Synthesizing and and Measuring the Efficacy of Zeolites

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Abstract

Polycyclic aromatic hydrocarbon (PAH) is a very common type of pollutant found in the environment. It is speculated that these pollutants can be removed by having them be absorbed into a porous material such as coal, zeolite, or magnetized zeolite. This experiment tested the absorptivity of each precipitant on a solution of procion red. It was found that magnetized zeolites absorbed the most amount of red dye solution, suggesting they might be a good material for removing PAHs from the enviornment.

1 Introduction

The production of materials by plants and factories has resulted in the constant release of harmful pollutants which leads to the need for a method that can withdraw these toxins from the environment. One group of pollutants of interest are polycyclic aromatic hydrocarbons (PAHs), because they are speculated to be carcongenic to humans and aquatic wildlife [1]. They are commonly found in cold-tar and asphalt sealants, in addition to industrial and municipal wastewater [2]. It is commonly thought that using porous materials would be a viable way to combat this problem in water environments through their ability to absorb chemicals. This paper attemps to test the efficacy of magnetic zeolites in absorbing a red dye solution in hopes of applying this method to the removal of PAHs in water sources.

2 Materials and Methods

2.1 Synthesizing the Zeolites

First, sodium hydroxide (3.0M NaOH, 50 mL) and sodium aluminate (NaAlO$_2$·5H2O; 3.7558 g) were added to a beaker which was then placed on a hotplate/stirrer (190° C; 240 rpm). Simeltaneously, distilled water (50 mL) was brought to a boil. Sodium silicate (Na$_2$SiO$_3$·5 H$_2$O; 2.6523 g) was added to the boiling water and stirred. Once both solutions were at a gentle boil, the sodium silicate solution was added to the sodium aluminate solution and held at 90° for 60 minutes while stirring. Lastly, the entire soultion was split between two centrifuge tubes (15 mL each) and placed in a centrifuge for 10 minutes at 5000 rpm.

2.2 Synthesizing the Magnetized Zeolites

Reference section 2.1. Synthesizing magnetized zeolites shares the same process as synthesizing regular zeolites, however, after holding the solution for 60 minutes, $FeCl_3$ (0.78 g) and $FeSO_4 \cdot 7\,H_2O$ (0.39 g) were then added until fully dissolved. Lastly, the same centrifuge step was applied and this solution was placed in a centrifuge for 10 minutes at 5000 rpm.

2.3 Preparing Samples for Spectrometer

First, a beaker was filled (100 mL) with a red dye stock solution (.05mM; procion red). Three centrifuge tubes were then filled (15ml each) with the red dye stock solution and either contained regular zeolite (.1021 g), magnetized zeolite (.1009 g), or coal (.1032 g; which was grinded with a mortar and pestle). The tubes were then placed in a centrifuge for 10 minutes at 2000 rpm. While the tubes were in the centrifuge, three serial dilutions of the stock solution (50%, 25%, and 12.5%) were made using a 5 mL pipet and a 10 mL volumetric flask. The samples containing the precipitants were allowed to sit for 5 minutes and soak up the red dye. Lastly, each precipitant solution was filtered into a cuvette for use in the spectrometer.

2.4 Data Collection

All solutions were placed inside of cuvettes in preparation for use with a spectrometer. A spectrometer was connected to a computer and calibrated with distilled water using the software Logger *Pro*. After calibrating the device, the stock solution was placed in the spectrometer and spectra data was collected to find λ_{max}. Lastly, the absorption for each sample was then collected at λ_{max}.

3 Results and Discussion

3.1 Data Summary

For section 2.4, it was found that λ_{max} was 535.5 nm for the red dye. This value corresponds with the wavelength where the absorption of the dye is at its maximum. According to Beer's Law, $A = \varepsilon bc$, where A is absorbance, b is the path length (cm), ε is the molar absorptivity ($mM^{-1} \cdot cm^{-1}$), and c is the concentration (mM). To find the concentrations of the precipitant solutions, a calibration curve was first made using the concentration and absorption data of the diluted samples to get an equation that represents the graph. The equation of the best-fit line was found to be $y = 13.286x$, which is Beer's Law $A = \varepsilon bc$.
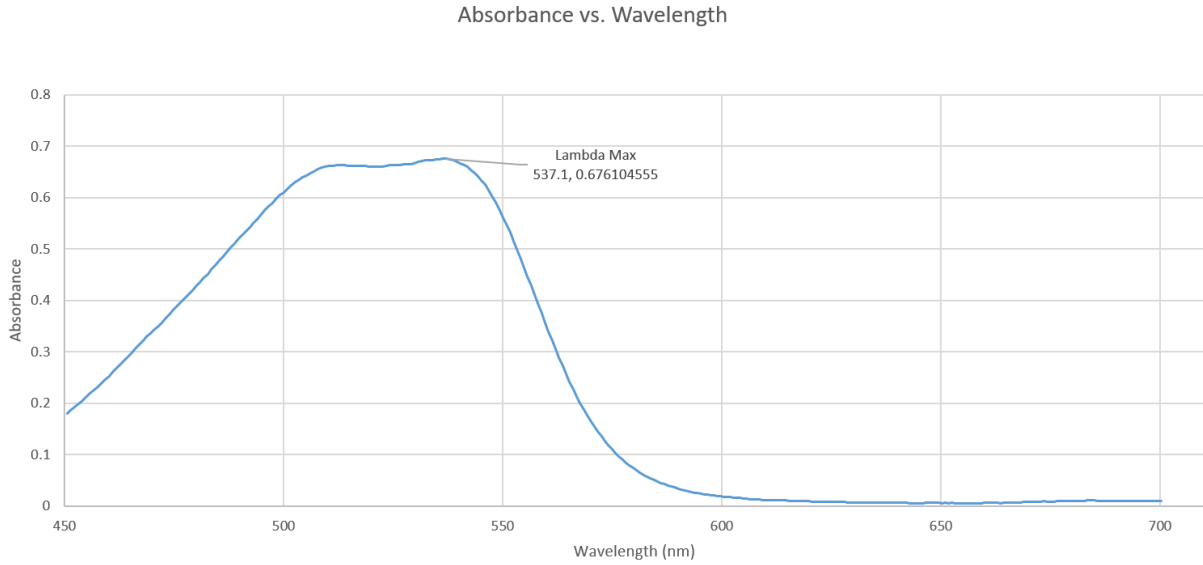
Figure 1: The absorbance vs. wavelength plot for the undiluted sample of procion red.

$$A = \varepsilon bc$$

$$c = \frac{A}{b \cdot \varepsilon}$$

$$c_{\text{coal solution}} = \frac{0.335}{13.286} \approx .025215 \text{ mM}$$

$$c_{\text{zeolite solution}} = \frac{0.382}{13.286} \approx .028752 \text{ mM}$$

$$c_{\text{mag zeolite solution}} = \frac{0.312}{13.286} \approx .002348 \text{ mM}$$

Table 1.1 summarizes the absorption for each sample at λ_{max} and the remaining concentrations of the preciptant solutions. The 'Corrected Absorbance' column is the difference between the sample's absorption at 535 nm and its absorption at 750 nm.

Sample	Concentration (mM)	Absorption (535.5 nm)	Absorption (750 nm)	Corrected Absorbance
100% .05mM Red Dye	.05	.666241	-	-
50% .05mM Red Dye	.025	.323556	-	-
25% .05mM Red Dye	.0125	.166226	-	-
12.5% .05mM Red Dye	.00625	.101474	-	-
Charcoal Solution	.025215	.400	.065	.335
Zeolite Solution	.028752	.440	.058	.382
Magnetized Zeolite Solution	.002348	.368	.056	.312

Table 1: The concentration of each solution and its absorbance at $\lambda_{\max}$.

Therefore, based on Table 1.1, the magnetized zeolite solution has the lowest corrected absorbance which refers to being more efficient at absorbing the red dye stock solution.

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These results suggest that magnetized zeolite is superior to charcoal and regular zeolite in absorbing procion red.

3.2 Discussion

There are a few parameters that can be used to compare the usefulness of charcoal to zeolites. One parameter is the method used in this experiment-absorptivity. A second parameter is the magnetic properties of each precipitant. The magnetic property of the material could effect the ability to absorb PAHs. Lastly, another parameter that could be of importance when choosing a material is the availability and cost of each. When deciding one material over the other, a few things the EPA should consider is the biodegradable property of each material, whether or not they give off harmful by-products, and their effects on the animals and ecosystem in which they were being placed.

The structure of procion red and Benzo(a)pyrene are similar to an extent. The structures are close enough for procion red to act as a suitable model for PAHs. Procion red is a fairly flat molecule and can be absorbed through intercalation.

A few possible sources of errors include (a) not making sure the cuvettes were entirely clean before placing them in the spectrometer, (b) one filter paper filtering a solution better than another filter paper, (c) not cleaning the lens on the spectrometer where the light is shot out of, and (e) having contaminates inside of the solutions such as small dirt particles or other things that would hinder the passage of light through the solution.

4 Conclusion

This experiment was performed to compare the usefulness of coal, zeolites, and magnetized zeolites in absorbing a red dye solution with hopes of applying this to absorbing harmful PAHs in the environment. It was found that magnetized zeolites absorbed more red dye than did coal and regular zeolites. This experiment successfully determined which precipitant is the most useful in absorbing procion red, and potentially the most useful in absorbing PAHs.

References

[1] Sudip K. Samanta, Om V. Singh, and Rakesh K. Jain. Polycyclic aromatic hydrocarbons: environmental pollution and bioremediation. *Trends in Biotechnology*, 20(62):243–248, 6 2002.

    KEY: PAH

[2] George R. Southworth. The role of volatilization in removing polycyclic aromatic hydrocarbons from aquatic environments. *Bulletin of Environmental Contamination and Toxicology*, 21(1):507–514, 1979.

    KEY: Southworth1979