A bomb calorimeter, or a constant volume calorimeter, is a device often used to determine the heat of combustion of fuels and the energy content of foods.

In an experiment, a 0.6738 g sample of benzoic acid (C7H6O2) is burned completely in a bomb calorimeter. The calorimeter is surrounded by 1.190×103 g of water. During the combustion the temperature increases from 25.91 to 28.80 °C. The heat capacity of water is 4.184 J g-1°C-1.

The heat capacity of the calorimeter was determined in a previous experiment to be 961.3 J/°C.

Assuming that no energy is lost to the surroundings, calculate the molar heat of combustion of benzoic acid based on these data.

C7H6O2(s) + (15/2) O2(g) 3 H2O(l) + 7 CO2(g) + Energy

Solution

We have a reaction of combustion, where heat is released. This heat is absorbed by water in calorimeter and calorimeter itself.

1. Find heat absorbed by water:
   $Q_{water} = cm\Delta T$;
   c= 4.184 J g-1°C-1;
   $m(H_2O)= 1.190\cdot10^3$ g= 1190 g;
   $\Delta T = T_2-T_1 = 28.80 – 25.91 = 2.89$ (°C);
   $Q_{water} = 4.184\cdot1190\cdot2.89 = 14389{,}19$ J.
2. Find heat absorbed by calorimeter:
   $Q_{cal}= C_{cal}\cdot\Delta T$;
   C_{cal} =961.3 J/°C;
   $\Delta T = T_2-T_1 = 28.80 – 25.91 = 2.89$ (°C);
   $Q_{cal} = 961.3\cdot2.89 = 2778.16$ J.
3. Find total heat absorbed by water and calorimeter:
   $Q_{surrounding} = Q_{water} + Q_{cal;}$
   $Q_{surrounding} = 14389.19 + 2778.16 = 17167.35$ (J)
4. Heat of combustion is the same in magnitude but opposite in sign(heat of combustion is the internal energy that is decreased while the external energy is increased).
   $Q_{reaction} = -Q_{surrounding} = -17167.35$ J.
5. Find molar heat of combustion:
   Chemical amount of benzoic acid $n(C_7H_6O_2)= m/M$;
   $M(C_7H_6O_2) = 12.01\cdot7 + 1.01\cdot6 + 16.00\cdot2 =122.13$ (g/mol);
   $n(C_7H_6O_2) = 0.6738/122.13 = 0.00552$ (mol).
   When 0.00552 mol of benzoic acid is burned -- heat of combustion is -17167.35 J,
   When 1 mole of benzoic acid is burned – heat of combustion is x J.

0.00552/1 = -17167.35/x;

x= -3110027.17;

ΔH_{comb} = -3110027.17 J/mol = -3110kJ/mol

Answer: -3110kJ/mol