We've Got 4.8 stars!

STUDY MATERIAL FOR MINING ENGINEERING EXAMS (MANAGER CERTIFICATE, GATE, PSU)

- 100% exam oriented
- Latest questions included
- Frequent updates
- Guided by IITR faculty

MORE INFO

+91-9412903929

AMIESTUDYCIRCLE.COM

AMIESTUDYCIRCLE@GMAIL.COM

CIVIL LINES, NEAR IIT, ROORKEE

MINE VENTILATION

COMPOSITION OF AIR

Air is the homogeneous mixture of gases that covers the Earth's surface. It consists mainly of N_2, O_2 and CO_2. Air composition is given below.

Gas	Vol%	Wt%
Nitrogen	78.09	75.55
Oxygen	20.95	23.13
CO_2	0.03	0.05
Other gases	0.93	1.27

For calculations involving quality control, it is customary to assume dry air and compute problems on a volume basis, taking the composition approximately as

Oxygen 21%

Nitrogen and "inert" gases 79%

MINE AIR/GASES

While mine air starts as regular atmospheric air, it can become contaminated with various gases and particulates during mining activities. These contaminants can include:

- **Gases**: Methane, carbon monoxide, carbon dioxide, hydrogen sulfide, nitrogen dioxide, etc.
- **Particulates**: Dust from rock drilling, blasting, and other operations.

A diverse group of gases can be found in underground environments. The main sources of these gases is shown below.

Gas	Sources
CO	Incomplete combustion Emanations Explosions Blasting
CO_2	Complete combustion Fermentation

	Breathing Chemical reactions between acidic water and carbonates Blasting
CH_4	Decomposition of organic matter in the presence of water Carbon blasting (methane in pores)
N_2	Blasting
NO_x	Diesel engines Explosions Blasting
H_2S	Rarely present Bacterial decomposition of organic matter Stagnant waters Diesel engines (sulphur in fuels)

OXYGEN

The human respiratory system requires oxygen in varying amounts to maintain life. The quantity of oxygen required is a function of physical activity. That is. the more active the individual, the higher the respiratory rate and the larger the volume of oxygen consumed. Oxygen inhaled (21% by volume of the air inhaled) is much greater than the oxygen consumed. When one breathes normal air, the air that is exhaled contains approximately 16% O_2, 79% N_2, and 5% CO_2. All active workings in coal mines be ventilated by a current of air containing not less than 19.5% oxygen and not more than 0.5% carbon dioxide.

Respiratory quotient, gives the ratio of carbon dioxide expelled to the oxygen consumed. In other words, a miner working at a moderate rate (respiratory quotient - 0.9) would consume 3.3 x 10^{-5} m^3/s) of oxygen and expel 2.97 x 10^{-5} m^3/s) carbon dioxide.

Physiological effects of an oxygen-deficient environment

The physiological effects of an oxygen-deficient environment vary from individual to individual and with the length of exposure. However, the following effects have been observed:

% Oxygen in air	**Effect**
17	Faster, deep breathing

15	Dizziness, buzzing in ears, rapid heartbeat
13	Possible loss of consciousness with prolonged exposure
9	Fainting, unconsciousness
7	Life endangerment
6	Convulsive movements, death

Detection of Oxygen

The percentage of oxygen present in an atmosphere can be estimated by using the principle of electrochemical method, paramagnetic method or the flame safety lamp.

Electrochemical method

In the **electrochemical method**, very small concentrations of the gas are detected by its influence on the output from an electrochemical cell. The MSA Oxygen Indicator Model 244, Auer Oxygen Indicator Model P etc. are based on this principle and use fuel cells as oxygen sensors. The cells contain a gold cathode and a lead anode in a basic electrolyte.

The whole setup is encapsulated in an inert plastic which is sealed off. A thin membrane is used to protect the sensing electrode and it allows oxygen to get diffused into the cell. The oxygen gets dissolved in the electrolyte and reacts with the gold cathode. Thus the gold cathode becomes positively charged. The lead anode becomes negatively charged through the formation of lead oxide and water. A current proportional to the oxygen concentration flows between the cathode and the anode which is used as a measuring signal.

Flame safety lamp method

The **flame safety lamp** is also used to find out the percentage of oxygen in the atmosphere. In this method, the length of the flame produced by the lamp because of the burning of the gas is used. Accordingly, the oxygen percentage can be found out by noticing the flame height.

NITROGEN

This gas is quite abundant in atmospheric air comprising about 4/5th of the atmosphere. It is colourless, odourless, tasteless, nearly as heavy as air with a sp. gr. of 0.967. It is practically insoluble in water, 100 vol. of water dissolving at 15°C only 1.8 vol. of nitrogen. It is an inert gas which neither bums nor supports combustion but it is important for the growth of plants and animal tissues.

When men work at pressures higher than atmospheric, the blood and tissues of the body begin to absorb nitrogen. But if the high pressure is abruptly reduced the nitrogen is also given up by the body quickly and this results in painful and dangerous conditions. This phenomenon is guarded against during caisson method of shaft sinking in heavily water bearing strata when men have to work in caisson and the air is forced into the caissons in the shaft at such a pressure that the water is pushed back into the ground to keep the working place dry. The worker is subjected to the high air pressure in 2-3 stages in different compartments when going to the work spot and the reverse process takes place when he returns to the surface having atmospheric air.

Nitrogen is sometimes used for quenching underground fires.

Oxides of nitrogen are formed underground during blasting and from the operation of internal-combustion engines. Nitric oxide is rapidly oxidized to nitrogen dioxide in the presence of moisture and air and is therefore seldom found in significant amounts underground.

Nitrogen dioxide is very toxic. The accepted TLV-TWA for both an 8-h exposure and short-term exposure is 5 ppm. The toxic oxides of nitrogen react with moisture to form nitrous and nitric acid. In this manner, relatively small quantities of these gases may cause death by combining with the moisture in the lungs and corroding the respiratory passages. Death from exposure to the oxides of nitrogen may be very quick if the exposure level is high or may occur several days later as a result of pulmonary edema (water in the lungs) or even weeks later as a result of infectious pneumonia. Some of the physiological effects at various concentrations are listed below.

Concentration (ppm)	**Effect**
60	Least amount causing immediate throat irritation
100	Least amount causing coughing
100-500	Dangerous even for short exposure
200-700	Rapidly fatal

CARBON DIOXIDE (CO_2)

This gas is colourless, odourless, bitter in taste, with a sp. gr. of 1.52. It is very soluble in water and forms weak acid. It is not combustible and does not support combustion. It does not sustain life. Critical temp is 32°C.

The gas is a product of the process like respiration by human beings and animals, oxidation and combustion. It is present in the return air of all mines in very small percentages and is found in the dip areas of depillaring districts in coal mines due to its heavier than air nature. It is produced in a mine by breathing by men, burning of flame lamps, decay of timber, slow oxidation of coal in mines, blasting, and working of internal combustion engines such as diesel locomotive. In some coal mines it may be given off by outburst of gas. Mine fires and explosions result in the formation of carbon dioxide along with other gases.

With the aid of sunlight during day plants absorb CO_2 from air and by photosynthesis split up the gas into constituent atoms, absorbing the carbon necessary for their growth and setting free the oxygen which is used by human beings and animals. In this way nature continually renews the oxygen content of the air, so keeping it almost at a constant percentage in the atmosphere.

Effects of breathing CO_2

The following are the effects of breathing air containing large percentage of CO_2.

If CO_2 replaces air by

3%	breathing doubled (at rest)
6%	violent panting, headache, exhaustion
10%	severe distress endurable for a few minutes; after half to one hour of work, suffocation and unconsciousness.
15%	consciousness loss
25%	death after hours

For a person affected by CO_2 recovery with artificial respiration is usually rapid because of rapid breathing when CO_2 is present in lungs.

Carbon dioxide has an extinguishing effect on the flame of a flame safety lamp; the flame becomes dim at low concentration and will extinguish if held in it for long. In still air flame of a flame safety lamp is extinguished at a CO_2 percentage of 3-4.

Death occurs rapidly at 18% CO_2. Quite often, a mixture of carbon dioxide and air is referred to in mining as "**blackdamp**." An example will demonstrate how minimum breathing requirements may be calculated on the basis of (1) oxygen depletion and (2) carbon dioxide contamination. Flowrate equations establish the quantity balance in each case.

BLACKDAMP

This is a **mixture of CO_2 and nitrogen** in percentages higher than the normal percentage in the mine air. The CO_2 percentage ranges from almost negligible to 20% and that of nitrogen ranges from about 80% to 100%.

The composition mostly depends upon the manner of formation of CO_2 in the mine; if it is from the oxidation of coal, then CO_2 - 5% and N_2 - 95% if from rotting timber, CO_2 - 20% and N_2 - 80%.

Physiological effects of blackdamp

The physiological effects of blackdamp (12% CO_2 and 88% N_2) are as follows:

- 25% blackdamp (75% air, i.e. 15% O_2 and 3% CO_2) rate of breathing doubled.

- 40% blackdamp (60% air i.e. 12% O_2 and 5% CO_2) more frequent and deeper breathing.
- 50% blackdamp (50% air, i.e. 10% O_2 and 6% CO_2) panting, headache and face turns blue.

Detection of blackdamp

The presence of blackdamp affects the flame of an oil flame safety lamp. For every 5% of blackdamp (corresponding to 1% reduction in the percentage of O_2) the light diminishes by 30% and extinguishes when the oxygen percentage falls to below 17.5% which corresponds to about 17% of blackdamp. The gas, if present, is near the floor of the roadway and a flame safety lamp or naked light dims when held near the floor but shows its normal brightness when held up unless the whole height of the roadway is full with gas.

Blackdamp can be partially cleared away by sprinkling of lime but large concentrations can be removed only by improving ventilation.

CARBON MONOXIDE OR WHITEDAMP (CO)

Carbon monoxide is a colourless, odourless, tasteless, toxic, and flammable gas produced by the incomplete combustion of carbonaceous material. Carbon monoxide is both poisonous at very low concentrations and explosive over a wide range (12.5-74% in air). It is formed underground by mine fires and explosions, blasting, frictional heating prior to open burning, low-temperature oxidation, and internal-combustion engines.

Physiological effects of CO

Although explosive, the property that makes carbon monoxide one of the gases most feared by the underground miner is its extreme toxicity. Carbon monoxide acts as a type of asphyxiant by displacing the oxygen normally carried by the haemoglobin of the blood. The affinity of the blood for carbon monoxide is approximately 3000 times that for oxygen. Therefore, if the air breathed into the lungs contains only a small amount of carbon monoxide, the haemoglobin will absorb it in preference to the oxygen present. The compound formed when oxygen joins with haemoglobin is called oxy-haemoglobin, and the compound formed by carbon monoxide and haemoglobin is known as carboxy haemoglobin (COHb).

When discussing the poisoning or toxic effects of carbon monoxide, the percentage COHb or blood saturation level is usually used. At levels as low as 5% COHb, the first effects of carbon monoxide poisoning appear. The COHb blood level is dependent on the carbon monoxide concentration, the length of exposure, and the level of activity of the individual exposed. At blood saturation levels of 70% COHb and above, the amount of oxygen being carried by the blood is insufficient to sustain life.

Blood Saturation (%COHb)	Symptoms
5-10	First noticeable effect, loss of some cognitive function
10-20	Tightness across forehead, possible headache
20-30	Headache, throbbing in temples
30-40	Severe headache, weakness, dizziness, dimness of vision, nausea and vomiting, and collapse
40-60	Increased likelihood of collapse and unconsciousness, coma with intermittent convulsions
60-70	Coma, possible death
70-80	Respiratory failure, death

Example

Find the percentages of blackdamp, whitedamp, firedamp and air in mine air sample having the following analysis (percent by volume):

$O_2 = 19.11$

$N_2 = 79.04$

$CO_2 = 0.25$

$CO = 0.02$

$CH_4 = 1.58$

What is the composition of blackdamp?

Solution

Standard composition is not given. These values can be taken as CO_2 – 0.03, O_2 – 20.93 and N_2 – 79.04 respectively (if not given).

CO_2 eq = CO_2 wrt O_2

$$= \left(\frac{CO_2^{std}}{O_2^{std}}\right)O_2^{ret} = \left(\frac{0.03}{20.93}\right)19.11$$

$$= 0.027$$

N_2 eq = N_2 wrt O_2

$$= \left(\frac{N_2^{std}}{O_2^{std}}\right)O_2^{ret} = \left(\frac{79.04}{20.93}\right)19.11$$

= 72.17

Excess N_2 = 79.04 – 72.17 = 6.87

Excess CO_2 = 0.25 – 0.027 = 0.223

Blackdamp = 6.87 + 0.223 = 7.09%

Detection of Carbon Monoxide

The P. S. detector

This detector consists of a glass tube containing silica gel impregnated with light yellow potassium palladium sulphite with silica gel at both ends for absorbing other gases. A fixed volume of air (120 cm^3) is drawn through the tube at a constant rate over a period of two minutes through a calibrated orifice by operating a rubber aspirator. Carbon monoxide in the air turns the light yellow colour of potassium palladium sulphite to brown and the length of colour change from one end of the tube indicates its concentration. Range of the instrument is 0.005% to 0.12% of CO.

The Hopcalite detector

The generation of heat on the oxidation of carbon monoxide to carbon dioxide has been utilised by a this detector.

The analyzing cell has two compartments, one filled with **active Hopcalite** catalyst and the other with **inactive Hopcalite**. Only the active catalyst will oxidize carbon monoxide.

A set of differential thermocouples, connected in series, extends through the partition separating the two compartments. One set of junctions of the thermocouples is embedded in the active Hopcalite, the other set in the inactive Hopcalite.

Carbon monoxide in the air passing through the cell is oxidized in the compartment containing active Hopcalite liberating heat, which subjects that set of junctions to a temperature higher than that of the set in the inactive catalyst, thus generating an electrical potential in the thermocouple circuit. The potential is indicated on a millivoltmeter that has a scale representing carbon monoxide in concentrations ranging from 0 to 0.15 percent.

Drager Multigas Detector

The Drager multigas detector is used to test the atmosphere within a space for toxic gases such as carbon dioxide, carbon monoxide, nitrogen dioxide, and hydrogen sulfide.

A separate detector bulb is used for each type of gas.

The unit consists of two main components— the bellows pump and the detector tube.

HYDROGEN SULPHIDE (STINK DAMP)

Hydrogen sulfide, often called "**stink damp**" because of its odour, which resembles that of rotten eggs, is a colourless, toxic, and explosive gas formed by the decomposition of sulfur compounds. Low concentrations may be found in air from heated gobs or may be released from water seeping in from the strata. Large concentrations occur in natural gas and oil fields and in some sulfur and gypsum mines. Hydrogen sulfide is quite soluble in water and may be carried into active mine workings by groundwater. It is slightly heavier than air and is explosive in air in the range of 4-44%.

Hydrogen sulfide is extremely toxic. Although hydrogen sulfide has a distinctive odour, the sense of smell cannot be relied upon as a means of detection, because after one or two inhalations, the olfactory nerves become paralyzed and the odour can no longer be detected. The lowest published lethal concentration is 600 ppm.

Concentration	Symptom
0.025 ppm	Threshold of odour
0.005-0.010%	Slight symptoms such as eye and respiratory-tract irritation after 1 h
0.010%	Loss of odour after 15-min exposure
0.02-0.07%	Increased eye irritation, headache, dizziness, nausea, dryness, and pain in nose, throat, and chest
0.07-0.10%	Unconsciousness, cessation of respiration and death
0.10%	Death in a few minutes

H_2S gas *occurs* ordinarily only in traces in relatively few coal and metal mines. It may be found in stagnant water in old workings, in areas of gob fires or spontaneous heating. It may issue from blowers or ‘feeders’ of gas along with CH_4 in a coal mine. In a metal mine it may be produced by the action of acidic waters on sulphide ores.

The gas is as poisonous as CO and it may cause death in a short time if inhaled in large quantities. The maximum permissible concentration in rooms for 8-hour exposure is given as 0.02%.

Detection of H_2S

Presence of the gas can be detected by its *disagreeable smell of rotten eggs*. A blotting paper soaked in lead acetate changes its colour to black in the presence of the gas. A moist silver coin would also change to black in its presence due to formation of black sulphide on the surface. The gas can be detected by Drager multigas detector and M.S.A. hydrogen sulphide detector which resembles the M.S.A. CO detector. The H_2S detector tube contains white granules of activated aluminium oxide coated with silver cyanide which turns greyish black if exposed to H_2S. When making a test for detecting the gas the aspirator bulb is squeezed 10 times. The air sample is drawn in the detector tube and the extent of discolouration gives the percentage which is read off directly on the movable graduated scale. C.M.R.S. has patented a H_2S detector tube which detects 1 to 50 ppm of H_2S.

METHANE

The most common contaminant gas found in coal mines is methane. Although frequently associated with coal and other carbonaceous rocks, methane is also found in some non coal mines.

Methane is colourless, odourless, tasteless, non-toxic, highly flammable, and lighter than air. This last attribute results in methane accumulations forming along rooflines and in high areas of mines.

During the formation of a coal bed (coalification), methane is produced along with carbon dioxide, higher hydrocarbons, and other inert gases. Increasing pressure and temperature during coalification tends to proceed toward early total elimination of oxygen with concurrent removal of some hydrogen and carbon, and then total removal of hydrogen with concurrent removal of some carbon. While carbon dioxide is a significant constituent of seam gas in brown coal, the main constituent of higher-rank coal seam gas is methane. The volume of these by-product gases increases with the rank of coal and is the highest for anthracite, where, for every ton of coal formed, nearly 565 m^3 of carbon dioxide and 765 m^3 of methane is produced. A large fraction of these gases is lost during burial of the decayed plant material.

The amount of gas retained per ton of coal is known as the **seam gas content**.

One popular index of seam gas content in mines has been **specific methane emission**, expressed as the volume of methane emitted per ton of coal produced.

Methane emission equation

The equation is:

Methane in intake air + methane emitted = methane in return air

Ventilating air required will be given by

$$Q_v.\frac{C_i}{100} + q_g = (Q_v + q_g).\frac{C_{r,\max}}{100}$$

or
$$Q_v = \frac{100q_g}{C_{r,\max} - C_i} - q_g$$

where