An Example of Calorimetry

Problem 7-32

A "coffee-cup" calorimeter contains 100.0 mL of 0.300 M HCl at 20.3°C. When 1.82 g Zn(s) is added, the temperature rises to 30.5°C. What is the heat of reaction per mol Zn? Make the same assumptions as in Example 7-4, and also that there is no heat lost to the H_2(g) that escapes.

$$\mathrm{Zn(s)} + 2\,\mathrm{H^+(aq)} \rightarrow \mathrm{Zn^{2+}} + \mathrm{H_2(g)}$$

Solution:

Write the first law for the problem:

$$q_{\mathrm{rxn}} + q_{\mathrm{soln}} = 0$$
$$n\Delta H_{\mathrm{rxn}} + m_{\mathrm{soln}} c_{\mathrm{soln}} \Delta T_{\mathrm{soln}} = 0$$

The necessary assumptions are:

1) $c_{\mathrm{soln}} = 4.18 \frac{\mathrm{J}}{\mathrm{g \cdot °C}}$

2) $d_{\mathrm{soln}} = 1.00\ \mathrm{g/mL}$

$$n_{\mathrm{Zn}} = 1.82\ \mathrm{g} \big/ 65.39\ \mathrm{g/mol} = 0.02783\ \mathrm{mol\ Zn\ (excess\ reagent)}$$
$$n_{\mathrm{HCl}} = 0.100\ \mathrm{L} \times 0.300\ \mathrm{M} = 0.0300\ \mathrm{mol\ H^+}\ \mathrm{(limiting\ reagent)}$$
$$n_{\mathrm{Zn}}^{\mathrm{reacted}} = 0.0300\ \mathrm{mol\ H^+} \times \frac{1\ \mathrm{mol\ Zn}}{2\ \mathrm{mol\ H^+}} = 0.0150\ \mathrm{mol\ Zn}$$
$$m_{\mathrm{soln}} = 100.0\ \mathrm{g}$$
$$\Delta T = 30.5°\mathrm{C} - 20.3°\mathrm{C} = 10.2°\mathrm{C}$$

$$(0.0150\ \mathrm{mol})\Delta H_{\mathrm{rxn}} + (100.0\ \mathrm{g})\left(4.18 \frac{\mathrm{J}}{\mathrm{g \cdot °C}}\right)(10.2°\mathrm{C}) = 0$$
$$(0.0150\ \mathrm{mol})\Delta H_{\mathrm{rxn}} = -4263.6\ \mathrm{J}$$

$$\Delta H_{\mathrm{rxn}} = -284000 \frac{\mathrm{J}}{\mathrm{mol}} = -284 \frac{\mathrm{kJ}}{\mathrm{mol}}$$