Work of expansion for a chemical reaction

If Zn metal reacts with HCl to generate H_2 gas the reaction generates heat and does work as the H_2 gas expands against atmospheric pressure. If 6 grams of Zn metal reacts with 1 M HCl in 0.2 L of solution, what Is the work of expansion against the atmosphere?

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Solution: Step 1. Write a balanced reaction

$$Zn(s) + 2\,HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Step 2. Calculate the number of moles of each reagent

$$n_{Zn} = \frac{m}{M_m} = \frac{6\ gm}{65.4\ gm/mol} = 0.092\ mol$$

$$n_{HCl} = c_{HCl}V_{HCl} = (1\ M)(0.2\ L) = 0.2\ mol$$

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Solution: Step 3. Compare the actual molar ratio to the stoichiometry. The actual ratio is

$$\frac{n_{HCl}}{n_{Zn}} = \frac{0.2}{0.092} = 2.17$$

which is greater than the stoichiometric ratio of 2. Therefore, there is an excess of HCl and Zn is the limiting reagent.

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Step 4. Calculate the yield of H_2 gas. Since H_2 has a 1:1 mole ratio with Zn, there are 0.092 moles of H_2 gas produced. Therefore, the work of expansion is:

$$w = -\Delta nRT$$

$$w = -(0.092\ mol)\left(8.31\ \frac{J}{molK}\right)(298\ K)$$

$$w = -227\ Joules$$