1) This problem is just a stoichiometry problem presented slightly differently. We have the balanced equation which tells us that pyruvic acid and carbon dioxide are in a 1:1 molar ratio. So when we determine the number of moles of CO$_2$, we also have the number of moles of pyruvic acid. Here we go.

\[
n = \left( \frac{394 \text{ mmHg}}{760 \text{ mmHg/atm}} \right) \left( \frac{0.0224 \text{ L}}{0.08206 \text{ Latm/Kmol}} \right) (310.15 \text{ K}) = 4.563 \times 10^{-4} \text{ moles CO}_2 \text{ and therefore, pyruvic acid.}
\]

The M$_m$ of pyruvic acid is: 88.063 g/mol, so we have \((88.063 \text{ g/mol})(4.563 \times 10^{-4} \text{ moles}) = 0.0402 \text{ g or 40.2 mg of pyruvic acid.}

2) Our analysis by mass means that out of 100 g of material, we have 34.4 g He, 51.6 g N$_2$ and 14.0 g O$_2$. Converting all of these masses into moles, we get:

\[
\text{moles He} = \frac{34.4 \text{ g}}{4.0026 \text{ g/mol}} = 8.59 \text{ moles}; \text{ moles N}_2 = \frac{51.6 \text{ g}}{28.0134 \text{ g/mol}} = 1.84 \text{ moles}; \text{ moles O}_2 = \frac{14.0 \text{ g}}{31.9988 \text{ g/mol}} = 0.438 \text{ moles}, \]

which gives us a total mole count of 10.868 moles.

Substituting all the information into PV = nRT, we can get the volume, V, occupied, and from that, the density. Rearranging, we get V = \(\frac{10.868 \text{ moles}(0.08206 \text{ Latm/Kmol})(290.15 \text{ K})}{4.94 \text{ atm}}\) = 52.38 L. We have 100 g of material in 52.38 L, so we have a density, \(\rho = \frac{100 \text{ g}}{52.38 \text{ L}} = 1.91 \text{ g/L} \).

3) The balanced equation is either:

\[
2 \text{ HCl} + \text{ Na}_2\text{CO}_3 \rightarrow \text{ H}_2\text{O} + \text{ CO}_2 + 2 \text{ NaCl}
\]

or

\[
\text{H}_2\text{SO}_4 + \text{ Na}_2\text{CO}_3 \rightarrow \text{ H}_2\text{O} + \text{ CO}_2 + \text{ Na}_2\text{SO}_4.
\]

We are given the volume of CO$_2$ produced, the temperature and pressure, and the concentration and volume of the acid used. From all these, we can make the necessary determination. Using PV = nRT, we can get the number of moles of CO$_2$, which is: n =
\[
\left( \frac{722 \text{ mmHg}}{760 \text{ mmHg/atm}} \right) \left( 0.125 \text{ L} \right) / \left( 0.08206 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol} \right) (298.15 \text{ K}) = 5.0 \times 10^{-3} \text{ moles CO}_2. \]

From the volume and molarity of the acid given, we can get the number of moles of acid used: moles acid = (0.2040 M)(0.04890 L) = 1.02 \times 10^{-2} \text{ moles acid}. Since the number of moles of acid = 2(\text{moles CO}_2), the only stoichiometric equation which fits is that for HCl, so we have hydrochloric acid, HCl.

4) Given: \[ \text{ZnS}_\text{(s)} + 2 \text{ HCl}_\text{(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{S}_\text{(g)} \]
\[ \text{PbS}_\text{(s)} + 2 \text{ HCl}_\text{(aq)} \rightarrow \text{PbCl}_2\text{(aq)} + \text{H}_2\text{S}_\text{(g)} \]
6.12 g of a combined sample.
Volume of the H\text{2S} produced = 1.049 L at P = 754 mm Hg = 0.992 atm and T = 20° C = 293.15 K so \[ n = \frac{(0.992 \text{ atm})(1.049 \text{ L})}{(0.08206 \text{ L} \cdot \text{atm}/\text{K} \cdot \text{mol})(293.15 \text{ K})} = 0.0433 \text{ moles H}_2\text{S produced}. \]

Let \( x \) = g ZnS and \( y \) = g PbS. Then we can say:
\[ x + y = 6.12 \text{ or } y = 6.12 - x. \]
Call this equation A.

For every mole of ZnS present, we get one mole of H\text{2S}, and the same for PbS, we can say:
\[ \frac{x}{97.456} + \frac{y}{239.266} = 0.0433 \text{ mol. or } 1.026 \times 10^{-2} x + 4.179 \times 10^{-3} y = 0.0433 \text{ mol. moles H}_2\text{S from ZnS} \]
\[ \frac{x}{97.456} + \frac{y}{239.266} = 0.0433 \text{ mol. or } 1.026 \times 10^{-2} x + 4.179 \times 10^{-3} y = 0.0433 \text{ mol. moles H}_2\text{S from PbS} \]

Call the above equation B

Substituting A into B, we get:
\[ 1.026 \times 10^{-2} x + 4.179 \times 10^{-3} (6.12 - x) = 0.0433 \text{ mol.} \]
\[ 6.081 \times 10^{-3} x = 1.772 \times 10^{-2} \text{ so } x = 2.915 \text{ g and } y = \frac{3.205}{2.915} \text{ g} \]
\[ \% \text{ZnS} = \frac{(2.915/6.12) \times 100}{100} = 47.6\% \text{ and } \% \text{PbS} = \frac{(3.205/6.12) \times 100}{100} = 52.4\% \]

5) Since we are given a moveable piston, it seems reasonable to assume that the pressure is to remain constant. Here is an equation which might help:
\[ X_\text{(g)} + Y_\text{(g)} \rightarrow XY_\text{(g)} \]

This equation shows that two moles of gas are going to one mole of gas. Since the pressure (and, presumably, the temperature) are remaining constant, the only thing which can vary along with the number of moles is the volume, which must be decreasing. This is because, as said above, two moles of gas are going to one mole of gas. (Remember the ideal gas law is independent of the identity of the gas.)