CHEM 211 UNIT 1 – THE PHYSICAL PROPERTIES OF GASES
PRACTICE QUESTIONS

Molar gas constant R = 8.31 $Jmol^{-1} K^{-1}$; L = 6.02 x 10^{23} mol^{-1}, k = 1.38 x 10^{-23} JK^{-1}

Lesson 1

1. (a) Describe the main postulates of the kinetic model of matter
(b) What is an ideal gas?
(c) Under which conditions is a gas most likely to display ideal behaviour? Which gases will show ideal behaviour over the widest range of conditions?

2. (a) State the ideal gas equation and use it to explain the meaning of the term "equation of state"
(b) State three laws which can be combined to give the ideal gas equation
(c) Calculate the volume occupied by one mole of a gas at 25 ^oC and 100 kPa
(d) Calculate the temperature of a gas if 0.5 moles occupy 1.2 dm^3 at a pressure of 200 kPa
(e) Calculate the mass of a sample of carbon dioxide which occupies 20 dm^3 at 27 ^oC and 100 kPa
(f) Calculate the relative molecular mass of a gas if a 500 cm^3 sample at 20 ^oC and 1 atm has a mass of 0.66 g
(g) Calculate the density of nitrogen gas at 298 K and 100 kPa
(h) A volatile organic compound weighing 0.2 g, on heating in Victor Meyer's tube, displaced 30 cm^3 of air at 27^oC; the pressure was found to be 98 kPa once the contribution of water vapour was removed; determine the molecular mass of the compound.
(i) A sample of an unknown compound is vaporised at a pressure of 103 kPa in a flask which, when empty and evacuated, has a mass of 25.3478 g; when vaporisation is complete and excess gas has escaped, the temperature is found to be 98 ^oC. The flask is sealed and found to have a mass of 25.6803 g. The flask and contents are then cooled to 25 ^oC, emptied, cleaned, filled with water and found to have a mass of 128.12 g when filled with water (the density of water is 0.997 gcm^{-3} at 25 ^oC). Determine the relative molecular mass of the compound.
(j) Calculate the total number of molecules remaining per cm^3 if a vessel is evacuated until its pressure is 7.7 Pa

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Lessons 2 and 3

3. (a) By considering N molecules each of relative molecular mass m_r moving with velocity v inside a cube of length l and volume V, derive the expression PV = $\frac{m_r n v^2}{3}$

(b) Given that $\frac{\mathbf{mv^2}}{\mathbf{2}} \propto$ T is one of the postulates of the kinetic model, use the expression PV = $\frac{m_r n u^2}{3}$ to derive the ideal gas equation

(c) Use the ideal gas equation to derive Dalton's law of partial pressures

4. (a) Use the ideal gas equation, the postulate $\frac{\mathbf{mv^2}}{\mathbf{2}} \propto$ T and the expression PV = $\frac{m_r n u^2}{3}$ to show that for one mole of a gas, KE = $\frac{\mathbf{3RT}}{\mathbf{2}}$

(b) Hence derive expressions for the heat capacity of a gas at constant volume (C_v) and at constant pressure (C_p)

(c) Deduce the root mean square velocity of a nitrogen molecule at 25 ^oC

(d) Calculate the average kinetic energy in $kJmol^{-1}$ of a sample of gas at 25 ^oC

5. (a) Assuming that dry air contains 79% N_2 and 21% O_2 by volume, calculate the density of moist air at 298 K at an atmospheric pressure of 101 kPa given that the partial pressure of the water vapour in the air is 3.2 kPa

(b) Calculate the total pressure in a 5 dm^3 vessel containing 2 g of ethane and 3 g of carbon dioxide at 50 ^oC

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Lessons 4 and 5

6. (a) Sketch the Maxwell-Boltzmann of molecular velocities in a sample of nitrogen gas at 25 ^{o}C
(b) On the same axes, sketch the Maxwell-Boltzmann of molecular velocities in a sample of hydrogen gas at 25 ^{o}C
(c) On the same axes, sketch the Maxwell-Boltzmann of molecular velocities in a sample of nitrogen gas at 0 ^{o}C

7. (a) Estimate the fraction of molecules at 300 K with a kinetic energy in excess of 50 $kJmol^{-1}$
(b) Estimate the fraction of molecules at 310 K with a kinetic energy in excess of 50 $kJmol^{-1}$
(c) Hence deduce the relative rates of reaction at 300 K and 310 K for a reaction with an activation energy of 50 $kJmol^{-1}$

8. Calculate the root mean square velocity, average velocity and most probable velocity of the molecules in a sample of argon gas at 298 K.

9. (a) Show that the collision frequency Z between identical molecules in a container is given by $2d^2N^2\sqrt{\frac{\pi RT}{m_r}}$ and state the meaning of the terms d and N.
(b) An apparatus of volume 500 cm^3 is evacuated at 298 K until the total pressure is just 7.0 Pa. Assuming that the remaining gas is oxygen, which has a diameter of 3.0 x 10^{-10} m, calculate:
(i) The frequency with which the oxygen molecules collide in the apparatus
(ii) The mean free path of the oxygen molecules in the apparatus

10. (a) Use your answer to 9 (a) to derive an expression for the collision frequency between two reacting particles A and B.
(b) An apparatus of volume 500 cm^3 is evacuated at 298 K until the total pressure is just 7.0 Pa. Assuming that the remaining gas is 80% nitrogen (d = 3.1 x 10^{-10} m) and 20% oxygen (d = 3.0 x 10^{-10} m, which has a diameter of 2.4 x 10^{-10} m, calculate the frequency of the collisions between nitrogen and oxygen atoms in the apparatus.

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Lesson 6

9. Explain what is meant by the "transport properties" of gases and give three examples.

10. (a) State Graham's Law of diffusion
(b) How many times faster will hydrogen effuse compared to neon?
(c) A gas is found to effuse 6.0 times slower than hydrogen. Deduce the rmm of the gas and suggest its identity.

11. Ammonia and hydrogen chloride react according to the following equation:
$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$
If both gases are allowed to diffuse towards each other from opposite ends of a cylinder, white fumes will be seen at the point at which the different gases come into contact.
(a) What is the ratio of the rate of diffusion of ammonia to that of hydrogen chloride?
(b) If the cylinder is 10 cm long, how far from the ammonia source should the white fumes be visible?

12. (a) Two identical porous containers are filled with neon and argon respectively. After 6 hours, two thirds of the neon has escaped from the first container. How long will it take for half of the argon to escape from the other container?
2.278 x 10^{-4} mol of an unidentified gas effuses through a tiny hole in 95.70 s. Under identical conditions, 1.738 x 10^{-4} mol of argon gas takes 81.60 s to effuse. What is the molar mass of the unidentified gas?

13. (a) Given that the molecular diameter of propane is 4.3 x 10^{-10} m, calculate the coefficient of diffusion, the viscosity and the thermal conductivity of propane at 298 K and 100 kPa.
(b) The viscosity of carbon dioxide is 1.38 x 10^{-5} $kgm^{-1}s^{-1}$ at 298 K. Estimate the molecular diameter of a carbon dioxide molecule.
(c) The mean free path of an ammonia molecule is 4.4 x 10^{-8} m at 298 K and 100 kPa; estimate the molecular diameter of ammonia and the diffusion coefficient of ammonia under these conditions.