AL- Mustaqpal University

Science College

Dep. Biochemistry

First Stage

Biophysics

Lec 6

Interpretation of Heat Analysis And Interpretation of Heat transfer Between Objects

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Interpretation of Heat Analysis

Thermal analysis (TA) is a group of physical techniques in which the chemical or physical properties of a substance, a mixture of substances or a reaction mixture are measured as a function of temperature or time, while the substances are subjected to a controlled temperature programmed heating or cooling rate.

In other words Thermal analysis is a branch of materials science in which the properties of materials are studied as they change with temperature. Several common methods are used – they are distinguished from each other by the characteristic to be measured :

- Dielectric thermal analysis (DET).
- Differential thermal analysis (DTA).
- Differential Quantitative Scanning (DSC).
- Dilatometry (DIL).
- Thermal Optical Analysis (TOA).
- Derivative imaging: (It is a complex method of thermal analysis).
- Thermal analysis is often used as a term for studying heat transfer through the structure of composites.

This method is applied to:

- Analysis of pharmaceutical substances.
- Polymer analysis (a large area in which thermal analysis finds strong applications; eg, **Thermogravimetric Analysis** (TGA) is used to measure the fiber content of composites by heating a sample to remove the gummy substance by applying heat and then determining the remaining mass).
- Metal analysis (a sample of liquid metal is removed from the furnace and poured into a sample cup with a thermocouple embedded in it. The temperature is then monitored, and a phase diagram is observed to stop).

- Food analysis (most foods are exposed to temperature changes during production, transportation, storage, and consumption changes in temperature cause changes in the physical and chemical properties of the food components that affect the general characteristics of the final product, for example, taste, appearance, and texture).

The program may involve heating or cooling at a fixed rate of temperature change, or holding the temperature constant at different time spam. The graphical results obtained are called the thermogram.

These methods are usually applied to solids, liquids and gels to characterize the materials for quality control.

- **The advantages** of TA over other analytical techniques can be summarized as follows:

(1) The samples can be studied over a wide temperature range using various temperature programs.

(2) Almost any physical from of sample (solid, liquid or gel) can be accommodated using a variety of sample vessels.

(3) A small amount of sample (0.1 μg – 10 mg) is required.

(4) The atmosphere of the sample can be standardized.

(5) The time required to complete an experiment ranges from several minutes to hours.

Thermal analysis techniques

The general components of TA apparatus are; a physical property sensor, a controlled temperature programmed furnace and a recording device (x-y recorder or a microcomputer). According to the measurement property, the best method for thermal analysis is : **Thermogravimetric Analysis (TGA)**

Thermogravimetric analysis is the study of the changes in weight of a sample as a function of temperature. The technique is useful strictly for transformations involving the absorption or evolution of gases from a specimen. Suitable samples for TGA are solids that undergo one of the two general of reactions :

Reactant(s) → Product(s) + Gas (a mass loss)

Gas + Reactant(s) → Product(s) (a mass gain)

A plot of the changes of the mass versus temperature, is called TGA thermogram.

It permits studying of the thermal stabilities, rate of reactions, reaction processes, and sample composition.

Measurements of changes in sample mass with the temperature are made using thermobalance. The balance should be in a suitably enclosed system .

Heat transfer Between Objects

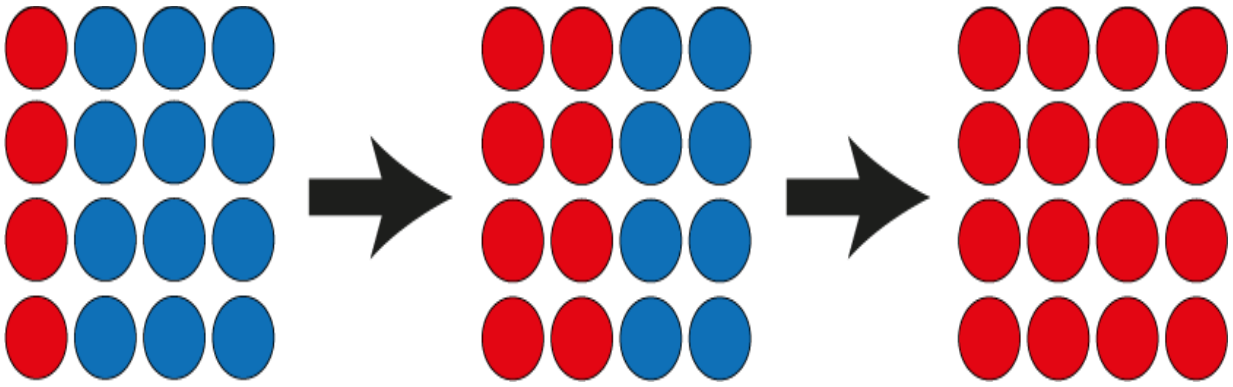
Heat transfer is the exchange of thermal energy between physical objects.
Heat will naturally flow from a hotter to a colder object.

Heat transfer occurs between states of matter whenever a temperature difference exists and heat transfer occurs only in the direction of decreasing temperature, meaning from a hot object to a cold object.

The transfer of heat can occur in three ways:

1- **Conduction. (It occurs between solid objects).**
2- **Convection. (It occurs between liquid as well as gaseous media).**
3- **Radiation. (It can occur in a vacuum).**

<u>Conduction</u> is the main method of heat transfer within solid objects or between solid objects in contact with each other.



• Molecules in the hotter part of the object vibrate faster than the molecules in the cooler parts. The faster moving molecules transfer part of the energy to their slower moving neighbours – so transferring heat through the object

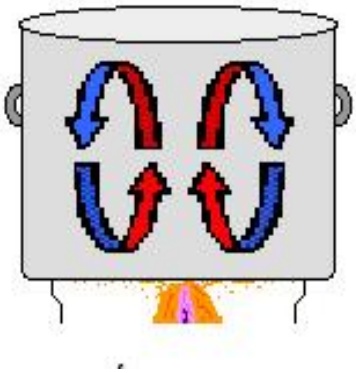
• A 'steady state' is achieved when the heat entering the object at one side is balanced by that being emitted from the other side. Throughout the period of time, the object's heat remains constant.

• Metals are highly conductive whereas gases are not.

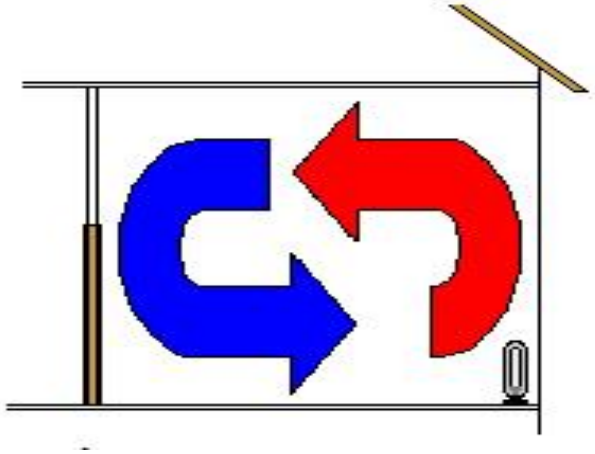
Convection

• Liquids and gases are fluids.

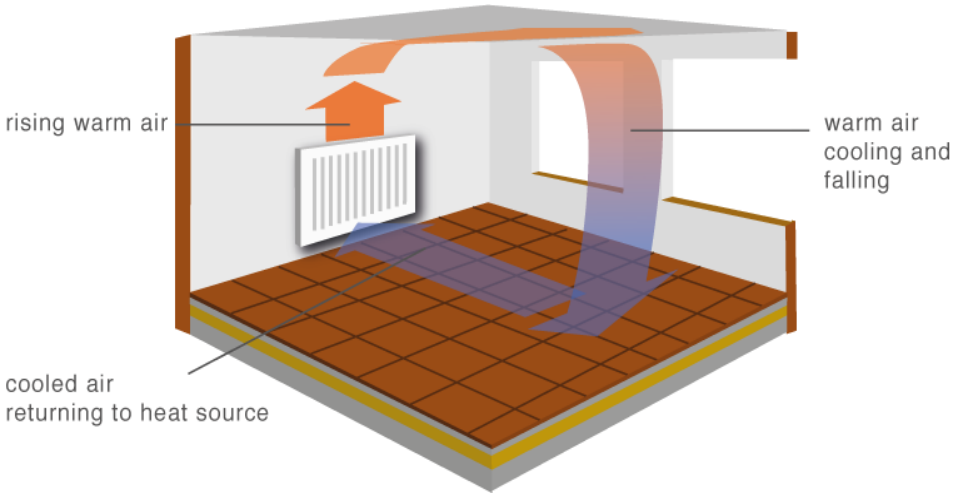
Convection is the movement of heat via currents as heated molecules move from hot places to cooler places.



- When molecules are heated in a fluid, they vibrate faster.
- Higher temperature fluid molecules expand the space they occupy.
- The resulting heated space is less dense compared with the cooler spaces
- The heated, less dense fluid rises to replace the denser, cooler fluid, which in turn sinks into the warmer areas.



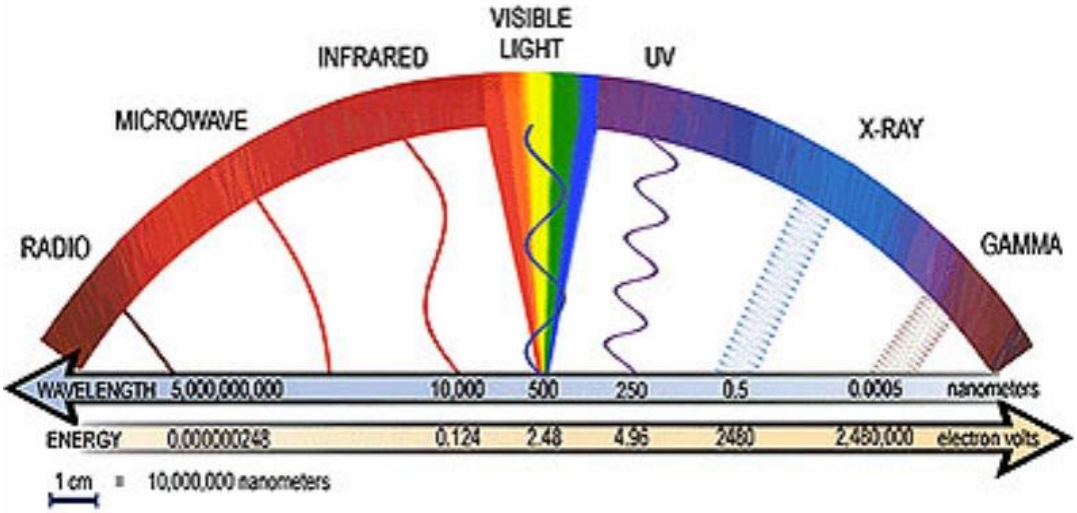
- The repeated rising and falling of warming and cooling liquid or gas sets up the convection current.
- Through warming up one side of a solid container of fluid, the convection currents can transfer heat to the other sides; or heat between two solid objects sandwiching a fluid.



Radiation

• All objects absorb and emit thermal radiation (Also known as infrared electromagnetic radiation).

• Heat energy is transferred via waves, not particles.



• The Earth is heated through thermal radiation from the Sun.

• Thermal radiation is emitted as a result of the random movements of atoms and molecules in matter. Since these atoms and molecules are composed of charged

particles (protons and electrons) their movement causes the emission of electromagnetic radiation, which carries energy away from the surface of the body.

• Thermal radiation is absorbed well by :

- Water, water vapour, glass, wood, brick, stone, concrete, asphalt, copper,

• Thermal radiation is reflected well by :

- Aluminium foil

Discussion

1. **What does thermal analysis primarily measure?**

A) Mass of a substance

B) Chemical or physical properties as a function of temperature or time

C) Volume of a substance

D) Surface area

E) Electrical conductivity

Correct Answer: B

2. Which method is used to measure the thermal stability of a material?

A) DSC

B) TOA

C) TGA

D) DIL

E) DET

Correct Answer: C

3. **Which of the following is NOT a common thermal analysis method?**

A) Differential Thermal Analysis (DTA)

B) Dielectric Thermal Analysis (DET)

C) Thermoelastic Testing

D) Dilatometry (DIL)

E) Differential Scanning Calorimetry (DSC)

Correct Answer: C

4. **What is a thermogram?**

A) A plot showing weight versus time

B) A graph representing changes in temperature with time

C) A graphical result of thermal analysis methods

D) A phase diagram

E) A chart of thermal conductivity

Correct Answer: C

5. **What is the role of the thermobalance in TGA?**

A) To control temperature changes

B) To measure weight changes

C) To record data

D) To measure temperature gradients

E) To regulate heating rates

Correct Answer: B

6. **Which industry uses TGA to determine fiber content in composites?**

A) Pharmaceutical

B) Polymer

C) Metal

D) Food

E) Ceramic

Correct Answer: B

7. **What is thermal analysis used for in food analysis?**

   A) Measuring fiber content

   B) Determining taste changes due to temperature

   C) Monitoring phase diagrams

   D) Analyzing metal content

   E) Evaluating combustion properties

   Correct Answer: B

8. **What does phase monitoring in liquid metals typically involve?**

   A) TGA

   B) DSC

   C) DTA

   D) Dilatometry

   E) Thermal imaging

   Correct Answer: C

9. **Which type of sample can be used for thermal analysis?**

   A) Solids only

   B) Liquids only

   C) Gels only

   D) Solids, liquids, and gels

   E) Vapors

   Correct Answer: D

10. **What is a significant advantage of thermal analysis techniques?**

    A) Requires only a large sample size

    B) Limited to narrow temperature ranges

    C) Works in controlled atmospheres

    D) Only applicable to gases

    E) Requires no sample preparation

    Correct Answer: C

11. **What is the main method of heat transfer in solids?**

A) Convection

B) Radiation

C) Conduction

D) Evaporation

E) Diffusion

Correct Answer: C

12. **Which heat transfer method requires no medium?**

A) Conduction

B) Convection

C) Radiation

D) Diffusion

E) Reflection

Correct Answer: C

13. **How does heat transfer by convection occur?**

A) Through electromagnetic waves

B) Via molecular vibrations

C) By currents in fluids

D) Through a vacuum

E) By surface conduction

Correct Answer: C

14. **Which material absorbs thermal radiation well?**

A) Aluminum foil

B) Water

C) Polished metal

D) Plastic

E) Reflective glass

Correct Answer: B

15. **Which property distinguishes convection from conduction?**

A) Convection occurs in solids

B) Conduction requires movement of fluid molecules

C) Convection involves heat transfer via currents in fluids

D) Conduction is faster than convection

E) Convection is a primary method of heat transfer in solids

Correct Answer: C

16. **Which material is a poor conductor of heat?**

A) Metals

B) Gases

C) Concrete

D) Stone

E) Asphalt

Correct Answer: B

17. **What happens during a steady state of conduction?**

A) Heat continues to accumulate

B) No heat transfer occurs

C) Heat entering equals heat leaving

D) Temperature rises indefinitely

E) Heat transfer reverses

Correct Answer: C

18. **What is the primary form of energy transfer from the Sun to Earth?**

A) Conduction

B) Convection

C) Thermal radiation

D) Evaporation

E) Diffusion

Correct Answer: C

19. **Which is NOT a requirement for thermal radiation?**

A) Matter with vibrating particles
B) Medium for wave propagation
C) Emission of electromagnetic waves
D) Surface properties affecting absorption
E) Thermal energy
Correct Answer: B

20. **What causes convection currents in fluids?**

A) Decreasing density with increasing temperature
B) Increasing density with increasing temperature
C) Uniform temperature distribution
D) Random molecular motion
E) Molecular collisions in solids
Correct Answer: A

21. **What component controls temperature in TA equipment?**

A) Thermocouple
B) Sensor
C) Furnace
D) Recorder
E) Thermometer
Correct Answer: C

22. **What is the sensitivity range of thermal analysis samples?**

A) 1 g – 10 g

B) 0.1 µg – 10 mg

C) 1 mg – 100 mg

D) 0.01 g – 1 g

E) 10 µg – 1 mg

Correct Answer: B

23. **Which method can provide information about the rate of a reaction?**

A) TGA

B) DIL

C) TOA

D) DET

E) DTA

Correct Answer: A

24. **What property does DSC measure?**

A) Mass loss

B) Heat flow

C) Sample density

D) Gas evolution

E) Thermal conductivity

Correct Answer: B

25. **Why is aluminum foil ineffective in absorbing thermal radiation?**

A) It is dense

B) It is reflective

C) It is a poor conductor

D) It is a poor emitter

E) It oxidizes quickly

Correct Answer: B