Fire Behavior

Module 1

Chapter 5

LEARNING OBJECTIVES

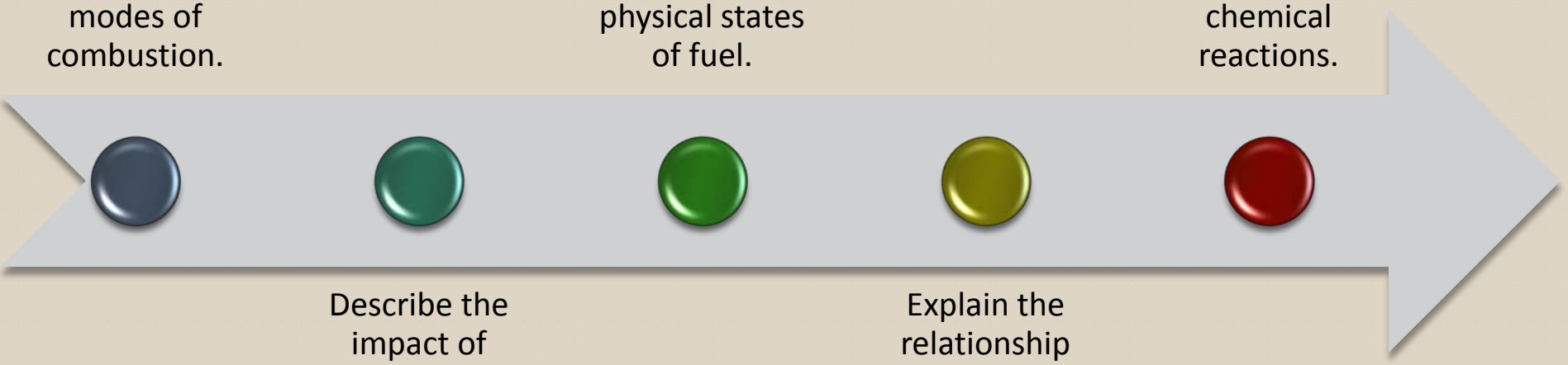
Explain the science of fire as it relates to energy, forms of ignition, and modes of combustion.

Describe the impact of thermal energy on heat, temperature, and heat transfer.

Recognize the physical states of fuel.

Explain the relationship between oxygen and life safety.

Identify the products of self-sustained chemical reactions.



UNDERSTANDING THE PHYSICAL SCIENCE OF FIRE CAN HELP FIREFIGHTER SAFETY.

Fire – Variety of forms

- Heat-producing chemical reaction between fuel and oxidizer

Knowledge can help

- Translate into practical knowledge of fire behavior
- Recognize what is happening – Predict potential behavior

THERE ARE TWO TYPES OF CHANGES FIREFIGHTERS SHOULD UNDERSTAND.

Physical change

- Changes in size, shape, appearance
- Substance chemically same

Chemical reaction

- From one type of matter to another
- Substance changes

THE CONCEPT OF ENERGY IS ALSO IMPORTANT FOR FIREFIGHTERS TO KNOW.

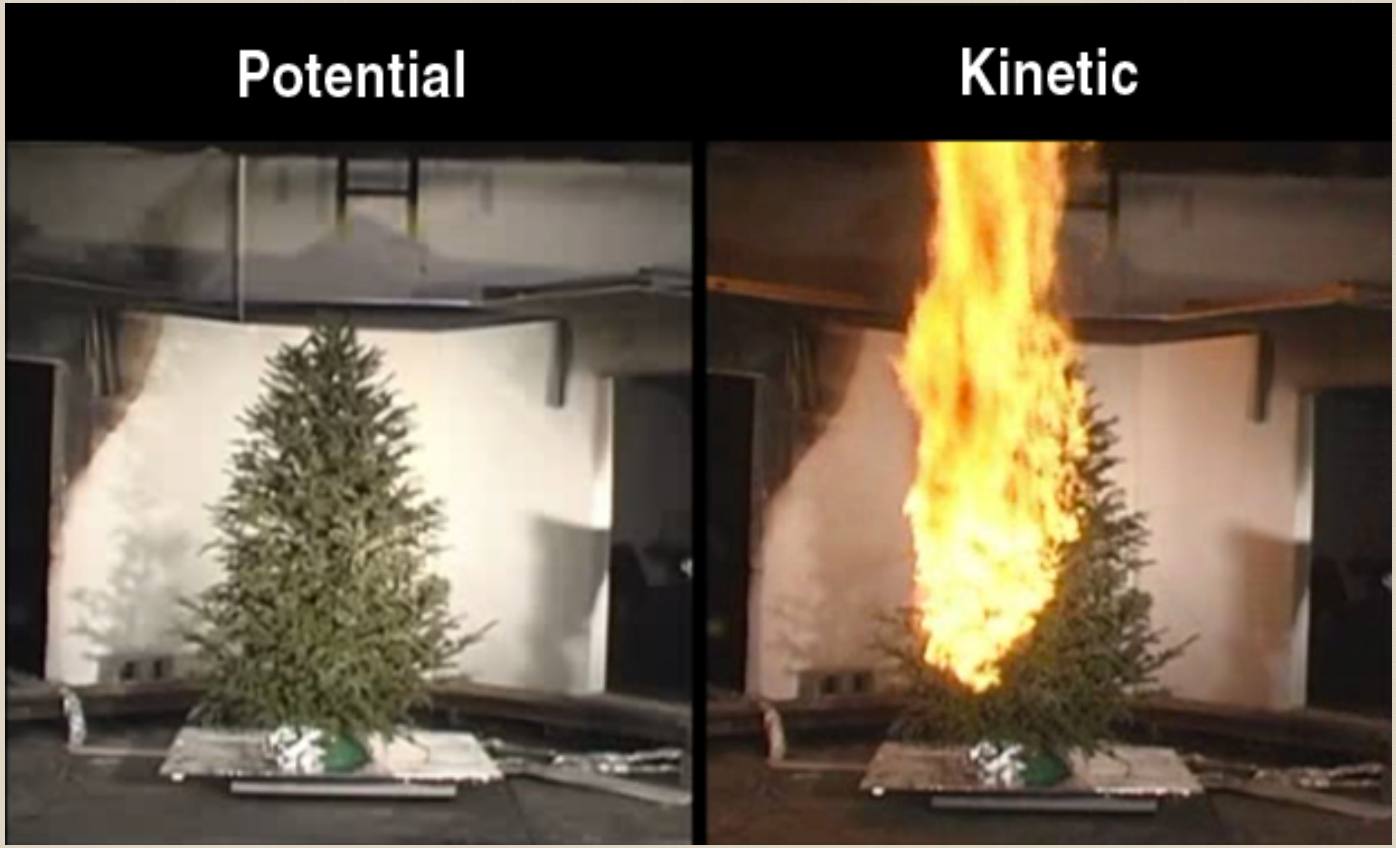
In heat defined as

- Increasing temperature of substance

Work occurs when

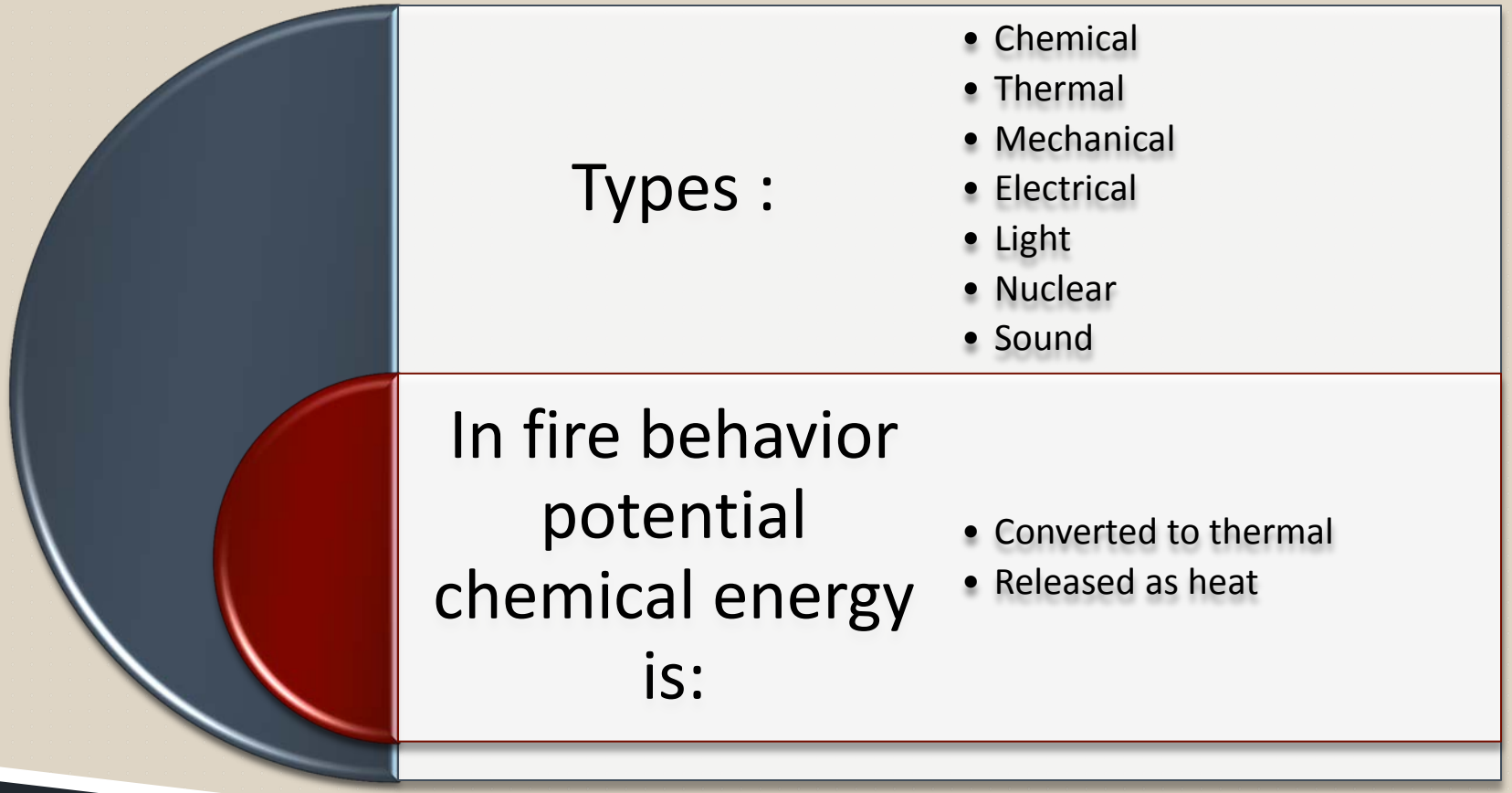
- Force is applied to object over distance
- Substance undergoes chemical, biological, physical change

THERE ARE TWO FORMS OF ENERGY THAT FIREFIGHTERS SHOULD KNOW ABOUT.



Courtesy of Dan Madrzykowski, NIST

THERE ARE MANY TYPES OF ENERGY AND ALL CAN CHANGE FROM ONE TYPE TO ANOTHER.



YOU SHOULD ALSO KNOW ABOUT HOW TO MEASURE AND THE EXCHANGE OF ENERGY.

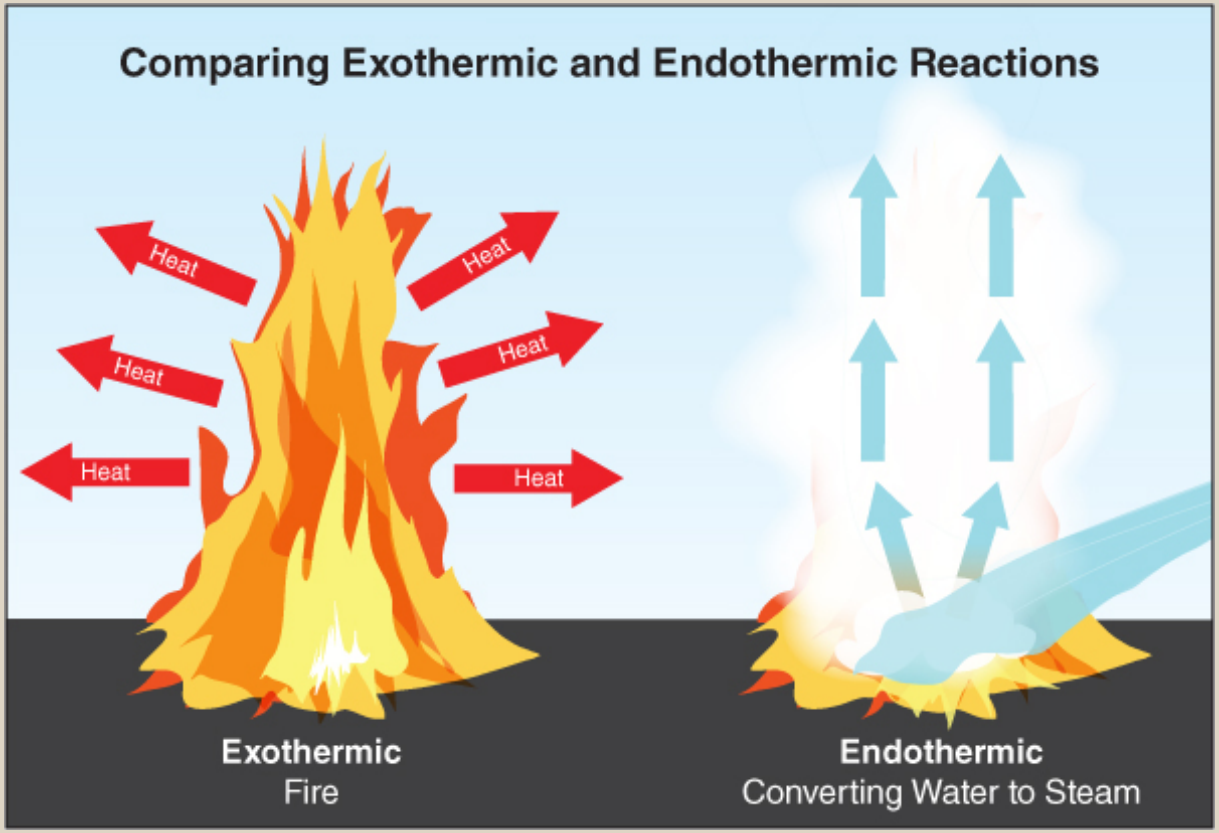
Measurement

- Joules (J) in SI
- British thermal unit (Btu) in customary

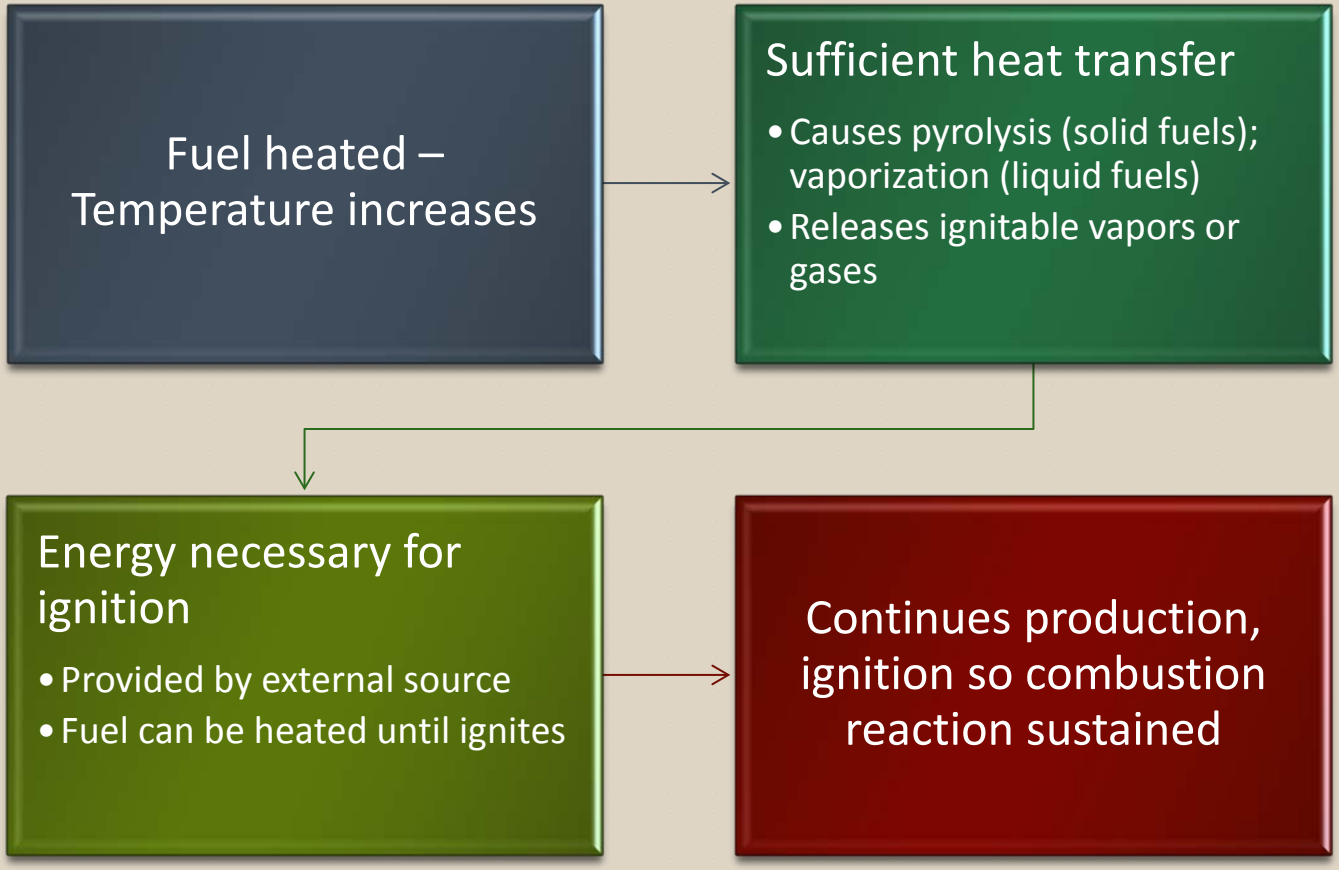
Chemical, physical changes involve exchange of energy

- Potential energy
  - Released during combustion
  - Converted to kinetic energy

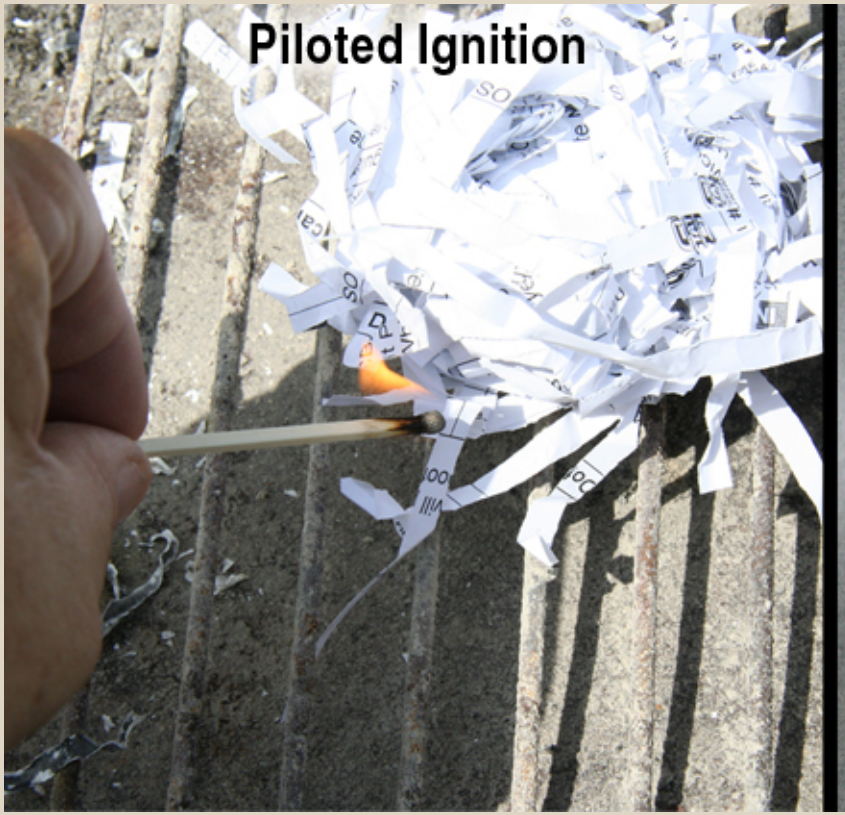
THERE ARE TWO TYPES OF ENERGY REACTIONS THAT YOU SHOULD UNDERSTAND.



THE PROCESS OF IGNITION FOLLOWS A SEQUENCE OF STEPS.



PILOTED AND AUTOIGNITION ARE THE TWO FORMS OF IGNITION.

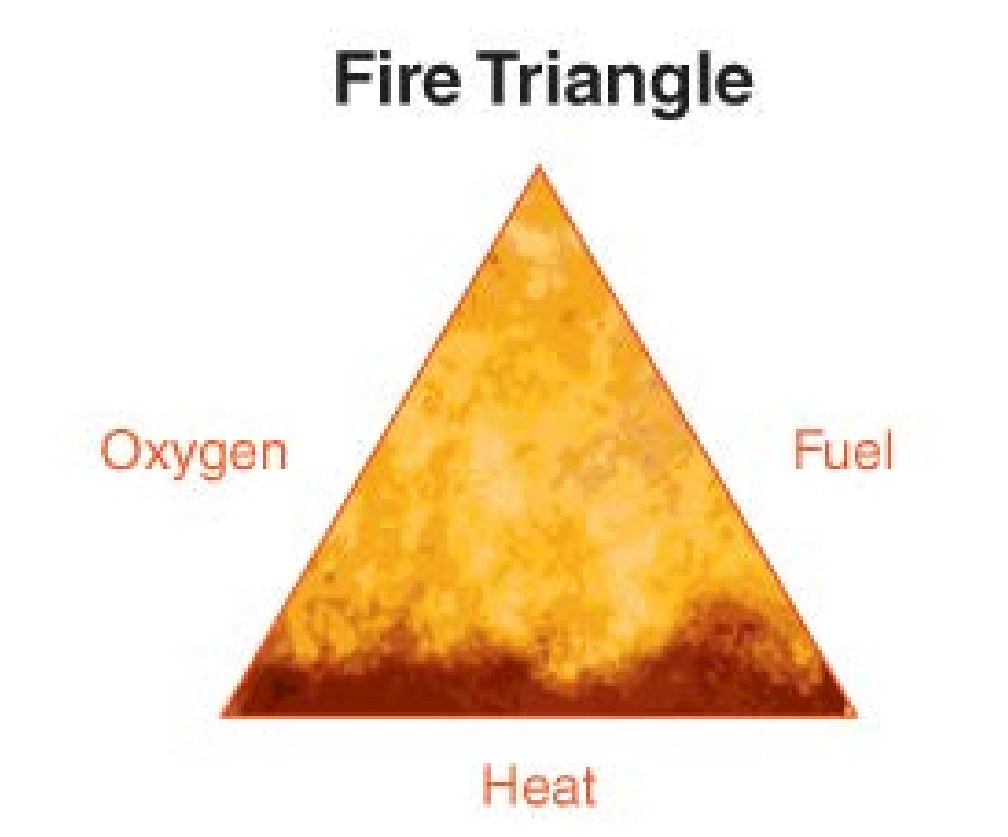


FIRE AND COMBUSTION REQUIRE SIMILAR CONDITIONS TO OCCUR.

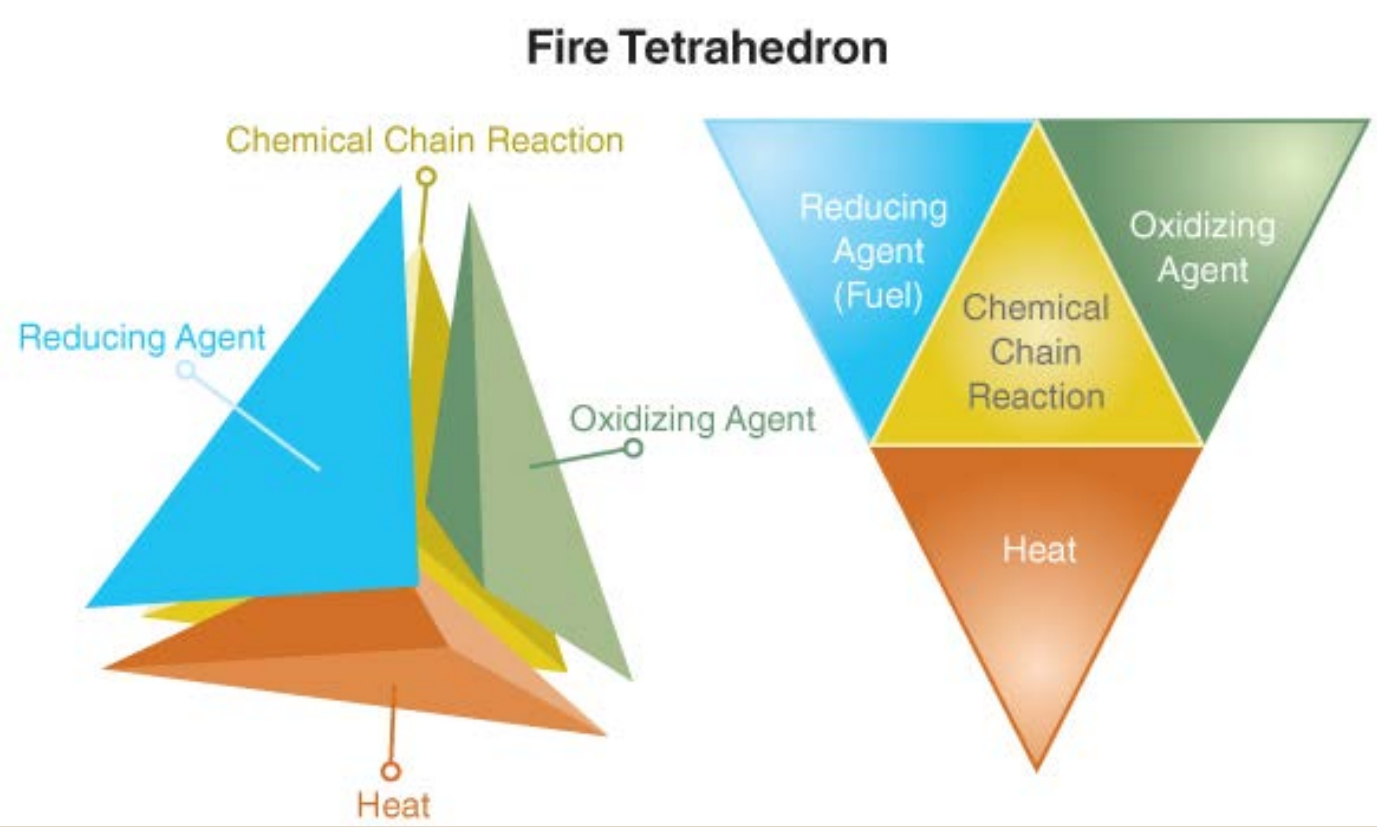
Combustion – Chemical reaction, can occur without fire

Fire – One possible result of combustion

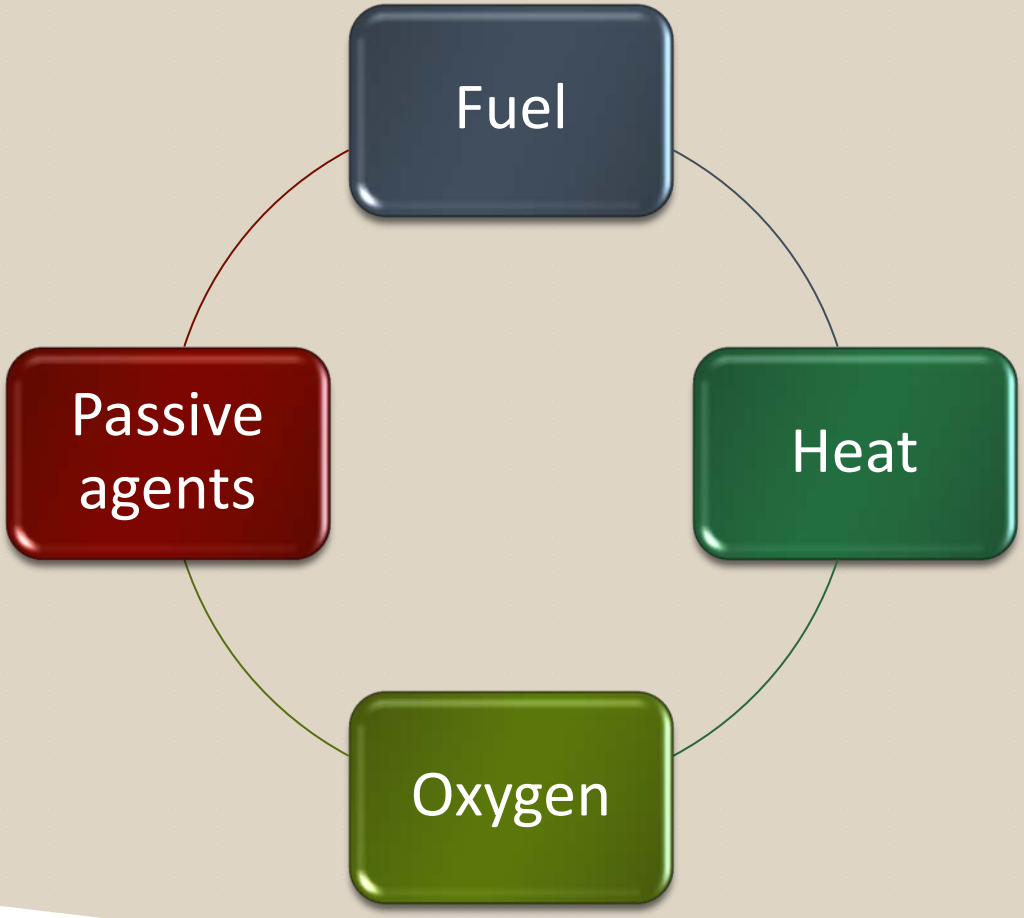
THE FIRE TRIANGLE IS THE OLDEST AND SIMPLEST FIRE MODEL.



THE FIRE TETRAHEDRON REPRESENTS THE UNINHIBITED CHAIN REACTION THAT MUST BE PRESENT FOR FIRE TO OCCUR.



THERE ARE SEVERAL MATERIALS THAT AFFECT BOTH IGNITION AND FIRE DEVELOPMENT.



THE TWO TYPES OF COMBUSTION OCCUR UNDER DIFFERENT CIRCUMSTANCES.

Nonflaming

Burning is localized on or near fuel's surface – Where in contact with oxygen

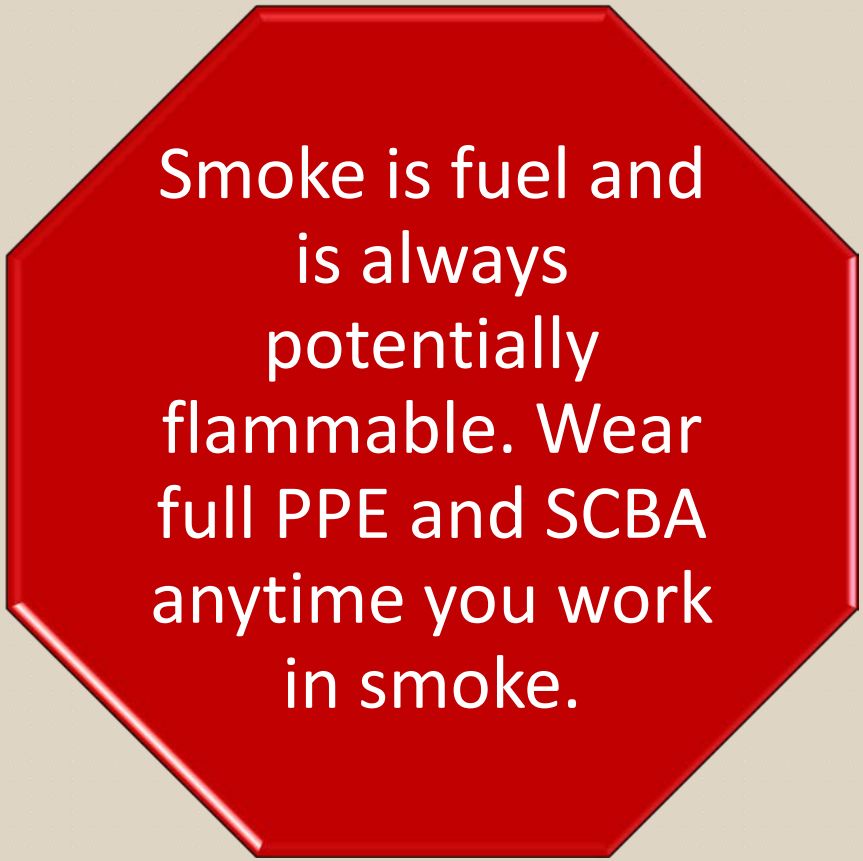
Flaming

Gaseous fuel mixes with oxygen in correct ratio, heated to ignition temperature

THE PRODUCTS OF COMBUSTION GENERATE AS FUEL BURNS AND CHANGES CHEMICAL COMPOSITION.

- Thermal energy
- Toxic smoke
- Smoke
- Carbon monoxide (CO)
- Hydrogen cyanide (HCN)
- Carbon dioxide (CO_2)
- Flame

WARNING


Smoke is fuel and is always potentially flammable. Wear full PPE and SCBA anytime you work in smoke.

THERMAL ENERGY (HEAT) IS THE ENERGY ELEMENT IN BOTH FIRE MODELS.

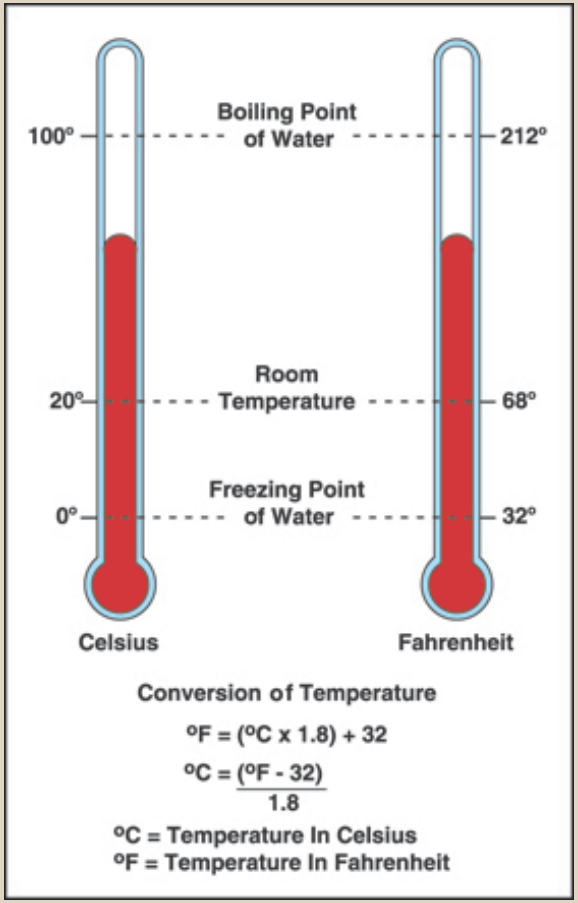
Kinetic energy transfers from high-temperature to low-temperature substance

Always in transit

Thermal kinetic needed to release potential chemical energy in fuel

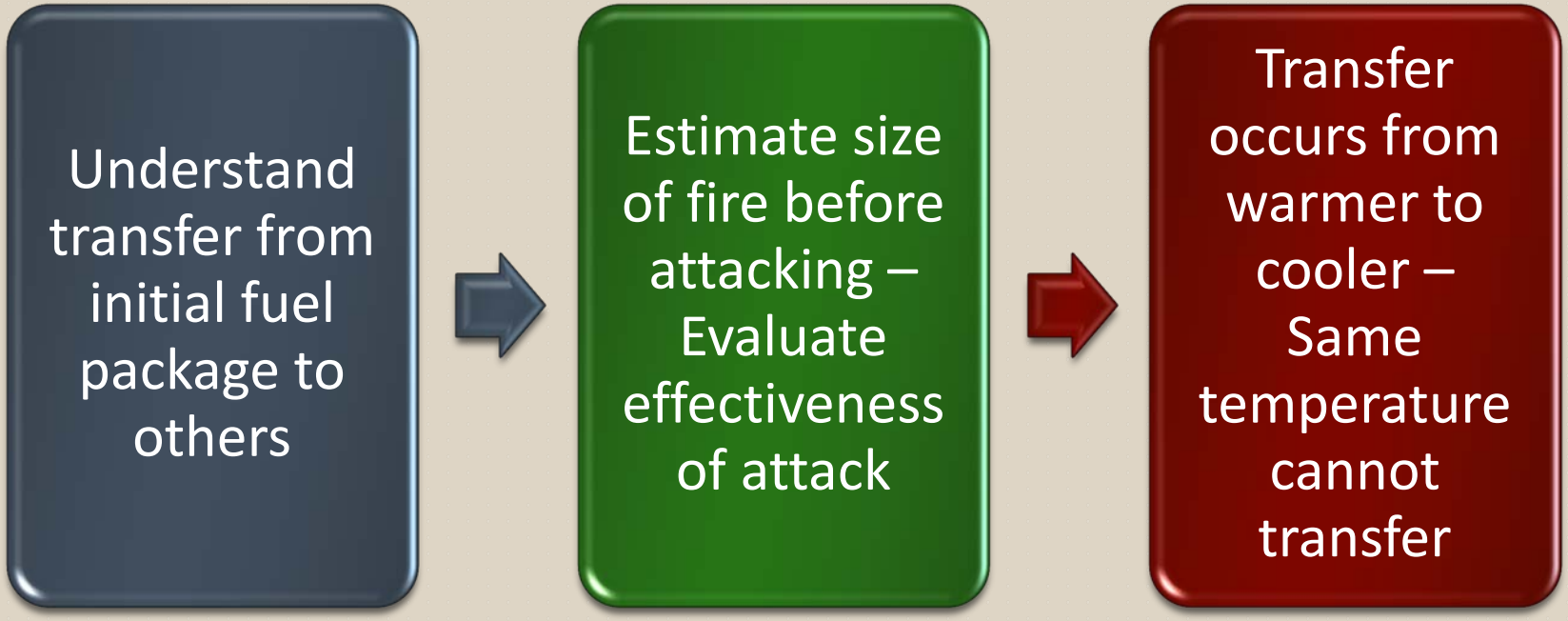
Vibrates molecules in fuel leading to break down, release of vapors

YOU SHOULD UNDERSTAND THE RELATIONSHIP BETWEEN HEAT AND TEMPERATURE.



THERE ARE SEVERAL SOURCES OF THERMAL ENERGY YOU SHOULD RECOGNIZE.

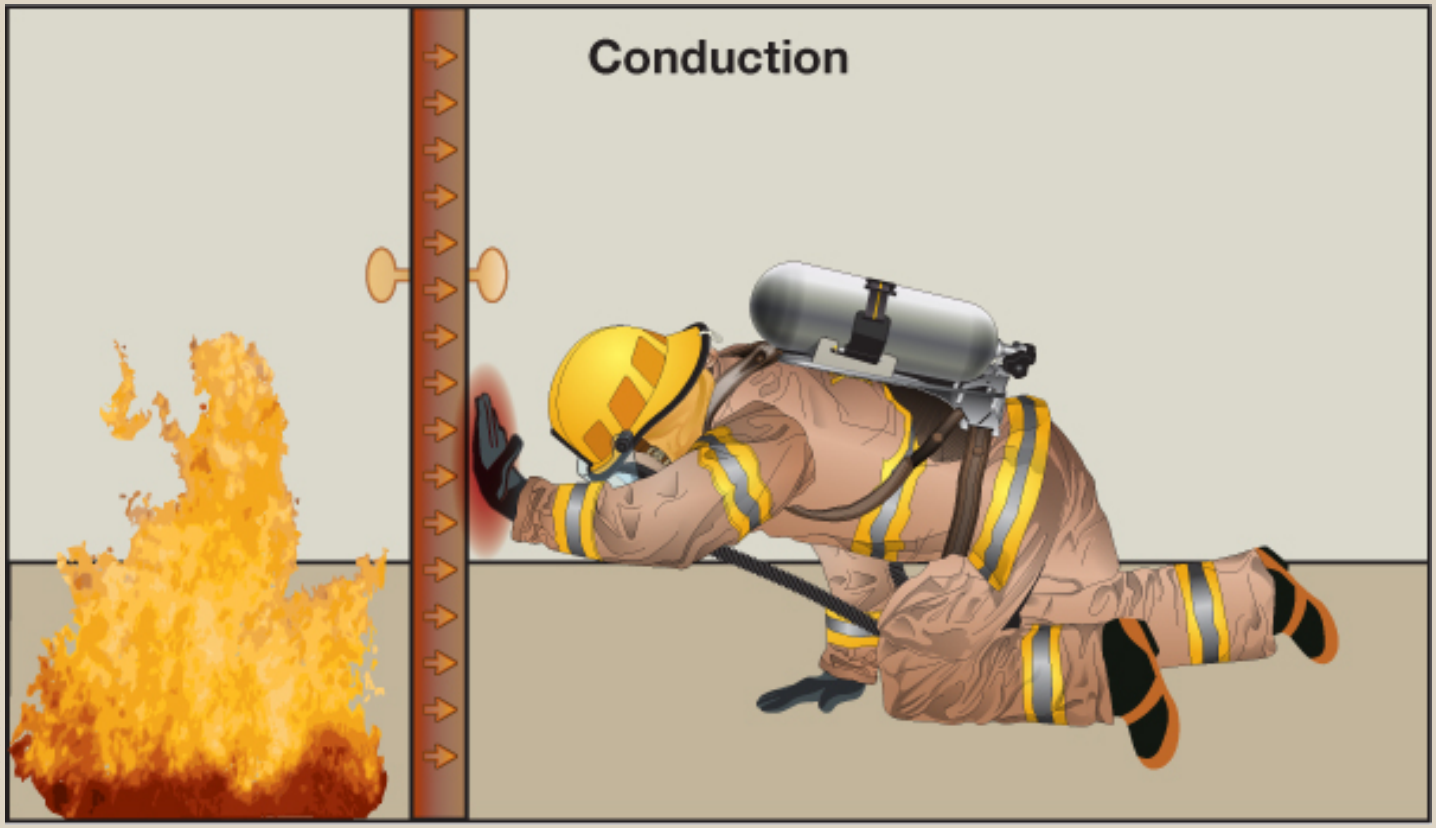
UNDERSTANDING THE CONCEPT OF HEAT TRANSFER CAN HELP IN SEVERAL WAYS.



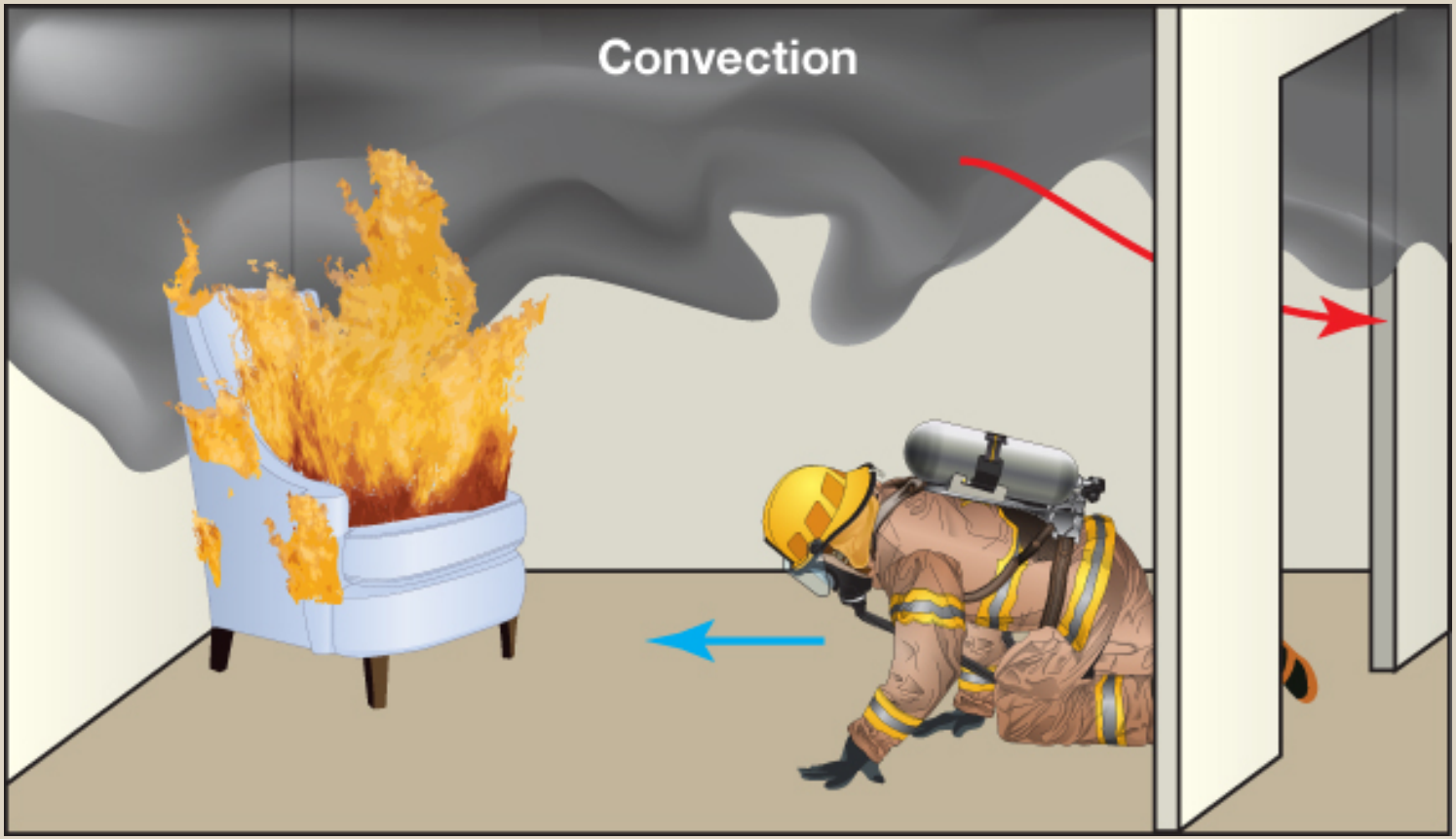
THE CONCEPT OF TRANSFER RATE IS INFLUENCED BY SEVERAL FACTORS.

- Related to temperature differential – Thermal conductivity
- Greater temperature difference – Greater transfer rate
- Heat flux

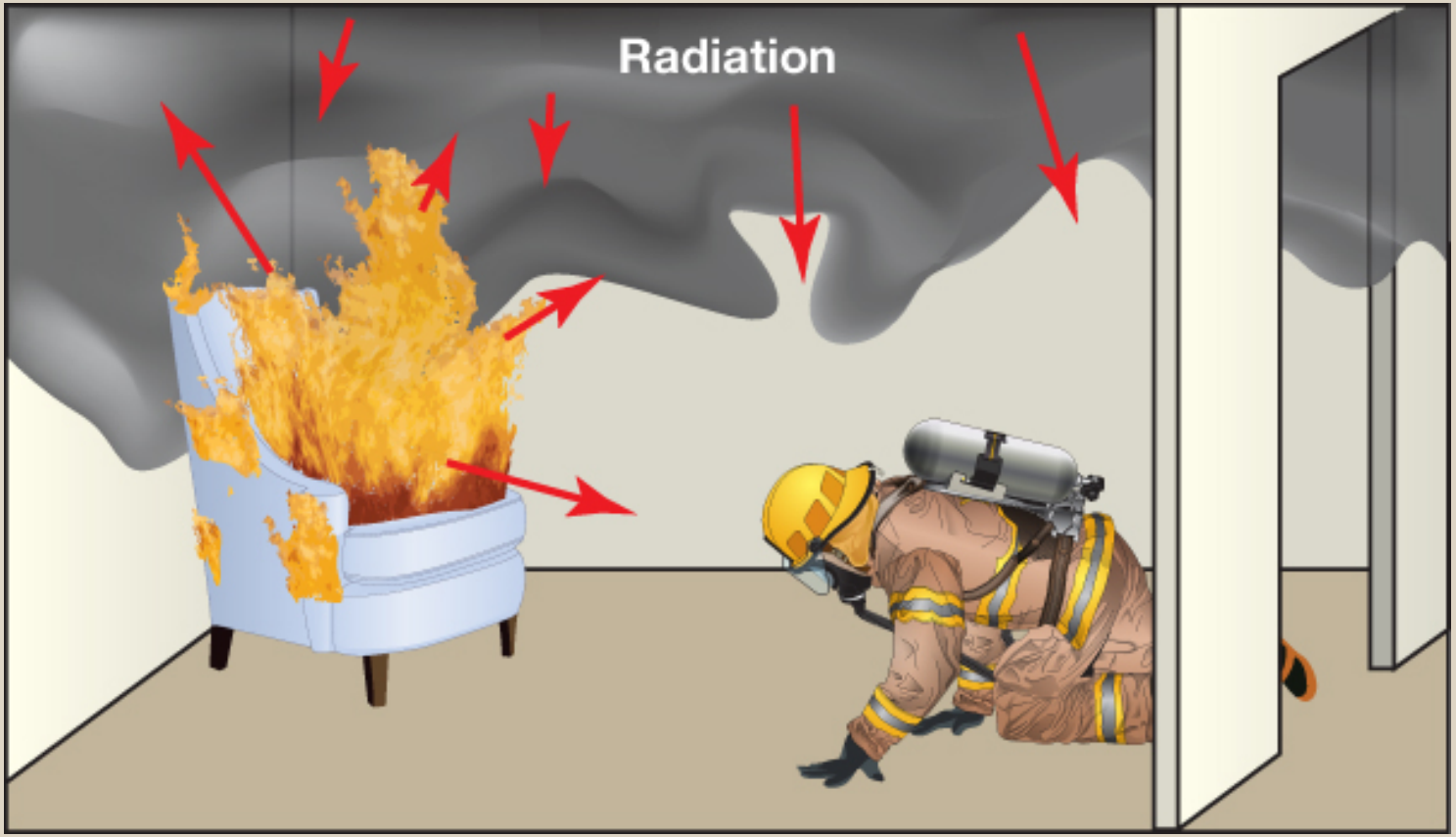
CONDUCTION IS THE TRANSFER OF HEAT THROUGH AND BETWEEN SOLIDS.



CONVECTION IS THE TRANSFER OF THERMAL ENERGY BY CIRCULATION OR MOVEMENT OF FLUID (LIQUID OR GAS).



RADIATION IS THE TRANSMISSION OF ENERGY AS AN ELECTROMAGNETIC WAVE, WITHOUT AN INTERVENING MEDIUM.



FUEL IS THE MATERIAL OR SUBSTANCE OXIDIZED OR BURNED IN COMBUSTION.

Inorganic

- Do not contain carbon

Organic

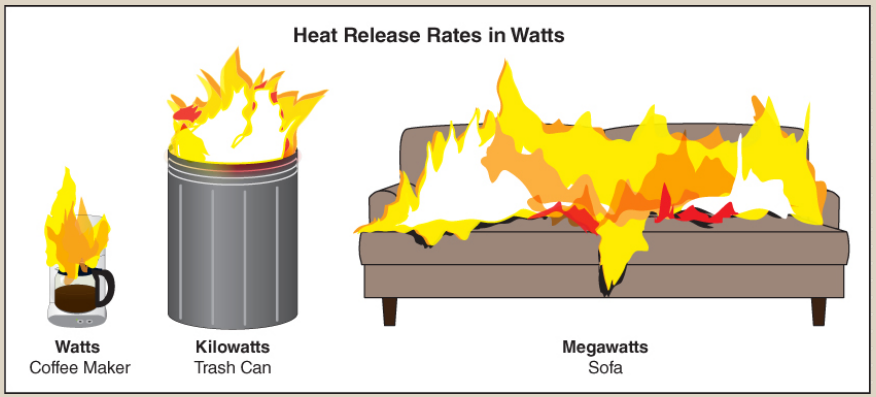
- Contain carbon, other elements

THE CHEMICAL CONTENT OF FUEL INFLUENCES HEAT OF COMBUSTION AND HEAT RELEASE RATE.

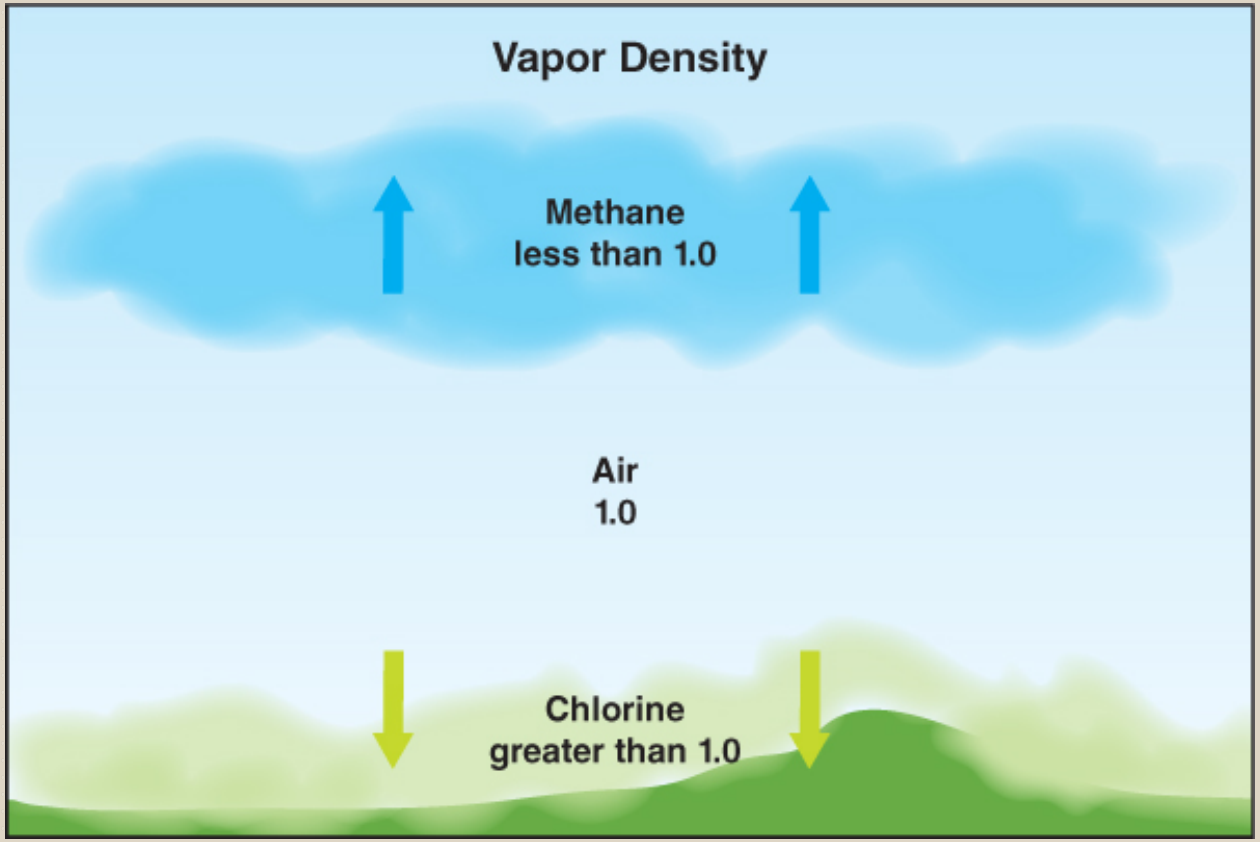
Heat of combustion

- Total amount of thermal energy released when specific amount of fuel oxidized (burned)

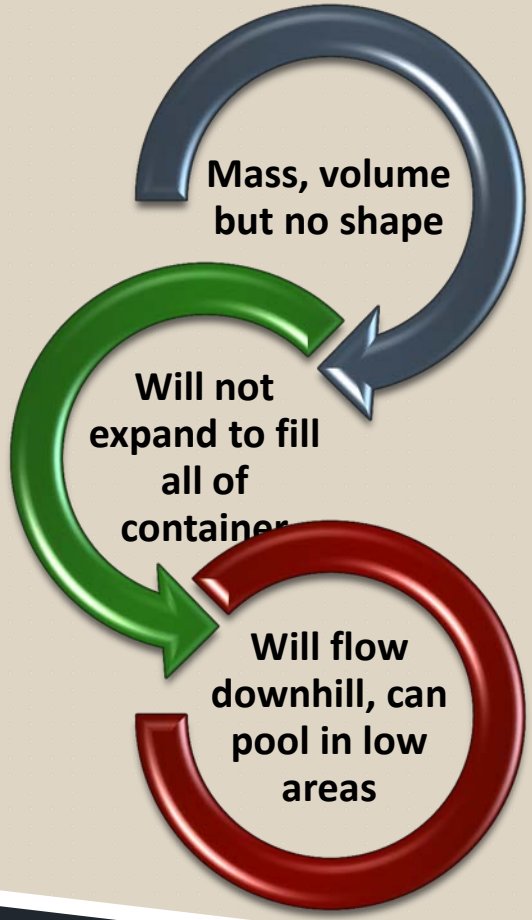
Heat release rates

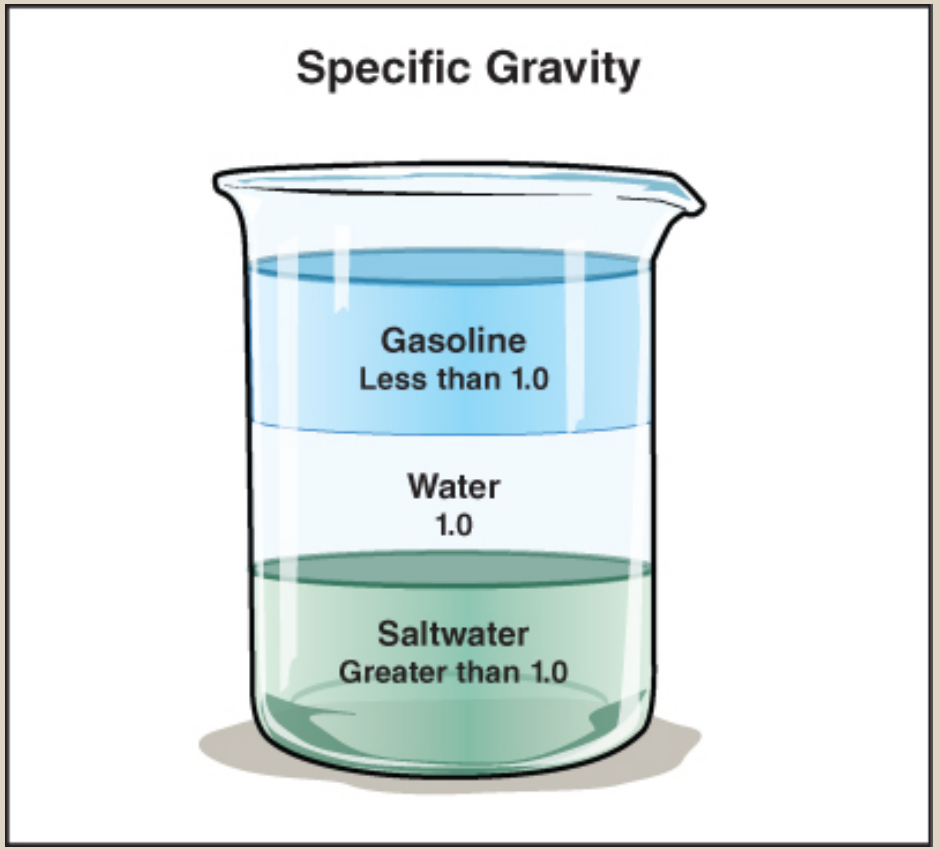


GASEOUS FUEL CAN BE THE MOST DANGEROUS OF ALL FUEL TYPES.



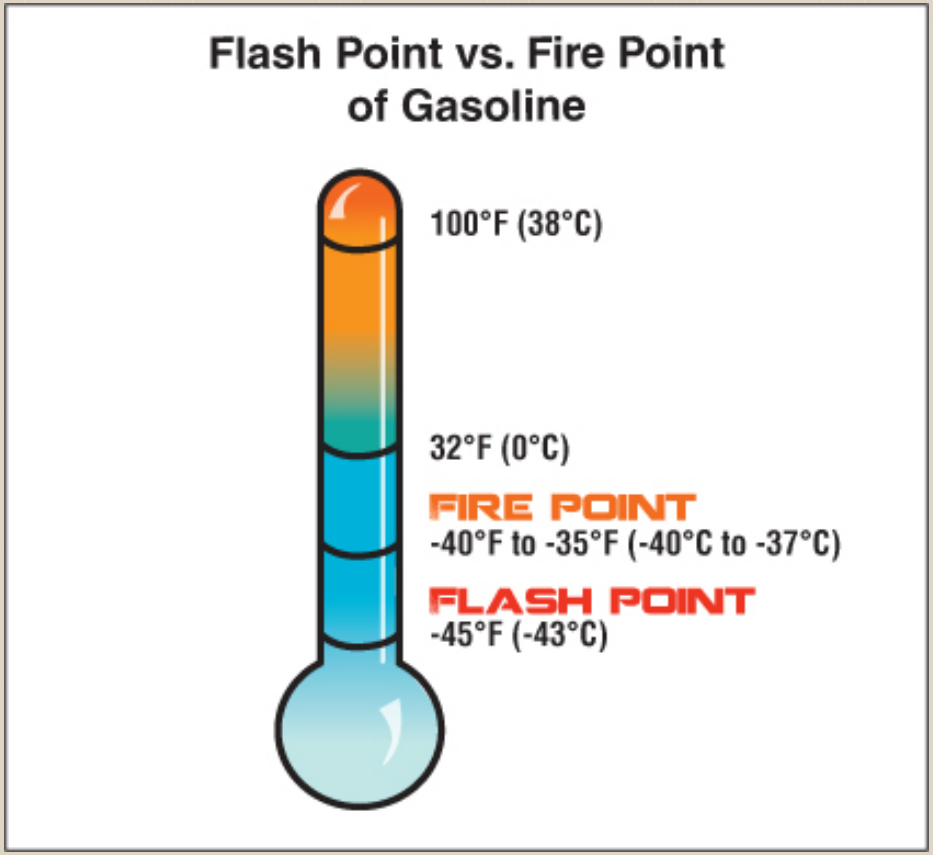
THE PROPERTIES OF LIQUID FUEL ARE IMPORTANT TO UNDERSTAND.





VAPORIZATION IS THE TRANSFORMATION OF A LIQUID TO A VAPOR OR GASEOUS STATE.

Flammable liquids with high vapor pressure present special hazard



SOLUBILITY IS A FACTOR TO CONSIDER REGARDING LIQUID FUELS.

Solubility – Extent to which substance will mix with water

- Miscible – Mix in any proportion
- Hydrocarbon – Do not mix
- Polar solvents – Readily mix

DENSITY IS ALSO A FACTOR TO CONSIDER REGARDING LIQUID FUELS.

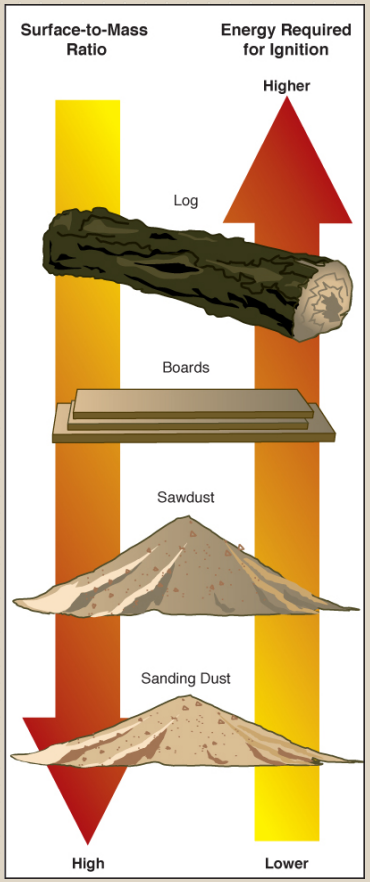
Liquids less dense than water difficult to extinguish with water alone

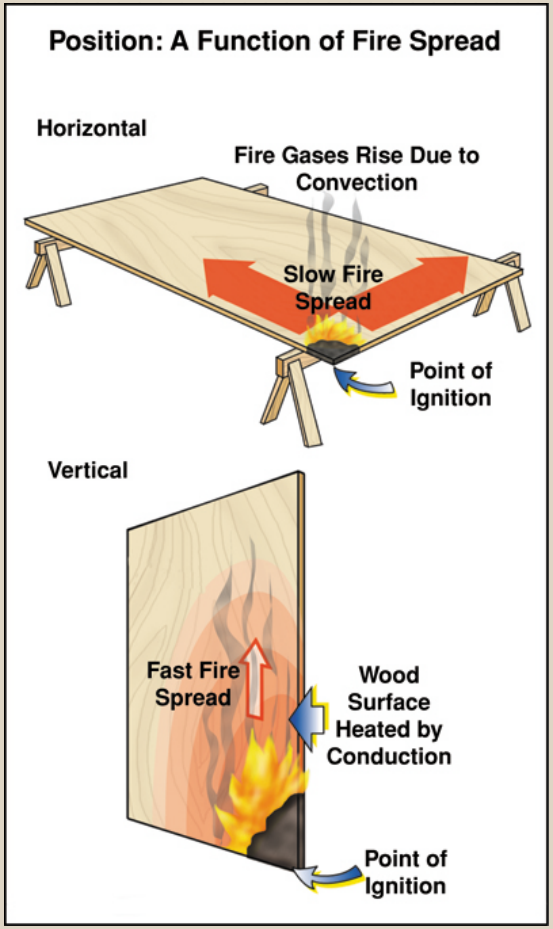
- Fuel will not mix with water – Adding may disperse burning liquid
- Extinguish with appropriate agent

Water-soluble mix with agent – Become less effective

- Avoid use with foams specifically designed for polar solvents

THE PROPERTIES OF SOLID FUEL INFLUENCE THE PROCESS OF PYROLYSIS.





OXYGEN IS THE PRIMARY OXIDIZING AGENT PRESENT AT MOST FIRES.

21 percent oxygen typical

At normal temperatures

- Materials can ignite, burn at concentrations as low as 14 percent

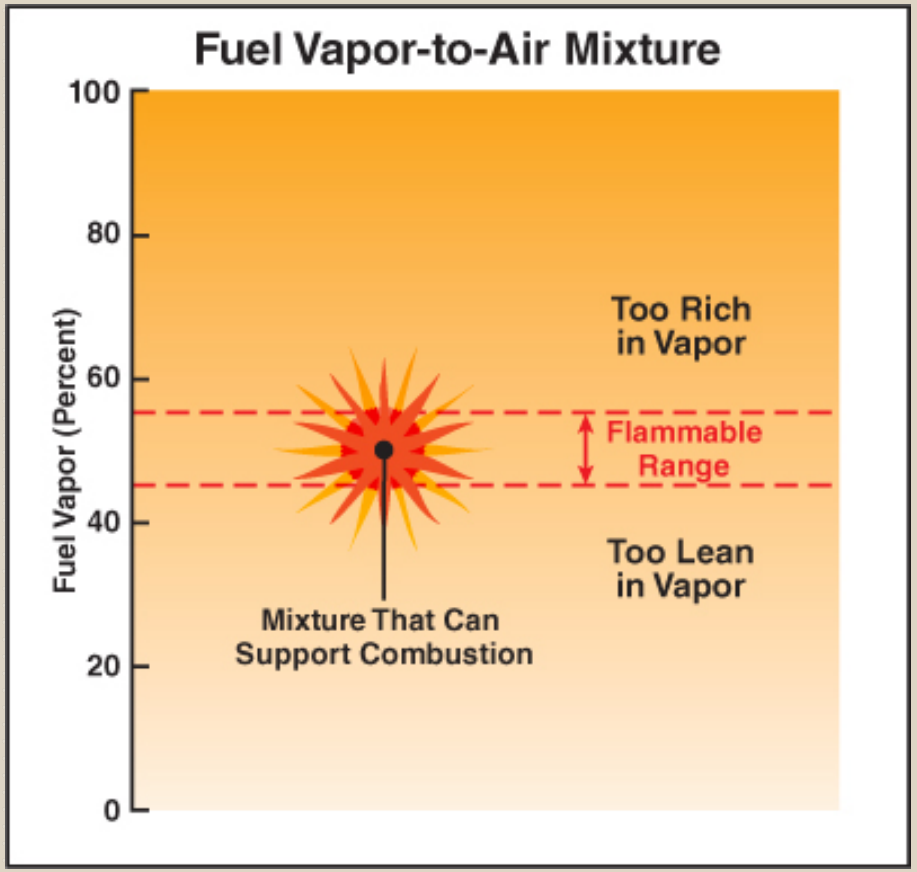
Limited oxygen diminishes flaming combustion

Ambient temperature impacts

- Nonflaming
- Flaming

Higher oxygen concentrations than normal

COMBUSTION OCCURS AFTER A FUEL HAS BEEN CONVERTED TO A GASEOUS STATE AND MIXED WITH AN OXIDIZER IN PROPER RATIO.



SELF-SUSTAINED CHEMICAL REACTIONS CREATE SEVERAL PRODUCTS.

Combustion of methane and oxygen

- Production of CO_2, water
- Release of energy in form of heat, light
- Production of CO, formaldehyde
- Different free radicals

Flaming combustion

- Free radicals
- Will burn until fuel or oxygen exhausted
- Chemical flame inhibition occurs when extinguishing agent applied

SUMMARY

You need to understand the combustion process, how fire behaves, and how to select appropriate extinguishing agents.