UNIVERSITY OF ALABAMA
Department of Physics and Astronomy

PH 125 / LeClair Spring 2009

Project Memo

The following is due 6 March 2009 at the end of the day.

In order to ensure progress on our ballistics project, I would like you to write me a short memo regarding your plans. Along with this memo, you should provide some preliminary data as evidence of your progress – for instance, motion graphs for your rockets in free-fall (i.e., $x(t)$, $v(t)$).

Some of the things you should discuss in your memo are:

- What are the appropriate equations of motion for your projectile, including drag? (You do not need to solve them . . . yet.)
- You will have the ability to measure target *distances*, but nothing more. What else do you need to know to set up your launch?
- What quantities can be determined experimentally ahead of time?
- What parameters should be controlled at launch time?
- What are your potential sources of error, and how can you characterize them?
- Discuss how you will determine how to hit a given target. Keep in mind the target may not be at the same height as your launcher. What parameters are required as input? What are the launch parameters to be determined?
- Very briefly, describe an algorithm for determining the launch parameters in terms of the experimental quantities you will know at launch time.

Some quantities you may want to think about are: launch velocity, drag force (velocity-dependent in general), launch angle, target distance, target height. Keep in mind as well that you will have one rocket launcher, turret control software, and one distance sensor.

Your memo should be approximately 1-2 pages, with one memo per group (with all group members' names on the memo). The next page contains a possible format for your memo.

Memorandum

To : Jebediah Q. Dingus, Product Development Manager, Poly(vinyl alcohol) Inc.

From : Patrick R. LeClair

Re : 40-60% Hydrolyzed poly(vinyl alcohol)

Date : March 7, 1996

Background

We have received your request to produce poly(vinyl alcohol) with a hydrolysis degree of 40-60%. Since the monomer which gives rise to poly(vinyl alcohol) (PVA) is unstable, and given the request for a specific degree of hydrolysis, we decided that a base-catalyzed hydrolysis of poly(vinyl acetate) with methanol and sodium hydroxide was the most practical way to perform this task. Fourier-transform infared spectroscopy (FT-IR) was used to characterize PVA samples with known degrees of hydrolysis; this data was used as a calibration for determining the degree of hydrolysis in our samples. A specific set of conditions yielding the desired range of hydrolysis has been found, and the accuracy of these results has been gauged. Suggestions for further characterization are given, in the event that a more refined range of hydrolysis is required.

Experimental Techniques

Since we are interested in finding out what fraction of carbonyl groups in poly(vinyl acetate) have been hydrolyzed to hydroxyl groups (thus forming poly(vinyl alcohol)), the sensitivity of FT-IR spectra to specific functional groups, as well as their relative quantities, makes it a near ideal characterization technique. By comparing the ratio of carbonyl intensity (peaks in the 3700-3000cm^{-1} region) to hydroxyl intensity (peaks in the 1900-1600 cm^{-1} region), the degree of hydrolysis can be inferred from a calibration plot (see following section).

Calibration Plot

PVA samples of known degrees of hydrolysis (0,80,88, and 98%) were cast into thin film form and analyzed with a Magna-IR 860 Spectrometer. From the Beer-Lambert law, we know $\mathrm{I}_{OH} = k_{OH}Nct$ and $\mathrm{I}_{CO} = k_{CO}N(1-c)t$, where I is the band intensity for hydroxyl and carbonyl groups respectively (*i.e.* the area under the carbonyl and hydroxyl peaks), k is a constant, N is the total number of acetate groups present initially, c is the percent hydrolysis, and t is the film thickness. Since our films were of unknown thickness, the ratio of $\frac{I_{OH}}{I_{CO}} \propto \frac{c}{1-c}$ was calculated for each sample, to remove any thickness dependence. By fitting a line to the intensity ratios we obtained for the samples with known degrees of hydrolysis, we obtained a calibration plot of $\frac{I_{OH}}{I_{CO}}$ *vs.* $\frac{c}{1-c}$ which was used to characterize later samples. (See figure 1.) From this analysis, we found that $\frac{I_{OH}}{I_{CO}} = 0.9508\frac{c}{1-c}$. For brevity, the FT-IR spectra themselves have been omitted, but are available upon request.

Experimental Procedure – Hydrolysis of PVA

In order to hydrolyze the poly(vinyl acetate) starting material, a small amount of the acetate was dissolved in methanol. Small aliquots of the acetate-methanol solution were withdrawn in 15 minute intervals and immediately mixed with a methanol-sodium hydroxide solution to stop the hydrolysis reaction. Small droplets of the resulting solution were placed on a Teflon filter to be analyzed *via* FT-IR. Intensities of the carbonyl and hydroxyl groups were calculated for each time interval, and their ratios were used along with the calibration plot to obtain a plot of

percent hydrolysis *vs* reaction time. (See figure 2.) Teflon was used in this case since it has no appreciable absorption in the carbonyl or hydroxyl regions.

Results and Discussion

As seen in figure 2, there is some scatter in the data obtained. Specifically, the data point at 45 minutes seems to be in error; if it is excluded, the data seem quite consistent. With the inclusion of the data at 45 minutes, we obtain a reaction window of approximately 27-40 minutes; with the exclusion of the 45 minute point, the upper limit is increased to approximately 47 minutes. However, these exact numbers should not be taken too seriously; too few points were taken to allow such accuracy. However, it should be noted that the 30 minute sample was approximately 50% hydrolized; keeping reaction time within $\pm$3-5 minutes of that should yield samples in the desired range of hydrolysis. Further, the calibration plot included no samples with intermediate degrees of hydrolysis; the accuracy of the calibaration is difficult to gauge in that region.

Conclusion

Samples of PVA with varying degrees of hydrolysis were prepared by the base-catalyzed hydrolysis of poly(vinyl acetate). The desired 40-60% hydrolysis seemed to occur for reaction times of approximately 25-40 minutes; in order to reliably produce samples in the desired range, a reaction time of 30 minutes ($\pm$3-5 minutes) is suggested. To improve the accuracy of these results, the hyrolysis experiment should be repeated, examining the 25-45 minute (approximately) region more closely (perhaps withdrawing samples every 5 minutes), if further refinement is required.