1) We are told we have a group 3A metal (a.k.a. a Group 13 metal), so we have two possibilities for the balanced equation with HCl (the gas produced almost certainly is $H_2$, as $Cl_2$ is yellowish-green; also, the idea of producing a metal hydride in water is quite silly):

$$2M + 2HCl \rightarrow 2MCl + H_2 (M \text{ in the } +1 \text{ state})$$

$$M + 3/2 \text{ HCl} \rightarrow MCl_3 + 3/2 \text{ H}_2 (M \text{ in the } +3 \text{ state})$$

We also have a density, an edge length, and the volume of gas produced. Let’s start working with what we have.

a) The gas volume data tells us that we have:

$$n = \left( \frac{740 \text{ mm Hg}}{760 \text{ mm Hg / atm}} \right) \left( \frac{4.00 \text{ L}}{0.08206 \text{ L} \cdot \text{ atm / K} \cdot \text{ mole}} \right) = 0.160 \text{ moles} \text{ of gas.}$$

This datum means that we have either 0.320 moles of M (M in the +1 state) or 0.107 moles of M (M in the +3 state). The density data, coupled with the volume of the chunk of M gives us the mass of M represented by either of these two numbers of moles. The mass of M = (2.70 $g/cm^3$)(1.07 $cm^3$) = 2.889 $g$. If we have M$^+$, then this 2.889 $g$ represents 0.320 moles, which gives a $M_m$ of 9.03 $g/mol$. There is no Group 3A metal with this atomic molar mass. Therefore, we must have M$^{3+}$, so 2.889 $g$ represents 0.107 moles, giving a $M_m$ = 27.08 $g/mol$ which is sufficiently close to Al to make the identification as Al.

b) The cubic cell data gives us:

$$V = l^3 = (404 \times 10^{-10} \text{ cm})^3 = 6.594 \times 10^{-23} \text{ cm}^3$$

This mass data, plus the knowledge that M = Al, allows to proceed as follows. One atom of Al has a mass of:

$$\frac{26.982 \text{ g / mol}}{6.022 \times 10^{23} \text{ atoms / mol}} = 4.481 \times 10^{-23} \text{ g.}$$

The mass of the unit cell needs to be either 1, 2, or 4 times this value. (Recall the number of atoms per unit cell for each of the three cubic types.) Therefore, dividing the mass of the unit cell by the mass of one atom gives us the number of
atoms/unit cell, and from that, the unit cell type. Here it is: \[
\frac{1.78 \times 10^{-22} \text{ g}}{4.48 \times 10^{-23} \text{ g/atom}} = 3.97 \approx 4
\]
so the unit cell is **face-centered cubic**.

c) For the face-centered cubic unit cell, we know (or can derive, as we did in class) that edge length, \( l = 2r\sqrt{2} \), so \( r = \frac{l}{2\sqrt{2}} = \frac{404 \text{ pm}}{2\sqrt{2}} = 143 \text{ pm} \).

2) From the volume, temperature and pressure of the argon, can determine the number of moles of argon thus: \( P = 760 \text{ mm Hg} = 1.0 \text{ atm}, V = 25.0 \text{ L}, T = 80.0^\circ \text{C} = 353.15 \text{ K} \), so \( n = \frac{PV}{RT} = \frac{(1.0 \text{ atm})(25.0 \text{ L})}{((0.08206 \text{ L} \cdot \text{atm/K} \cdot \text{mol})(353.15 \text{ K}))} = 0.863 \text{ moles} \). This same number of moles of argon are present after the experiment. For the water, 7.30 g are found to have evaporated; \( M \_\text{m} \) of water = 18.02 g/mol. so the number of moles of **water** = \( \frac{7.30 \text{ g}}{18.02 \text{ g/mol}} = 0.405 \text{ moles} \). Recall the Law of Partial Pressures, and note that the total number of moles of gas (vapor) present is: \( 0.863 + 0.405 = 1.268 \text{ moles} \). The mole fraction of water is \( \frac{0.405}{1.268} = 0.319 \), and the **vapor pressure of the water** is \( (\text{mole}_\text{fraction})(\text{total}_\text{pressure}) = (0.3195)(760 \text{ mm Hg}) = 242.74 \text{ mm Hg} \). (Not in terribly good agreement with the textbook value of 355.1 mm Hg, but one does what one can!)

3) To do this problem, we need to recognize that three thermochemical equations to consider:

\[
\text{Hg}_\text{(s)} (-50^\circ \text{C}) \rightarrow \text{Hg}_\text{(s)} (-38.9^\circ \text{C}) \quad \text{heat needed to raise the temperature of the solid}
\]

\[
\text{Hg}_\text{(s)} \rightarrow \text{Hg}_\text{(l)} \quad \text{heat of fusion for the Hg.}
\]

\[
\text{Hg}_\text{(s)} (-38.9^\circ \text{C}) \rightarrow \text{Hg}_\text{(s)} (+50.0^\circ \text{C}) \quad \text{heat needed to raise the temperature of the liquid}
\]

We also have 7.50 g of Hg, which represents \( \frac{7.50 \text{ g}}{200.59 \text{ g/mol}} = 3.74 \times 10^{-2} \text{ moles} \).

Here are the calculations:
\[
(3.74 \times 10^{-2} \text{ moles})[\{(11.1^\circ \text{C})(28.2 \text{ J/}^\circ \text{C} \cdot \text{mol}) + (2330 \text{ J/mol}) + (88.9^\circ \text{C})(27.9 \text{ J/mol} \cdot ^\circ \text{C})\}] = 191.6 \text{ J} (=0.192 \text{ kJ}) \text{ of heat is needed.}
\]

4) From the total vapor pressure of 146 mm Hg (=0.192 atm), and the given density of 0.702 g/L, we can get the **average** molecular mass of the vapor: \( M_m = (dRT)/P \) or \( M_m = \)
(0.702 g/L)(0.08206 L•atm/K•mol)(344.45 K)/(0.192 atm) = 103.346 g/mole. The $M_m$ of acetic acid monomer is: 60.05268 and of the dimer is $M_m=120.10536$. Let $A =$ mole fraction of monomer and $B =$ mole fraction of dimer. Then we know: $A + B = 1$ and $60.05268A + 120.10536B = 103.346$ (average molar mass equals the sum of the relative percents of the two components contributing to it.) Since we are after dimer, solve the first equation for $A$ in terms of $B$ and substitute into the second. This gives:

$$60.05268 (1-B) + 120.10536B = 103.346$$ or

$$60.05268 + 60.05268B = 103.346$$ which goes to: $60.05268B = 43.29332$ and $B = \textbf{0.721 or 72.1\% dimer}$ in the vapor.

5) Looking at problem 3 above sort of gives us a hint on this question. Water vapor at 100°C, upon contacting your skin, first has to condense from the vapor phase to the liquid phase, all at 100°C, before it can start to cool down. Liquid water, on the other hand, can start to cool immediately. The heat from the vapor to your skin is greater, thereby inducing greater damage, and a more severe burn.