Benha University
Benha Faculty of Engineering
Mechanical Engineering Department
Examiners: Dr. Ali Mahmoud Ali Attia

Environment & Pollution (M1333)
First Semester – Final Exam
Time: 120 Min.
Date: 4/01/2016

Model Answer

1. *Define the following terms: aerosols, criteria pollutants, radiation inversion, aerodynamic diameter, absorption.* *(5)*

a- Aerosols are small solid or liquid particles (fine drops or droplets) that are suspended in air.
b- Criteria pollutants are the major regulated (seven major) conventional pollutants for which maximum ambient air levels are mandated; including Sulfur Dioxide, Carbon Monoxide, Hydrocarbons, Lead, Nitrogen Oxides, Particulates, and Photochemical Oxidants
c- Radiation inversion is a type of thermal inversion that the earth's radiation tends to be absorbed by water vapor occurs close to the ground, mostly during the winter, and last for only a matter of hours.
d- Fuel desulfurization process: is the removing of sulfur contents from fuel before it is burned. Coal contains sulfur in two forms; (a) mineral sulfur in the form of inorganic pyrite: mineral sulfur can be removed by physical coal cleaning, and (b) organic sulfur which is chemically bound to the coal: organic sulfur requires chemical cleaning. either from fuel or from flue gases, it may be done physically (if the sulfur exist as elemental compound) or chemically (when sulfur exists within organic-bond).
e- Particulate matter: any finely divided liquid or solid substance including smoke, dust, or some forms of fine mist and is entrained in effluent gas streams or suspended in ambient air.
f- Smog: type of air pollution that contains two groups of pollutants; Smoke and fog referring to smoky fog as that detected in London (1952) and Loss- Anglos (1943).
g- Fumigation: is the sudden return of pollutants emitted into atmosphere back to the earth.

2. *For certain Natural Gas (NG) mixture that consists of 80 % CH4, 10 % C3H8, 5 % C4H10, and 5 % H2 by volume is used to operate a boiler that emits an exhaust gaseous of the following dry volumetric composition 12.5 % CO2, 0.5% CO, 5 % O2. Determine the mass analysis of this mixture. Determine the following: (i) stoichiometric air-to-fuel ration, (ii) Equivalence ratio, (iii) the water vapor partial pressure in the exhaust gaseous at 1.2 bar , and (iv) the dry mass analysis of the exhaust gaseous.* *(10)*

The theoretical reaction of the specified fuel will be:

$$0.8CH_4+0.1C_3H_8+0.05C_4H_{10}+0.05H_2+a_{th}(O_2+3.76N_2) \rightarrow xCO_2+yH_2O+zN_2$$

By performing elemental balance of carbon, hydrogen, and oxygen then:

C: 0.8+0.3+0.2=x, or x=1.3

H: 3.2+0.8+0.5+0.1=2y or y=2.3

O: $2a_{th}$=2x+y or a=2.45

N: then z=9.21

$$0.8CH_4+0.1C_3H_8+0.05C_4H_{10}+0.05H_2+2.45(O_2+3.76N_2) \rightarrow 1.3CO_2+2.3H_2O+9.21N_2$$

The theoretical air-to-fuel ratio=2.45*4.76*28.84/(0.8*16+0.1*44+0.05*58+0.05*2)=336.3/20.2=16.65

For actual reaction, let one mole of fuel is burnt, then:

$$0.8CH_4+0.1C_3H_8+0.05C_4H_{10}+0.05H_2+ a(O_2+3.76N_2) \rightarrow X(0.125CO_2+0.05O_2+0.005CO+0.82N_2)+YH_2O$$

By performing elemental balance of carbon, hydrogen, and oxygen then:

C: 1.3=X(0.125+0.005), or X=1.3/0.13=10

H: 4.6=2Y or Y=2.3

O: 2a=X(0.25+0.1+0.005)+Y or a=2.925

Then the actual reaction will be:

$$0.8CH_4+0.1C_3H_8+0.05C_4H_{10}+0.05H_2+ 2.925(O_2+3.76N_2) \rightarrow 1.25CO_2+0.5O_2+0.05CO+8.2N_2+2.3H_2O$$

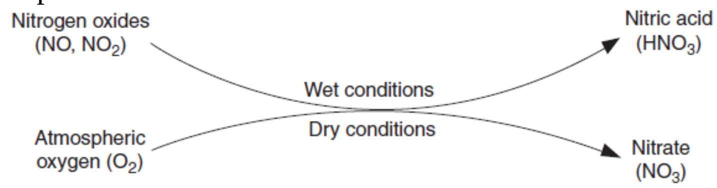
The equivalence ratio=a_{th}/a=2.45/2.925=0.837 or excess air is about 20%

Element i	Number of moles n_i	Molecular weight M_i [kg/kmole]	Mass of *i* $m_i=y_iM_i$	Mass fraction $M_{fi}=m_i/m_m$
CO_2	1.25	44	55	0.182
CO	0.05	28	1.4	0.005
O_2	0.5	32	16	0.053
N_2	8.2	28	229.6	0.76
mixture	12.8		302	1

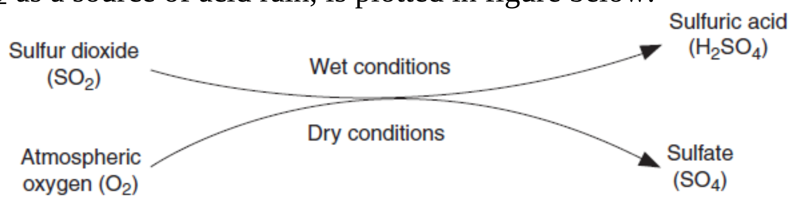
The water vapor partial pressure will be=2.3/(1.8+8.2+2.3)*1.2=0.224 bar

3. *What are the forms and composition of the following pollutants (with schematic representation about their formation pathways and transformation into atmosphere):* *(5)*
   a. *Nitrogen oxides*
   b. *Sulfur oxides*
   c. *Particulate matters*

a. Nitrogen oxides: Oxides of nitrogen include nitrous oxide (N_2O), nitric oxide (NO), nitrogen dioxide (NO2), nitrogen trioxide (N_2O_3), and nitrogen pentoxide (N_2O_5) and all collectively referred as NO_x. Of them there are primary of concern as air pollutants; NO and NO_2. NO - a colorless gas is an active compound in photochemical reactions producing smog. NO_2 - reddish brown gas gives color to smog, contributes to opacity in flue gas plumes from stacks, and is major contribution for acidic rain as a precursor to nitric acid (HNO_3) in atmosphere.



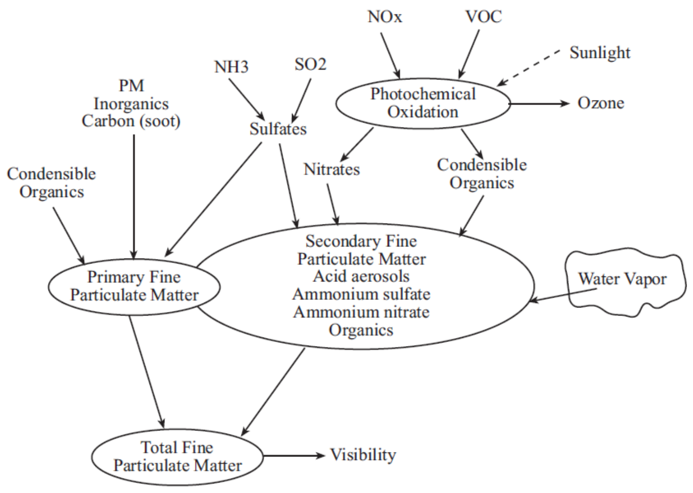
b. Sulfur oxides: Sulfur dioxide (SO_2) is a corrosive acid gas, colorless with a sharp irritating odor. Other forms of sulfur emissions, including H_2S, SO_3, and sulfuric acid mist will be discussed. The declining trend in SO_2 emissions, which is largely as a result of efforts to control SO_2 as a source of acid rain, is plotted in figure below.



Transforming sulfur dioxide to sulfuric acid and sulfate

c. Particulate Matters: There are six major components account for nearly all of the PM10 mass in most urban areas:

1) Geological material (oxides of metals);
2) Organic carbon;
3) Elemental carbon;
4) Sulfate;
5) Nitrate; and
6) Ammonium.



Fine particulate formation pathways

4. *What are:* *(5)*
   a. *the major principles for particulate removing,*
   b. *the combustion techniques to reduce NO_x emissions,*
   c. *the main approaches for pollution control.*

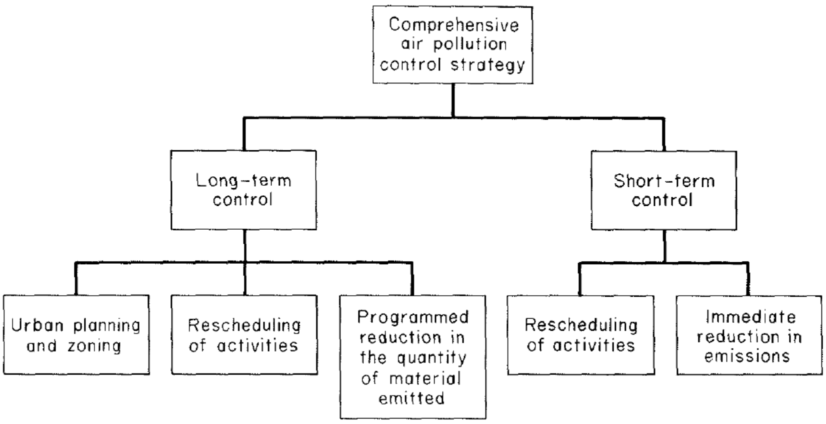
a. The principles used in many practical devices to control particulate emissions include:
   1. Electrostatic Precipitation (particle obstruction)
   2. Fabric Filters (particle obstruction)
   3. Venturi Scrubbers (particle obstruction and gravity forces)
   4. Cyclones (enhancement of centrifugal forces)
   5. Settling Chambers (enhancement of gravity forces)

b. Realization of combustion techniques: A variety of combustion control techniques can be realized to reduce the peak flame temperature; reduce the oxygen concentration in the primary flame zone, or to promote reconverting NOx back into nitrogen and oxygen.

c. Air pollution can be controlled by performing different approaches, such as
   1. Regulations on auto industry
   2. Fines to enforce bans; Incentives for reduction
   3. Switch from high sulfur coal to low sulfur coal
   4. Switch to oil, gas, wind, solar, nuclear power
   5. "Scrubbers" on smoke stacks to remove sulfur after use

5. *State with details a comparison between* *(5)*
   a. *long-term and short-term air pollution control strategies,*
   b. *atmospheric layers.*
   c. *physisorption and chemisorption.*

a. long-term and short-term air pollution control strategies

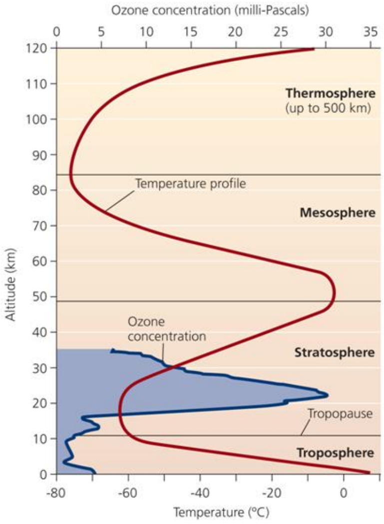


Requirements for long-term planning	Requirements for real-time control
Air quality objective	Air quality objective
Airshed model (dynamic or static)	Dynamic model
Survey of control techniques and their costs	Rapid communications
Meteorological probabilities	Strict enforcement of measures

b. Atmospheric layers

The atmosphere is layered in to four distinct zones of contrasting temperature due to differential absorption of solar energy. The four atmospheric layers are: Troposphere, stratosphere, mesosphere, and thermosphere.

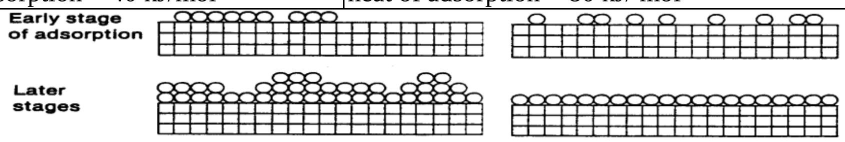
- **Troposphere** is the bottommost layer adjacent to earth's surface up to about 16 km that characterizes by:
  - Air for breathing, weather and all live activities occur in this layer
  - Temperature declines with altitude
  - Contains water vapor, gases and dust
  - The residence time of particle in the troposphere is short due to rain, gravity, air movement
  - Mixing time is rapid due to wind or turbulence
  - Limiting mixing between troposphere and the layer above it



- **Stratosphere** extends from the tropopause up to about 50 km, with the following characteristics:
  - There is no water vapor nor dust
  - Drier and less dense, with little vertical mixing
  - Colder in its lower regions
  - Contains UV radiation-blocking ozone, 17-30 km above sea level
  - Amount of ozone vary depending on location and season; lowest above the equator and increase towards the poles, increased markedly between fall and spring
  - Mixing time is lower, so Pollution entering in this region tends to remain long time due to low mixing
- **Mesosphere** extends above the stratosphere (from 50 to 80 km), temperature diminishes again (up to -80°C) creating the mesosphere (middle) layer. Other characteristics of mesosphere:
- **Thermosphere** is the top layer extending from altitude of 80 km up to 500 km containing highly ionized gases and very high temperature due to high solar and cosmic radiations. Other characteristics of thermosphere
  - Emit visible light
  - There is no sharp boundary that marks the end of the atmosphere
  - Pressure and density decreases gradually approaching the vacuum conditions of interstellar space
  - The composition gradually merges with that of interstellar space (mostly of H_e and H_2)

c. Physisorption and chemisorption

Physisorption	**chemisorption**
Van der Waals forces between molecules	Chemical bond (stronger than Van der Waals bonds)
multilayer adsorption	monolayer
predominates at low temperatures	chemical adsorption decreases at low temperatures
occurs rapidly	activation energy involved
reversible	irreversible
heat of adsorption < 40 kJ/mol	heat of adsorption > 80 kJ/ mol



Best wishes, Ali M.A. Attia