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Removing Water from an Azeotropic Ethanol-Water Mixture through Adsorption

A Major Qualifying Project Proposal Submitted to: William Clark, David DiBiasio, and Stephen Kmiotek

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Abstract

Adsorption was explored as a mechanism to further separate azeotropic ethanol-water mixtures to produce pure ethanol for biofuel use. A bench-scale adsorption column was designed and tested. The variables in the experiment were the type of adsorbent, the amount of adsorbent, and the flow rate. The results showed that using 60 grams of Zeolite 3A at 5mL/minute produced optimal adsorption. An adsorption experiment was designed for the Unit Operations II Laboratory at Worcester Polytechnic Institute.

Acknowledgements

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Problem Statement

Developing a sustainable and long-term solution to meet the growing energy demand while securing energy supplies is a pressing global issue. Energy is the root of every economic, environmental, and developmental issue. Clean, efficient, and reliable energy systems are important in meeting the long-term needs for economic growth and development. By 2035, global energy consumption is expected to increase by 41% to meet the needs of a population increase of about 1.5 billion people (Why Biofuels?, 2014). The issue of energy sustainability is directly linked to current global challenges, such as poverty and climate change. These issues are most prevalent in developing countries. Developing nations are expected to be responsible for most of the increase in carbon dioxide emissions in the next three decades (United Nations Industrial Development Organization, n.d.). Their emissions greatly exceed that of developed nations because of rapid economic growth and continued use of fossil fuels. China and India alone will account for half of the world's total increase in energy use through 2040 (Leader, 2013).

With the exhaustion of petroleum deposits and the growing concern of global climate change, alternative fuels have gained popularity. Alternative fuels, which include biofuels, ethanol, hydrogen, and natural gas, help reduce petroleum consumption. Ethanol, specifically, is a renewable fuel made from corn and other plant materials known as biomass. Its use is widespread, and almost all gasoline in the United States contains 10% ethanol. Ethanol is also available in E85, an 85%-ethanol blend used in flexible fuel vehicles (Alternative Fuels Data Center, 2014). Ethanol is renewable and domestically produced; consequently reducing imported oil and greenhouse gas emissions.

Producing anhydrous ethanol has become a prevalent effort in the production of biofuels, as fermentation followed by distillation does not result in the production of pure ethanol, the necessary form for fuel use. The process of anhydrous alcohol production consists of fermentation, distillation, and dehydration. An important challenge in this process is the water removal process, which largely contributes to the production cost. Standard distillation removes water to a certain point but an extra process is required before blending pure ethanol with gasoline due to the ethanol-water azeotrope (Pruksathorn & Vitidsant, 2009). The purpose of this process is to decrease the energy consumption incurred by distillation.

This study examined the effect of adsorption on water-ethanol separation with the goal of optimizing a pure ethanol yield. Specifically, this study determined the effectiveness of several adsorbents on the separation of water and ethanol. In addition, an adsorption experiment was developed for the Unit Operations II course in the Chemical Engineering Department at Worcester Polytechnic Institute, in order to study the efficacy of different adsorbents. The adsorption design will help to decrease energy consumption incurred by many distillation stages. Considering several different adsorbents will enable this project to develop a robust and efficient ethanol-water separation process that can be adapted to different areas of the world that have varying adsorbent resources.

Background

Concept of Adsorption

In a heterogeneous system, the boundary between phases is called the interface. When a molecule under kinetic motion hits a surface (i.e. a phase boundary), it will either bounce back elastically or, more commonly, the molecule will stay at the surface for a period called the residence time. The interaction of molecules or atoms at the surface can be observed in gas-solid, gas-liquid, liquid-solid, liquid-liquid, and rarely solid-solid phase systems. Sorption is defined as the surface interaction between two phases. There are two types of sorption: adsorption and absorption. Adsorption is when molecules or atoms being sorbed are only concentrated at the interface, while absorption is when molecules or atoms being sorbed are distributed in the bulk of interacting phases. Adsorption can only occur when there is a solid phase present. The term *adsorbent* refers to the surface while *adsorbate* refers to the adsorbed molecule (Schweitzer, 1979).

Once an adsorbent becomes saturated with the adsorbate, it cannot adsorb anymore and therefore must be *desorbed* before the adsorbent can be used again. Desorption is the process in which the adsorbate is removed from the adsorbent.

Desorption

Once the pores of the adsorbent are full, the saturation point has been reached, and no more adsorbate can be adsorbed. Therefore, the adsorbent must now be desorbed in order to be reused. There are four common methods of desorption:

1. Pressure swing desorption is usually isothermal and occurs via the use of a low pressure or a vacuum to desorb the bed. Some advantages of using pressure swing desorption are fast cycling, which results in less adsorbent stock and a smaller adsorber, the ability to use gas compression as a major energy supply, and the direct production of a high purity product (UOP LLC Adsorbents).
2. Thermal swing is desorption using elevated temperatures, also known as the reactivation temperature, which is normally between 400-600°F for most systems. After this temperature is reached, a dry purge gas is flushed through the bed, or the pressure is reduced. Then the system is ready for adsorption. An advantage of this method is that from the adsorbent, large amounts of water and impurities can be obtained after a cooling step (UOP LLC Adsorbents).
3. Purge gas stripping utilizes a non-adsorbing purge gas stream, which desorbs the bed by decreasing the partial pressure of the adsorbed substance. More efficient stripping occurs when the operating pressure is extreme. Advantages of purge gas stripping include less power required because a liquid pump can be used instead of a blower, and an effluent stream that can be condensed in order to separate the desorbed component by simple distillation (UOP LLC Adsorbents).
4. Displacement cycles desorb by using a purge that displaces the adsorbed component. The cost of this method of desorption can be reduced by using a purge that is strongly adsorbed. This will completely desorb the bed, however, the purge will be more difficult to remove (UOP LLC Adsorbents).

Basic Equations for Adsorption

The number of molecules present per unit surface area, σ, depends on n, the number of molecules falling on a surface area of 1 cm^2 per second. It also depends on t, the average time a molecule remains on the surface, as given in Equation 1 (Schweitzer, 1979).

$$\sigma = nt \tag{1}$$

Adsorption Forces

Adsorption forces are simply the same forces that cause events such as cohesion in solids and deviations from the ideal gas law. The forces involved in adsorption can be broken down into two main categories: physical and chemical. Physical adsorption forces correspond to Van der Waals, or intermolecular forces, while chemical adsorption refers to chemical forces involving electron transfer. Physical forcers are in play if the characteristics of the adsorbate and adsorbent are preserved. In contrast, chemical adsorption occurs when the adsorbate and adsorbent transfer or share electrons (Schweitzer, 1979).

Adsorption Rate in Porous Adsorbents

The boundary layer is the most important aspect of phase interaction. Therefore, to achieve a high adsorption rate, the maximum obtainable surface area must be created. Commonly, in adsorbents, the surface area is increased by making a large amount of micro-capillaries in the solid. The time required for molecules to reach these pores is given by Equation 4. In this equation, t_r is the time required to complete the adsorption process, σ_t is the σ value at t_r, k_d is a constant inversely proportional to the square of the distance the molecules have traveled and proportional to the diffusion constant, D, which is obtained from Equation 3. In Equation 3, D_0 is a constant and Q_d is the activation energy (Schweitzer, 1979).

$$\sigma_t = (1 - e^{k_d} t_r) \tag{2}$$

$$D = \frac{D_0 e^{-Q_d}}{RT} \tag{3}$$

Adsorption Equilibrium

Adsorption equilibrium occurs when the number of molecules arriving on the surfaces is equal to the number leaving the surface. Adsorbed molecules exchange energy with the surface and, if given the required time, will reach thermal equilibrium with the surface atoms. In order to leave the surface, the adsorbed molecule must obtain sufficient energy to surpass a holding limit. This energy is obtained through fluctuations of thermal energy at the surface (Schweitzer, 1979).

Adsorption Isotherms

Isotherms for gas adsorption are graphs of the amount adsorbed versus increasing adsorbate vapor pressure at constant temperature. They can provide information about the adsorption process and indicate the fraction of surface coverage, which is used to find the final surface area of the saturated adsorbents. There are six basic types of adsorption isotherms as described in Figure 1 and shown in Figure 2.

Type I:	• Systems where adsorption does not proceed beyond the formation of mono-molecule layer • Obtained when oxygen adsorbed on carbon black at -183^oC
Type II:	• Indicates an indefinite multilayer formation after completion of monolayer • Adsorption of water vapor on carbon black at 30^oC
Type III:	• Obtained when amount of gas adsorbed increases without limit as its relative saturation approaches unity • Obtained when bromine is adsorbed on silica gel at 20^oC
Type IV:	• Variation of type II with finite multilayer formation; complete capillary filling • Obtained by adsorption of water vapor on active carbon at 30^oC
Type V:	• Similar variation of Type III obtained when vapor adsorbed on activated carbon at 100^oC
Type VI:	• Borderline cases between above types, with step-like properties, each step corresponding to formation of a complete monolayer • Obtained by adsorbing nitrogen on special carbon

Figure 1 shows the types of adsorption based on isotherm properties.

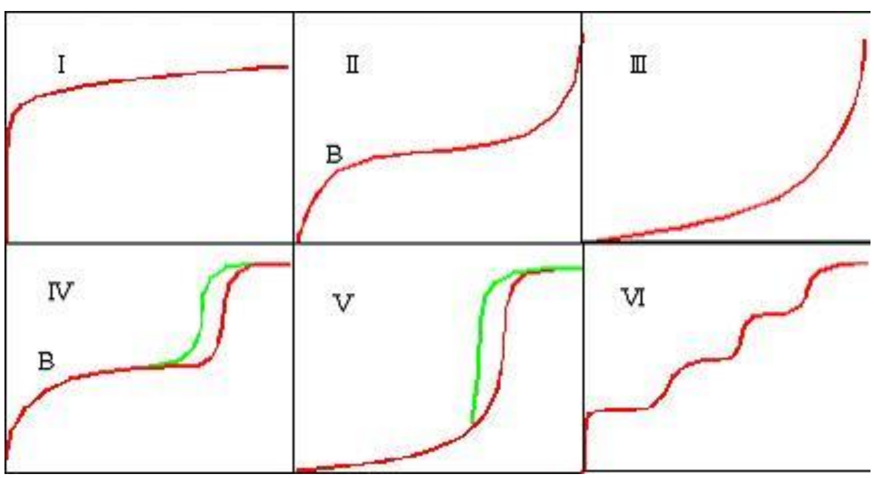


Figure 2 illustrates isotherm graphs demonstrating the different types of adsorption by plotting amount adsorbed vs. vapor pressure. The red represents the adsorption and the green represent desorption. (Oxford, 2014).

The forces holding the molecule to the adsorption surface diminish with distance. The attraction is measured by adsorption potential, E. For activated carbon, it has been found empirically that for any two given gases:

$$\frac{E_{01}}{E_{02}} = \left(\frac{a_1}{a_2}\right)^{1/2} \quad (4)$$

Where a is the van der Waals constant, and E is the adsorption potential. This (Polanyi equation) is powerful and can be used to predict isotherms for any gas.

To determine the work done in liquid adsorption, the following equation can be used, which can be set equal to the value of E_{01} or E_{02} when assuming 100% efficient adsorption:

$$E_1 = RTln\left(\frac{P_0}{P_s}\right)^{1/2} \quad (5)$$

Where P_s is the equilibrium vapor pressure in the gas phase, and P_0 is vapor pressure in the adsorbed phase.

The Polanyi theory of adsorption describes volume filling micro-pores in adsorbent structure, and is expressed by the equation:

$$W = W_0 exp(-kE^2) \quad (6)$$

Where, W is volume of adsorbate as liquid, W_0 is volume of adsorbent filled when E decreases to zero, which is usually total pore volume of adsorbent.

Plotting W/W_0 against E, the curve represents relationship between volume of available adsorption volume and adsorption potential, and is a statistical relationship expressing the fraction of the pore volume filled at different adsorption potential E values.

The volume filled by the adsorbent can be determined using Equation 7, where a is a constant and v_m is the molar volume of the adsorbate.

$$W = av_m \tag{7}$$

From Equation 5, the temperature variance of the adsorption potential is known. Using the relation in Equation 8, it is possible to calculate the adsorption isotherm of almost every substance at any temperature from one measured adsorption isotherm at a single temperature.

$$\frac{E_1}{E_2} = \beta \approx \frac{v_{m-1}}{v_{m-2}} \approx \frac{\hat{P}_1}{\hat{P}_2} \tag{8}$$

In Equation 8, β represents the affinity coefficient and $\hat{P}$ is the parachor for the bulk liquid phase.

Langmuir deduced the following equation to represent an adsorption isotherm for an ideal monolayer. In the Langmuir equation, Equation 9, V is the volume of a gas adsorbed per unit mass of adsorbent, Vm is the volume of the gas adsorbed per unit of adsorbent with a layer one molecule thick and b is an empirical constant.

$$V = \frac{v_m bp}{1+bp} \tag{9}$$

The Langmuir equation was expanded by Brunauer, Emmett and Teller to include multilayer adsorption. In the BET equation, Equation 10, V_m and C are empirical constants and x is equal to p/p_s.

$$V = \frac{V_m Cx}{(1-x)[1+(C-1)x]} \tag{10}$$

Even though the BET equation has limitations, it is very useful because it can be used to determine the surface area occupied by a single molecule of adsorbent and the number of molecules necessary to form the monolayer.

The most common use for adsorption isotherms is to select an adsorbent or even the adsorption process for a particular separation.

Adsorption isobars can be calculated using Equation (11, which relates the number of molecules adsorbed and the temperature.

$$\sigma = k_2 \frac{e^{Q/RT}}{\sqrt{T}} \tag{11}$$

In order to determine the relationship between temperature and pressure on the same degree of surface coverage, σ is held constant, resulting in Equation 12. This equation is most useful when a certain amount of contaminant must be adsorbed.

$$p = k_3 \sqrt{T} e^{-Q/RT} \tag{12}$$

This equation can be simplified by assuming the effect of the square root of temperature to be small. The equation then becomes:

$$lnp = -\frac{Q}{RT} + B_a \tag{13}$$

Adsorbents

In this project, the optimal adsorbent will be determined experimentally by testing several different options. The following discusses possible adsorbent options.

Activated Carbons

Activated carbons are produced by thermal decomposition of carbon materials followed by controlled oxidation using steam, carbon dioxide, air, or some mixture, which burn pores into the material. This can also be done by thermal treatment of cellulosic materials with phosphoric acid or zinc chloride. Activated carbons are slightly polar due to their surface oxides, but they are much less polar than other adsorbents. Many carbons contain ash, which may influence reactions between the adsorbed molecules; therefore it is necessary to investigate the catalytic effects before selecting this adsorbent for a process (Schweitzer, 1979).

Activated Alumina

Activated alumina and alumina gel are porous aluminum oxides with high surface areas. Alumina are nontoxic and can adsorb liquids, vapors, and gases without changing form or properties, and without swelling or disintegrating. They also have high resistance to shock and abrasion. Activated alumina is often used in maintenance programs to neutralize acids and adsorb moisture from transformers and lubricating oils in order to prevent oil deterioration and sludge formation. By taking advantage of the preferential adsorption of alumina, gases and liquids, including but not limited to water, can be adsorbed (Schweitzer, 1979).

Silica Gel

Silica gel is an adsorbent consisting of tiny spherical particles (2-20 nm) stuck together. The chemical formula for silica gel is SiO_2*nH_2O. The surface of this gel is made up of polar bonds between SiOH and SiOSi, which make it an excellent adsorber of water due to their similar properties.

Zeolite

Alumina and silicates are often combined to create a more efficacious adsorbent; this combination is called zeolite. Zeolite is a type of molecular sieve that has a tetrahedral network, formed by four oxygen atoms surrounding a silicon or aluminum cation. Alumina is trivalent, which causes the tetrahedron to be negatively charged; therefore it requires a cation to balance it. For this reason, the final structure has sodium, potassium, or calcium ions, which are exchangeable ions of the zeolite structure. A three dimensional crystal lattice is formed when each of the oxygen anions are shared with an aluminum or silicon atom in every direction. The general formula for zeolite with sodium as its cation is $Na_2O(Al_2O_3)(xSiO_2)(yH_2O)$. Zeolites preferentially adsorb molecules based mainly on size and configuration. In mixtures of similarly sized molecules that are small enough to enter the pores, zeolites will hold crystal molecules that have a higher polarity, lower volatility and a greater degree of unsaturation tighter (UOP LLC Adsorbents).

Type A Molecular Sieves:

Type A is the most common form of zeolite. It contains a truncated octahedron formed from the tetrahedral groups. These truncated octahedrons are connected in a cubic array. The central cavities formed by this framework have a diameter of about 11 angstroms. In order to arrive at these cavities, molecules must pass through one of six circular apertures, which are formed by rings of eight oxygen atoms. These apertures have a diameter of about 4.2 angstroms. Together, these central cavities and six passageways form what is referred to as the alpha cage. The truncated octahedron also have beta cages which have smaller cavities (6.6 angstroms) and passageways (2.2 angstroms). The structures are represented chemically by $Na_{12}(AlO_2)_{12}(SiO_2)_{12}*27H_2O$, where sodium can be replaced by other cations (UOP LLC Adsorbents).

There are 3 main subtypes of Type A molecular sieves: Type 3A, Type 4A, and Type 5A. In Type 3A, some of the sodium ions are replaced by potassium ions. This increase in ion size causes the pore size to decrease to about 3.2 angstroms. In Type 4A the sodium ions result in an aperture size of approximately 3.5 angstroms, but at normal operating temperatures molecules up to 4 angstroms can pass through. Type 5A is when some sodium ions are replaced by calcium ions. This results in the largest aperture size of the Type A sieves, which is about 4.2 angstroms (UOP LLC Adsorbents).

Type X Molecular Sieves:

Type X zeolites have a similar structure to Type A except that the beta cages are connected in a tetrahedral manner instead of a cubic array. This results in larger cavities of about 13 angstroms. The structure is represented chemically by $Na_{86}(AlO_2)_{86}(SiO_2)_{106}*264H_2O$, where sodium can be replaced by other cations and water can be removed by moderate heating (UOP LLC Adsorbents).

High Silica Molecular Sieves

High silica molecular sieves, as their name suggests, contain a higher ratio of silica to alumina than other forms of zeolite. They adsorb molecules based on size, similar to Type A and Type X zeolite. Since there is less alumina, the cation density is less, resulting in adsorbents that are hydrophobic, organophilic, and stable at a low pH and high temperature.

Silicalite

Silicalite is an adsorbent that has a structure similar to zeolite, however, it contains no alumina. The absence of alumina results in a lack of ion-exchange, making it hydrophobic, unlike zeolite which is hydrophilic. As a result, rather than adsorbing water molecules, as zeolite would, silicalite adsorbs non-polar molecules At the same time, the lack of alumina allows for a more stable structure that can withstand up to 1000^{o}C.

Organic Material

Research has shown that some organic materials such as corn, cornmeal, sticky rice, and sweet potatoes can also be used as adsorbents due to their starchy surfaces (Wang, 2010). Using these organic materials will decrease energy and material cost for the adsorption column.

Sticky Rice

Previous research has been done on the ability of sticky rice to remove water selectively from ethanol-water mixtures (Wang, et al, 2010). The water selectivity of sticky rice is due to its starchy surface which contains amylopectin.

Cornmeal

Research has shown that cornmeal is able to dehydrate a vapor phase ethanol-water mixture because of its starch and fiber components (Hong, Voloch, Ladisch, & Tsao, 1981). In a bench top adsorption experiment using cornmeal as the adsorbent, researchers from Purdue University were able to separate an azeotropic ethanol-water mixture. Not only were they able to show that cornmeal has adsorption capabilities, they were able to achieve 99.6% ethanol by weight (Ladisch, Voloch, Hong, Blenkowski, & Tsao, 1984). This gives hope that starchy organics can be utilized as adsorbents.

Adsorption Systems

Adsorption columns can operate as a fixed bed or as a moving bed. The fixed bed operation is the oldest and most common form of adsorption systems. In this system, the feed fluid passes through a stable packed bed of adsorbent. The bed must be removed periodically to regenerate the adsorbent through desorption. In the moving bed operation, the liquid feed enters from the bottom and flows up the column. Simultaneously, adsorbent enters the adsorption column from the top and exits out the bottom. The exhausted adsorbent is continually removed while adsorbent is continually added. Because the adsorbents used in this project are solid, a packed column design was used.

Azeotropic Ethanol-Water Mixture

Separating water and ethanol mixtures using distillation at standard conditions can only separate to a certain point, called the azeotrope. This occurs because when the azeotrope value is boiled, the vapor has the same proportions of constituents as the liquid mixture, as shown in Figure 3. The value of this point for simple water-ethanol distillation is 95.6 mass % ethanol. In order to get past this separation point, other methods must be employed. Such methods include adsorption, and extractive, reactive, or pressure-swing distillation.

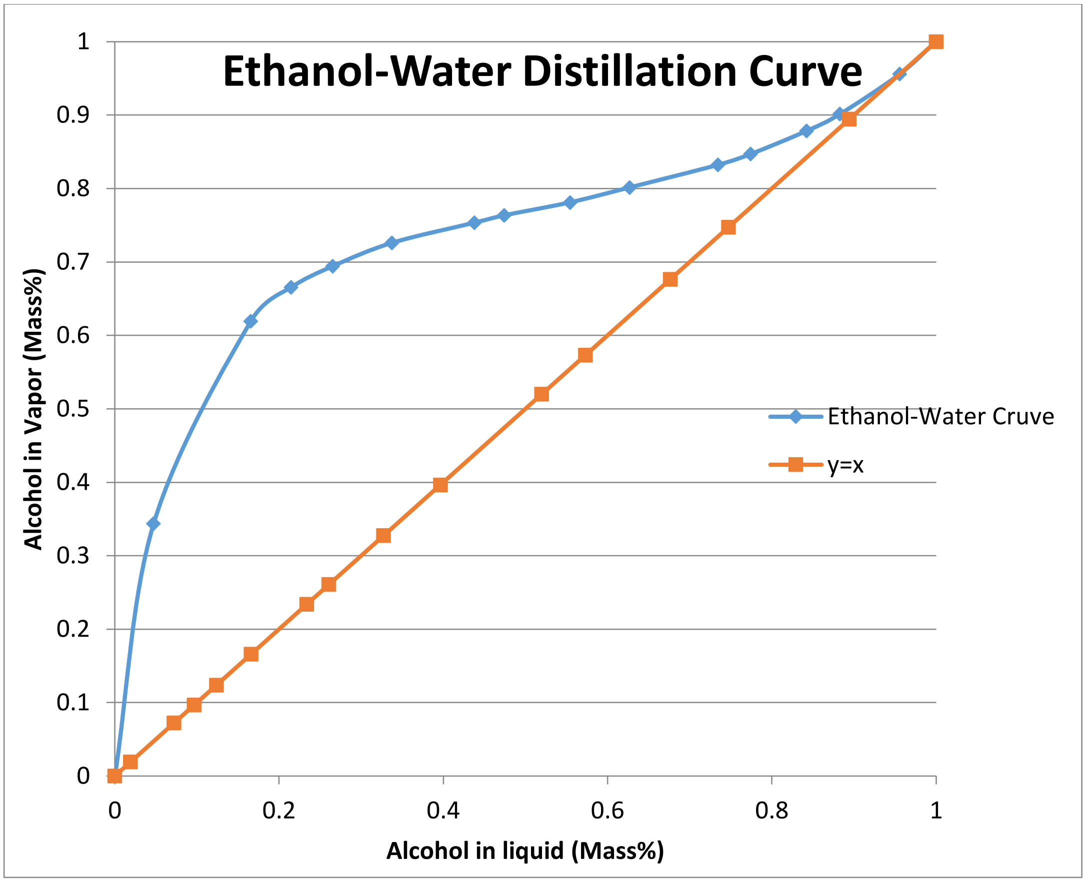


Figure 3 is a graph of ethanol-water distillation, demonstrating azeotrope which occurs at 95.6% mass ethanol.

Because the azeotropic concentration is the furthest point simple distillation can separate ethanol from water, the starting solution for the adsorption process in this project will be a concentration of about 95.6% ethanol.

Methodology

The goal of this project was to obtain the highest possible ethanol recovery from an azeotropic ethanol-water mixture using adsorption. The knowledge obtained was used to design a Unit Operations II experiment and potentially for applications in third world countries. This goal was accomplished by designing and building a small scale adsorption column. In order to achieve this goal, there were three main objectives:

Objective 1: To design and experiment with an adsorption column to remove water from ethanol-water mixtures.

Objective 2: To determine the optimal adsorbent for removing water from azeotropic ethanol-water mixtures. The optimal adsorbent will be defined as the adsorbent yielding a final product with the highest percentage of ethanol.

Objective 3: To utilize the results obtained to design an experiment for the Unit Operations II course in the Chemical Engineering Department at Worcester Polytechnic Institute.

Objective 1

To design and experiment with an adsorption column to remove water from ethanol-water mixtures.

Column Design specifications

In order to achieve the highest possible ethanol recovery from an azeotropic ethanol-water mixture, the team designed a small scale adsorption column. The design specifications of the column were based on time constraints and feasibility. The adsorption column is made of polycarbonate tubing so that it can withstand ethanol. The column is 18 inches in height with a one inch outside diameter and a three quarters inch inside diameter. For safety, the column was encased in another polycarbonate tube. This tube has a two and a quarter inch outside diameter and a two inch inside diameter. The two tubes were held together by a top cap and a bottom cap both made out of white acetyl plastic material. This material again was chosen so that it can withstand ethanol. Each cap contains four screws and an O-ring to seal the column. The column design can be shown in the figure below.

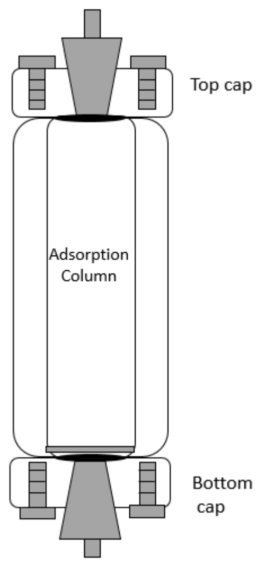


Figure 4 is a diagram of the final column design.

Experiment Design

Along with the adsorption column itself, the experiment consisted of four other parts: a MasterFlex peristaltic pump, Tygon tubing, an adsorbent, and an Anton Paar density meter to measure ethanol concentration. A peristaltic pump was used to control the inlet flow rate of the ethanol-water mixture. A portion of Tygon Extended Life Silicone Tubing peristaltic tubing was used for the pump itself, and had an inside diameter of three-eighth inches. This tubing was connected to a quarter inch inside diameter Tygon tubing on both sides of the pump. This tubing was used for the ethanol-water mixture feed as well as the column feed and the effluent exiting the column. The figure below depicts the experimental set up.

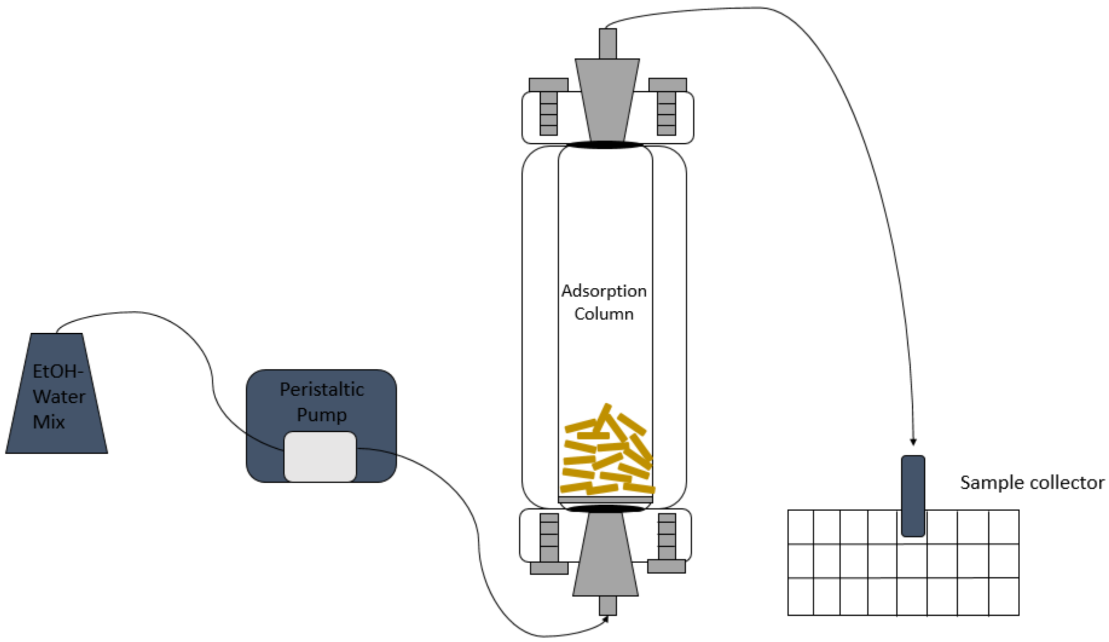


Figure 5 shows the experimental set up.

Three different adsorbents, Zeolite 3A, Zeolite 4A, and sticky rice, were used to pack the column. Before the adsorbents could be used in the column they were washed and desorbed. The adsorbents were washed with pure ethanol multiple times in order to get rid of any excess residue. For the desorption process, they were then placed in an oven at a certain temperature corresponding to the adsorbent. The zeolites were placed in the oven at a temperature of around 200°C for at least eight hours. The organic adsorbents were dried at a lower temperature of 90°C for four hours so that they would not burn. These temperatures were chosen because they are well above boiling points for water and ethanol and was low enough for the zeolites to not be damaged when heated.

Method for Measuring Ethanol Concentration

A gas chromatograph (GC), an ultraviolet-visible spectrometer, xylene, and a density meter can all be used to measure ethanol concentrations. Gas chromatography is a common way to measure alcohol concentrations but it cannot register high percentages of alcohol. This would mean the samples coming out of the adsorption column would have to be diluted before putting it through the GC, leading to more potential error (Murphy, n.d.). An ultraviolet-visible spectrophotometer, commonly known as a UV-Vis, is an instrument used to measure intensity of light. A light is passed through a sample and at certain wavelengths, the alcohol percentage of each compound in the liquid can be determined (UV-Visible Spectroscopy, Michigan State University). In order to use this, a UV-Vis would have to be accessible, and the exact wavelength would have to be known for the ethanol-water mixture. Another method that can be used to measure alcohol concentrations is by adding the ethanol-water mixture, drop by drop, to five milliliters of xylene. Recording the number of drops that causes turbidity of xylene and then the number of drops that makes the liquid clear again can give an approximation of percentage of alcohol in water. However, the test is unable to detect water in 98% and 99% alcohol because these high percentage alcohols will not become turbid when xylene is added.

The previously described methods were ruled out due to their limitations for this type of experiment. The method chosen was a density meter test. When a sample is taken from the adsorption column, density and temperature measurements are recorded and compared to an alcohol table to determine the percentage of ethanol in the sample. In order to determine the accuracy of this method, preliminary testing was conducted.

Preliminary Testing

An experiment was designed to determine if the Anton Paar DMA 35N density meter was accurate in determining the density of ethanol-water mixtures at high ethanol concentrations. In this experiment, several vials were first prepared with high-concentration ethanol-water mixtures in one-percent increments, ranging from 90% to 100% mass ethanol. Samples were made in 10 mL vials, and were measured by mass. For example, approximately one gram of water and nine grams of ethanol were measured and put in the vial to make the 90% ethanol mixture. The different concentrations were then measured using the density meter.

Once the samples were formulated at the specified concentrations, the density meter was flushed with tap water three times to remove contamination from previous use. The instrument was rinsed three times with the 90% ethanol sample. Next, the mixture was taken into the density meter and the density and temperature were recorded. The sample was expelled and this process was repeated twice more. This same procedure was repeated exactly for the 91% to 100% ethanol mixtures.

To analyze the data, the known density of each mixture was determined using the table below according to the concentration and temperature.

wt %	Temperature (degC)			
Ethanol	20	25	30	35
90	0.81797	0.81362	0.80922	0.80478
91	0.81529	0.81094	0.80655	0.80211
92	0.81257	0.80823	0.80384	0.79941
93	0.80983	0.80549	0.80111	0.79669
94	0.80705	0.80272	0.79835	0.79393
95	0.80424	0.79991	0.79555	0.79114
96	0.80138	0.79706	0.79271	0.78831
97	0.79846	0.79415	0.78991	0.78542
98	0.79547	0.79117	0.78684	0.78247
99	0.79543	0.78814	0.78382	0.77946
100	0.78934	0.78506	0.78075	0.77641

Figure 6 is an example of an alcohol table used to determine ethanol concentrations (Green & Perry, 1997).

Intermediate values were obtained through interpolation, using the formula below.

$$\rho = \rho_0 + (\rho_1 - \rho_0)\left[\frac{T - T_0}{T_1 - T_0}\right] \tag{20}$$

Once these three numbers were obtained, they were averaged and compared to the known density.

Preliminary Testing

The experimental and known densities were compared on a bar graph. The data was also plotted to show if the density meter could differentiate between high percentages of ethanol. The plot below shows the results. Most of the densities match up with exception to the 96% and 99% samples. A trend is still visible with a declining density as the percentage of ethanol increases.

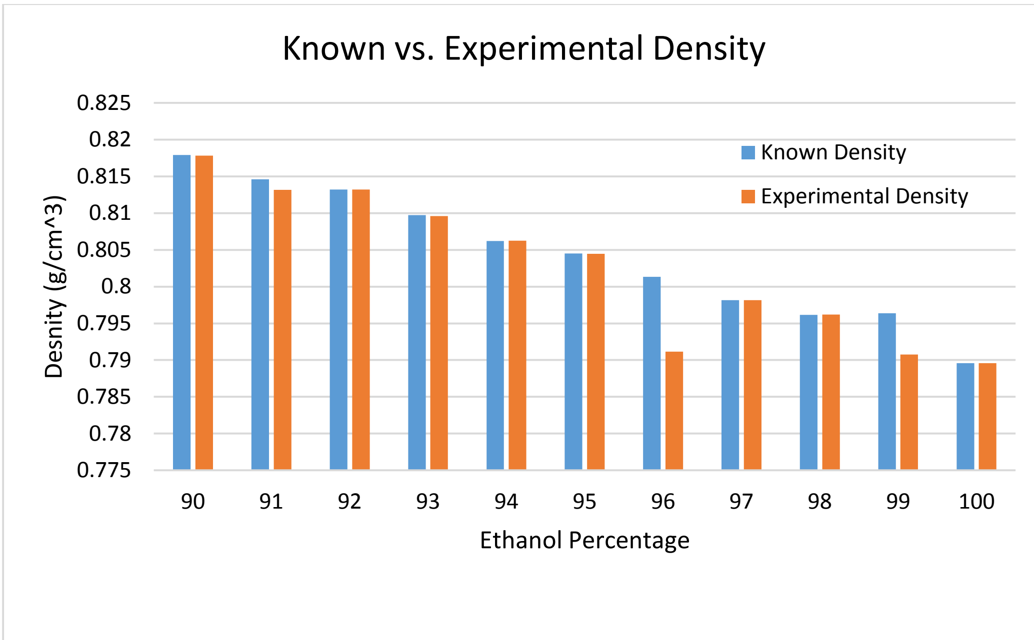


Figure 7 is a graph depicting the density meter testing results.

Objective 2

To determine the optimal adsorbent for removing water from azeotropic ethanol-water mixtures. The optimal adsorbent will be defined as the adsorbent yielding a final product with the highest percentage of ethanol.

To determine to the optimal adsorbent for removing water from azeotropic ethanol-water mixtures, many adsorbents were considered. The adsorbents considered were activated carbon, alumina, silica gel, various types of zeolites, and organic materials such as rice and cornmeal. Based on background research, it was decided to experiment with zeolites because they combine the desired characteristics of alumina and silicates. Further research revealed that for ethanol-water mixtures, Zeolite 3A and Zeolite 4A have desirable geometries. The third world application of this project fueled the decision to include an organic material as a possible adsorbent. Sticky rice was chosen because its surface properties were suspected to preferentially adsorb water over ethanol.

In order to determine which of these adsorbents was best, various operating conditions were tested. For each adsorbent, both the mass of adsorbent and the flow rate were varied. The mass of adsorbent was determined based on the column dimensions. Twenty grams was selected because it filled about a quarter of the column. Similarly, 40 and 60 grams filled half and three quarters of the column, respectively. After preliminary testing, the flow rates of five and ten milliliters per minute were determined to be the most feasible considering the necessary column pressure. Additionally, the experiments were two hours or less using these flow rates, which coincided well with the allotted laboratory time for the Unit Operations class. In total, 18 experiments were completed, six for each adsorbent: three different masses at two different flow rates.

Objective 3

To utilize the results obtained to design an experiment for the Unit Operations II course in the Chemical Engineering Department at Worcester Polytechnic Institute.

The Unit Operations of Chemical Engineering I and Unit Operations of Chemical Engineering II are senior-level courses that enable students to apply fundamental theories to chemical engineering operations in the laboratory. The courses are a combination of laboratory projects and lectures in fluid-flow through media such as pressure drop in packed towers (UO I) and heat and mass transfer such as distillation and rotary drying of solids (UO II). Students are expected to plan and execute the experiments and analyze and report results through written and oral reports.

The ethanol-water adsorption experiment will be integrated into the Unit Operations of Chemical Engineering II course. The team's adsorption experiment is designed to fit the time frame. Two 4-hour lab sessions is allotted for each experiment. The Unit Operations adsorption experiment consists of a pump pumping 95.6% ethanol-water mixture into a column filled with adsorbent material that would adsorb the water from the mixture to ideally yield pure ethanol. Students will choose two of the three variables to study for their experiment: type of adsorbent (3A zeolite, 4A zeolite, and/or sticky rice), flow rates (5 mL/min or 10 mL /min), and amount of zeolite (20 g, 40 g, and/or 60 g). The experiment description, laboratory procedure, and pre-lab module can be seen in the *Deliverables* section.

Results and Discussion

Upon completion of the eighteen experiments according to the procedure in Objective 2, the data was interpolated using the temperature reading on the density meter. The raw data and interpolated results can be found in Appendix's A and B. All of the following graphs are all plots of the percentage of ethanol versus time. The starting concentration for all of the experiments is 95.6% ethanol, or azeotropic ethanol. The duration of the experiments depended on the amount of time it took for the effluent to approach the starting concentration. At this point, it was assumed that all the adsorbent in the column was saturated, therefore it could no longer take in water and the experiment was complete.

The first graph, Figure 8, illustrates the results for Zeolite 3A at the slower flow rate of five milliliters per minute. As one can see, the sixty grams of Zeolite 3A outperformed the forty grams, which outperformed the twenty grams. By outperformed it is meant that a higher concentration of ethanol was obtained and sustained for the period of time studied. Figure 9 shows the plot for Zeolite 4A at five milliliters per minute. It follows the same trend as the Zeolite 3A at this flow rate, where sixty grams adsorbs more water than forty grams, which adsorbs more water than twenty grams. Lastly, Figure 10 shows the results for sticky rice at the same flow rate. This graph is not consistent with the performance of the zeolites as twenty grams is slightly higher than forty grams.

Zeolite 3A and 4A at this flow rate have a similar trend: more adsorbent results in greater adsorption of water from the ethanol-water mixture. Having more adsorbent in the column means that there is more surface area for the water to adhere to. Since the flow rate is low, there is ample time for this process to occur. Another trend exhibited by this data is the spike in ethanol percentage early in the experiment then a gradual decrease back to starting ethanol concentration. As the cavities' fill in the beginning of the experiment, a substantial amount of water is removed from the solution so the ethanol percentage jumps up. Then, as fewer and fewer cavities are available for water to enter, some must leave in the effluent stream. At the end of the experiments, the zeolites become saturated with water and no more adsorption can occur. This can be seen in the data as the graphs become nearly horizontal at the end of the time frame studied.

The sticky rice did not behave like the zeolites; in fact, it did not significantly affect the concentration of the solution as there was less than a one percent change in ethanol concentration throughout the duration of the test. It was expected that the starchy surface properties of the sticky rice would allow it to be used as an adsorbent; however, the data does not confirm this hypothesis. It cannot be concluded that the sticky rice preferentially binds water over ethanol, although the concentration of ethanol increased in some of the experiments. Though this experiment does not show sticky rice as a formidable adsorbent, this team believes it may be possible to utilize sticky rice but vary the conditions of the experiment. By perhaps altering the temperature, pressure, or flow rate maybe the sticky rice will behave as hypothesized. Further research should explore sticky rice as a potential adsorbent or perhaps another organic material such as cornmeal.

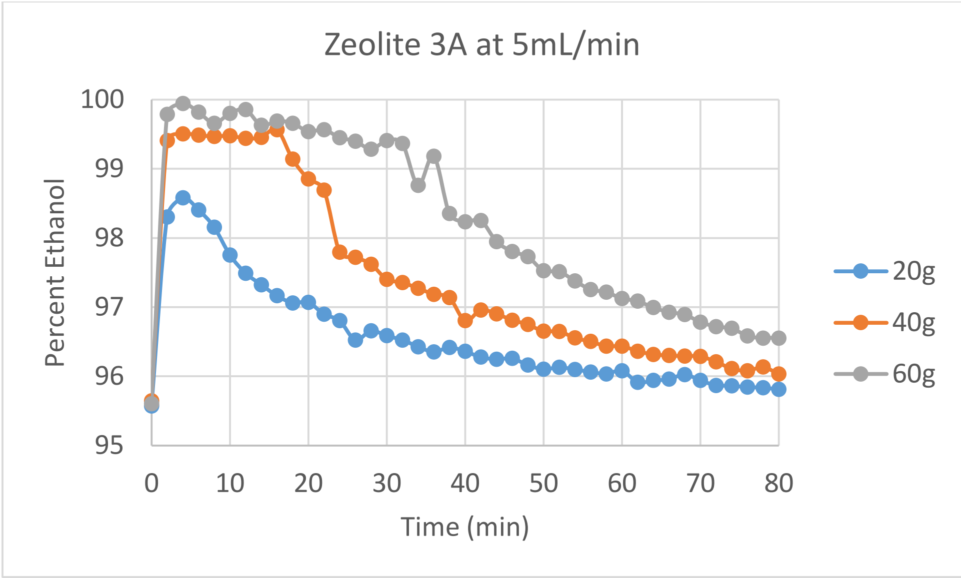


Figure 8 shows the results of the Zeolite 3A experiments at five milliliters per minute. The independent variable among the three experiments was the amount of adsorbent, which ranged from twenty, forty, and sixty grams.

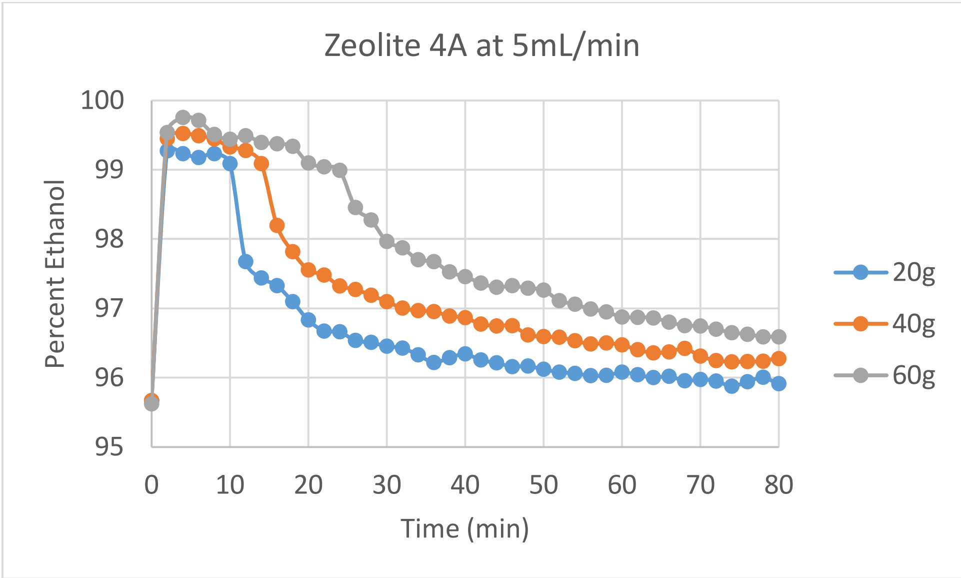


Figure 9 is a plot of the results of the Zeolite 4A experiment at five milliliters per minute. The amount of adsorbent was tested at twenty, forty, and sixty grams.

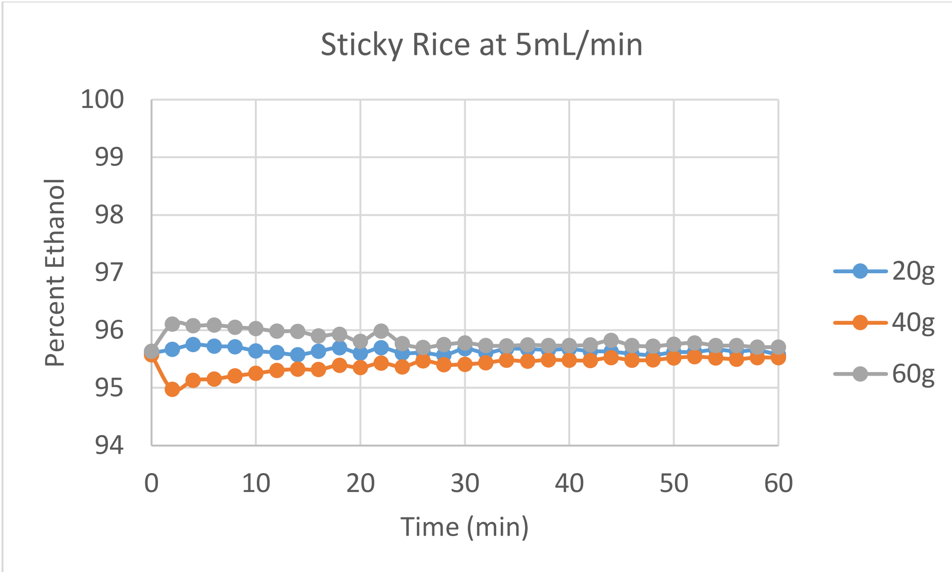


Figure 10 shows the results of the sticky rice experiments at five milliliters per minute. The amount of adsorbent was altered from twenty to forty to sixty grams.

The following three plots show the data obtained for the three adsorbents at the higher flow rate of ten milliliters per minute. Figure 11 shows the results for Zeolite 3A, Figure 12 for Zeolite 4A, and Figure 13 for sticky rice. The Zeolite 3A and 4A graphs at this flow rate have both similarities and differences to the corresponding plots at the slower flow rate. One similarity is that the sixty grams adsorbs water better than the smaller amounts. Another is that the sixty grams is able to reach an ethanol percentage greater than ninety nine percent. The major contrast between the two flowrates occur at the smaller amounts of adsorbent. After approximately twenty to thirty minutes, the forty and twenty gram plots intersect and overlap for most of the remaining time. Since this trend is seen on both the Zeolite 3A and 4A graphs, it is believed that the higher flow rate causes this. Perhaps, the speed of ten milliliters per minute does not allow enough time for the water to find and enter the cavities in the zeolite. It is also possible that the higher flow rate, increases the pressure to a point where the binding of the water to the zeolites is affected. Either way, it can be concluded that increasing the flow rate from five to ten milliliters per minute is not advantageous for obtaining a higher concentration of ethanol in the effluent stream.

As for the sticky rice, the graph at ten milliliters per minute is fairly similar to the graph at five milliliters per minute. This agrees with the previous assertions that sticky rice at these conditions is not a viable adsorbent.

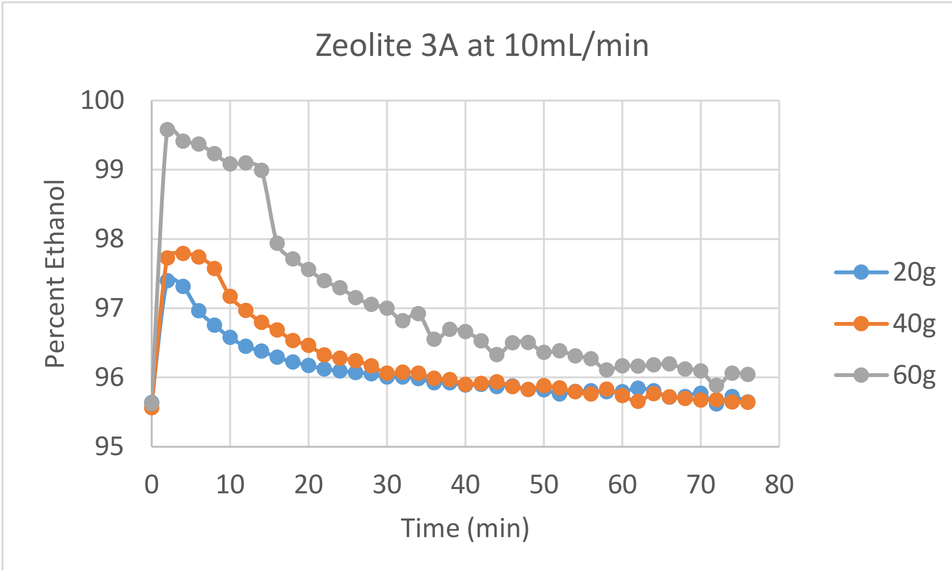


Figure 11 illustrates the results of the Zeolite 3A test at ten milliliters per minute. The independent variable, the mass of adsorbent, was varied from twenty to forty to sixty grams.

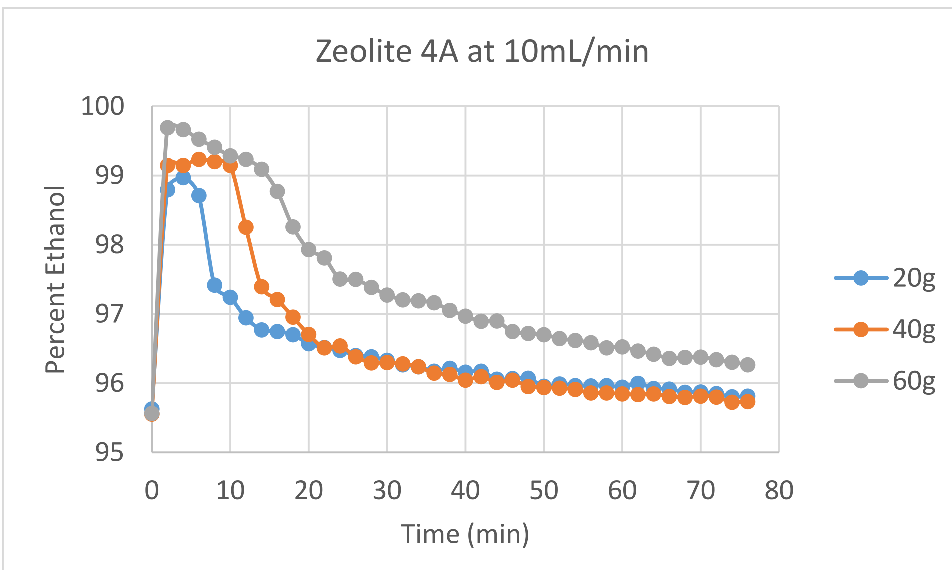


Figure 12 is the graph of the Zeolite 4A experiment at ten milliliters per minute. Again, the mass of adsorbent was changed from twenty to forty to sixty grams.

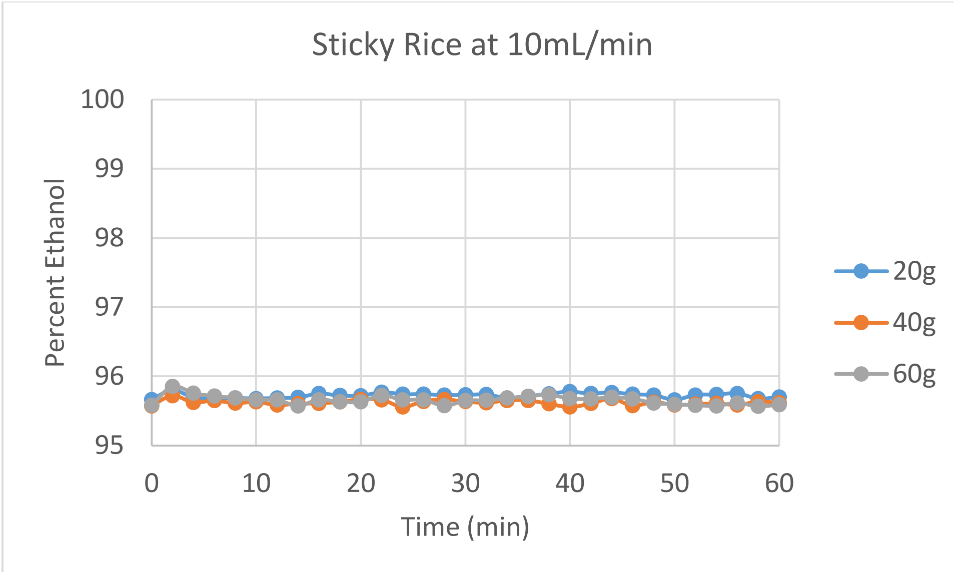


Figure 13 shows the results of the sticky rice experiment at ten milliliters per minute. The changing amount of adsorbent remained the same as in previous experiments.

To determine the optimal adsorbent, Figure 14 was created. It is a plot of the highest percentage of ethanol that each adsorbent was able to achieve. It is reasonable that this occurred at five milliliters per minute and sixty grams of adsorbent for both Zeolite 3A and 4A. As the graph displays, the Zeolite 3A was able to achieve the highest percent ethanol, 99.9%, and maintain a higher percentage throughout most of the duration of the experiment. Zeolite 3A has a smaller pore size, about 3 Angstroms, than Zeolite 4A, about 4 angstroms. Since ethanol is about 3.8 angstroms, it makes sense that Zeolite 3A would adsorb less ethanol than Zeolite 4A and thus achieve a higher percentage of ethanol in the effluent. Therefore, it was concluded that Zeolite 3A is the optimal adsorbent.

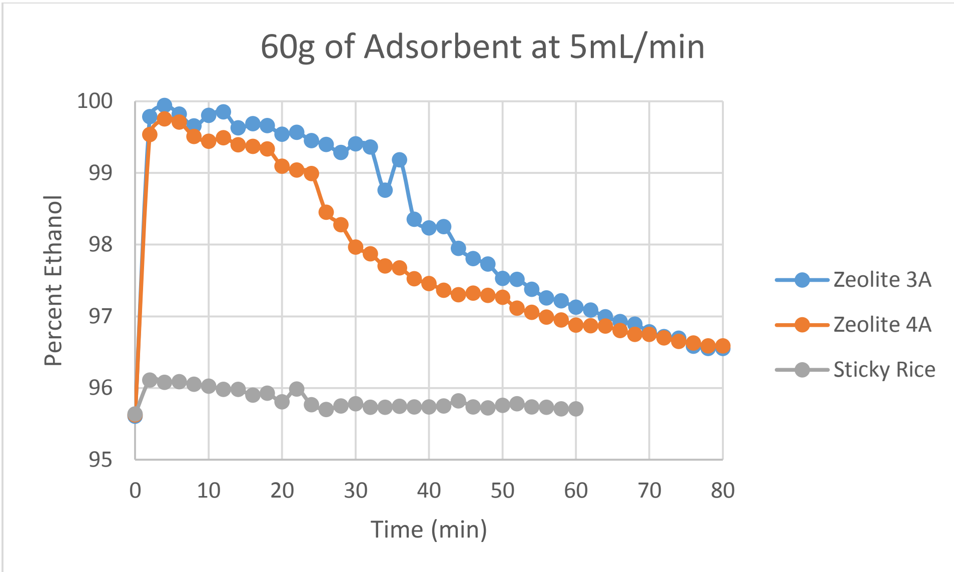


Figure 14 shows the best results for each adsorbent, which occurs at 60g of adsorbent at 5 mL/min.

Error

There were several potential sources of error in the running of these experiments that reduce the reproducibility of the runs. These include tubing, air bubbles, packing geometry, sealing, timing, starting solution, and evaporation.

Air Bubbles

Throughout various experiments, air bubbles would occasionally form, delaying the filling of the column. These air bubbles could slow down the flow rate, which would prevent accurate readings to be made at each time interval. Additionally, air bubbles could have built up the pressure in the tubing leading to the column, and then when pushed through the adsorbent column could release bubbles that would disrupt the steady flow rate. This may have affected the density data at each time interval as the solutions became mixed.

Packing Geometry

Due to the shape of the adsorbents used, the packing geometry of the adsorbent pellets was never identical for any two experiments. The variation in packing may have affected pressure build-up of the fluid going into the column, the height of the packing in the column, and the surface interaction the inlet liquid had with the adsorbent. A less dense geometry would allow the liquid to run through the column quicker, however, it would reduce the residence time on the adsorbent, which could decrease the adsorption of water molecules. The way the pellets were packed could not be controlled nor quantified, which reduces reproducibility in the experiment.

Sealing

Sections of tubing that were attached the absorption column had the potential for leaking if not properly sealed, which could affect the flow of the liquid into and out of the column, therefore altering the concentrations obtained. In order to eliminate this source of error, tubes that were attached to the column were sealed with Parafilm. However, his sealing with laboratory film was not ideal because often when removed after the experiment the film was somewhat saturated and thus a possibly source of error in the experiment.

Timing of Samples

Samples for each run were measured every two minutes. This time was chosen because it was the shortest time interval in which there was enough liquid to do a density meter reading, for both of the flow rates (five and ten milliliters per minute). Since the measurements were taken at specified time intervals rather than volume of sample accumulated, comparing the absorption between two different runs, even at the same flow rate, may not be directly comparable. This is because the flow rates varied depending on the adsorbent, amount of adsorbent, and packing. Additionally, samples may have been taken a few seconds off of the recording time, due to the short time lag between switching out sample collection tubes. Despite these possible sources of error, time was the most consistent way to measure across each of the experiments, and made the different runs comparable.

Different Starting Solutions

The starting solution prepared for each run was about 95.6% $\pm$ 0.05 ethanol by mass. While the solution was prepared to be the same mass percent, since it was prepared separately each time there is room for error as each starting solution may be off by a few hundredths of a percent. This could lead to slightly different outlet concentrations.

Evaporation

Ethanol has a lower boiling point than water, so when an ethanol-water solution is left uncovered, ethanol is more likely to evaporate than water. This was kept in mind when running the experiment, and every effort was made to keep the ethanol-water mixtures covered, however when switching samples and taking density readings, there were windows of time when ethanol could have evaporated, which would have affected the final concentrations at each given time.

Conclusions and Recommendations

A water-ethanol adsorption experiment was successfully designed. The design is an 18-inch tall column with a diameter of ¾ inch inside diameter and one inch outside diameter, with ¼ inch tubing for the inlet and outlet stream. Using this column and the various adsorbents at a specified flow rate, water was successfully removed from ethanol. The highest concentration of ethanol produced was 99.94%, which was produced using 60 grams zeolite 3A at flow rate of five milliliters per minute.

The best adsorbent was determined to be zeolite 3A. Zeolite 3A managed to remove the most water from the ethanol, and sustain a high concentration of ethanol in the outlet stream for longer than Zeolite 4A. It was also determined that a slower flow rate yields higher adsorption, and more adsorbent also leads to more adsorption. For further experimentations, the team recommends trying lower flow rates to increase adsorption, however the flow rates must be high enough to overcome the pressure build up in the column and overcome the force of gravity. Zeolite 4A also resulted in a high ethanol concentration, however it did not sustain as long as the 3A outlet did. Additionally, using the rice as an adsorbent resulted in a slightly higher ethanol concentration in the outlet; however further testing needs to be done to determine if it can be used to selectively adsorb water. From the testing, it has also been recommended to try different starch-based organics that may selectively adsorb water more successfully. Some suggested organics include cornmeal, corn cob, sweet potato, and other starches.

It was determined that this particular adsorption experiment is well suited for the Unit Operations II, as the column takes a maximum of two hours to reach breakthrough, so throughout two four-hour unit operations periods, at least three different experiments can be run to test at least two experimental variables.

Deliverables

Unit Operations II Experiment

Worcester Polytechnic Institute

Department of Chemical Engineering

ChE 4402 Water Adsorption in a Packed Column B term

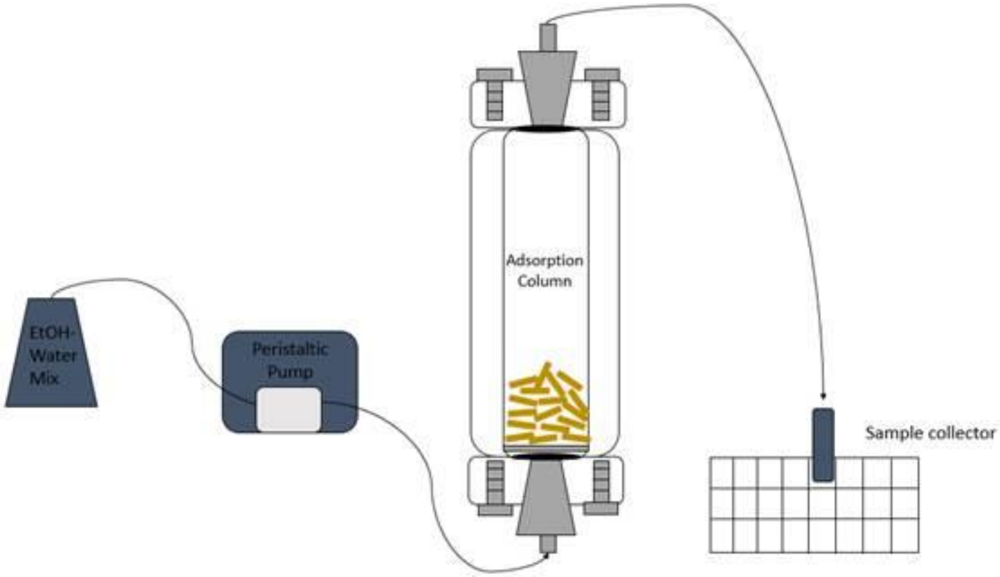
Introduction and Objectives

Developing a sustainable and long-term solution to meet the growing energy demand while securing energy supplies is a pressing global issue. Clean, efficient, and reliable energy systems are important in meeting the long-term needs for economic growth and development. With the exhaustion of petroleum deposits and the growing concern of global climate change, alternative fuels have gained popularity. Ethanol, specifically, is a renewable fuel made from corn and other plant materials known as biomass. Its use is widespread, and almost all gasoline in the United States contains 10% ethanol. Ethanol is renewable and domestically produced; consequently reducing imported oil and greenhouse gas emissions.

Anhydrous ethanol production has become a prevalent effort in the production of biofuels. The process of anhydrous alcohol production consists of fermentation, distillation, and dehydration. An important challenge in this process is the water removal process, which largely contributes to the production cost. Standard distillation removes water to a certain point but an extra process is required before blending pure ethanol with gasoline due to the ethanol-water azeotrope. By contrast, adsorption decreases the energy consumption incurred by distillation. Liquid adsorption is achieved in a column packed with packing material, known as adsorbents, that allows the adhesion of liquid molecules to its surface.

In this experiment, you will examine the effect of adsorption on water-ethanol separation with the goal of obtaining a pure ethanol yield. Specifically, this experiment will help you study the mass transfer of the adsorbents' interface by varying the type and amount of adsorbents as well as the flow rate.

Apparatus



Materials:

1. Column – The column is an 18-inch tall polycarbonate column with a 1" OD and ¾" ID, encased in another polycarbonate tube with 2-1/4" OD and 2" ID.
2. Liquid Supply – The supply to the column is an azeotropic (~95.6%) ethanol-water solution being pumped by a peristaltic pump and enters the bottom of the column. Make sure you prepare enough solution to carry out each run.
3. Peristaltic Pump
    a. Settings:
4. Tubing
    a. Tygon tubing: ¼" ID
    b. Peristaltic tubing: 3/8" ID
5. Density Meter
    a. Model: Anton Paar DMA 35N
6. Adsorbents:
    a. Zeolite 3A
    b. Zeolite 4A
    c. Sticky rice
7. Other lab equipment:
    - 1 L flask
    - 250 mL flask
    - 100 mL beaker
    - 50 mL test tubes
    - Funnel
    - Crucibles
    - Scale
    - Timer

Procedure

Experiment Preparation:

You are required to understand the set up and operation of the adsorption column before you complete any experimental work. Choose two of the three types of adsorbents. You have three variables to experiment with: flow rates (5 or 10 mL/min), type of adsorbent (3A zeolite, 4A zeolite, and/or sticky rice), and amount of zeolite (20 g, 40 g, and/or 60 g). Choose two variables to study in your experiment. You are required to run a total of four experiments.

Experimental Procedure:

1. Assemble the column by screwing in the bottom piece as well as the outer jacket. Secure the column on a stand so that it is fully upright.
2. Weigh out the desired amount of rinsed or desorbed adsorbent and insert into the inner tube of the column using a funnel.
3. Screw in the top of the column and attach Tygon tubing to both ends.
4. Insert the peristaltic tubing into the pump.
5. Prepare a flask with 95.6% ethanol- 4.4% water solution. (Amount depends on flowrate and number of desired samples.)
6. Place the tubing leaving the pump into the flask containing starting solution. Use laboratory film to secure the tube in place and prevent ethanol evaporation.
7. Take the tube exiting the top of the column and place in a 50 mL test tube.
8. Set the pump to the proper tube diameter and desired flow rate.
9. Start the pump. Prime the tubing connected to the bottom of the column so that the solution reaches just below the bottom opening of the column. Allow time for the column to fill. The column is approximately 100 mL, so the time to fill can be determined using the flow rate. For example, if the flow rate is 10mL/min, it should take about 10 minutes to reach the top of the column.
10. Once the column is full, start a timer as soon as the first drop of solution reaches the test tube.
11. After 2 minutes, switch the tube leaving the column to another test tube.
12. Put the cover on the sample and if necessary put in a warm water bath to adjust the temperature.
13. Take the density of the sample using the density meter in triplicate.
14. Repeat steps 11-13 until the density of the exiting solution is equal to the density of the starting solution. Once this point is reached, the saturation point of the adsorbent has been reached and it can no longer adsorb any water. The experiment is over.
15. Stop the pump.
16. Remove the tubing at the bottom of the column and place a flask under the column for it to empty into.
17. Unscrew and take off the top of the column and remove the adsorbent.
18. Remove all tubing, taking care to not spill any solution that may be left inside the tubing.
19. Clean all column parts and allow to dry.

Desorbing Procedure:

1. Turn on oven and set to desired temperature. (90°C for rice and 200°C for zeolite)
2. Take the “used” adsorbent and place into crucible(s).
3. Carefully place crucible(s) in the oven.
4. Allow time for complete desorption. (about 4 hours for rice and at least 8 hours for zeolite)

Rinsing Procedure: For new zeolite or rice, prior to first use

1. Take desired amount of adsorbent and use a funnel to insert into inner tube of column.
2. Set up column similar to explanation in *Experimental Procedure.*
3. Run pure ethanol through the column instead of azeotropic ethanol-water solution.
4. After the adsorbent appears to be fully saturated, turn off the pump and follow Steps 6-9 of the Experimental Procedure.
5. Place adsorbent in crucible(s).
6. Put crucible(s) in oven at temperatures and amounts of time specified in *Desorbing Procedure.*

Theory

Sorption is defined as the surface interaction between two phases. There are two types of sorption: adsorption and absorption. Adsorption is when molecules or atoms being sorbed are only concentrated at the interface, while absorption is when molecules or atoms being sorbed are distributed in the bulk of interacting phases. Adsorption can only occur when there is a solid phase present. The term adsorbent refers to the surface while adsorbate refers to the adsorbed molecule. In this experiment, you will study the adsorption forces of three types of adsorbents: Zeolite 3A, Zeolite 4A, and sticky rice. Zeolites are a combination of alumina and silicates. They are a type of molecular sieve that has a tetrahedral network, formed by four oxygen atoms surrounding a silicon or aluminum cation. They preferentially adsorb molecules based mainly on size and configuration. Sticky rice, a starch-based adsorbent, contains amylopectin, which physically traps water molecules in the matrix of chain branches.

Desorption is the process in which the adsorbate is removed from the adsorbent.

Once the pores of the adsorbent are full, the saturation point has been reached, and no more adsorbate can be adsorbed. Therefore, the adsorbent must now be desorbed in order to be reused. In this experiment, you will desorb your adsorbents by placing them in the oven after they have been used.

Calculations

Use the interpolation equation below to estimate your density readings based on the given temperature. Make sure you take the density reading of each sample three times to get accurate data.

Linear interpolation:

$$y = y_1 + (x - x_1)\frac{y_2 - y_1}{x_2 - x_1}$$

Results and Discussion

A discussion of the errors in the results due to experimental uncertainty and their effect on the results through propagation of error should be included. How meaningful are your results when errors are considered. It is not sufficient to simply state your results in numerical form. They should be interpreted in terms of physical phenomena occurring within the process. Do the trends in the data make sense? What conditions yielded the highest percentage of ethanol? How does varying the adsorbent, flow rate, and/or amount of adsorbents affect your data? Are there any mass transfer limitations occurring inside the column?

Report Requirements

The pre-lab report should contain an introduction stating the objective of the experiments, including the rationale for choosing your two variables, some background on water adsorption and the adsorbents of your choice, a description of the equipment and purpose of each item, including a detailed schematic drawing, and a stepwise procedure, that would allow someone who is unfamiliar with the equipment to perform the experiment.

These results are to be presented informally to the instructor before the second week's experiments. Error analysis is not required at this stage. The final report should contain the usual sections as specified in the course descriptions. In addition, error bars are to be included on all plots.

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Appendix

Appendix A: Double Interpolation of Alcohol Tables

	A	B	C	D	E	F	G	H
1		Temp				New Temp	New Temp	New Temp
2	Wt%	20	25	30	35	21.7	21.5	21.3
3	90	0.81797	0.81362	0.80922	0.80478	0.816491	0.816665	0.816839
4	91	0.81529	0.81094	0.80655	0.80211	0.813811	0.813985	0.814159
5	92	0.81257	0.80823	0.80384	0.79941	0.8110944	0.811268	0.8114416
6	93	0.80983	0.80549	0.80111	0.79669	0.8083544	0.808528	0.8087016
7	94	0.80705	0.80272	0.79835	0.79393	0.8055778	0.805751	0.8059242
8	95	0.80424	0.79991	0.79555	0.79114	0.8027678	0.802941	0.8031142
9	96	0.80138	0.79706	0.79271	0.78831	0.7999112	0.800084	0.8002568
10	97	0.79846	0.79415	0.78991	0.78542	0.7969946	0.797167	0.7973394
11	98	0.79547	0.79117	0.78684	0.78247	0.794008	0.79418	0.794352
12	99	0.79543	0.78814	0.78382	0.77946	0.7929514	0.793243	0.7935346
13	100	0.78934	0.78075	0.78075	0.77641	0.7864194	0.786763	0.7871066
14					Density	0.8014	0.8009	0.801
15					Actual Percen	95.47882098	95.71438572	95.73990341
16								
17						AVG:	95.64437003	

1. Cells B3-E13 hold the density values for the corresponding weight percent at a given temperature.
2. Cells F2, G2, and H2 are the temperature at which each of the three trials were read.
3. Rows 3-13 under columns F,G, and H hold the density values for each weight percent at the trial temperature. These values were found by interpolating based on the temperature in row 2 and the given data.
4. Cells F13, G13, and H13 are the densities at which each of the three trials were read.
5. Cells F14, G14, and H14 are the calculated weight percents. These were calculated by taking the densities in row 14 and interpolating them with their density data (highlighted in red) and weight percent values, in column A.

Appendix B: Data Tables

Zeolite 4A data Tables

	10 mL/min								
	Time	% Ethanol	Ethanol Conc	Density Meter 1	Temp 1	Density Meter 2	Temp 2	Density Meter 3	Temp 3
60 grams	0	95.56459915	0.955645992	0.8007	22	0.8007	22	0.8012	22.1
	2	99.69248267	0.996924827	0.789	21.2	0.7889	21.4	0.7887	21.7
	4	99.66403127	0.996640313	0.7885	21.8	0.788	22	0.7882	22
	6	99.52376932	0.995237693	0.7888	22.1	0.7887	22.2	0.7887	22.3
	8	99.40818541	0.994081854	0.7893	22.4	0.7892	22.5	0.7886	22.6
	10	99.28636829	0.992863683	0.7897	22.5	0.7896	22.7	0.7895	22.8
	12	99.2344325	0.992344325	0.7898	22.8	0.7898	22.8	0.7898	22.7
	14	99.09263292	0.990926329	0.7907	22.8	0.7907	22.8	0.7906	22.9
	16	98.7744067	0.987744067	0.792	22.7	0.7916	22.7	0.792	22.7
	18	98.25764875	0.982576487	0.7937	21.8	0.7936	21.8	0.7935	21.9
	20	97.93242454	0.979324245	0.794	21.7	0.7943	21.8	0.794	22
	22	97.80957353	0.978095735	0.7946	21.8	0.7944	21.9	0.7943	21.9
	24	97.50508995	0.975050899	0.7955	21.7	0.7954	21.8	0.7953	21.9
	26	97.50043549	0.975004355	0.7957	21.6	0.7953	21.7	0.7955	21.8
	28	97.38572906	0.973857291	0.7958	21.6	0.7962	21.6	0.7957	21.7
	30	97.27567241	0.972756724	0.7964	21.6	0.7963	21.6	0.7959	21.8
	32	97.20561677	0.972056168	0.7966	21.5	0.7965	21.6	0.7963	21.7
	36	97.16252183	0.971625218	0.7964	21.8	0.7969	21.4	0.7964	21.7
	38	97.05319699	0.97053197	0.7974	21	0.7973	21.2	0.7971	21.4
	40	96.97134813	0.969713481	0.7977	21	0.7976	21.1	0.7974	21.3
	42	96.89610099	0.96896101	0.7979	21.1	0.7977	21.2	0.7975	21.4
	44	96.89925154	0.968992515	0.798	21.2	0.7975	21.3	0.7974	21.4
	46	96.74600057	0.967460006	0.7983	21	0.7982	21.2	0.798	21.4
	48	96.7195714	0.967195714	0.7979	21.2	0.7983	21.4	0.7981	21.5
	50	96.70186568	0.967018657	0.798	21.1	0.7985	21.2	0.7983	21.4
	52	96.64586769	0.966458677	0.7982	21.4	0.7982	21.5	0.7982	21.6
	54	96.6178611	0.966178611	0.7984	21.4	0.7981	21.7	0.798	21.8
	56	96.58514179	0.965851418	0.7983	21.5	0.7983	21.7	0.7981	21.8
	58	96.51437108	0.965143711	0.799	21	0.7989	21.1	0.7988	21.3
	60	96.52735984	0.965273598	0.7989	21	0.7989	21.1	0.7987	21.4
	62	96.46710921	0.964671092	0.7992	20.9	0.7991	21.1	0.7989	21.3
	64	96.41984827	0.964198483	0.7993	20.9	0.7992	21.1	0.7992	21.2
	66	96.36067565	0.963606757	0.7994	21	0.7992	21.3	0.7991	21.5

68	96.37571615	0.963757162	0.7995	20.9	0.7993	21.1	0.7992	21.3
70	96.37776797	0.96377768	0.7998	20.7	0.7993	20.9	0.7994	21.1
72	96.34194106	0.963419411	0.7999	20.6	0.7997	20.9	0.7993	21.1
74	96.30455144	0.963045514	0.7999	20.7	0.7999	20.8	0.7996	20.9
76	96.2666601	0.962666601	0.8	20.7	0.7997	21	0.7996	21.2

40 grams									
	0	95.55546083	0.955554608	0.8017	21	0.8017	21.1	0.8017	21.2
	2	95.55546083	0.955554608	0.792	21.5	0.7915	22.1	0.7913	22.3
	4	99.14625708	0.991462571	0.792	21.2	0.7917	21.6	0.7915	21.7
	6	99.23314483	0.992331448	0.7919	21.5	0.7914	21.8	0.7916	21.8
	8	99.20180775	0.992018078	0.7915	21.9	0.7911	22.3	0.791	22.5
	10	99.14621529	0.991462153	0.7932	22.3	0.7927	22.5	0.793	22.6
	12	98.25231259	0.982523126	0.7956	22.2	0.7949	22.3	0.7955	22.3
	14	97.39283797	0.97392838	0.7961	22.5	0.7957	22.5	0.7955	22.5
	16	97.20957385	0.972095738	0.7966	22.5	0.7961	22.5	0.7966	22.5
	18	96.95542511	0.969554251	0.7979	21.5	0.7969	22.3	0.7967	22.6
	20	96.70614724	0.967061472	0.7982	21.5	0.7975	21.6	0.7982	21.6
	22	96.51030792	0.965103079	0.7987	21.4	0.7985	21.6	0.7985	21.6
	24	96.53786489	0.965378649	0.7987	21.5	0.798	21.7	0.7985	21.7
	26	96.38470249	0.963847025	0.7992	21.2	0.799	21.5	0.7991	21.4
	28	96.2952473	0.962952473	0.7995	21.2	0.7994	21.3	0.7992	21.5
	30	96.30198929	0.963019893	0.7996	21.2	0.7992	21.2	0.7995	21.3
	32	96.28170773	0.962817077	0.8002	20.6	0.7996	20.8	0.7998	21
	34	96.23862749	0.962386275	0.8	21	0.7994	21.1	0.7998	21.2
	36	96.14620198	0.96146202	0.8004	20.8	0.8001	20.8	0.8002	20.9
	38	96.12699913	0.961269991	0.8007	20.5	0.8001	20.7	0.8005	20.8
	40	96.04705134	0.960470513	0.8007	20.5	0.8007	20.7	0.8006	20.8
	42	96.09429121	0.960942912	0.8007	20.6	0.8002	20.7	0.8006	20.8
	44	96.0112373	0.960112373	0.8008	20.6	0.8008	20.6	0.8008	20.7
	46	96.04651212	0.960465121	0.8007	20.8	0.8001	20.9	0.8006	21
	48	95.95532151	0.959553215	0.8013	20.2	0.8011	20.4	0.801	20.7
	50	95.9404989	0.959404989	0.8014	20.2	0.8013	20.4	0.801	20.5
	52	95.93200697	0.95932007	0.8014	20.2	0.8011	20.6	0.8011	20.5
	54	95.91027404	0.95910274	0.8013	20.4	0.8013	20.4	0.8011	20.6
	56	95.85889136	0.958588914	0.8015	20.3	0.8015	20.4	0.8014	20.4
	58	95.85889136	0.958588914	0.8015	20.3	0.8014	20.4	0.8015	20.4
	60	95.84664894	0.958466489	0.8012	20.6	0.8014	20.6	0.8013	20.6
	62	95.83557288	0.958355729	0.8017	20.1	0.8015	20.4	0.8014	20.6
	64	95.84565354	0.958456535	0.8017	20.2	0.8016	20.3	0.8013	20.5
	66	95.80850807	0.958085081	0.8017	20.3	0.8015	20.5	0.8012	20.8

68	95.79585832	0.957958583	0.8019	20	0.8018	20.3	0.8015	20.5
70	95.81601082	0.958160108	0.8019	20	0.8017	20.2	0.8016	20.4
72	95.80277337	0.958027734	0.8019	20	0.8018	20.2	0.8017	20.3
74	95.72749387	0.957274939	0.8019	20.2	0.8019	20.3	0.8019	20.4
76	95.73441432	0.957344143	0.8021	20	0.802	20.2	0.8018	20.4
20 grams								
0	95.63175788	0.956317579	0.8017	21.2	0.8012	21.2	0.8012	21.3
2	98.7962049	0.987962049	0.7953	20.1	0.7947	20.5	0.7945	20.8
4	98.97166589	0.989716659	0.7945	20.5	0.7944	20.6	0.7942	20.9
6	98.7101684	0.987101684	0.7942	21.1	0.7936	21.7	0.7936	21.8
8	97.41705132	0.974170513	0.7968	20.6	0.7963	20.8	0.7963	21.2
10	97.2413407	0.972413407	0.7973	20.8	0.7968	21.2	0.7961	21.5
12	96.94731787	0.969473179	0.7981	20.7	0.7977	20.8	0.7978	21.1
14	96.77199114	0.967719911	0.7983	20.9	0.798	21.3	0.7978	21.6
16	96.74956854	0.967495685	0.7985	20.8	0.7982	21	0.7982	21.3
18	96.70187003	0.9670187	0.7984	21	0.7983	21.3	0.7981	21.4
20	96.57195096	0.96571951	0.7991	20.8	0.7988	20.9	0.7989	21
22	96.51593692	0.965159369	0.7991	20.9	0.7988	21.2	0.7987	21.4
24	96.47760124	0.964776012	0.7993	21	0.7984	21.7	0.7982	22
26	96.40168769	0.964016877	0.7992	21	0.7992	21.2	0.7992	21.3
28	96.38293617	0.963829362	0.7997	20.5	0.7996	20.8	0.7995	21
30	96.33206867	0.963320687	0.7999	20.6	0.7995	20.8	0.7995	21.3
32	96.26560637	0.962656064	0.8003	20.4	0.7999	20.7	0.7998	21
34	96.2412075	0.962412075	0.8004	20.4	0.8001	20.6	0.7998	21
36	96.17631694	0.961763169	0.8007	20.3	0.8003	20.5	0.8003	20.7
38	96.21679938	0.962167994	0.8003	20.4	0.8001	20.6	0.8002	20.9
40	96.15970057	0.961597006	0.8004	20.5	0.8003	20.6	0.8004	20.8
42	96.17631552	0.961763155	0.8005	20.4	0.8004	20.5	0.8004	20.6
44	96.0574581	0.960574581	0.8009	20.3	0.8009	20.4	0.8008	20.5
46	96.06833647	0.960683365	0.8005	20.5	0.8008	20.6	0.8006	20.8
48	96.07300416	0.960730042	0.8006	20.6	0.8006	20.7	0.8004	20.9
50	95.95690862	0.959569086	0.8012	20.3	0.8012	20.4	0.8009	20.7
52	95.98833161	0.959883316	0.8013	20.2	0.8012	20.4	0.8007	20.6
54	95.96855836	0.959685584	0.801	20.2	0.8012	20.5	0.801	20.7
56	95.96381136	0.959638114	0.8012	20.2	0.8012	20.4	0.8011	20.5
58	95.96857015	0.959685702	0.8013	20.3	0.8011	20.4	0.8008	20.7
60	95.94581847	0.959458185	0.8015	20.2	0.8012	20.2	0.8013	20.3
62	95.99925496	0.95999255	0.8008	20.7	0.8007	20.9	0.8004	21
64	95.92725248	0.959272525	0.8013	20.2	0.8013	20.3	0.8013	20.5
66	95.91819028	0.959181903	0.8011	20.5	0.8011	20.6	0.801	20.8
68	95.87155229	0.958715523	0.8013	20.5	0.8013	20.6	0.801	20.8

70	95.87587454	0.958758745	0.8013	20.2	0.8015	20.2	0.8018	20.3
72	95.84939787	0.958493979	0.8015	20.1	0.8018	20.2	0.8017	20.2
74	95.80534307	0.958053431	0.8016	20.4	0.8015	20.4	0.8015	20.6
76	95.81383654	0.958138365	0.8016	20.2	0.8017	20.3	0.8014	20.7

	5 mL/min								
	Time	% Ethanol	Ethanol Conc	Density Meter 1	Temp 1	Density Meter 2	Temp 2	Density Meter 3	Temp 3
60g	0	95.62295992	0.956229599	0.8007	22.1	0.8007	22	0.8007	22
	2	99.53741353	0.995374135	0.7866	23.6	0.7866	23.5	0.7873	22.9
	4	99.75412895	0.99754129	0.7875	21.8	0.7876	22	0.787	22.5
	6	99.71051858	0.997105186	0.7871	22	0.7874	22.4	0.787	22.8
	8	99.51086908	0.995108691	0.7866	23.5	0.7862	23.9	0.7865	23.7
	10	99.44096954	0.994409695	0.7866	24	0.7866	24.1	0.7868	23.5
	12	99.49233432	0.994923343	0.7885	22.5	0.7885	22.5	0.7884	22.5
	14	99.39238058	0.993923806	0.788	23.2	0.7873	23.5	0.7876	23.7
	16	99.37314916	0.993731492	0.7892	22.5	0.7892	22.5	0.7891	22.7
	18	99.33774399	0.99337744	0.7894	22.5	0.7892	22.7	0.789	22.9
	20	99.09676039	0.990967604	0.7913	22.3	0.7912	22.5	0.7909	22.7
	22	99.04104374	0.990410437	0.7916	22.3	0.7921	22.1	0.792	22.3
	24	98.9912377	0.989912377	0.7923	22	0.7924	22.3	0.792	22.4
	26	98.4541342	0.984541342	0.7931	22	0.7929	22.3	0.7929	22.3
	28	98.27663191	0.982766319	0.7935	22.1	0.793	22.2	0.7931	22.3
	30	97.9656439	0.979656439	0.7931	22.7	0.7927	23.4	0.7927	23.5
	32	97.87304376	0.978730438	0.7928	23.5	0.7929	23.7	0.7923	23.9
	34	97.70153873	0.977015387	0.7942	22.5	0.7937	23.1	0.7937	23.1
	36	97.67480375	0.976748037	0.7943	22.4	0.7944	22.6	0.794	22.7
	38	97.5243089	0.975243089	0.7955	21.6	0.7954	21.8	0.7953	21.8
	40	97.45734374	0.974573437	0.7959	21.5	0.7954	21.8	0.7955	21.9
	42	97.36559767	0.973655977	0.7964	21	0.7964	21.3	0.7962	21.3
	44	97.30329553	0.973032955	0.7965	21.2	0.7964	21.3	0.7964	21.4
	46	97.32594423	0.973259442	0.7968	21	0.7967	21	0.7962	21.2
	48	97.29268296	0.97292683	0.7959	21.9	0.7959	22	0.7957	22.2
	50	97.26451315	0.972645131	0.7966	21.5	0.7961	21.7	0.796	21.8
	52	97.11206868	0.971120687	0.7972	21.1	0.797	21.3	0.7969	21.4
	54	97.05782008	0.970578201	0.7973	21.2	0.797	21.3	0.7972	21.4
	56	96.98985746	0.969898575	0.7978	20.8	0.7978	20.8	0.7978	20.8
	58	96.94810218	0.969481022	0.7975	21.3	0.7974	21.4	0.7974	21.4
	60	96.87680417	0.968768042	0.798	20.9	0.7979	21.1	0.7978	21.2

62	96.87051107	0.968705111	0.7982	20.8	0.798	20.9	0.7979	21.1
64	96.86264766	0.968626477	0.7984	20.7	0.7983	20.7	0.7979	20.9
66	96.80197332	0.968019733	0.7983	20.8	0.7983	20.9	0.7981	21.1
68	96.75000022	0.967500002	0.7986	20.7	0.7985	20.8	0.7984	20.9
70	96.74643053	0.967464305	0.7985	20.8	0.7984	21	0.7982	21.1
72	96.69759997	0.966976	0.7987	20.8	0.7986	20.9	0.7984	21
74	96.65034067	0.966503407	0.7989	20.8	0.7987	20.8	0.7986	21
76	96.62592828	0.966259283	0.799	20.7	0.7988	20.8	0.7987	21
78	96.58963887	0.965896389	0.7989	20.8	0.7987	21.1	0.7987	21.2
80	96.58873187	0.965887319	0.7986	21.2	0.7983	21.6	0.7982	21.7
82	96.50811058	0.965081106	0.7991	21	0.7991	21	0.7989	21
84	96.48573428	0.964857343	0.7993	20.7	0.7994	20.7	0.7992	20.9
86	96.42550103	0.96425501	0.7996	20.6	0.7996	20.7	0.7994	20.8
88	96.41203503	0.96412035	0.7995	20.8	0.7994	20.9	0.7993	21
90	96.4276665	0.964276665	0.7989	21.2	0.7992	21.2	0.7991	21.3
92	96.34349963	0.963434996	0.7997	20.8	0.7996	20.9	0.7995	21
94	96.4057855	0.964057855	0.7998	20.7	0.7998	20.8	0.799	20.8
96	96.2822098	0.962822098	0.8001	20.5	0.8001	20.6	0.8	20.6
98	96.351798	0.96351798	0.7993	20.8	0.7999	20.8	0.7997	20.9
100	96.28588587	0.962858859	0.7998	21	0.7993	21.2	0.7996	21.2
102	96.20538571	0.962053857	0.8003	20.6	0.8002	20.6	0.8002	20.7
104	96.24120266	0.962412027	0.8003	20.6	0.7998	20.6	0.8002	20.8
106	96.19396549	0.961939655	0.8004	20.6	0.8002	20.6	0.8002	20.7
108	96.14516974	0.961451697	0.8005	20.5	0.8005	20.5	0.8004	20.7
110	96.13686283	0.961368628	0.8006	20.6	0.8003	20.6	0.8004	20.7
112	96.07820566	0.960782057	0.8007	20.6	0.8006	20.6	0.8006	20.6
114	96.06002899	0.96060029	0.8007	20.6	0.8006	20.7	0.8005	20.8
116	96.05536522	0.960553652	0.8008	20.6	0.8007	20.6	0.8006	20.6
118	96.03252478	0.960325248	0.8008	20.6	0.8008	20.6	0.8007	20.6
120	96.01644399	0.96016444	0.8009	20.5	0.8009	20.5	0.8009	20.5

40g

0	95.67025581	0.956702558	0.8007	21.9	0.8007	21.9	0.8007	21.9
2	99.45057077	0.994505708	0.7903	21.4	0.7902	21.6	0.79	21.8
4	99.52206069	0.995220607	0.7901	21.3	0.79	21.4	0.7898	21.6
6	99.49239493	0.994923949	0.7901	21.4	0.79	21.5	0.7899	21.7
8	99.44385544	0.994438554	0.7901	21.6	0.7901	21.7	0.7898	21.9
10	99.32730779	0.993273078	0.7903	21.9	0.7903	22	0.7903	22.2
12	99.27616012	0.992761601	0.791	21.5	0.7914	21.7	0.7912	21.8
14	99.08963722	0.990896372	0.7925	21.5	0.7924	21.7	0.7922	21.9
16	98.1972757	0.981972757	0.7941	21.4	0.7937	21.8	0.7934	22.1

18	97.81631037	0.978163104	0.7949	21.3	0.7947	21.5	0.7945	21.8
20	97.55468695	0.975546869	0.7956	21.4	0.7954	21.6	0.7951	22
22	97.48091025	0.974809103	0.7954	21.8	0.7954	22	0.7951	22.2
24	97.32307862	0.973230786	0.7959	21.9	0.7957	22	0.7958	22
26	97.27291449	0.972729145	0.7966	21.3	0.7962	21.4	0.7966	21.4
28	97.1910086	0.971910086	0.7963	21.5	0.7965	21.8	0.7963	22
30	97.09637003	0.9709637	0.7968	21.6	0.7962	22.3	0.796	22.5
32	97.00473276	0.970047328	0.7973	21.4	0.797	21.6	0.7969	21.8
34	96.96621758	0.969662176	0.7963	22.5	0.797	21.9	0.7966	22.3
36	96.95385897	0.96953859	0.7972	21.4	0.7971	21.8	0.797	22
38	96.89055803	0.96890558	0.7973	21.4	0.7975	21.6	0.7974	21.8
40	96.86489812	0.968648981	0.7967	22.1	0.7971	22.3	0.7969	22.4
42	96.77314386	0.967731439	0.798	21.4	0.7979	21.5	0.7975	21.7
44	96.74713365	0.967471336	0.7978	21.2	0.7982	21.5	0.7978	21.7
46	96.74913297	0.96749133	0.7981	21	0.798	21.3	0.7982	21.5
48	96.61673913	0.966167391	0.7987	21	0.7983	21.4	0.7982	21.7
50	96.5914113	0.965914113	0.7983	21.5	0.7981	21.8	0.7979	22.1
52	96.58200476	0.965820048	0.7982	21.5	0.7983	21.6	0.7984	21.7
54	96.53426685	0.965342668	0.7985	21.6	0.7982	21.8	0.7981	22
56	96.48494222	0.964849422	0.7984	21.8	0.7982	21.9	0.7982	22.2
58	96.49825122	0.964982512	0.799	21	0.799	21	0.7991	21.1
60	96.47227697	0.96472277	0.7991	20.9	0.7994	20.9	0.799	21.1
62	96.4016956	0.964016956	0.7995	20.9	0.7993	21.2	0.7988	21.4
64	96.35755344	0.963575534	0.7994	21	0.7994	21.2	0.7991	21.4
66	96.37258192	0.963725819	0.7992	20.8	0.7996	21.1	0.7994	21.2
68	96.42077324	0.964207732	0.7998	20.8	0.7997	20.9	0.7994	20.1
70	96.31185236	0.963118524	0.7993	21.1	0.7996	21.2	0.7994	21.3
72	96.24486479	0.962448648	0.7998	21	0.7996	21.3	0.7994	21.4
74	96.22878521	0.962287852	0.7991	21.8	0.7991	21.9	0.7991	21.9
76	96.23031553	0.962303155	0.7996	21	0.7997	21.2	0.7998	21.3
78	96.23862436	0.962386244	0.7996	21	0.7998	21.1	0.7998	21.2
80	96.27596841	0.962759684	0.8002	20.5	0.8001	20.6	0.7999	20.7
82	96.18925726	0.961892573	0.8005	20.6	0.8001	20.1	0.8005	20.9
84	96.1040784	0.961040784	0.7995	21.8	0.7992	22.2	0.799	22.4
86	96.02620831	0.960262083	0.8007	20.8	0.8	21.5	0.8001	21.3
88	96.06415896	0.96064159	0.8005	20.8	0.8005	21	0.7999	21.3
90	96.05686029	0.960568603	0.8002	21.3	0.8002	21.3	0.7997	21.5
92	96.05519458	0.960551946	0.7999	21.2	0.8003	21.3	0.8	21.5
94	96.0478257	0.960478257	0.8003	20.7	0.8007	20.9	0.8003	21.2
96	96.07363706	0.960736371	0.8002	20.8	0.8002	21	0.8005	21.2
98	96.0525253	0.960525253	0.8004	20.7	0.801	20.8	0.8002	20.9

100	95.97163183	0.959716318	0.8007	21	0.8002	21.3	0.8002	21.5
102	95.96652688	0.959665269	0.8004	20.7	0.801	20.9	0.8006	21.2
104	95.92553983	0.959255398	0.8009	20.8	0.8007	21	0.8005	21.3
106	95.93086483	0.959308648	0.801	20.7	0.8007	20.9	0.8007	21.1
108	95.89627612	0.958962761	0.8013	20.6	0.8013	20.7	0.8007	20.7
110	96.01351144	0.960135114	0.8013	20.5	0.8006	20.7	0.8003	20.9
112	95.86189179	0.958618918	0.8008	21.1	0.8008	21.2	0.8007	21.2
114	95.9622814	0.959622814	0.8007	20.7	0.8006	20.8	0.801	21
116	95.93007161	0.959300716	0.8006	20.8	0.8008	21.2	0.8004	21.4
118	95.91603251	0.959160325	0.8008	20.7	0.8011	20.8	0.8008	21
120	95.81206818	0.958120682	0.8012	20.8	0.8008	21.2	0.8009	21.3

20 g

0	95.6664021	0.956664021	0.8018	20.6	0.8017	20.8	0.8016	20.8
2	99.2746539	0.992746539	0.7935	20.5	0.7931	20.5	0.793	20.1
4	99.23255026	0.992325503	0.7929	20.6	0.7927	20.8	0.7925	21.2
6	99.17678542	0.991767854	0.7928	20.9	0.7923	21.4	0.7921	21.6
8	99.23316555	0.992331655	0.793	20.4	0.7931	20.7	0.7929	20.9
10	99.08847457	0.990884746	0.7946	20.1	0.7943	20.4	0.794	20.7
12	97.67416114	0.976741611	0.7963	20.2	0.7961	20.4	0.7959	20.6
14	97.43657531	0.974365753	0.7969	20.3	0.7966	20.6	0.7965	20.8
16	97.32772394	0.973277239	0.7959	21.9	0.7958	22.1	0.7954	22.2
18	97.09628917	0.970962892	0.7977	20.6	0.7971	21.3	0.7967	21.6
20	96.83194093	0.968319409	0.7986	20.4	0.7985	20.6	0.7982	20.8
22	96.67318504	0.96673185	0.799	20.5	0.7986	20.9	0.7984	21.2
24	96.66132794	0.966613279	0.7989	20.8	0.7987	21.2	0.7979	21.3
26	96.53501681	0.965350168	0.7995	20.4	0.7994	20.6	0.799	20.8
28	96.50920817	0.965092082	0.799	21	0.7988	21.3	0.7986	21.5
30	96.45194554	0.964519455	0.7998	20.3	0.7995	20.6	0.7995	20.7
32	96.42792335	0.964279234	0.7991	21.2	0.7989	21.5	0.7988	21.6
34	96.32788726	0.963278873	0.8001	20.3	0.7999	20.6	0.7998	20.8
36	96.21940742	0.962194074	0.8003	20.5	0.7998	21	0.7997	21.3
38	96.28633325	0.962863333	0.8005	20	0.8004	20.2	0.8003	20.3
40	96.3413559	0.963413559	0.7998	20.2	0.8002	20.4	0.8002	20.5
42	96.2531362	0.962531362	0.8005	20.2	0.8003	20.5	0.8	20.6
44	96.21386274	0.962138627	0.8002	20.7	0.8	20.9	0.7999	21.1
46	96.15917914	0.961591791	0.8002	20.7	0.8002	20.9	0.8001	21
48	96.1672188	0.961672188	0.8009	20.1	0.8004	20.4	0.8006	20.6
50	96.11921649	0.961192165	0.8008	20.2	0.8005	20.6	0.8005	20.7
52	96.08029369	0.960802937	0.8009	20.2	0.8008	20.4	0.8007	20.6
54	96.06266093	0.960626609	0.8012	20	0.801	20.3	0.8007	20.5

56	96.02996135	0.960299613	0.8012	20.1	0.8011	20.3	0.8008	20.5
58	96.03189015	0.960318902	0.8012	20.2	0.801	20.3	0.801	20.5
60	96.07750859	0.960775086	0.7986	22.8	0.7985	23.1	0.7985	23.2
62	96.04185027	0.960418503	0.8009	20.6	0.8003	20.8	0.8005	21
64	95.99966117	0.959996612	0.8011	20.4	0.8008	20.6	0.8006	20.9
66	96.02101027	0.960210103	0.8015	20.1	0.8011	20.4	0.8004	20.6
68	95.9537376	0.959537376	0.8013	20.2	0.8011	20.4	0.8011	20.6
70	95.97229625	0.959722962	0.8011	20.1	0.8014	20.3	0.8011	20.5
72	95.95159386	0.959515939	0.8013	20.4	0.8011	20.6	0.8006	20.8
74	95.87687957	0.958768796	0.8016	20.2	0.8012	20.5	0.8011	20.8
76	95.93980858	0.959398086	0.8008	21	0.8004	21.5	0.8	21.5
78	96.00438904	0.96004389	0.7998	22.2	0.7992	22.2	0.7994	22.2
80	95.91243772	0.959124377	0.8018	20.1	0.8014	20.3	0.801	20.4
82	95.90177945	0.959017794	0.8014	20.5	0.8008	20.5	0.8014	20.6
84	95.88421558	0.958842156	0.801	20.8	0.8009	20.9	0.8009	21
86	95.88911828	0.958891183	0.8017	20.2	0.8016	20.3	0.8011	20.3
88	95.87429892	0.958742989	0.8019	20	0.8015	20.2	0.8013	20.4
90	95.85888379	0.958588838	0.8016	20	0.8015	20.5	0.8013	20.6
92	95.89545291	0.958954529	0.8017	20.3	0.8013	20.4	0.801	20.5
94	95.92827257	0.959282726	0.8014	20.5	0.8011	20.6	0.8007	20.7
96	95.87530064	0.958753006	0.8018	20.4	0.8012	20.5	0.801	20.5
98	95.74607112	0.957460711	0.802	20.1	0.8019	20.2	0.8019	20.3
100	95.7312562	0.957312562	0.8021	20	0.802	20.2	0.802	20.2
102	95.84407415	0.958440741	0.8019	20.2	0.8016	20.3	0.8012	20.4
104	95.79151939	0.957915194	0.8017	20.4	0.8017	20.7	0.8008	20.9
106	95.78676944	0.957867694	0.8017	20.4	0.8014	20.7	0.8014	20.6
108	95.77195172	0.957719517	0.8018	20.4	0.8018	20.5	0.8012	20.6
110	95.85573324	0.958557332	0.8021	20.2	0.8013	20.3	0.8012	20.4
112	95.79112037	0.957911204	0.8022	20.1	0.8018	20.2	0.8015	20.2
114	95.75080729	0.957508073	0.8022	20	0.8015	20.3	0.8018	20.6
116	95.7763073	0.957763073	0.8023	20	0.8021	20.1	0.8014	20.2
118	95.81858399	0.95818584	0.8013	20.4	0.8019	20.5	0.8012	20.6
120	95.79924073	0.957992407	0.8021	20.2	0.8015	20.4	0.8016	20.5

Zeolite 3A Data Tables

	10 mL/min								
	Time	% Ethanol	Ethanol Conc	Density Meter 1	Temp 1	Density Meter 2	Temp 2	Density Meter 3	Temp 3
40 grams	0	95.56460513	0.955646051	0.802	20.7	0.802	20.8	0.8018	20.9
	2	97.72494357	0.977249436	0.7948	22	0.7945	21.9	0.7945	22
	4	97.78801665	0.977880166	0.795	21.3	0.7952	21	0.7951	21.2
	6	97.74151118	0.977415112	0.7927	24	0.7926	24.1	0.7925	24.6
	8	97.57187085	0.975718708	0.7941	23.3	0.7938	23.2	0.794	23.2
	10	97.17024373	0.971702437	0.7961	22	0.7968	21.6	0.7963	21.8
	12	96.96619937	0.969661994	0.7969	21.8	0.7966	22.4	0.7964	22.5
	14	96.79630687	0.967963069	0.7966	22.8	0.7976	21.7	0.7971	22.3
	16	96.68548082	0.966854808	0.799	20.1	0.7996	20	0.7985	21.1
	18	96.53344956	0.965334496	0.7995	20.4	0.7993	20.6	0.7992	20.7
	20	96.46522225	0.964652222	0.7987	21.7	0.7983	22	0.7978	22.4
	22	96.32320577	0.963232058	0.8002	20.2	0.8	20.5	0.7999	20.7
	24	96.2807464	0.962807464	0.7991	21.6	0.7986	22.3	0.7988	22.1
	26	96.24327107	0.962432711	0.8004	20.2	0.8002	20.6	0.8002	20.6
	28	96.16798301	0.96167983	0.7996	21.3	0.7991	22.2	0.7987	22.6
	30	96.05948678	0.960594868	0.8007	20.5	0.8004	21	0.8001	21.3
	32	96.07596014	0.960759601	0.7992	22.3	0.7986	23	0.7979	23.7
	34	96.0635628	0.960635628	0.7993	22.2	0.7999	21.7	0.7992	22.1
	36	95.98557669	0.959855767	0.8001	21.5	0.8	21.8	0.7998	22
	38	95.96903442	0.959690344	0.8006	20.7	0.8003	21.5	0.7997	22.2
	40	95.90119911	0.959011991	0.8015	20.1	0.801	20.8	0.8005	21.4
	42	95.91361848	0.959136185	0.8002	21.8	0.7995	22.5	0.7987	23.2
	44	95.93777427	0.959377743	0.8009	20.7	0.801	20.8	0.8007	20.9
	46	95.86996837	0.958699684	0.8015	20.3	0.8013	20.5	0.8009	21
	48	95.8276642	0.958276642	0.8018	20	0.8016	20.2	0.8017	20.4
	50	95.87931451	0.958793145	0.801	20.9	0.8002	21.7	0.8	22
	52	95.84695145	0.958469515	0.7987	23.5	0.7984	23.8	0.7985	24.1
	54	95.79289163	0.957928916	0.8007	21.4	0.8007	21.4	0.8008	21.5
	56	95.76187918	0.957618792	0.8022	20	0.8015	20.6	0.8011	21
	58	95.83006238	0.958300624	0.8013	21.1	0.8002	21.2	0.8009	21.4
	60	95.73915296	0.95739153	0.802	20.2	0.8018	20.3	0.8018	20.4
	62	95.65413228	0.956541323	0.8019	20.7	0.8016	21	0.8011	21.2
	64	95.7675919	0.957675919	0.8005	21.8	0.8018	20.3	0.8015	20.6

66	95.72118014	0.957211801	0.8022	20	0.802	20.2	0.8019	20.3
68	95.69603596	0.95696036	0.8015	20.7	0.8017	20.7	0.8013	21.2
70	95.67489727	0.956748973	0.8019	20.3	0.8015	21.1	0.8018	20.6
72	95.67964028	0.956796403	0.8018	20.6	0.8016	20.7	0.8015	21
74	95.64780806	0.956478081	0.8018	20.7	0.8016	20.7	0.8016	21.1
76	95.6389652	0.956389652	0.8021	20.3	0.8021	20.5	0.802	20.4

20 grams

0	95.63439643	0.956343964	0.802	20.6	0.802	20.7	0.8019	20.7
2	97.39597389	0.973959739	0.7964	21	0.7963	21.1	0.7962	21.3
4	97.3126828	0.973126828	0.7974	20.2	0.7972	20.3	0.7972	20.4
6	96.96307679	0.969630768	0.7985	20.1	0.7984	20.2	0.7982	20.4
8	96.75671084	0.967567108	0.7987	20.6	0.7986	20.7	0.7984	20.8
10	96.57847397	0.96578474	0.7997	20	0.7996	20.1	0.7996	20.1
12	96.44773278	0.964477328	0.8	20.1	0.7999	20.2	0.7998	20.3
14	96.37923003	0.9637923	0.8001	20.2	0.8001	20.2	0.8001	20.2
16	96.29101161	0.962910116	0.8003	20.2	0.8003	20.3	0.8003	20.3
18	96.22250594	0.962225059	0.8005	20.2	0.8005	20.3	0.8005	20.3
20	96.17372243	0.961737224	0.8007	20.2	0.8007	20.2	0.8007	20.2
22	96.12285891	0.961228589	0.8008	20.3	0.8007	20.3	0.8007	20.4
24	96.09482402	0.96094824	0.8008	20.3	0.8007	20.5	0.8006	20.6
26	96.07198672	0.960719867	0.8009	20.3	0.8008	20.5	0.8006	20.6
28	96.05225525	0.960522553	0.8008	20.4	0.8008	20.6	0.8007	20.6
30	96.00557108	0.960055711	0.8011	20.2	0.8011	20.3	0.8012	20.3
32	96.00810325	0.960081033	0.801	20.4	0.8009	20.5	0.8007	20.8
34	95.98442123	0.959844212	0.8009	20.7	0.8007	20.8	0.8006	20.9
36	95.92351579	0.959235158	0.8012	20.4	0.8012	20.5	0.8011	20.6
38	95.92092156	0.959209216	0.8015	20.1	0.8015	20.2	0.8013	20.3
40	95.88911628	0.958891163	0.8016	20.1	0.8014	20.3	0.8014	20.4
42	95.89962199	0.95899622	0.8011	20.7	0.801	20.7	0.801	20.8
44	95.86896579	0.958689658	0.8015	20.2	0.8015	20.4	0.8014	20.4
46	95.87788268	0.958778827	0.8012	20.6	0.801	20.8	0.801	20.9
48	95.82608747	0.958260875	0.8019	20	0.8017	20.2	0.8016	20.3
50	95.82134395	0.958213439	0.8019	20	0.8019	20	0.8017	20.2
52	95.76225252	0.957622525	0.8012	21	0.8012	21	0.8011	21.1
54	95.79724284	0.957972428	0.8011	21	0.801	21.1	0.8011	21
56	95.80593594	0.958059359	0.8019	20.1	0.8017	20.2	0.8016	20.4
58	95.79506835	0.957950684	0.801	21.2	0.8009	21.2	0.8008	21.3
60	95.79546311	0.957954631	0.8005	21.7	0.8005	21.7	0.8004	21.8
62	95.84375455	0.958437546	0.7988	23.8	0.7987	23.1	0.7983	24.3
64	95.80596321	0.958059632	0.7981	24.4	0.7986	24	0.7983	24.1

66	95.71425887	0.957142589	0.802	20.3	0.802	20.2	0.8019	20.3
68	95.72252315	0.957225232	0.8013	21	0.8013	21	0.8015	20.8
70	95.77289694	0.957728969	0.7998	22.5	0.7996	22.8	0.7996	22.9
72	95.61788005	0.956178801	0.8017	21.6	0.8011	21.3	0.8009	21.4
74	95.72410261	0.957241026	0.8013	21	0.8013	21	0.8014	20.9
76	95.64437003	0.9564437	0.8014	21.7	0.8009	21.5	0.801	21.3

60 grams									
	0	95.62427164	0.956242716	0.8009	22	0.7998	23.1	0.7994	23.3
	2	99.5765223	0.995765223	0.7908	20.6	0.7907	20.8	0.7904	21
	4	99.41466385	0.994146638	0.7906	21.4	0.7904	21.6	0.7902	21.8
	6	99.3702444	0.993702444	0.7916	20.9	0.7914	21.1	0.7914	21.3
	8	99.2336384	0.992336384	0.7922	21.1	0.7921	21.3	0.7918	21.5
	10	99.08246037	0.990824604	0.7923	21.7	0.7921	22	0.7921	21.9
	12	99.09812331	0.990981233	0.7934	20.9	0.7933	21	0.7932	21.2
	14	98.99383902	0.98993839	0.7939	20.9	0.7938	21	0.7936	21.3
	16	97.93976492	0.979397649	0.7951	20.6	0.7949	20.9	0.7948	21
	18	97.71201013	0.977120101	0.7958	20.6	0.7957	20.8	0.7956	20.8
	20	97.55779483	0.975577948	0.7958	21.2	0.7953	21.7	0.7948	22.3
	22	97.39660919	0.973966092	0.7968	20.6	0.7967	20.6	0.7966	20.8
	24	97.29401627	0.972940163	0.7969	20.7	0.7968	21	0.7962	21.6
	26	97.15467772	0.971546777	0.7976	20.4	0.7976	20.5	0.7975	20.6
	28	97.05314128	0.970531413	0.7982	20.2	0.7981	20.2	0.798	20.3
	30	96.99921749	0.969992175	0.7969	21.8	0.7967	22.1	0.7967	22
	32	96.82084176	0.968208418	0.798	21.2	0.7978	21.4	0.7977	21.4
	34	96.92323287	0.969232329	0.7975	21.8	0.7972	21	0.7973	21.9
	36	96.55131974	0.965513197	0.7988	21.2	0.7985	21.5	0.7983	21.6
	38	96.6931473	0.966931473	0.7981	21.4	0.798	21.6	0.798	21.6
	40	96.6611195	0.966611195	0.7979	21.9	0.7975	22.1	0.7976	22.2
	42	96.52846378	0.965284638	0.7987	21.3	0.7986	21.5	0.7985	21.5
	44	96.33001948	0.963300195	0.7997	20.8	0.7994	21.2	0.7993	21.3
	46	96.49888109	0.964988811	0.799	21.1	0.7984	21.7	0.7984	21.8
	48	96.50670958	0.965067096	0.7986	21.5	0.7985	21.7	0.7982	21.9
	50	96.3613193	0.963613193	0.7994	20.8	0.7992	21.4	0.7989	21.7
	52	96.3872424	0.963872424	0.7989	21.7	0.7987	22	0.7984	21.8
	54	96.30979443	0.963097944	0.7996	21	0.7992	21.5	0.799	21.7
	56	96.26771618	0.962677162	0.7998	21	0.7994	21.3	0.7994	21.4
	58	96.10878685	0.961087869	0.7999	21.3	0.7998	21.5	0.7996	21.7
	60	96.17007971	0.961700797	0.8	20.8	0.8002	21.1	0.7996	21.4
	62	96.16178427	0.961617843	0.8008	20.2	0.8005	20.4	0.8003	20.7
	64	96.17996277	0.961799628	0.8008	20.2	0.7998	21.2	0.7992	21.8

66	96.19502525	0.961950253	0.7983	22.9	0.7981	23.1	0.798	23.3
68	96.12233492	0.961223349	0.801	20.1	0.8005	20.6	0.8001	21
70	96.09482551	0.960948255	0.8011	20	0.8007	20.5	0.8003	20.9
72	95.88541748	0.958854175	0.8011	20.4	0.801	21.2	0.8003	21.6
74	96.06158179	0.960615818	0.8011	20.1	0.8005	20.8	0.8001	21.3
76	96.04131126	0.960413113	0.8008	20.6	0.8003	21.1	0.8	21.4

	5 mL/min								
	Time	**% Ethanol**	**Ethanol Conc**	**Density Meter 1**	**Temp 1**	**Density Meter 2**	**Temp 2**	**Density Meter 3**	**Temp 3**
60g	0	95.60461491	0.956046149	0.8024	20.2	0.8024	20.2	0.8023	20.1
	2	99.78658767	0.997865877	0.7892	20.6	0.7894	20.9	0.7895	20.8
	4	99.94395333	0.999439533	0.7896	20	0.7894	20	0.7892	20.5
	6	99.81976847	0.998197685	0.7884	21.3	0.7884	21.3	0.7885	21
	8	99.65802868	0.996580287	0.7873	22.7	0.7877	22.3	0.7882	21.8
	10	99.80242966	0.998024297	0.789	21	0.7893	20.8	0.7895	20.5
	12	99.85497321	0.998549732	0.7899	20.3	0.7901	20.1	0.79	20
	14	99.62856903	0.99628569	0.7886	22.1	0.7891	21.5	0.7895	21.1
	16	99.68967826	0.996896783	0.7897	21.1	0.7897	20.8	0.7902	20.6
	18	99.65963267	0.996596327	0.7904	20.8	0.7907	20.4	0.7907	20.3
	20	99.538991	0.99538991	0.7902	21.4	0.7905	21.1	0.7908	20.6
	22	99.56737758	0.995673776	0.7911	20.3	0.7915	20.4	0.7914	20.5
	24	99.45020485	0.994502049	0.7917	20.6	0.7915	20.8	0.7914	20.8
	26	99.40027679	0.994002768	0.7926	20	0.7929	20.2	0.7927	20.3
	28	99.2845874	0.992845874	0.7911	21.8	0.7916	21.4	0.7915	21.3
	30	99.40620663	0.994062066	0.7927	20.2	0.7928	20.1	0.7929	20
	32	99.36439812	0.993643981	0.7931	20.1	0.7926	20.3	0.793	20.2
	34	98.76068799	0.98760688	0.7945	20.8	0.7934	21.6	0.794	20.8
	36	99.1824564	0.991824564	0.7942	20.1	0.7933	20.5	0.7938	20.5
	38	98.3530136	0.983530136	0.7942	21.3	0.7938	21.6	0.794	21.2
	40	98.23528638	0.982352864	0.7922	23.4	0.7928	22.8	0.7936	21.7
	42	98.25165666	0.982516567	0.795	20.7	0.7948	20.6	0.7949	20.5
	44	97.94913969	0.979491397	0.7945	21.6	0.7946	20.9	0.7955	20.6
	46	97.80486404	0.97804864	0.7961	20.3	0.7954	20.4	0.7958	20.3
	48	97.72836374	0.977283637	0.7963	20.3	0.7957	20.5	0.7959	20.3
	50	97.52800721	0.975280072	0.7954	21.7	0.7958	21.3	0.796	21
	52	97.51504271	0.975150427	0.7944	23.2	0.7944	22.8	0.7949	22.2
	54	97.37857602	0.97378576	0.7951	22.6	0.7953	22.2	0.7959	21.8
	56	97.25662136	0.972566214	0.7953	23	0.7953	22.7	0.7955	22.4
	58	97.21696115	0.972169611	0.7973	20.6	0.7973	20.4	0.7978	20.2
	60	97.12584707	0.971258471	0.7975	20.7	0.7976	20.6	0.7976	20.5

62	97.08818331	0.970881833	0.797	21.7	0.797	21.2	0.7974	20.8
64	96.99428957	0.969942896	0.798	20.7	0.7976	20.7	0.7981	20.6
66	96.92678225	0.969267822	0.795	24.2	0.7954	23.8	0.797	22
68	96.89335577	0.968933558	0.798	21	0.7978	20.9	0.7981	20.9
70	96.78456642	0.967845664	0.7978	21.7	0.7975	21.5	0.798	21.4
72	96.71843835	0.967184383	0.7984	20.9	0.7983	21.2	0.7983	21.2
74	96.69314638	0.966931464	0.7982	21.3	0.7979	21.6	0.798	21.7
76	96.5853939	0.965853939	0.7992	20.5	0.799	20.8	0.799	20.8
78	96.55067345	0.965506735	0.7993	20.6	0.7988	21.1	0.7988	21.1
80	96.55269538	0.965526954	0.7993	20.8	0.799	20.8	0.7991	20.6
82	96.43691492	0.964369149	0.7998	20.4	0.7995	20.5	0.7992	21.2
84	96.42827696	0.96428277	0.7992	21.2	0.7985	21.8	0.7982	22.2
86	96.33322276	0.963332228	0.7994	21.2	0.7987	22	0.7982	22.5
88	96.42117361	0.964211736	0.7973	23.3	0.7978	22.7	0.7981	22.4
90	96.22357824	0.962235782	0.8005	20.3	0.7994	21.6	0.799	21.9
92	96.1373139	0.961373139	0.7991	22	0.7988	22.7	0.7983	23.1
94	96.25894356	0.962589436	0.7988	22.4	0.7982	22.5	0.799	21.9
96	96.11607499	0.96116075	0.8002	21	0.8	21.2	0.7999	21.3
98	96.03040007	0.960304001	0.8007	20.6	0.8004	21	0.8007	20.8
100	96.05212641	0.960521264	0.7994	22.1	0.7996	21.9	0.7995	22
102	95.948982	0.95948982	0.8014	20	0.8012	20.4	0.8012	20.5
104	95.96059481	0.959605948	0.8012	20.4	0.8011	20.3	0.8014	20.2
106	95.93329514	0.959332951	0.8002	21.5	0.8003	21.5	0.8008	21
108	95.88120404	0.95881204	0.8015	20.2	0.8017	20.1	0.8017	20
110	95.94207948	0.959420795	0.8011	20.4	0.8013	20.5	0.8012	20.3
112	95.84706599	0.95847066	0.8013	20.9	0.8007	21.3	0.8006	21.1
114	95.78024004	0.9578024	0.801	21.1	0.8009	21.3	0.8011	21.1
116	95.78398788	0.957839879	0.801	21.3	0.8013	21	0.8011	20.7
118	95.79783717	0.957978372	0.8016	20.6	0.8012	20.7	0.801	21.1
120	95.74705318	0.957470532	0.8019	20.3	0.8018	20.4	0.8014	20.7

40g

0	95.64493271	0.956449327	0.8024	20.1	0.8021	20	0.8026	20
2	99.40616048	0.994061605	0.7925	20.2	0.7929	20	0.793	20.1
4	99.50589663	0.995058966	0.7918	20.3	0.7917	20.5	0.7918	20.3
6	99.48525376	0.994852538	0.792	20.2	0.792	20.4	0.792	20.3
8	99.46725184	0.994672518	0.792	20.4	0.7918	20.5	0.7919	20.4
10	99.47839309	0.994783931	0.7922	20.1	0.79187	20.5	0.7919	20.4
12	99.43884978	0.994388498	0.7919	20.5	0.7917	20.7	0.792	20.5
14	99.45304312	0.994530431	0.7922	20.1	0.7915	20.8	0.7918	20.7
16	99.56745263	0.995674526	0.7919	20	0.7915	20.3	0.7914	20.4

18	99.13779525	0.991377952	0.7927	21.2	0.7923	21.6	0.7925	21.4
20	98.85372186	0.988537219	0.7935	21.3	0.7933	21.6	0.7936	21.4
22	98.68991785	0.986899178	0.7953	20.1	0.7952	20.2	0.7952	20.2
24	97.79371063	0.977937106	0.796	20.1	0.7957	20.5	0.7957	20.4
26	97.72032002	0.9772032	0.7963	20	0.7958	20.6	0.7957	20.7
28	97.62066483	0.976206648	0.7959	20.9	0.7956	21.3	0.7953	21.3
30	97.40375074	0.974037507	0.7973	20	0.7971	20.1	0.7971	20.2
32	97.35606152	0.973560615	0.7974	20	0.7973	20.1	0.7974	20
34	97.27305086	0.972730509	0.7976	20	0.7974	20.3	0.7975	20.2
36	97.18659288	0.971865929	0.7979	20	0.7976	20.4	0.797	21
38	97.13711113	0.971371111	0.7968	21.5	0.7966	21.7	0.7967	21.5
40	96.80396266	0.968039627	0.7979	20.7	0.7986	20.7	0.7987	20.8
42	96.95848137	0.969584814	0.7971	21.9	0.797	21.9	0.7969	21.7
44	96.90437679	0.969043768	0.798	20.9	0.7976	21.3	0.7976	21.3
46	96.81297761	0.968129776	0.7981	21	0.798	21.2	0.7979	21.3
48	96.7504278	0.967504278	0.7987	20.5	0.7987	20.6	0.7987	20.6
50	96.65146594	0.966514659	0.7987	21	0.7984	21.2	0.7984	21.2
52	96.65102148	0.966510215	0.7985	21.3	0.7983	21.4	0.7981	21.4
54	96.55426477	0.965542648	0.7993	20.7	0.799	20.8	0.799	20.8
56	96.50388312	0.965038831	0.7994	20.6	0.7993	20.7	0.7993	20.7
58	96.43583693	0.964358369	0.7997	20.4	0.7998	20.4	0.7997	20.5
60	96.43644294	0.964364429	0.7993	21	0.7992	20.9	0.7994	20.9
62	96.36371133	0.963637113	0.7999	20.5	0.7998	20.6	0.7997	20.7
64	96.31590439	0.963159044	0.8004	20	0.8004	20.1	0.8004	20.1
66	96.30242891	0.963024289	0.8002	20.2	0.8004	20.2	0.8002	20.4
68	96.29101004	0.9629101	0.8004	20.3	0.8004	20.3	0.8001	20.2
70	96.29052667	0.962905267	0.7966	24.4	0.7976	23.6	0.7974	23.6
72	96.20902074	0.962090207	0.7985	22.6	0.7984	22.7	0.7986	22.6
74	96.11299649	0.961129965	0.8007	20.4	0.8008	20.3	0.8007	20.4
76	96.07869028	0.960786903	0.8	21.3	0.8002	21.1	0.8004	20.9
78	96.13422457	0.961342246	0.7994	21.6	0.7994	21.9	0.7995	21.9
80	96.03555921	0.960355592	0.8001	21.4	0.8	21.4	0.8001	21.4
82	95.96913041	0.959691304	0.8014	20	0.8015	20	0.8009	20.7
84	95.98223361	0.959822336	0.8006	21	0.8005	21	0.8006	21
86	95.94106738	0.959410674	0.8013	20.2	0.8015	20.1	0.8015	20.1
88	95.94943558	0.959494356	0.8009	20.8	0.8009	20.8	0.8007	20.8
90	95.91056967	0.959105697	0.8003	21.7	0.8001	21.7	0.8001	21.7
92	95.92756722	0.959275672	0.8004	21.5	0.8001	21.6	0.8002	21.6
94	95.87946637	0.958794664	0.801	20.8	0.801	20.8	0.8011	20.8
96	95.86347503	0.95863475	0.8009	21	0.8006	21.3	0.8007	21.3
98	95.82807435	0.958280743	0.8013	20.7	0.8012	20.7	0.8013	20.7

100	95.82630873	0.958263087	0.8007	21.5	0.8006	21.4	0.8007	21.3
102	95.81582338	0.958158234	0.8013	20.9	0.8011	21	0.8009	20.9
104	95.80732224	0.958073222	0.801	20.9	0.8011	21	0.8011	21.1
106	95.75870597	0.95758706	0.8017	20.6	0.8015	20.6	0.8018	20.2
108	95.76285101	0.95762851	0.8013	20.8	0.8013	20.8	0.8015	20.8
110	95.7067301	0.957067301	0.8017	20.6	0.8017	20.6	0.8017	20.6
112	95.75849197	0.95758492	0.8009	21.2	0.801	21.2	0.8012	21.2
114	95.72131224	0.957213122	0.8009	21.4	0.8009	21.4	0.8011	21.4
116	95.72349943	0.957234994	0.801	21.3	0.801	21.2	0.8014	21.1
118	95.69944514	0.956994451	0.8021	20.2	0.8021	20.2	0.802	20.2
120	95.69252291	0.956925229	0.802	20.3	0.802	20.3	0.802	20.3
122	95.65316258	0.956531626	0.8017	20.8	0.8017	20.8	0.8019	20.5

20 g

0	95.57153852	0.955715385	0.802	20.7	0.802	20.7	0.802	20.7
2	98.30452402	0.98304524	0.7913	24	0.7911	24.2	0.7921	23.2
4	98.57950076	0.985795008	0.79	24.1	0.7909	24.1	0.7906	24.1
6	98.40659086	0.984065909	0.7903	24.6	0.7901	24.8	0.7903	24.8
8	98.1553051	0.981553051	0.7927	22.8	0.7926	22.9	0.7929	22.9
10	97.7550463	0.977550463	0.7932	23.6	0.7929	23.6	0.7933	23.5
12	97.49241534	0.974924153	0.7944	23	0.7944	23	0.7945	22.9
14	97.32518903	0.97325189	0.7954	22.5	0.795	22.9	0.795	22.8
16	97.16441427	0.971644143	0.7967	21.4	0.7968	21.3	0.7967	21.6
18	97.06250705	0.97062507	0.7963	22.3	0.7963	22.4	0.7961	22.4
20	97.07082593	0.970708259	0.796	22.2	0.7967	22.1	0.7967	21.9
22	96.89803384	0.968980338	0.7969	22	0.797	22	0.7972	22
24	96.80396501	0.96803965	0.7984	20.8	0.7983	20.7	0.7985	20.7
26	96.52608821	0.965260882	0.7999	20	0.7996	20.2	0.7996	20.3
28	96.65821629	0.966582163	0.7972	22.5	0.7969	23	0.7972	22.7
30	96.58737969	0.965873797	0.7984	21.6	0.7977	22.3	0.7972	22.7
32	96.52533376	0.965253338	0.7992	20.8	0.7985	21.7	0.7983	21.6
34	96.4292321	0.964292321	0.7997	20.5	0.7991	21.2	0.7983	22.1
36	96.35229161	0.963522916	0.8001	20.3	0.7998	20.7	0.7996	20.8
38	96.41936884	0.964193688	0.799	21.3	0.799	21.3	0.7991	21.3
40	96.36165936	0.963616594	0.7995	20.8	0.7995	20.8	0.7999	20.8
42	96.27803438	0.962780344	0.8003	20.1	0.8007	20	0.8001	20.6
44	96.24594638	0.962459464	0.799	21.9	0.7985	22.5	0.7987	22.3
46	96.25946791	0.962594679	0.7995	21.5	0.799	22	0.7981	22.6
48	96.16177237	0.961617724	0.8001	20.9	0.7999	21.2	0.7997	21.4
50	96.10260559	0.961026056	0.801	20.2	0.8004	20.7	0.8002	21
52	96.13061357	0.961306136	0.8002	20.9	0.8	21.3	0.7996	21.5

54	96.09994078	0.960999408	0.7996	21.7	0.7994	21.9	0.7996	21.8
56	96.06361717	0.960636172	0.8002	21.2	0.8	21.3	0.8001	21.3
58	96.03645138	0.960364514	0.7995	22.2	0.799	22.5	0.7991	22.5
60	96.08281923	0.960828192	0.7998	21.5	0.8	21.5	0.7999	21.3
62	95.91532465	0.959153247	0.8	21.8	0.8001	21.8	0.8001	21.8
64	95.94049489	0.959404949	0.8014	20.1	0.8012	20.4	0.8011	20.6
66	95.95837808	0.959583781	0.8006	21	0.8003	21.4	0.8004	21.3
68	96.02652725	0.960265272	0.799	22.6	0.7986	23.1	0.7981	23.8
70	95.94180438	0.959418044	0.8005	21.3	0.8001	21.4	0.8005	21.4
72	95.86980828	0.958698083	0.8008	21.1	0.8005	21.4	0.8005	21.5
74	95.86506005	0.9586506	0.8007	21.2	0.8005	21.4	0.8009	21.1
76	95.84289926	0.958428993	0.8011	20.8	0.8012	20.8	0.8012	20.7
78	95.83739087	0.958373909	0.8003	21.7	0.8004	21.7	0.8006	21.5
80	95.81107906	0.958110791	0.8011	20.9	0.8012	20.8	0.8013	20.8
82	95.79249867	0.957924987	0.8011	21	0.8012	20.9	0.8012	20.9
84	95.77570509	0.957757051	0.8017	20.4	0.8017	20.3	0.8018	20.3
86	95.75081019	0.957508102	0.8018	20.3	0.8018	20.3	0.8019	20.3
88	95.70478872	0.957047887	0.8023	20	0.8021	20.1	0.8021	20.1
90	95.77293701	0.95772937	0.8014	20.8	0.801	20.9	0.8017	20.6
92	95.71583782	0.957158378	0.8019	20.3	0.8019	20.3	0.802	20.3
94	95.72229046	0.957222905	0.8009	21.5	0.8004	21.9	0.8009	21.6
96	95.73033246	0.957303325	0.7994	23.1	0.7993	23.3	0.7998	22.8
98	95.66008973	0.956600897	0.802	20.4	0.8018	20.6	0.8017	20.8
100	95.68835059	0.956883506	0.7995	23	0.7995	23.3	0.7996	23.2
102	95.65227545	0.956522755	0.8009	21.7	0.8009	21.7	0.801	21.6
104	95.70952709	0.957095271	0.7995	23.3	0.7994	23.4	0.799	23.4
106	95.61980408	0.956198041	0.8009	21.9	0.8007	22	0.8007	22
108	95.62353442	0.956235344	0.8021	20.5	0.8021	20.6	0.8017	20.6
110	95.60336797	0.95603368	0.8021	20.5	0.802	20.6	0.8018	20.8
112	95.59391009	0.955939101	0.8023	20.3	0.8022	20.4	0.802	20.6
114	95.62038194	0.956203819	0.8022	20.4	0.8021	20.5	0.8018	20.6
116	95.58855552	0.955885555	0.8022	20.5	0.8021	20.6	0.8019	20.6
118	95.62133599	0.95621336	0.8022	20.4	0.8016	20.8	0.8016	21.1
120	95.66263727	0.956626373	0.802	20.7	0.8014	20.9	0.8013	21.1

Rice Data Tables

	10 mL/min								
	Time	% Ethanol	Ethanol Conc	Density Meter 1	Temp 1	Density Meter 2	Temp 2	Density Meter 3	Temp 3
60 g	0	95.58162266	0.955816227	0.802	20.7	0.802	20.6	0.802	20.7
	2	95.85180992	0.958518099	0.801	20.9	0.8008	21.2	0.8005	21.5
	4	95.75751102	0.95757511	0.8014	20.8	0.8012	21	0.8012	21
	6	95.71341171	0.957134117	0.8012	21.1	0.8011	21.3	0.8011	21.3
	8	95.68850317	0.956885032	0.8013	21.2	0.8013	21.2	0.8011	21.2
	10	95.65885983	0.956588598	0.8014	21.1	0.8014	21.1	0.8015	21
	12	95.65851331	0.956585133	0.8019	20.6	0.8017	20.6	0.802	20.5
	14	95.57342657	0.955734266	0.8026	20	0.8026	20	0.8026	20
	16	95.66228316	0.956622832	0.8019	20.4	0.802	20.4	0.8021	20.4
	18	95.63203917	0.956320392	0.8021	20.5	0.8018	20.5	0.8021	20.5
	20	95.63265755	0.956326576	0.8022	20.1	0.8024	20.2	0.802	20.5
	22	95.72447344	0.957244734	0.8011	21.3	0.8008	21.5	0.8008	21.6
	24	95.66139951	0.956613995	0.801	21.3	0.8013	21.4	0.8012	21.4
	26	95.66175049	0.956617505	0.8009	21.8	0.8005	21.9	0.8008	21.9
	28	95.57469047	0.955746905	0.802	20.7	0.8019	20.8	0.8019	20.8
	30	95.64877189	0.956487719	0.8013	21	0.8014	21.2	0.8016	21.1
	32	95.65377877	0.956537788	0.8021	20.5	0.8019	20.5	0.8019	20.4
	34	95.68605662	0.956860566	0.8004	22.1	0.8003	22.1	0.8006	22.2
	36	95.7109849	0.957109849	0.8005	22.1	0.8003	22.2	0.8002	22.2
	38	95.73493308	0.957349331	0.8005	21.9	0.8004	22	0.8005	21.9
	40	95.67780482	0.956778048	0.8009	21.5	0.8011	21.5	0.8011	21.4
	42	95.67332777	0.956733278	0.8018	20.7	0.8017	20.6	0.8018	20.6
	44	95.69639962	0.956963996	0.8011	21.3	0.801	21.4	0.8011	21.4
	46	95.67587189	0.956758719	0.8015	20.9	0.8015	20.9	0.8015	21
	48	95.61411391	0.956141139	0.8012	21.5	0.8011	21.6	0.801	21.7
	50	95.59676273	0.955967627	0.8017	21	0.8014	21.3	0.8013	21.4
	52	95.58351937	0.955835194	0.8016	21.1	0.8015	21.2	0.8015	21.3
	54	95.57374283	0.955737428	0.8024	20.2	0.8021	20.6	0.802	20.7
	56	95.61565192	0.956156519	0.8024	20.3	0.802	20.4	0.802	20.5
	58	95.5664959	0.955664959	0.8026	20	0.8025	20.1	0.8025	20.2
	60	95.59108037	0.955910804	0.8018	20.8	0.8018	20.9	0.8018	20.9
40 g	0	95.57374521	0.955737452	0.8024	20.3	0.8021	20.6	0.802	20.6

2	95.72059661	0.957205966	0.7992	23.3	0.7991	23.6	0.7989	23.9
4	95.62353914	0.956235391	0.8023	20.3	0.8021	20.4	0.8015	21
6	95.64911525	0.956491153	0.8014	21.1	0.801	21.6	0.8006	22.1
8	95.61253728	0.956125373	0.8014	21.3	0.8011	21.6	0.8009	21.8
10	95.63085844	0.956308584	0.8009	21.9	0.8005	22.2	0.8002	22.5
12	95.5847749	0.955847749	0.8021	20.5	0.802	20.7	0.8017	21
14	95.60622249	0.956062225	0.8016	21	0.8013	21.4	0.8009	21.9
16	95.60971984	0.956097198	0.8017	21	0.8005	22.3	0.8001	22.7
18	95.6315308	0.956315308	0.7998	23.1	0.7995	23.3	0.7997	23.2
20	95.66684343	0.956668434	0.8007	22.1	0.8001	22.4	0.7998	22.9
22	95.66209645	0.956620964	0.8004	22.2	0.8002	22.4	0.8003	22.5
24	95.55830281	0.955583028	0.8024	20.3	0.8022	20.5	0.8016	21.2
26	95.63908881	0.956390888	0.8002	22.6	0.7999	22.8	0.7997	23.2
28	95.66569228	0.956656923	0.7989	24	0.7986	24.2	0.7987	24.3
30	95.6349075	0.956349075	0.8015	21	0.8012	21.3	0.8012	21.6
32	95.61851479	0.956185148	0.8018	20.8	0.8013	21.3	0.8012	21.5
34	95.65270034	0.956527003	0.8	22.9	0.7992	23.5	0.7991	23.8
36	95.65165778	0.956516578	0.8009	21.9	0.8007	21.8	0.8006	22
38	95.6024191	0.956024191	0.8026	20	0.8023	20.2	0.8017	20.9
40	95.55610174	0.955561017	0.8023	20.5	0.802	20.8	0.8014	21.3
42	95.60684004	0.9560684	0.8016	20.8	0.8016	21.2	0.8012	21.6
44	95.67763866	0.956776387	0.7996	23.1	0.7992	23.5	0.7992	23.7
46	95.57500955	0.955750095	0.8016	21.2	0.8016	21.2	0.8013	21.4
48	95.62826916	0.956282692	0.8022	20.4	0.8019	20.6	0.8015	21
50	95.58539998	0.955854	0.8025	20.2	0.802	20.4	0.8019	20.9
52	95.59862969	0.955986297	0.8023	20.2	0.8022	20.3	0.8017	21.1
54	95.60714575	0.956071458	0.8024	20.3	0.802	20.4	0.8019	20.7
56	95.58792926	0.955879293	0.8024	20.2	0.8017	21	0.8015	21.2
58	95.63339096	0.95633391	0.8004	22.3	0.8003	22.5	0.8001	22.7
60	95.61755626	0.956175563	0.8019	20.6	0.8017	20.9	0.8014	21.3

20 g	0	95.66455923	0.956645592	0.8011	21.4	0.8012	21.4	0.801	21.5
	2	95.80080753	0.958008075	0.7987	23.6	0.7991	23.6	0.7988	23.5
	4	95.69396474	0.956939647	0.7999	22.5	0.8004	22.2	0.8005	22.2
	6	95.67806452	0.956780645	0.8014	21	0.8019	20.6	0.8017	20.6
	8	95.68728186	0.956872819	0.8008	21.9	0.8012	21.3	0.8005	21.8
	10	95.67938337	0.956793834	0.801	21.6	0.8009	21.5	0.8011	21.4
	12	95.68788764	0.956878876	0.8011	21.6	0.801	21.4	0.801	21.3
	14	95.69517896	0.95695179	0.8007	21.7	0.8006	21.9	0.8007	21.9
	16	95.75058935	0.957505893	0.8011	21.1	0.8013	21	0.8012	21
	18	95.72275843	0.957227584	0.802	20.2	0.802	20.2	0.802	20.2

20	95.71815133	0.957181513	0.8011	21.2	0.8009	21.4	0.8011	21.4
22	95.77114118	0.957711412	0.8007	21.5	0.8009	21.4	0.8007	21.5
24	95.74148479	0.957414848	0.8008	21.4	0.8011	21.3	0.801	21.3
26	95.74306454	0.957430645	0.8009	21.4	0.8009	21.4	0.801	21.3
28	95.72823779	0.957282378	0.8011	21.3	0.8009	21.3	0.8011	21.3
30	95.73200235	0.957320023	0.8013	21	0.8011	21.2	0.8011	21.2
32	95.73734546	0.957373455	0.8013	21	0.8013	21	0.8012	21
34	95.68717909	0.956871791	0.8017	20.5	0.8022	20.4	0.8018	20.4
36	95.71146715	0.957114672	0.8017	20.7	0.8015	20.7	0.8016	20.7
38	95.74960942	0.957496094	0.8014	20.8	0.8014	20.8	0.8015	20.7
40	95.77826935	0.957782694	0.8015	20.7	0.8013	20.6	0.8016	20.6
42	95.75178928	0.957517893	0.8016	20.6	0.8016	20.6	0.8016	20.5
44	95.76720761	0.957672076	0.8017	20.4	0.8017	20.4	0.8017	20.4
46	95.74133389	0.957413339	0.8021	20.1	0.802	20.1	0.802	20.1
48	95.72749683	0.957274968	0.8021	20.1	0.802	20.2	0.8016	20.6
50	95.66228316	0.956622832	0.8018	20.4	0.8021	20.4	0.8021	20.4
52	95.73101915	0.957310192	0.8016	20.6	0.8013	20.8	0.8013	21.2
54	95.73810797	0.95738108	0.8011	21.4	0.8001	22.2	0.8	22.4
56	95.75369261	0.957536926	0.7997	23	0.7993	23.1	0.7993	23.1
58	95.67832168	0.956783217	0.8022	20	0.8022	20	0.8025	20
60	95.70259659	0.957025966	0.8021	20.1	0.8019	20.2	0.802	20.5

	5 mL/min								
	Time	**% Ethanol**	**Ethanol Conc**	**Density Meter 1**	**Temp 1**	**Density Meter 2**	**Temp 2**	**Density Meter 3**	**Temp 3**
60 grams	0	95.58162266	0.955816227	0.802	20.7	0.802	20.6	0.802	20.7
	2	96.03462441	0.960346244	0.8012	20.2	0.801	20.3	0.8006	20.7
	6	96.05799573	0.960579957	0.8009	20.1	0.8011	20.2	0.8012	20.2
	10	96.0286639	0.960286639	0.8012	20	0.8015	20	0.8011	20.1
	14	96.03081727	0.960308173	0.8011	20.4	0.8008	20.5	0.8005	20.8
	18	95.94638695	0.959463869	0.8014	20	0.8015	20	0.8017	20
	22	95.83024308	0.958302431	0.8014	20.6	0.8014	20.5	0.8015	20.4
	26	95.82491608	0.958249161	0.8009	21	0.8015	20.5	0.8016	20.4
	30	95.84090832	0.958409083	0.8014	20.4	0.8017	20.2	0.8018	20.1
	34	95.84506777	0.958450678	0.8011	20.8	0.8014	20.5	0.8015	20.4
	38	95.81917524	0.958191752	0.8014	20.5	0.8018	20.2	0.8018	20.1
	42	95.87588328	0.958758833	0.8011	20.6	0.8016	20.1	0.8019	20
	46	95.84307361	0.958430736	0.8017	20.1	0.8018	20	0.8019	20
	50	95.79744069	0.957974407	0.8015	20.5	0.8018	20.2	0.8018	20.2
	54	95.89790769	0.958979077	0.801	21	0.8006	21.2	0.7997	22.1

58	95.88924561	0.958892456	0.8	22.2	0.7998	22.1	0.7995	22.4
62	95.7984313	0.957984313	0.7999	22.4	0.7998	22.5	0.7996	22.7
66	95.78815082	0.957881508	0.8005	21.6	0.8009	21.2	0.8011	21.2
70	95.76336782	0.957633678	0.7999	23.1	0.7997	22.4	0.8	22.1
74	95.87483347	0.958748335	0.799	23	0.7994	22.6	0.7999	22.4
78	95.72154885	0.957215489	0.8017	20.6	0.8016	20.7	0.8015	20.7
82	95.71499205	0.957149921	0.801	21.4	0.8011	21.2	0.8012	21.2
86	95.71754736	0.957175474	0.8006	21.7	0.8009	21.6	0.801	21.4
90	95.72642402	0.95726424	0.8	22.5	0.8006	21.8	0.8007	21.7
94	95.72568333	0.957256833	0.8012	21.1	0.8015	20.9	0.8012	21
98	95.72385576	0.957238558	0.8003	22.3	0.801	21.5	0.8008	21.3
102	95.73636783	0.957363678	0.8015	20.8	0.8014	20.7	0.8016	20.7
106	95.80455612	0.958045561	0.8008	21.7	0.8001	21.4	0.8012	21.2
110	95.68402135	0.956840213	0.802	20.3	0.8019	20.4	0.802	20.4

40 g

0	95.57595586	0.955759559	0.8014	21.4	0.8012	21.6	0.8012	21.6
2	94.9751949	0.949751949	0.8021	22.1	0.8022	22.2	0.8023	23
4	95.12945713	0.951294571	0.8026	21.5	0.8027	21.4	0.8025	21.5
6	95.15332186	0.951533219	0.8036	20.3	0.803	20.9	0.8029	21
8	95.20867609	0.952086761	0.8027	21	0.8025	21.4	0.8027	21.1
10	95.25110832	0.952511083	0.8034	20.2	0.803	20.4	0.8033	20.4
12	95.30177214	0.953017721	0.8029	20.6	0.8027	20.8	0.8028	20.6
14	95.32467071	0.953246707	0.8004	23.4	0.8006	23.2	0.8008	22.8
16	95.31679823	0.953167982	0.8025	21	0.8023	21.1	0.802	21.6
18	95.39293652	0.953929365	0.8007	22.7	0.8004	23.1	0.8015	22
20	95.35112916	0.953511292	0.802	21.4	0.802	21.5	0.8019	21.5
22	95.43175389	0.954317539	0.8011	22.3	0.8007	22.8	0.8009	22.2
24	95.36594068	0.953659407	0.802	21.4	0.8017	21.7	0.8019	21.5
26	95.46965453	0.954696545	0.8012	22	0.8012	22	0.8011	22
28	95.40225871	0.954022587	0.8023	21	0.8021	21.1	0.8021	21.1
30	95.40894652	0.954089465	0.8029	20.3	0.8026	20.5	0.8025	20.6
32	95.43502318	0.954350232	0.802	21.1	0.8019	21.3	0.8018	21.4
34	95.47975051	0.954797505	0.8012	21.9	0.8011	22	0.8012	22
36	95.4605764	0.954605764	0.8021	21	0.802	21	0.8019	21.2
38	95.48669621	0.954866962	0.8013	21.8	0.8013	21.8	0.8011	22
40	95.47760784	0.954776078	0.8021	20.9	0.8021	20.9	0.802	21
42	95.47639636	0.954763964	0.8029	20	0.8027	20.2	0.8026	20.3
44	95.52489423	0.955248942	0.8021	20.6	0.8022	20.7	0.8021	20.8
46	95.48075599	0.95480756	0.802	21	0.8019	21.1	0.8021	20.9
48	95.48361846	0.954836185	0.8025	20.4	0.8024	20.6	0.8022	20.7

50	95.52013078	0.955201308	0.8011	21.8	0.8013	21.8	0.8011	21.9
52	95.5406458	0.955406458	0.8018	21	0.8017	21	0.8019	21.1
54	95.51953333	0.955195333	0.802	20.9	0.8021	20.8	0.802	20.8
56	95.49813537	0.954981354	0.8028	20.1	0.8027	20.1	0.8026	20.2
58	95.52617164	0.955261716	0.8027	20.1	0.8026	20.2	0.8023	20.4
60	95.52459655	0.955245966	0.8027	20.1	0.8026	20.2	0.8024	20.3

20 g	0	95.60336916	0.956033692	0.8017	20.7	0.8021	20.6	0.8021	20.6
	2	95.66833122	0.956683312	0.8011	21.4	0.8013	21.2	0.8013	21.2
	4	95.74961024	0.957496102	0.8014	20.8	0.8016	20.7	0.8013	20.8
	6	95.72312787	0.957231279	0.8014	20.7	0.8018	20.7	0.8015	20.7
	8	95.71025353	0.957102535	0.801	21.4	0.8012	21.1	0.8014	21
	10	95.64273361	0.956427336	0.8022	20	0.8023	20.3	0.8021	20.4
	12	95.61000468	0.956100047	0.8011	21.6	0.8016	21.1	0.8015	21.1
	14	95.57594774	0.955759477	0.8024	20.2	0.8023	20.3	0.8023	20.4
	16	95.63519699	0.95635197	0.8016	20.7	0.8021	20.5	0.8021	20.5
	18	95.69446126	0.956944613	0.8015	20.8	0.8017	20.8	0.8014	20.9
	20	95.60146582	0.956014658	0.8026	20	0.8025	20.1	0.8022	20.2
	22	95.69421974	0.956942197	0.8003	22.1	0.8011	21.4	0.8013	21.2
	24	95.60244881	0.956024488	0.8008	21.9	0.8012	21.5	0.8014	21.4
	26	95.61029653	0.956102965	0.8021	20.6	0.8019	20.5	0.8021	20.5
	28	95.57090508	0.955709051	0.8019	20.7	0.8018	21.1	0.8017	21
	30	95.67683837	0.956768384	0.8012	21.2	0.8013	21.2	0.8013	21.2
	32	95.6106294	0.956106294	0.8013	21.3	0.8017	21	0.8018	20.8
	34	95.67709695	0.95677097	0.8019	20.5	0.8019	20.4	0.8019	20.5
	36	95.67490701	0.95674907	0.8016	20.8	0.8018	20.6	0.8018	20.6
	38	95.65912808	0.956591281	0.802	20.4	0.8021	20.3	0.8021	20.3
	40	95.67368265	0.956736826	0.8011	21.3	0.8014	21.1	0.8015	21
	42	95.63738907	0.956373891	0.8021	20.3	0.8022	20.4	0.802	20.4
	44	95.62893495	0.95628935	0.8005	22.3	0.8011	21.5	0.8014	21.2
	46	95.59078008	0.955907801	0.8012	21.6	0.8009	21.8	0.8014	21.4
	48	95.56996496	0.95569965	0.8024	20.3	0.8019	20.8	0.8018	20.9
	50	95.61726969	0.956172697	0.8008	21.9	0.8012	21.6	0.8011	21.5
	52	95.62234458	0.956223446	0.8001	22.5	0.8006	22.2	0.8008	22.1
	54	95.6626309	0.956626309	0.8015	21	0.8016	20.9	0.8016	20.8
	56	95.63395158	0.956339516	0.8015	21.2	0.8016	21	0.8015	20.9
	58	95.65001293	0.956500129	0.8022	20.4	0.8017	20.7	0.8016	20.8
	60	95.57469422	0.955746942	0.8024	20.3	0.8018	20.9	0.8016	21.1