

# **SURFACE FREE ENERGY CHARACTERIZATION OF POWDERS**

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## **ABSTRACT**

Microcalorimetric measurements and contact angle measurements were conducted to study the surface chemistry of powdered minerals. The contact angle measurements were conducted on both flat and powdered talc samples, and the results were used to determine the surface free energy components using Van Oss-Chaudhury-Good (OCG) equation. It was found that the surface hydrophobicity of talc increases with decreasing particle size. At the same time, both the Lifshitz-van der Waals ( $\gamma_s^{LW}$ ) and the Lewis acid-base ( $\gamma_s^{AB}$ ) components (and, hence, the total surface free energy ( $\gamma_s$ )) decrease with decreasing particle size. The increase in the surface hydrophobicity and the decrease in surface free energy ( $\gamma_s$ ) can be attributed to preferential breakage of the mineral along the basal plane, resulting in the exposure of more basal plane surfaces to the aqueous phase.

Heats of immersion measurements were conducted using a flow microcalorimeter on a number of powdered talc samples. The results were then used to calculate the contact angles using a rigorous thermodynamic relation. The measured heat of immersion values in water and calculated contact angles showed that the surface hydrophobicity of talc samples increase with decreasing particle size, which agrees with the direct contact angle measurements. A relationship between advancing water contact angle  $\theta_a$ , and the heat of immersion ( $-\Delta H_i$ ) and surface free energies was established. It was found that the value of  $-\Delta H_i$  decrease as  $\theta_a$  increases.

The microcalorimetric and direct contact angle measurements showed that acid-base interactions play a crucial role in the interaction between talc and liquid. Using the

Van Oss-Chaudhury-Good's surface free energy components model, various talc powders were characterized in terms of their acidic and basic properties. It was found that the magnitude of the Lewis electron donor,  $\gamma_s^-$ , and the Lewis electron acceptor,  $\gamma_s^+$ , components of surface free energy is directly related to the particle size. The  $\gamma_s^-$  of talc surface increased with decreasing particle size, while the  $\gamma_s^+$  slightly decreased. It was also found that the Lewis electron-donor component on talc surface is much higher than the Lewis electron-acceptor component, suggesting that the basal surface of talc is basic.

The heats of adsorption of butanol on various talc samples from n-heptane solution were also determined using a flow microcalorimeter. The heats of adsorption values were used to estimate % hydrophilicity and hydrophobicity and the areal ratios of the various talc samples. In addition, contact angle and heat of butanol adsorption measurements were conducted on a run-of-mine talc sample that has been ground to two different particle size fractions, i.e.,  $d_{50}=12.5 \mu\text{m}$  and  $d_{50}=3.0 \mu\text{m}$ , respectively. The results were used to estimate the surface free energy components at the basal and edge surfaces of talc. It was found that the total surface free energy ( $\gamma_s$ ) at the basal plane surface of talc is much lower than the total surface free energy at the edge surface. The results suggest also that the basal surface of talc is *monopolar basic*, while the edge surface is *monopolar acidic*. The results explain why the basicity of talc surface increases with decreasing particle size as shown in the contact angle and microcalorimetric measurements.

Furthermore, the effects of the surface free energies of solids during separation from each other by flotation and selective flocculation were studied. In the present work, a kaolin clay sample from east Georgia was used for the beneficiation tests. First, the crude kaolin was subjected to flotation and selective flocculation experiments to remove discoloring impurities (i.e., anatase ( $\text{TiO}_2$ ) and iron oxides) and produce high-brightness clay with GE brightness higher than 90%. The results showed that a clay product with +90% brightness could be obtained with recoveries (or yields) higher than 80% using selective flocculation technique. It was also found that a proper control of surface hydrophobicity of anatase is crucially important for a successful flotation and selective flocculation process. Heats of immersion, heats of adsorption and contact angle measurements were conducted on pure anatase surface to determine the changes in the

surface free energies as a function of the surfactant dosage (e.g. hydroxamate) used for the surface treatment. The results showed that the magnitude of the contact angle and, hence, the surface free energy and its components on anatase surface varies significantly with the amount of surfactant used for the surface treatment.

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## TABLE OF CONTENTS

<b>CHAPTER 1 INTRODUCTION .....</b>	<b>1</b>
1.1 General.....	1
1.2 Literature Review.....	3
1.2.1 Surface Free Energy and Acid-Base Interactions.....	3
1.2.1.1 Lifshitz-Van der Waals Interactions.....	3
1.2.1.2 Polar or Acid-Base Interactions.....	15
1.2.1.3 Van Oss-Chaudhury-Good Equation.....	20
1.2.2 Contact Angle Measurements.....	23
1.2.2.1 Sessile Drop and Captive Bubble Techniques.....	23
1.2.2.2 Wilhelmy Plate Technique.....	24
1.2.2.3 Capillary Rise and Thin Layer Wicking Techniques.....	25
1.2.2.4 Contact Angle Determination From Heat of Immersion.....	28
1.2.3 Limitations of Contact Angle Measurements.....	31
1.2.3.1 Spreading Pressure.....	31
1.2.3.2 Surface Heterogeneity – Contact Angle Hysterisis.....	33
1.2.4 Contact Angle, Surface Hydrophobicity and Surface Free Energies.....	35
1.3 Report Organization.....	36
1.4 References.....	38
<b>CHAPTER 2 DETERMINATION OF SURFACE FREE ENERGIES OF TALC FROM CONTACT ANGLES MEASURED ON FLAT AND POWDERED SAMPLES.....</b>	<b>51</b>
2.1 Introduction.....	51
2.1.1 Van Oss-Chaudhury-Good Equation.....	53
2.1.2 Contact Angle Measurements.....	56
2.1.2.1 On Flat Surfaces.....	58
2.1.2.2 On Powdered Surfaces.....	59
2.2 Experimental.....	61
2.2.1 Samples.....	61
2.2.2 Liquids.....	61

2.2.3	Contact Angle Measurements.....	62
2.2.3.1	On Flat Surfaces.....	62
2.2.3.2	On Powdered Surfaces.....	63
2.3	Results and Discussion.....	65
2.3.1	Contact Angles.....	65
2.3.2	Surface Free Energies of Talc.....	70
2.4	Conclusions.....	76
2.5	References.....	77

**CHAPTER 3 CONTACT ANGLES OF POWDERS FROM HEAT OF IMMERSION.....98**

3.1	Introduction.....	98
3.2	Theory.....	100
3.2.1	Contact Angles from Heat of Immersion.....	100
3.2.2	Surface Free Energy Components of Talc.....	102
3.3	Experimental.....	103
3.3.1	Materials.....	103
3.3.2	Experimental Apparatus and Procedure.....	104
3.4	Results and Discussion.....	104
3.4.1	Surface Area and Particle Size.....	104
3.4.2	Heats of Immersion.....	105
3.4.3	Contact Angles from Heat of Immersion.....	106
3.4.4	Surface Free Energy Components of Talc from Microcalorimetric Measurements.....	109
3.5	Conclusions.....	112
3.6	References.....	112

**CHAPTER 4 SURFACE FREE ENERGY CHARACTERIZATION OF BASAL AND EDGE SURFACES OF TALC BY FLOW MICROCALORIMETRY.....128**

4.1	Introduction.....	128
4.1.1	Determination of Hydrophobic and Hydrophilic Surface Sites of Talc.....	130
4.1.2	Determination of Acidic and Basic Surface Sites of Talc.....	131
4.1.3	Determination of Areal Ratios of Talc Samples.....	132
4.1.4	Surface Free Energy Characterization of Basal and Edge Surfaces.....	133

4.2	Experimental.....	134
4.2.1	Material.....	134
4.2.2	Experimental Apparatus and Procedure.....	135
4.2.2.1	Heat of Adsorption of Butanol on Talc Surface from n-Heptane.....	136
4.2.2.2	Heat of Adsorption of Organic Acids and Bases on Talc Surface from Toluene.....	136
4.2.2.3	Determination of Areal Ratio Values of Talc Samples.....	137
4.2.2.4	Determination of Surface Free Energy Components at Basal and Edge Surfaces of Talc.....	137
4.3	Results and Discussion.....	138
4.3.1	Percent Hydrophilic Surface.....	138
4.3.2	Acidic and Basic Site Distribution of Talc.....	140
4.3.3	Areal Ratios of Talc Samples.....	141
4.3.4	Surface Free Energies of Talc at Basal and Edge Surfaces of Talc.....	143
4.4	Conclusions.....	148
4.5	References.....	149

**CHAPTER 5 CORRELATION BETWEEN SURFACE FREE ENERGY PARAMETERS OF SOLIDS AND SEPARATION EFFICIENCY IN MINERAL BENEFICIATION .....161**

5.1	Introduction.....	161
5.1.1	Contact Angle.....	162
5.1.2	Heat of Immersion and Adsorption Enthalpies.....	163
5.1.3	Surface Free Energies.....	164
5.2	Experimental.....	168
5.2.1	Materials.....	168
5.2.2	Reagents.....	168
5.2.2.1	For Flotation and Selective Flocculation.....	168
5.2.2.2	For Contact Angle Measurements.....	170
5.2.2.3	For Microcalorimetric Measurements.....	170
5.2.3	Procedure.....	171
5.2.3.1	Flotation.....	171
5.2.3.2	Selective Flocculation.....	171
5.2.3.3	Surface Treatment of Anatase with Hydroxamates.....	172

5.2.3.4	Contact Angle Measurements.....	172
5.2.3.5	Microcalorimetric Measurements.....	173
5.3	Results and Discussion.....	174
5.3.1	Flotation and Selective Flocculation.....	174
5.3.2	Contact Angles.....	180
5.3.3	Microcalorimetry.....	182
5.3.4	Surface Free Energy.....	184
5.4	Conclusions.....	190
5.5	References.....	192
<b>CHAPTER 6 SUMMARY AND CONCLUSIONS .....</b>		<b>220</b>
<b>CHAPTER 7 FUTURE WORK .....</b>		<b>223</b>
<b>VITA .....</b>		<b>225</b>

## LIST OF FIGURES

Figure 1.1.	Schematic representation of the contact angle formed between a liquid droplet and a solid surface. $\cos\theta$ is a measure of the equilibrium between the molecules of liquid L (horizontal arrows) and adhesion between liquid L and solid S (vertical arrows). Apolar energies are indicated by solid horizontal or vertical lines and arrows; polar (Lewis-acid base) energies are shown by dashed horizontal or vertical lines and arrows (21).....	49
Figure 1.2.	Schematic representation of (a) advancing and (b) retreating contact angles formed on a solid surface. When liquid is injected into the sessile drop the contact line advances, and when liquid is withdrawn from the drop the contact line recedes.....	49
Figure 1.3.	The values of hydrophobicity constant (K) and surface free energy parameters of methylated silica surfaces vs. advancing contact angle ( $\theta_a$ ) plot taken from the work of Pazhianur (135).....	50
Figure 2.1.	Schematic representation of the contact angle formed between a liquid droplet and a solid surface. $\cos\theta$ is a measure of the equilibrium between the molecules of liquid L (horizontal arrows) and adhesion between liquid L and solid S (vertical arrows) (21).....	88
Figure 2.2.	Wetting of Montana talc powder by different liquids in capillary rise at 20 °C.....	89
Figure 2.3.	Wetting of Select-A-Sorb talc powder with low-energy liquids (alkanes) in the thin layer wicking experiments measured at 20 °C.....	90
Figure 2.4.	Wetting of Select-A-Sorb talc powder with high-energy liquids in the thin layer wicking experiments measured at 20 °C.....	91
Figure 2.5.	Plot of $2\eta l^2/t$ vs. $\gamma_L$ obtained from thin layer wicking on Select-A-Sorb talc powder with the low-energy liquids (alkanes).....	92
Figure 2.6.	The surface free energy components of various flat and powdered talc samples determined using Wilhelmy plate and capillary rise techniques, plotted as a function of advancing contact angle, $\theta_a$ .....	93
Figure 2.7.	The surface free energy components of various powdered talc samples determined using thin layer wicking technique, plotted as a function of advancing contact angle, $\theta_a$ .....	94
Figure 2.8.	Schematic representation of the cleavage of talc layers and creation of basal plane surfaces by grinding.....	95

Figure 2.9.	ESCA spectrum for the Select-A-Sorb talc powder.....	96
Figure 2.10.	ESCA spectrum for the Select-A-Sorb talc powder.....	97
Figure 3.1.	Microscal Flow Microcalorimeter.....	119
Figure 3.2.	Schematic diagram of the flow microcalorimeter used for the heat of immersion measurements.....	120
Figure 3.3.	Surface area vs. $1/d_{50}$ for the talc samples.....	121
Figure 3.4.	Typical thermal output of flow microcalorimeter including heat of immersion in water and heat of calibration peaks obtained for run-of-mine Montana talc sample. Areas under the curves are proportional to the heat created.....	122
Figure 3.5.	Advancing and retreating contact angles of water on Montana talc as a function of temperature, measured using Wilhelmy plate technique.....	123
Figure 3.6.	Advancing and retreating contact angles of formamide on Montana talc as a function of temperature, as measured using KSV Sigma70.....	124
Figure 3.7.	Advancing contact angles of water on various talc powders as a function of temperature, measured using capillary rise technique.....	125
Figure 3.8.	Advancing contact angles of formamide on various talc powders as a function of temperature, measured using capillary rise technique.....	126
Figure 3.9.	The heat of immersion enthalpies in water obtained from Table 3.2 and the surface free energy components obtained from Tables 2.10 and 2.12, plotted as a function of $\theta_a$ .....	127
Figure 4.1.	Schematic representation of (a) butanol adsorbed on talc from water (b) butanol adsorbed on talc from n-heptane.....	157
Figure 4.2.	Schematic diagram of the flow microcalorimeter used for the adsorption and displacement studies.....	158
Figure 4.3.	Typical thermal output of flow microcalorimeter including heat of immersion (n-heptane), heat of calibration, and heat of adsorption (butanol) peaks obtained for Yellowstone talc sample. Areas under the curves are proportional to the heat created.....	159
Figure 4.4.	Change in the values of heat of adsorption enthalpies of butanol from n-heptane on the Montana talc surface as a function of particle size.....	160

Figure 5.1.	Schematic representation of the procedure employed for the batch selective flocculation experiments.....	202
Figure 5.2.	Grade vs. recovery curves for east Georgia clay obtained using Aero 6493 as collector at various dosages.....	203
Figure 5.3.	Grade vs. recovery curves for east Georgia clay obtained using Aero 6973 as collector at various dosages.....	204
Figure 5.4.	Grade vs. recovery curves for east Georgia clay obtained using Aero 6493 and Aero 6973 at 4 lb/t reagent dosage.....	205
Figure 5.5.	Relationship between TiO <sub>2</sub> content and brightness for the beneficiated east Georgia clay (Reproduced from the data given in Ref. 24).....	206
Figure 5.6.	Grade vs. recovery curves for east Georgia clay obtained using various polymer flocculants in the selective flocculation.....	207
Figure 5.7.	Effect of Sharpefloc 9131 polymer flocculant dosage on the yields and TiO <sub>2</sub> contents of clay product obtained from selective flocculation of east Georgia kaolin.....	208
Figure 5.8.	The selective flocculation of anatase from kaolin clay as a function of polymer flocculant (Sharpefloc 9131) dosage. From left to right: 25, 45, 62.5 and 125 g/t polymer addition.....	209
Figure 5.9.	Comparison between flotation and selective flocculation methods on the TiO <sub>2</sub> contents and yields for clay product at 4 lb/t Aero 6493 dosage.....	210
Figure 5.10.	Wetting kinetics of anatase powder treated with 4 lb/t Aero 6493 using low-energy (alkanes) and high-energy liquids in the thin layer wicking experiments measured at 20 °C.....	211
Figure 5.11.	Plot of $2\eta l^2/t$ vs. $\gamma_L$ obtained from thin layer wicking on anatase powder treated with 4 lb/t Aero 6493 using the low-energy liquids (alkanes).....	212
Figure 5.12.	Heat of displacement enthalpies of water from n-heptane on anatase surfaces treated with varying concentrations of hydroxamate reagent.....	213
Figure 5.13.	Heat of butanol adsorption from n-heptane on anatase surfaces treated with varying concentrations of hydroxamate reagent.....	214
Figure 5.14.	Effect of Aero 6493 concentration on the surface free energy and its components for anatase.....	215

Figure 5.15. The surface free energy parameters,  $\gamma_s$ ,  $\gamma_s^{LW}$ ,  $\gamma_s^{AB}$ ,  $\gamma_s^+$ , and  $\gamma_s^-$  and percentage of hydrophilic surfaces obtained for surface treated anatase powders of varying hydrophobicities. The surface free energy parameters and percentage of hydrophilic surface are plotted as a function of the advancing water contact angle. The hydrophilic surface percentage values are presented in Table 5.8 and the individual components of surface free energy are given in Table 5.9.....216

Figure 5.16. The surface free energy parameters,  $\gamma_s$ ,  $\gamma_s^{LW}$ ,  $\gamma_s^{AB}$ ,  $\gamma_s^+$ , and  $\gamma_s^-$  and the Gibbs free energy of interaction ( $-\Delta G_{131}$ ) obtained for surface treated anatase powders of varying hydrophobicities. The surface free energy parameters and the values of  $-\Delta G_{131}$  are plotted as a function of the advancing water contact angle. The  $-\Delta G_{131}$  values are presented in Table 5.10 and the individual components of surface free energy are given in Table 5.9.....217

## LIST OF TABLES

Table 1.1.	Hamaker constants for two identical media interacting across vacuum .....45	45
Table 1.2.	Hamaker constants for two media interacting across another medium .....46	46
Table 1.3.	Values of the surface tension components (in mJ /m <sup>2</sup> ) and of the viscosities (in poise) of various liquids used in direct contact angle determination, or in the capillary rise and thin layer wicking experiments (21) .....47	47
Table 1.4.	Surface tension components and parameters of various solid surfaces at 20 °C in mJ/m <sup>2</sup> (21, 26, 94-95, 97, 109) .....48	48
Table 2.1.	Values of the surface tension components (in mJ /m <sup>2</sup> ) and of the viscosities (in poise) of the liquids used in the capillary rise and thin layer wicking experiments .....81	81
Table 2.2.	Equilibrium contact angles of various liquids on flat Montana and Vermont talc surfaces measured using sessile drop technique (at 20±2 °C) .....81	81
Table 2.3.	Contact angles of various liquids on flat Montana and Vermont talc surfaces measured using Wilhelmy plate technique (at 20±2 °C) .....82	82
Table 2.4.	Advancing contact angles of various liquids on powdered talc samples obtained from capillary rise method (at 20±2 °C) .....82	82
Table 2.5.	Average pore size (r <sup>*</sup> ) determined by thin layer wicking on various talc powders (at 20±2 oC) .....82	82
Table 2.6.	Contact angles $\theta$ (deg) of various liquids on powdered talc samples measured using thin layer wicking technique (at 20±2 °C) .....83	83
Table 2.7.	Effect of particle size on the values of water and formamide contact angles for Montana and Vermont talc samples .....83	83
Table 2.8.	Effect of water exposure on the values of contact angles of Select-A-Sorb talc powder measured using thin layer wicking technique .....84	84
Table 2.9.	Surface free energy and its components of Montana and Vermont talc samples calculated from $\theta_{eq}$ measured using sessile drop technique .....84	84
Table 2.10.	Surface free energy components of flat and powdered Montana and Vermont talc samples .....85	85
Table 2.11.	Surface free energy and its components of powdered talc samples obtained from capillary rise measurements .....86	86

Table 2.12.	Surface free energy and its components of powdered talc samples obtained from thin layer wicking measurements .....	86
Table 2.13.	Chemical composition of Mistrion-100 and Select-A-Sorb powders as determined from ESCA measurements .....	87
Table 3.1.	Specific surface areas and average particle size of the studied talc samples.....	115
Table 3.2.	The heat of immersion enthalpies of various liquids on talc samples studied (20±2 °C) .....	115
Table 3.3.	The value of $\partial\cos\theta/\partial T$ for water on various talc surfaces obtained using Wilhelmy plate and capillary rise techniques .....	116
Table 3.4.	The value of $\partial\cos\theta/\partial T$ for formamide on various talc surfaces obtained using Wilhelmy plate and capillary rise techniques .....	116
Table 3.5.	Comparison of the water contact angles calculated using Eq. [3.8] with those obtained using other methods (at 20±2 °C) .....	117
Table 3.6.	Comparison of the formamide contact angles calculated using Eq. [3.8] with those obtained using other methods (at 20±2 °C) .....	117
Table 3.7.	Surface free energy components of talc samples obtained from microcalorimetric measurements .....	118
Table 4.1.	% Hydrophilic surface and specific hydrophilic surface area of the talc samples .....	152
Table 4.2.	Effect of particle size on the values of % hydrophilic surface and hydrophilic surface area for Montana talc .....	152
Table 4.3.	Heat of displacement enthalpies of trifluoroacetic acid (TFAA) and butylamine (BA) from toluene on various talc powders .....	153
Table 4.4.	Effect of particle size on the values of hydrophobic/hydrophilic surface sites and of basal-to-edge area ratios for Montana talc .....	153
Table 4.5.	Basal-to-edge ratio values of various talc samples determined using flow microcalorimeter .....	154
Table 4.6.	The fraction of the basal surface ( $f_b$ ) and that of the edge ( $f_e$ ) surface obtained from two different measurement techniques .....	155

Table 4.7.	Contact angles (degree) of various liquids on Yellowstone and Mistron Vapor-P talc samples measured using thin layer wicking technique (at 20±2 °C) .....	155
Table 4.8.	Surface Free energy components and parameters (mJ/m <sup>2</sup> ) for Yellowstone and Mistron Vapor-P talc powders obtained from thin layer wicking measurements .....	156
Table 4.9.	Surface free energy components and parameters (mJ/m <sup>2</sup> ) at the basal and edge surfaces of talc obtained using two different aspect ratio determination techniques .....	156
Table 5.1.	Specific surface areas of anatase sample treated with varying amounts of Aero 6493 .....	196
Table 5.2.	The properties of polymer flocculants used in the selective flocculation tests.....	196
Table 5.3.	Values of the surface tension components (in mJ /m <sup>2</sup> ) and of the viscosities (in poise) of the liquids used in the microcalorimetric and contact angle measurements .....	197
Table 5.4.	The results of selective flocculation testing conducted on east Georgia kaolin using various polymer flocculants at two different dosages .....	198
Table 5.5.	Effect of hydroxamate dosage on the selective flocculation of east Georgia kaolin clay .....	199
Table 5.6.	Average pore size (r*) of TiO <sub>2</sub> samples treated with varying amounts of Aero 6493 determined by thin layer wicking (at 20±2 °C) .....	199
Table 5.7.	The values of contact angles for various liquids on TiO <sub>2</sub> surface treated with varying amounts of Aero 6493 measured using thin layer wicking technique.....	199
Table 5.8.	The heat of immersion enthalpies of various liquids on TiO <sub>2</sub> surfaces treated with varying amounts of Aero 6493 (20±2 °C) .....	200
Table 5.9.	% Hydrophilic surface and specific hydrophilic surface area of TiO <sub>2</sub> treated with varying amounts of Aero 6493 .....	200
Table 5.10.	Surface free energy and its components of TiO <sub>2</sub> treated with varying amounts of Aero 6493 .....	201
Table 5.11.	Values of water contact angles (θ <sub>adv</sub> ) and ΔG <sub>131</sub> for anatase treated with varying amounts of Aero 6493 .....	201