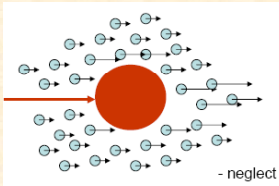
Viscosity Measurements

Prof. Dr. Virtudes Moreno Martínez
Departamento de Química Inorgánica
Universidad de Barcelona
Martí Franquès 1-11, 08028-Barcelona
(España)
Tf. 0034 934021274
virtudes.moreno@qi.ub.es

Viscometry

When a macromolecule moves in solution (e.g. of water), it induces net motions of the individual solvent molecules, i.e. the solvent molecules will feel a force.



- neglect Brownian motion.

Viscosity, then, which is also determined as a viscosity coefficient, is a measure of a fluid's resistance to flow.
It is the substance constant indicating the magnitude of the fluidity of a fluid. In general, viscosity is associated only with liquid.

When rotating a drum container filled with water on its vertical central axis, the water that was at rest in the beginning starts moving as it is dragged by the container's inside wall and then whirls completely together with the container as if it were a single rigid body.
This is caused by the force (resistance) generated in the direction of the flow (movement) on the surfaces of the water and the container's inside wall.

A fluid that generates this kind of force is regarded as having viscosity.

Viscous fluid is divided into two broad categories (constant temperature):

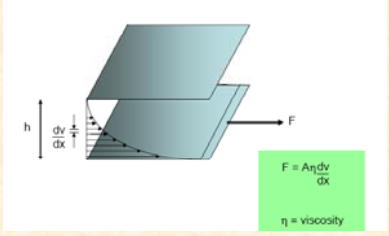
- **Newtonian fluid, subject to Newton's law of viscosity, viscosity is constant regardless of the flow (movement).**
- **Non-Newtonian fluid, which is not subject to Newton's law of viscosity, viscosity changes according to the flow (movement).**

Temperature is a very important factor for measuring viscosity. In fluids, as temperature goes up, viscosity goes down and *vice versa*. In the case of distilled water, if the temperature changes 1 centigrade, it produces a difference of 2 % to 3 % in viscosity.

As viscosity units, P (poise) , cP (centi-poise) – CGS unit system
Pa.s (pascal second), mPa.s (mili pascal second) – SI unit system

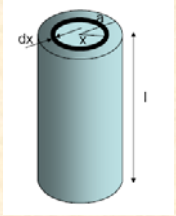
The viscosity of distilled water is 1.002 mPa.s at 20.00 centigrade at 1 atm

To describe this force, let us consider two sheets of fluid, of area A



To measure viscosity, the capillary effect is used. The force for the movement of solvent depends on the hydrostatic pressure, i.e.

$$F_{up} = P\pi a^2$$



For a small cylindrical sheet, at a radial distance x, the differential force will be

$$dF_{up} = 2P\pi x\, dx$$

If the fluid is flowing through the capillary at a steady state, this force must be balanced by a frictional force, i.e.

$$F_{down} = -A\,\eta dv/dx = -2\pi x l \eta dv/dx$$

where the negative sign indicates that it is in the direction opposite to the applied force

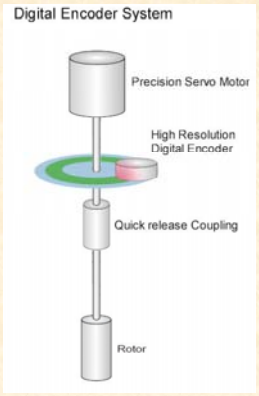
Finally, the Poiseuille's law allow to relate velocity of flow with different parameters and the viscosity η

$$\frac{dV}{dt} = \frac{\pi P a^4}{8 \eta l}$$ Poiseuille's law

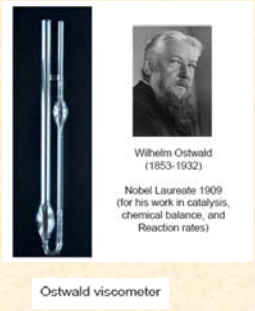
MEASURING VISCOSITY

Several types of viscometers exist and are classified into five types by their measurement principles.

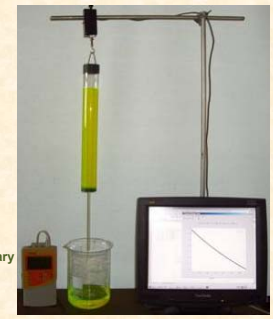
1. Vibro Viscometer: Measures viscosity by controlling the amplitude of the transducer immersed in a sample and measuring the electric current that drives the transducer



2. ***Rotational Viscometer: Measures viscosity by measuring the running torque of the cylindrical rotors immersed in a sample.***

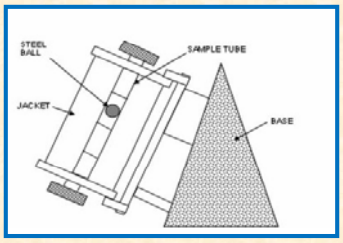


Ostwald viscometer



Simple capillary viscometer

3. Capillary Viscometer: Obtains viscosity by letting a sample flow inside the capillary and measuring the difference in pressures between both ends of the capillary.



4. Falling-Ball Viscometer: Obtains viscosity by measuring the time it takes for a cylindrical or spherical object to fall through a sample over a specific distance.

5. Cup-Type Viscometer: Obtains viscosity by measuring the time it takes a sample to flow out of the orifice of the sample container.

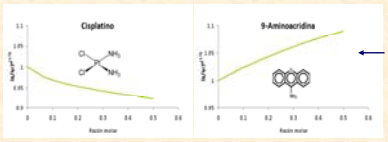
Measuring DNA viscosity and its variation

The DNA helix lengthens, as the base pairs are separated to accommodate the bound ligand for the intercalation of the molecule, leading to increase in DNA viscosity. Viscosity measurement is thus a suitable method to detect such changes and, in the absence of crystallographic structural data, it is an essential evidence to support an intercalation model.

In contrast, nonclassical intercalation of ligands could bend (or kink) the DNA helix, reduce its effective length and in turn, its viscosity.

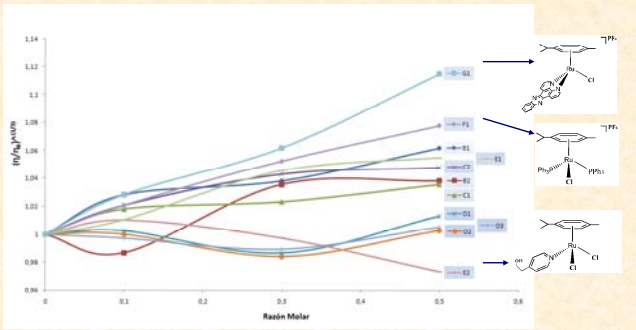
Two examples of covalent bond (cisplatin) to DNA and intercalation (9-aminoacridine) between DNA base pairs

Viscosity decreases — **Viscosity increases**

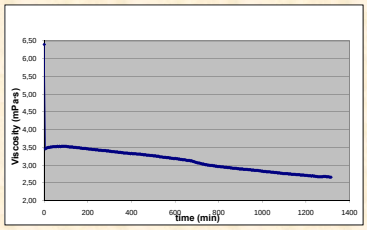
Covalent → 

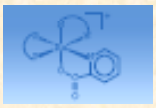
← Intercalator

Variation of viscosity of Calf Thymus DNA incubated with several ruthenium complexes (R_i=0.5) for 54 h at 25 ºC.



The viscosity decreases along time for a compound of ruthenium incubated with Calf Thymus DNA

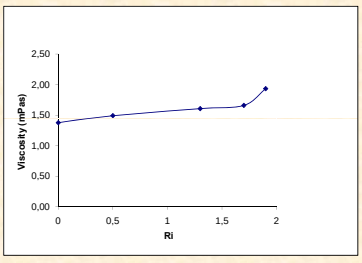


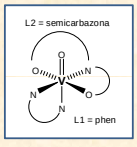


Example for weak interactions of the ligands with DNA or covalent bond by hydrolysis of carboxylate bond of picolinic acid with time

$[Ru(pic)(bipy)(dppb)]PF_6$

The viscosity increases when the molar ratio increases for a compound of vanadium incubated with Calf Thymus DNA





Example for Intercalation

CONCLUSION:

Measurement of viscosity is a very simple, available, complementary, chea p and excellent method to know the mode of binding of metal complexes (ruthenium, platinum, vanadium, galliu m, iron drugs…) to DNA