I.11 Surface Phenomena and Catalysis

Civil Services 2016–2026: **21** parts, **225** marks · IFoS 2016–2025: **15** parts, **152** marks

Syllabus. Adsorption from gases and solutions on solid adsorbents; Langmuir and B.E.T. adsorption isotherms; determination of surface area, characteristics and mechanism of reaction on heterogeneous catalysts.

Marks	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CSE	25	20	25	10	25	20	20	10	25	25	20
IFoS	20	10	0	38	18	15	18	10	10	13	

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(j) Why low temperature favours adsorption of a gas [5 marks]

Spontaneous adsorption of gas on solid surface favours low temperature. Explain, why.

CSE 2026 · Q4(c) Pressure dependence of the order of a surface-catalysed decomposition [15 marks]

The kinetic order of the solid-surface catalyzed gas-phase decomposition reaction varies with the pressure of the gaseous reactant. Explain with plausible mechanism.

2025

CSE 2025 · Q5(c) Surface area of charcoal from a nitrogen monolayer [5 marks]

At 0 °C and 1 atm pressure, the volume of nitrogen (N_2) gas required to form a monolayer on a sample of charcoal is 155.5 $cm^3\ gm^{-1}$ of charcoal. Calculate the surface area per gram of charcoal. Area of cross-section of a N_2 molecule is 0.160 $(nm)^2$.

[Given: N_A = 6.022 × 10^{23} mol^{-1}; Molar volume of gas (at 0 °C and 1 atm pressure), V_m = 22.414 $dm^3\ mol^{-1}$]

CSE 2025 · Q6(c) Langmuir adsorption isotherm [20 marks]

Mentioning the requisite assumptions, derive the equation of the Langmuir adsorption isotherm. Show that the Langmuir isotherm holds at low pressure but fails at high pressure.

IFoS 2025 · Q5(b) Langmuir adsorption isotherm [8 marks]

State the assumptions on which Langmuir's adsorption isotherm is based. Derive Langmuir's isotherm, $\theta = \frac{KP}{1+KP}$, where θ is the fraction of the total surface covered by the adsorbed molecules, P is the pressure of the gas and K is the adsorption coefficient.

IFoS 2025 · Q6(b)(ii) Heterogeneous catalysis [5 marks]

(ii) What is heterogeneous catalysis? Explain giving one example. [5]

2024

CSE 2024 · Q5(b) How water condenses onto glass; Time to form half a monolayer at 2.0×10^{-11} torr [10 marks]

(i) How does water condense onto glass? *5*

(ii) How long will it take for about one-half of a monolayer to form on the surface if the surface is exposed to a pressure of 2.0×10^{-11} torr? Assume that a monolayer formation needs an exposure of 1 Langmuir. Also give reason for using such low pressure in cleaning the surface. *5*

CSE 2024 · Q6(b) Heterogeneous catalysis; PH_3 on tungsten [15 marks]

What is meant by heterogeneously catalyzed reactions? Mention the consecutive steps for a reaction to occur on a surface.

Using Langmuir adsorption theory, account for the experimental observation that the decomposition of PH_3 on tungsten follows first order kinetics at low pressure and zeroth order kinetics at high pressure.

IFoS 2024 · Q4(c) BET surface-area measurement [10 marks]

What is the meaning of isotherm? Write BET equation and explain how specific surface area of a solid is determined.

2023

CSE 2023 · Q7(c) Rate expression for a bimolecular surface reaction [10 marks]

Derive a rate expression for a bimolecular surface reaction. Discuss the kinetics of such a reaction, when the gaseous reactants, say *A* and *B*, are adsorbed in the following way:

$$A + B \rightarrow \text{Product}$$

(i) *A* and *B* are sparsely adsorbed.

(ii) *A* is relatively more strongly adsorbed than *B*.

IFoS 2023 · Q6(c) Catalysts and the Freundlich isotherm [10 marks]

(i) Write five characteristic features of a catalyst.

(ii) Discuss the important features, conditions and range of applicability of Freundlich adsorption isotherm.

2022

CSE 2022 · Q7(d) Surface area of an adsorbent from the nitrogen monolayer [10 marks]

At 0 °C and 1 atm pressure, the volume of nitrogen gas required to cover a sample of an adsorbent is found to be 130 $cm^3\ g^{-1}$. Calculate the surface area per gram of adsorbent. Given that area occupied by a nitrogen molecule is 0.162 $(nm)^2$.

[$N_A = 6.022 \times 10^{23}\ mol^{-1}$]

CSE 2022 · Q8(e) Langmuir isotherm and the kinetics of surface reactions [10 marks]

Derive Langmuir adsorption isotherm. How does Langmuir adsorption isotherm help in elucidation of kinetics of a gaseous reaction on solid surface?

IFoS 2022 · Q5(b) Fractional surface coverage [8 marks]

Obtain the expression for fraction of surface sites adsorbed by gas molecules from Langmuir theory of adsorption.

IFoS 2022 · Q7(a) Adsorption isotherms and BET theory [10 marks]

Draw various types of adsorption isotherm curves involved in monolayer and multilayer formation. Explain these curves based on Brunauer-Emmett-Teller Theory.

2021

CSE 2021 · Q6(c) Langmuir adsorption isotherm; first-order and zero-order limits [20 marks]

Derive an equation for Langmuir's adsorption isotherm. Show that under limiting conditions of pressure, the system follows both first-order and zero-order of adsorption.

IFoS 2021 · Q7(a) Langmuir adsorption and the Freundlich form [15 marks]

Derive an expression for Langmuir's adsorption isotherm. Show that at normal pressures, Langmuir's unimolecular adsorption reduces to Freundlich adsorption isotherm.

2020

CSE 2020 · Q2(d) Surface-catalysed decomposition: zero order at high pressure [15 marks]

Show that a surface catalysed decomposition reaction follows zero order kinetics with respect to reactant when its pressure is high enough.

CSE 2020 · Q5(d) Signs of ΔH, ΔS and ΔG for spontaneous adsorption [10 marks]

What would be the sign; negative, positive or zero; for ΔH, ΔS and ΔG for the process of spontaneous adsorption of gas on solid surface at constant temperature. Give reasons.

IFoS 2020 · Q2(c) Types of electrokinetic phenomena [10 marks]

Discuss concisely the types of electrokinetic phenomena.

IFoS 2020 · Q5(e) Steps of a fluid-phase reaction on a solid; the RDS [8 marks]

Provide the steps involved in fluid-phase reactions on a solid and identify the rate-determining step.

2019

CSE 2019 · Q5(e) Surface reactions: first order at low pressure, zero order at high [10 marks]

Unimolecular surface catalysed gas phase reactions follow first order kinetics at low pressures and zero order kinetics at high pressures. Why?

IFoS 2019 · Q5(a) BET isotherm for multilayer (Type II) adsorption [8 marks]

For multilayer physical adsorption (Type-II), describe Brunauer – Emmett – Teller isotherm. Why is BET isotherm nowadays employed extensively for the determination of surface area?

IFoS 2019 · Q7(a) Langmuir isotherm; surface area of silica gel [20 marks]

(i) Define Adsorption isotherm. Using simple model of the solid surface, derive an equation for Langmuir isotherm. What happens to the fraction of adsorption sites occupied by adsorbate (θ) at equilibrium in the low and high pressure limit according to the Langmuir isotherm? 12

(ii) The volume of N_2 gas (at STP) needed to cover a sample of silica gel with a monomolecular layer is 122 cc/gm. Calculate the surface area of gel. Each nitrogen molecule occupies 15·7 $Å^2$. 8

IFoS 2019 · Q8(c) Industrial solid catalysts; CO oxidation on platinum [10 marks]

Give at least three examples of industrial chemical reactions run in the presence of solid catalysts. Discuss the oxidation of CO on a platinum catalyst.
Why should a good catalyst have moderate values for the enthalpies of adsorption of the reactants?

2018

CSE 2018 · Q5(b) Langmuir isotherm at very low and very high pressure [10 marks]

Explain Langmuir adsorption isotherm
(i) when the gas pressure 'P' is very small and
(ii) when the gas pressure 'P' is very high.

CSE 2018 · Q7(a)(i) BET equation and the surface area of a solid [10 marks]

Write BET equation. Explain the terms involved in it. How is it useful for the determination of surface area?

CSE 2018 · Q7(a)(ii) Mechanism of heterogeneous catalysis [5 marks]

Explain the mechanism of reaction on heterogeneous catalysis.

2017

CSE 2017 · Q5(c) Signs of ΔG, ΔS and ΔH for adsorption of a gas [10 marks]

At constant pressure and temperature, adsorption of a gas on solid surface occurs spontaneously. For this natural process, what will be the signs of (i) ΔG, (ii) ΔS and (iii) ΔH? Give reason(s) in support of your answer.

CSE 2017 · Q6(a)(i) Essential characteristics of catalysis; surface catalysis [10 marks]

What are the characteristics, essential for catalysis with specific reference to surface catalysis?

IFoS 2017 · Q8(b) BET equation and surface area [10 marks]

Derive the B.E.T. equation for adsorption on a solid surface. How can the surface area be determined with the help of B.E.T. equation?

2016

CSE 2016 · Q3(a)(i) Adsorption theory of catalysis; catalyst and equilibrium [15 marks]

Explain the adsorption theory of catalysis. Give one example and indicate the type of adsorption involved. What effect does a catalyst have on an equilibrium system?

CSE 2016 · Q8(c) Surface area of silica gel from the nitrogen monolayer [10 marks]

Volume of nitrogen gas at 1 atm and 273 K required to cover 1 g of silica gel is 0.129 dm^3. Calculate the surface area of the gel if each nitrogen molecule occupies an area of 16.2×10^{-10} m^2.

IFoS 2016 · Q2(c) Adsorption theory of catalysis: steps and example [10 marks]

Explain the adsorption theory of catalysis. What are the various steps involved in it? Give one example to support your answer.

IFoS 2016 · Q4(a)(ii) Surface area of silica gel from the nitrogen monolayer [10 marks]

The volume of nitrogen gas at 1 atmosphere and 273 K required to cover one gram of silica gel is 0.129 dm^3. Calculate the surface area of the gel if each nitrogen molecule occupies an area of 16.2×10^{-10} m^2. (Given $N_A = 6.023 \times 10^{23}$)