Syllabus

1. Introduction

2. Fluids

1. **General Characteristics**
2. Dispersions
3. Thermodynamics
4. Transport Phenomena
5. Solutions
6. Surface Tension
7. Electrical Properties
8. Optical Properties
9. Biological Fluids

3. Physics of Microfluidic Systems

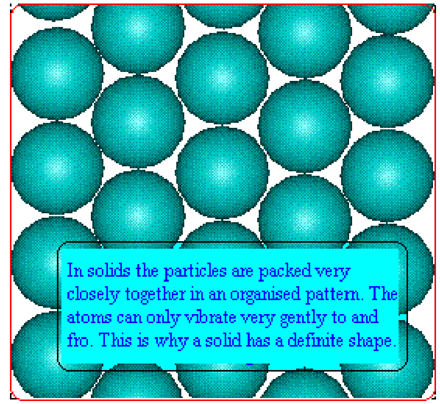
1. Navier-Stokes Equation
2. Laminar and Turbulent Flow
3. Fluid Dynamics
4. Fluid Networks
5. Transport of Heat
6. Interfacial Surface Tension
7. Electrokinetics

2.1. General Characteristics

1. **The Three States of Matter**
2. Mass, Moles and Density

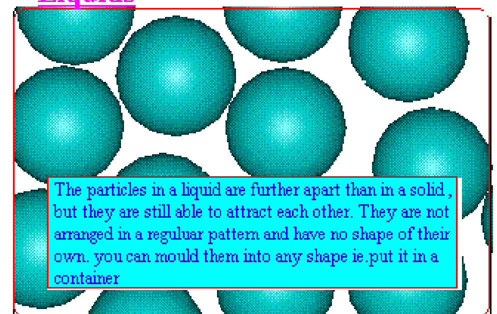
2.1.1. Liquids and Gases

- Three States of Matter
  - Solid
  - Liquid
  - Gaseous

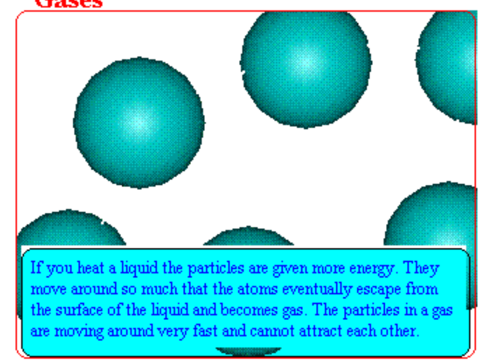


- Differences
  - Reaction to external forces
    - Restoration of original shape
  - Strength of intermolecular forces
  - Internal energy

Liquids



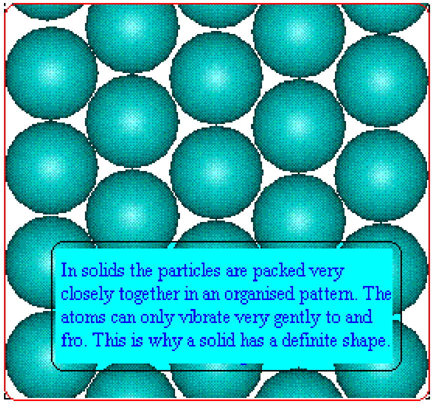
Gases



- Fluids
  - Liquids
  - Gases

2.1.1. Liquids and Gases

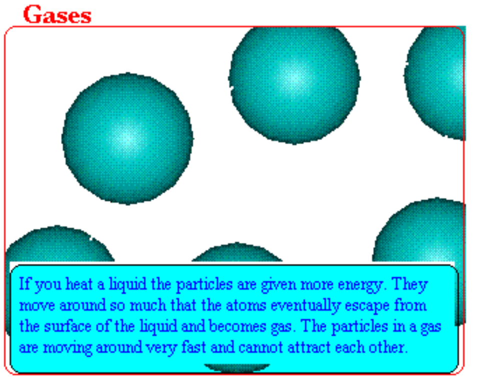
- Three States of Matter
  - **Solid**
    - Relatively fixed molecular structure
    - Strong cohesive forces between molecules over long distances
    - Reaction to external forces: restoring of external shape
    - Lowest internal energy
    - <u>Crystalline state</u>: atoms arranged periodically (silicon, metals, ...)
    - <u>Non-crystalline state</u>: atoms not organized within regular lattice (glass, plastics, ...)
    - <u>Quasi-crystalline</u>: patterns not repeating at regular intervals (alloys)



  - Liquid
  - Gaseous

<u>Microfluidics</u>:
Chip materials
Solid phase for (bio-)assays

2.1.1. Liquids and Gases

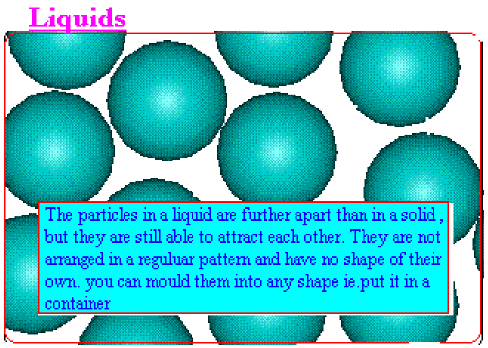


- Three States of Matter
  - Solid
  - Liquid
  - **Gaseous**
    - No defined shape
    - Occupying whole volume provided
    - Reaction to pressure gradient ↦ transport of particles / matter
    - Steady state: equal pressure within whole volume
    - Forces between molecules very low or negligible (e.g., ideal gas)
    - Random motion and occasional collisions with other molecules

Microfluidics:
Analyte
Pneumatic medium

2.1.1. Liquids and Gases

- Three States of Matter
  - Solid
  - **Liquid**
    - Intermediate state compared to solid and gas
      - Cohesive forces between molecules compared to gases
      - Molecular alignment on molecular length scales
      - No temporally fixed molecular positions
    - Higher kinetic energy stronger than cohesive intermolecular forces compared to solids



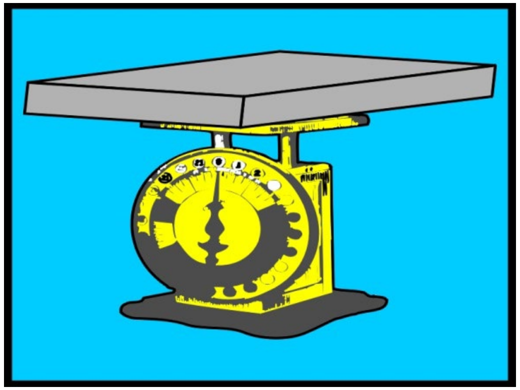
    - Reaction to pressure gradient
      - (Convective) transport of particles / matter
    - Shape defined by minimum of potential energy
      - Surface tension
      - Interfacial forces with solids and gases
      - Spherical surface in absence of gravity
  - Gaseous

Microfluidics:
Reagent / Analyte
Suspending medium
Hydraulic medium

2.1. General Characteristics

1. The Three States of Matter
2. **Mass, Moles and Density**

2.1.2. Mass, Moles and Density



- Mass m of body

$$m = NM$$

  - Number of molecules N
  - Molecular mass M

- Total number N of molecules in given sample

$$N = N_\mathrm{A} n$$

$$N_\mathrm{A} = 6.022 \times 10^{23}\,\mathrm{mol}^{-1}$$

  - Avogadro‘s constant N_A
  - Number of moles n

- Particle density

$$\varrho_N = \frac{N}{V}$$

2.1.2. Densities

- Volume per mole

$$V_n = \frac{V}{n} \simeq 22.4\,\mathrm{l}\,\mathrm{mol}^{-1} \quad \text{(for gases)}$$

- (Mass) density

$$\varrho = \frac{m}{V}$$

Molar mass

$$M_n = \frac{m}{n}$$

substance	density $\varrho/\mathrm{g\,cm^{-3}}$
silica glass	2.66
lead	11.35
ethanol	0.7892
water	0.9982
mercury	13.5459
carbon dioxide	1.9769×10^{-3}
air	1.2929×10^{-3}
hydrogen	0.0899×10^{-3}

Table 2.1. Densities of selected solids and liquids at 20°C and gases at 0°C

Summary

Mass m
particles N
Molecular weight M

$$m = NM$$

Avogadro constant N_A

$$N = N_{\mathrm{A}} n$$

$$N_{\mathrm{A}} = 6.022 \times 10^{23}\,\mathrm{mol}^{-1}$$

Particle number density

$$\varrho_N = \frac{N}{V}$$

Mass density

$$\varrho = \frac{m}{V}$$