Stabiliser Effects on Flow Synthesis of Iron Oxide Nanoparticles in Polyol Medium

L. Van Leuven[1], T. Vangijzegem[1], D. Stanicki[1], S. Laurent[1,2]

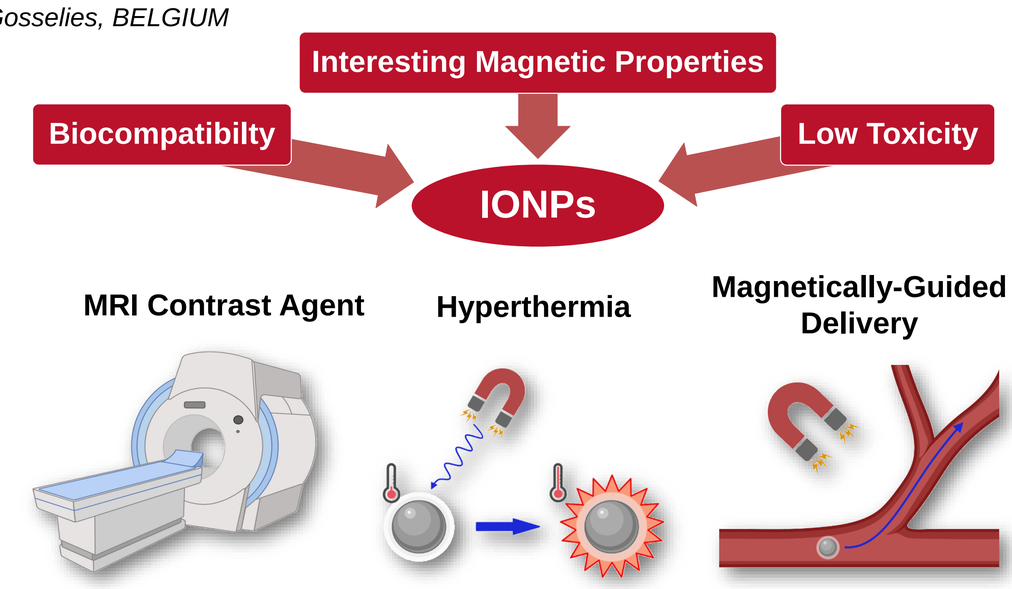
[1]*General, Organic and Biomedical Chemistry Unit, NMR and Molecular Imaging Laboratory, University of Mons (UMONS), 7000 Mons, BELGIUM*

[2] *Center for Microscopy and Molecular Imaging (CMMI), 6041 Gosselies, BELGIUM*

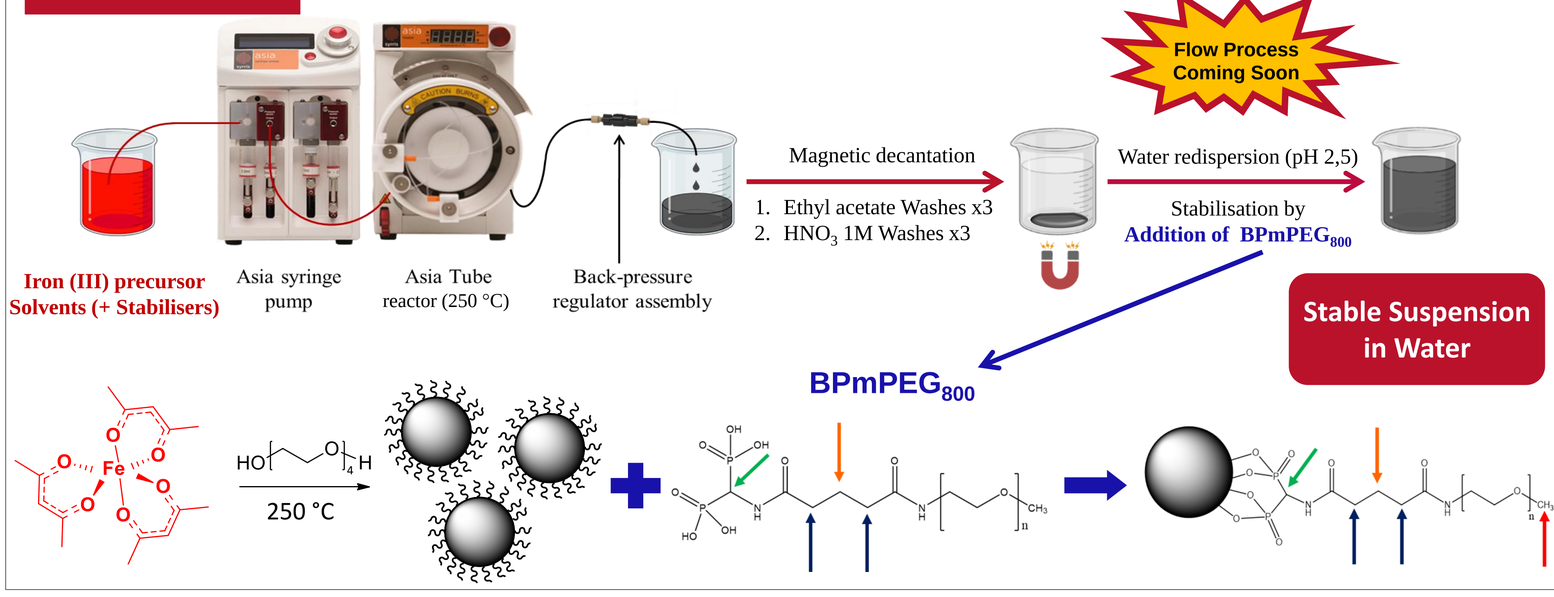
Iron oxide nanoparticles (IONPs) have received significant attention due to their superparamagnetic properties, which make them ideal as contrast agents for MRI. Among the various synthetic routes described, one of the most popular is the thermal decomposition (TD) of organometallic compounds in a polyol medium. This method is particularly effective because it allows for good control over the size, shape, and crystallinity of the IONPs. The use of polyols provides several advantages, including a high boiling point, reducing properties, and stabilizing capabilities that help to regulate particle growth during synthesis.

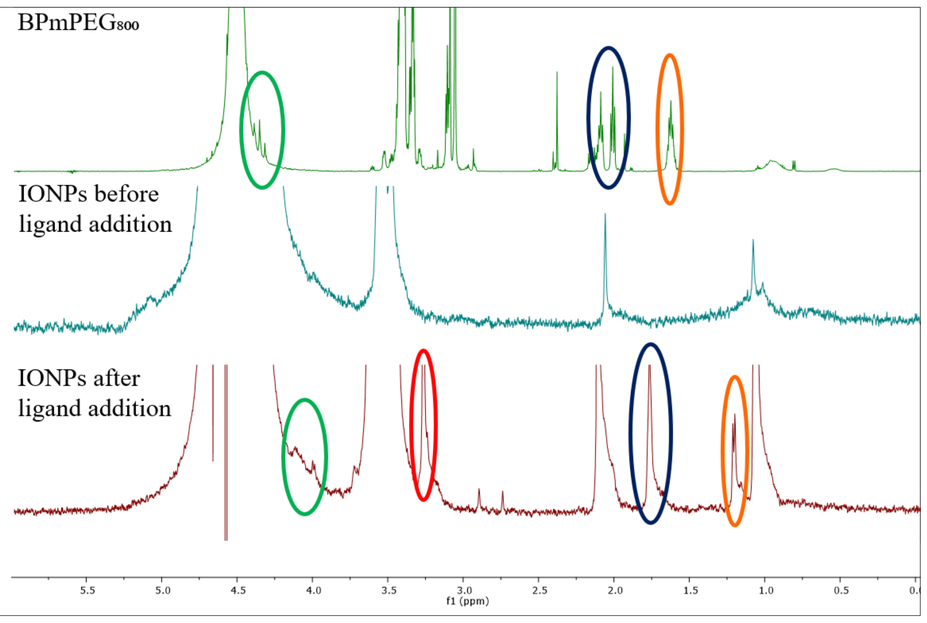
In our study, tetraethylene glycol (TREG) was identified as a suitable solvent for the flow synthesis of IONPs. To modulate the properties of the particles, we explored the use of aminated and/or carboxylated oligoethyleneglycol stabilizers, drawing analogies to other conventional high-temperature processes. A flow chemistry approach was adopted to achieve better control over the synthesis parameters, enhance the scale-up potential, and improve the safety of the process.

Following isolation and purification, the resulting batches of IONPs were characterized using techniques such as TEM, relaxometry, and VSM. These analyses aimed to determine the impact of different stabilisers on the final properties of the nanoparticles and to propose a possible mechanism for their formation.



Methods





Stabilisers Influence

Addition of different stabilisers during the thermal decomposition step to modify IONPs properties.

Stabilisers were selected by analogy with surfactants used in classical TD that are known to increase IONPs magnetisation.

Unchanged parameters:

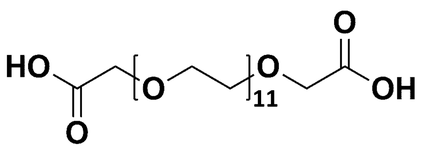
- Solvent: TREG
- Precursor: $Fe(acac)_3$ 50 mM
- T°: 250°C
- Tubing: Length: 1 m, I.D.: 1 mm
- Flowrate: 1 mL.min^{-1}

Heating process of 48 s

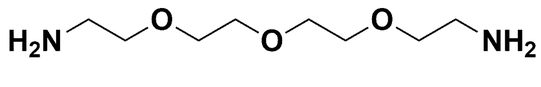
Modified parameters:

- Nature of stabiliser
- Iron to stabiliser molar ratio: 1:0, 1:1, 1:2, 1:3

PEG_{600}-diacid

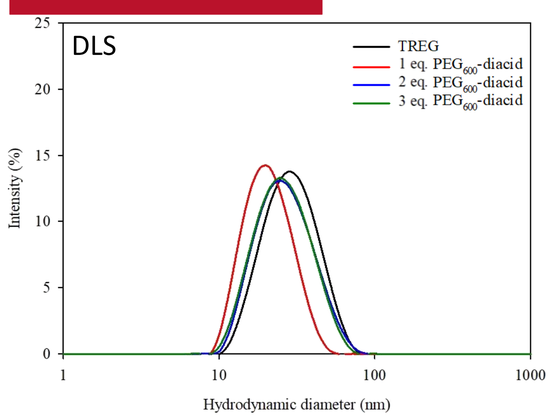


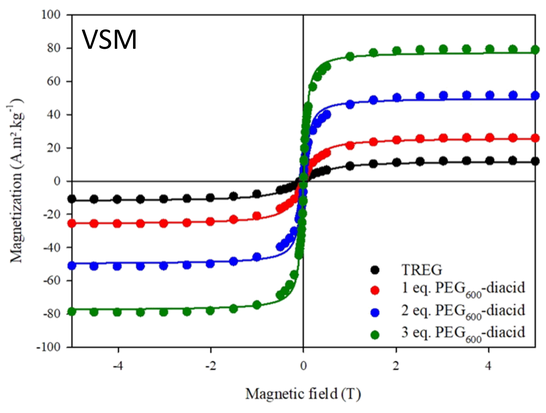
Diamino tetraethylene glycol ($TREG-NH_2$)



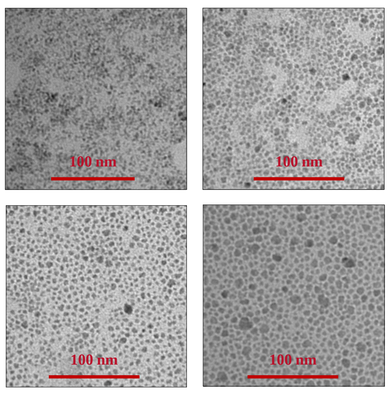
We suppose that the **stabilisers** can both act as **capping agent** for the growing particles and **form new iron complexes** with the precursor.

PEG-diacid





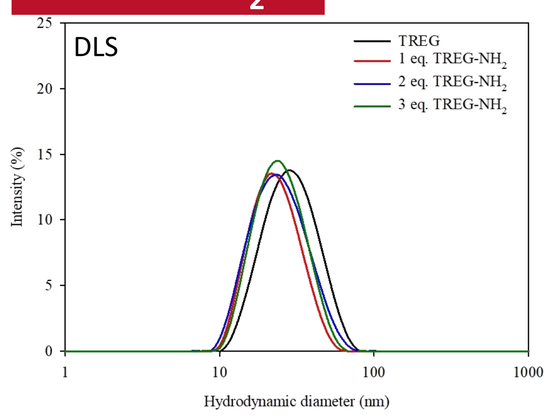
TEM

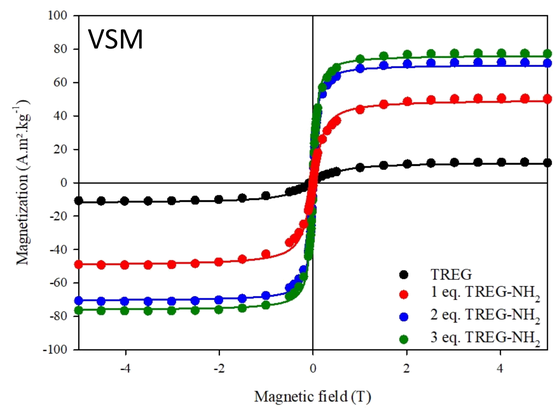


# Eq. PEG_{600}-diacid	D_{TEM} (nm)	PDI	M_S^{VSM} (A.m².kg$^{-1}_{Fe}$)
0	4.4 ± 0.9	1.15	12.2
1	5.4 ± 1.3	1.18	26.1
2	6.0 ± 1.3	1.16	50.0
3	7.0 ± 1.6	1.16	77.8

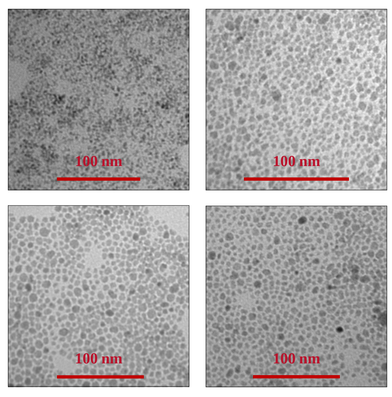
DLS → Monomodal size distribution
TEM → Steady increase in diameter
VSM → Steady increase in saturation magnetisation

$TREG-NH_2$





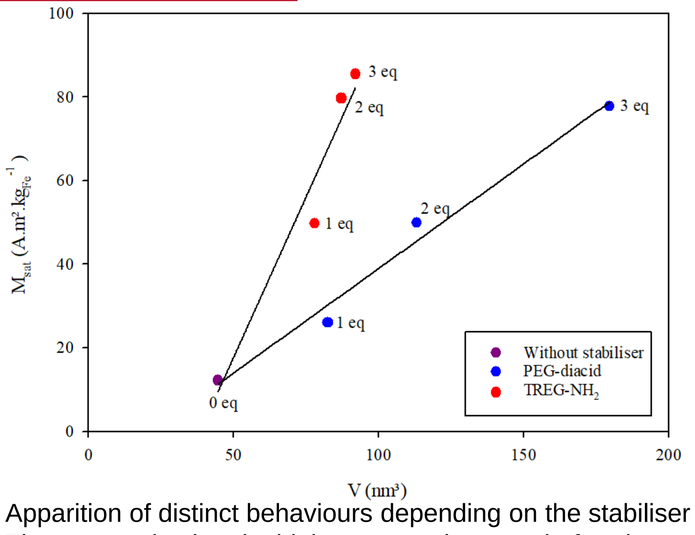
TEM



# Eq. $TREG-NH_2$	D_{TEM} (nm)	PDI	M_S^{VSM} (A.m².kg$^{-1}_{Fe}$)
0	4.4 ± 0.9	1.15	12.2
1	5.3 ± 1.3	1.24	49.8
2	5.5 ± 1.2	1.15	79.7
3	5.6 ± 1.1	1.12	82.5

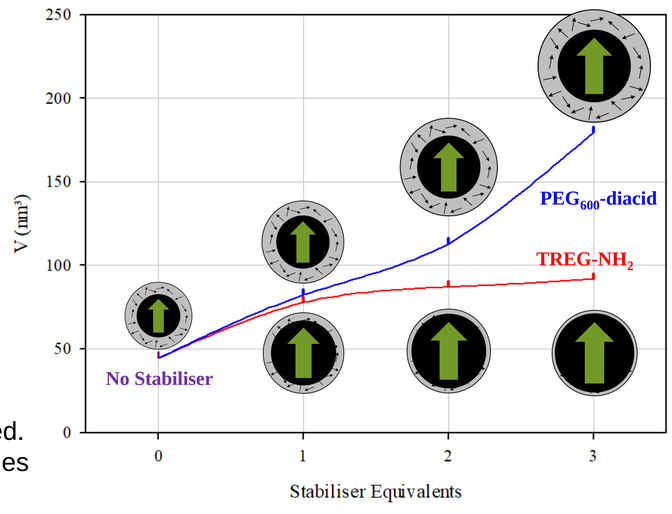
DLS → Monomodal size distribution
TEM → Slight increase in diameter
VSM → Plateau in saturation magnetisation

Discussion



Apparition of distinct behaviours depending on the stabiliser used. The magnetisation is higher per volume unit for the particles synthesized with the $TREG-NH_2$.

This suggest that the addition of $TREG-NH_2$ promotes the formation of a more crystalline iron oxide phase.



Conclusion

This process allows the synthesis of stable IONPs suspension for biomedical applications, with some control over the size and magnetic properties of the particles with the addition of our stabilisers.

We hypothesized that the stabilisers play a dual role: initially stabilising the iron precursor and then acting as capping agents for the growing particles.

We observed that two different behaviours arise depending on the stabiliser used during the thermal decomposition process, suggesting differences in the crystalline phase of the nanoparticle core.

Acknowledgments

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