Question 1

Adsorption of O_2 gas on a platinum surface.

Q1 - Adsorption of O_2 on Pt can be either physisorption or chemisorption.

At low temperature, which type of adsorption is expected to dominate, and why?

At higher temperature, which type of adsorption dominates, and how can this be explained in terms of Gibbs free energy?

Q2 – Platinum is often described as having a “moderate” interaction strength with adsorbates.

Why would too strong adsorption or too weak adsorption both lead to poor performance for gas adsorption applications?

Comparing Pt(100) and Pt(111) surfaces, which one is expected to adsorb O_2 more strongly, and why does surface orientation matter?

Question 2

You are preparing a thin gold film on a silicon wafer using thermal evaporation.
After deposition, you notice that the film **shows poor adhesion and patchy delamination** when you try to use it in a device.

Q1. What could be the origin of the problem?

Q2. What contaminants may be present on the wafer surface?

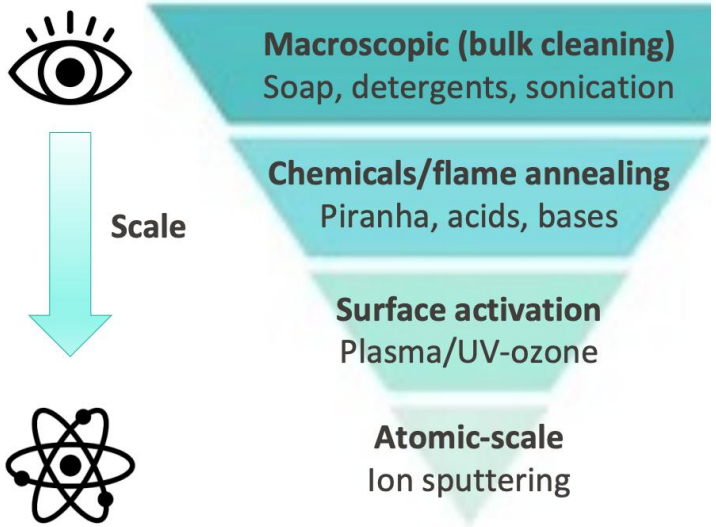
Q3. What could you already do, without stating over completely?

Q4. What could you change in your process to avoid this issue next time?

Question 3

For each of these cleaning categories, find:

- Real-life application
- Mechanism (how it works)
- Effect on the surface (pros + cons)



Question 1:

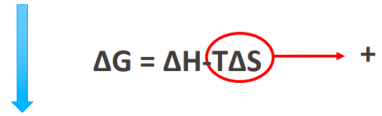
A1: Physisorption or Chemisorption:

Multilayer physisorption dominates the process **at low temperature**, since certain temperature is required to reach the activation energy barrier for chemisorption;

Chemisorption dominates the process **at higher temperature (not too high)**

Spontaneous process: ΔG<0

Adsorbate loses degrees of freedom upon adsorption: ΔS<0

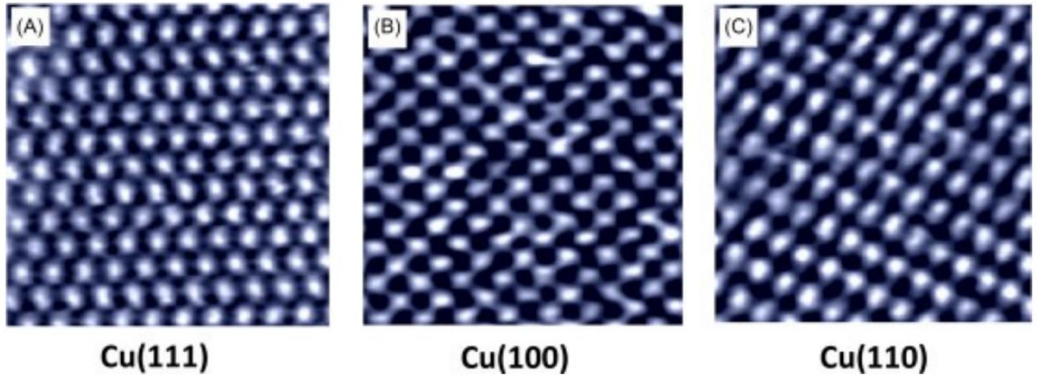


Almost always exothermic: ΔH<0

Physisorption and chemisorption are both exothermic, ΔH<0;
For physisorption, ΔH ~ minus tens of kJ/mol;
For chemisorption, ΔH ~ minus hundreds of kJ/mol;
With temperature increase, ΔG of physisorption can be converted to positive (far earlier than ΔG of chemisorption), leading to non-spontaneous process of physisorption → Chemisorption dominates

A2: Strong/Weak adsorption

Strong adsorption of gas molecule leads to difficult desorption (poisoning the surface), leading to fully occupation of active sites on the surface without efficient dynamic molecule exchange. Low desorption can prevent continuous reaction on the surface;
Weak adsorption cannot initiate efficient chemical bond breakage & rebuilt that required in the reaction.



Compared with Pt(111), Pt(100) is expected to have stronger oxygen adsorption;

Pt atoms are packed on the Pt(100) surface in a lower density
→ Larger atom distance → electrons in Pt more unsaturated → stronger attraction to the electron pairs in O atoms

Question 2:

A1: Origin of problem:
Incomplete cleaning of the silicon wafer. Likely thin organic films or adsorbed water residues remained.

A2: Possible contaminants:
- Organic residues from handling or solvents.
- Thin oxide/hydrocarbon layers on the wafer.
- Adsorbed water from ambient air.

A3: Corrective steps (without losing current wafer):
- Use **oxygen plasma treatment or UV–ozone** to remove organic films and increase surface energy.
- Gentle heating under vacuum to desorb water.

A4: Process improvements for the future:
- Add a **piranha or RCA clean** before deposition to remove organics/oxides.
- Handle wafers only with tweezers/gloves in a cleanroom.
- Store wafers in sealed, dry containers before use.
- Introduce a **plasma activation step** directly before deposition.

Question 3:

1. Macroscopic (bulk cleaning)
Example: Washing laboratory glassware with detergent and sonication.
What is used: Soap/detergents + ultrasonic bath.
Mechanism: Detergent molecules have hydrophilic and hydrophobic parts → they emulsify grease and organic dirt; sonication creates cavitation bubbles that physically dislodge particles.
Effect on surface: Removes visible dirt, grease, and large particles. But may leave thin organic films or adsorbed residues → surface not truly "clean" at molecular level.

2. Chemical / Flame Annealing
Example: Cleaning silicon wafers in microelectronics with **piranha solution (H_2SO_4 + H_2O_2)**.
What is used: Strong oxidizing acids (piranha, nitric acid) or base etches.
Mechanism: Oxidizes and dissolves organic layers, strips oxides. High temperature/flame can burn off carbon.
Effect on surface: Produces a hydrophilic, oxide-rich surface. However, can roughen the surface and leave chemical residues. Hazardous to handle.

3. Surface Activation
Example: Plasma cleaning of polymer medical implants before coating or bonding.
What is used: Oxygen plasma or UV–ozone treatment.
Mechanism: High-energy reactive oxygen species (radicals, ozone) break down hydrocarbons and polymer contaminants into volatile CO_2 and H_2O. Also introduces polar functional groups (–OH, –COOH).
Effect on surface: Increases surface energy and wettability (better adhesion, biocompatibility). But does not restore crystallinity; limited penetration depth.

4. Atomic-scale Cleaning
Example: Ion sputtering of metal surfaces in **ultra-high vacuum (UHV)** before thin-film deposition.
What is used: Argon ion gun.
Mechanism: Accelerated Ar^+ ions bombard the surface, physically ejecting adsorbates and damaged surface layers (sputtering).
Effect on surface: Produces atomically clean surface free of adsorbates. Essential for surface science experiments. But expensive, requires UHV, and can damage/crystallographically disorder the top atomic layers.