# THE EFFECT OF VARIATION IN TEMPERATURE AND DIFFERENT ALKALI SALTS ON THE ABSORPTIVITY OF SODIUM POLYACRYLATE

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The study of smart materials such as Sodium polyacrylate has led to numerous extremely useful applications in the field of chemistry; most importantly, polymers like Sodium polyacrylate not only absorb moisture to serve as a material that can be embedded in diapers, but also, being a smart material, salts can modify its structure and cause a great decrease in its absorptivity. The main area of investigation of the researcher's investigation to find whether the variation in temperature of the environment causes sodium polyacrylate to change its water absorptivity and whether the addition different 0.5M salt solutions like Sodium chloride (NaCl), Sodium sulfate ($Na_2SO_4$), Potassium chloride (KCl), and Potassium sulfate ($K_2SO_4$), will affect the water absorptivity of the smart material. It was found that the as the temperature increased from 15.8ºC to about 40.5ºC for the environment, the absorptivity of the sodium polyacrylate sample greatly decreased from about 44mL to 25mL, revealing an inverse relationship between the water absorptivity of the polymer and the temperature of the environment around it. As for the addition of the different alkali salts, both the sodium salts showed a much less absorptivity of the smart material (2.7mL for NaCl and 1.7 for $Na_2SO_4$), compared to that of the potassium salts (3.5mL for KCl and 3.3mL for $K_2SO_4$). The evident data allowed the researcher to conclude not only that the temperature has a clear inverse relationship with the temperature of the environment and the absorptivity of Sodium polyacrylate, but also there was a clear distinction between the absorptivity of the polymer achieved with the addition of the four different alkali salts.

Introduction

Polymers in the modern world comprise a major part of the society. Some polymers may be natural, while others might be manmade. Many of the natural polymers have helped human beings make different textiles out of them, but in the current time, manmade polymers are dominating the chemical market. Smart materials such as Sodium polyacrylate serve numerous purposes, the primary one being their ability to absorb moisture (Wilson, B. n.d.), as much as 800 times its own mass, of water (Gelfand n.d.). At a certain temperature, the water absorptivity of Sodium polyacrylate varies, and with the purity level of the deionized water, the absorptivity of the polymer changes. When salts are added to the smart material's composition holding the water, the structure of the polymer gets altered, causing the polymer to lose its water absorptivity almost completely. With an apparatus set up similar to the one shown in Figure 1, the experimenter tested the absorptivity in two different parts of the study: one was to determine the effect of the environment temperature on the absorptivity of Sodium polyacrylate, and the second was to determine the effects of different alkali salt solutions on the absorptivity of the smart material.

Approximate Apparatus Setup

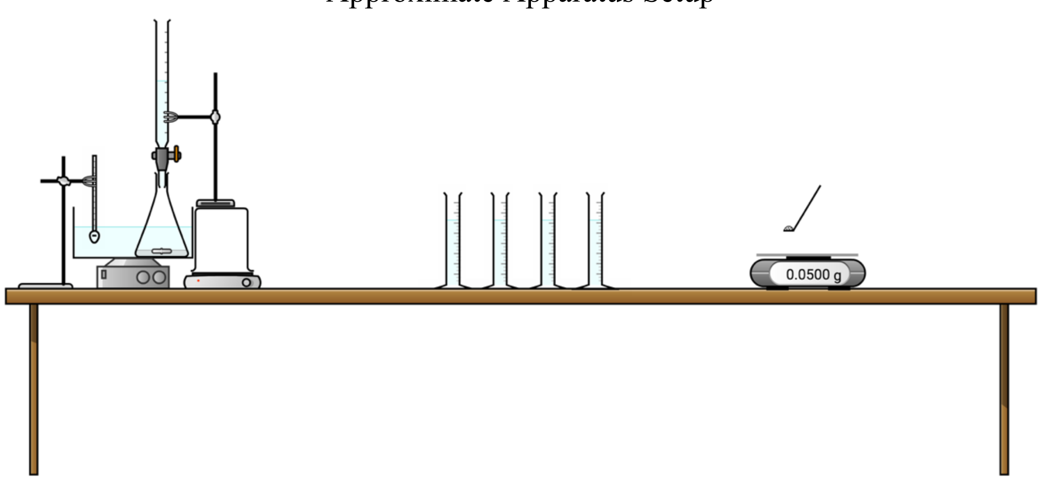


**Figure 1: This figure shows the close replication of the apparatus setup the experimenter used in the lab during the study.**

The main application of the Sodium acrylate polymer is its heavy use in the manufacturing and composition of diapers. Hence, it is important to study the effects of temperature, with respect to the temperature of the human body, on the amount of liquid the diaper can potentially absorb. While temperature served as a direct cause of study, a slightly indirect, yet extremely important factor to consider is the salt composition in the body of a human. The perspiration by an individual also might cause a change in the composition of the absorbing smart material, leading to a variation in the absorptivity of the diaper. In the experiment that the researcher will be performing, by adding only half to a full milliliter of either solely distilled water, or an alkali salt solution to 0.05 gram of sodium polyacrylate sample until it cannot hold more water, the absorptivity of the polymer will be determined.

An in-depth study of the absorptivity of sodium polyacrylate will provide the diaper-manufacturing companies more detailed information as to when the diaper is more likely to hold as much water as possible and the environments in which the diaper may not perform as expected. Although there might several compromising factors for the diaper such as the liquid being absorbed and the size of the diaper, body perspiration and temperature seem common to the entire population of diaper users, hence these two factors remain the constants in all experiments, but will serve as some of the most important variables in this investigation (Sieveb1 2010, and 1caeirojen, 2015).

During the experiment, the researcher will study how changing the temperature of the environment in which sodium polyacrylate will absorb water, and adding common body salts, specifically, alkali salts like Sodium chloride (NaCl), Sodium sulfate ($Na_2SO_4$), Potassium chloride (KCl), and Potassium sulfate ($K_2SO_4$), will affect the water absorptivity of the smart material. The researcher, during the analysis phase of the experiment, will also perform a comparative analysis on the effects of the four different salts by classifying them by either their parent alkali metal they are composed of (Sodium or Potassium), or even the anion they are made of (Chloride or Sulfate).

## Hypotheses

$H_0$: With the increase in temperature of environment, the absorption of Distilled $H_2O$ by the Sodium polyacrylate will not change. There will be no difference in the absorptivity of the Sodium polyacrylate between the 0.5M Sodium and the Potassium salt solutions.

$H_1$: With the increase in temperature of environment, the absorption of Distilled $H_2O$ by the Sodium polyacrylate will increase. 0.5M Sodium salt solutions will lead to higher absorptivity of $H_2O$ in the Sodium polyacrylate than the Potassium salt solutions.

$H_2$: With the increase in temperature of environment, the absorption of Distilled $H_2O$ by the Sodium polyacrylate will decrease. The 0.5M Sodium salt solutions will lead to lower absorptivity of $H_2O$ in the Sodium polyacrylate than the Potassium salt solutions.

## Purpose

The purpose of this investigation is to study and find out the effects variations in temperature and the use of different alkali salts like Sodium chloride (NaCl), Sodium sulfate ($Na_2SO_4$), Potassium chloride (KCl), and Potassium sulfate ($K_2SO_4$) on the distilled water absorptivity of Sodium polyacrylate.

Materials

Reagents

- Deionized water, $H_2O$
- 2.0 g Sodium polyacrylate, $(C_3H_3NaO_2)_n$
- 2.922g Sodium Chloride, NaCl
- 7.102g Sodium Sulfate, $Na_2SO_4$
- 3.728g Potassium Chloride, KCl
- 8.713g Potassium Sulfate, $K_2SO_4$
- Tap Water
- Ice

Equipment

- Hot Plate
- Magnetic stir bar
- 1- 400-500 mL Beaker
- 1 - Erlenmeyer flask
- Thermometer
- 4 - 100 mL Graduated Cylinders
- Weighing paper
- Scoopula or spatula
- Weighing scale
- Ring stand
- 2 - Utility Clamps
- 1 - 50mL Buret
- 1 - Buret Clamp

Methods

*Extreme care was taken when handling any solid chemicals or solutions during the experiment, and it was ensured that safety goggles were worn at all times. Any chemical contact with the skin or eyes and any respiratory ingestion of the substances could have resulted in a health risk, and was therefore carefully avoided* (Material Safety Data Sheet 2005).

**Part One:** *To study the effects of the variation in temperature of the reaction on the $H_2O$ absorptivity of Sodium polyacrylate.*

All Apparatus was setup as shown in Figure 1, with the four graduated cylinders set aside for Part Two, but the weighing scale was used for both the parts. 3 samples of 0.0500g Sodium polyacrylate were measured on three different pieces of weighing paper. 50mL of deionized or distilled $H_2O$ was measured and poured in the 50mL buret. It was made sure that the temperature of the environment within the flask was approximately 25ºC. If not, the environment was appropriately heated or cooled to satisfy the constant temperature requirement. The buret's initial level was made sure to be 0mL, and a magnetic stir bar was dropped into the flask. The stirring was started on the hot plate at a steady pace to prevent any splashes or excessive movement inside the flask. Slowly, the buret's distilled $H_2O$ content was emptied out into the flask, by every 1mL until it was noticed that even after some more time of stirring, the solution of the polymer and the distilled water was close to the viscosity or consistency of a liquid, with no clearly visible solid particles, showing that the Sodium polyacrylate couldn't hold any extra $H_2O$. The final volume of pure water added to the flask and the latest temperature of the environment was recorded and the flask was cleaned out, in order to repeat two more trials at the same temperature. Also, the buret was refilled to the 0mL mark. The previous steps were repeated, but this time, using the hot plate, with the large 400-500mL beaker filled less than half-way with tap water, heated to approximately a constant 40ºC using the hot plate and submerging the flask environment in the larger beaker. The previous steps were repeated, but this time, only with the large 400-500mL beaker and some ice up to the point where the ice submerges the flask, to maintain approximately a constant 10ºC using the hot plate and submerging the flask environment in the larger beaker. All data was averaged (including the volumes and the temperatures), and tabulated.

**Part Two:** *To study the effects of the different salts.*

In order to make 100mL 0.5M solutions of each salt, the researcher used 0.05 moles of each salt and made a 100mL solution with each of the measured quantities of salts, by calculating the respective half-mole masses for each salt (0.5 * the molar mass of the anhydrous salt). The buret used from the previous part was thoroughly cleaned and dried, then the 0.5M NaCl solution was poured into the buret to fill the buret up to the 0mL mark. The same procedure to add every mL of the salt solution, but this time, graduations of 0.5mL were used, and the final volume of the salt solution added to Sodium polyacrylate in the flask was recorded, then two more trials with a fully filled Buret with the salt solution were performed, then recording their data. The same steps were carried out for the other three salts ($Na_2SO_4$, KCl, and $K_2SO_4$), while still cleaning and drying the Buret thoroughly between trials of different salt solutions. Finally, all data collected in this part was averaged for each salt, and tabulated according to the salt and the salt data was classified as either a Chloride or Sulfate salt, or, as a Sodium or Potassium salt.

Results (and Data Tables)

Absorptivity of Sodium polyacrylate with respect to Temperature

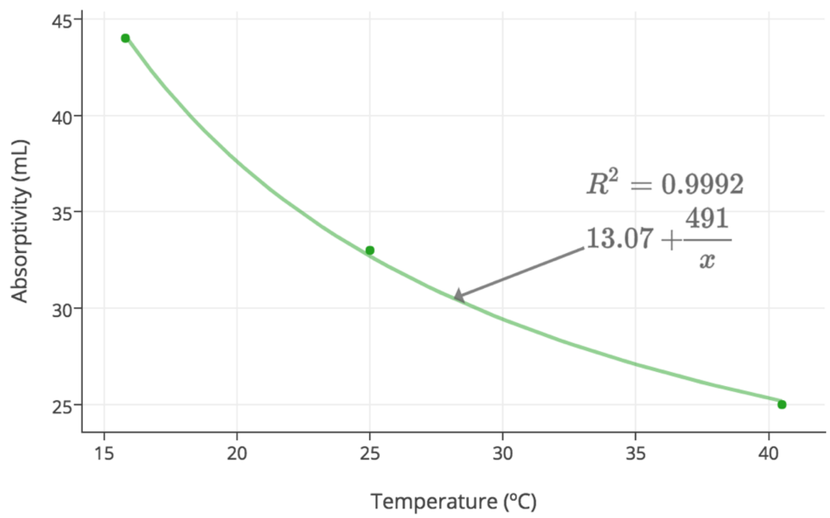


**Figure 2: The line of regression made to fit the absorptivity is an Inverse-function curve, with an $R^2$ value of approximately 0.9992.**

The researcher measured the deionized water absorptivity of three 0.05g sodium polyacrylate samples for each of the three temperature values, then averaged both the temperatures of the environment and the three absorptivity levels achieved at approximately that temperature. After plotting the three data points and calculating the line of best-fit, it was found that the curve with the highest $R^2$ value of approximately 0.9992 was the inverse function. According the averaged data points shown in Figure 2, it can be clearly seen that starting at about 15.8ºC and 44mL for absorptivity, as temperature increases to about 25ºC, the absorptivity falls sharply to about only 33mL, then falling more to 25mL at about 40.5 ºC. The absorptivity, as a result, showed a regression curve similar to that of the inverse function, here, the equation being: $\boldsymbol{Absorptivity\ (mL) = 13.07 + \frac{491}{Temperature\ (^{\circ}C)}}$. This shows that even a slightest increase in temperature of the environment in which water is being absorbed by the sodium polyacrylate sample will cause its absorptivity to drastically decrease.

Average Absorptivity of Sodium Polyacrylate of Different 0.5M Alkali Salt Solutions

| 0.5M Salt Solution | Average Absorptivity of Sodium polyacrylate (mL) |
|---|---|
| NaCl | 2.7 |
| $Na_2SO_4$ | 1.7 |
| KCl | 3.5 |
| $K_2SO_4$ | 3.3 |

**Table 1: Absorptivity of 0.05g Sodium polyacrylate when adding to it 0.5M alkali salt solutions mentioned above.**

The researcher discovered some surprising results in the second part of the investigative study, according to Table 1. While it wasn't quite expected, it was concluded that the same amount (0.05g) of sodium polyacrylate sample only absorbed a really minute amount of the salt solution. When the absorption of the 0.5M salt solutions took place, it was observed that only 2.7mL of the sodium chloride solution was absorbed by the sodium polyacrylate while just 1.7mL of the sodium sulfate solution was absorbed. As for the potassium salts, the absorptivity levels compared much higher: the absorptivity of sodium polyacrylate was about 3.5mL when the 0.5M potassium chloride salt solution was used, while it was 3.3mL with the use of the 0.5M potassium sulfate solution. As demonstrated by the data, the average absorptivity in the presence of the sodium salt solutions was much lower compared to the potassium salt solutions' presence. Not only this, but another conclusion was drawn that both the chloride salt solutions seemed to lead to a much higher absorptivity in the sodium polyacrylate sample than the sulfate salt solutions.

Conclusion & Discussion

After collecting the data, the researcher was successfully able to reject the null and the first alternative hypothesis; there was clear quantitative correlation between the temperature of the environment (in ºC) and the absorptivity of sodium polyacrylate (in mL). Not only this, but also a trend in the distinguishable absorptivity levels between the two types of alkali (sodium and potassium) salts was clearly justifiable with the data, showing that the both the sodium salt solutions when mixed with the sodium polyacrylate sample showed a much lower absorptivity level in the smart material compared to both of the potassium salt solutions. As for the trend between the same salts, but looked through the lens of the anions that they are composed of, it was seen by the data in Table 1 that the chloride salts showed higher water absorptivity levels in the polymer compared to the salts composed of the sulfate ion.

It was expected according to Chemical Kinetics Laws that increasing the temperature of the environment would cause the "reaction" to proceed faster, hence leading to the smart material's absorptivity increasing, but the results proved otherwise (see Figure 2, page 8). A logical explanation of this can be derived from the study of entropy in the system (Josh for Congress 2013). The higher amount of temperature causes rapid motion amongst the dense polymer molecules, causing them to hold much less water molecules than they would have between them. Likewise, if their motion was much less with lower temperature, the number of water molecules they hold between them would increase, hence increasing the absorptivity of the polymer as a whole.

For the second part, when the 0.5M salt solution is made, the salt dissociates into cations (the alkali salt ions—either $Na^+$ or $K^+$) and anions (either $Cl^-$ or $SO_4^{2-}$). The polymer would continue to absorb the water molecules along with the ions until it couldn't hold any more of the moisture, due to the high enough $Na^+$ or $K^+$ and $Cl^-$ or $SO_4^{2-}$ concentrations in the solution to break down the chained structure of the polymer, causing its moisture absorptivity levels to drop drastically (guy 2013). The greater absorptivity for the potassium salts can be explained by studying the bond strengths of the different solids, showing the greater attraction between sodium and chlorine, compared to potassium and chlorine. On a similar note, the sodium-sulfate bond would display more ionic character compared to the potassium-sulfate bond.

Overall, the researcher was able to successfully reject the null and the first alternative hypotheses. All data proved the second hypothesis to be completely acceptable with enough evidence. Although the temperature values for the first part were averaged and so were the volumes, there was approximately solidity in rejecting the first two hypotheses and accept the last one. The second part yielded approximately equal values of absorptivity for each trial for every salt, hence this also reinforces the statements the second alternative hypothesis makes regarding the higher water absorptivity with the potassium salt solutions compared to that with the sodium salt solutions.

The theory that is studied in this experiment is the theory of positional entropy—the idea that pertains to the change of positional entropy and the movement of particles with respect to the amount of energy added to the system. While it was inferred that the reaction, conducted at higher temperatures, would lead to increasing the absorptivity of the sample of sodium polyacrylate, the positional entropy idea came into being, leading to the conclusion that as the temperature increases, the sodium polyacrylate molecules tend to absorb less water molecules. The same results are also applicable to the results provided for this experiment. Using the collision theory of particles and the theory of positional entropy, we can explain the results that were produced in this investigation.

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