Recovery of rare earth elements from fluorescent lamp phosphor powders

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Introduction

- Production and usage of fluorescent lamps rapidly increased over the past decades
  - ✓ Consume 75% less energy
  - ✓ Longer life span
- Vast amounts discarded every year. 4 800 million lamps were scraped in 2011 (Zhang, 2012)
- Fluorescent lighting relies mainly on six REEs: Y, La, Eu, Ce, Tb and Gd
- Less than 1% of REE recycling in 2011 despite vast research (Binnemans and Jones, 2014).
- Most preferred method of recovering REEs from powders is hydrometallurgy.

Introduction

Fluorescent powder composition		
Phosphor type	**Possible compounds**	**Typical quantity in tri-band lamps**
Red	$Y_2O_3:Eu^{3+}$ (YOX)*	55% (contains mostly yttrium; 4-10% europium)
Blue	$BaMgAl_{10}O_{17}:Eu^{2+}$(BAM) $(Sr,Ca,Ba)_5(PO4)_3Cl:Eu^{2+}$	10% (contains <5% europium)
Green	$CeMgAl_{10}O_{17}:Tb^{3+}$ $(Ce,Tb)MgAl_{11}O_{19}$(CAT) $(Ce,Gd,Tb)MgB_5O_{10}$	35% (contains ~10% terbium)

Aim and Objectives

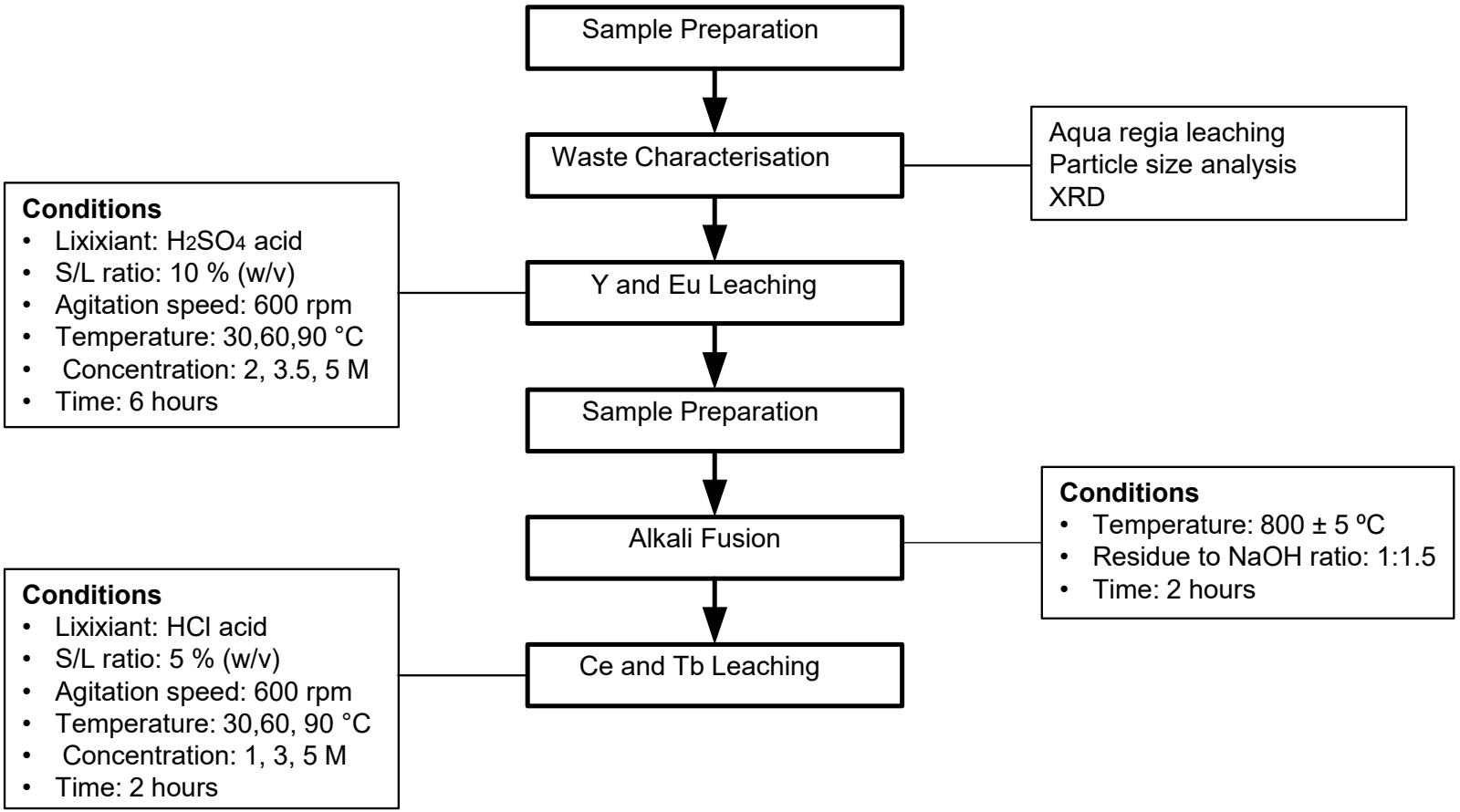
Project Aim

- To evaluate and compare different processes that could be used for REE recovery from phosphor powders in South Africa.

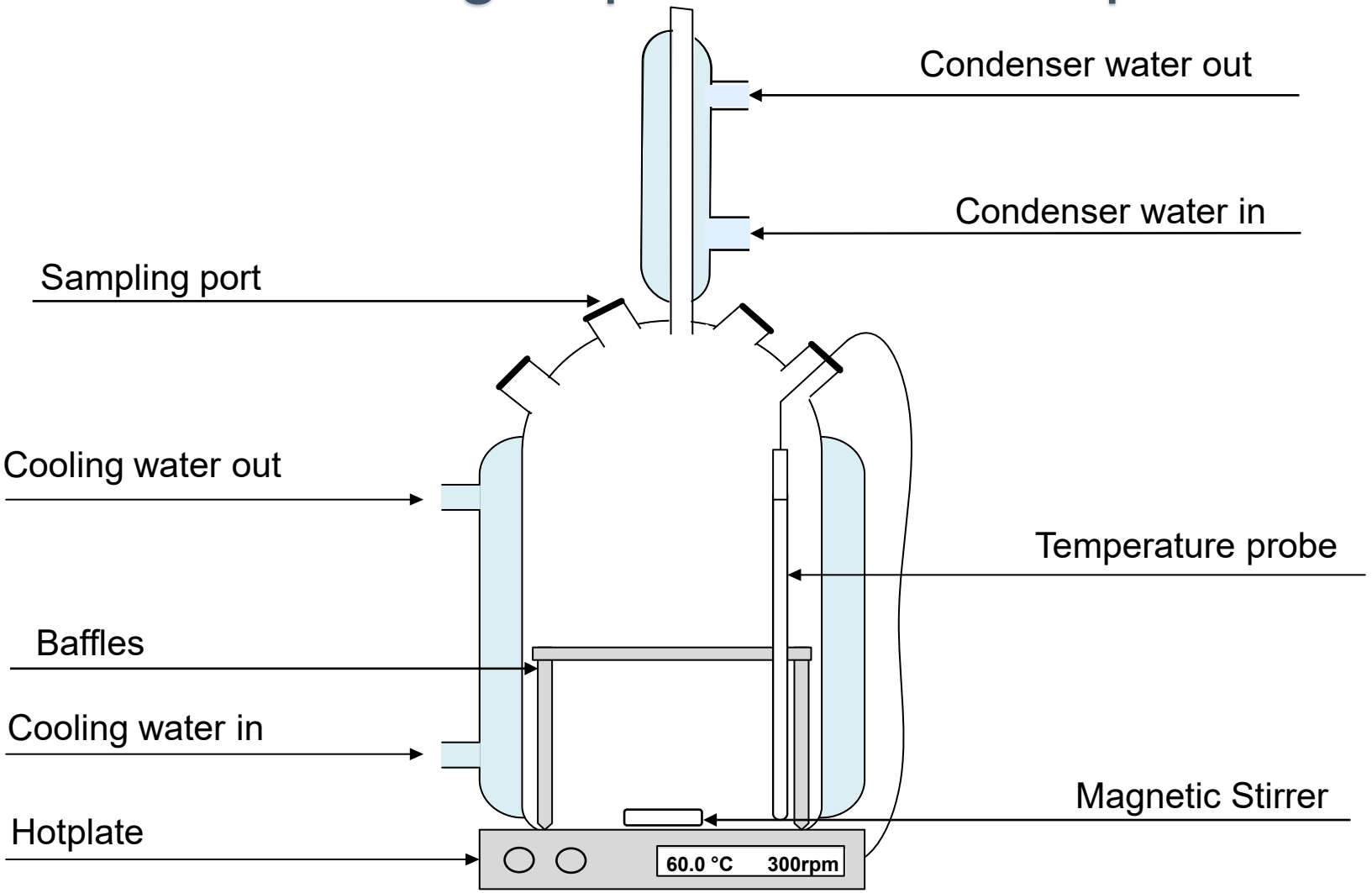
Objectives

- Perform a comprehensive literature review on the current leaching practices.
- Perform experimental work to evaluate the conceptual flow sheet and to identify remaining processing challenges.
- Perform mass balances for different possible REE recovery flow sheets.

Experimental Overview



Leaching Experimental Setup

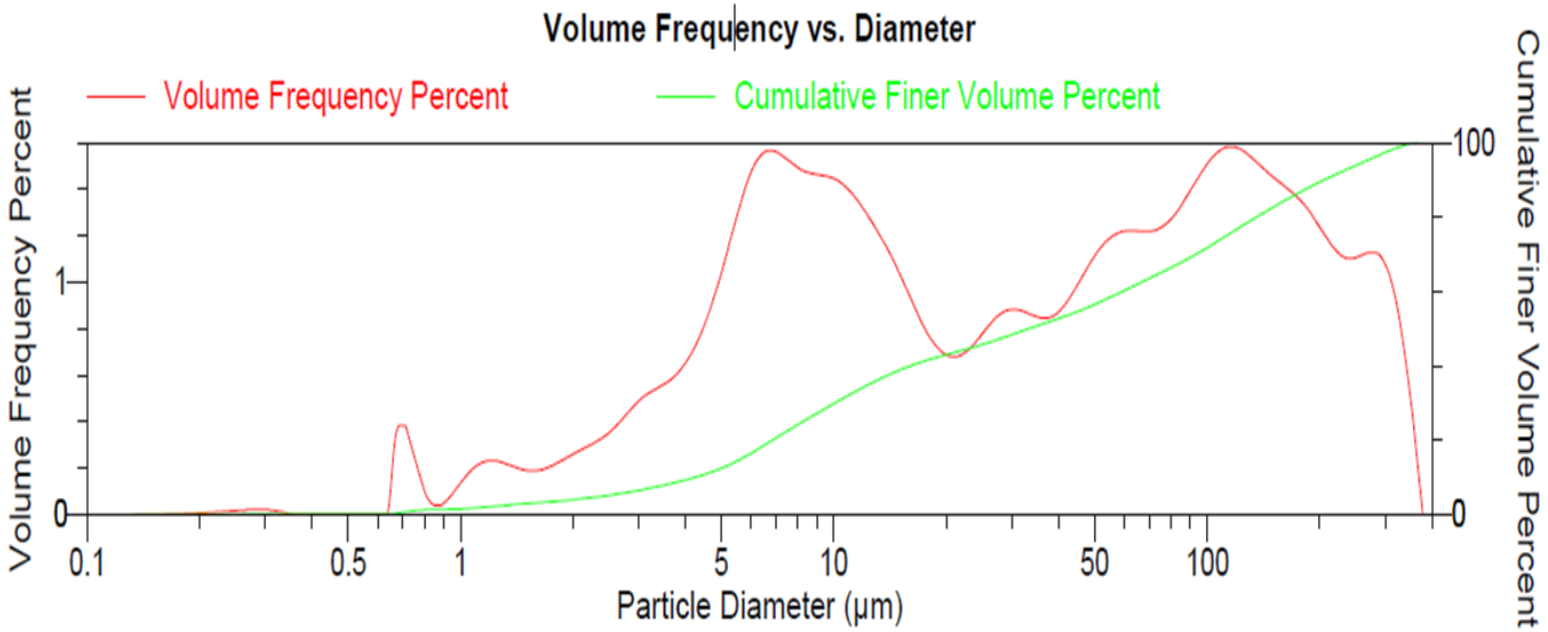


Alkali Fusion Setup

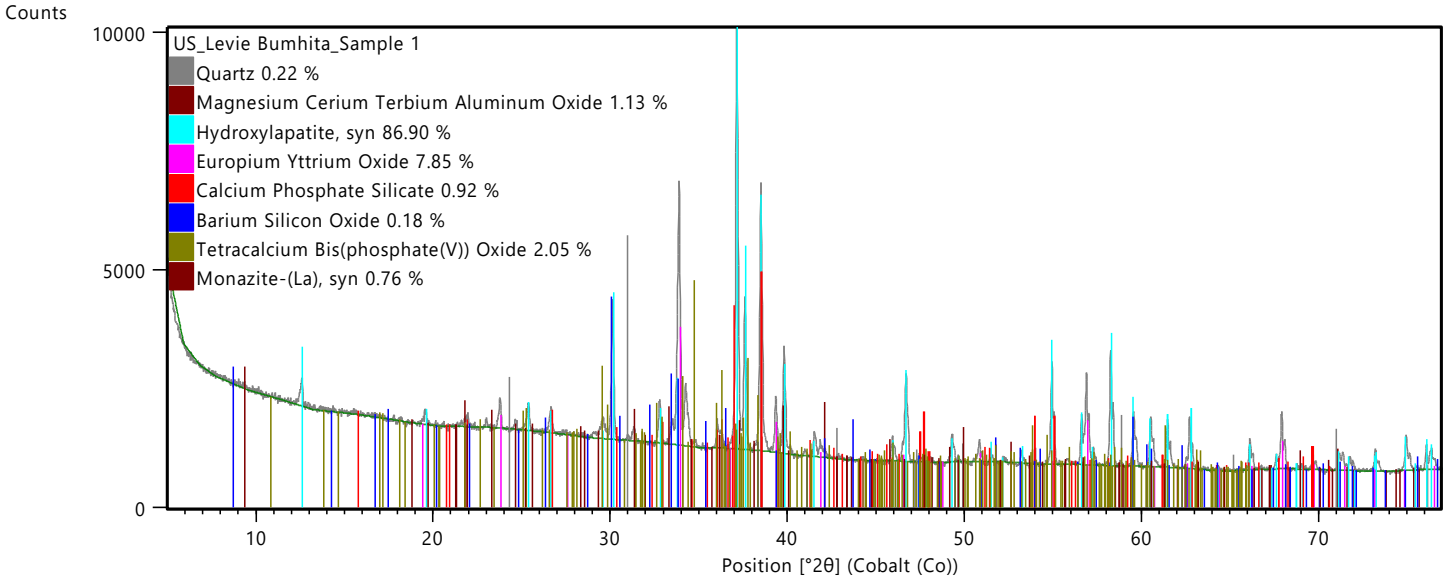
Results - Metal Content

Metal	Average metal content (g/kg)	Metal	Average metal content (g/kg)
Al	7.5 ± 0.09	Fe	5.6 ± 0.2
B	0.55 ± 0.03	Gd	0.8 ± 0.03
Ba	1.2 ± 0.09	La	2.2 ± 1.3
Ca	231 ± 7.1	Mg	2.9 ± 0.04
Ce	2.1 ± 0.5	Tb	1.8 ± 0.2
Cu	0.6 ± 0.03	Y	42.3 ± 0.02
Eu	2.9 ± 0.02	Zn	7.1 ± 3.9

Results - Particle Size Analysis

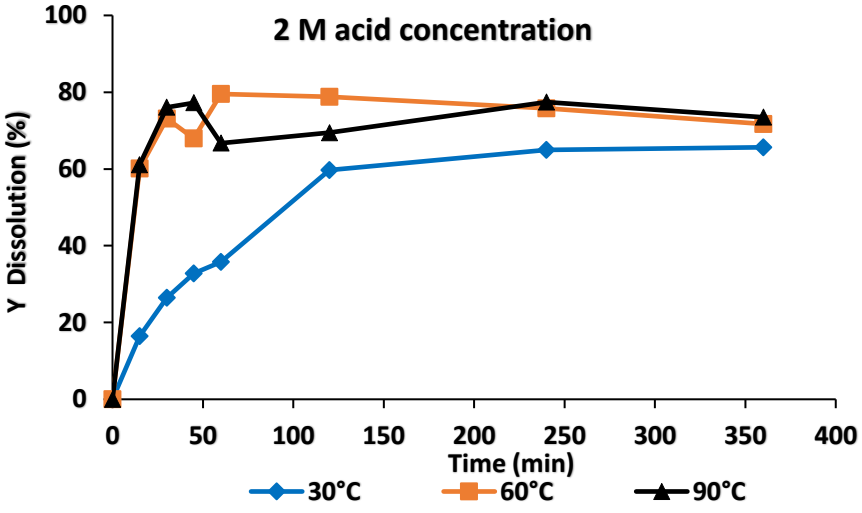


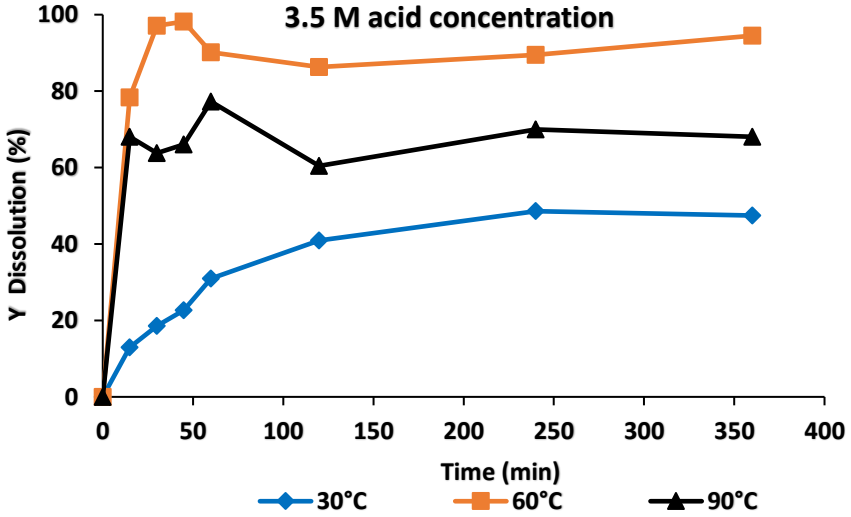
Results - XRD

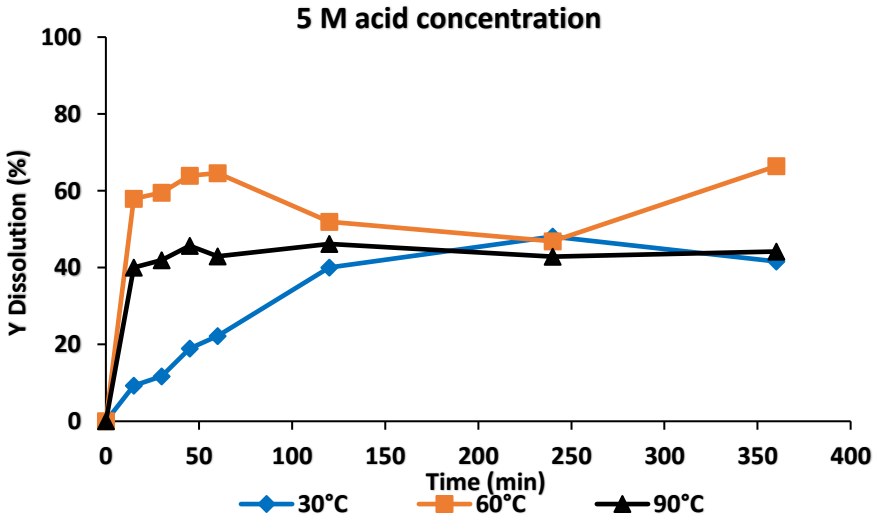


Phase	Formula	Phase	Formula
Quartz	SiO_2	Barium Silicon Oxide	$BaSiO_3$
Magnesium Cerium Terbium Aluminum Oxide	$(Ce,Tb)MgAl_{11}O_{19}$	Tetracalcium Bis(phosphate(V)) Oxide	$Ca_4(PO4)_2O$
Hydroxylapatite	$Ca_5(PO_4)_3(OH)$	Monazite-(La)	(La,Ce,Nd)PO4
Europium Yttrium Oxide	$Y_2O_3:Eu^{3+}$		

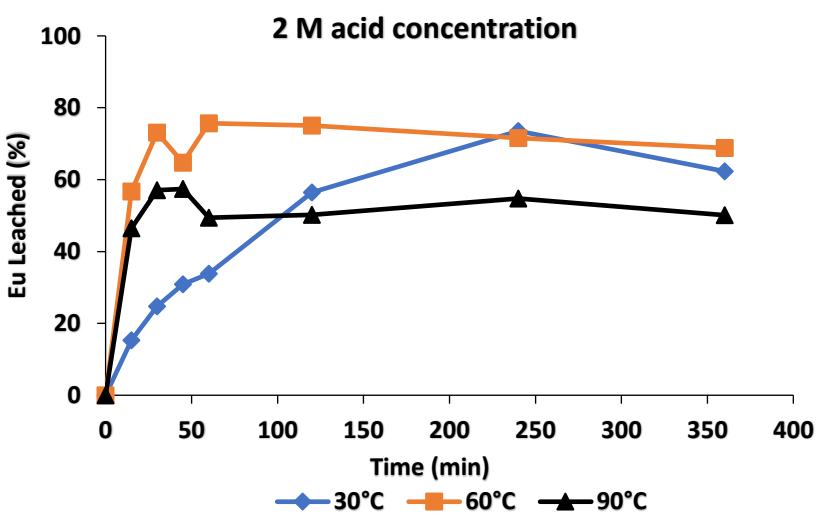
Results - Yttrium Leaching

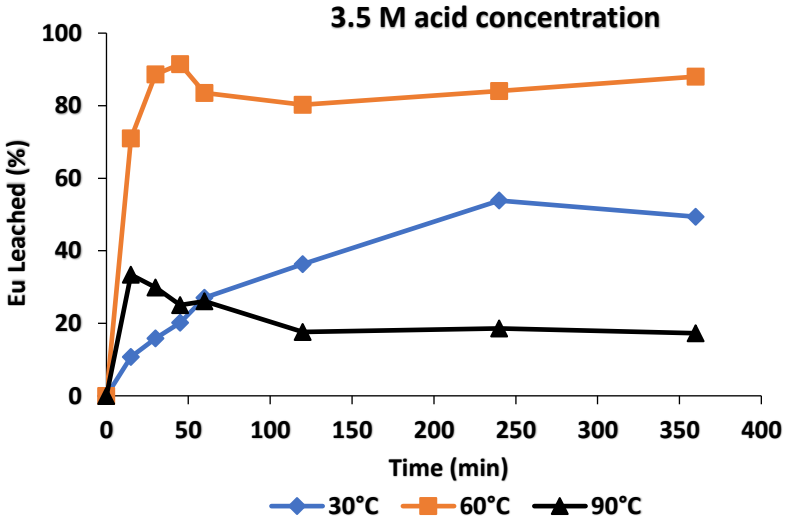


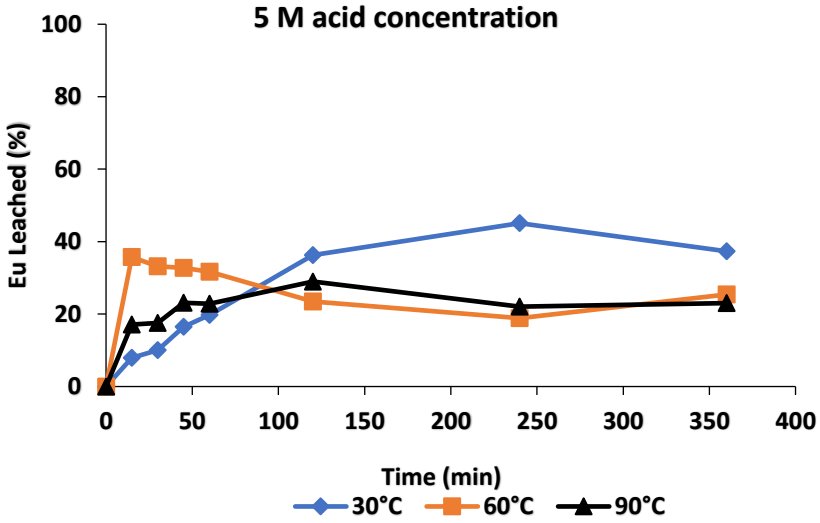




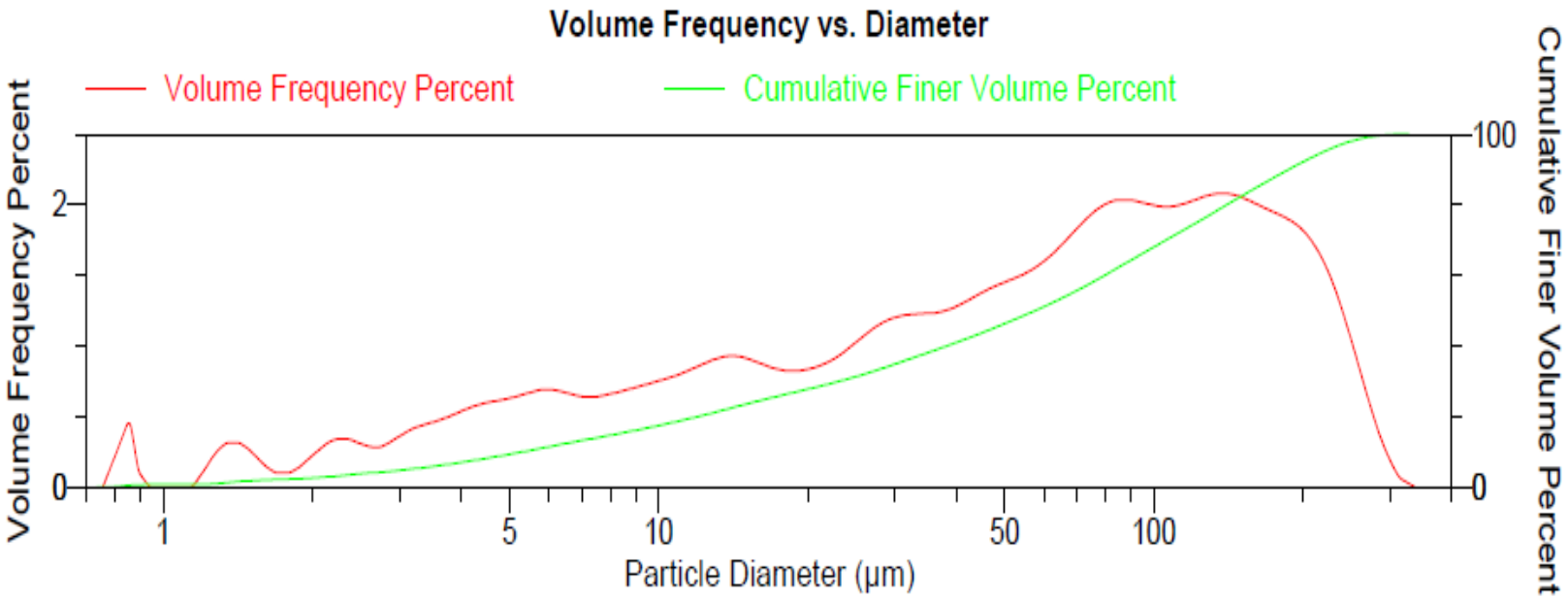
Results - Eu Leaching



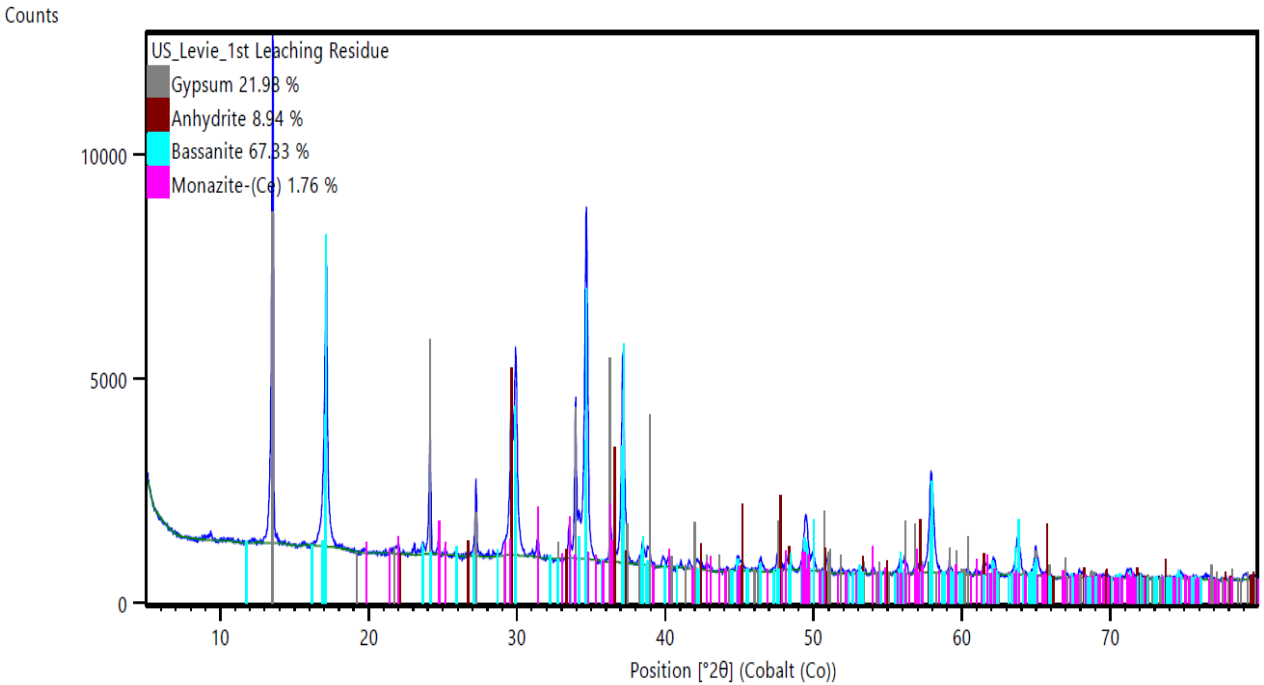




Results - Leach Residue Particle Size Analysis

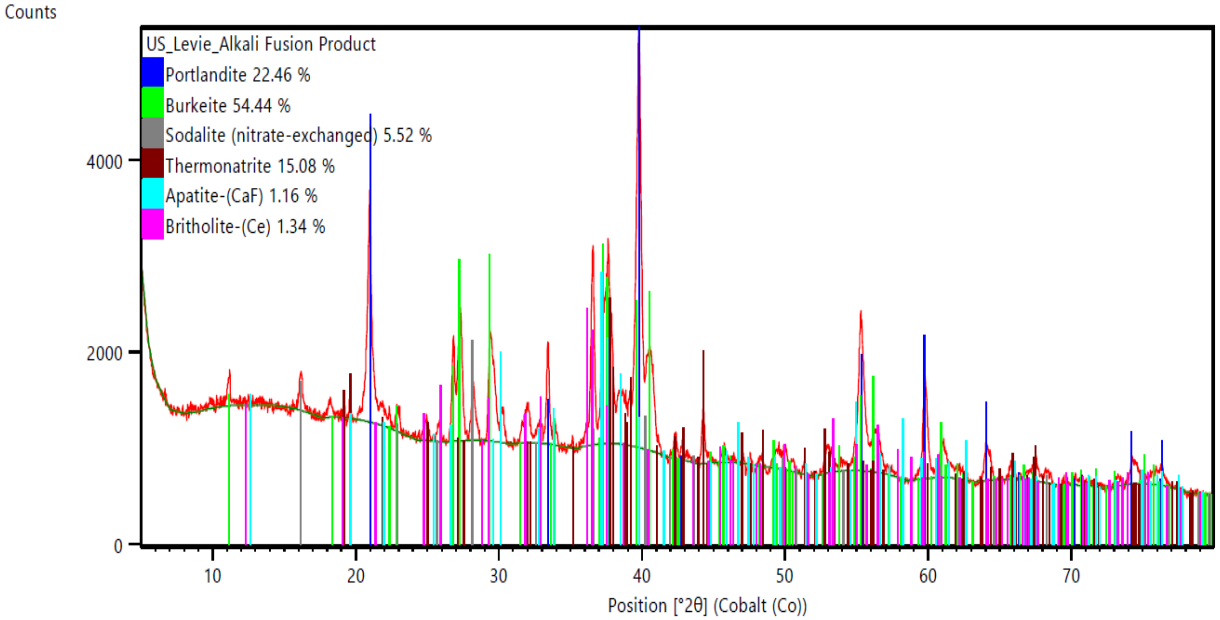


Results - Leach Residue XRD



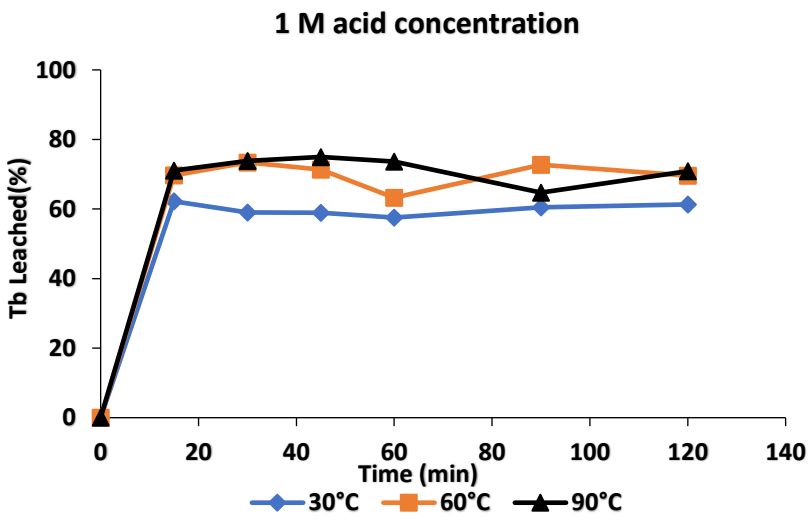
Phase	**Formula**
Gypsum	$CaSO_4 \cdot 2H_2O$
Anhydrite	$CaSO_4$
Bassanite	$2CaSO_4 \cdot H_2O$
Monazite	$(Ce,La,Nd,Th)(PO_4,SiO_4)$

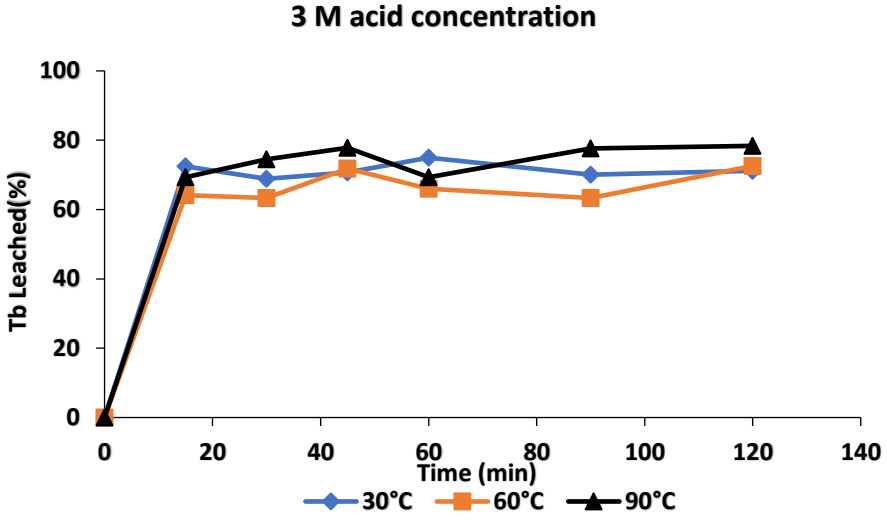
Results - Alkali Fusion Product XRD

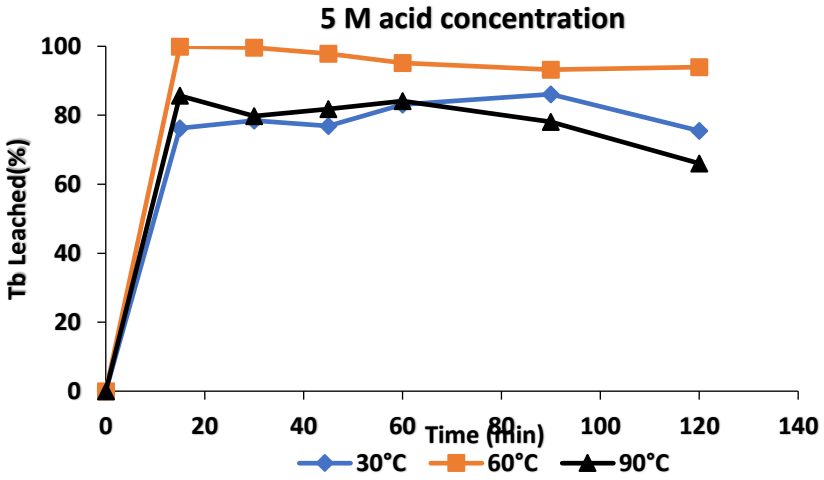


Phase	Formula
Portlandite	$Ca(OH)_2$
Burkeite	$Na_6(CO_3)(SO_4)_2$
Sodalite	$Na_8(Al_6Si_6O_{24})Cl_2$
Thermonatrite	$Na_2CO_3.(H_2O)$
Apatite	$Ca_5(PO_4)_3(OH,F,Cl)$
Britholite	$(Ce,Ca)_5(SiO_4)_3OH$

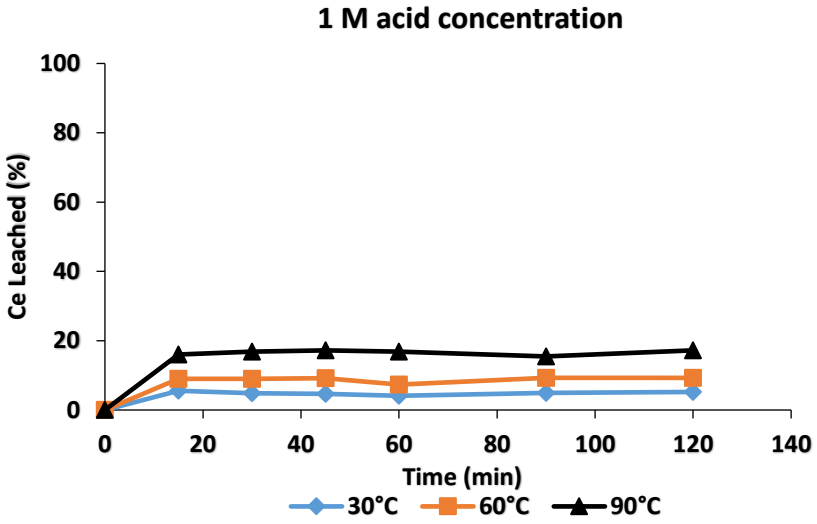
Results - Tb Leaching

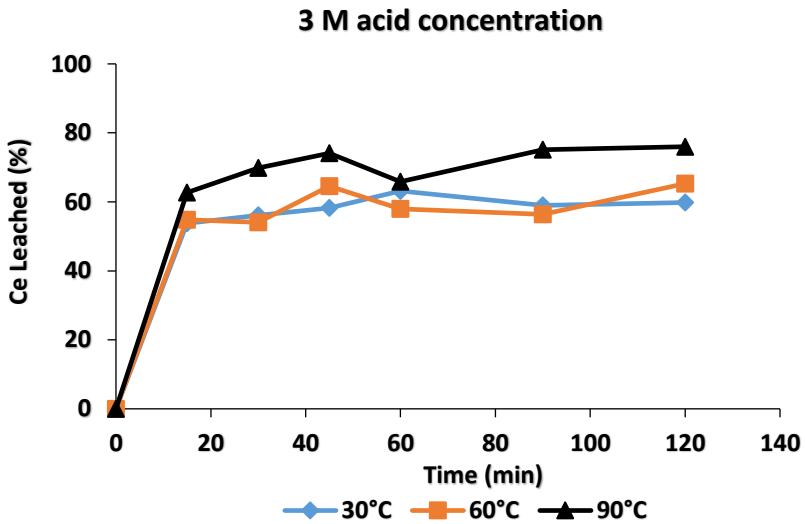


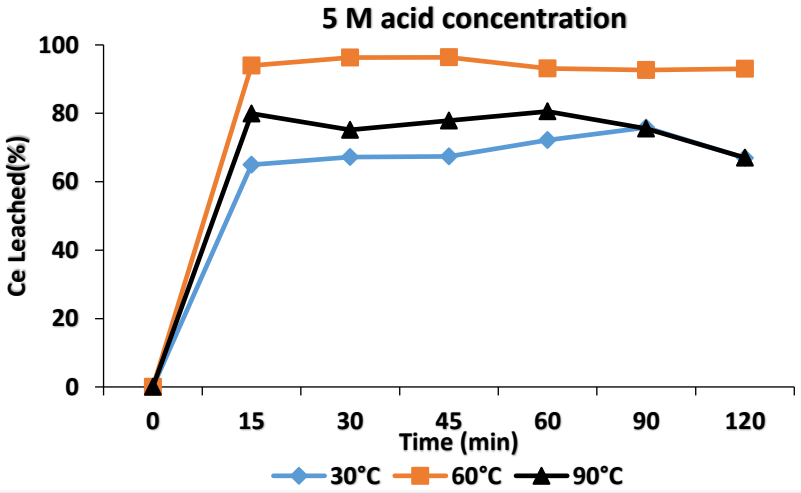




Results - Ce Leaching







Conclusions

- The red phosphor powder can be readily leached by sulphuric acid since they exist as oxides
- Over 98 % Y and 94 % Eu recoveries obtained using a temperature of 60°C and acid concentration of 3.5 M
- The green and blue phosphors could only be leached after alkali fusion
- Over 99 % Tb and 96% Ce recoveries obtained using an HCl concentration of 5 M and temperature of 60°C

Thank you for your attention

Any questions

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