Transport Theory (Suggestions)

1. **What is the difference between a random motion and a steady motion?**

2. **What is the basic difference between Brownian particles and gas molecules in kinetic theory?**

3. **Consider a vertical column (assume it is along positive z-direction) of emulsion, obtain the probability distribution of the particles along z direction.**

4. **Consider a vertical column (assume it is along positive z-direction) of emulsion, from the probability distribution of the particles along z-axis, obtain an expression for Avogadro number.**

5. **Establish the Langevin equation. Explain the physical origin of the forces acting on the Brownian particles.**

6. **Integrating the Langevin equation, obtain an expression for the ensemble average $< x\dot{x} >$.**

7. **Assuming that each Brownian particle starts moving randomly from $x = 0$ at $t = 0$, obtain $< x^2 >$. Hence show that $[< x^2 >]^{1/2}$ is proportional to $t^{1/2}$.**

8. **Assume that the Brownian particles are carrying charge e. Then write down the modified form of Langevan equation in presence of an external electric field E. Hence obtain the Einstein relation $\mu/D = e/(kT)$, where the symbols have their usual meaning.**

9. **What do you mean by self-diffusion? Establish the equation governing self-diffusion.**

10. **Show that the self diffusion may be treated as a kind of random walk. Hence establish the approximate relation $D = \overline{v}\overline{l}/3$, where the symbols carry their usual meaning.**

11. Consider the self diffusion for a dilute gas. Obtain an expression for the effective diffusion current in terms of diffusion coefficient and density gradient. Express the diffusion coefficient in terms of temperature and average pressure of the system.

12. Establish the relation $D/\eta = 1/\rho$, where the symbols have their usual meaning.

13. Establish the relation $K/\eta = C_v/\mu$, where K is the heat conductivity, η is the viscosity coefficient, C_v is the molar specific heat and μ is the molecular heat. How the molecular weight is defined in terms of actual mass?

14. Establish Wiedemann-Franz law.

15. Obtain the diffusion equation in one-dimension and give its solution in separable form. Discuss the various initial conditions of the solutions.

16. Establish the classical Vlasov equation using the Poisson bracket.

17. Establish the operator relation

$$\frac{d}{dt} = \frac{\partial}{\partial t} + \vec{v}.\nabla$$

18. Write down the Boltzmann transport equation. Obtain the transport coefficients from Boltzmann transport equation with relaxation time approximation and assuming that the system is very close to its equilibrium configuration.

19. Establish the Clausius-Clapeyron equation.

20. Show that the vapour pressure is a very rapidly increasing function of temperature.

21. Establish the virial theorem

$$\overline{E_k} = \frac{k}{2}\overline{U}$$

where the symbols carry their usual meaning. Hence show that for classical harmonic oscillator

$$\overline{U} = \overline{E_k} = \frac{E}{2}$$

What are the corresponding results for gravitational interaction or attractive Coulomb interaction.

22. What is Markoff process? Establish the Fokker-Planck equation.

23. Obtain the solution for Fokker-Planck equation and show that for time $t \longrightarrow \infty$, the solution reduces to Boltzmann distribution.

24. Consider a rapidly fluctuation function $F(t)$. Define the two point correlation function $K(s)$ for this function. Show that $K(s) =< (F(t)^2 >$ for $s = 0$ and $K(s) = 0$ for $s = \infty$.

25. Show that $-K(0) \leq K(s) \leq K(0)$ and $K(-s) = K(s)$.

26. State and establish the Fluctuation dissipation theorem.

27. Explain briefly the physical meaning of phase space, phase space representative points and statistical ensemble.

28. Show that the time average of a variable in a particular ensemble is exactly identical with the ensemble average for a particular time.

29. Consider a classical harmonic oscillator, show that its classical phase space will be an ellipse for a fixed energy.

30. Define phase space density. Obtain the classical Liovuille's equation using the Poisson bracket.

31. Why the Fourier analysis is mostly used for randomly varying function with time?

32. Consider a random function $F(t)$ which is real. Show that its Fourier transform satisfies the relation $C^*(\omega) = C(-\omega)$

33. Consider a random walk problem, show that $\overline{n_1} = pN$ and $\overline{m} = 0$ for $p = q$, else it is non-zero.

34. Establish the Wiener-Khintchine relation.

35. Establish the Nyquist's theorem.