

### Question #57790, Chemistry / Physical Chemistry

A 0.3 M solution of HCl with a volume of 450 ml is poured into a chemically resistant balloon which contains excess zinc metal and which is otherwise empty. The balloon is immediately sealed. The HCl in solution completely reacts with the zinc metal, forming zinc ions and H<sub>2</sub> gas that expands the balloon. Assuming that balloon expands against constant pressure of 1.10 atm at the constant temperature of 20 °C, calculate the expansion work done by the gas. Assume that gas is ideal and that the volume of the liquid does not change.

#### Answer:

Work done by gas  $W$ , which expands at constant pressure  $p$ , can be calculated as:

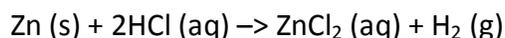
$$W = p \cdot \Delta V$$

In our case the change of volume  $\Delta V$  is equal to the volume of produced hydrogen  $V(H_2)$ . We can find it, taking in account the external conditions ( $T$ , K and  $p$ , Pa):

$$V(H_2) = V_0(H_2) \cdot p_0 \cdot T / (p \cdot T_0)$$

Where  $V_0(H_2)$  – volume of hydrogen, calculated from the chemical reaction equation at STP ( $T_0 = 273$  K,  $p_0 = 101325$  Pa).

According to the task conditions, a following reaction takes place:



As we can see, 2 moles of hydrochloric acid produce 1 mol (or 22.4 L at STP) of hydrogen. Amount of substance of the acid can be found as:

$$n(\text{HCl}) = C(\text{HCl}) \cdot V(\text{HCl}) = 0.3 \cdot 0.45 = 0.135 \text{ mol}$$

Thus, volume of produced hydrogen and work, done by its expanding will be:

$$V_0(H_2) = n(\text{HCl}) \cdot 22.4 / 2 = 1.51 \text{ L} = 1.51 \cdot 10^{-3} \text{ m}^3$$

$$W = p \cdot V(H_2) = V_0(H_2) \cdot p_0 \cdot T / T_0 = 1.51 \cdot 10^{-3} \cdot 101325 \cdot (20+273) / 273 = 164 \text{ J}$$