1) air $20\%\ O_2 \rightarrow 32\ g/mol$

$80\%\ N_2 \rightarrow 28\ g/mol$

Average molar mass

$$0.2(32\ g/mol) + 0.8(28\ g/mol) = \underline{28.8\ g/mol}$$

$$p = \rho RT$$

$$\rho = \frac{p}{RT} = \frac{101325\ Pa}{(287\ J/kg\,K)(288\ K)} = 1.226\ kg/m^3$$

$$28.8\ g/mol = 0.0288\ kg/mol$$

$$0.0288\ \frac{kg}{mol}\left(\frac{1\ mol}{6.022\times10^{23}\ particles}\right)$$

$$= 4.78\times10^{-26}\ kg/particle$$

$$V = \left(\frac{4.78\times10^{-26}\ kg/particle}{1.226\ kg/m^3}\right)\left(10^6\ particles\right)$$

$$= 3.9\times10^{-20}\ m^3$$

$$a = \sqrt[3]{V} = \sqrt[3]{3.9\times10^{-20}\ m^3} = \boxed{3.4\times10^{-7}\ m}$$

2) $\rho = 1000\ kg/m^3$

molar mass $H_2O = 18\ g/mol = 0.018\ kg/mol$

$$0.018\ \frac{kg}{mol}\left(\frac{1\ mol}{6.022\times10^{23}\ particles}\right) = 3.0\times10^{-26}\ \frac{kg}{particle}$$

$$V = \left(\frac{3.0\times10^{-26}\ kg/particle}{1000\ kg/m^3}\right)(10^6\ particles)$$

$$= 3\times10^{-23}\ m^3$$

$$a = \sqrt[3]{V} = \sqrt[3]{3\times10^{-23}\ m^3}$$

$$\boxed{a = 3.1\times10^{-8}\ m}$$

2) left prob:

$$P_L = P_R \Rightarrow \rho_{oil}(3\,cm) + \rho_{Hg}(0.5\,cm) = \rho_{H_2O}(h)$$

$$h = \frac{\rho_{oil}(3\,cm) + \rho_{Hg}(0.5\,cm)}{\rho_{H_2O}} = \frac{(925\ kg/m^3)(3\,cm) + (13594\ kg/m^3)(0.5\,cm)}{1000\ kg/m^3}$$

$$\boxed{h = 9.57\,cm}$$

right prob:

$$P_L = P_R$$

$$\rho_L(6\,cm) + \rho_{H_2O}(1\,cm) = \rho_{Hg}(0.25\,cm)$$

$$\rho_L = \frac{\rho_{Hg}(0.25\,cm) - \rho_{H_2O}(1\,cm)}{6\,cm}$$

$$= \frac{13594\ kg/m^3(0.25\,cm) - 1000\ kg/m^3(1\,cm)}{6\,cm} = \boxed{400\ kg/m^3}$$