



Ain shams university
Faculty of science
Chemistry department

Preparation of Nanofluid system (NFs) for Heat Exchanger

Thesis submitted for the degree of master

In

Inorganic and Analytical Chemistry

Presented by

Mohamed Abd-Elaziz Mahmoud

B.Sc. (First class honor) (2014)

*Physics and Chemistry Department, Faculty of Science, Ain Shams
University*

Supervised by

Prof. Dr. Saad El-Sayed Mohamed Hassan

Prof. of Analytical Chemistry, Faculty of Science, Ain Shams University

Prof. Dr. Ahmed Mohamed Al-Sabagh

Prof. of Applied Chemistry, Egyptian Petroleum Research Institute

Dr. Rania El-Sayed Morsi

*Associate Prof. of Physical Chemistry, Egyptian Petroleum Research
Institute*

2019



Ain shams university
Faculty of science
Chemistry department



Preparation of Nanofluid systems (NFs) for Heat Exchangers

Thesis submitted by

Mohamed Abd-Elaziz Mahmoud

For the Degree of M.Sc. of Science in
(Inorganic & Analytical Chemistry)

To

Department of Physics and Chemistry
Faculty of Science
Ain Shams University

2019



"Preparation of Nanofluid systems (NFs) for Heat Exchangers"

Thesis Advisors

Prof. Dr. Saad El-Sayed Mohamed Hassan

Prof. of Analytical Chemistry,

Faculty of Science, Ain Shams University

Thesis Approval

.....

Prof. Dr. Ahmed Mohamed Al-Sabagh

Prof. of Applied Chemistry,

Egyptian Petroleum Research Institute

.....

Dr. Rania El-Sayed Morsi

Associate Prof. of Physical Chemistry,

Egyptian Petroleum Research Institute

.....

Head of Chemistry department

Prof. Dr. Ibrahim Hosiny Ali Badr

2019

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا
إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ
الْعَلِيمُ الْحَكِيمُ

صدق الله العظيم

سورة البقرة - الآية (32)

Acknowledgements

Foremost, I would like to thank Allah for his gifts and for giving me the power and patience to accomplish this work.

I would like to express my sincere gratitude to My parents and brothers for their support and encouragement especially, to my inspiration and My biggest support one ever, My Dad, for his encouragement to be always the best one, and my continuous support My Mom, for her patience, prayers and support while this work in progress.

I would like to express my sincere gratitude to ***prof. Dr. Saad El-Sayed Mohamed***, Professor of Analytical Chemistry, Faculty of Science, Ain Shams University, for his support, valuable advice, gentle treatment and continued to follow up the progress of the work with keen interest.

Great thanks are owed to ***Prof. Dr. Ahmed Mohamed Al-Sabagh***, Professor in Petroleum Application department (EPRI), for his suggestion the topics in this work, support, special advice, and valuable guidance during all stages of this work and follow up the progress of the work with keen interest.

Great thanks are also owed to ***Dr. Rania El-Sayed Morsi***, Associate professor in Analytical and Evaluation department (EPRI), for her guidance, assistance, help, and supervision with keen interest.

Special thanks to ***Dr. Radwa Abass El-Salamony***, Associate professor in Process Development department (EPRI), for her, continues to support, motivation, enthusiasm, assistance, supervision and for completely guidance step by step and follow up the work stages with keen interest.

My sincere thanks also go to ***Prof. Dr. Amal Hamdy Khalil***, Professor in Analytical and Evaluation department (EPRI) for her encourage, inspire and imparting her knowledge with keen interest.

Finally, My cordial gratitude to my fellow colleagues for their encouragement, support, and cooperation

Mohamed Abd-Elaziz Mahmoud

❖ **Published Papers Extracted From The Master Thesis:**

1. **“Using an ionic surfactant to prepare stable tungsten oxide nanofluids through reducing the particle size distribution”**
Mohamed Z. Abd-Elaziz, Radwa A. El-Salamony, Rania E. Morsi, Ahmed M. Al-Sabagh, Saad S. M. Hassan, **Global Journal of Engineering Science and Researches (GJESR)**, 6(2), 76-89. DOI-10.5281/zenodo.2563727.
2. The 22nd International conference on petroleum, mineral resources and development **“Preparation and characterization of rutile titania nanofluids stabilized in different surfactants base fluids”** Mohamed Z. Abd-Elaziz, Radwa A. El-Salamony, Rania E. Morsi, Ahmed M. Al-Sabagh, Saad S. M. Hassan.
3. **“Preparation and characterization of rutile titania nanofluids stabilized in different surfactants base fluids”**
Mohamed Z. Abd-Elaziz, Radwa A. El-Salamony, Rania E. Morsi, Ahmed M. Al-Sabagh, Saad S. M. Hassan. has been accepted for publication in "Nanoscience & Nanotechnology-Asia" , BMS-NNA-2019-12.

Contents

	<i>Page</i>
<i>List of contents</i>	<i>i</i>
<i>List of Figures</i>	<i>v</i>
<i>List of tables</i>	<i>ix</i>
<i>List of abbreviations</i>	<i>xi</i>
<i>Summary</i>	<i>xiii</i>

Chapter (I)

General introduction

<i>Part (I): Difinitionand properties of nano fluids (NFs)</i>	1
1.1. Difinition of nano fluids(NFs)	1
1.2. Application of nano fluids	2
1.3. Preparation methods of nanofluids	4
<i>1.3.1. Two step method</i>	5
<i>1.3.2. one step method</i>	5
1.4. Stability of nanofluids	6
1.5. Factors affecting stability of nanofluid	6
<i>1.5.1. Effect of pH (NP surface charge)</i>	7
<i>1.5.2. Effect of surface modifiers</i>	7
<i>1.5.3. Effect of fabrication method</i>	8

1.5.4. Effect of concentration of nanoparticles	9
1.5.5. Mixing methods	9
1.6. Common tools to evaluate the stability of nanofluids.....	10
1.7. Thermo-physical and transport properties of NFs	11
1.8. Factor affecting on Thermal Conductivity (TC) of NFs	12
1.8.1. Effect of surface modifiers	13
1.8.2. Effect of temperature	14
1.8.3. Effect of base liquid	14
1.8.4. Effect of NPs morphology	14
1.8.5. Effect of NP composition	16
1.8.6. Effect of NPs concentration	16
1.8.7. Effect of NFs fabrication and NPs dispersion method.....	16
1.8.8. Effect of stability of NFs	17
1.8.9. Effect of particle crystal structure	17
 Part (II): Structure and applications of Titanium dioxide and Tungsten oxide.....1	
1.1. Chemical structure of Titanuim dioxide (TiO ₂) nanoparticles ..	18
1.2. Application of Titanium dioxide nanofluid (TNF)	19
1.3. Chemical structure of Tungsten oxide (WO ₃) nanoparticles.....	21
1.4. Application of WO ₃ nanofluids.....	22
1.5. References	24

Chapter (II)

Preparation and characterization of rutile titania Nano fluids stabilized in different surfactants base fluids

2.1. Introduction	36
2.2. Experimental.....	37
<i>2.2.1. Apparatus.....</i>	<i>37</i>
<i>2.2.2. Materials</i>	<i>38</i>
<i>2.2.3. Preparation of titanium dioxide nanoparticles</i>	<i>38</i>
<i>2.2.4. Nanofluid preparation.....</i>	<i>38</i>
2.3. Results and Discussion.....	39
<i>2.3.1. Characterization of TiO₂- Nanoparticles (TNP).....</i>	<i>39</i>
<i>2.3.2. Characterization of Titania Nanofluid (TNF)</i>	<i>40</i>
<i>2.3.3. Zeta Potential and Particle Size Distribution of Titania Nanofluids (TNF)</i>	<i>41</i>
<i>2.3.4. Stabilization of Titania Nano fluids</i>	<i>46</i>
<i>2.3.5. Physical Properties of Titania Nano fluids</i>	<i>52</i>
2.4. Conclusion	57
2.5. References	58

Chapter (III)

Using an ionic surfactant to prepare stable tungsten oxide nanofluids through reducing the particle size distribution

3.1. Introduction	62
3.2. Experimental.....	64
<i>3.2.1. Method and materials</i>	<i>64</i>
<i>3.2.2. Nanofluids Preparation</i>	<i>64</i>
<i>3.2.3. Characterization Techniques</i>	<i>64</i>
3.3. Results and Discussion.....	65
<i>3.3.1. Characterization of WO₃ Nanoparticles</i>	<i>65</i>
<i>3.3.2. Characterization of WO₃ Nanofluid</i>	<i>66</i>
<i>3.3.3. Zeta Potential and Particle Size Distribution of Tungsten Nanofluids</i>	<i>67</i>
<i>3.3.4. Stabilization of Tungsten Nanofluids</i>	<i>72</i>
<i>2.3.5. Physical Properties of Tungsten Nanofluids</i>	<i>76</i>
2.4. Conclusion	79
2.5. References	81
<i>Arabic summary</i>	

List of Figures:

		Page
<i>Chapter (I)</i>		
Figure (1.1)	Dispersion of nanoparticles in the basefluid scheme.	2
Figure (1.2)	Nanofluids different potential applications.	3
Figure (1.3)	Nanofluids stability factors.	6
Figure (1.4)	Nanofluids stability assess techniques.	11
		Page
Figure (1.5)	Factors affecting on thermophysical properties	12
Figure (1.6)	TiO ₂ Anatase (a) and Rutile (b) crystal structure phases, Large light-blue and small red spheres are Ti ⁴⁺ and O ²⁻ ions, respectively [copy right cc BY 4.0]	19
<i>Chapter (II)</i>		
Figure (2.1)	XRD pattern (a), N ₂ adsorption-desorption isotherm (b) and TEM image (c) of TiO ₂ nanoparticles.	40

Figure (2.2)	TEM images of TiO ₂ /CTAB (a) and TiO ₂ /SDS (b) Nanofluids,	41
Figure(2.3)	Aggregate size distribution of the prepared nanofluid.	43
Figure (2.4)	Zeta potential of the prepared nanofluids.	45
Figure (2.5)	Stability assessment of TiO ₂ /CTAB nanofluids.	47
Figure (2.6)	Stability assessment of TiO ₂ /SDS nanofluids.	48
Figure (2.7)	Particle size distribution of different concentrations of TiO ₂ /CTAB nanofluids at time intervals; zero time, after 2 days, 5 days up to 10 days measured by dynamic light scatterings (DLS).	50
Figure (2.8)	Particle size distribution of different concentrations of TiO ₂ /SDS nanofluids at time intervals; zero time, after 2days, 5days up to 10 days measured by dynamic light scatterings (DLS).	51

Figure (2.9)	Variation of thermal conductivity with temperatures of TiO ₂ /CTAB (a) and TiO ₂ /SDS (b) nanofluids.	53
Figure (2.10)	Change of heat flow with temperature of the base fluid and the prepared nanofluids	56
		Page
<i>Chapter (III)</i>		
Figure (3.1)	XRD pattern (a), N ₂ adsorption-desorption isotherm (b) and TEM image (c) of WO ₃ nanoparticles.	66
Figure (3.2)	TEM images of WO ₃ /CTAB (a) and WO ₃ /SDS (b) nanofluids	67
Figure (3.3)	Aggregate size distribution of the prepared nanofluids	69
Figure (3.4)	Zeta potential of the prepared nanofluids	71
Figure (3.5)	Stability assessment of WO ₃ /CTAB nanofluids	73

		Page
Figure (3.6)	Stability assessment of WO ₃ /SDS Nano fluids.	74
Figure (3.7)	Particle size distribution of different concentrations of WO ₃ /CTAB nanofluids at time intervals; zero time, after 2 days, 5 days up to 10 days measured by dynamic light scatterings (DLS).	75
Figure (3.8)	Particle size distribution of different concentrations of WO ₃ /SDS nanofluids at time intervals; zero time, after 2days, 5days up to 10 days measured by dynamic light scatterings (DLS)	76
Figure (3.9)	Variation of thermal conductivity with temperatures of WO ₃ /CTAB (a) and WO ₃ /SDS (b) nanofluids.	77
Figure (3.10)	Change of heat flow with temperature of the prepared nanofluids	79

List of tables:

		Page
<i>Chapter (I)</i>		
Table (1.1)	TiO ₂ crystal structure data	18
		Page
<i>Chapter(II)</i>		
Table (2.1)	Average particle size (nm) of the prepared nanofluids.	42
Table (2.2)	Zeta potential values of the prepared nanofluids.	44
Table (2.3)	Physical properties of titania nanofluid.	54
Table (2.4)	Thermophysical parameters of prepared fluids	55
		Page
<i>Chapter(III)</i>		
Table (3.1)	Average particle size (nm) of the prepared nanofluids.	68
Table (3.2)	Zeta potential values of the prepared nanofluids.	72
Table (3.3)	Physical properties of tungsten oxide nanofluid	78