2011a(16)/2006b(12): Explain the difference between viscosity and density. Outline the effects of changes in viscosity and density on the flow of gases and liquids

Viscosity (η): Used to indicate a fluid’s internal resistance to flow. Also thought of as a measure of the friction of a fluid.
- e.g. honey has a high viscosity than water and as such moves much slower if poured

Density (ρ): relates the mass of a substance to its volume such that ρ = kg/m³
Although some gases may have similar viscosity, their densities may be different (e.g. O₂ and He)

Flow measure of volume of fluid / gas moved per unit of time (e.g. ml/min).
Flow through tubes can either be laminar or turbulent

Laminar flow
- For flow to be laminar, the tube in which it is travelling must have smooth, parallel sides with no branches in the system
- Gas / fluid moves in small concentric tubes in parallel to the sides such that the movement of substance in the centre is twice the velocity of the movement of substance at the walls (there is no flow at the walls)
- There is a linear relationship between pressure and flow
- Resistance can be calculated by Hagan-Poiseuille Equation:
  \[ R = \frac{8\eta l}{\pi r^4} \]
  - Viscosity of the gas / fluid is directly proportionate to resistance: ↑η → ↑R → ↓flow
    o Density has no effect on the flow of gas during laminar flow.
  - Altering the other variables will change R as seen

Turbulent Flow
- Occurs in other situations
- Flow is disorganised with small eddies forming → creates a square wavefront
- Pressure is proportionate to flow²
- Resistance proportional to density and not viscosity
  \[ R \propto \frac{\rho l}{\pi r^5} \]
- Reynold’s number can predict the likelihood of turbulent flow occurring
  \[ Re = \frac{2r\nu\eta}{\rho} \]
  \[ >2000 \rightarrow \uparrow \text{probability of turbulent flow} \]
- Density is the major determinant of Re: ↑ρ (N₂ v He) → ↑turbulent flow
  o Flow is inversely proportional to ρ
- η has a much smaller contribution to the determination of Re: ↓η → ↑probability of turbulent flow

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