I.4 Gaseous State and Transport Phenomenon

Civil Services 2016–2026: **27** parts, **245** marks · IFoS 2016–2025: **11** parts, **118** marks

Syllabus. Equation of state for real gases, intermolecular interactions and critical phenomena and liquefaction of gases, Maxwell's distribution of speeds, intermolecular collisions, collisions on the wall and effusion; thermal conductivity and viscosity of ideal gases.

Marks	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CSE	10	35	25	20	20	20	20	30	25	20	20
IFoS	0	10	10	28	15	10	10	10	20	5	

How to use this chapter. Read every question once and mark the ones that repeat. Pick three, write them by hand against the clock (about 7 minutes for 10 marks), then compare with the model answers on vkcscience.com.

2026

CSE 2026 · Q1(a) Attraction and repulsion parameters of the van der Waals equation [5 marks]

One real gas equation is van der Waals equation

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

Which parameter in the above equation reflects the intermolecular force of attraction and which one reflects the intermolecular force of repulsion? Give their units in SI system.

CSE 2026 · Q2(a) Maxwell distribution of speeds: effect of T and of M [15 marks]

The Maxwell distribution of molecular speed of a gaseous system is

$$dN_c = 4\pi N \left(\frac{M}{2\pi RT}\right)^{3/2} c^2 e^{-Mc^2/2RT}\, dc$$

(Symbols have their usual meanings)

Plot $\left(\frac{1}{N} \times \frac{dN_c}{dc}\right)$ against c—

(i) at two different temperatures T_1 and T_2; $T_2 > T_1$;

(ii) at two molar masses M_1 and M_2; $M_2 > M_1$.

Justify your plots.

2025

CSE 2025 · Q1(d) Heat conduction between two copper sheets through air [5 marks]

Two sheets of copper of area 1.50 m^2 are separated by 10 cm. What is the rate of transfer of heat by conduction from the warm sheet (50 °C) to the cold sheet (–10 °C)? What is the rate of loss of heat? (Assume the space between the two sheets is filled with air)

Given: Coefficient of thermal conductivity of air = 2.4×10^{-2} J s^{-1} m^{-1} K^{-1}

CSE 2025 · Q1(h) Sealed sample: ethane, neon or a mixture [5 marks]

A sealed container contains a gaseous sample at 300 K consisting of either pure ethane, or pure neon, or a mixture of the two. The pressure inside the container at this temperature is 1.00 atm. When the container is cooled to 150 K, the pressure is 0.37 atm. What is the composition of the sample; pure ethane, pure neon or a mixture of both? Explain your answer.

Given: Vapour pressure of C_2H_6 at 150 K is 0.10 atm

Critical temperature of neon = 44 K

CSE 2025 · Q3(a) Collisions of O_2 with the wall [10 marks]

Calculate the number of collisions that oxygen makes per second on 1.00 cm^2 of the surface of the vessel containing them if the pressure is 1.00×10^{-6} atm and the temperature is 25 °C.

IFoS 2025 · Q3(b)(i) Composition after hydrogen leakage [5 marks]

(i) A balloon is filled with H_2 and O_2. Both the gases leak through pores in the balloon. If 45% of H_2 leaks, what is the ratio of O_2/H_2 left in the balloon? 5

2024

CSE 2024 · Q1(b)(i) Separation factor for $^{235}UF_6$ and $^{238}UF_6$ in one effusion stage [5 marks]

(i) The ^{235}U isotope undergoes fission when bombarded with neutrons. However, its natural abundance is only 0.72 percent. To separate it from more abundant ^{238}U isotope, U is first converted to UF_6, which is easily vaporized above room temperature. The mixture of $^{235}UF_6$ and $^{238}UF_6$ gases is then subjected to many stages of effusion. Calculate the separation factor, that is enrichment of ^{235}U relative to ^{238}U after one stage of effusion. *5*

CSE 2024 · Q1(d)(i) Will CCl_2F_2 condense at 18 atm and 20 °C? [5 marks]

(i) The compound dichlorodifluoromethane (CCl_2F_2) has a normal boiling point of −30 °C, a critical temperature of 112 °C, and a corresponding critical pressure of 40 atm. If the gas is compressed to 18 atm at 20 °C, will the gas condense? Give your answer on the basis of graphical presentation. *5*

CSE 2024 · Q3(a) Viscosity of air at 298 K and at 0 K; Boyle temperature of Ar, CH_4 and C_6H_6 [15 marks]

(i) Calculate the coefficient of viscosity of air at temperatures: (I) 298 K and (II) 0 K.
Assume that the collision cross-section ($\pi\sigma^2$) of air is 0.28 $(nm)^2$ and average molar mass of air is 29 g mol^{-1}. *10*

(ii) Arrange Boyle's temperature of the gases Ar, CH_4 and C_6H_6 in increasing order. Give reason(s) for the answer. *5*

IFoS 2024 · Q8(a) Equal mean speeds of oxygen and hydrogen [10 marks]

Calculate the temperature at which the average velocity of oxygen equals to that of hydrogen at 20 K.

IFoS 2024 · Q8(b) Critical compressibility of a van der Waals gas [10 marks]

Using critical constants P_c, V_c and T_c for a real gas that satisfies van der Waals equation, find the critical compression factor of the gas near critical point.

2023

CSE 2023 · Q1(d) Root-mean-square speed of water molecules [10 marks]

(i) Find the temperature at which the water molecules can have the root-mean-square speed of 719 m s^{-1}.
(ii) What is the root-mean-square velocity of water molecules at 473 K?

CSE 2023 · Q4(a) van der Waals constant b, compression factor, interactions [20 marks]

The volume of a certain gas is found to be 5.0×10^{-4} m^3 mol^{-1} at 273 K and 3.0×10^6 Pa. This gas obeys the van der Waals' equation with a = 0.50 m^6 Pa mol^{-2}.
(i) Calculate the other van der Waals' constant, b.
(ii) What is the compression factor for this gas at the same temperature and pressure?

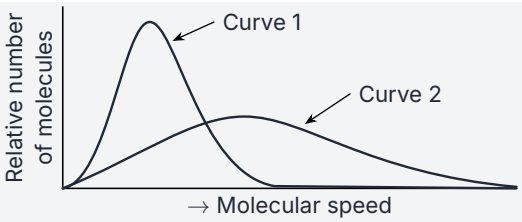
(iii) Comment on the nature of the molecular interactions of this gas.

IFoS 2023 · Q3(c) Ideal and van der Waals pressures [10 marks]

What is the difference between pressures (in atm) calculated using ideal gas equation and the van der Waals' gas equation of 7.0 moles of CO_2 gas confined in a volume of 10.4 L at 47 °C?
(Given: a = 3.59 atm L^2/mol^2 and b = 0.0427 L/mol)

2022

CSE 2022 · Q3(c) Speed distribution curves of argon and helium [10 marks]



The graph above shows the distribution of molecular speeds for Argon and Helium at the same temperature.
(i) Which curve, 1 or 2 better represents the behavior of Argon?
(ii) Which curve represents the gas that effuses more slowly?
(iii) Which curve more closely represents the behavior of fluorine gas? Explain.

CSE 2022 · Q4(a) The state of H_2 corresponding to N_2 at 126 K and 1 atm [10 marks]

By using the following given data, find that under what conditions is H_2 in the state corresponding to N_2 at 126 K and 1 atm?

Gas	T_c/K	P_c/atm
H_2	33	13
N_2	126	39

IFoS 2022 · Q4(a) Excluded volume of hard-sphere molecules [10 marks]

What is excluded volume? Explain with illustration. Show that the excluded volume per molecule is four times the actual volume of the gas molecule.

2021

CSE 2021 · Q4(b) Thermal conductivity of the gas in an ageing foam; van der Waals constants of NO and CCl_4; nearness to ideal behaviour [20 marks]

(i) A certain closed cell foam used as an insulating material is initially filled with polyatomic gas of molecular weight $\sim$ 60. Later, the gas diffuses out of the foam and is replaced by dry air (mean molecular weight $\sim$ 30). Assuming that insulating property arises largely from the thermal conductivity of the gas, explain the factors which influence the thermal conductivity of the gas. For each factor, make an argument whether insulating ability increases or decreases. What is the overall effect upon the insulating ability? 10
(ii) The critical temperature and pressure for NO gas are 177 K and 64 atm, respectively, and for CCl_4, they are 550 K and 45 atm, respectively. Which gas has the smaller values of the van der Waals' constants, a and b? Which is the most nearly ideal in behaviour at 300 K and 10 atm? 10

IFoS 2021 · Q3(a) Maximum low-pressure slope of Z [10 marks]

At what temperature does the slope of Z versus P curve as $P \to 0$ have its maximum value for a Van der Waals gas? What is the value of the maximum slope?

2020

CSE 2020 · Q5(b) van der Waals constants of ethylene from Tc and pc [10 marks]

Calculate van der Waals constants for ethylene.
Given : critical temperature (T_c) = 282 K and critical pressure (P_c) = 50 atm.

CSE 2020 · Q6(a) c_{mp}, c_{av}, c_{rms} on the Maxwell distribution curve [10 marks]

What does most probable speed (C_{mp}), average speed (C_{av}) and root mean square speed (C_{rms}) mean? Indicate these speeds on a Maxwell distribution curve. What does the area under the Maxwell distribution curve represent?

IFoS 2020 · Q2(a) Mean free path of hydrogen atoms in intergalactic space [15 marks]

Astronomers have suggested that intergalactic space contains hydrogen atoms at a temperature of $7{\cdot}8\times10^5$ K, with about 1 atom per 100 dm^3.
(i) Calculate the mean free path of a hydrogen atom in the intergalactic space.
(ii) Calculate the approximate average time in years, between collisions of an atom.
Assume that the collision diameter of a hydrogen atom is 200 pm.

2019

CSE 2019 · Q1(c) Internal pressure $(\partial U/\partial V)_T$ of a van der Waals gas [10 marks]

van der Waals' equation states that $(P + \frac{a}{\bar{V}^2})(\bar{V} - b) = RT$ (a and b are constants).
Find $(\frac{\partial u}{\partial v})_T$ for van der Waals' gas.

CSE 2019 · Q1(e) Maxwell distribution of molecular speeds and the effect of temperature [10 marks]

Write Maxwell's distribution of molecular velocities for gases. What is the effect of temperature on the distribution? Represent graphically.

IFoS 2019 · Q1(c) Effect of temperature on the distribution of molecular velocities [8 marks]

Explain the effect of temperature on the distribution of molecular velocities.

IFoS 2019 · Q4(a) Critical constants of a van der Waals gas; entropy with temperature [20 marks]

(i) Derive the expressions for the critical pressure, critical temperature and critical volume of a Van der Waals gas. 10
(ii) Deduce an expression for the variation of entropy with temperature at constant volume and pressure. 10

2018

CSE 2018 · Q2(b)(ii) Effect of temperature on viscosity [5 marks]

Discuss the effect of temperature on the viscosity of liquids and gases.

CSE 2018 · Q4(b)(ii) Cold air descending into a valley [5 marks]

What happens to the air temperature in a valley when cold air blowing from the mountain tops descends into the valley?

CSE 2018 · Q4(c)(i) Effusion of H_2 and N_2 through a fine glass filter [10 marks]

One side of glass cylinder is initially filled with H_2 at a pressure P and other side with N_2 at a pressure 2P. This glass cylinder is closed at both ends and a glass filter in the middle of the cylinder divides it into two compartments of equal volume. Describe what happens, starting at time, t = 0 at constant temperature and assuming that the pores of filter have a diameter much smaller than the mean free paths of the gases.

CSE 2018 · Q4(c)(ii) Vapour and gas from the critical temperature [5 marks]

Account for the difference between vapour and gas on the basis of critical temperature.

IFoS 2018 · Q3(a) Z versus P for an ideal gas, H_2 and NH_3 [10 marks]

At 27 °C, for fixed amount of (i) ideal gas, (ii) hydrogen gas, (iii) ammonia gas; show the plots of 'Z' (compressibility factor) against P (pressure) on the same diagram.

2017

CSE 2017 · Q1(b) Most probable speed from the Maxwell distribution [10 marks]

For an ideal gas, the distribution law of molecular speed is,

$$dN_c = 4\pi N \left(\frac{m}{2\pi k_B T}\right)^{3/2} c^2 \, e^{-mc^2/2k_B T} \, dc,$$

where,

dN_c = Number molecules within the speed range c and $(c + dc)$.
N = Total number of molecules.
m = Molecular mass.
T = Temperature in Kelvin scale.

Derive the expression of most probable speed of this gaseous system.

CSE 2017 · Q2(a)(i) Viscosity coefficient: dimension, SI unit, and its rise with T in a gas [10 marks]

What is the dimension of viscosity co-efficient? What is its unit in SI system? The temperature effect on viscosity co-efficient of ideal gas is positive. Explain.

CSE 2017 · Q2(a)(ii) Boyle temperature of a van der Waals gas [15 marks]

Define Boyle temperature of non-ideal gas. Obtain its expression for van der Waals' gas.

IFoS 2017 · Q3(c) **Pressure of CO_2 from the van der Waals equation** [10 marks]

According to Van der Waals' equation, calculate the pressure required to confine one mole of CO_2 in a volume of 1 litre at 0 °C.

Given : R = 0·082 litre atm
a = 3·60 atm litre^2/mol^2
b = 4·27 × 10^{-2} litre/mol

2016

CSE 2016 · Q1(d) **Continuity of state: Andrews' isotherms of CO_2** [10 marks]

Explain "continuity of state" with the help of isotherms of CO_2. How is it affirmed by van der Waals' equation?