Thermal Energy Transfer

Thermal energy flows from the hotter substance to the colder one

Example : hot metal submerged in water

metal : system
water : surrounding

$$q_{sys} = -q_{surr}$$

$$q_{metal} = -q_{surr}$$

$$m_{metal} \cdot c_{s,metal} \cdot \Delta T_{metal} = -(m_{H_2O} \cdot c_{s,H_2O} \cdot \Delta T)$$

A 20.0 g cube of Fe initially at 63.5°C is submerged in 150 g of water at 10°C. What is the final temperature of both substances at thermal equilibrium?

$C_s(Fe) = 0.499\ J/g°C \qquad C_s(H_2O) = 4.18\ J/g°C$

$$q_{Fe} = -q_{H_2O}$$

$$m_{Fe} \cdot C_s(Fe) \cdot \Delta T_{Fe} = -[m_{H_2O} \cdot C_s(H_2O) \cdot \Delta T_{H_2O}]$$

$$20.0g \cdot 0.499\ J/g°C \cdot \Delta T_{Fe} = -[150g \cdot 4.18\ J/g°C \cdot \Delta T_{H_2O}]$$

$$9.98\ J/°C\ \Delta T_{Fe} = -627\ J/°C\ \Delta T_{H_2O}$$

$$\Delta T_{Fe} = -62.83\ \Delta T_{H_2O}$$

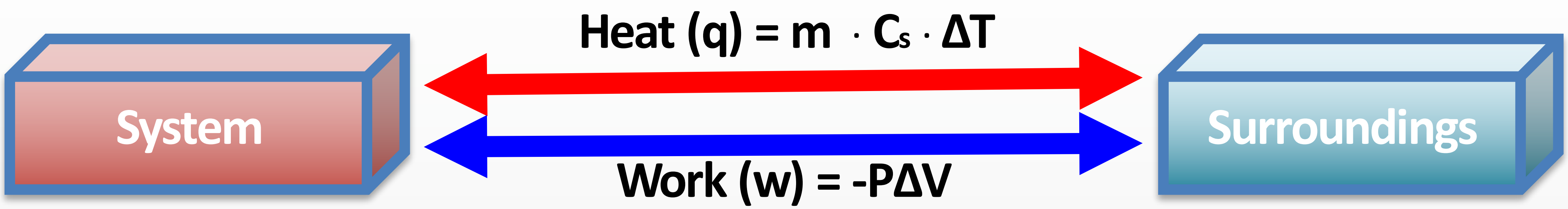
$$T_f - T_i(Fe) = -62.83\,(T_f - T_i(H_2O))$$

$$T_f + 62.83\,T_f = 62.83\,T_i(H_2O) + T_i(Fe)$$

$$63.83\,T_f = 62.83 \cdot 10°C + 63.5°C$$

$$T_f = 10.84°C$$

Constant Volume Calorimetry

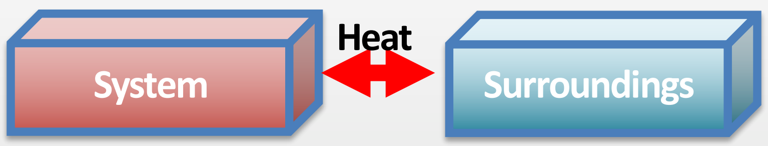


$$\Delta E = q + w$$

at constant volume $w = -P\Delta V = 0$

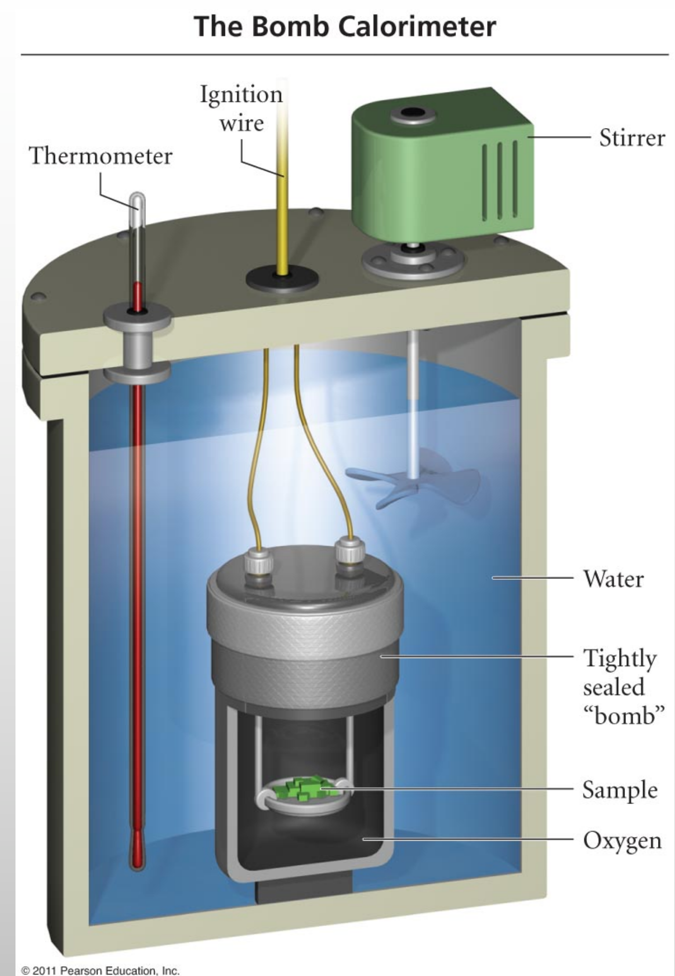
$$\Rightarrow \Delta E = q_v$$

Bomb Calorimetry



constant volume

observe change
In temperature



$$q = \underbrace{m \cdot C_s}_{C_{cal}} \cdot \Delta T$$

$$q_{cal} = C_{cal} \cdot \Delta T$$

$$q_{rxn} = -q_{cal}$$

$$q_{rxn} = \Delta E$$

When 0.514g of biphenyl $C_{12}H_{10}$ undergoes combustion in a bomb calorimeter, the temperature rises from 25.8°C to 29.4°C. Find ΔE_{rxn} !

$C_{cal} = 5.86\ kJ/°C$

$$q_{cal} = C_{cal} \cdot \Delta T = 5.86\ kJ/°C \cdot (29.4°C - 25.8°C)$$
$$= 21.1\ kJ$$

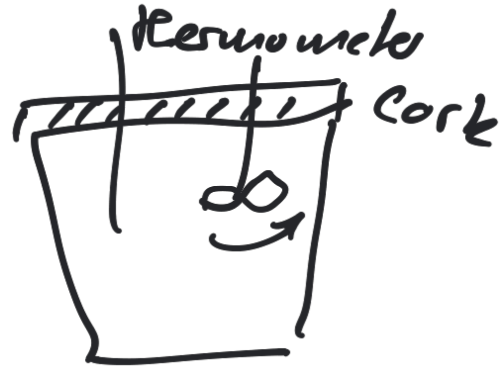
$$q_{rxn} = -q_{cal} = -21.1\ kJ$$

$$\Delta E_{rxn} = \frac{q_{rxn}}{\#\,moles}$$

$$\#moles\ (C_{12}H_{10}) = 0.514g \cdot \frac{1\,mol}{154.2g} = 0.00333\ mol$$

$$\Delta E_{rxn} = \frac{-21.1\ kJ}{0.00333\ mol} = -6.3 \cdot 10^3\ kJ/mol$$

Constant Pressure Calorimetry
(coffee cup calorimeter)



$$q_{soln} = m_{soln} \cdot C_{s,soln} \cdot \Delta T$$

$$q_{rxn} = -q_{soln}$$

$$q_{rxn} = q_p = \Delta H$$

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

when 0.103g of Zn is combined with enough HCl to make 50.0 mL of solution in a coffee cup calorimeter, all of Zn reacts, raising the temp. of the solution from 22.5°C to 23.7°C

Find ΔH_{rxn}. $d_{soln} = 1.00\ g/mL$ $\quad C_{s,soln} = 4.18\ J/g°C$

$$q_{soln} = m_{soln} \cdot C_{s,soln} \cdot \Delta T$$

$$m_{soln} = 50.0\ mL \cdot 1.00\ g/mL = 50.0\ g$$

$$q_{soln} = 50.0\ g \cdot 4.18\ J/g°C \cdot (23.7°C - 22.5°C)$$

$$q_{soln} = 250.8\ J$$

$$q_{rxn} = -q_{soln} = -250.8\ J$$

$$\#moles\ (Zn) = 0.103\ g \cdot \frac{1\ mol}{65.37\ g} = 0.00158\ mol$$

$$\Delta H_{rxn} = \frac{q_{rxn}}{\#moles} = \frac{-250.8\ J}{0.00158\ mol} = -1.6 \cdot 10^5\ J/mol$$

$$= -160\ kJ/mol$$

$$NH_4NO_3 \xrightarrow{H_2O} NH_4^+(aq) + NO_3^-(aq)$$

To measure the enthalpy change for this reaction, 1.25g of NH_4NO_3 is dissolved in enough H_2O to make 25.0 mL. The initial temp. is 25.8°C and the final temp. is 21.9°C

$d_{soln} = 1.00 g/mL \qquad C_{s,soln} = 4.18\ J/g°C$

$q_{soln} = 25.0g \cdot 4.18\ J/g°C \cdot (21.9°C - 25.8°C)$

$q_{soln} = -407.6\ J$

$q_{rxn} = -q_{soln} = +407.6\ J$

moles (NH_4NO_3) $\rightarrow \rightarrow$ 0.0156 mol

$\Delta H_{rxn} = \dfrac{407.6\ J}{0.0156\ mol} = 2.6 \cdot 10^4\ J/mol = 26\ kJ/mol$