Calorimetry

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the science of measuring heat

based on observing the temperature change when a body absorbs or discharges energy as heat.

$$q = nC\,\Delta T$$

moles

grams

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Molar heat capacity

Specific heat capacity

Heat Capacity (C)

the amount of heat needed to raise the temperature of a certain amount of material 1K or 1°C

Molar heat capacity $\frac{J}{K\ mol}$ or $\frac{J}{^{o}C\ mol}$

Specific heat capacity $\frac{J}{K\ g}$ or $\frac{J}{^{o}C\ g}$

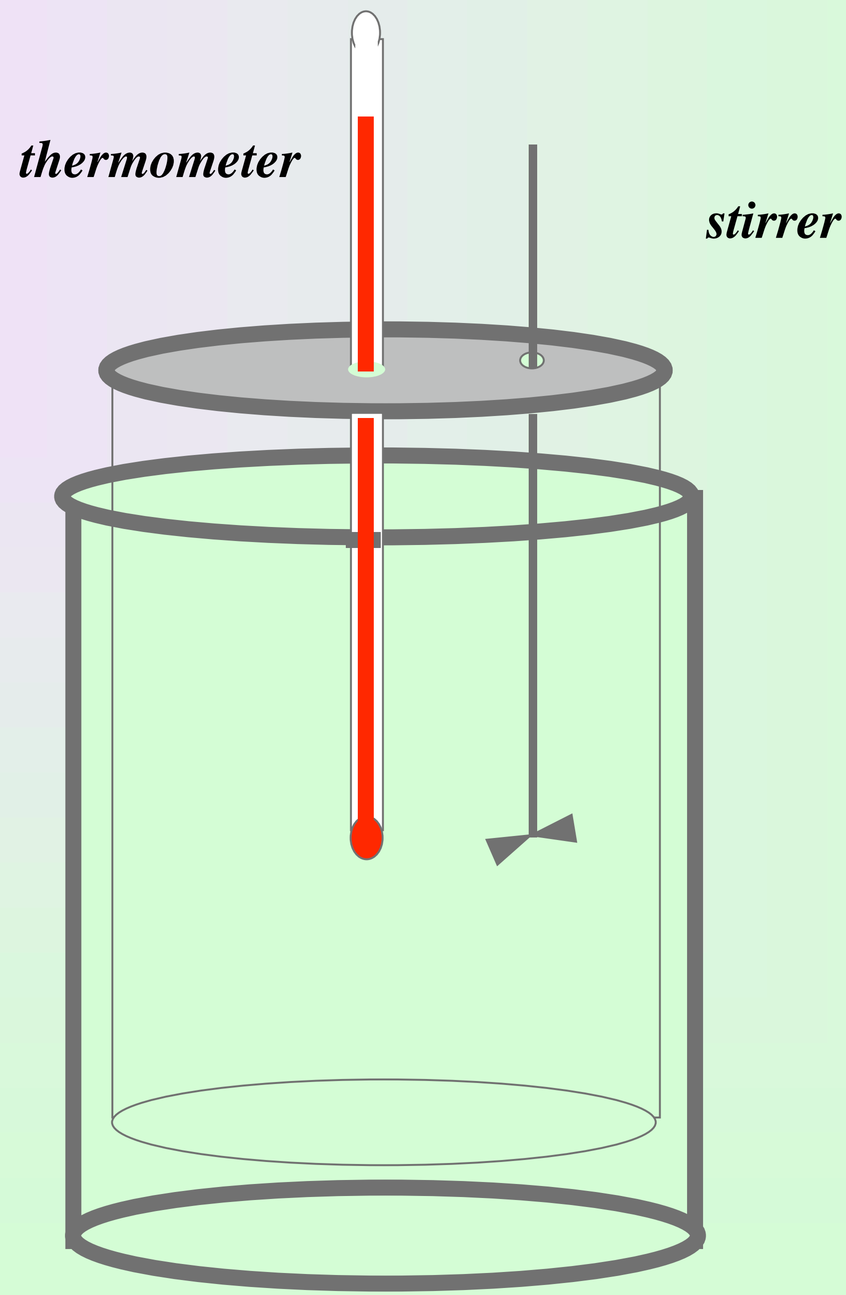
Constant Pressure Calorimeter

takes place at constant pressure

(*atmospheric pressure*)

used to determine the changes in enthalpy (□□) occurring in a solution

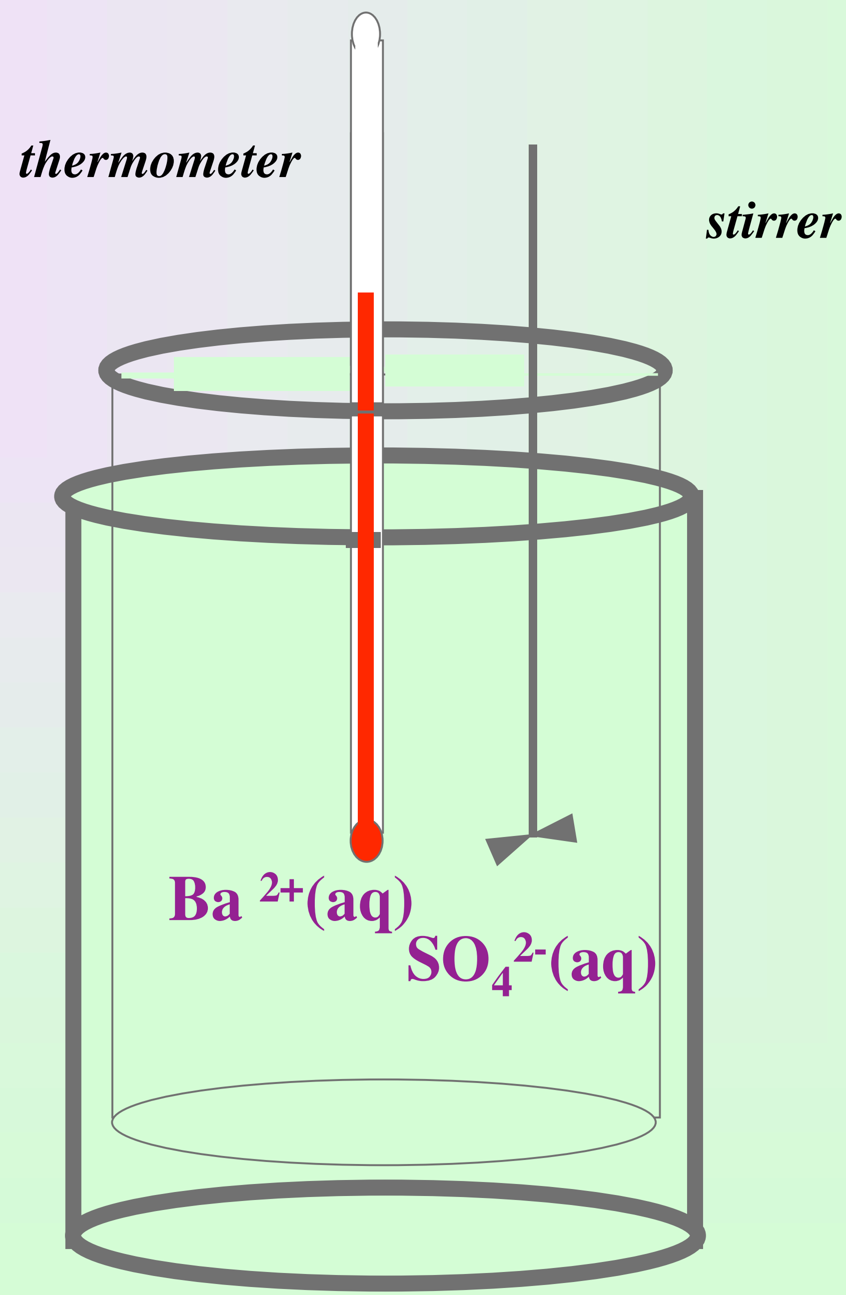
Coffee Cup calorimeter

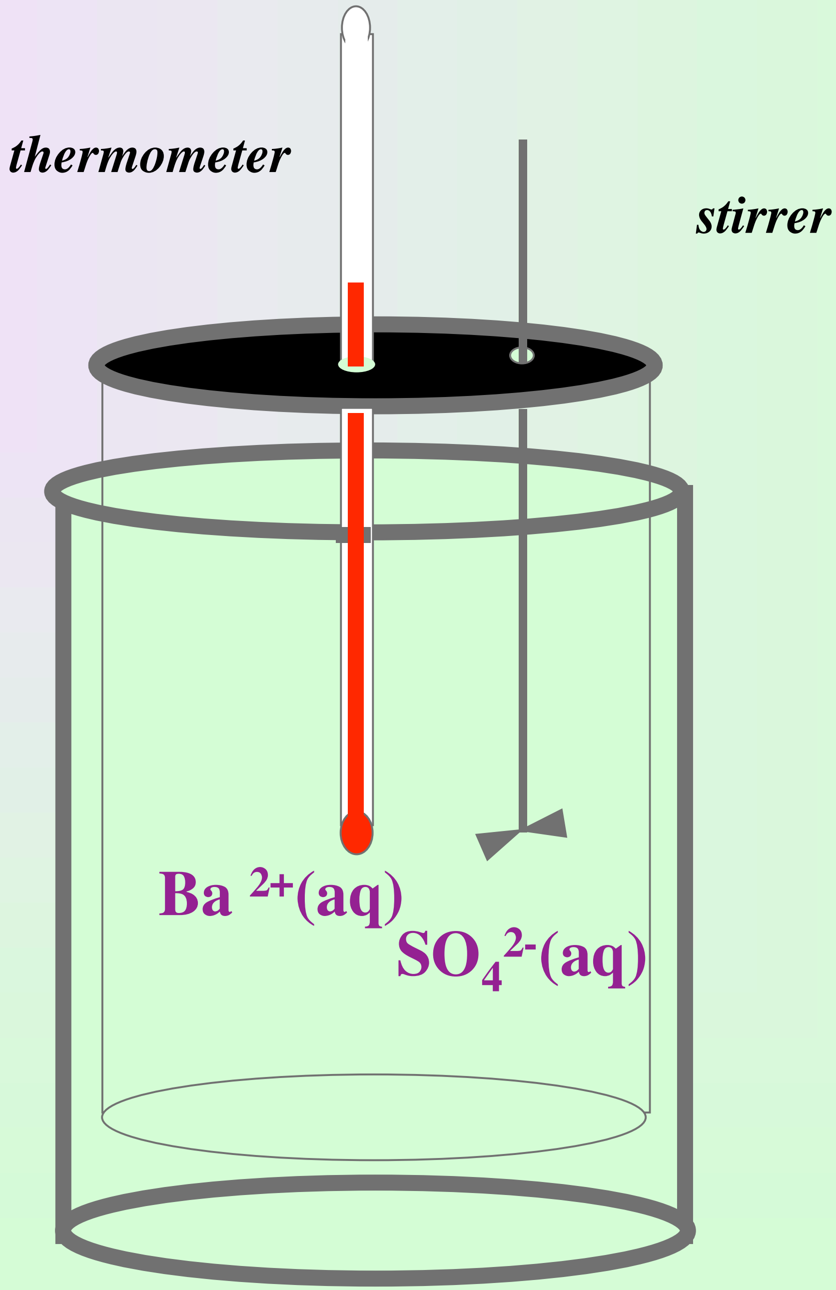


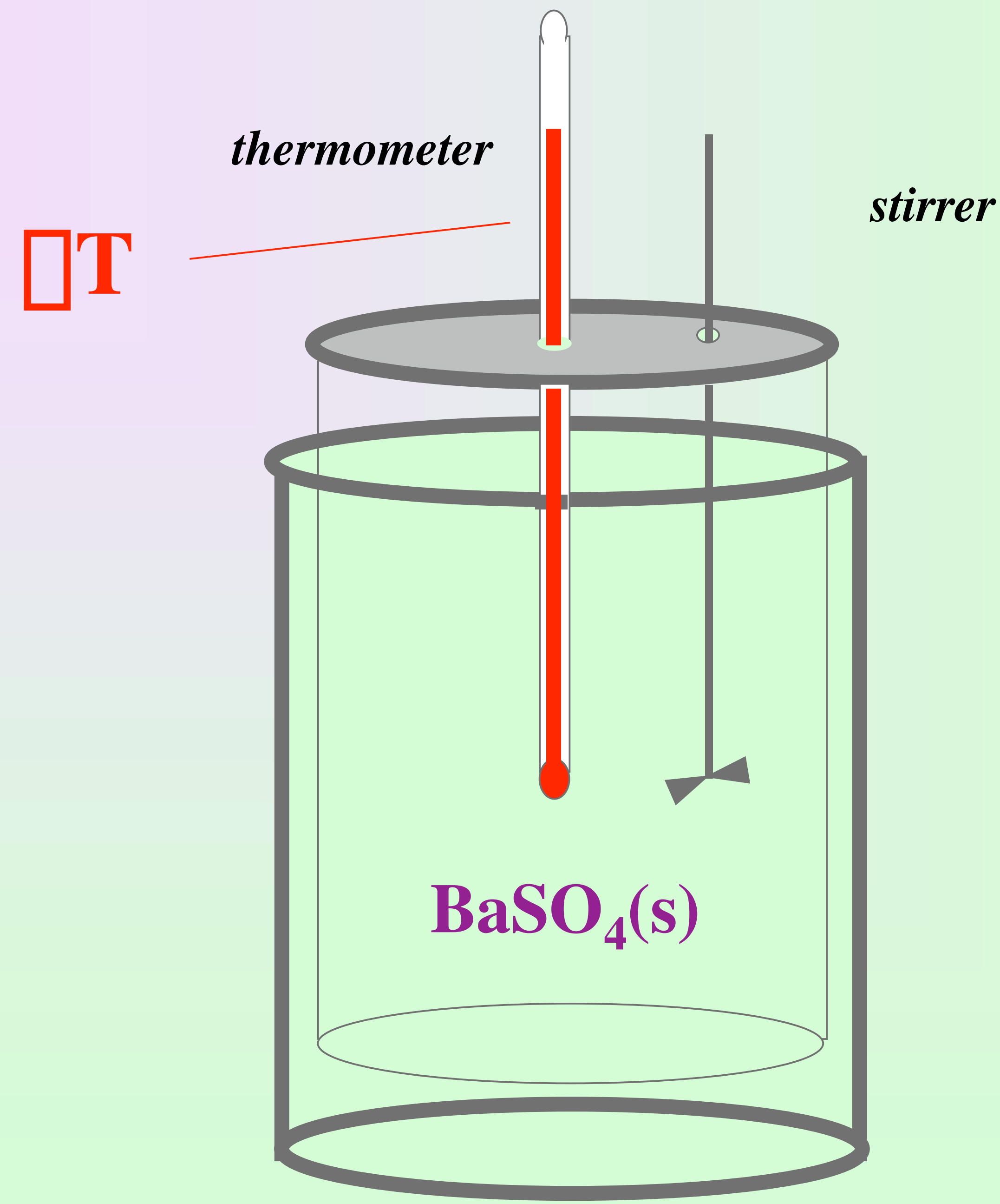
Example:

When 1.0L of 1.0 M $Ba(NO_3)_2$ at 25 °C is mixed with 1.0 L of 1.0 M Na_2SO_4 at 25 °C in a calorimeter, the white solid $BaSO_4$ forms and the temperature increases to 28.1 °C. The specific heat capacity of the solution is 4.18J $°C^{-1}$ g^{-1} , and the density of the final solution is 1.0g/ml, calculate the enthalpy (□□) change per mole of $BaSO_4$.

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$$


thermometer
stirrer
Ba 2+(aq)
SO4 2-(aq)


thermometer
stirrer
Ba 2+(aq)
SO4 2-(aq)


thermometer
stirrer
T
BaSO4(s)

Example:

$Ba^{2+}(aq) + SO_4^{-}(aq) \longrightarrow BaSO_4(s)$

Energy released by the reaction = Energy absorbed by the solution

= Mass of the solution x Specific heat capacity x Increase in temperature

$$q = nC\Delta T$$

Example:

$$Ba^{+}(aq) + SO_4^{-}(aq) \longrightarrow BaSO_4(s)$$

Volume solution

Density solution

Mass of the solution

$$2.0L \times \frac{1000\ ml}{1L} \times \frac{1.0\ g}{1ml} = 2.0 \times 10^3 g$$

Increase in temperature

$$\underset{T_{final}}{28.1\ ^{o}C} - \underset{T_{int}}{25\ ^{o}C} = 3.1\ ^{o}C$$

Example:

$$Ba^{+}(aq) + SO_4^{-}(aq) \longrightarrow BaSO_4(s)$$

$$\frac{-26\ kJ\ \ BaSO_4}{mol}$$

$$q = nC\ \Delta T$$

$$= (2.0 \times 10^3 g)\,(4.18 J\ {}^{o}C^{-1}\ g^{-1})(3.1\ {}^{o}C)$$

Heat absorbed by the solution

$$= 2.6 \times 10^4 J$$

Heat released by the system

$$= q_p = \Delta H = -2.6 \times 10^4 J \times \frac{1kJ}{1000J} = -26\ kJ$$

$$1L\ Ba^{+} \times \frac{1mol\ Ba^{+}}{1L} \times \frac{1mol\ BaSO_4}{1mol\ Ba^{+}} = 1mol\ BaSO_4$$

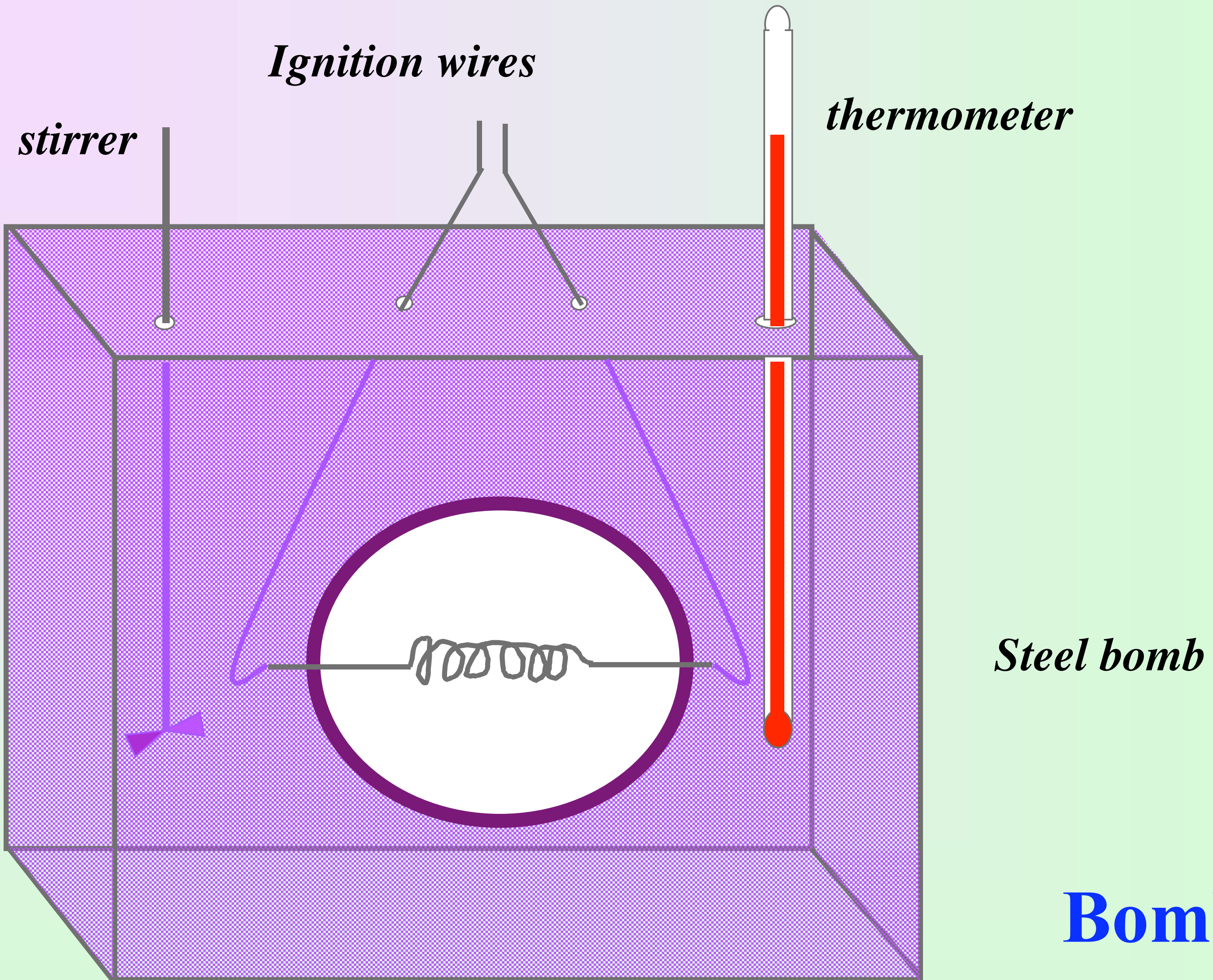
Constant Volume Calorimeter

takes place at constant volume

A bomb calorimeter

Weighed reactants are placed inside a rigid steel container and ignited

The energy change is determined by measuring the increase in temperature of the calorimeter

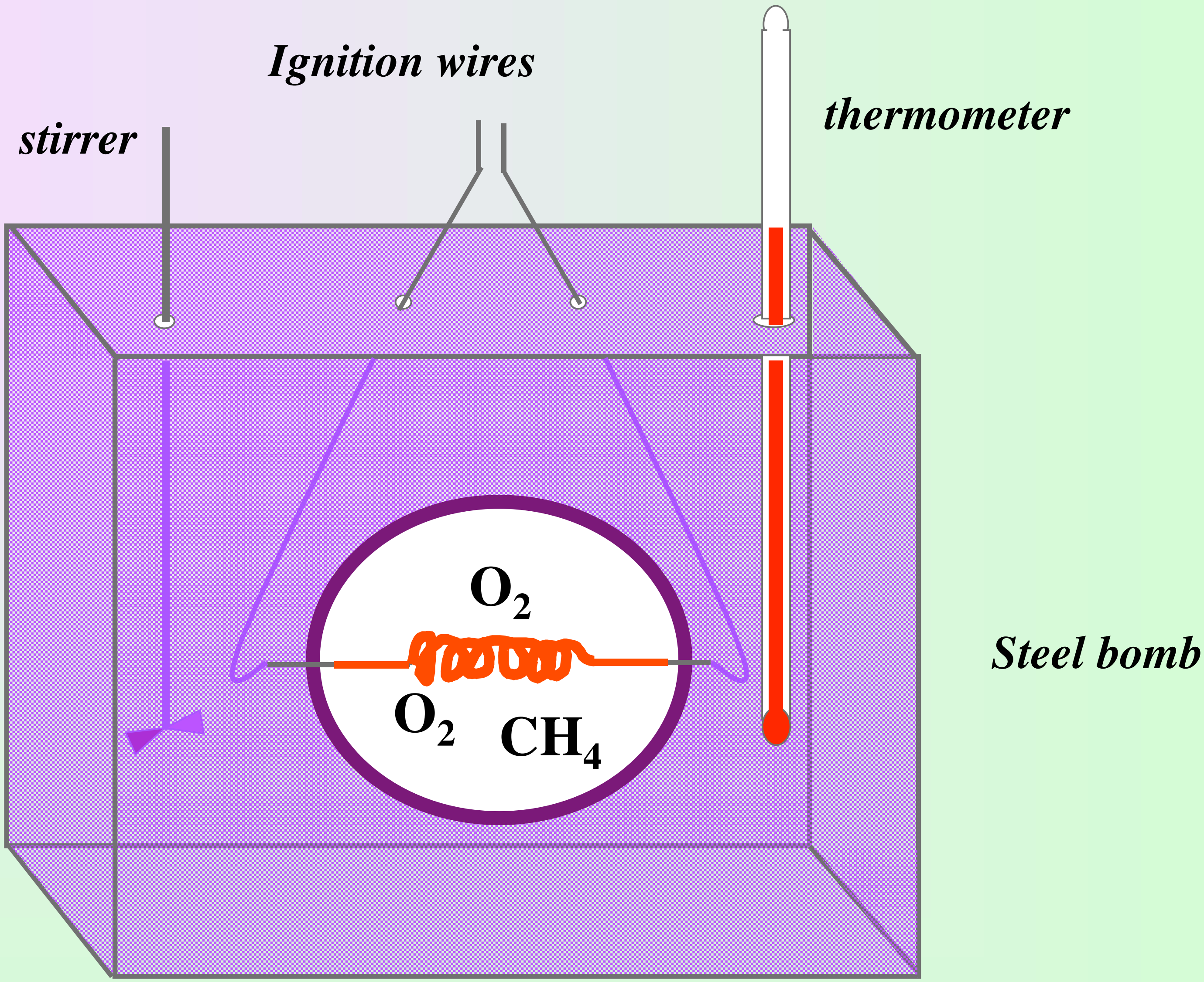


Bomb calorimeter

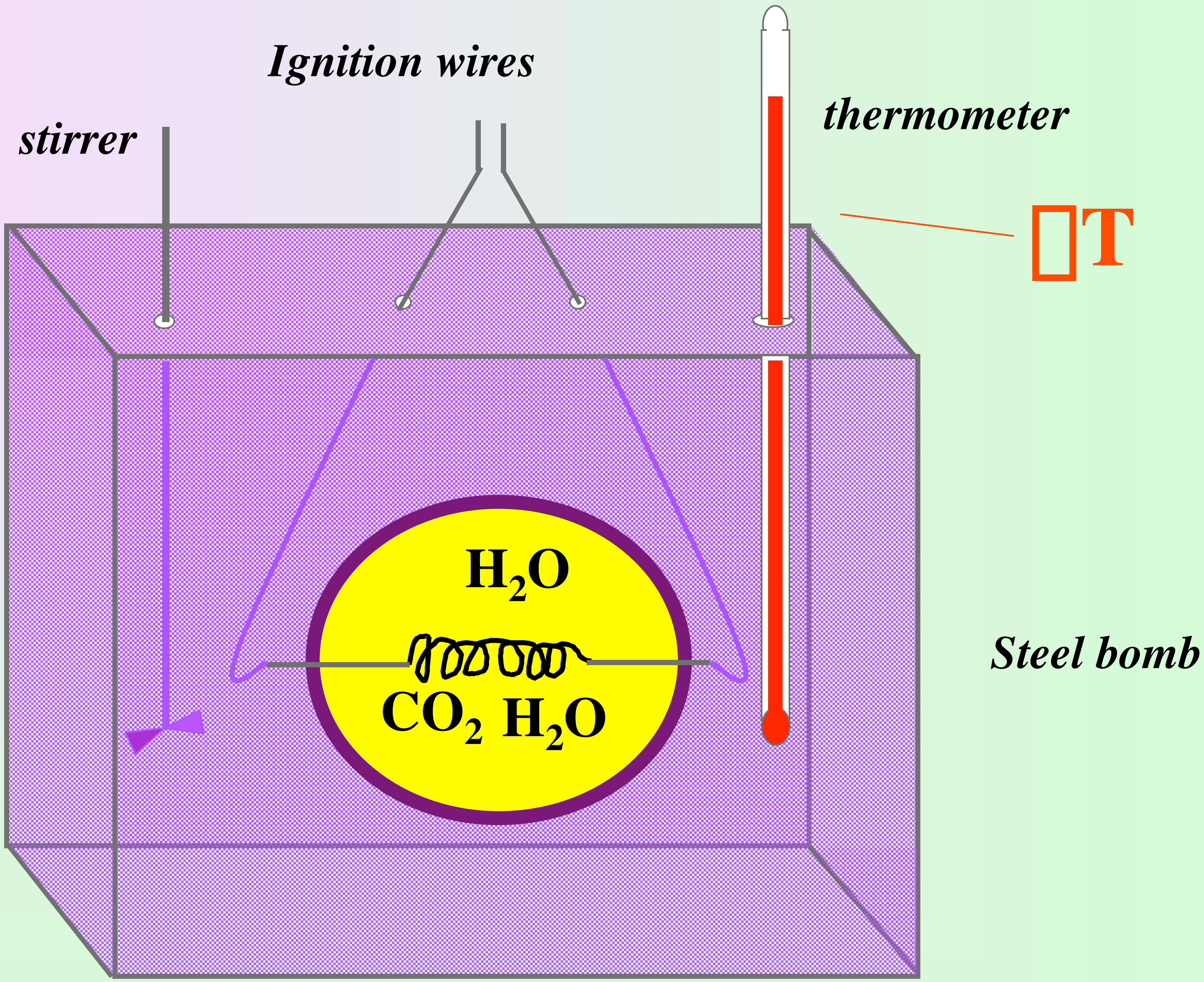
Example:

1.50g sample of methane gas was burned with excess oxygen in a bomb calorimeter causing a temperature change of 7.3 ^oC. Calculate the energy of combustion (per gram) if the heat capacity of the calorimeter was 11.3 kJ/ ^oC.

$$CH_4\,(g) \;+\; 2O_2\,(g) \longrightarrow CO_2(g) \;+\; 2H_2O\,(g)$$



Ignition wires
stirrer
thermometer
O_2
O_2
CH_4
Steel bomb


Ignition wires
stirrer
thermometer
T
H_2O
CO_2 H_2O
Steel bomb

Example:

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

Energy released in the combustion of 1.50g of CH_4 $= (11.3\ kJ/{}^{o}C)(7.3\ {}^{o}C) = 83\ kJ$

$$\frac{83\ kJ}{1.50g} = 55\ kJ/g$$