

Chemical, Petroleum and Environmental Engineering

The Influence of the Preparation and Stability of Nanofluids for Heat Transfer

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ABSTRACT

Recently the use of nanofluids represents very important materials. They are used in different branches like medicine, engineering, power, heat transfer, etc. The stability of nanofluids is an important factor to improve the performance of nanofluids with good results. In this research two types of nanoparticles, TiO₂ (titanium oxide) and γ -Al₂O₃ (gamma aluminum oxide) were used with base fluid water. Two-step method were used to prepare the nanofluids. One concentration 0.003 vol. %, the nanoparticles were examined. Scanning Electron Microscopy (SEM), Atomic Force Microscopy (AFM) and X-ray diffraction (XRD) were used to accomplish these tests. The stability of the two types of nanofluids is measured by zeta potential and UV-vis spectrophotometer. The results showed that γ -Al₂O₃/water has more stable than TiO₂/ water for the same period of time.

Key Words: nanofluids, nanoparticles, SEM, stability.

تأثير تحضير واستقرارية المائع النانوي في انتقال الحرارة

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الخلاصة

في الاونة الاخيرة استخدام الموائع النانوية تعتبر مواد ذات اهمية كبيرة في مختلف المجالات مثل الطب، الهندسة ، الطاقة ، انتقال الحرارة و الى اخره. ان استقرارية الموائع النانوية هي شئ مهم لنجاح اداء المائع النانوي للحصول على نتائج افضل. في هذا البحث تم استخدام نوعين من الدقائق النانوية وهي اوكسيد التيتانيوم وكاما اوكسيد الالمنيوم مع مائع اساس هو الماء، استخدمت طريقة two step لتحضير الموائع النانوية بتركيز حجمي 0.003 %. ان مواصفات الدقائق النانوية وصفت باستخدام المجهر الالكتروني الماسح (SEM) ، مجهر القوة الذرية (AFM)، مقياس الاشعة السينية (XRD) ، واستقرارية الموائع النانوية المحضرة قيست باستخدام الزيتا والاشعة المرئية وال فوق بنفسجية. اظهرت النتائج ان المائع النانوي لكاما اوكسيد الالمنيوم/ماء اكثر استقرارية من المائع النانوي اوكسيد التيتانيوم /ماء في نفس المدة الزمنية.
الكلمات الرئيسية: الموائع النانوية، الدقائق النانوية، المجهر الالكتروني الماسح، الاستقرارية.

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1. INTRODUCTION

Nanoparticles are found as nanofibers, nanotubes, nanosheet. The nanoparticles dispersed in the base fluid like water, oil, ethylene glycol, propylene glycol or other fluids. The first time nanofluid was prepared by Choi in 1995 as in **Sayantana, 2013**. The mean nano of the particle size is between 1-100 nm. The nanoparticles have new properties compared with the bulk particles due to the increased surface area to the volume. The nanofluids are used to increase the thermal properties such as viscosity, thermal conductivity has a better response as heat transfer medium and heat transfer coefficient of the base fluids, **Taylor, 2013**. The nanoparticles were prepared firstly by physical and chemical ways for example by laser ablation, sol-gel method ect., that were suspended in the base fluid as in **Paul, et al., 2011**. **Basma and Noor, 2017** prepared two types of nanofluids at two concentration 0.004 and 0.002% vol. for TiO_2 and $\gamma\text{-Al}_2\text{O}_3$ nanoparticles. There are two ways to prepare nanofluids by one step and two step the first method has many disadvantage low quantity of product and high cost of production. Two-step method represents the cheapest way to produce nanofluids in large scale and because of having the large surface area, the nanoparticles become to agglomerate because of strong Van der Waals force among nanoparticles. There are many ways to make the nanofluids stable by sonication it, as well as adding stabilizer or pH added to the nanofluids. There are many ways to measure the stability of nanofluids. This done by sedimentation method, centrifugation, UV-vis, and zeta potential as in **Michal, 2012**. Zeta potential is the difference of electrical potential between the bulk fluid and the fluids around the nanoparticles. There are different values of zeta potential and every value means different imagination to the nanofluids, while the value of 25 mV means that the nanofluids have low stability. The values of zeta potential between (40-60) mV represent the good or very good stability of nanofluids, which means nanoparticles were suspended into the base fluid and there was no agglomeration between nanoparticles as in **Yu and Xie, 2012**.

The purpose of this research is to prepare two types of nanofluids (TiO_2 & $\gamma\text{-Al}_2\text{O}_3$) at 0.003 % vol. concentration by synthesis of nanoparticles in different ways, the nanofluids stability was measured by using UV-vis and zeta potential.

2. MATERIALS

Two types of nanoparticles were used (TiO_2 and $\gamma\text{-Al}_2\text{O}_3$) from (EPRUI Nanoparticles and Microspheres China) 99.9% purity.

3. NANOFUIDS PREPARATION

Two-step method was used to prepare nanofluids. The nanoparticles were added into the base fluid (water) at concentration 0.003 % by vol. An electronic balance was used to weigh the nanoparticles, all these steps are done in the hood of the laboratory to prevent the dispersal of nanoparticles.

Nanofluids were prepared each time in 250 ml flask. A mixer of high-speed type (Ultra – Turax Janke and Kunkel KG) was used to made nanoparticles in motion. By this step, stabilization of the suspension and prevention of agglomeration and sedimentation are ensured. The rotation speed was at 10000 rpm. Mixing continued 2.5 hours. The process of agitation took a time of 48 hours.



4. SYNTHESIS of NANOPARTICLES RESULTS

The change in the morphology of nanoparticles surface (TiO_2 and $\gamma\text{-Al}_2\text{O}_3$) was examined by using SEM "Scanning electron microscope" as in **Fig.1**, it is generally used to investigate the stability of nanofluids by observing the distribution and aggregation of nanoparticles. This figure shows the TiO_2 nanoparticles are in spherical shape with agglomerate nanoparticles before added into the base fluid. **Fig. 2** shows the surface of $\gamma\text{-Al}_2\text{O}_3$ which has spherical shape too.

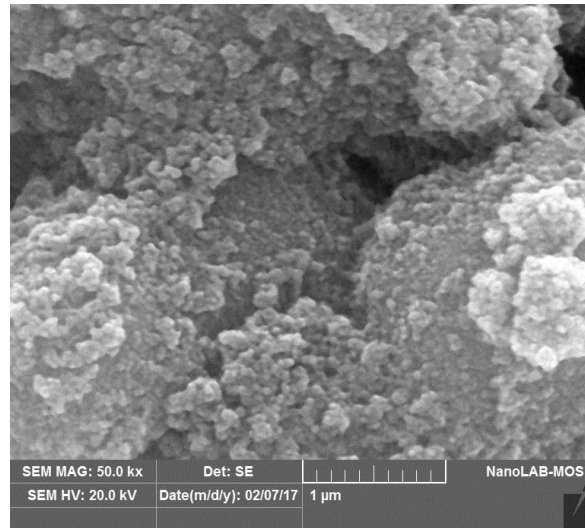


Figure 1. TiO_2 Nanoparticles Scanning Electron Microscopy (SEM).

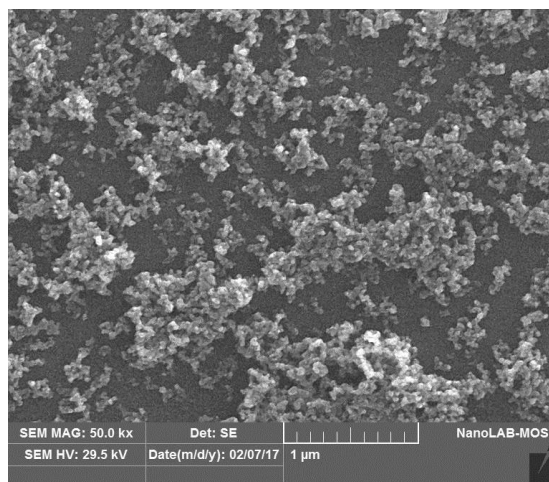


Figure 2. $\gamma\text{-Al}_2\text{O}_3$ Nanoparticles Scanning Electron Microscopy (SEM).

TiO_2 and $\gamma\text{-Al}_2\text{O}_3$ particle distribution and size were scanned by Atomic force microscopy (AFM). **Figs. 3** and **4** show the distribution of the size of nanoparticles, the average diameter for TiO_2 and $\gamma\text{-Al}_2\text{O}_3$ particle was 75 nm and 85 nm respectively. **Figs. 5** and **6** show the surface of nanoparticle for (TiO_2 and $\gamma\text{-Al}_2\text{O}_3$) in three dimension image.

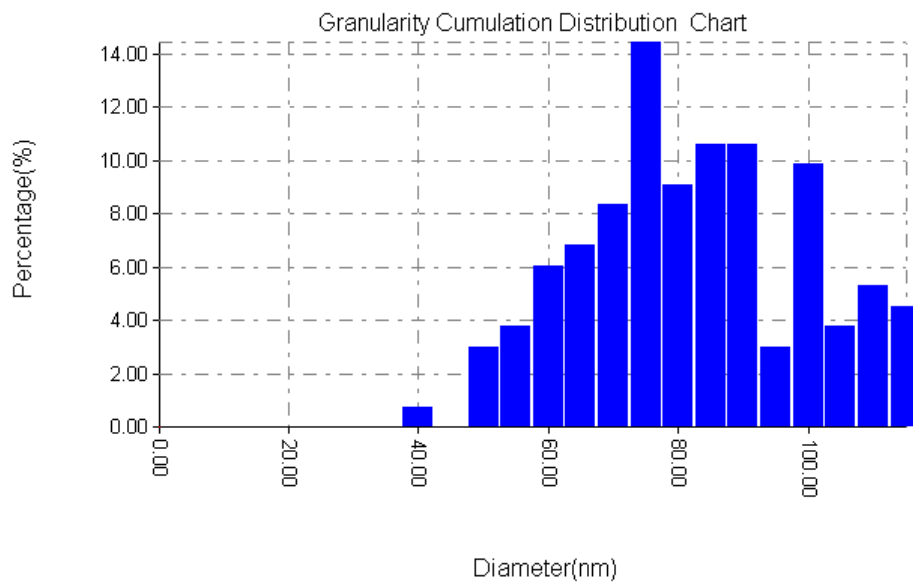


Figure 3. The Diameter distribution of TiO₂ nanoparticles.

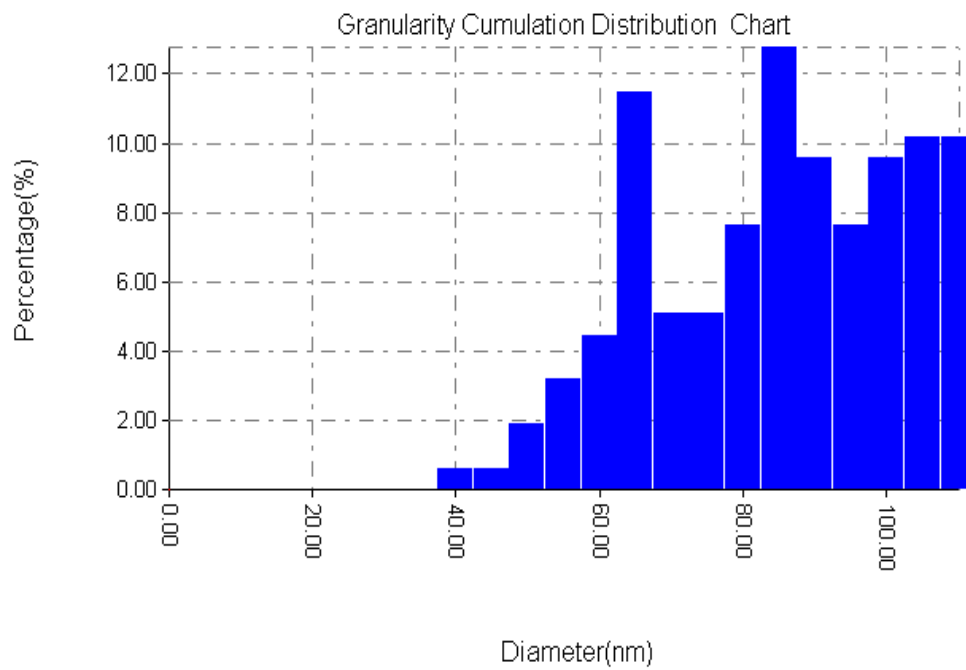


Figure 4. The Diameter distribution of γ -Al₂O₃ nanoparticles.

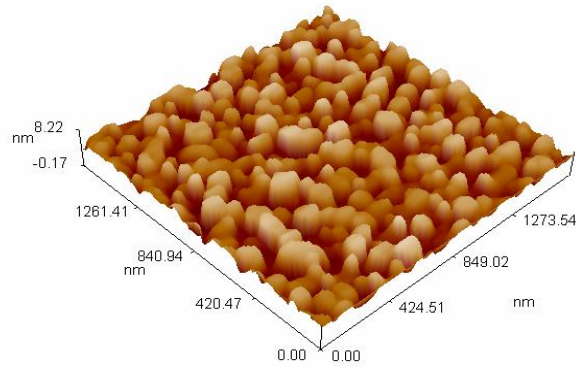


Figure 5. The 3D image of TiO₂ nanoparticles surface.

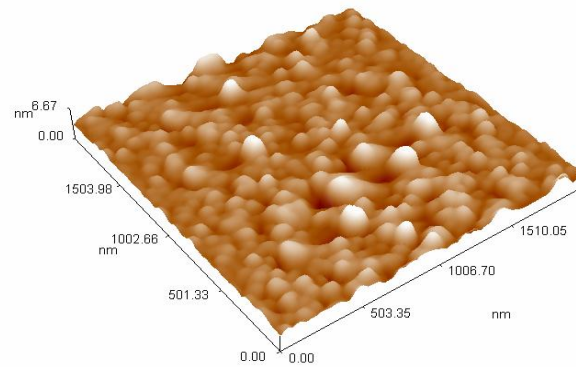


Figure 6. The 3D image of γ -Al₂O₃ nanoparticles surface.

The TiO₂ nanoparticles were examined by using X-ray diffraction method type (Shimadzu X-Ray Diffractometer XRD 6000) with 2 θ range of (10 – 70) °.

The peaks of TiO₂ were shown in **Fig.7**. The strong peaks were seen: 25°, 48° and 37.5°. These matched the standard of Anatase phase of TiO₂. This agrees with **SharmilaDevi, 2014**.

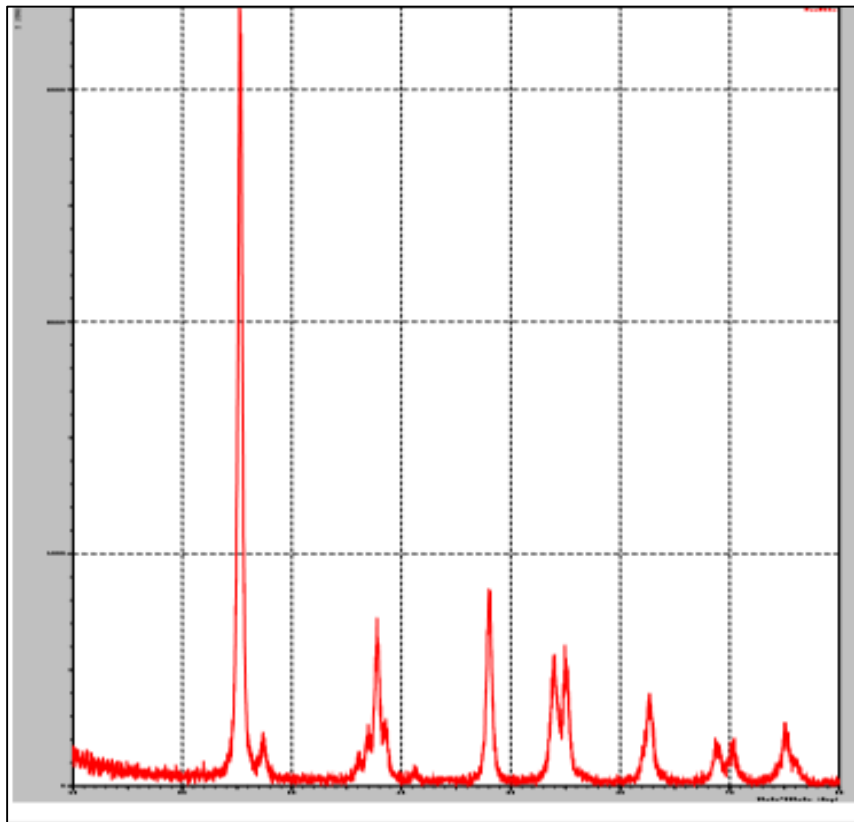


Figure 7. XRD of TiO₂ Nanoparticles.

Scherrer equation, **Masoumeh, 2012**, used to calculate the size of crystal from the data of TiO₂ peaks.

$$t = \frac{k \lambda}{\beta \cos 2\theta} \quad (1)$$

The size crystalline of TiO₂ particles was 16 nm.

The γ -Al₂O₃ nanoparticles were examined by using an X-ray diffraction method with 2θ range of (10 – 70) °. In **Fig. 8** γ -Al₂O₃ nanoparticles were confirmed.

The peaks of γ -Al₂O₃ were shown. These matched the standard of γ -Al₂O₃. Four strong peaks were seen at (67.042°, 45.97°, 36.636°, 32.64°), and these results are in good agreement with **Yvan, 2012**. Sharp peaks of γ -Al₂O₃ were shown in **Fig. 8**. These matched the standard of aluminum. Three strong peaks were seen (77.28°, 64.35, 43.98°). The crystallite nanoparticle size is 18.7nm.

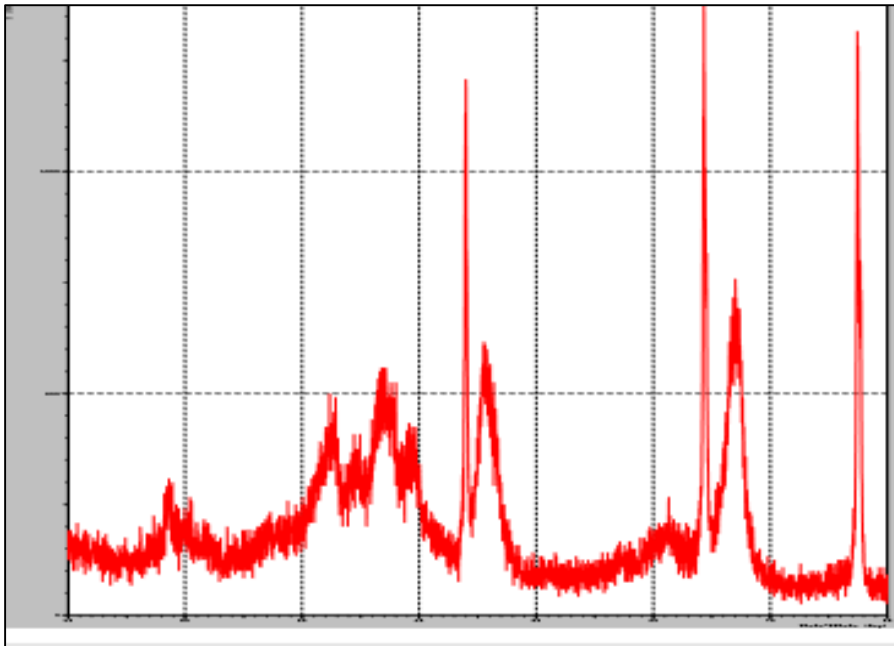


Figure 8. XRD of γ -Al₂O₃ Nanoparticles.

5. STABILITY OF NANOFLUIDS

5.1 Zeta Potential

The zeta potential is one of the most important ways to measure the stability of nanofluids. The range of zeta potential between (40-60) mV represents the good stable fluids. The zeta potential was measured for two types of nanofluids TiO₂/water and γ -Al₂O₃/water of 0.003 vol. % concentration.

The zeta potential was measured just after the preparation and during 30 days, these results were shown in Fig. 9. The values of zeta potential for the two types represent a high stability state of nanofluids and this agrees with Deodhar, 2014.

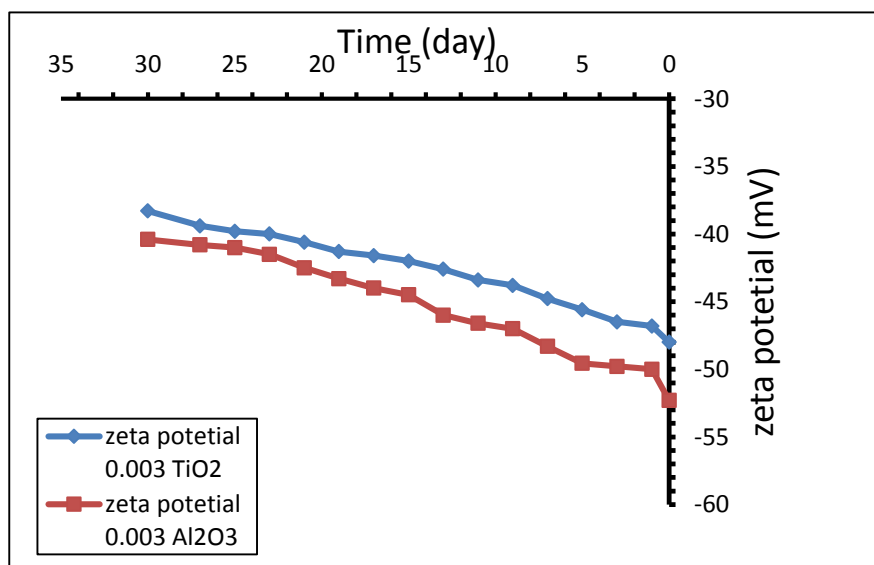


Figure 9. Zeta potential of the two types of nanofluids.

5.2 UV- Vis spectrophotometer

The stability of prepared nanofluids $\text{TiO}_2/\text{water}$ and $\gamma\text{-Al}_2\text{O}_3/\text{water}$ can be measured simply using the absorbency of light wavelength. Just after preparation to nanofluids. **Fig.10** shows that the $\text{TiO}_2/\text{water}$ and $\gamma\text{-Al}_2\text{O}_3/\text{water}$ of concentration of 0.003 % the absorbency light at wavelength of 220 nm and 330 nm respectively after preparation, then after 30 days another test was taken to the nanofluids showing that the absorbance light at wavelength of 252 nm and 363 nm, this agrees with **Deodhar, 2014** which represents good stability of the two types nanofluids at 0.003 % concentration as shown in **Fig.11**.

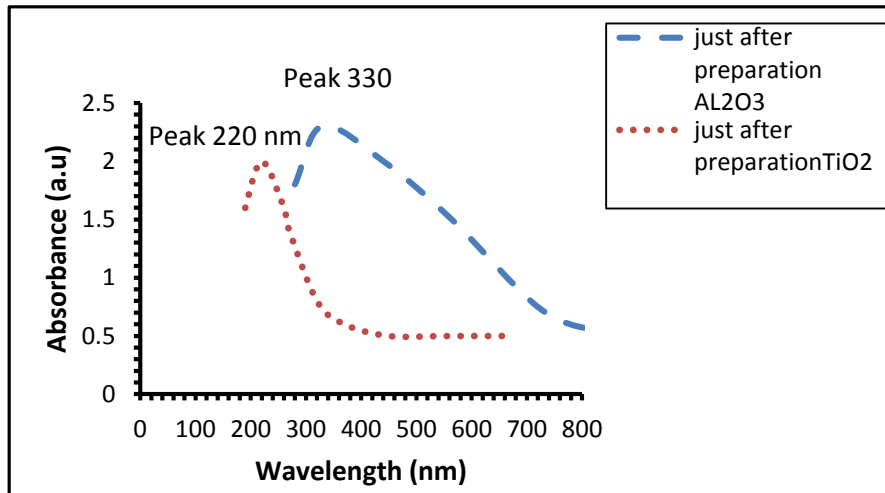


Figure 10. UV-vis just after preparation 0.003% for $\text{TiO}_2/\text{water}$ & $\gamma\text{-Al}_2\text{O}_3/\text{water}$ nanofluids.

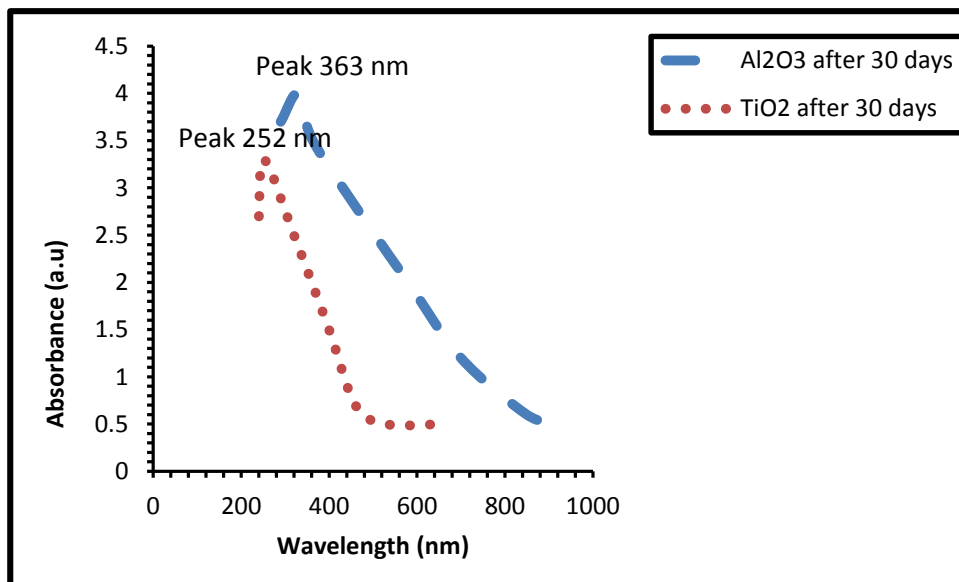


Figure 11. UV-vis spectrum after 30 days of 0.003% $\text{TiO}_2/\text{water}$ & $\gamma\text{-Al}_2\text{O}_3/\text{water}$ nanofluids.



6. RESULTS AND DISCUSSION

1. There are many ways to measure the stability of nanofluids, one of these ways is the measuring of the zeta potential of the nanofluids. It is shown that the zeta potential of the two types of nanofluids is over (40-60) mv. This means that the nanofluids have good stability over 20 days. The γ -Al₂O₃/water has more stability than the TiO₂/water nanofluids, this is due to the repulsion force that is larger than the attractive force between nanoparticles in the fluid this agrees with **Aadil, 2014** and **Wei, 2012**.
2. The second way to measure the stability of nanofluids used in the paper was by measuring the wavelength of two types of nanofluids at 0.003% vol. concentration by using UV-spectrophotometer. The wavelength of TiO₂/water & γ -Al₂O₃/water nanofluids are nearly in the same range of wavelength over 30 days and this means that the nanofluids have good stability.

7. CONCLUSIONS

Preparation of nanofluids with concentrations of 0.003% was done using a two-step method. This method has many advantages, one of them is that: this way would be prepared in a large amount of nanofluids and can be prepared in a specific concentration of nanoparticles. Continuous mixing was used to keep the nanoparticles in motion and remain the nanofluids in a stable state. The stability of TiO₂/water and γ -Al₂O₃/water is confirmed by measuring the zeta potential and UV-spectrophotometer for 0.003 % vol. concentration. From the results, the nanofluids have a good stability means good thermal conductivity in a process.

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NOMENCLATURE

Symbol Description

K= constant depending on the crystalline shape (0.9)

T= is the size of crystallite, m

Greek Symbols

Units= Description

λ = X-ray wavelength, nm

β = full width of middle max., nm

θ = The angle of x-ray diffraction, °