Introduction to the MQ135 Gas Sensor: Conceptual overview at a deeper level and Applications:

In today's developing world, we experience the newest innovative technologies of our time and those emerging trends, far ahead of our time as well. We come across various instances where different gases are released, and it becomes increasingly necessary for one to monitor these gases and their impact on the surroundings.

This is where the MQ 135 Gas Sensor comes into play. The **MQ135 gas sensor** is a versatile and widely used sensor for detecting gases in the air, including Ammonia (NH_3), Nitrogen oxides (NOx), Benzene, Alcohol, and other volatile organic compounds (VOCs). As part of the MQ series, which is manufactured by **Hanwei Electronics**, the MQ135 is a **metal oxide semiconductor (MOS)** sensor that functions based on the interaction between the target gases and a sensitive metal oxide layer. This sensor is known for the following:

1)It's affordability

2)Ease of integration

3)Suitability for applications in air quality monitoring, environmental sensing, and industrial safety.

Conceptual Overview:

The MQ 135, at its core works based on a MOS or a Metal-oxide semiconductor sensing material which is usually Tin Oxide (SnO_2) coated on the heating element.

The gas sensor module consists of a steel exoskeleton under which a sensing element is housed. This sensing element is subjected to current through connecting leads. This current is known as the Heating Current and through it, the gases coming close to the sensing element get ionized and are absorbed by the sensing element. This changes the resistance of the sensing element, altering the value of the current going out of it.

Oxidation or reduction occurs on the metal oxide surface which is caused due to change in resistance which is further due to the adsorption of gas molecules on the metal oxide surface which alters the conductivity of the metal.

The key components and processes involved are as follows:

1] **Heater Coil**: A built-in heater maintains our sensor at an optimal temperature (200-300 Celsius) to facilitate chemical reactions between the sensing layer and the adsorbed gas molecules.

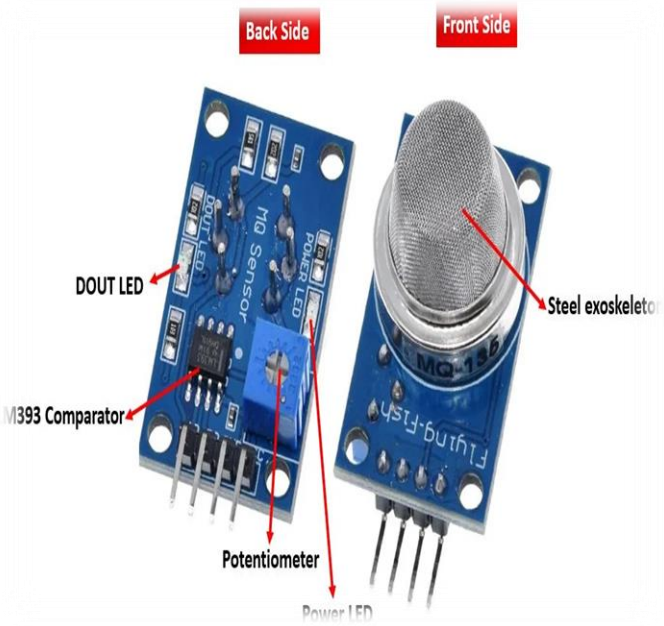
2] **Sensing Laye**r: Coming to the sensing layer, it is a thin layer of tin oxide deposited on a ceramic substrate, which causes it to have a higher affinity to gas molecules.

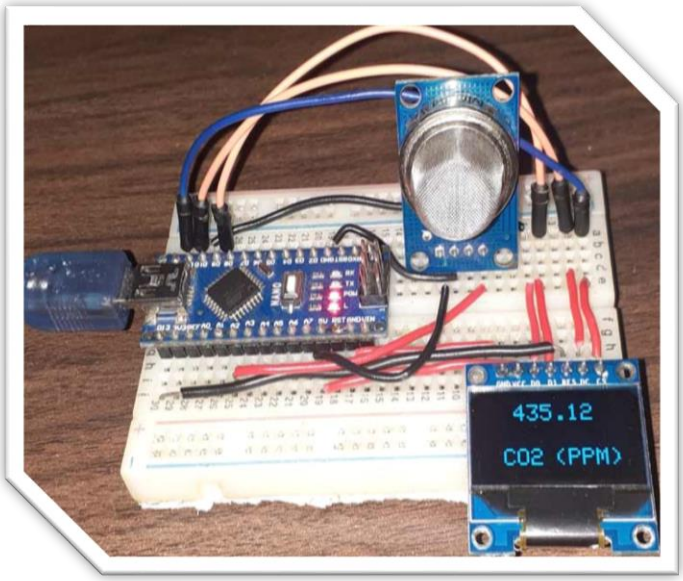
3] **Gas Detection Mechanism**: As the gas molecules encounter the sensing layer, they are adsorbed onto the surface. These interactions end up altering the surface charge density, leading to a change in the electrical conductivity of the sensor. The gas concentrations impact the extent of the conductivity to a great level.

4] **Signal Conversion**: Cange in conductivity is converted into a voltage signal by the design of a single circuit. This signal can be read by the microcontroller or any external device that are capable of interpreting the concentration of gases.

Following are the main gases that can be detected by the sensor sensitivity:

a) Ammonia
b) Nitrogen Oxides
c) Carbon Dioxide
d) Alcohol Vapors
e) Smoke
f) Benzene





The above images showcase the structure of an MQ135 Gas Sensor and how it is connected to an Arduino, OLED display and a breadboard, where it carries out its function of sensing the air quality. MQ-135 Gas Sensor and OLED Display module both are powered with +5V and GND.

Pin Configuration of the MQ-135 gas sensor:

From left to right first pins are as follows:

A0	Analog output	D0	Digital output
GND	Ground	Vcc	Supply (5V)

S.No	OLED Module Pin (if connected)	Arduino Pin
1	GND	Ground
2	VCC	5V
3	D0	10

4	D1	9
5	RES	13
6	DC	11
7	CS	12

When there is no gas detected, the digital output is 1 while the analog output can go up to 1023., which is the maximum value. As soon as the gas is detected, the digital output showcased is 0 and the analog output is much less than 1023. Using the potentiometer on the chip, the turning OFF point of the digital pin may be controlled at a particular value of the analog pin. The resistance value of MQ-135 is different to various kinds and various concentration gases. So, when using these components, sensitivity adjustment is very necessary. It is recommended that the detector must be calibrated for 100ppm NH3 or 50ppm Alcohol concentration in air and a value of Load resistance can be (R_L) about 20 KΩ (10KΩ to 47 KΩ). When accurately measuring, the proper alarm point for the gas detector should be determined after considering the temperature and humidity influence. Lower the value, lower is the sensor sensitivity. Higher the value, less accurate is the sensor for higher concentrations of gas at the same surrounding conditions. The load resistor may be calibrated if only a single gas is to be measured specifically.

Specifications:

A. Standard work conditions:

Symbol	Parameter name	Technical condition	Remarks
V_C	Circuit Voltage	5V ±0.1	AC or DC
V_H	Heating Voltage	5V ±0.1	AC or DC
R_L	Load Resistance	Can adjust	
R_H	Heater Resistance	33Ω±5%	Room Temperature
P_H	Heating Consumption	less than 800mw	

B. Environment conditions:

Symbol	Parameter name	Technical conditions	Remarks
Tao	Using temperature	-10C to -45C	
Tas	Storage temperature	-20 to -70	
R_H	Related humidity	Less than 95% Rh	
O_2	Oxygen concentration	21% (standard condition) Oxygen concentration can affect sensitivity	Minimum value is over 2%

C. Sensitivity characteristics

Symbol	Parameter name	Technical parameter
Rs	Sensing Resistance	30KΩ-200KΩ (100ppm NH_3)
α (200/50) NH_3	Concentration Slope rate	≤0.65
Standard Detecting Condition	Temp: 20C±2C Vc:5V±0.1 Humidity: 65%±5% (20% to 90%RH) Vh: 5V±0.1	Temp: 20C±2C Vc:5V±0.1 Humidity: 65%±5% (20% to 90%RH) Vh: 5V±0.1
Preheat time	24 to 48 hours	24 to 48 hours

D. Structure and configuration of the basic circuit:

Parts	Materials
Gas Sensing layer	SnO_2
Electrode	Au
Electrode line	Pt
Heater coil	Ni-Cr alloy
Tubular ceramic	Al2O3
Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
Clamp ring	Copper plating Ni i
Resin base	Bakelite
Tube Pin	Copper plating Ni

Dimensions: Compact and lightweight module measuring approximately 32 mm x 20 mm x 22 mm

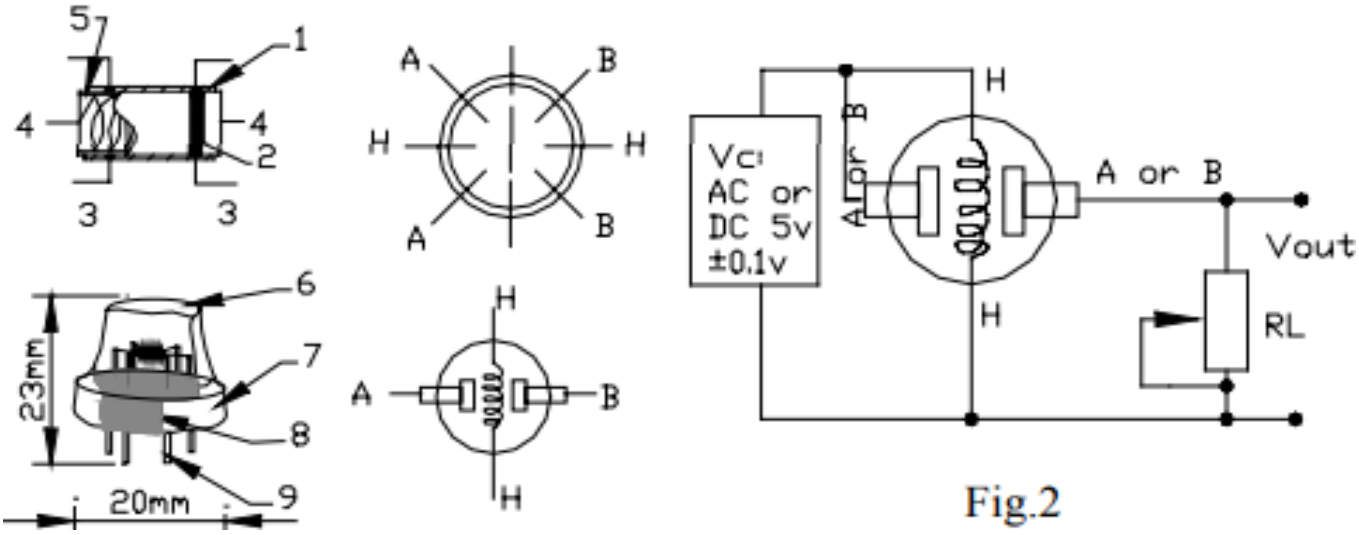


Fig.2

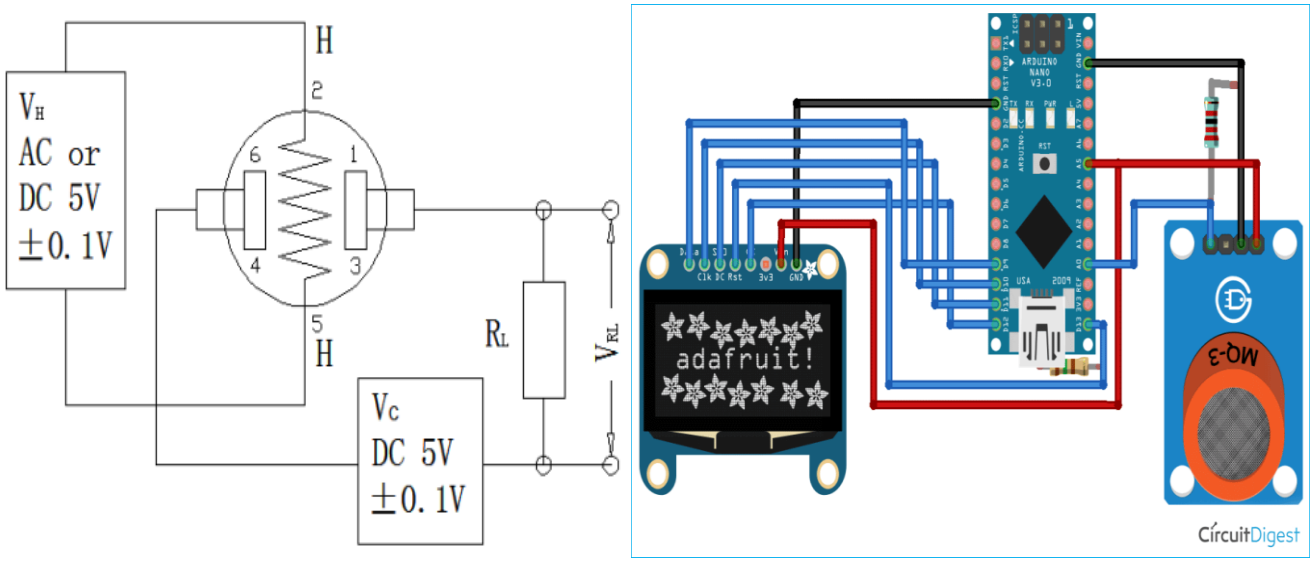
Technical Parameters:

Model			MQ135
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite, Metal cap
Target Gas			ammonia gas, sulfide, benzene series steam
Detection range			10～1000ppm(ammonia gas, toluene, hydrogen, smoke)
Standard Circuit Conditions	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.1V AC or DC
	Load Resistance	R_L	Adjustable
Sensor character under standard test conditions	Heater Resistance	R_H	29Ω±3Ω (room tem.)
	Heater consumption	P_H	≤950mW
	Sensitivity	S	Rs(in air)/Rs(in 400ppm H_2)≥5
	Output Voltage	Vs	2.0V～4.0V （in 400ppm H_2）
	Concentration Slope	α	≤0.6(R_{400ppm}/R_{100ppm} H_2)
Standard test conditions	Tem. Humidity		20℃±2℃； 55%±5%RH
	Standard test circuit		Vc:5.0V±0.1V； V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

Features of MQ-135 GAs Sensor:

1) A wide detecting Scope
2) Stabe and long life
3) Fast response
4) High Sensitivity to toxic gases
5) A simple drive circuit
6) Low cost

Circuit Diagram:



The above fig is the basic test circuit of MQ135. The sensor requires two voltage inputs: heater voltage (V_H) and circuit voltage (V_C). VH is used to supply standard working temperature to the sensor, and it can adopt DC or AC power, while VR_L is the voltage of load resistance R_L which is in series with sensor. Vc supplies the detected voltage to load resistance R_L and it should adopt DC power

Once the hardware and code are ready, it is time to test the sensor. Hence, while testing the circuit, sample sketch must be inserted into the Arduino IDE and using a USB cable, ports from the Arduino must be connected to the computer. A program like the above must be uploaded and results shall be shown on the serial monitor.

Code for interfacing MQ-135 Gas Sensor with the Arduino:

```
int sensorValue;
 int digitalValue;
 void setup()
 { Serial.begin(9600); // sets the serial port to 9600
pinMode(13, OUTPUT);
pinMode( 3, INPUT);
 }
 void loop()
{ sensorValue = analogRead(0); // read analog input pin 0
 digitalValue = digitalRead(2);
 if(sensorValue>400)
{
 digitalWrite(13, HIGH);
 }
 else digitalWrite(13, LOW);
Serial.println(sensorValue, DEC); // prints the value read
 Serial.println(digitalValue, DEC);
delay(1000); // wait 100ms for next reading
 }
//The OLED display need not be included as the results will be exhibited on the serial monitor as well.
```

Result:

On serial monitor you can see values of analog pin being detected.

- Normal air returns approximately 100-150.
- Alcohol returns approximately 70.
- Lighter gas returns approximately 750.

Cautions to be followed:

1} Sensing material will lose sensitivity and never recover if the sensor absorbs organic silicon steam. Sensors must avoid getting exposed to silicon bond, fixature, silicon latex, putty or plastic containing silicon environment.

2} If the sensors are exposed to high concentrations of corrosive gas (such as H_2 S, SOx, Cl_2, HCl etc.), it will not only result in corrosion of sensors structure, but also causes severe sensitivity attenuation.

3} The sensor's performance will be changed badly if they are sprayed or polluted by alkali metals or salt, especially brine or if exposed to halogen such as fluorine.

4} Sensitivity of the sensors will be reduced when spattered or dipped in water.

5} Icing must be avoided on the sensor's surface; else the sensing material will be broken, and sensitivity will be lost.

6} Applied voltage on sensor should not be higher than stipulated value, even if the sensor is not physically damaged or broken, as it causes down-line or heater damage, and the sensor's sensitivity characteristics will change badly.

7} Indoor conditions like slight water condensation will influence sensors' performance lightly. However, if water condenses on the sensor's surface, it loses its sensitivity.

8} Irrespective of the sensor being electrified or not, if it is placed in high gas concentration for a long time, sensor characteristics will be affected. If lighter gas is sprayed on the sensor, it will cause extreme damage.

9} Continual vibration will result in the sensors down-lead response and then break it. In the transportation or assembling line, pneumatic screwdriver/ultrasonic welding machines can lead to this vibration.

Welding Conditions for the sensor:

1. Soldering flux: Resin soldering flux containing chlorine

2. Homothermic soldering iron

3. Temperature about 250 degree C

4. Time less than 3 seconds

Soldering Conditions for the sensor:

1. Soldering flux as mentioned above

2. Speed about 1-2 meter/minutes

3. Warm up temperature about 100 degree C

4. Welding temperature about 250 degree C

5. One time pass wave crest welding machine

Applications of MQ-135 Gas Sensor:

The versatility and affordability of the MQ-135 sensor have led to its use in several critical domains:

1. Air Quality Monitoring:

a. Measures indoor and outdoor air quality by detecting pollutants such as CO2, ammonia, and NOx.

b. Used in smart city projects to assess and improve environmental conditions.

2. Industrial Safety:

a. Detection of harmful gases in factories and industrial plants to prevent hazardous situations.

b. Included in gas leak detection systems to ensure the safety of workers.

3. Home Automation:

a. Installed in smart homes for monitoring air quality and ensuring a healthy living environment.

b. Used in IoT-based systems to trigger air purifiers or ventilation systems automatically.

4. Automotive Industry:

a. Monitors exhaust gases in vehicles to ensure compliance with emission standards.

b. Enhances air quality by detecting harmful gases.

5. Healthcare:

a. Used in medical facilities to monitor air quality for sensitive environments.

b. Used in devices for breath analysis to detect alcohol or other compounds.

6. Educational and Research Applications:

a. Used in academic projects to teach sensor technology and environmental monitoring.

b. Serves as a base for developing more sophisticated multi-gas detection systems.

Advantages:

• Cost-Effective: The sensor is affordable, making it accessible for both commercial and DIY applications.

• Wide Detection Range: Capable of detecting multiple gases, enhancing its utility.

• Compact and Lightweight: Easy to integrate into various devices and systems.

Limitations:

• Calibration Requirements: Needs periodic calibration for accurate readings.

• Cross-Sensitivity: May react to unintended gases, leading to false positives.

• Environmental Sensitivity: Performance can be affected by temperature and humidity changes.

Sensitivity characteristic curve of the MQ-135 Gas Sensor:

This graph shows the typical sensitivity characteristics of the MQ-135 for several gases.

Temperature: 20C

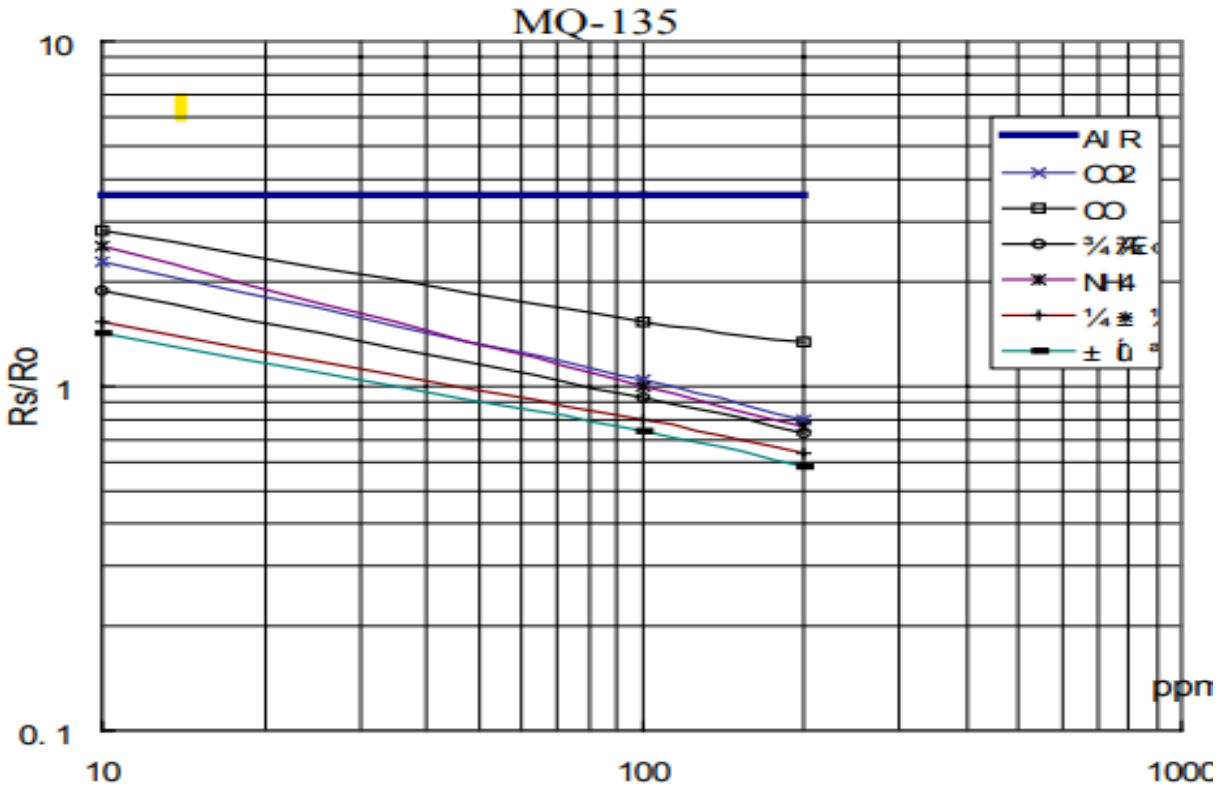
Humidity: 65%

Oxygen concentration: 21%

Load resistance: 20 kΩ

Ro: sensor resistance at 100ppm of NH3 in the clean air

Rs: sensor resistance at various concentrations of gases.



Freundlich Adsorption Isotherm:

The Freundlich adsorption theorem is a relationship that describes the adsorption of gas molecules onto the surface of a solid at a constant set of conditions. It is represented by the following:

$$q=K_f\, C^{1/n}$$

Where:

a) q is the amount of gas adsorbed per unit mass of the adsorbent.
b) C is the equilibrium pressure of the gas.
c) K and n are Freundlich constants that depend on the adsorbent-adsorbate system and temperature.

Note: K is related to adsorption capacity.

If n>1, it indicates the adsorption intensity and surface heterogeneity.

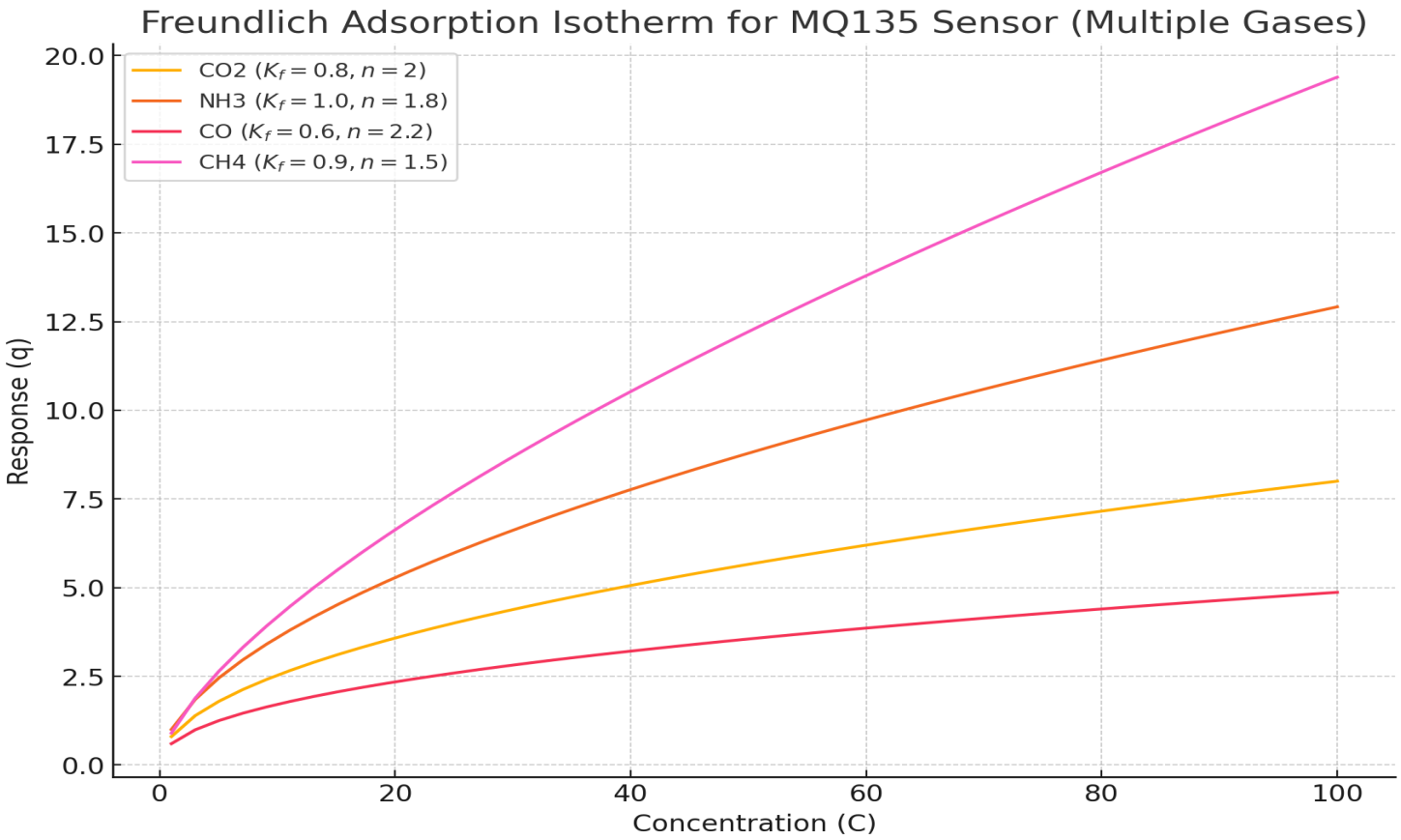
To plot the Freundlich adsorption isotherm:

1. Use hypothetical or experimental data for C (gas concentration) and q (sensor response).
2. Fit the Freundlich equation to the data to estimate K_f and /n.
3. Plot q against C.

Graph for Freundlich Adsorption Isotherm:

1} q is on the x-axis: how adsorption varies with varying gas pressure.

2} C is on the y-axis.



Future Impact:

The MQ-135 sensor plays a crucial role in advancing technologies for a cleaner, safer, and more efficient world. Its integration with AI and IoT platforms is driving innovation in air quality management, predictive maintenance, and automated safety systems. By enabling precise monitoring of environmental and industrial conditions, the sensor supports global efforts to combat pollution, enhance sustainability, and improve public health.

Conclusion:

The MQ-135 gas sensor exemplifies how accessible technology can address complex challenges. Its capability to detect a variety of harmful gases makes it a cornerstone in air quality monitoring, industrial safety, and smart systems. With continued advancements in sensor technology, the MQ-135 and similar devices will likely remain at the forefront of environmental and safety solutions, fostering a healthier and more sustainable future.