1) a) f is amplitude of scattered wave as in $f \frac{e^{ikr}}{r}$. As a result $|f|^2 = \frac{d\sigma}{d\Omega}$

For large r the exact solution to SE will be $\frac{1}{r}\cos(kr - \frac{\pi}{2}(\ell+1) + \delta_\ell)$
whereas in the absence of a potential " " $\frac{1}{r}\cos(kr - \frac{\pi}{2}(\ell+1) + 0)$
so $\delta_\ell$ is a phase shift caused by potential

3) For small k, eg $k = .5$, the plots show $\delta_1 \,\&\, \delta_2 \sim \pi$, $\delta_\ell = 0$ for $\ell > 2$
ie only $\delta_0$ is significant ($\sin\delta \neq 0$)
so $\sum_\ell$ in formula for f reduces to $\ell = 0$ term alone so $f \sim P_0(\cos\theta)$ which is a constant

At $k = 1.4656$ both $\delta_0$ & $\delta_3$ are significant
so $f \sim P_0 + P_3 \rightarrow |P_3|^2$ by itself has zeros at $\cos\theta = 0, \pm .77$ ie $\theta = .69, \pi/2, 2.5$
which is a good match ↖ $\sqrt{\frac{3}{5}}$

Note that $\sin(\delta_3)$ is zero both for k a bit less than 1.4656 and for k greater than 1.4656 — so there will be an extra contribution to $\sigma$ just at $k = 1.4656$ — ie a resonant peak