# Chapter 8

# Conclusion

We have built and demonstrated a Penning trap which accumulates positrons from a 10 mCi sodium-22 source at a rate of 0.2 positrons per second. Positrons are stored under cryogenic (4 K), ultra-high vacuum ($< 5 \times 10^{-17}$ Torr) conditions and are counted non-destructively via their interaction with a detection circuit, so positron loss from the trap is inconsequential. In one demonstration, positrons loaded steadily for 52 hours, yielding more than $3.6 \times 10^4$ trapped positrons. Larger numbers are anticipated with longer accumulation times. At the demonstrated rate, $1.2 \times 10^5$ positrons would accumulate in one week, and $10^6$ in two months.

The use of a positron moderator is an important feature of our apparatus. In order to achieve a high trapping rate, the moderator must eject positrons with a high efficiency $\eta$ and a small energy spread $\Delta$E. Field emission point arrays are very useful for cleaning and annealing moderators at temperatures exceeding 2000 K inside the sealed, cryogenic, high magnetic field environment of the trap. Unfortunately, we encountered some difficulties with the long-term reliability of these devices in this environment. When this problem is solved, we hope to optimize the moderator performance. Achieving values of $\eta$ and $\Delta$E equivalent to the best reported in the literature would increase our trapping rate by a factor of 4 or more.

The demonstrated positron loading rate depends on bias voltages and other trapping parameters as expected. The maximum trapping rate we measure is within our expectations, based upon positron dynamics in the trap and detailed calculations of the electrostatic potentials near the trap entrance apertures. Several modifications to the Penning trap apertures, the loading tubes, the damping circuit, and the position of the radioactive source in the magnetic field would potentially increase the trapping rate by as much as two additional orders of magnitude or more.

Trapped positrons could be useful as a buffer plasma to cool and trap highly stripped ions. The trap vacuum enclosure, liquid helium dewar, superconducting magnet, support apparatus, and detection electronics used in this experiment are all nearly identical to those used to capture, accumulate, and study antiprotons in a Penning trap. The number and density of trapped positrons achievable with this apparatus are sufficient to produce antihydrogen at a high rate when the cold, trapped plasmas of antiprotons and positrons are mixed. Studies of antihydrogen would provide important tests of CPT invariance and the weak equivalence principle.