EXPERIMENT 5

CALORIMETRY (PART I)

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Calorimetry

All chemical reactions do one of two things:

1) Release energy to their surroundings
2) Absorb energy from their surroundings

More often than not, the energy involved is thermal energy (HEAT).
ΔH_{rxn} is the (thermal) energy lost/gained by a reaction under constant pressure.

EXOTHERMIC

If a reaction releases energy *into* the surroundings, the temperature of the surroundings go up.
Since the products are touching the surroundings, the temperature of the products also go up.

2 Na (s) + 2 H^+ (aq) → 2 Na^+ (aq) + H_2 (g)

$$\Delta H_{\text{rxn}} = -480\,\frac{\text{kJ}}{\text{mol}}$$

ENDOTHERMIC

If a reaction absorbs energy *from* the surroundings, the temperature of the surroundings go down.
Since the products are touching the surroundings, the temperature of the products also go down.

$NaHCO_3$ (s) + CH_3COOH (aq) → Na^+ (aq) + CH_3COO^- (aq) + H_2O (l) + CO_2 (g)

$$\Delta H_{\text{rxn}} = +49\,\frac{\text{kJ}}{\text{mol}}$$

Today

Process B1

$$NH_4NO_3\ (s) + H_2O\ (l) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq)$$

ammonium nitrate

Process B2

$$C_2H_2O_4\ (s) + 2\ NaOH\ (aq) \rightarrow 2\ Na^+\ (aq) + C_2O_4^{2-}\ (aq) + H_2O\ (l)$$

oxalic acid

oxalate

Olden Days → Specific heat of water was defined as

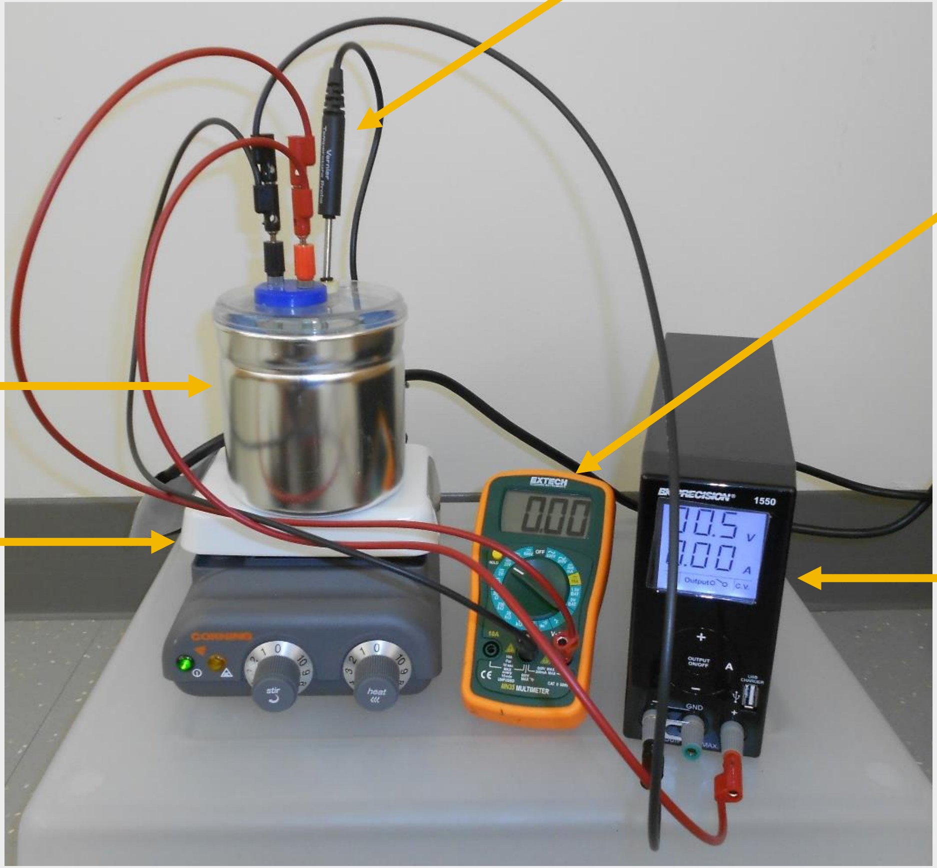
1 calorie/g·°C = 4.184 J/ g·°C

Nowadays → Heat capacity of the "calorimeter + contents" defined as the calibration factor.

Units : J/K = J/°C

Calorimeter

Thermocouple temperature sensor (TTS)
→ *read to 0.01 °C*



Calorimeter
(resistor inside)

Stir plate
(stir bar inside)

Voltmeter
(measures voltage, V)
→ *start at 0 V*

Power supply &
Ammeter
(measures current, A)
→ *start at 0 A*
→ *bring to ~0.5 V*

Calibrating the calorimeter + contents

Run the reaction by mixing reactants, and measure the temperature change: ΔT_{rxn}.

↓

Pass a known electrical current (Ampere, A) through a resistor (immersed in the calorimeter's contents) for a known amount of time (seconds, s) by applying a known electrical potential difference (Voltage, Volt, V).

Measure the temperature change: ΔT_{el}.

↓

Calibration factor (CF)

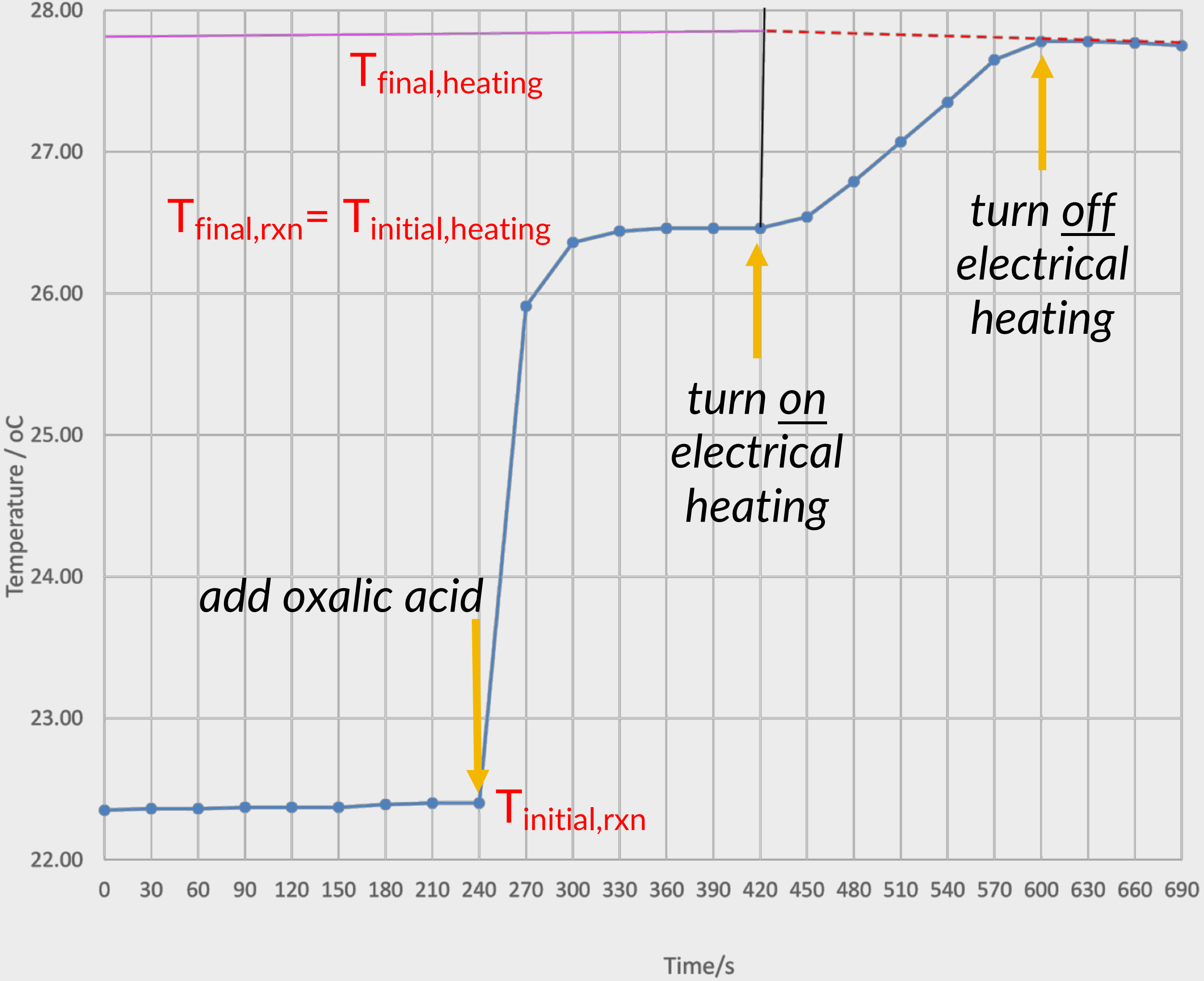
$$\mathrm{CF} = \frac{V \times A \times t}{\Delta \mathrm{T_{el}}}$$

↓

$$q_{\mathrm{rxn}} = \mathrm{CF} \times \Delta \mathrm{T_{rxn}}$$

$$\Delta H_{\mathrm{rxn}} = \frac{q_{\mathrm{rxn}}}{n_{\mathrm{LR}}}$$

Sample data



28.00
27.00
26.00
25.00
24.00
23.00
22.00
Temperature / oC
0 30 60 90 120 150 180 210 240 270 300 330 360 390 420 450 480 510 540 570 600 630 660 690
Time/s
T final,heating
T final,rxn = T initial,heating
T initial,rxn
add oxalic acid
turn on electrical heating
turn off electrical heating

Notes

1. Change temperature precision to 0.01 °C
2. Change data collection duration to 1000 s.