2.1.2

FIRE EMERGENCIES IN INTRODUCTORY COURSES

Preview This section describes the categories of fires, what kinds of fires are most likely in introductory lab courses, and how to extinguish these common fires.

Great emergencies and crises show us how much greater our vital resources are than we had supposed.

William James[1]

INCIDENT 2.1.2.1 FIRE FROM FRAYED ELECTRICAL WIRING[2]

A beaker of acetone, a very flammable organic solvent, was placed near a hot plate. The acetone fumes, heavier than air, crept along the top of the bench and at some point the frayed electrical wiring of the hot plate generated a spark and ignited the fumes. An instructor's clothing caught fire. One alert student safely extinguished the fire and another wrapped the instructor in a fire blanket. There were no serious injuries or damage.

What lessons can be learned from this incident?

Prelude

Fires in laboratories can be incredibly dangerous. Besides the danger of receiving burns, burning chemicals can produce toxic fumes and the risk of explosions. Fortunately, in introductory lab courses the nature and amounts of flammable substances are quite limited so that "worst case" scenarios and explosions are not likely. This section discusses the most common situations that might occur in introductory laboratory courses and explains the necessary background information to help you understand the risks of fires in laboratories. Section 2.2.1 presents more about fires in advanced chemistry and research labs where the hazards are likely to be more significant.

It may be that your instructor is most interested in having you learn when and how to use a fire extinguisher in a laboratory. If so, it is possible to read only the section below on "Using Fire Extinguishers." While that minimally prepares you to use an extinguisher we encourage you to learn more about the various classes of fires since we believe that the more you understand the nature of fire and kinds of fire that can occur the more likely you will be successful in extinguishing a small fire (or *preventing* a fire). If possible you should participate in any hands-on training opportunity to practice using a fire extinguisher since this experience is more realistic.

Classes of Fires

Fires that you might expect to encounter in introductory laboratories typically will involve "ordinary combustibles materials" or "flammable liquids." These phrases introduce us to the four general categories of fire, shown in Table 2.1.2.1.

Let's look at an overview of the four classes of fire and how the most common extinguishing agent, water, interacts with them.

Most fires that people (and firefighters) encounter in *nonlaboratory* situations are Class A fires. Some examples are burning houses and their contents, clothes and wood, burning cars, a trash dumpster on fire, and forest fires. As we will see below, these Class A fires are readily extinguished using water.

TABLE 2.1.2.1 Classes of Fires

Class	Description	Examples
A	Fires involving ordinary combustible materials	Paper, wood, clothing, furniture, plastics
B	Fires involving flammable liquids	Ether, hexanes, gasoline, oil
C	Fires involving energized electricity	Hot plates, spectrometers, computers
D	Fires involving reactive metals	Sodium, lithium, metal hydrides

Most laboratories do not use water (extinguishers) because fires with chemicals and electrical equipment should be extinguished with other agents.

Class B fires are burning organic liquids. Gasoline that is burning inside an automobile engine is a controlled Class B fire. Using "lighter fluid" on a charcoal grill is a Class B fire. Many organic solvents used in chemistry labs generate Class B fires. Trying to extinguish a fire involving organic solvents with water is counterproductive since most organic solvents do not mix with water and will float on top of water. A stream of water is more likely to spread the solvent and fire. For this reason, water should be not used to extinguish solvent fires. A different type of extinguishing agent is needed for Class B fires (see below).

Class C fires are any fires (Class A or Class B) that *also* involve energized electricity. A burning computer is a Class C fire. Toast burning in a toaster (that is "on") is a Class C fire. Since water conducts electricity, using water on these fires allows for the possibility of spreading the electrical charge back to the person using water to extinguisher the fire. Since this raises the possibility of fatal electrical shock, *water should never be used on a Class C fire*.

Class D fires are pretty rare outside of specific chemical laboratories or workplaces. Some industrial processes that involve very hot metals such as aluminum or magnesium can lead to a fire if water contacts these metals. In labs, we often use elemental sodium or lithium and these are very reactive with water. Compounds called "hydrides" are also very reactive and will catch fire upon contact with water. Class D fires are called "active metal" fires.

Class C and D fires are discussed more in Section 2.2.1.

But, what are we most likely to find on fire in a chemistry lab? While it's possible that some Class A materials might be on fire, there is a very good chance the some Class B organic liquid will also be on fire. And, since there is often equipment involving electricity in labs, some fire can easily be Class C as well. So, these are not fires that you should try to extinguish with water, and you'll probably have a hard time locating a pressurized water fire extinguisher in a lab. You will learn more about other types of extinguishers below.

To understand what extinguisher to use, and why, we should next learn about the fire triangle and the fire tetrahedron.

The Fire Triangle and the Fire Tetrahedron

For many years, fire scientists considered fire to consist of three components: oxygen, fuel, and heat. These three features comprised the fire triangle (Figure 2.1.2.1). We can use the fire triangle to think about how to prevent a fire from starting by not allowing all three components to meet. Keeping any one of them away from the other two will prevent a fire from starting. We use the fire triangle to understand how to *prevent* fires. We now better understand the details of the chemistry of fire and this triangle has been replaced by the fire tetrahedron because there is a fourth element that is needed to explain how fires are extinguished. (Figure 2.1.2.2). The fourth component is the chain reaction. By *removing* any one of these four components we can *extinguish* a fire. We use the fire tetrahedron to understand how to *extinguish* fires.

Let's look at each part of the tetrahedron.

Fuel is an obvious component of a fire. The most common fuels are Class A materials like paper, wood, cloth, or plastic or Class B liquids such as gasoline or some common organic solvents used in labs. Removing the fuel is usually not easy to do although sometimes containing the fuel or moving it

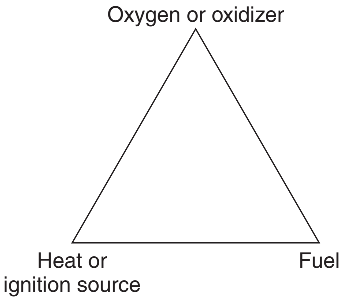

FIGURE 2.1.2.1 The Fire Triangle. The fire triangle helps explain how fires work and how to prevent fires.

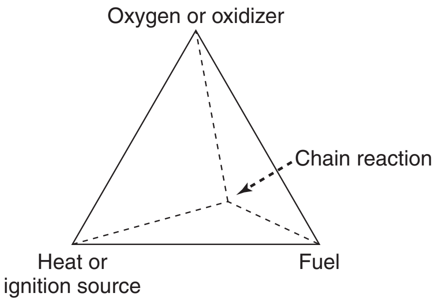

FIGURE 2.1.2.2 The Fire Tetrahedron. The fire tetrahedron helps explain how fires can be extinguished.

(such as taking a burning trash can outside) may stop the spread of the fire by limiting the availability of additional fuel.

All fires involve *oxidizing agents* (that oxidize or burn the fuel) and this is almost always atmospheric oxygen, O_2. If we can remove air from the fire, or vice versa, the fire will extinguish. This is sometimes easy. A small beaker of flammable liquid on fire will quickly extinguish if a watch glass (or other noncombustible "lid") is placed on the top of the open beaker. The remaining air in the beaker will be quickly consumed and the fire will self-extinguish. Similarly, a piece of paper on fire will extinguish if a book is placed on top of it. The book excludes air from the site of combustion. Or, the traditional "stop, drop, and roll" technique extinguishes burning clothing when one "rolls" on the fire and momentarily excludes oxygen. Finally, if we can "coat" a burning liquid with a powder or other substance that excludes the atmospheric oxygen from the liquid, the fire will extinguish.

A *source of energy*, usually heat or an electric spark, is required to start and sustain a fire. Removing the heat is done with water since water is such a great cooling agent. And since fuel and atmospheric oxygen are commonly available, most fire prevention measures are designed to prevent the initial source of heat from starting a fire.

The *chain reaction* is the least obvious component of the fire tetrahedron since this is occurring at the molecular level and we don't observe it directly. The exact mechanism by which chemicals burn is complicated but we know it involves a catalytic chain reaction. Some extinguishers work not by removing fuel, oxygen, or heat but by interfering with the chemical reaction in a fashion that stops the fire.

The value of understanding the components of the fire tetrahedron is that *removing any one* of the components stops the fire.

How Fires Burn

It may surprise you to learn that liquids and solids don't burn! This statement seems at odds with the common experience of paper, wood, or gasoline burning, but in fact, at the molecular level, the solid or liquid has to be vaporized before it will burn. When a match ignites paper or some flammable liquid, the heat from the match first pyrolyzes (decomposes) the material so that some vapor is produced. (See *Special Topic 2.1.2.1* Pyrolysis and Fires.) The heat also starts the chemical reaction of the flammable vapor combining with oxygen gas, which becomes the chain reaction: the exothermic (heat-releasing) reaction provides more heat to pyrolyze more of the flammable liquid or solid and the fire keeps burning.

SPECIAL TOPIC 2.1.2.1

PYROLYSIS AND FIRES

Pyrolysis is the decomposition of solid or condensed material by heating.[3] The term pyrolysis come from the Greek term for fire, *pyro*, and the Greek term meaning losing or breaking down, *lysys*. When sufficient heat is applied to a material, both intermolecular and intramolecular bonds break, and smaller components or compounds are generated that are volatile and often flammable. At the elevated temperatures these breakdown products can burn in air. When you see a solid material burning, it is really not the solid that is aflame, but the gases and volatiles that are released as the pyrolysis process continues releasing more gases.

In some homes there is inadequate clearance between chimneys or metal exhaust systems from fireplaces or furnaces and surrounding structural wood such that the radiant heat can pyrolyze the wood and, over time, eventually generate enough volatile flammable materials to ignite. This is the cause of some house fires. In fact, all burning wood and vegetation is a result of pyrolysis.

Pyrolysis is a major method of processing in the chemical industry. Petroleum is subjected to pyrolysis processes, known as cracking and catalytic cracking, to produce alkanes or alkenes that can be further used to produce fuels, such as gasoline. Pyrolysis has long been used to make charcoal from wood and other similar products such as shells. Pyrolysis occurs in our foods when we cook them—so when you take a bite of that golden brown apple pie remember it is produced by pyrolysis chemistry.

Why is this important? Just momentarily cooling a burning liquid can stop the fire, which eliminates the rapid vaporization of the liquid. This is a common way to extinguish Class B fires, as we will see below. The same is sometimes true of solids, although sometimes a burning solid will be hot enough (retaining enough residual heat through its own heat capacity) that a momentary cooling does not help. The very hot solid might be momentarily cooled, but the fire can restart spontaneously once air comes in contact with the fuel again.

Classes of Fires and Types of Fire Extinguishers

Fire extinguishers are categorized by the class of fires (see Table 2.1.2.1 above) that they extinguish. Wouldn't it be great if there was just one extinguisher that worked on all four classes of fires that was also cheap to manufacture and purchase? Well, we don't quite have that happy a situation, but the options are still pretty good. Table 2.1.2.2 shows the types of fire extinguishers. Below we'll discuss carbon dioxide extinguishers and dry chemical extinguishers since these are the most likely fire extinguishers to be used in a lab. In Section 2.2.1 we'll discuss Class D fires and the appropriate fire extinguishers. We'll also make brief mention of water as an extinguishing agent, although it is usually not the best agent for lab fires.

TABLE 2.1.2.2 Types of Fire Extinguishers

Type of extinguisher	A	B	C	D	Comments
Pressurized water	X				Usually in a silver container; uncommon in labs
Carbon dioxide	X	X			Usually red; common in labs; large cone; no pressure gauge
Dry chemical (BC)		X	X		Usually red; common in labs; small cone; pressure gauge
Dry chemical (ABC)	X	X	X		Usually red; common in labs; small cone; pressure gauge
Class D powder				D	Commercial versions uncommon (but available); a bucket of sand is more common

Using Water to Extinguish a Fire

Since most lab fires are Class B and/or Class C fires, water is usually *not* a good first choice to extinguish a fire in a lab. The only exception to this would be, for example, a situation where some papers caught on fire in a lab. This is clearly a Class A fire and can be doused easily with water or by, if possible, moving the papers into a nearby sink and turning on the water.

Water extinguishes a Class A fire primarily by cooling the burning fuel. Type A extinguishers are not likely to be found in laboratories. This removes the "heat" from the fire tetrahedron and the fire stops burning. (See *Chemical Connection 2.1.2.1* Why Firefighters Love Water.)

CHEMICAL CONNECTION 2.1.2.1

WHY FIREFIGHTERS LOVE WATER

Water has several advantages as an extinguishing agent for Class A fires. Some of these advantages may seem "obvious" or even unimportant, but when compared to other possible extinguishing agents, this list becomes very important.

1. It is cheap.
2. It is abundant.
3. It is nontoxic.
4. It doesn't react in a fire, and therefore produces no toxic by-products.
5. It has a very high heat capacity. This means that, on a per gram basis, it is able to absorb heat very well without increasing its own temperature dramatically. Since the main mode of "action" of water on a fire is to reduce heat (by absorbing heat), having a high heat capacity is great.
6. It is possible to dissolve other chemicals in water so that it becomes an even more effective extinguishing agent. Firefighters sometimes add a foaming agent to water in a system embedded in the pump in a fire engine. "Class A foam" is sometimes used on burning houses to allow the water to better soak into the wood, which provides additional protection against a "rekindle." Class A foam is a surfactant, a kind of detergent molecule that you will learn about in an introductory chemistry course. "Class B foam" is an agent that creates a nonflammable foam that will cover the surface of a Class B liquid fire, thus preventing oxygen from contact with the vapor of the liquid and stopping the fire.

The only minor disadvantage to water for firefighters is that in an enclosed room with a very hot fire, some of the water used to cool the fire may turn into steam. This steam can penetrate through openings in a firefighter's protective gear and cause serious burns. Firefighters typically have no exposed skin while fighting an interior fire, but the steam can circumvent this imperfect protection.

Carbon Dioxide Extinguishers

A common type of fire extinguisher to be found in a lab is a heavy metal container with several pounds of liquid carbon dioxide inside and a large wide-mouth black nozzle (see Figure 2.1.2.3). The CO_2 extinguisher is for Class B or Class C fires. The vapor pressure of liquid CO_2 at 20 °C is about 58 atm. When this extinguisher is discharged, gas immediately exits the extinguisher through a large nozzle and is reduced to local atmospheric pressure. The method of extinguishing the fire is to reduce the concentration of atmospheric oxygen to a very low level by creating a "blanket" of CO_2 gas at the site of the fire. This momentarily extinguishes the fire, and in the case of a burning liquid, the rate of vaporization of the liquid is greatly reduced. For just a moment, no more fuel or heat is available to allow the fire to continue to burn. After the CO_2 quickly dissipates and oxygen returns, the heat from the fire is gone and the fire can't restart. Thus, even though the fuel and oxygen are present, interrupting the fire eliminates the heat needed to continue chemical reaction. Most liquids have lower heat capacities so the liquid itself never gets very warm.

FIGURE 2.1.2.3 CO_2 Fire Extinguisher. This extinguisher should be used only on Class B and Class C fires.

What happens if a CO_2 extinguisher is used on a Class A fire such as a burning piece of wood? The fire is momentarily extinguished due to the lack of oxygen, but when the CO_2 dissipates the very hot wood can easily reignite when oxygen returns. Thus, CO_2 extinguishers should not be used on Class A fires.

CO_2 extinguishers are good for Class B fires (organic liquids) but can also be used successfully on some Class C fires. An electrical fire might be extinguished by a CO_2 extinguisher. However, unless the equipment is deenergized by shutting off the electricity supply, the fire may restart. Similarly, solvent fires might reignite if there is sufficient source of heat (besides the heat of the fire itself, which will be eliminated once the fire is extinguished).

Dry chemical extinguishers are preferred for solvent fires, as described below.

Dry Chemical Extinguishers

There are two types of dry chemical extinguishers: BC and ABC, referring to the classes of fires that they extinguish.

BC dry chemical extinguishers contain powder that is designed to coat the surface of a flammable liquid and to eliminate the vaporization of the liquid. This stops fire since no more fuel is available.

ABC dry chemical extinguishers work like BC, except that the powder used is also selected so that it forms a sticky solid layer on solid (Class A) materials. This layer prevents oxygen from attacking the fuel, even though it may still be hot enough to burn (see Figure 2.1.2.4).

Which Extinguisher Should I Use?

With the information provided above, you should be able to carefully select the correct extinguisher. And, the labels on fire extinguishers (A, BC, ABC) help you select the correct extinguisher, too. But, happily and with prior preparation, in the moment of panic that often accompanies a fire, you probably won't have to think about classes of fire and types of extinguishers. Why not?

Fire codes require that buildings have the kinds of fire extinguishers that are appropriate for the most likely kinds of fires that occur in those buildings. So, in an emergency, you can always rely on the fact that the fire extinguishers on the wall or in the hallway will be effective for the fire that you encounter. Since chemistry and other science labs might have a wide range of flammable and

FIGURE 2.1.2.4 ABC Fire Extinguisher. This extinguisher can be used on Class A, B, and C fires. It is the most common type of extinguisher found in chemistry laboratories. It leaves a powdery mess after use, but this is better to clean up than the destruction a fire may cause.

combustible materials in them, it's likely that the available extinguisher will be an ABC dry chemical extinguisher. Look at the extinguisher; it is labeled with large letters and pictograms showing what fires it can, and cannot, extinguish.

It is possible that some labs may have BC extinguishers—either CO_2 or dry chemical. Don't use these on a Class A fire since they may not be as effective as a type A fire extinguisher.

If you use dry chemical extinguishers on electronic equipment, such as computers or laboratory instrumentation, the electronics will likely be seriously damaged. A CO_2 extinguisher is a preferable "first choice" extinguisher on electronic equipment, if you have the choice of what type of extinguisher to use. It is more likely that you will use whatever extinguisher is available. Most electronic equipment in the introductory lab is relatively inexpensive, in the range of thousands of dollars, particularly in comparison to advanced instruments, which can cost hundreds of thousands or even millions of dollars. Extinguishing the fire at the cost of destroying an instrument, to prevent a *larger* fire with *more* damage, is a top priority.

The most common extinguishing agent is still water and it works great on Class A fires. If a piece of paper is on fire in a lab, water will put out the fire. If a person's clothing is on fire, the safety shower will put out the fire. But, don't assume that the first large beaker of clear liquid you see is water! It may be a flammable organic solvent and throwing this on a Class A fires generates another fire, now Class B!

Using Fire Extinguishers

The best way to learn how to use an extinguisher is to practice in a fire class with a firefighter. Many fire departments give free hands-on training to the public and educational institutions. Don't pass up this opportunity to handle an extinguisher. The instructions below are appropriate to read but there is no substitute for hands-on training.

All portable fire extinguishers work the same way. This commonality of design makes them easy to use. An easy way to remember how to use the extinguisher is the PASS technique: pull, aim, squeeze, and sweep.

- *Pull* the pin. Fire extinguishers have a safety pin near the handle to prevent accidental discharge. This pin should be secured in place with a plastic tie that can be broken with a good tug on it. If, even with adrenaline flowing, you cannot break the tie by pulling, try to twist it to break it or place the extinguisher flat (sideways) on the ground, kneel on it and pull the pin to break the plastic tie.

- *Aim* the extinguisher at the base of the fire. Sometimes there is a detachable nozzle connected to the extinguisher by a flexible hose. In other designs the nozzle may simply "swing up" from the side.
- *Squeeze* the handle to begin the discharge. Dry chemical extinguishers make a little noise and CO_2 extinguishers make a loud noise!
- *Sweep* the discharge back-and-forth horizontally across the base of the fire.

If the handle if released, the extinguisher will stop discharging the agent. But, it is usually best to discharge the *entire* extinguisher. A flammable liquid fire that is 99% extinguished will quickly reignite and thwart whatever initial attempt you made to extinguish it. Your first effort will have been wasted and used part of the extinguisher. Dry chemical extinguishers produce a real mess when discharged, but cleaning up a powdery mess is better than watching a building burn to the ground or risking lives. Extinguishers don't last long, 30 seconds to a few minutes, depending on the size. If you discharge a fire extinguisher, report it immediately to your lab supervisor or instructor. This will ensure that the empty extinguisher is refilled and put back in place.

Of course, you can only use a fire extinguisher if you know where it is located. Fire code requires that portable extinguishers be located in conspicuous locations, along normal paths of travel and no more than 5 feet above the floor. Most labs will have fire extinguishers inside the lab. In labs that have Class B hazards (i.e., contain flammable liquids) the fire extinguisher must be no more than 50 feet from the door in a hallway. You should always visually scan any lab that you work in to see the location(s) of the fire extinguisher(s) and then also determine what type they are.

What If *You* Are on Fire?

If an incident occurs that sets your clothing on fire, there are a few ways to respond to this. Burning clothing, or skin, is a Class A fire. Since responding very quickly is important, the fastest effective response is the best one when several choices are available.

Modern laboratories all have safety showers that are designed primarily to quickly rinse the whole body in the event of some chemical contamination from a spill or explosion. These safety showers are also an extremely effective and rapid way to extinguish burning clothing. If you do need to use one, be prepared for the shock from the cold water—these showers don't use warm water. The only disadvantage to safety showers is the distance that someone may need to run to get to one.

Some labs may have faucets with long flexible attachments (commonly called drench hoses) on them, perhaps even with eyewash capabilities. For a small fire, this may be an effective option and may allow a victim to be lowered to the ground near a sink so that the water stream can quickly be applied to the fire.

Burning clothing can sometimes be extinguished by the "stop, drop, and roll" method, where the victim rolls on the floor. The rolling action will extinguish some of the fire; it is helpful if others also "pat" the area of the fire starting at the head and moving down the body. "Patting" with a towel or a jacket will help protect the hands of those who are helping. Do not "pat" a burning person with your bare hands or while wearing gloves that could melt.

Some labs may have fire blankets available. These nonflammable blankets can be used to wrap around a victim to smother the fire. If you are on fire, using a safety shower is the best option; but if this is not quickly available you can "stop, drop, and roll." If a fire blanket is available, it is best used by someone assisting you to help smother the fire. You should be aware that if you are on fire and standing, wrapping in a fire blanket could produce a "chimney" effect that not only may not extinguish the fire but could promote continued burning and injuries from the fire. Fire blankets can also be used to warm someone who has stepped into a safety shower or held up to provide privacy for someone who needs to remove burnt or contaminated clothing.

Should a portable fire extinguisher be used on a person? Ideally, no, since a CO_2 extinguisher (BC) is not designed to extinguish a Class A fire and using either a BC or ABC dry chemical extinguisher exposes the victim to possibly inhaling some of the powder. However, any of these extinguishers is better than no extinguisher. These should be used only when water or fire blankets are not available, and the "stop, drop, and roll" method has not been effective.

Should You Fight the Fire?

A small fire can usually be extinguished by a trained person with the proper extinguisher. But, life preservation trumps property loss. Only try to fight a fire if:

- It is a "small fire." There is no clear definition of small, but "flames from floor to ceiling" or "an entire lab bench" is not a small fire. If it *seems* too big, it *is* too big.
- You have the correct extinguisher and can retrieve is rapidly.
- You know how to use the extinguisher.
- You always keep an exit available away from the fire. Never allow a fire to get between you and your only exit.

What Else to Do

In an introductory lab, there should always be some instructor available and there will likely be several students around if a fire occurs. If you choose to attempt to quickly put out a fire, you should:

- Yell to others that there is a fire and you are attempting to put it out.
- Have someone call 911.
- Make sure that someone else tells the instructor what is happening.
- Make sure that someone else is starting to evacuate the lab.

A quickly extinguished fire represents a very brief and very exciting and alarming moment during a lab experiment. It can start and be over in 30 seconds. Or, the fire can grow and the science building can be destroyed. In many situations it is perfectly appropriate to pull the fire alarm and call 911, even when only minutes later the situation is under control and no further hazard exists. Firefighters *do not like false alarms that are pranks* for a host of good reasons, but firefighters do not at all mind responding to a genuine emergency that was ultimately taken care of before they arrived. It is always safe to assume that the worst can happen when something starts to go wrong and take the necessary steps to keep yourself and others safe.

There's More

This has been a fairly brief introduction to fires, written as an appropriate introduction for the first year of chemistry labs at most colleges and universities. There is more to learn about fires and various fire hazards that can present themselves in advanced and research labs. Section 2.2.1 continues this discussion.

The RAMP paradigm can be used to think about fire hazards and how to prepare for fire emergencies.

- *Recognize* the flammable and combustible materials, particularly organic solvents, in the laboratory. *Recognize* any electrical equipment that may pose a fire hazard or the presence of any active metals.
- *Assess* the risk of the fire hazard by considering the quantities of materials and possible ignition sources.
- *Minimize* the risk by using and storing flammable liquids and active metals appropriately and by checking electrical equipment.
- *Prepare* for fire emergencies by knowing where extinguishers are located, how to use them, and where exits and fire alarms are located.

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2. F. Majtabai and J. Kaufman (editors). *Learning by Accident*, Vol. 1, The Laboratory Safety Institute, Natick, MA, 1997, #46.
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QUESTIONS

1. The best way to learn how to use a fire extinguisher is to
   (a) Use one during a real fire emergency
   (b) Read the label on the extinguisher
   (c) Practice using a fire extinguisher during a training course
   (d) Practice using a fire extinguisher anytime you are not busy during a lab experiment
2. Class A fires involve
   (a) Energized electricity
   (b) Flammable liquids
   (c) Ordinary flammables
   (d) Reactive metals
3. Class B fires involve
   (a) Ordinary flammables
   (b) Reactive metals
   (c) Energized electricity
   (d) Flammable liquids
4. Class C fires involve
   (a) Ordinary flammables
   (b) Energized electricity
   (c) Flammable liquids
   (d) Reactive metals
5. Class D fires involve
   (a) Ordinary flammables
   (b) Flammable liquids
   (c) Energized electricity
   (d) Reactive metals
6. A burning computer that is being used is what class of fire?
   (a) A
   (b) B
   (c) C
   (d) D
7. A burning lab notebook is what class of fire?
   (a) A
   (b) B
   (c) C
   (d) D
8. If some organic solvent has spilled onto an operating hot plate and caught fire, what class of fire is this?
   (a) B only
   (b) C only
   (c) B and C
   (d) A and C
9. A fire involving sodium hydride is what class of fire?
   (a) A
   (b) B
   (c) C
   (d) D
10. What part of the fire tetrahedron was not originally included in the fire triangle?
    (a) Fuel
    (b) Oxidizing agent
    (c) Ignition source
    (d) Chain reaction
11. Most fire prevention methods involve the elimination of what part of the fire tetrahedron?
    (a) Fuel
    (b) Oxidizing agent
    (c) Ignition source
    (d) Chain reaction
12. What phase(s) of matter do not burn?
    I. Solid
    II. Liquid
    III. Gas
    (a) I and II
    (b) I and III
    (c) Only I
    (d) II and III
13. Water is a useful extinguishing agent on what class(es) of fire?
    (a) Only A
    (b) A and B
    (c) A and C
    (d) Only D
14. Why are pressurized water extinguishers not found in chemistry laboratories?
    (a) They are too expensive.
    (b) They are too heavy for some people to operate.
    (c) Most lab fires are Class B or Class C fires.
    (d) Most lab fires are Class D fires.
15. Why is a carbon dioxide extinguisher not always effective against a Class A fire?
    (a) The CO_2 will further “feed” the Class A fire.
    (b) The fire might momentarily be extinguished but the hot fuel can reignite when air hits the fire.
    (c) Carbon dioxide cannot cool the flames enough.
    (d) They typically last only 10–15 seconds, which is not long enough to extinguish the fire.

16. BC fire extinguishers work by
    (a) Cooling the fire
    (b) Stopping the chain reaction
    (c) Preventing vaporization of a flammable liquid
    (d) “Deactivating” the fuel
17. ABC fire extinguishers work by
    (a) Cooling the fire
    (b) Chemically neutralizing the fuel
    (c) Preventing vaporization of a flammable liquid
    (d) Forming a sticky layer that prevents oxygen (in the air) from reacting with the fuel
18. Why is the most handy fire extinguisher in a chemistry lab almost always the appropriate fire extinguisher?
    (a) It is the cheapest to use, and therefore easily replaced.
    (b) It is probably an ABCD extinguisher that works on all classes of fires.
    (c) Fire code requires that available fire extinguishers be the appropriate type for the most likely type of fire.
    (d) It is the type of extinguisher that most folks know how to use.
19. What is the correct sequence of actions in order to use any fire extinguisher properly?
    (a) Aim, pull, sweep, and squeeze
    (b) Aim, pull, squeeze, and sweep
    (c) Pull, aim, squeeze, and sweep
    (d) Pull, aim, sweep, and squeeze
20. Portable fire extinguishers typically discharge for about
    (a) 5–10 seconds
    (b) 10–30 seconds
    (c) 30 seconds to a few minutes
    (d) 5–10 minutes
21. When using a fire extinguisher it is best to
    (a) Use it only in “short bursts” until the fire is out
    (b) Use it continuously until the fire is out
    (c) Discharge the entire extinguisher to optimize the use of extinguishing agent
    (d) Discharge it until it starts to make too much of a mess in the lab
22. The best extinguishing agent for a person on fire is
    (a) Type BC
    (b) Type ABC
    (c) Water
    (d) Type ABCD
23. A student should attempt to use a fire extinguisher
    (a) Only if an instructor says it is OK
    (b) Always, before sounding an alarm or alerting anyone else
    (c) Only if the fire is small enough and the student can confidently use the available extinguisher
    (d) On all fires, no matter how small or large because the fire will certainly get larger and cause considerable damage