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Negative Hamaker Coefficients: Application to the Human Immunodeficiency Virus (HIV) – Blood Interactions in Antiretroviral Drug Media

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Abstract
Negative Hamaker coefficients approach was used as a thermodynamic tool in determining the HIV-blood interactions in the presence of antiretroviral drugs. Expressions required for the computation of the Negative Hamaker coefficients were obtained using the Lifshitz theory which is a function of the absorbance of the interacting systems. The methodology involved the serial dilution of the five different antiretroviral drugs (two HAART/FDC and three single drugs) and the subsequent incubation with the blood samples collected from ten HIV infected persons. Absorbance measurements were performed using a digital Ultraviolet Visible MetaSpecAE1405031Pro Spectrophotometer. The MATLAB software tools were employed in the mathematical analysis of the very large body of data generated from the experiments. The Hamaker constants A_{11}, A_{22}, A_{33} and hence the combined Hamaker coefficients A_{132} were derived. The absolute values for the combined Hamaker coefficient, A_{132abs} obtained for each of the five antiretroviral drugs interacting with infected lymphocytes varied from -0.02481×10^{-21}Joule for drug D4 to -0.05845×10^{-21}Joule for D3. The negative senses of the absolute combined Hamaker coefficients imply net negative van der Waals forces indicating a possible repulsion or blocking of the invading virus by the administered drug which is assumed to coat the lymphocytes. Such repulsion will in principle suggest that contact might not occur between the virus and the lymphocyte and hence possibly, the virus will not penetrate into the lymphocyte. This may result in reduction of viral load and increase of CD4 counts. The findings of this work may be useful to Pharmaceutical industries in drug design.

Keywords: Absorbance, Hamaker constant, Hamaker coefficient, Human immunodeficiency virus, Antiretroviral drug

1. Introduction

1.1 Background

UNAIDS [1] declared that an estimated 35.5 (32.2 to 38.8) million people were living with HIV in 2012. About 15 million people with HIV are expected to be reached with the lifesaving antiretroviral treatment by 2015. Hence, the world is within the reach of providing antiretroviral therapy to a good number of HIV infected people across the globe. In 2012, 9.7 million people in low and middle income countries received antiretroviral therapy. Antiretroviral therapy not only prevents AIDS – related illness and death: it also has the potential to significantly reduce the risk of HIV transmission and the spread of tuberculosis. From 1996 to 2012, antiretroviral therapy averted 6.6 million AIDS – related deaths worldwide, including 5.5 million deaths in low and middle income countries. Antiretroviral therapy reduces the risk that a person living with HIV will develop tuberculosis [1].

It could also be noted that the antiretroviral regimens have yet to completely and permanently suppress the virus in HIV – infected people. Although, many antiretroviral drugs are being manufactured for the eradication of the HIV infections; but approximately 40,000 new HIV infections occur each year in the United States according to the Joint United Nations Programmes [2]. The power of highly active antiretroviral therapy (HAART) to suppress HIV has revolutionized the clinical management of HIV disease in the developed world [3]. The capacity for HIV to develop resistance to antiretroviral drugs, however, is a significant cause of the failure of

HAART. Genotypic and phenotypic resistance tests have the potential to help identify which drugs in a regimen are failing and to guide the selection of drugs for new regimens [4]. The discovery and application of highly active anti-retroviral therapy (HAART) to suppress HIV has revolutionized the clinical management of HIV/AIDS cases. The HIV however, has the capacity to develop resistance to the antiretroviral drugs and this phenomenon has turned out to be a significant cause of failure of HAART [5]. HIV, which is a rapidly mutating RNA-based virus, lacks the ability to checkmate the possible genetic mutations that can occur during replication. Hence, this rapid genetic variation has become the major factor for which this menace has consistently defiled clinical solutions. The increasing rate of HIV infection globally is blamed on the ineffectiveness of some available antiretroviral therapy to block or resist perfectly this virus from invading the uninfected white blood cells.

The understanding of the mechanism by which drugs can block the virus may need more attention to increase drug effectiveness. The interaction between the HIV and the white blood cells in the presence of antiretroviral drugs, may pose a challenge. The problem of formulating drugs that can summarily eliminate HIV also remains a challenge. The question arises as to how effective the available antiretroviral drugs are? The answer to such question may be sought through a surface thermodynamic approach. Achebe [5] proposed a possible method of determining a characteristic surface property of drugs as additive(s) to the serum that could possibly render the absolute combined Hamaker coefficient A_{132abs} negative. There are several classes of drugs, which are usually used in combination, to treat HIV infection. The determination of the surface properties of these drugs in relation to the blood components and the use of such information to estimate HIV - drug interactions may go a step further in the understanding of the interaction mechanisms.

The antiretroviral drugs or agents are natural blockers - they block the virus at different stages based on viral life cycle. The drugs are variously capable of providing functional cure to various degrees by blocking viral replication in HIV infected patients. Obviously, the optimism stemming from the great successes recorded with this approach in related areas of biology and medicine has strengthened our resolve to advance the research through the surface thermodynamics approach.

There are several classes of drugs, which are usually used in combination, to treat HIV infection. Use of these drugs in combination can be termed anti-retroviral therapy (ART), combination anti-retroviral therapy (cART) or highly active anti-retroviral therapy (HAART). Anti-retroviral (ARV) drugs are broadly classified by the phase of the retrovirus life-cycle that the drug inhibits. Typical combinations include 2 NRTIs as a "backbone" along with 1 NNRTI or 1 PI as a "base" [6].

1.2. Concept of Negative Hamaker coefficients

The concept of Hamaker constants can be explained from van der Waals explanation of the derivations of the ideal gas law:

$$PV = RT \qquad (1)$$

It was discovered that the kinetic energy of the molecules which strike the container wall is less than that of the bulk molecules. This effect was explained by the fact that the surface molecules are attracted by the bulk molecules even when the molecules have no permanent dipoles. It then follows that molecules can attract each other by some kind of cohesive force [7]. These forces have come to be known as van der Waals forces. van der Waals introduced the following corrections to eqn.(1);

$$\left[P + \frac{a}{V^2}\right](V - b) = RT \qquad (2)$$

The correction term to the pressure, $\left(\frac{a}{V^2}\right)$ indicates that the kinetic energy of the molecules which strike the container wall is less than that of the bulk molecules.

After the development of the theory of quantum mechanics, London quantified the van der Waals statement for molecules without a dipole and so molecular attraction forces began to be known as London/van der Waals forces [8].

Hamaker [9] made an essential step in 1937 from the mutual attraction of two molecules. He deduced that assemblies of molecules as in a solid body must attract other assemblies. The interaction energy can be obtained by the summation of all the interaction energies of all molecules present.

For a sphere of radius, R and a semi-infinite body at a minimum separation distance, d the van der Waals force, F_{vdw} of attraction is given by;

$$F_{vdw} = -\left[\frac{A_{11}R}{6d^2}\right] \qquad (3)$$

where A_{11} is the Hamaker Constant. This is the non-geometrical contribution to the force of attraction, based on molecular properties only.

According to Hamaker, the constant $A_{11} = \pi^2 q_1^{\,2} \beta_{11}$, where q_1 is the number of atoms per cm^3 and β_{11} is the London/van der Waals constant for interaction between two molecules. Values for β can be obtained in approximation from the ionization potential of the molecules of interest, and so the Hamaker constant can be calculated. The corresponding van der Waals force between two condensed bodies of given geometry can be calculated provided their separation distance is known.

For combination of two different materials 1 and 2 in approximation: $B_{12} \approx \sqrt{\beta_{11}\beta_{22}}$ and hence

$$A_{12} = \sqrt{A_{11}A_{22}} \qquad (4)$$

For a combination of three materials when the gap between 1 and 2 is filled with a medium 3, from Hamaker's calculations;

$$A_{131} = A_{11} + A_{33} - 2A_{13} \qquad (5)$$

$$A_{232} = A_{22} + A_{33} - 2A_{23} \qquad (6)$$

Also;

$$A_{132} = A_{12} + A_{33} - A_{13} - A_{23} \qquad (7)$$

Rewriting these equations will give;

$$A_{131} = \left(\sqrt{A_{11}} - \sqrt{A_{33}}\right)^2 ;$$

$$A_{232} = \left(\sqrt{A_{22}} - \sqrt{A_{33}}\right)^2 ;$$

$$A_{132} = \left(\sqrt{A_{11}} - \sqrt{A_{33}}\right)\left(\sqrt{A_{12}} - \sqrt{A_{33}}\right) \qquad (7a)$$

Equation (7a) shows that, for a three-component system involving three different materials, 1, 2 and 3, the combined Hamaker coefficient A_{132} can become negative;

i.e. $$A_{132} \prec 0 \qquad (8)$$

if $A_{11} < A_{33} < A_{22}$ or $A_{11} > A_{33} > A_{22}$ (9)

The implication of this is that two adhering bodies 1 and 2 of different compositions will separate spontaneously upon immersion in a liquid 3 provided the conditions given by eqn.(9) are fulfilled.

The limitations of Hamaker's approach led to the development of an alternative derivation of van der Waals forces between solid bodies [10]. The interaction between solids on the basis of their macroscopic properties considers the screening and other effects in their calculations.

Lifshitz's equation was further approximated by several authors [11 - 14] since it is rather difficult to use. The "physical" meaning of that equation has been demonstrated [15]. It was shown that for a group of materials like polymers, the curves are identical while starting at a different position at zero frequency. Applying the absorption data of polystyrene, the value of A_{11} becomes;

$$A_{11} = 2.5\left[\frac{\varepsilon_{10} - 1}{\varepsilon_{10} + 1}\right]^2 = 2.5\left[\frac{n_1^{\,2} - 1}{n_1^{\,2} + 1}\right]^2 \qquad (10)$$

Where ε_{10} is the dielectric constant and n_1 the refractive index of the polymer at zero frequency, both being bulk material properties which can easily be obtained. Eq.(10) has been used successfully in different biological applications and so we have confidence in its applicability in the systems under consideration.

To be able to use equation (9) and equation (10), the relevant optical parameters must be determined from absorbance data. The following relationships apply:

$$\bar{a} + T + R = 1 \;\; ; \;\; T = 10^{-\bar{a}} \qquad (11)$$

Where absorbance **ā,** transmittance T and the reflectance R.

With the values of ā ascertained from experiment and T calculated with eq. (11), R can easily be derived.

The next step is to find a value for the refractive index, *n* employing the mathematical relation [16]

$$n = \left[\frac{1 - R^{1/2}}{1 + R^{1/2}}\right] \qquad (12)$$

2. Methodology

2.1 Sample Collection

The popular and commonly used Antiretroviral drugs (three single tablets and two HAART), from the University of Nigeria Teaching Hospital (UNTH) APIN CENTRE PEPFAR, Ituku – Ozalla, Enugu State were collected [17]. Table 1 shows the details

of the five different antiretroviral drugs used in the study. Drugs 1 and 2 are both Highly Active Antiretroviral Therapy (HAART) as well as Fixed Dose Combination (FDC), while drugs 3, 4 and 5 are single antiretroviral drugs. Drugs 1, 3 and 5 are administered to HIV patients twice daily while drugs 2 and 4 are taken once a day. It is worth noting that all the antiretroviral drugs used were not expired during the period of the experiments.

Blood samples were collected from Nnamdi Azikiwe University Teaching Hospital (NAUTH) Nnewi and Anambra State Teaching Hospital, Amaku. as follows:

- from ten HIV infected persons
- from ten HIV negative persons.

Altogether, a total of twenty samples from different individuals were collected and screened to determine the infection status and stored in anticoagulant test tubes and ice packs to ensure the freshness and to avoid the samples becoming lysed. The samples were thereafter stored in a refrigerator for proper preservation.

Table 1 Details of the five antiretroviral drugs [17]

Drug Number	Tablets	Abbreviation	Size	Batch Number	Expiration Date	Pharmaceutical Company
1	Lamivudine, Nevirapine & Zidovudine	3TC + NVP + ZDV	150mg/200mg/300mg	7220929	01/2016	Strides Arcolab Limited
2	Tenofovir, Lamivudine & Efavirenz	TDF + 3TC + EFV	300mg/300mg/600mg	3018522	09/ 2015	Mylan Laboratories Limited
3	Nevirapine	NVP	200mg	7216348	04/2015	Strides Arcolab Limited
4	Efavirenz	EFV	600mg	E121035A	07/2015	HETERO LABS LIMITED
5	Lamivudine	3TC	150mg	LEX – 023	04/ 2016	MCNEIL & DRUGS Pharmaceuticals Ltd.

2.2 Sample Preparation

The drugs passed through serial dilution at Tahilah Diagnostic Laboratories, Awka, in order to get the right concentration of drug in the blood. After the serial dilutions to 10^{-2}, the drug solution mixed with the blood was incubated at normal body temperature (37°C) to facilitate drug – blood interactions. The knowledge of the onset and duration of action of each drug was used in administering the start dose and the maintenance dose in the blood samples. These collected samples with drug concentrations were loaded into a centrifugal separator and the blood components were separated at Tahilah Diagnostic Laboratories, Awka. This helped to obtain such components as White Blood Cells (WBC) also called the Lymphocytes, Red Blood Cells (RBC), and the Plasma or Serum, each sample at a time. Glass slides were prepared and smeared with the samples for absorbance measurements. The slide preparations and sample smearing were done at the same laboratory. About 400 slides were successfully prepared in the laboratory [17].

2.3 Measurements

To be able to calculate the individual Hamaker constants and the relevant combined Hamaker coefficients, values of the absorbance for the interacting systems must normally be known.

Absorbance measurements were done on all the different blood components of all twenty samples incubated in antiretroviral drugs. A digital Ultraviolet Visible MetaSpecAE1405031Pro Spectrophotometer was used at the laboratory of the Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka in the measurements. The absorbance values of the samples were measured over a range of wavelength spanning between 230 and 970 **Å** alongside with their corresponding transmittance values. The data collected [17] were used to obtain the plots as presented in this research work.

3. Results and Discussion

3.1. Absorbance data

The absorbance measured for a given sample, HIV infected or uninfected, has been plotted for each drug as given in figs. 1 to 5.

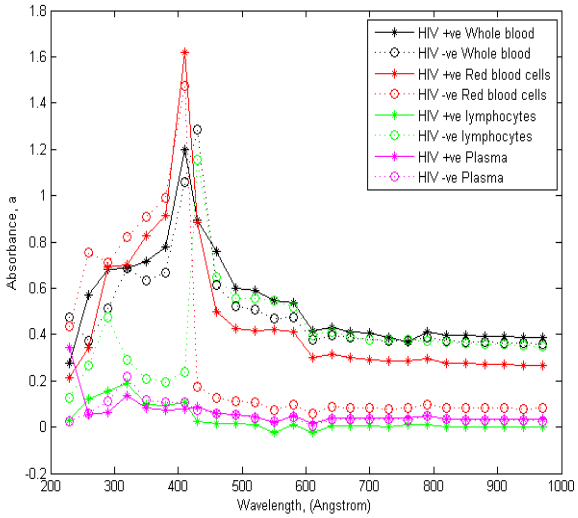

Fig 1. Absorbance, á versus Wavelength, λ for Drug 1 on HIV positive and negative Whole blood and its three main components

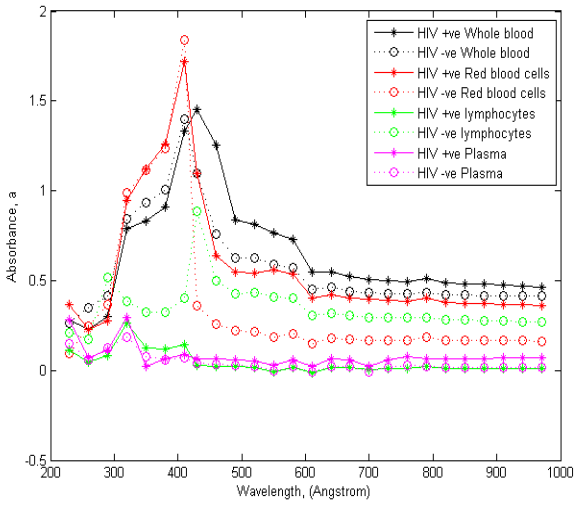

Fig 2. Absorbance, á versus Wavelength, λ for Drug 2 on HIV positive and negative Whole blood and its three main components.

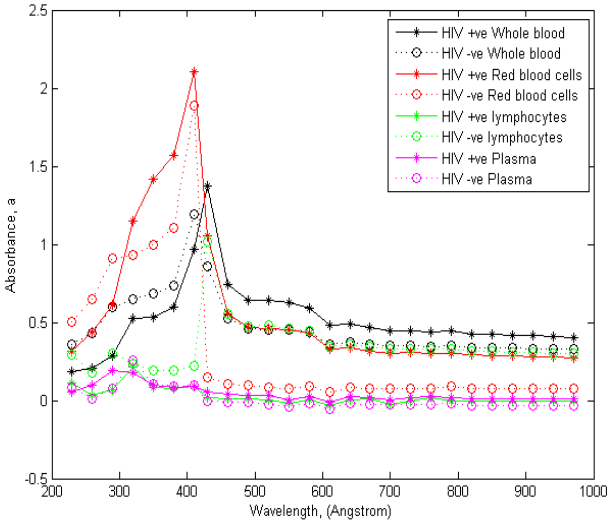

Fig 3. Absorbance, á versus Wavelength, λ for Drug 3 on HIV positive and negative Whole blood and its three main components

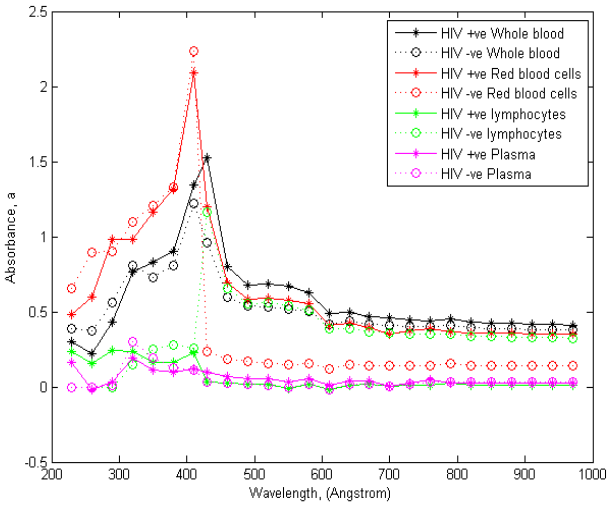

Fig 4. Absorbance, á versus Wavelength, λ for Drug 4 on HIV positive and negative Whole blood and its three main components.

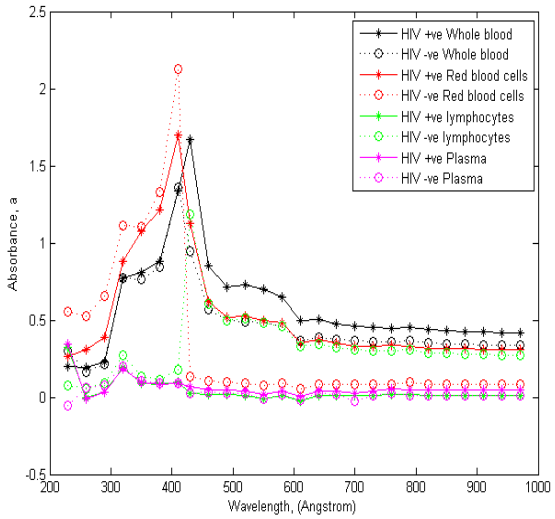

Fig 5. Absorbance, á versus Wavelength, λ for Drug 5 on HIV positive and negative Whole blood and its three main components

Figs 1 to 5 give the absorbance data plotted as a function of wavelength for the HIV infected and uninfected blood components treated with each drug. The following features are observed:

- Each blood sample, whether infected with HIV or not, exhibits a maximum in its absorbance.
- The graph for each blood sample has a different peak absorbance value.
- The whole blood and red blood cells samples exhibited maximum absorbance at a wavelength of 410 Å while the white blood cells and plasma samples exhibited maxima in absorbance at a wavelength of 320Å.
- The wavelengths at which the maxima occurred were not affected by drug treatment of the blood component.
- On the whole, the peak absorbance varies between 1.05 and 2.28 for HIV negative blood components and between 0.08 and 2.10 for HIV positive blood components. The tendency appears to be that, on the average, HIV lowers the absorbance of blood components.

Table 2 Peak absorbance and wavelength values for HIV- negative blood components

Drug	Whole blood		WBC		RBC		Plasma	
	λ, Å	α (peak)	λ, Å	α (peak)	λ, Å	α (peak)	λ, Å	α (peak)
1	410	1.05	320	0.48	410	1.50	320	0.22
2	410	1.40	320	0.52	410	1.88	320	0.18
3	410	1.20	320	0.30	410	1.90	320	0.26
4	410	1.24	320	0.28	410	2.28	320	0.30
5	410	1.38	320	0.27	410	2.18	320	0.20

Table 3 Peak absorbance and wavelength values for HIV-positive blood components

Drug	Whole blood		WBC		RBC		Plasma	
	λ, Å	α (peak)	λ, Å	α (peak)	λ, Å	α (peak)	λ, Å	α (peak)
1	410	1.20	320	0.18	410	1.60	320	0.16
2	410	1.36	320	0.26	410	1.76	320	0.08
3	410	1.00	320	0.20	410	2.10	320	0.19
4	410	1.40	320	0.30	410	2.08	320	0.28
5	410	1.36	320	0.19	410	1.70	320	0.20

3.2 Coating effectiveness of antiretroviral drug films on blood components

This study focused on all the blood components and the whole blood. However, the antiretroviral drugs have been specifically designed to block the viral infection from attaching its CD8+ cells on the wild CCR5 dendrites of the blood CD4+ T4 cells. We sought to determine, using the absorbance data, the influence of the drug films on the surfaces of the lymphocytes. To do this, an expression for coating effectiveness η_a was proposed [17] as

$$\eta_a = \frac{\tilde{\alpha}_{bd} - \tilde{\alpha}_b}{\tilde{\alpha}_d - \tilde{\alpha}_b} \quad (13)$$

Where $\tilde{\alpha}_d$ is peak absorbance for drug film only,

$\tilde{\alpha}_b$ is peak absorbance for blood component only, and $\tilde{\alpha}_{bd}$ is peak absorbance for drug film coated given blood component

This consideration assumes that since the drug is dissolved in the plasma, its film coats the surface of each blood component. Eq. (13) is actually saying that, from absorbance concept, the difference the drug film makes in the absorbance of a blood component when compared with the difference in the absence of the drug, can give us an idea of the effectiveness of the coating. Using the data of table 2 together with those of the drug film alone as reported by Ani [17], the coating effectiveness was found as in table 4.

Table 4 Effectiveness of coating, η_a

Drug	Red blood cells	White blood cells	Plasma
1	1.1142	0.8970	0.3236
2	-6.2146	0.6813	0.1635
3	-0.1162	0.6793	0.5704
4	-0.9857	0.1725	0.2006
5	-0.3240	0.5868	0.3887

Table 4 shows the effectiveness of coating of the blood components with the antiretroviral drugs. The effectiveness of coating on Red blood cells gave inconsistent results, one positive and the rest negative values. These suggest that the drugs do not have specific defined effect on the red blood cells surfaces as also reported by Ozoihu [18]. The values of coating effectiveness for the white blood cells and plasma are positive for five different antiretroviral drugs. The average values of the coating effectiveness for RBC, WBC and plasma are -1.31, 0.60 and 0.33, respectively. Since the mean value for the WBC is the largest positive value, the effect of the coating on WBC is more pronounced. Note also that the drugs are in solution in the plasma and so are bound to affect its property of the plasma, as observed.

As a result of the above discussion, subsequent analysis of HIV interactions will consider only the lymphocytes as the target with the plasma as the intervening medium [5].

3.3 Computation of Hamaker constants

The approach in the Hamaker constants classification for this study is as follows:

A_{11} = Hamaker constant used for drug – coated HIV negative lymphocytes,

A_{22} = Hamaker constant for drug – coated HIV positive lymphocytes (as the virus) and

A_{33} = Hamaker constant for the infected plasma, as intervening medium.

The infected lymphocytes are used in lieu of the virus because there is currently no known means of isolating the virus. The assumption here is that the infected lymphocyte is an approximation of the actual virus owing to the manner of the infection. The mechanism of the viral infection is such that it actually attaches its CD8+ cells on the wild CCR5 dendrites of the blood CD4+ T4 cells while changing the nature of the cells. The important issue is that the virus does not encyst the blood cells as it were but actually infuses the cells thereby altering the nature and characteristics of the cells. This thus makes the use of the infected lymphocytes a close replacement for the virus in calculating the Hamaker coefficients.

Eq. (10), in terms of the refractive was used and the Hamaker constants A_{11}, A_{22} and A_{33} were thereafter calculated using the MATLAB software tools because of the very large body of data generated.. The refractive index *n* was calculated using eq. (12) for a given value of the reflectance *R* calculated using eq. (11) and data of figs. 1 to 5 for each of the *26* wavelengths for a given sample. Average values of the Hamaker constants for a given sample per wavelength were obtained using eq. (14), where *N =26*.

$$A_{ij} = \frac{\sum_{0}^{N}(A_{ij})}{N} \qquad (14)$$

The Hamaker constant obtained from eq. (14) for each sample of lymphocytes was added together and divided by ten, and the results are presented in tables 4. Using eqs. (4) and (7), the combined Hamaker coefficient A_{132} was also calculated for lymphocyte and for each drug and also listed in tables 5.

Table 5 The values of $A_{11,}$ A_{22}, A_{33} and A_{132} for each antiretroviral drug

Variable ($\times 10^{-21}$ Joule)	D1	D2	D3	D4	D5
A_{11}	1.186941	1.052179	1.083603	0.986577	1.119971
A_{33}	0.458831	0.571147	0.40075	0.491265	0.481885
A_{22}	0.276751	0.347462	0.232341	0.378151	0.292538
A_{132}	-0.03998	-0.05305	-0.05845	-0.02481	-0.05844

Table 5 reveals that A_{11} is greater than A_{33} which is also greater than A_{22} for each antiretroviral drug in HIV positive lymphocyte which is a condition for rendering the combined Hamaker coefficient, A_{132} negative (see equations (8) and (9)). This indicates that the five different antiretroviral drugs treatment in the study have rendered the combined Hamaker coefficients negative which show repulsive van der Waals forces are present. This suggests that the drug – coated lymphocytes would repel or block the HIV from attacking the lymphocytes. If this happens, it is expected that the virus will eventually die off if it does not gain access into the lymphocyte (where it replicates) thus leading to a reduction in viral load. The resultant effect will be the increase in the CD4 cells count and probable elimination of the virus in the system.

It is worth noting that the combined Hamaker coefficients were all found to be positive in ref. [5] showing there was attraction between the virus and the lymphocytes. This work shows, as discussed above, that treatment with antiretroviral drugs has rendered the combined Hamaker coefficient negative, and hence possible repulsion between the virus and the lymphocytes. Drugs 1, 2, 3 and 5 appear to have comparatively higher negative values of the combined Hamaker coefficients showing the possibility of their exhibiting stronger repulsion than drug 4. This is not an endorsement of any of the drugs but a conclusion drawn from the application of negative Hamaker coefficient concept.

3.4 Absolute combined Hamaker coefficients

The combined Hamaker coefficients A_{131} and A_{232} obtained by appropriate change of variables and A_{132} for each drug interacting with the lymphocytes were calculated using eqs. (5), (6) and (7) respectively. The absolute combined Hamaker coefficients, A_{132abs} and A_{13Iabs} for each drug as well as for all drugs on both infected and uninfected lymphocytes were also calculated as follows:

Applying the limits of integration (for the minimum and maximum values of A_{132} respectively), the absolute value for the combined Hamaker coefficient for each antiretroviral drug interacting with infected lymphocyte could thus be derived from [5].

$$A_{132abs} = \frac{\sum_{0}^{N}(A_{132})}{N} \tag{15}$$

Similarly, the absolute combined Hamaker coefficients A_{232abs} and A_{131abs} for each antiretroviral drug interacting with infected and uninfected lymphocyte are given by

$$A_{131abs} = \frac{\sum_{0}^{N}(A_{131})}{N} \tag{16}$$

And,

$$A_{232abs} = \frac{\sum_{0}^{N}(A_{232})}{N} \tag{17}$$

A_{131} represents an interaction energy between two uninfected lymphocytes in the plasma while A_{232} represents the interaction energy between two infected lymphocytes. The values calculated as above are listed in table 6 together with those for the interatcion between HIV and the lymphocyte with the plasma as an intervening medium, A_{132}.

Table 6. The absolute values of A_{131} for uninfected lymphocytes and $A_{132,}$ A_{232} for Infected lymphocytes in the five different antiretroviral drugs

Variable ($\times 10^{-21}$ Joule)	D1	D2	D3	D4	D5
$\mathbf{A_{131}}$	0.367603	0.463371	0.530208	0.509707	0.495986
$\mathbf{A_{232}}$	0.213619	0.276577	0.141540	0.186744	0.144346
$\mathbf{A_{132}}$	-0.03998	-0.05305	-0.05845	-0.02481	-0.05844

Table 6 reveals that the interaction energy among the lymphocytes, A_{131} is greater than the interaction energy among the virus (HIV) infected lymphocytes, A_{232}, the difference varying from about 42% with drug 1 to about 73% with drug 3. This shows that the virus actually has the tendency to weaken the lymphocyte, as expected.

The results of this study show that the combined Hamaker coefficients, $A_{132,}$ which had been found to be positive for HIV infected lymphocytes (and hence strong attraction between them) [5, 19 - 22] are rendered negative to different degrees by the addition of antiretroviral drugs (this suggests that there is force of repulsion between virus and blood component). This repulsion, in principle, suggests that the virus would not come in contact with the lymphocyte as to adhere on it and attack it. All the drugs studied showed that propensity, based on the values of combined Hamaker coefficients, to varying degrees. One expects that the drug that gives the highest negative Hamaker coefficient will have the capacity to cause stronger repulsion between the virus and the lymphocyte. All these confirm the applicability of the concept of negative Hamaker coefficients in the study of HIV-blood interactions in the presence of antiretroviral drugs.

4. Conclusion

The significance of engineering thermodynamics in contributing to various biological processes is an interesting phenomenon. In the twenty first century research works, there is a growing need to achieve a more reliable research result through a synergy between engineers and biological researchers.

The well known fact that HIV targets the lymphocytes and that the drugs are designed specifically to block the virus, has been shown to hold true from absorbance measures.

The concept of negative Hamaker coefficient formerly declared in principle has been validated in practice. The absolute values for the combined Hamaker coefficient, A_{132abs} obtained for each of the five antiretroviral drugs interacting with infected lymphocytes were found to vary from -0.02481×10^{-21} Joule for drug 4 to -0.05845×10^{-21}Joule for drug 3. The negative values of the absolute combined Hamaker coefficients obtained for the five antiretroviral drugs on HIV positive lymphocytes indicate that there are repulsive van der Waals forces which means that the interacting bodies (HIV and drug-coated lymphocytes) repel each other. This is to say that the antiretroviral drugs on the surface of the lymphocytes may succeed in stopping the HIV at different stages of its replication. Another significance of this negative value of the absolute combined Hamaker coefficient is that the introduction of each of the five antiretroviral drugs tends to increase the surface energy of the HIV positive lymphocytes. The interacting systems involving drugs 1, 2, 3 and 5 gave fairly high negative absolute combined Hamaker coefficients A_{132} and hence higher energy of interaction.

This work shows that when an HIV infected lymphocyte is treated with any of the five antiretroviral drugs studied, the combined Hamaker coefficient is rendered negative. This is very significant since the combined Hamaker coefficients obtained for HIV infected lymphocytes [5] that had not been treated with antiretroviral drugs were found to be positive. The result shows that treatment with antiretroviral drugs changes the possible attraction between the virus and the lymphocyte to repulsion providing the possibility of preventing lymphocyte attack by the virus, reduction in viral load and possible increase in CD4 cell count on an HIV infected person. This finding may be important to Pharmacists in drug design.

Note that this research was not intended to recommend any drug over the other but was designed to test the application of the concept of negative Hamaker coefficients in HIV-blood interactions in the presence of antiretroviral drugs.

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