Spin-Exchange Optical Pumping (SEOP) uses high power laser light to spin-polarize optically thick vapors of heavy alkali-metal atoms (K, Rb, Cs) in the presence of noble-gas atoms such as $^3$He and $^{129}$Xe. The alkali-metal and noble-gas atoms interact via binary collisions and (for Xe) in van der Waals molecules. When the electron clouds of the two atoms overlap, there are hyperfine interactions between the alkali-metal electrons and the noble-gas nuclei that cause polarization-transfer, a.k.a. spin-exchange, back and forth between the two species. Because the laser light continuously and quickly replenishes any electron spin-polarization loss to the noble-gas nuclei, the electrons remain highly polarized while the noble-gas nuclear polarization slowly builds up to its equilibrium value. If the whole process occurs in a glass cell with nuclear spin-relaxation times that are much longer than the alkali-noble-gas spin-exchange times, in principle the noble-gas polarization approaches unity, with each polarized nucleus requiring on the order of a few 10s of photons.

The above simple picture of SEOP [1] was elucidated in the 1980s by experiments done with watt-scale lasers and even resonance lamps. With the advent in the early 1990s of diode lasers with 10s to 100s of watts of power, pioneers applied SEOP to make high performance spin-polarized targets and to image human air spaces in the 1990s. Impressive as the advances in these and other applications of SEOP were, the quantities of polarized gas that were produced were never as large as predicted by simple scaling of known SEOP physics. Over the past 20 years, many but certainly not all the issues that affect high-throughput SEOP have been elucidated. The insights so obtained have in many cases allowed the polarized gas throughput to steadily improve. A bar-graph of SEOP neutron spin-filter performance, adapted from [2], shows about 2 orders of magnitude improvement over that time period.

This talk will cover the "theoretical minimum" of SEOP—what, in the speaker’s opinion, SEOP researchers ought to know, or know they don’t know. The “know” category includes the significance of spectrally narrowed lasers, the use of alkali mixtures (hybrid SEOP), the temperature dependence of wall relaxation, using EPR spectroscopy for absolute noble-gas polarimetry, and the pressure/magnetic field dependence of molecular spin-exchange. What we “don’t know” includes matters such as how high internal gas temperatures affect SEOP, the formation and effects of particulates, the effects of walls on flowing Xe SEOP, why the temperature dependence of wall relaxation seems to be going away, if there is persistent molecular spin-exchange at atmospheric pressures...

For $^3$He, there seemed to some of us that there was enough in the “know” category to justify describing the current state of the art in [2]. For $^{129}$Xe, the situation seems much more chaotic and the speaker hopes that this conference will help clarify the situation, or at least identify the most important issues that need addressing to realize the full potential of $^{129}$Xe SEOP.

This work is supported by the National Science Foundation and Northrop-Grumman Corp.