Module 2 – Mine Gases

Gas Detection (pages 2-3)

Gas detection is an important part of any rescue or recovery operation. Your team will make frequent tests for gases as it advances beyond the Fresh Air Base. For your own safety, you'll want to know what harmful gases are present, how much oxygen is in the atmosphere, and whether or not gas levels are within the explosive range.

Knowing what gases are present and in what concentrations provide you with important clues as to what has happened in the mine. Test results can also give you an idea about existing conditions.

For example, if you get carbon monoxide (CO) readings, there's probably a fire. The amount of carbon monoxide indicates something about the extent of that fire.

Gas Detector Requirements (pages 2-3)

Regulations require mine rescue stations to have four gas detectors appropriate for each type of gas that may be encountered at the mines served. Gas detectors must measure concentrations of methane from 0.0 percent to 100 percent of volume, oxygen from 0.0 percent to at least 20 percent of volume, and carbon monoxide from 0.0 parts per million to at least 9,999 parts per million (**30 CFR Parts 49.6(a)(6)** and **49.16(a)(6)).**

Diffusion of Gases (pages 2-5)

The volume of a gas changes in response to any change in atmospheric pressure or temperature. For example:

- An increase in pressure causes a gas to contract.
- A decrease in pressure causes a gas to expand.
- An increase in temperature causes a gas to expand.
- A decrease in temperature causes a gas to contract.

Atmospheric Pressure and its Effects on Rate of Diffusion (pages 2-6)

Pressure exerted on a gas is usually atmospheric pressure. Atmospheric pressure is measured on a barometer. A rise in the barometric reading indicates an increase in pressure. A drop in barometric reading indicates a decrease in pressure. The atmospheric pressure varies within a mine, just as it does on the surface.

Atmospheric pressure affects the diffusion rate of a gas. For example, if the barometer rises, indicating increased pressure, gas responds by contracting. A gas that's squeezed into a smaller area like this is more concentrated, so it diffuses more slowly.

It's much easier for concentrations of explosive gases to build up when the barometric pressure is high. On the other hand, when barometric pressure falls, the pressure on the gas is reduced. The gas responds by expanding. Once the gas expands, it is less concentrated, so it diffuses more quickly.

Temperature and its Effects on Rate of Diffusion (pages 2-6)

It's important to understand how temperature affects the rate of diffusion of a gas. High temperatures (or heat) cause gases to expand, so they diffuse more quickly. Consequently, heat from a fire in the mine will cause gases to expand and be dispersed more easily. Lower temperatures work the opposite way: Gases respond to cold by contracting and by diffusing more slowly.

Specific Gravity or Relative Weight (pages 2-6 and 2-7)

Specific gravity is the weight of a gas compared to an equal volume of normal air under the same temperature and pressure. (This is also referred to as "relative weight.") The specific gravity of normal air is 1.0. The weight of air acts as a reference point from which we measure the relative weight of other gases. For example, a gas that is heavier than air has a specific gravity higher than 1.0. A gas that is lighter than air will have a specific gravity less than 1.0.

If you know the specific gravity of a gas, you will know where it will be located in the mine and where you should test for it. Gases issuing into still air without mixing tend to stratify according to the gas's specific gravity. Light gases or mixtures tend to stratify against the roof and heavy gases or mixtures tend to stratify along the floor.

Methane, for example, has a specific gravity of 0.5545. This is lighter than normal air. Knowing this, you can predict that methane will rise and collect in greater concentrations near the top or roof of a mine. This is why you test for methane near the top.

Sulfur dioxide has a specific gravity of 2.2638. This is much heavier than normal air. Knowing this, you can predict that sulfur dioxide will collect in greater concentrations near the bottom or in low areas of a mine. This is why you test for sulfur dioxide in low areas of the mine.

If the weight of a gas you're testing for is lighter than normal air, you'll know to test for it within 12 inches of the mine roof. That's because lighter gases tend to rise, so you can expect to find them in greater concentrations in high areas of the mine.

Besides helping you determine where to test for a gas, specific gravity also indicates how quickly the gas will diffuse and how easily it can be dispersed by ventilation. In still air, the ordinary process of diffusion is a very slow process.

However, under usual mine conditions, ventilating air currents and convection currents produced by temperature differences cause a rapid mechanical mixing of gases with air.

Once the gases are mixed, they will not separate or stratify again.

Light gases, such as methane or hydrogen, diffuse rapidly and are fairly easy to disperse. Heavier gases such as sulfur dioxide and carbon dioxide do not diffuse rapidly, so they're more difficult to disperse.
It's much easier to remove a concentration of a light gas like methane by ventilation than it is to remove the same concentration of a heavier gas like carbon dioxide.

Specific gravity is not the only factor that determines how quickly a gas will diffuse or disperse. Temperature and pressure also affect it. An increase in temperature makes a gas diffuse more rapidly. A decrease in temperature slows down the rate of diffusion.
Atmospheric pressure works just the opposite: An increase in pressure slows down the rate of diffusion. A decrease in pressure speeds it up.

Explosive Range and Flammability (pages 2-7 and 2-8)

A gas that will burn is said to be "flammable." Any flammable gas can explode under certain conditions. In order for a flammable gas to explode, there must be enough of the gas in the air, enough oxygen, and a source of ignition.

The range of concentrations within which a gas will explode is known as its "explosive range." Figures representing the higher and lower limits of the explosive range are expressed in percentages.

The amount of oxygen that must be present for an explosion to occur is also expressed as a percentage. When the necessary oxygen concentration approaches that found in normal air, the level is expressed simply as "normal air."

The explosive range of methane, for example, is 5 to 15 percent in the presence of at least 12.1 percent oxygen.

Solubility (pages 2-8)

Solubility is the ability of a gas to be dissolved in water. Some gases found in mines are soluble and can be released from water. Sulfur dioxide and hydrogen sulfide, for example, are water-soluble gases. Both may be released from water.

Solubility is an important factor to consider during recovery operations. When a mine is sealed off for any length of time, water can collect in it. This water may have occurred naturally, or it may have been introduced during firefighting.

Whatever the case, pools of water can release water-soluble gases into the air when they are stirred up. Pumping water from such pools, or walking through them, can release large amounts of soluble gases which would not otherwise be found in the mine atmosphere.

Color/Odor/Taste (pages 2-8)

Color, odor, and taste are physical properties that can help you identify a gas, especially during barefaced exploration. Hydrogen sulfide, for example, has a distinctive “rotten egg” odor.

Some gases may taste bitter or acid; others sweet. The odor of blasting powder fumes, together with a reddish-brown color, indicates there are oxides of nitrogen present.

Of course, you can’t rely on only your senses to positively identify a gas. Only detectors and chemical analysis can do that. Many hazardous gases, such as carbon monoxide, have no odor, color, or taste. Keep these properties in mind as we discuss each gas you may encounter in the mine. One or more of these properties may be your first clue that a particular gas is present.

Health Hazards

Toxic Gases (pages 2-8 and 2-9)

Some gases found in mines are toxic (poisonous). This can refer either to what happens when you breathe the gas, or what happens when the gas comes into contact with exposed areas of your body.

The degree to which a toxic gas will affect you depends on three factors:

(1) how concentrated the gas is,
(2) how toxic the gas is, and
(3) how long you’re exposed to the gas.

For example, the TLV for carbon monoxide (CO) is relatively low—50 PPM (or .005 percent). This means that the most CO you can be exposed to over **an 8-hour daily period without harmful effects is 1/200 of one percent.** That isn’t much. The TLV for carbon dioxide (CO_2) is higher—5,000 PPM (.500 percent). You can tolerate concentrations of up to ½ of 1 percent CO_2 over an 8-hour daily period without harmful effects.

Some toxic gases are harmful to inhale. A self-contained breathing apparatus (SCBA) will protect you from such gases, as long as your face-to-facepiece seal is tight. Other toxic gases harm the skin or can be absorbed by the skin. An SCBA won’t protect you from such gases. If you wear your SCBA in petroleum-based fumes for prolonged or successive periods, the fumes can eventually permeate its rubber parts so that the apparatus no longer provides you with adequate protection. Your team may be forced to leave an area where such gases are detected.

Asphyxiating Gases (pages 2-9)

“Asphyxiate” means to suffocate or choke. Asphyxiating gases cause suffocation. They do this by displacing oxygen in the air, thus producing an oxygen-deficient atmosphere. Since your self-contained breathing apparatus supplies you with oxygen, it will protect you against asphyxiating gases.

Review Questions (pages 2-10)

1. How do temperature and pressure affect a gas, and how do these factors affect mine rescue?

2. What is specific gravity?

3. What can you determine if you know the specific gravity of a particular gas?

4. What is the explosive range of a gas and why is it important for rescue team members to know the explosive range of gases they encounter?

5. What is a toxic gas?
6. How can you protect yourself from toxic gases?

7. How does an asphyxiating gas produce an oxygen-deficient atmosphere? Answer: It displaces oxygen.

8. How do you protect yourself in an oxygen-deficient atmosphere?

9. Why is it important for you to know about the solubility of certain gases in water?

10. Why should you know about the characteristic color, odor, and taste of gases you may encounter?

ANSWER SHEET (pages 2-10)

1. **Answer:** Temperature increases cause expansion. Temperature-decreases cause contraction. Pressure-increases cause contraction. Pressure-decreases cause expansion. Implication: These factors affect the diffusion rate of gases in the mine.

2. **Answer:** The specific gravity (or relative weight) of a gas is its weight in relation to an equal amount of normal air under the same temperature and pressure.

3. **Answer:** Specific gravity determines where the gas will stratify in still air in the mine (whether it will rise or fall). It also determines how easily a gas can be diffused or flushed out of the mine by ventilation.

4. **Answer:** The explosive range of a gas is the concentrations within which a flammable gas can explode when there is a specific amount of oxygen present. It's important for you to know the explosive ranges of gases you encounter and the amount of oxygen necessary for an explosion so you will immediately know when you encounter a potentially explosive atmosphere.

5. **Answer:** A gas that is capable of causing damage to living tissues, impairment of the central nervous system, severe illness or, in extreme cases, death when it is ingested, inhaled, or absorbed by the skin or eyes.

6. **Answer:** Wearing a self-contained breathing apparatus (SCBA) will protect you from many of them. However, an SCBA does not provide you with protection against gases that attack the skin or enter the body through the skin. Neither will it provide protection if you wear it for prolonged or successive periods in petroleum-based fumes, because such fumes may permeate the rubber. In the presence of such gases, your team may be forced to leave the area of the mine where they're located.

7. **Answer:** It displaces oxygen.

8. **Answer:** Wear an SCBA, which supplies you with oxygen.

9. **Answer:** Gases dissolved in water can be liberated in large quantities when mine rescue teams disturb the water by walking through it, or by beginning pumping operations.

10. **Answer:** The characteristic color and, if the team is barefaced, odor or taste of a gas may be the first clue a rescue team has that the gas is present in the mine atmosphere.

Normal Air (pages 2-11)

The air we breathe is actually a mixture of gases. Clean, dry air at sea level is made up of 78 percent nitrogen and 21 percent oxygen. The remaining one percent is made up of argon, carbon dioxide, and small traces of other gases. Other gases in air are: neon, helium, krypton, xenon, hydrogen, methane, nitrous oxide, and ozone.

Even internal combustion engines and battery-charging stations can be sources of contamination because they can produce hazardous fumes. Normally, these contaminants are carried away by the mine's ventilation system. But during a disaster situation, the mine's ventilation system may be partially or totally disrupted.

Fires and explosions can disrupt ventilation by damaging ventilation controls. Falls and rock bursts can disrupt ventilation by obstructing the flow of air. In addition, the disaster itself may provide additional sources of contamination.

Fires and explosions, for example, often produce dangerous gases. Inundations may release water-soluble gases.

Oxygen (O_2) (pages 2-12)

Specific Gravity. 1.1054

Explosive Range and Flammability. Oxygen is not an explosive gas, but it does support combustion.

Health Hazards. Oxygen found in normal air is nontoxic. In fact, it is essential for life. It is harmful to breathe air that is low in oxygen, and breathing extremely oxygen-deficient air can kill you.

There are five main causes of oxygen deficiency in the mine: (1) insufficient or improper ventilation which fails to bring enough oxygen to the work area, (2) displacement of the air's oxygen by other gases, (3) a fire or explosion that consumes oxygen, (4) the absorption of oxygen by coal, particularly at freshly cut faces, and (5) consumption of oxygen by workers.

Carbon Dioxide (CO_2) (pages 2-13)

Specific Gravity. 1.5291

Explosive Range and Flammability. Carbon dioxide will neither burn nor explode.

Health Hazards. Normal air contains about 0.04 percent carbon dioxide. When present in high concentrations (2 percent or higher), carbon dioxide causes you to breathe deeper and faster. Breathing air containing 5 percent carbon dioxide increases respiration 300 percent, causing difficult breathing. Breathing air containing 10 percent carbon dioxide causes violent panting and can lead to death.

Solubility. Carbon dioxide is soluble in water.

Color/Odor/Taste. Carbon dioxide is colorless and odorless. High concentrations may produce an acid taste.

Cause or Origin. Carbon dioxide is a normal component of air and is a product of complete combustion (burning). Oxidation and the decay of timbers also produce carbon dioxide. Carbon dioxide is also a by-product of the respiration (breathing) process. Fires, explosions, and blasting operations produce CO_2. In some mines, it is liberated from the rock strata.

Methane (CH_4) (pages 2-14)

Specific Gravity. 0.5545

Explosive Range and Flammability. Methane is flammable. Its explosive range is 5 to 15 percent when there is at least 12.1 percent oxygen. Methane is most explosive, however, in the 9.5 to 10 percent range.

Methane’s explosive range is not an absolute measure of safety. There are several other important factors to take into consideration. For example, the presence of other combustible gases with wider explosive ranges or lower ignition points than methane may result in a more highly explosive mixture.

Coal dust in the air also lowers methane’s explosive limits. A mixture containing as little as 1 ½ to 2 percent methane, together with coal dust, may be explosive.

Because moisture tends to keep dust levels down, dust will be more of a problem underground in the winter months when the mine air is less humid.

Solubility. Slightly soluble in water.

Color/Odor/Taste. Colorless, odorless, tasteless.

Cause or Origin. Methane is the most common flammable gas found in coal mines. It is a normal component of coal, originating from the decomposition of vegetable matter during its formation.

Methane can be liberated in large quantities from feeders and blowers or from clay veins in coal mines. It’s also often liberated from virgin (uncut) coal and released from freshly broken coal faces.

Carbon Monoxide (CO) (pages 2-15 and 16)

Specific Gravity. 0.9672

Explosive Range and Flammability. Carbon monoxide is explosive and flammable. Its explosive range in normal air is 12.5 to 74.2 percent.

Health Hazards. Carbon monoxide is highly toxic even in very low concentrations. Exposure to as little as .15 to .20 percent CO is extremely dangerous. Carbon monoxide is so toxic because it combines easily with your red blood cells (hemoglobin) —the cells that normally carry oxygen to your body's tissues. Once the cells have taken up CO, they no longer have the capacity to carry oxygen.

It doesn't take much CO to interfere with your blood's oxygen-carrying capacity because the gas combines with hemoglobin 200 to 300 times more readily than oxygen.

The first symptom of carbon monoxide poisoning is a slight tightening across your forehead and possibly a headache. Carbon monoxide poisoning is cumulative over time. As you continue to be exposed to it, the poisoning effects build up accordingly. As little as 500 PPM (0.05 percent) can kill you in three hours. If you're exposed to a high CO concentration, you may experience very few symptoms before losing consciousness.

Solubility. Carbon monoxide is slightly soluble in water.

Cause or Origin. Carbon monoxide is a product of the incomplete combustion of any carbon material. It is produced by mine fires and explosions of gas.

Nitrogen (N_2) (pages 2-16)

Explosive Range and Flammability. Nitrogen is not an explosive gas and it will not burn.

Health Hazards. Nitrogen is nontoxic. However, in above-normal concentrations, it acts as an asphyxiant, because it lowers the oxygen content of the air.

Cause or Origin. Normal air contains approximately 78 percent nitrogen, making nitrogen the largest component of normal air. Underground, nitrogen levels may increase as coal faces adsorb oxygen. Gas blowers and feeders may give off nitrogen, and nitrogen is also released from coal during mining.

Another source of nitrogen in underground mines is the detonation of explosives.

Mine Gases and Their Properties

GAS	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLUBILITY	COLOR/ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Normal Air	-	1.0	-	-	-	-	-	-
Oxygen	O_2	1.1054	Supports combustion n	Moderate	-	Respiratory/cardiovascular in oxygen deficient atmosphere	8 - 10%	All areas of opening
Carbon Dioxide	CO_2	1.5291	-	Soluble	Acidic taste high concentrations	Respiratory/ cardiovascular in high concentrations	40,000 ppm	Low areas near floor
Methane	CH_4	0.5545	5 - 15%	Slight	-	-	-	High areas near roof
Carbon Monoxide	CO	0.9672	12.5 - 74.2%	Slight	-	Highly toxic to cardiovascular system even in low concentrations	1,200 ppm	Near center of openings
Nitrogen	N_2	0.9674	-	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Near face areas
Nitrogen Dioxide	NO_2	1.5894	-	Very slight	Reddish brown color- high concentrations, odor/taste of blasting powder	Highly toxic to respiratory system even in low concentrations	20 ppm	Low areas near floor
Hydrogen	H_2	0.0695	4 - 74.2%	-	-	Asphyxiant in higher concentrations due to oxygen displacement	-	High areas- especially near battery charge stations
Hydrogen Sulfide	H_2S	1.1906	4.3 - 45.5%	Soluble	Rotten egg odor/ slightly sweet taste	Highly poisonous to respiratory system and eyes even in low concentrations	100 ppm	Low areas- especially near water accumulation
Sulfur Dioxide	SO_2	2.2638	-	High	Sulfur odor/acidic taste	Highly toxic to respiratory system and eyes even in very low concentrations	100 ppm	Low areas near floor
Ethane	C_2H_6	1.0493	3 - 12.5%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
GAS	CHEMICAL SYMBOL	SPECIFIC GRAVITY	EXPLOSIVE RANGE	SOLUBILITY	COLOR/ODOR/ TASTE	HEALTH HAZARDS	IDLH	TEST LOCATION
Propane	C_3H_8	1.5625	2.12 - 9.35%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
Butane	C_4H_{10}	2.0100	1.86 - 8.41%	Slight	-	Asphyxiant in higher concentrations due to oxygen displacement	-	Low areas- especially near gas and oil wells
Acetylene	C_2H_2	0.9107	2.5 - 80%	Very slight	Slight garlic odor	Asphyxiant in higher concentrations due to oxygen displacement	-	All areas after methane explosion
Radon	Rn	7.526	-	High	-	Continuous exposure linked to lung cancer	-	Most prevalent in uranium mines

Gas Detection Chart

GAS	DETECTION METHODS	WHEN TO TEST
Oxygen (O_2)	Oxygen indicator. Chemical analysis.	During any team exploration.
Nitrogen (N_2)	Chemical analysis.	When an oxygen deficient atmosphere is suspected. In mines where nitrogen issues from rock strata. In inactive areas where ventilation has been inadequate.
Carbon Dioxide (CO_2)	Carbon dioxide detector. Multi-gas detector. Chemical analysis.	After a fire or explosion. When entering abandoned areas. When reopening sealed areas.
Carbon Monoxide (CO)	Carbon monoxide detector. Multi-gas detector. Chemical analysis.	During any team exploration, especially when fire is suspected.
Nitrogen Dioxide (NO_2)	Nitrogen dioxide detector. Multi-gas detector. Chemical analysis. Color.	After mine fires or explosions. When diesel equipment is used. After detonation of explosives.
Hydrogen (H_2)	Multi-gas detector. Chemical analysis.	After mine fire or explosion. Near battery-charging stations. When steam is produced by water, mist, or foam in fire-fighting.
Hydrogen Sulfide (H_2S)	Hydrogen sulfide detector. Multi-gas detector. Chemical analysis. Eye irritation.	In poorly ventilated areas. During unsealing operations. Following mine fires.
Sulfur Dioxide (SO_2)	Multi-gas detector. Chemical analysis. Odor, taste, and respiratory tract irritation.	When standing water is disturbed. After mine fires or explosions and when reopening sealed areas of the mine after mine fires.
Methane (CH_4)	Methane detector. Chemical analysis.	During any team exploration. When normal ventilation is disrupted. When entering abandoned workings.
Heavy Hydrocarbons Ethane (C_2H_6) Propane (C_4H_{10}) Butane (C_3H_8)	Multi-gas detector. Chemical analysis.	Following fires or explosions when methane is present. Following accidental entry into adjacent oil or gas well casings.
Acetylene (C_2H_2)	Multi-gas detector. Chemical analysis. Odor.	Following a methane explosion in air which is low in oxygen.
Radon (Rd)	Survey meter.	When normal ventilation is disrupted and during unsealing operations.

Smoke, Rock-Strata Gases, and the Damps

Smoke

Smoke is a result of combustion. It consists of tiny particles of solid and liquid matter suspended in the air. The particles in smoke are usually soot or carbon, and tar-like substances such as hydrocarbons.

Although smoke may irritate your lungs when you inhale it, it is not normally considered to be an asphyxiant. However, smoke usually contains carbon monoxide and other toxic or asphyxiating gases produced by fires. This is why it is so dangerous to inhale smoke.

Also, if there is a sufficient amount of hydrocarbons in the smoke, the hydrocarbons can make the smoke explosive.

Besides the dangers involved in inhaling smoke and its potential for explosion, smoke is also hazardous in another important way: The presence of smoke limits your visibility. This single factor adds an extra element of difficulty to any rescue or recovery operation.

Rock-Strata Gases (pages 2-25)

Rock-strata gases occur in some metal mining districts in the United States, particularly in Colorado and Nevada. Commonly called rock gas, it is assumed to be largely nitrogen and carbon dioxide, and is released from the rock strata under the influence of atmospheric pressures.

Because rock gas is largely nitrogen and carbon dioxide, the effect of rock gas is to produce an oxygen-deficient atmosphere. This can cause a person to suffocate if breathing protection is not worn.

The Damps (pages 2-25)

"Damps" are the names early miners gave to mixtures of gases. Many of these terms are still in use today. These names often describe what causes the mixtures or how they affect miners

The damps most commonly found in mines are:

Whitedamp. Whitedamp is a mixture of carbon monoxide and air which results from a mine fire. It gets the name "whitedamp" from the fact that it is found in high concentrations in black powder smoke, which is white. The carbon monoxide in this mixture makes it toxic.

Stinkdamp. This is a mixture of hydrogen sulfide and air. Stinkdamp gets its name from the characteristic "rotten egg" odor of hydrogen sulfide. It is highly toxic and in certain concentrations it can be explosive.

Afterdamp. This is a mixture of carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen. It is called “afterdamp” because it’s usually found after a mine fire or explosion. Afterdamp is toxic to breathe, and it may also be oxygen-deficient.
Carbon monoxide is the most poisonous of the gases in afterdamp.

Blackdamp. Blackdamp gets its name from the fact that this mixture caused miners’ lights to go out. It is actually a mixture of carbon dioxide, nitrogen, and air. Blackdamp is produced by methane fires and explosions, so it also probably contains carbon monoxide. This mixture is oxygen-deficient so it makes breathing difficult, and can cause suffocation.

Firedamp. This is a mixture of methane and air that will burn or explode when ignited. The “fire” in firedamp comes from the fact that the mixture is flammable.

Review Questions (pages 2-27)

1. What are the five main causes of oxygen deficiency in the mine?
2. What are the explosive gases that may occur in the mine or mines you may be called to work in?
3. Name the gases that can be detected by color, odor, or taste, and explain these identifying features.
4. Of the gases we've talked about, which ones are toxic if you inhale them?
5. What are the five major damps? Explain what each mixture contains and why it's dangerous.

ANSWER SHEET (pages 2-28)

1. **Answer:**
   1) insufficient or improper ventilation which fails to bring enough oxygen to the work area,
   2) displacement of the air's oxygen by other gases,
   3) a fire or explosion that consumes oxygen,
   4) the absorption of oxygen by coal, particularly at freshly cut faces, and
   5) consumption of oxygen by workers.

2. **Answer:**
   1) Carbon monoxide 12.5 to 74.2%
   2) Hydrogen 4.0 to 74.2% even with as little as 5% oxygen present
   3) Hydrogen sulfide 4.3 to 45.5%
   4) Methane 5 to 15% in at least 12.1% oxygen
   5) Ethane 3.0 to 12.5%
   6) Propane 2.12 to 9.35%
   7) Butane 1.86 to 8.41%
   8) Acetylene 2.5 to 80%

3. **Answer:**
   1) Carbon dioxide—acid taste in high concentrations.
   2) Nitrogen dioxide—reddish brown in higher concentrations, odor and taste of blasting powder fumes.
   3) Hydrogen sulfide—rotten egg odor (however, continued exposure deadens your sense of smell), slight sweetish taste.
   4) Sulfur dioxide—sulfur odor, acid taste.
   5) Propane and butane—"gassy" odor in certain concentrations.
   6) Acetylene—slight garlic odor.

4. **Answer:**

   Carbon monoxide, oxides of nitrogen, hydrogen sulfide, sulfur dioxide, and acetylene.

5. **Answer:**
   1) Whitedamp—carbon monoxide and air. Toxic.
   2) Stinkdamp—hydrogen sulfide and air. Toxic, and may be explosive.
   3) Afterdamp—carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen. Toxic, explosive, and can be oxygen-deficient.
   4) Blackdamp—carbon dioxide, nitrogen, and air. Oxygen-deficient. Can cause suffocation.
   5) Firedamp—methane (5 to 15%) and air. Can explode.

Mine Gases General Review
(Pages 2-49 thru 2-51)

Choose the correct answer to each of the following questions:

1. Normal air contains approximately what percent oxygen?
   a. 15%
   b. 21%
   c. 31%
   d. 79%

2. The explosive range of a methane/air mixture (normally 5-15%) will change if:
   a. certain other combustible gases are present.
   b. coal dust is suspended in the atmosphere.
   c. there is less than 12.1% oxygen in the atmosphere.
   d. all of the above.

3. Carbon monoxide is:
   a. a gas found in all mining operations
   b. a normal constituent of air
   c. detected during a mine fire or explosion
   d. a product of the breathing process

4. An elevated concentration of carbon dioxide in mine air can be harmful because:
   a. it is highly explosive
   b. it increases the breathing rate
   c. it is highly toxic in small concentrations
   d. all of the above

5. An elevated concentration of nitrogen in mine air can be harmful because:
   a. it can lower the oxygen content of the air
   b. it is highly explosive
   c. it is highly toxic
   d. all of the above

6. Oxides of nitrogen can occur in a mine atmosphere:
   a. when certain explosives are used
   b. when diesel-powered equipment is being used
   c. when electric equipment produces arcs or sparks
   d. all of the above

7. Accumulations of hydrogen in the mine atmosphere are dangerous because hydrogen:
   a. is highly toxic
   b. is highly soluble in water
   c. is highly explosive
   d. gives off a suffocating odor

8. Characteristics of hydrogen sulfide include:
   a. explosive
   b. highly toxic
   c. can be liberated from pools of stagnant water
   d. all of the above

9. Which of the following is not true of sulfur dioxide?
   a. it is explosive
   b. it is highly toxic
   c. it is highly soluble in water
   d. it can occur during mine fires

10. The most likely source of ethane, propane, or butane in a mine is:
   a. use of diesel equipment
   b. battery charging stations
   c. leakage from adjacent gas or oil wells
   d. all of the above

11. Acetylene would normally be found in a mine atmosphere where:
   a. diesel equipment is used
   b. methane has burned or exploded in air with a lowered oxygen content
   c. leakage has occurred from adjacent oil or gas wells
   d. battery charging stations are located

12. Match each damp with its components:

1. Firedamp	a. Carbon monoxide and air
2. Blackdamp	b. Hydrogen sulfide and air
3. Afterdamp	c. Carbon dioxide, nitrogen, and air
4. Whitedamp	d. Carbon monoxide, carbon dioxide, methane, oxygen, nitrogen, and hydrogen
5. Stinkdamp	e. Methane and air

13. Mine rescue teams are required by Federal law to have available:
    a. one detecting device for every gas listed as dangerous by the U. S. Bureau of Mines
    b. one detecting device for each gas normally encountered in the mine(s) the team serves
    c. four detecting devices for each gas normally encountered in the mine(s) the team serves
    d. one detecting device for each team member

14. Atmospheric pressure and temperature are important factors because they:
    a. affect the rate of diffusion of a gas by ventilation
    b. can cause false readings on gas detection instruments
    c. lower oxygen content in the mine
    d. all of the above

15. Two gases that are highly soluble in water are:
    a. methane and acetylene
    b. hydrogen sulfide and hydrogen
    c. nitrogen and sulfur dioxide
    d. hydrogen sulfide and sulfur dioxide

16. A gas that is normally found near the roof or in high places in the mine is said to have a low:
    a. level of toxicity
    b. level of explosivity
    c. specific gravity
    d. level of solubility

17. The amount of coal dust suspended in the mine atmosphere is most important because:
    a. it can alter the explosive range of methane.
    b. it can affect the specific gravity of oxygen.
    c. hydrogen is liberated from the coal dust.
    d. coal dust lowers the oxygen content in the mine atmosphere.

18. A nontoxic gas can still be dangerous because it can:
    a. displace oxygen
    b. burn
    c. explode
    d. all of the above

19. The type of coal mine where the greatest amount of methane would be likely to be found would be a:
    a. drift mine with tight and compact adjoining strata
    b. drift mine with loose or broken adjoining strata
    c. shaft mine with tight and compact adjoining strata
    d. shaft mine with loose or broken adjoining strata

20. Gases that are neither toxic nor explosive:
    a. are not found in mine atmospheres
    b. are not dangerous
    c. can be dangerous because they can displace oxygen
    d. cannot be detected with today’s detection instruments

GENERAL REVIEW ANSWER KEY (IG XX pages 2-52)

1. **b**
2. **d**
3. **c**
4. **b**
5. **a**
6. **d**
7. **c**
8. **d**
9. **a**
10. **c**
11. **b**
12.
    1) **e**
    2) **c**
    3) **d**
    4) **a**
13. **c**
14. **a**
15. **d**
16. **c**
17. **a**
18. **d**
19. **c**
20. **c**