

Practical Work Chemistry II

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Objectives



This lab is intended for first-year undergraduate students in science and technology. At the end of this course, the learner will be able to:

In terms of knowledge:

- Become familiar with laboratory equipment.
- Know how to carry out a series of measurements in an organized and rigorous manner.
- Know how to use the information provided in various materials to write literal and numerical expressions, as well as equations modeling the situations proposed in the problems.

In terms of practical skills:

- Know how to use the calorimeter and the different laboratory equipment to measure the various parameters required in the problem.
- Know how to perform calculations to determine different parameters (heat capacities, specific heat capacity, concentration, pH, etc.).
- Write reports with rigor and clarity.

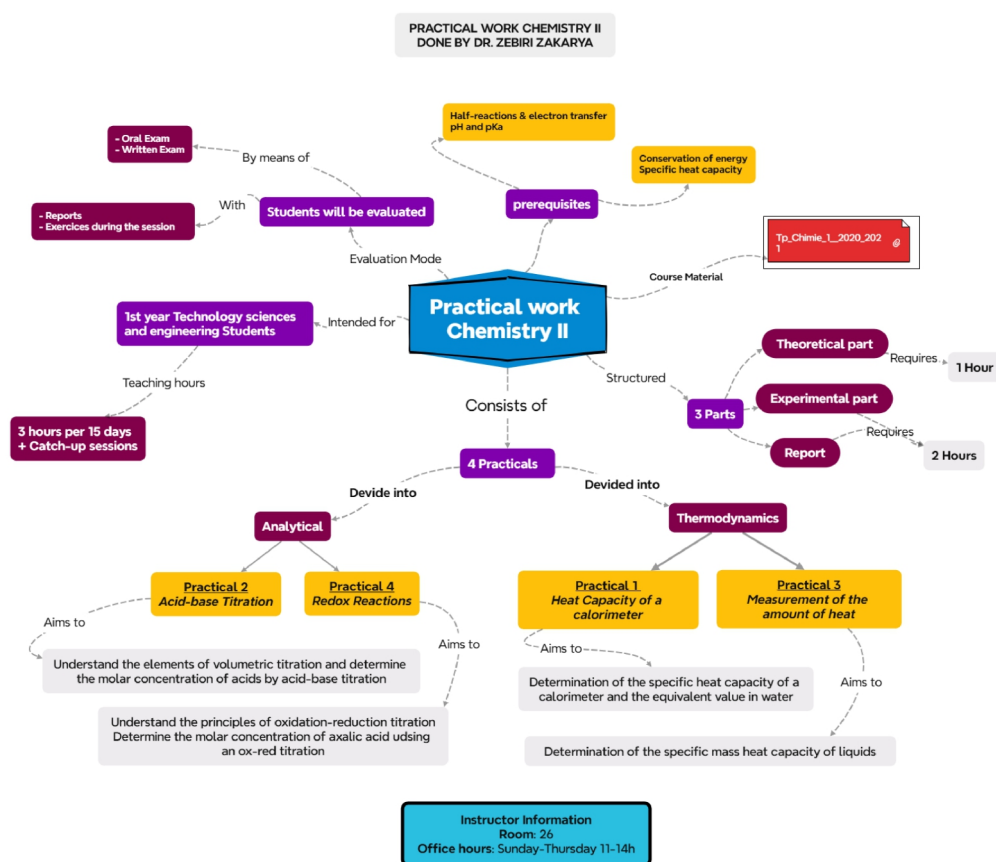
In terms of attitudes (professional behavior):

- Develop awareness of the two fundamental principles of calorimetry: the principle of equality of heat exchange (what is lost by one system is gained by another) and the principle of reverse transformations.
- Develop awareness of the principles of acid–base colorimetric titration and redox titration.

Introduction



This module introduces key experimental techniques in thermochemistry and analytical chemistry through calorimetry and acid–base titration. It covers the determination of a calorimeter's specific heat capacity, highlighting heat transfer and energy conservation principles. It also develops skills in quantitative analysis via titration, focusing on neutralization, equivalence points, and accurate measurement.



Presented with xmind

Mind map.

Practical Session No. 01: Specific Heat Capacity of a Calorimeter



1. Introduction



Thermodynamics

Thermodynamics is the study of the dynamics of thermomechanical systems. In other words, it is the study of a system during its evolution as a function of exchanges of mechanical energy (work) and thermal energy (heat) with the external environment.

2. Objective of the Practical Session

At the end of this lab (practical work), the learner will be able to:

- Determine the heat capacity of a calorimeter (Ccal).
- Write the calorimetric equation that expresses the principle of conservation of energy.

3. Prerequisites

Learners are recommended to have knowledge of some theoretical aspects of calorimetry.

4. Quiz : Prerequisite Test

With what do we measure the quantity of heat?

- ☐ Thermometer
- ☐ Potentiometer
- ☐ Calorimeter

5. Theoretical Part



A **thermodynamic system** is the name given to the portion of space under study (for example, a reactor and its contents); everything that is not part of the system constitutes the external environment. Thermodynamics also makes it possible to predict **energy exchanges** between the **system** and the **external environment** during a **chemical transformation**.

For example, when a chemical reaction is carried out in a test tube, the test tube and its contents constitute the system, while the rest of the universe is the external environment.

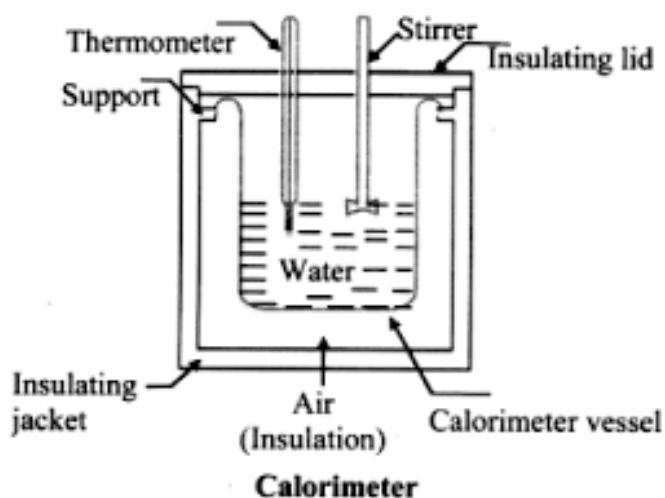
- There are three types of systems: open, closed, and isolated.

Calorimetry is the branch of thermodynamics concerned with **measuring quantities of heat**. It is the experimental part of thermodynamics that involves measuring heat quantities, and it is often used to determine **specific heats**, **latent heats**, and/or **heats of chemical reactions**.

This method is based on the principle of equality of heat exchange: **when two bodies exchange only heat, the amount of heat gained by one is equal to the amount lost by the other**. These measurements are carried out in special devices called **calorimeters**.

A **calorimeter**, like a thermos flask, is an **isolated thermodynamic system** that **does not exchange any energy** with the external environment (**neither work nor heat**). Its walls are rigid and **adiabatic** in order to minimize thermal losses.

There are several types of calorimeters depending on the nature of the measurements performed, including the **isothermal** calorimeter, the **adiabatic** calorimeter, and the **differential** calorimeter.



Adiabatic calorimeter



- A calorimeter is characterized by its specific heat capacity (or specific thermal capacity), denoted “**C_{cal}**.”
- The latter is **the amount of heat** that must be supplied to a unit mass of a substance **in order to raise its temperature by 1 [°C] or 1 [K]**. It is expressed in (J·kg⁻¹·K⁻¹) or (cal·kg⁻¹·K⁻¹).



When the temperature of a given mass changes, the heat required for this change can be calculated using the following relation:

$$Q = mc(T_f - T_i)$$

where:

- **Q**: the quantity of heat exchanged
- **m**: the mass
- **C**: the specific heat capacity of the mass
- **T_f**: final temperature (**thermal equilibrium**)
- **T_i**: initial temperature

If the system is the calorimeter itself, we use the following relation:

$$Q_{cal} = C_{cal}(T_f - T_i)$$

where:

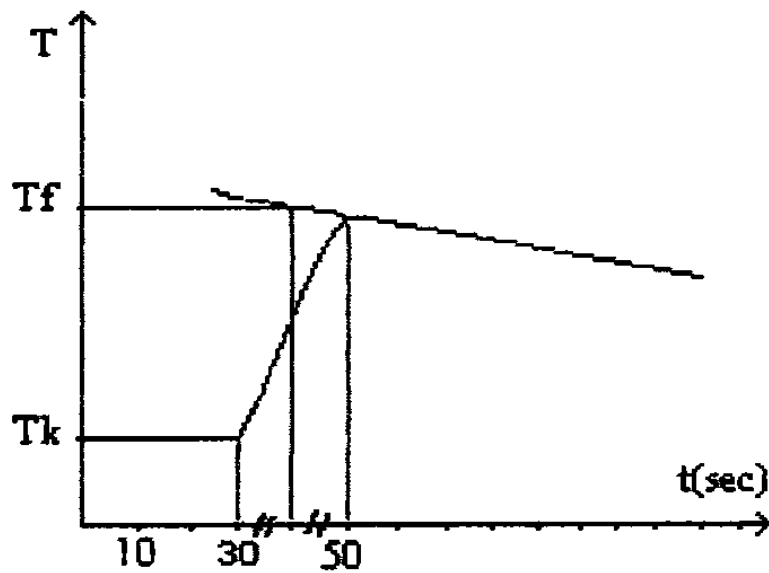
C_{cal}: the specific heat capacity of the calorimeter

To determine the specific heat capacity of the calorimeter, we must allow it to exchange heat with another substance. For this purpose, we use a known mass of hot water (whose specific heat capacity, **C_w**, is known). Since the heat exchange process between the hot water and the cold calorimeter occurs inside the calorimeter (without heat loss), at thermal equilibrium, we have:

$$Q_{cal} + Q_w = 0 \rightarrow C_{cal}(T_f - T_i) + m_w C_w (T_f - T_i)$$

C_w: specific heat capacity of water, equal to 1 cal·g⁻¹·°C⁻¹

The walls of any calorimeter do not provide perfect insulation, and there is always some heat loss. To account for the heat lost to the external environment through the walls and openings of the calorimeter, the temperature **T** is determined graphically by extrapolating the curve, as shown in the graph below.

*Determination of T_f*

6. Experimental Part

6.1. Materials and substances used

Calorimeter, stopwatch, balance, thermometer, resistor, beaker, distilled water

6.2. Experimental procedure

Using a balance, weigh 400 g of distilled water and heat it to 40 °C. Meanwhile, record the temperature in the empty calorimeter every 10 seconds for 30 seconds using the first thermometer, in order to determine the value of T_{cal} , using a stopwatch. At this stage, accurately determine the temperature of the hot water T_e using the second thermometer, record it in the attached table, then quickly pour the hot water into the calorimeter. Close it and gently stir while recording the temperature every 10 seconds for three minutes (180 seconds).

Repeat the experiment three times, ensuring that the calorimeter returns to ambient temperature between each trial. To cool it, fill it with cold water at room temperature and let it sit for a while (about 5 minutes).

Experiment 1		Experiment 2		Experiment 3	
Tw=		Tw=		Tw=	
t(s)	T(°C)	t(s)	T(°C)	t(s)	T(°C)
0		0		0	
10		10		10	
20		20		20	
30		30		30	
40		40		40	
50		50		50	
60		60		60	
70		70		70	
80		80		80	
90		90		90	
100		100		100	
110		110		110	
120		120		120	
130		130		130	
140		140		140	
150		150		150	
160		160		160	
170		170		170	
180		180		180	



Since three experiments were conducted, three curves should be plotted.

7. Use of the results

- Determine graphically the value of T_f
- Using the principle of energy conservation in an adiabatic system, express the specific heat capacity C_{cal} as a function of T_w , T_{cal} , C_w , and m_w .
- Calculate the specific heat capacity C_{cal1} , C_{cal2} , and C_{cal3} , then deduce the average value C_{cal} .

8. Exercise

8.1. Specific heat capacity calculation

An empty calorimeter has a temperature of 15 °C. Into it, 1000 g of water at 65 °C is poured. The equilibrium temperature of the mixture is 50 °C. Calculate the heat capacity of the calorimeter. The specific heat capacity of water is given as $C_{water} = 4.180 \text{ J/°C}$

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