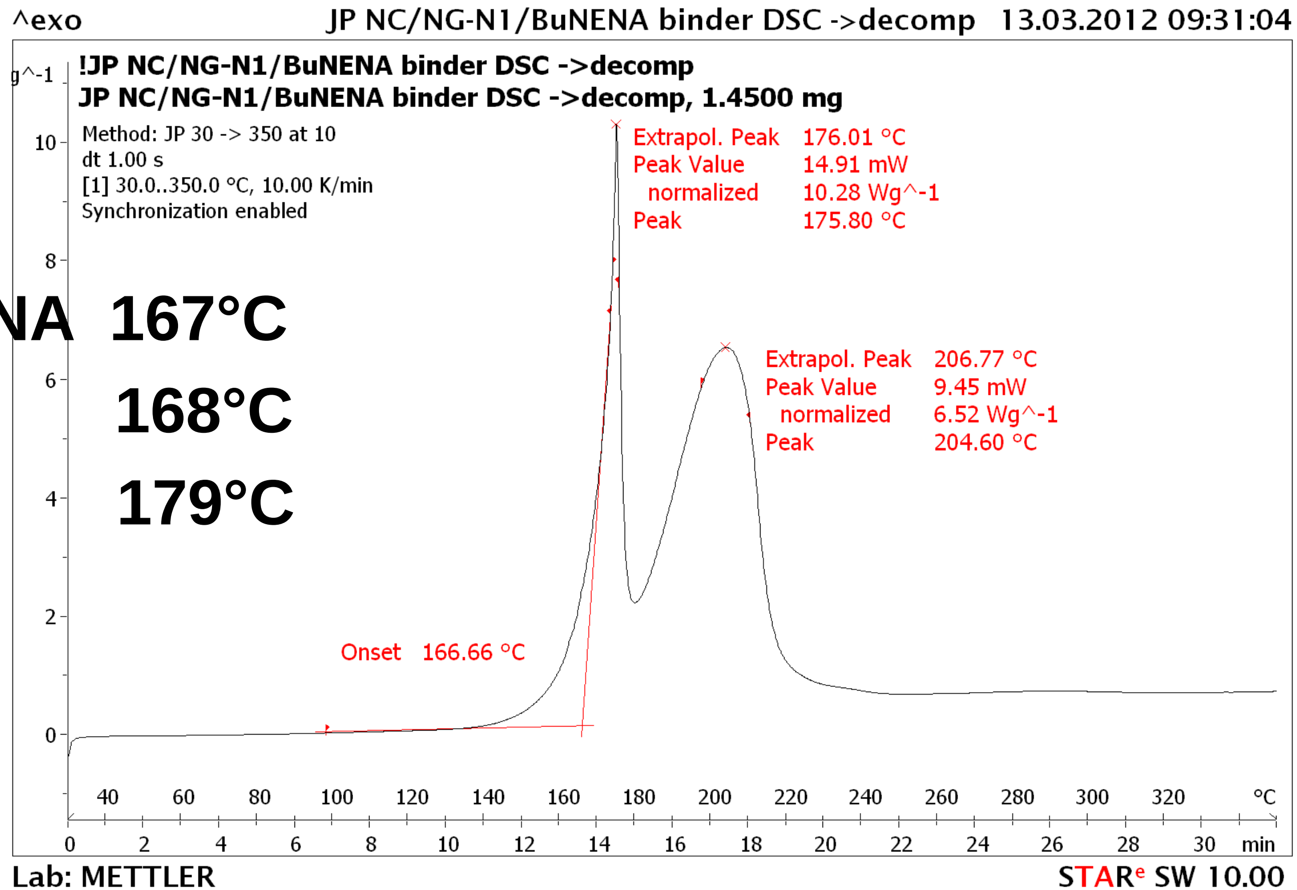
- **Several weeks after mixing, precipitation of NG-N1 observed in DNEB binder. Solvent evaporation? Limited miscibility?**

Binder Properties

Binder	Tg (°C)	Density (g/cc) (Measured)	Energy (kJ/cc) (Calculated)
NC + K10	-65.2	1.400	4.993
NC + NG-N1 / DNEB (33.3 / 66.6)	-60.3	1.428	5.549
NC + NG-NG / BuNENA (40 / 60)	-64.1	1.379	5.915
NC + NG-NG / BuNENA (50 / 50)	-62.6	1.408	6.155

DSC decomposition

- NG-N1/BuNENA 167°C
- NG-N1/DNEB 168°C
- K10 179°C



Formulation with HMX

- Selected binders formulated with HMX
- Intended to use constant VOLUME % of binder
  - Ensures any differences between formulations (especially hazard properties) are a direct result of change in binder system
  - HMX / NC - K10 Formulation 91 : 9 weight % HMX : binder
  - Exact composition of others adjusted to keep constant vol% of HMX

Explosive performance (calculated - Cheetah V4)

- V of D (km/s)	8.59	8.67	8.70
- P of D (GPa)	32.2	33.2	33.8

- Charges pressed
- Plate dent tests planned for initial comparison of formulations – firing results not yet available

Powder hazard test results

Test	HMX / NC / K10	HMX / NC / NG-N1 / BuNENA (40:60)	HMX / NC / NG-N1 / BuNENA (50:50)
BAM Impact (50% method; EMTAP Test 43B)	7.7 J (s.d. 0.12 J)	6.2 J (s.d. 0.04 J)	6.0 J (s.d. 0.09 J)
Rotary Friction (EMTAP Test 33)	3.7	2.8	2.7
Electric Spark Test (EMTAP Test 6)	Ignites at 4.5 J; No ignitions at 0.45 J	Ignites at 4.5 J; No ignitions at 0.45 J	Ignites at 4.5 J; No ignitions at 0.45 J
Isothermal TGA (15hrs at 100°C)	-2.9% mass loss	-2.8% mass loss	-2.5% mass loss

Conclusions

- Binder Studies
  - NG-N1 / ButylNENA mix successful in gelatinising NC
    - Glass transition temperature comparable to NC / K10
    - Energy of binder system exceeds NC / K10
  - NG-N1 / DNEB mix successful in gelatinising NC
    - Issues with phase separation in proportions studied

- HMX formulations
  - Calculated performance data shows noticeable performance increase in pressure and velocity of detonation
  - NG-N1 containing compositions show increased impact and friction sensitivity over NC-K10 binder system

Further work

To finish current study

- Measure explosive performance properties of formulations
  - Plate dent and rate stick tests intended

- Potential future work with NG-N1:
  - Revisit NG-N1/DNEB binder system
  - Measure / optimise mechanical properties of binder systems
  - Investigate alternative energetic liquids to Butyl NENA and DNEB
  - Study miscibility of NG-N1 with alternative energetic polymers/binders, e.g. polyNIMMO, polyGLYN

  - Potential applications in propellants as NG alternative

Questions