I'm not a robot

A combustion reaction is a type of chemical reaction in which a compound and an oxidant are reacted to produce heat and a new product. The general form of a combustion reaction can be represented by the reaction between a hydrocarbon and oxygen, which yields carbon dioxide and water: hydrocarbon + O2 → CO2 + H2O In addition to heat, it's also common (although not necessary) for a combustion reaction to release light and produce a flame. For a combustion reaction to begin, the activation energy for the reaction must be overcome. Often, combustion reactions begin with a burning match or another flame, which provides the heat needed to initiate the reaction. Once combustion starts, enough heat might be produced to sustain the reaction until it runs out of either fuel or oxygen. Examples of combustion reactions include: 2 H2 + O2 → 2H2O + heatCH4 + 2 O2 → CO2 + 2 H2O + heat Other examples include lighting a match or a burning campfire. To recognize a combustion reaction, look for oxygen in the reactant side of the equation and the release of heat on the product side. Because it isn't a chemical product, heat isn't always shown. Sometimes the fuel molecule also contains oxygen. A common example is ethanol (grain alcohol), which has the combustion reaction: C2H5OH + 3 O2 → 2 CO2 + 3 H2O Science Chemistry Emission of light is a characteristic feature of combustion. Infrared, visible, and ultraviolet bands of molecules and atomic lines are usually observed in flame spectra. Moreover, continuous spectra from incandescent particles or from recombination of atoms, radicals, and ions are frequently observed. The sources of flame radiation are the thermal energy of gas (thermoluminescence) and the chemical energy released in exothermic elementary reactions (chemiluminescence). In a Bunsen burner fed with a sufficient amount of air, up to 20 percent of the reaction heat is released as infrared energy and less than 1 percent as visible and ultraviolet radiation, the infrared being mostly thermoluminescence. Radiation from the inner cone of the Bunsen flame in the visible and ultraviolet regions represents chemiluminescence. Many flames contain electrons and positive and negative ions, a fact evident from the electrical conductivity of flames, and also from the deviation of the flame cone in an electric field (the charges are attracted or repelled, distorting the flame), a phenomenon usually interpreted as a mechanical effect called electric wind. The resulting change of the flame shape can affect the burning velocity. Ionization, like the emission of light, can be the result of equilibrium processes, when it is called thermal ionization, or it can be related to chemical processes and called chemical ionization. Thermal ionization may be expected in very hot flames containing alkali metals or alkaline-earth metals (for example, sodium and calcium) as impurities because of their low-ionization potentials. The high concentrations of ions and electrons in the flames of organic species are undoubtedly due to chemical, rather than to thermal, ionization. This is seen in the fact that electroconductivity in the inner cone of the Bunsen flame is several times higher than that of the outer cone. The reactions of ions and electrons may yield atoms and radicals and in this way affect the burning velocity. Formation of soot is a feature of all hydrocarbon flames. It makes the flame luminous and nontransparent. The mechanism of soot formation is accounted for by simultaneous polymerization, a process whereby molecules or molecular fragments are combined into extremely large groupings, and dehydrogenation, a process that eliminates hydrogen from molecules. A combustion reaction is a chemical reaction in which a fuel undergoes oxidation by reacting with an oxidising agent, resulting in the release of energy (usually in the form of heat). Combustion Reaction Explanation Combustion reactions are generally highly exothermic redox reactions between an oxidant and a fuel. The product formed in a combustion reaction is usually the oxidised fuel (which is mostly liberated in the gaseous state). This is often referred to as smoke. It is not uncommon for combustion reactions to be accompanied by flames. However, it is essential to note that not all combustion reactions result in fires. Solid fuels like coal and wood are known to initially undergo endothermal pyrolysis, resulting in the creation of gaseous fuels. The combustion of these gaseous fuels is known to provide the heat required to drive more combustion. Also, it is not uncommon for combustion to also be sufficiently hot to generate incandescent light in the form of either a flame or some flickering. The transformation of hydrogen and oxygen into water vapour, a process widely used to power rocket engines, can be seen as a simple example of combustion. Here, hydrogen is used as a fuel and oxygen is used as an oxidising agent. This combustion reaction is known to release over 242 kilojoules of heat per mole of fuel subjected to combustion. Recommended Videos Examples of Combustion Reactions in our Day-to-Day Lives Common examples of combustion reactions that are very common in the day to day lives of human beings are provided below. The combustion of LPG fuel in gas stoves for the cooking of food involves a combustion reaction between the oxygen present in the atmosphere and the liquefied petroleum gas. The engines of cars, bikes, and other fossil-fuel based automobiles source their power to the combustion reaction between petrol (or diesel) with oxygen. The lighting of matchsticks is also based on a combustion reaction. The red phosphorus at the tip of the matchstick is heated up by striking it on a rough surface, sparking a combustion reaction between the phosphorus and the atmospheric oxygen. The explosion of fireworks is also a combustion reaction. In these redox reactions, certain specific ions are incorporated into the fuel to impart a colour to the flame. Apart from these basic combustion reactions, many other such reactions are employed in a wide range of industries. For example, the space industry is known to exploit the combustion reaction between hydrogen and oxygen for the generation of clean energy in rocket ships. Chemical Equations of Important Combustion Reactions Some important combustion reactions and their chemical equations are listed below. The combustion of methanol (sometimes referred to as 'wood alcohol') involves a chemical reaction between methanol and oxygen. The chemical equation for this reaction is given by: 2CH3OH + 3O2 → 4H2O + 2CO2 The combustion reactions undergone by methane are also known to yield water and carbon dioxide as products. This reaction can be represented by the following chemical equation: CH4 + 2O2 → 2H2O + CO2 The combustion of propane, which is widely employed in cooking setups like fire grills, is represented by the following chemical equation: 2C3H8 + 7O2 → 8H2O + 6CO2 Another important combustion reaction involving the oxidation of a hydrocarbon is the combustion of ethane. The chemical equation for the reaction between ethane and oxygen that yields carbon dioxide and water is provided below. 2C2H6 + 7O2 → 6H2O + 4CO2 Naphthalene also undergoes combustion in the presence of oxygen to afford carbon dioxide gas and water. The chemical equation for this reaction is given by: 12O2 + C10H8 → 4H2O + 10CO2 Complete combustion reactions, sometimes referred to as clean combustion reactions, involve the complete oxidation of the fuel (usually a hydrocarbon). Such reactions often liberate only water and carbon dioxide as the products. A common example of a clean combustion reaction is the combustion undergone by wax candles. Wax is a hydrocarbon which undergoes clean combustion to yield only carbon dioxide and small amounts of water as the product. It can also be noted that no ash/byproducts are left behind when the entire candle is burnt out. Incomplete combustion reactions (sometimes referred to as 'dirty' combustion reactions) are the combustion reactions that involve the formation of by-products such as ash and soot. It is not uncommon for such combustion reactions to also liberate carbon monoxide (a highly poisonous gas with the chemical formula CO) as one of the products. A common example of an incomplete combustion reaction is the burning of wood. A combustion reaction is a kind of chemical reaction in which a reaction between any combustible substance and an oxidiser takes place in order to form an oxidised product. Combustion reactions are often accompanied by fires and the release of energy in the form of heat. In most combustion reactions, a hydrocarbon normally reacts with oxygen to create carbon dioxide and water. Overall, combustion is an exothermic reaction given off or exiting , which means that energy is released. Usually, heat and light are released during a combustion reaction. Oxygen supports the chemical processes that occur during fire. When fuel burns, it reacts with oxygen from the surrounding air, releasing heat and generating combustion products (gases, smoke, embers, etc.). This process is known as oxidation. To learn more about combustion reactions and other important types of chemical reactions such as decomposition reactions, register with BYJU'S and download the mobile application on your smartphone. Put your understanding of this concept to test by answering a few MCQs. Click 'Start Quiz' to begin! Select the correct answer and click on the "Finish" buttonCheck your score and answers at the end of the quiz Visit BYJU'S for all Chemistry related queries and study materials 0 out of 0 arewrong 0 out of 0 are correct 0 out of 0 are Unattempted View Quiz Answers and Analysis Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Science Chemistry Combustion, with rare exceptions, is a complex chemical process involving many steps that depend on the properties of the combustible substance. It is initiated by external factors such as heat, light, and sparks. The reaction sets in as the mixture of combustibles attains the ignition temperature. The combustion spreads from the ignition source to the adjacent layer of gas mixture; in turn, each point of the burning layer serves as an ignition source for the next adjacent layer, and so on. Combustion terminates when equilibrium is achieved between the total heat energies of the reactants and the total heat energies of the products. Most reactions terminate when what is called thermal equilibrium has been attained—i.e., when the energy of the reactants equals the energy of the products. A relationship exists between the ignition temperature and the pressure of the mixture under specific conditions. The figure shows the relationship for a mixture of hydrogen and oxygen. Only one temperature corresponds to a given pressure, whereas one or three pressures, called the explosion limits, may correspond to one temperature. The mechanism of the reaction determines the explosion limits: the reaction can proceed only when the steps in the sequence of reactions occur faster than the terminal steps. Thus, for combustion to be initiated with light or with a spark, the light intensity or the spark energy must exceed certain minimal values. The complexity of the combustion reaction mechanism and the rapidly varying temperatures and concentrations in the mixture make it difficult and often impossible to derive an equation that would be useful for predicting combustion phenomena over wide temperature and concentration ranges. Instead, use is made of empirical expressions derived for specific reaction conditions. Reactions of oxygen with hydrogen, with carbon monoxide, and with hydrocarbons are most important from the standpoint of theory and, at the same time, are of great practical value. Hydrogen combustion proceeds by complicated branched-chain reactions involving the interaction of hydrogen and oxygen atoms with oxygen and hydrogen molecules, respectively, to produce hydroxyl radicals. The final reaction product is water, formed by the combination of hydroxyl with hydrogen molecules. Reactions that terminate the chain, such as recombination of atoms and fragments of molecules, and the adsorption of active particles on solid surfaces, also play an important part in the mechanism of hydrogen combustion. The knowledge of rate constants for these processes derived empirically makes possible a quantitative description of all combustion characteristics, such as explosion limits, delay of ignition, and burning velocity. Combustion of carbon monoxide is mainly restricted to mixtures containing hydrogen or hydrogen compounds. In this case the reaction mechanism differs from that of hydrogen combustion chiefly in that it involves a step of fast interaction between hydroxyl and carbon monoxide. Pure mixtures of carbon monoxide and oxygen (or air) can be ignited only with sparks of high energy or under high pressures and temperatures. The chemical mechanism of their combustion is not yet clear, probably because oxidation of carbon monoxide, a reaction that is part of the combustion of practically all natural fuels, usually occurs in the presence of hydrogen or hydrogen compounds: the breakdown of wood, coal, petroleum, etc., during burning produces carbon monoxide, hydrogen, and compounds of carbon and hydrogen. The mechanisms of combustion of hydrocarbons and of other organic compounds are known in general outline only. Many elementary steps of hydrocarbon combustion involving oxygen and hydrogen atoms, hydroxyl, and organic radicals are similar to those for hydrogen; however, the overall mechanism of hydrocarbon combustion is complicated by the diversity of molecules and radicals involved. Moreover, with oxidation, thermal decomposition, a breakdown of complex organic compounds without oxidation, also takes place. Two types of hydrocarbon combustion have been defined: (1) slow combustion at temperatures below 500 °C, including cool flames observed at certain pressures, and (2) combustion at higher temperatures, accompanied by hot flames. Ignition in two stages is characteristic of higher hydrocarbons, in which a cool-flame stage yielding readily oxidizable products precedes that of the hot flame. In addition to chemical reactions, physical processes that transfer mass and energy by diffusion or convection occur in gaseous combustion. In the absence of external forces, the rate of component diffusion depends upon the concentration of the constituents, pressure, and temperature changes, and on diffusion coefficients (a measure of the speed of diffusion). The latter are either measured or calculated in terms of the kinetic theory of gases. The process of diffusion is of great importance in combustion reactions, in flames—that is, in gaseous mixtures, and in solids or liquids. Diffusion heat transfer (by molecular means) follows a law (Fourier's law) stating that the heat flux (a measure of the quantity of heat) is proportional to the temperature gradient (the difference in temperature between two limiting temperatures). The coefficient of proportionality, called the thermal conductivity coefficient, is also measured or calculated in terms of the kinetic theory of gases, like the diffusion coefficient. Convective transport of mass and energy may be accounted for by buoyant forces, external forces, and turbulent and eddy motions. Convection is in the main responsible for the mixing of gases (e.g., in furnaces). Sublimation (the direct evaporation of a solid without intermediate liquid stage), evaporation of liquids, and the mechanical destruction of burning samples, all methods of transforming solids and liquids into gases, greatly contribute to their ease of combustion. In general, the combustion of condensed systems—i.e., liquids and solids—is more complex than that of gases, which accounts for the greater development of the gas combustion theory. Energy transport in combustion may also occur by the emission of light, mostly in the infrared. burn, damage caused to the body by contact with flames, hot substances, certain chemicals, radiation (sunlight, X rays, or ionizing radiation from radioactive materials), or electricity. The chief effects of contact with flame, hot water, steam, caustic chemicals, or electricity are apparent promptly. There is a delay of several hours before the full effects of sun or ultraviolet burns are apparent and a delay of 10 to 30 days before the full effects of ionizing radiation burns are apparent.The severity of a burn depends largely on the depth of tissue destruction and the amount of body surface affected. Other factors—including the patient's age and prior state of health, the location of the burn wound, and the seriousness of any associated injuries—can also influence recovery from a burn.For an appreciation of how depth and size of a burn affect the severity of the injury, some understanding of the anatomy and physiology of the skin is necessary. Human skin is composed of two layers: an upper layer called the epidermis, and a lower layer known as the dermis (or corium). The largest of the body's organs, skin performs a number of vital functions. Its foremost job is to separate the external environment from the body's interior. The epidermis, the outer surface of which consists of dead, cornified cells, prevents infectious microorganisms and other harmful environmental agents from gaining entrance to the body. The dermis, by contrast, is made up of fibrous connective tissues that prevent the evaporation of body fluids. Embedded within the dermis and opening to the skin surface are the sweat glands. These secrete perspiration, the evaporation of which helps regulate body temperature. Perspiration also contains small amounts of sodium chloride, cholesterol, aluminum, and urea; it thus plays a role in regulating the composition of body fluids. The dermis also contains all of the skin's blood vessels and nerves, including sensory nerve endings that respond to touch, pressure, heat, cold, and pain. The skin therefore also serves as a sense organ that enables a person to adjust to changing environmental conditions. One final function of the skin is the synthesis of vitamin D, a compound essential to growth and maintenance, particularly of bone. Vitamin D is formed by the action of sunlight on certain cholesterol compounds in the dermis. Destruction of the skin by deep or extensive burns can disrupt all of these functions, subjecting the victim to serious complications.Physicians have traditionally categorized burns as first-, second-, or third-degree injuries, according to the depth of skin damage (see illustration). In a first-degree burn, only the epidermis is affected. These injuries are characterized by redness and pain; there are no blisters, and edema (swelling due to the accumulation of fluids) in the wounded tissue is minimal. A classic example of a first-degree burn is moderate sunburn.The damage in a second-degree burn extends through the entire epidermis and part of the dermis. These injuries are characterized by redness and blisters. The deeper the burn the more prevalent the blisters, which increase in size during the hours immediately following the injury. Like first-degree burns, second-degree injuries may be extremely painful. The development of complications and the course of healing in a second-degree burn depend on the extent of damage to the dermis. Unless they become infected, most superficial second-degree burns heal without complications and with little scarring in 10 to 14 days. A Visit with the Word Doctor: Medical Vocabulary Quiz Third-degree, or full-thickness, burns destroy the entire thickness of the skin. The surface of the wound is leathery and may be brown, tan, black, white, or red. There is no pain, because the pain receptors have been obliterated along with the rest of the dermis. Blood vessels, sweat glands, sebaceous glands, and hair follicles are all destroyed in skin that suffers a full-thickness burn. Fluid losses and metabolic disturbances associated with these injuries are grave.Occasionally burns deeper than a full thickness of the skin are incurred, as when part of the body is entrapped in a flame and not immediately extricated. Electrical burns are usually deep burns. These deep burns frequently go into the subcutaneous tissue and, at times, beyond and into the muscle, fascia, and bone. Such burns are of the fourth degree, also called black (because of the typical colour of the burn), or char, burns. Fourth-degree burns are of grave prognosis, particularly if they involve more than a small portion of the body. In these deep burns toxic materials may be released into the bloodstream. If the char burn involves only a small part of the body, it should be excised down to healthy tissue. If an extremity is involved, amputation may be necessary. Surgeons measure the area of a burn as a percentage of the body's total skin area. The skin area on each arm is roughly 9 percent of the body total, as is the skin covering the head and neck. The percentage on each leg is 18, and the percentage on the trunk is 18 on the front and 18 on the back. The percentage of damaged skin affects the chances of survival. Most people can survive a second-degree burn affecting 70 percent of their body area, but few can survive a third-degree burn affecting 50 percent. If the area is down to 20 percent, most people can be saved, though elderly people and infants may fail to survive a 15 percent skin loss.Severe burns cause immediate nervous shock. The victim grows pale and is confused, anxious, and frightened by the pain and may faint. Much more dangerous is the secondary shock that comes a few hours later. Its chief features are a dramatic fall in blood pressure that leads to pallor, cold extremities, and eventual collapse. This secondary shock is precipitated by loss of fluid from the circulation, not just the fluid lost in the destroyed tissue but fluid that leaks from the damaged area that has lost its protective covering of skin.Burns kill not just by damaging tissue but by allowing this leakage of fluid and salts. If more than a fifth of the blood volume is lost to the circulation, insufficient blood returns to the heart for it to maintain blood pressure. And the loss of salts, particularly sodium and potassium salts, not only disturbs their balance in the body but changes the osmotic balance of the blood and body fluids. The significance of these physiological changes was understood in 1905, but not until the 1930s were doctors able to correct them with transfusions of blood or plasma.The treatment of a burn is, of course, dependent upon the severity of the injury. In general, first-degree burns can be adequately treated with proper first-aid measures. Second-degree burns that cover more than 15 percent of an adult's body or 10 percent of a child's, or that affect the face, hands, or feet, should receive prompt medical attention, as should all third-degree burns, regardless of size. Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Combustion is a chemical reaction that makes heat and light by burning a fuel with oxygen.Combustion needs a start of energy but can keep going once it starts.Complete combustion makes only carbon dioxide and water, while incomplete makes more different products. Combustion is a chemical reaction that occurs between a fuel and an oxidizing agent that produces energy, usually in the form of heat and light. Combustion is considered an exergonic or exothermic chemical reaction. It is also known as burning. Combustion is considered to be one of the first chemical reactions intentionally controlled by humans. The reason combustion releases heat is because the double bond between oxygen atoms in O2 is weaker than the single bonds or other double bonds. So, although energy is absorbed in the reaction, it is released when the stronger bonds are formed to make carbon dioxide (CO2) and water (H2O). While the fuel plays a role in the energy of the reaction, it's minor in comparison because the chemical bonds in the fuel are comparable to the energy of the bonds in the products. Combustion occurs when fuel and an oxidant react to form oxidized products. Typically, energy must be supplied to initiate the reaction. Once combustion starts, the released heat can make combustion self-sustaining. For example, consider a wood fire. Wood in the presence of oxygen in the air does not undergo spontaneous combustion. Energy must be supplied, as from a lit match or exposure to heat. When the activation energy for the reaction is available, the cellulose (a carbohydrate) in wood reacts with oxygen in the air to produce heat, light, smoke, ash, carbon dioxide, water, and other gases. The heat from the fire allows the reaction to proceed until the fire becomes too cool or the fuel or oxygen is exhausted. A simple example of a combustion reaction is the reaction between hydrogen gas and oxygen gas to produce water vapor: 2H2(g) + O2(g) → 2H2O(g) A more familiar type of combustion reaction is the combustion of methane (a hydrocarbon) to produce carbon dioxide and water: CH4 + 2O2 → CO2 + 2H2O which leads to one general form of a combustion reaction: hydrocarbon + oxygen → carbon dioxide and water The oxidation reaction may be thought of in terms of electron transfer rather than the element oxygen. Chemists recognize several fuels capable of acting as oxidants for combustion. These include pure oxygen and also chlorine, fluorine, nitrous oxide, nitric acid, and chlorine trifluoride. For example, hydrogen gas burns, releasing heat and light, when reacted with chlorine to produce hydrogen chloride. Combustion isn't usually a catalyzed reaction, but platinum or vanadium can act as catalysts. Combustion is said to be "complete" when the reaction produces a minimal number of products. For example, if methane reacts with oxygen and produces only carbon dioxide and water, the process is complete combustion. Incomplete combustion occurs when there is insufficient oxygen for the fuel to convert completely to carbon dioxide and water. Incomplete oxidation of a fuel may also occur. It also results when pyrolysis occurs before combustion, as is the case with most fuels. In pyrolysis, organic matter undergoes thermal decomposition at high temperatures without reacting with oxygen. Incomplete combustion may yield many additional products, including char, carbon monoxide, and acetaldehyde. The NASA Glenn homepage has moved. Please update your bookmarks. A combustion reaction is an exothermic chemical reaction between substances, usually including oxygen gas and accompanied by the generation of heat, energy, and light (flame). The products of a combustion reaction depend on the combusted substance. When metals and nonmetals burn in the presence of oxygen, they will give off their corresponding oxides. On the other hand, hydrocarbons give off carbon dioxide and water upon combustion. A hydrocarbon is a compound made up solely of carbon and hydrogen. Hydrocarbons are the primary constituent of fossil fuels, namely natural gas, petroleum, and coal. They are used as fuel because their combustion releases enormous amounts of energy. Since different hydrocarbons have different ratios of hydrogen to carbon, they produce different ratios of water to carbon dioxide [1-6]. General Equation The general equation for combustion reaction of metals and nonmetals is: x M + (y/2) O2 → MxOy The general equation for the combustion of hydrocarbon is [1]: CxHy + (x+y/4) O2 → x CO2 + (y/2) H2O Combustion Reaction Complete combustion reactions, also known as clean combustion reactions, is the complete oxidation of the fuel. Such reactions often liberate only water and carbon dioxide as the products, apart from heat and light. An example could be the combustion of propane in the presence of oxygen. Incomplete combustion reactions are the combustion reactions that involve the formation of by-products such as ash and soot. This reaction happens when the supply of oxygen is inadequate, and carbon and carbon monoxide are produced. An example could be the combustion of propane in an environment where the oxygen is deficient [7]. A combustion reaction is a reaction in which one of the reactants is oxygen, and the other reactant is usually a hydrocarbon. The products are carbon dioxide and water, accompanied by heat and light (flame). The products are either complete or incomplete, in which case, carbon and carbon monoxide results. Inorganic substances can also burn in the presence of oxygen to give vapors of oxides [6]. Method 1: Balancing it directly. Consider the combustion of the hydrocarbon propane (C3H8) in the presence of oxygen (O2), resulting in carbon dioxide (CO2) and water (H2O). C3H8 (g) + O2 (g) → CO2 (g) + H2O (g) We start with the carbon atom. We note that there are three atoms on the left-hand side of the equation and one on the right. So, we multiply CO2 by 3. C3H8 (g) + O2 (g) → 3 CO2 (g) + H2O (g) Then, we move to the hydrogen atom. We note that there are eight atoms on the left and two on the right. So, we multiply H2O by 4. C3H8 (g) + O2 (g) → 3 CO2 (g) + 4 H2O (g) Finally, we focus on oxygen. We find that there are ten atoms on the right and two on the left. So, we multiply O2 by 5. C3H8 (g) + 5 O2 (g) → 3 CO2 (g) + 4 H2O (g) This equation is now a balanced equation representing the combustion of propane. Method 2: Using the general equation We can also use the general equation to balance the combustion reaction equation. CxHy + (x+y/4) O2 → x CO2 + (y/2) H2O Here, x = 3 and y = 8. C3H8 (g) + 5 O2 (g) → 3 CO2 (g) + 4 H2O (g) There are a few examples of combustion reactions of metals, nonmetals, and hydrocarbons. The reactions, along with the formulas of the compounds, are given below [1-10]. Combustion Reaction Examples Metals and nonmetals combine with oxygen to give their corresponding oxides. These oxides are released in the atmosphere as gases. Some examples are as follows: Hydrogen (H2) reacts with oxygen (O2) to give water vapor (H2O). 2 H2 (g) + O2 (g) → 2 H2O (g) Carbon or coal (C) burns with oxygen to give and carbon monoxide (CO) and carbon dioxide (CO2) 2 C (s) + O2 (g) → 2 CO (g) C (s) + O2 (g) → CO2 (g) Sulfur (S) burns with oxygen to give carbon dioxide (SO2) S (s) + O2 (g) → SO2 (g) Magnesium (Mg) burns in oxygen (O2) to give magnesium oxide (MgO) 2 Mg (s) + O2 (g) → MgO (g) Combustion of nitrogen (N2) with oxygen results in nitric oxide (NO) and nitrogen dioxide (NO2) N2 (g) + O2 (g) → 2 NO (g) N2 (g) + 2 O2 (g) → 2 NO2 (g) Hydrocarbons are an organic compound primarily made up of carbon and hydrogen. They are an excellent source of fuel as they ignite easily in the presence of oxygen to give carbon dioxide (CO2) and water (H2O). CH4 (g) + 2 O2 (g) → CO2 (g) + 2 H2O (g) 2 C2H6 (g) + 7 O2 (g) → 4 CO2 (g) + 6 H2O (g) 2 C4H10 (g) + 13 O2 (g) → 8 CO2 (g) + 10 H2O (g) 2 C6H14 (g) + 13 O2 (g) → 12 CO2 (g) + 3 H2O (g) 2 C8H18 (g) + 25 O2 (g) → 16 CO2 (g) + 18 H2O (g) 2 CH3OH (l) + 3 O2 (g) → 2 CO2 (g) + 4 H2O (g) C2H4 (g) + 3 O2 (g) → 2 CO2 (g) + 2 H2O (g) C3H6O (l) + 4 O2 (g) → 3 CO2 (g) + 3 H2O (g) C10H8 (s) + 12 O2 (g) → 10 CO2 (g) + 4 H2O (g) 2 C6H5CO2H (s) + 15 O2 (g) → 14 CO2 (g) + 6 H2O (g) There are a few examples and uses of combustion reactions in real life [10]. Heating homes using wood or coalRunning vehicles using petrol or dieselLighting candles, which is made from paraffin wax, a hydrocarbon fuelCooking food on a stovetop using natural gas or liquefied petroleum gas (LPG)Lighting a lighter, which consists of butane, a highly flammable hydrocarbon fuelLighting a matchstick due to the presence of sulfurProduction of energy from coal, oil, and natural gas in thermal power plants generates electricityBursting of firecrackers, which contain many flammable chemicalsCombustion of rocket propellent, which contains many hydrocarbons and its derivatives Q.1. Is combustion a redox reaction? Ans. No. Not all combustion reactions are redox reactions. Science Chemistry All flames can be classified either as premixed flames or as flames that burn without premixing. Flame combustion is most prominent with fuels that have been premixed with an oxidant, either oxygen or a compound that provides oxygen, for the reaction. The temperature of flames with this mixture is often several thousand degrees. The chemical reaction in such flames occurs within a narrow zone several micrometres thick. This combustion zone is usually called the flame front. Dilution of the burning mixture with an inert gas, such as helium or nitrogen, lowers the temperature and, consequently, the reaction rate. Great amounts of inert gas extinguish the flame, and the same result is achieved when substances that remove any of the active species are added to the flame. Conditions must be such that the flame is fixed at the burner nozzle or in the combustion chamber; this positioning is required in many practical uses of combustion. Various devices, such as pilot flames and recirculation methods, are designed for this purpose. The principal quantitative characteristic of a flame is its normal, or fundamental, burning velocity, which depends on the chemical and thermodynamic properties of the mixture and on pressure and temperature, under given conditions of heat loss. The burning velocity value ranges from several centimetres to even tens of metres per second. The dependence of the burning velocity on molecular structure, which is responsible for fuel reactivity, is known for a great many fuel-air mixtures. A widely applied thermal theory, one of the first flame propagation theories, implies that combustion proceeds primarily at temperatures close to the maximum the flame can achieve. A set of differential equations developed for thermal conductivity and diffusion is reduced to one equation that yields the burning velocity value. Further development of the theory has been made, and computers now make most simplifications unnecessary. human genetic disease: Combustion products According to thermal theories, flame propagation is accounted for by heat energy transport from the combustion zone to the unburned mixture, which raises the temperature of the mixture. Diffusion theory assumes that thermodynamic equilibrium sets in behind the flame front at a maximum temperature and that radicals produced in this zone diffuse into the unburned mixture and ignite it. Both heat transport and diffusion of active particles must be considered essential for ignition. combustion: stagesStages of the combustion process.Diffusion flames, smoothly flowing (laminar) or turbulent, belong to the class of flames whose ingredients are not mixed prior to entering the burning zone. Molecular or turbulent diffusion is responsible for the mixing of the gases in such flames. The distribution of the combustible material and of oxygen over various flame cross sections is regular in laminar flames but becomes much more complicated in turbulent gas flows. The transition from laminar to turbulent flames occurs at a certain point of the flow and depends upon the actual conditions. Industrial flames, including those activated in furnaces, belong to the turbulent diffusion type. The theory of diffusion flames, however, is less advanced than that of premixed flames and, since gas intermixing is mainly responsible for the structure and the features of diffusion flames, the theory operates more in terms of physics and thermodynamics than chemical reactions. Flames such as those of candles, of liquid droplets, and of many propellants and condensed fuels are diffusion flames. Bunsen burner flameFigure 2: Cone of a Bunsen burner flame.When a premixed flame burns in open air with an excess of fuel, there appears in addition to the flame zone a zone of diffusion flame; this is accounted for by the diffusion of atmospheric oxygen, as, for example, in the Bunsen flame produced by a burner to which the air intake can be regulated, thereby altering the flow from an intensely hot one—in which most of the fuel gases are oxidized to carbon dioxide and water—to a relatively low temperature flux in which most of the fuel gas is only partially oxidized. Such flames consist of an inner core and an outer cone—two zones in which different chemical reactions take place, the reducing and oxidizing zones, respectively. The oxidizing nature of the outer cone is due to excess oxygen (see figure). PURCHASE TICKET BRYAN ORRCo-Founder and President at Kalos Services, Bryan has been involved in HVAC training for over 13 years. Bryan started HVAC School to be free training HVAC/R across many mediums, For Techs, By Techs. Read more Subscribe to free tech tips. Follow Us On Social Media And Podcast Platforms Check our latest Tech Tips Size and Orientation of Return Grilles and Supply Registers Proper sizing and orientation of grilles, registers, and diffusers may seem like such a simple thing, but it's an area where confusion and mistakes are commonly made. First, let's define some terms. Return A return draws air into a return duct system with negative pressure compared to the space, usually via a fixed "grille" (also […] Read more How to Diagnose a TXV Failure There has been much written and many jokes made about the misdiagnosis of TXV (thermostatic expansion valves), and rightly so. This article will cut straight to the point to help those of you who may still need a bit of clarification, and hopefully, we will save the lives of a few TXVs and the pocketbooks […] Read more Checking Disconnects Disconnects walk the fine line of being HVAC or electrical, but the HVAC technician is allowed to repair and replace disconnects in most places. Even if you work at a place where it isn't allowed, finding problems is a diagnostic skill you will want to have. As always, work safely with proper safety gear and […] Read more The HVAC School site, podcast and tech tips made possible by generous support from Science Chemistry The transition from combustion to explosion is caused by an acceleration of the reaction, induced either by a rise in temperature or by increasing lengths of the reaction chain. The first is called thermal explosion, and the second is called chain explosion. Thermal explosion theory is based on the idea that progressive heating raises the rate at which heat is released by the reaction until it exceeds the rate of heat loss from the area. At a given composition of the mixture and a given pressure, explosion will occur at a specific ignition temperature that can be determined from the calculations of heat loss and heat gain. The thermal explosion theory accounts for temperature rise and fuel consumption during the induction period. At sufficiently high rates of consumption the explosion will not occur. It follows from the theory of branched-chain reactions that there is a limit to ignition, or to explosion, without a rise of temperature. In this case, what is called a chain explosion will occur when the probabilities of chain branching and of termination are equal. Usually, however, explosions are of a chain-thermal nature (i.e., both heat accumulation and chain auto-acceleration contribute to explosion). The progressive acceleration of reaction accounted for by the flame front area advancing at a supersonic velocity and by transition from laminar to turbulent flow gives rise to a shock wave. The increase in temperature due to compression in the shock wave results in self-ignition of the mixture, and detonation sets in. The shock wave–combustion zone complex forms the detonation wave. Detonation differs from normal combustion in its ignition mechanism and in the supersonic velocity of 2–5 kilometres per second for gases and 8–9 kilometres per second for solid and liquid explosives. Detonation is impossible when the energy loss from the reaction zone exceeds a certain limit. The detonation limits observed for high explosives are also eventually dependent on factors responsible for the chemical reaction rate: for example, the charge and diameter of the grain. Combustion refers to a high-energy chemical reaction in which fuel is oxidized and converted into a mixture of often gaseous products. Combustion is an exothermic reaction, in that it involves the release of energy in the form of light and heat. The most common oxidizing agent in combustion reactions is atmospheric oxygen (O), but other oxidizing agents include: chlorine (Cl), fluorine (F), and nitrous oxide (N_2O) Combustion reaction occur in many places in nature and were among the first chemical reactions that humans harnessed control over (fire). Combustion reactions are extremely useful technologically, as they can be exploited to produce high amounts of energy that can be used to perform physical work. Several technologies exist for converting heat energy generated during combustion into mechanical energy, such as the internal combustion engine of a car, or into electrical energy, such as an electric power plant. Basics Of Combustion Combustion reactions require three main ingredients: reactants (fuel), an oxidizing agent, and heat. By far, the most common kinds of fuel for combustion reactions are hydrocarbon compounds, like methane (CH_4), propane (C_3H_8) or octane (C_8H_{18}). The most common oxidizing agent is atmospheric oxygen. Thus, the majority of examples of combustion we will consider involve the combustion of hydrocarbon compounds in an oxygenated atmosphere. "Success isn't a result of spontaeneous combustion. You must set yourself on fire." — Arnold Glasow For example, methane is a common combustible fuel. The general form of the chemical equation for the combustion of methane in oxygen is: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_20$ So during the combustion of methane, one methane molecule and 2 diatomic oxygen molecules split and recombine to for one carbon dioxide molecule and 2 water molecules. Since combustion is an exothermic reaction, one of the products of the reaction is energy in the form of heat. The amount of heat released by a chemical reaction is called the reaction's enthalpy of change. The enthalpy of change is a measure of how much heat a chemical reaction emits or absorbs from the environment. The standard notation for representing enthalpy is ΔH. The standard SI unit used to measure the enthalpy of change is the joule (J). If a reaction is endothermic (absorbs heat), the ΔH will be positive. If a reaction gives off energy (exothermic) then ΔH will have a negative value. Combustion is always exothermic, so the enthalpy of change for any combustion reaction will always be negative. For example, the enthalpy of change for a methane combustion reaction is ΔH = -891 per kJ/mol. A methane combustion reaction releases 891 kilojoules of heat energy per mole of methane. The energy produced by a combustion reaction comes from the energy stored in the fuel's chemical bonds that is released when the reactants split apart and are rearranged into the products. The combustion of hydrocarbon reactants is energetic in particular due to the high energy bonds in hydrocarbon compounds oxygen molecules. Combustion occurs with many other hydrocarbon products, not just methane. The products of a hydrocarbon reaction are always carbon dioxide (or carbon monoxide) and water. For example, the formula for the combustion reaction of propane is: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ (ΔH = -2043.455 kJ/mol) Propane has a higher enthalpy of change due to the presence of more hydrocarbon bonds in the initial reactant. Likewise, the formula for the combustion of ethane (C2H6) is: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ (ΔH = -3120 kJ/mol) In general, the formula for a hydrocarbon combustion reaction in oxygen is: $C_xH_y + zO_2 \rightarrow xCO_2 + (y/2)H_2O$ where z = x + (y/4). In most cases of combustion, the source of oxygen is normal atmospheric air. Atmospheric air also contains large quantities of nitrogen (N). In our atmosphere, oxygen is outnumbered by nitrogen in a ratio of about 3.77 nitrogen molecules per mole of oxygen molecules. So most combustion reactions that use plain air also produce nitrogenous products. Nitrogen is not normally considered a combustible material, but combustion reactions in air produce a small amount of nitrous oxide (compounds in the form of NO_x) "Information is the oil of the 21st century, and analytics is the combustion engine." — Peter Sondergaard Combustion requires the presence of oxygen, otherwise, it cannot occur. Thus, one way to stop a combustion reaction is to remove is oxygen source. This is the main principle behind the design of fire extinguishers. Fire extinguishes spray carbon dioxide near a fire. Carbon d

Establishments Disestablishments Works category Works vte 1898 in various calendarsGregorian calendar1898MDCCCXCVIIIAb urbe condita2651Armenian calendar1347ՌԼ ՌՅԼԱssyrian calendar6648Bahá'í calendar54–55Balinese saka calendar1819–1820Bengali calendar1304–1305Berber calendar2848British Regnal year61 Vict. 1 – 62 Vict. 1Buddhist calendar2442Burmese calendar1260Byzantine calendar7406–7407Chinese calendar丁酉年 (Fire Rooster)4595 or 4388 — to 一戊戌年 (Earth Dog)4596 or 4389Coptic calendar1614–1615Discordian calendar3064Ethiopian calendar1890–1891Hebrew calendar5658–5659Hindu calendars - Vikram Samvat1954–1955 - Shaka Samvat1819–1820 - Kali Yuga4998–4999Holocene calendar11898Igbo calendar898–899Iranian calendar1276–1277Islamic calendar1315–1316Japanese calendarMeiji 31(明治 3 1年)Javanese calendar1827–1828Julian calendarGregorian minus 12 daysKorean calendar4231Minguo calendar14 before ROC民前14年Nanakshahi calendar430Thai solar calendar2440–2441Tibetan calendar阴火鸡年(female Fire-Rooster)2024 or 1643 or 871 — to 一阳土狗年(male Earth-Dog)2025 or 1644 or 872 Wikimedia Commons has media related to 1898. 1898 (MDCCCXCVIII) was a common year starting on Saturday of the Gregorian calendar and a common year starting on Thursday of the Julian calendar, the 1898th year of the Common Era (CE) and Anno Domini (AD) designations, the 898th year of the 2nd millennium, the 98th year of the 19th century, and the 9th year of the 1890s decade. As of the start of 1898, the Gregorian calendar was 12 days ahead of the Julian calendar, which remained in localized use until 1923. Calendar year 1898 world map January 1 – New York City annexes land from surrounding counties, creating the City of Greater New York as the world's second largest. The city is geographically divided into five boroughs: Manhattan, Brooklyn, Queens, The Bronx and Staten Island. January 13 – Novelist Émile Zola's open letter to the President of the French Republic on the Dreyfus affair, J'Accuse...!, is published on the front page of the Paris daily newspaper L'Aurore, accusing the government of wrongfully imprisoning Alfred Dreyfus and of antisemitism. February 12 – The automobile belonging to Henry Lindfield of Brighton rolls out of control down a hill in Purley, London, England, and hits a tree; thus he becomes the world's first fatality from an automobile accident on a public highway.[1] February 15 – Spanish–American War: The USS Maine explodes and sinks in Havana Harbor, Cuba, for reasons never fully established, killing 266 men. The event precipitates the United States' declaration of war on Spain, two months later.February 15: USS Maine is sunk. February 23 – Émile Zola is imprisoned in France, after writing J'Accuse…!. March 1 – Vladimir Lenin creates the Russian Social Democratic Labour Party in Minsk March 14 – Association football and sports club BSC Young Boys is established in Bern, Switzerland, as the Fussballclub Young Boys. March 16 – In Melbourne the representatives of five colonies adopt a constitution, which will become the basis of the Commonwealth of Australia.[2] March 24 – Robert Allison of Port Carbon, Pennsylvania, becomes the first person to buy an American-built automobile, when he buys a Winton automobile that has been advertised in Scientific American. March 26 – The Sabie Game Reserve in South Africa is created, as the first officially designated game reserve. April 5 – Annie Oakley promotes the service of women in combat situations, with the United States military. On this day, she writes a letter to President McKinley "offering the government the services of a company of 50 'lady sharpshooters' who would provide their own arms and ammunition should war break out with Spain."[3] April 22 – Spanish–American War: The United States Navy begins a blockade of Cuban ports and the USS Nashville captures a Spanish merchant ship. April 23 – Spanish–American War: A conference of senior Spanish Navy officers led by naval minister Segismundo Bermejo decide to send Admiral Pascual Cervera's squadron to Cuba and Puerto Rico. April 25 Spanish–American War: The United States declares war on Spain; the U.S. Congress announces that a state of war has existed since April 21 (later backdating this one more day to April 20). In Essen, German company Rheinisch-Westfälisches Elektrizitätswerk RWE is founded.[4] April 26 – An explosion in Santa Cruz, California, kills 13 workers, at the California Powder Works.[5] April 29 – The Paris Auto Show, the first large-scale commercial vehicle exhibition show, is held in Tuileries Garden.[6] May 1 – Spanish–American War – Battle of Manila Bay: Commodore Dewey destroys the Spanish squadron, in the first battle of the war, as well as the first battle in the Philippines Campaign. May 2 – Thousands of Chinese scholars and Beijing citizens seeking reforms protest in front of the capital control yuan. May 7–9 – Bava Beccaris massacre: Hundreds of demonstrators are killed, when General Fiorenzo Bava Beccaris orders troops to fire on a rally in Milan, Italy. May 8 – The first games of the Italian Football Federation are played, in which Genoa played against Torino. May 12 – Spanish–American War: The Puerto Rican Campaign begins, with the Bombardment of San Juan. May 22 – The German Federation football club SV Darmstadt 98 is formed. May 27 – The territory of Kwang-Chou-Wan is leased by China to France, according to the Treaty of 12 April 1892, as the Territoire de Kouang-Tchéou-Wan, forming part of French Indochina.[7] May 28 – Secondo Pia takes the first photographs of the Shroud of Turin and discovers that the image on the Shroud itself appears to be a photographic negative.The original flag of the Philippines as conceived by General Emilio Aguinaldo. The blue is of a lighter shade than the currently mandated royal blue, the sun has eight points as currently but many more rays and it has a mythical face. June 1 – The Trans-Mississippi Exposition World's Fair opens, in Omaha, Nebraska. June 7 – William Ramsay and Morris Travers discover neon at their laboratory at University College London, after extracting it from liquid nitrogen.[8] June 9 – The British government arranges a 99-year rent of Hong Kong from China. June 10 – Tuone Udaina, the last known speaker of the Dalmatian language, is killed in an explosion. June 11 – The Guangxu Emperor announces the creation of what would later become Peking University.[9][10] June 12 – Philippine Declaration of Independence: After 333 years of Spanish dominance, General Emilio Aguinaldo declares the Philippines' independence from Spain. June 13 – Yukon Territory is formed in Canada, with Dawson chosen as its capital. June 19 – Food processing giant Nabisco is founded in New Jersey.[page needed] June 21 – Spanish–American War: The United States captures Guam, making it the first U.S. overseas territory. June 28 – Effective date of the Curtis Act of 1898 which will lead to the dissolution of tribal and communal lands in Indian Territory and ultimately the creation of the State of Oklahoma in 1907. August 28: Caleb Bradham names his soft drink Pepsi-Cola July 1 – Spanish–American War: Battle of San Juan Hill – United States troops (including Buffalo Soldiers and Theodore Roosevelt's Rough Riders) take a strategic position close to Santiago de Cuba from the Spanish. July 3 Spanish–American War: Battle of Santiago de Cuba – The United States Navy destroys the Spanish Navy's Caribbean Squadron. American adventurer Joshua Slocum completes a 3-year solo circumnavigation of the world. July 4 – En route from New York to Le Havre, the ocean liner SS La Bourgogne collides with another ship and sinks off the coast of Sable Island with the loss of 549 lives. July 7 – The United States annexes the Hawaiian Islands. July 17 – Spanish–American War: Battle of Santiago Bay. Troops under United States General William R. Shafter take the city of Santiago de Cuba from the Spanish. July 18 – "The Adventures of Louis de Rougemont" first appear in The Wide World Magazine, as its August 1898 issue goes on sale.[11] July 25 – Spanish–American War: The United States invasion of Puerto Rico begins, with a landing at Guánica Bay. August 12 – Spanish–American War: Hostilities end between American and Spanish forces in Cuba. August 13 – Spanish–American War: Battle of Manila – By prior agreement, the Spanish commander surrenders the city of Manila to the United States, in order to keep it out of the hands of Filipino rebels, ending hostilities in the Philippines. August 20 – The Gornergrat railway opens, connecting Zermatt to the Gornergrat in Switzerland. August 21 – Clube de Regatas Vasco da Gama is founded in Rio de Janeiro. August 23 – The Southern Cross Expedition, the first British venture of the Heroic Age of Antarctic Exploration, sets sail from London. August 24 – Chickasaw and Choctaw tribes sign the Atoka Agreement, a requirement of the Curtis Act of 1898. August 25 – 700 Greeks and 15 Englishmen are slaughtered by the Turks in Heraklion, Greece, leading to the establishment of the autonomous Cretan State. August 28 – American pharmacist Caleb Bradham names his soft drink Pepsi-Cola. September 2 – Battle of Omdurman (Mahdist War): British and Egyptian troops led by Horatio Kitchener defeat Sudanese tribesmen led by Khalifa Abdullah al-Taashi, thus establishing British dominance in the Sudan. 11,000 Sudanese are killed and 1,600 wounded in the battle.[12] September 10 – Italian anarchist Luigi Lucheni assassinates Empress Elisabeth of Austria in Geneva, as an act of propaganda of the deed. September 18 – Fashoda Incident: A powerful flotilla of British gunboats arrives at the French-occupied fort of Fashoda on the White Nile, leading to a diplomatic stalemate, until French troops are ordered to withdraw on November 3. September 21 Empress Dowager Cixi of China engineers a coup d'état, marking the end of the Hundred Days' Reform; the Guangxu Emperor is arrested. Geert Adriaans Boomgaard of Groningen in the Netherlands becomes the world's first validated supercentenarian. October 1 – The Vienna University of Economics and Business is founded, under the name K.u.K. Exportakademie. October 3 – Battle of Sugar Point: Ojibwe tribesmen defeat U.S. government troops, in northern Minnesota. October 6 – The Sinfonia Club, later to become the Phi Mu Alpha Sinfonia fraternity, is founded at the New England Conservatory of Music in Boston by Ossian Everett Mills. October 15 – The Fork Union Military Academy is founded, in Fork Union, Virginia.[13] October 21 – General Leonard Wood, the U.S. military governor of Cuba, issues a proclamation guaranteeing personal rights to the Cuban people.[14] October 22 – In a race riot near Harperville, Mississippi in the U.S., 14 African-Americans and one white person are killed.[14] October 23 – An anarchist, suspected of plotting the assassination of Germany's Kaiser Wilhelm II, is arrested in Egypt at Alexandria.[14] October 24 – The last Spanish soldiers in Puerto Rico, led by General Ortega, depart on ships to return to Spain.[14] U.S. President William McKinley extends the deadline for all Spanish troops to leave Cuba. Set to expire on December 1, the last day to depart is extended to January 1, 1899.[14] Chinese soldiers attack a party of British engineers at the Marco Polo Bridge on the Beijing to Hankou railway.[14] October 26 – A collision between two Japanese steamers at sea kills 60 Japanese sailors.[14] The U.S. begins the release and repatriation of Spanish Navy sailors who had been taken as prisoners of war in the Philippines, and sends them back to Spain.[14] October 27 – The Court of Cassation in Paris hears arguments from lawyers regarding a new trial in the Dreyfus case.[14] The Court grants the request on October 29. October 29 – France's Court of Cassation grants a rehearing on the Dreyfus case.[14] Kaiser Wilhelm II of Germany and his wife arrive at Jerusalem in Ottoman-ruled Palestine and visit the Church of the Holy Sepulchre.[14] October 30 – The Imperial Russian government announces that the leaders of the world's major nations have accepted the invitation of the Tsar to take part in a proposed conference on disarmament.[14] October 31 – The Lutheran Church of the Redeemer, Jerusalem, is dedicated after the Sultan of the Ottoman Empire presents the area, said to be the site of the Virgin Mary's home, to Germany's Roman Catholics.[14] Count Ōkuma Shigenobu, Japan's Prime Minister, announces his resignation along with that of his cabinet of ministers.[14] November 1 – Charles Dupuy forms a new government as Prime Minister of France following the resignation of Henri Brisson.[14] November 3 – With increasing violence threatened by rebels in China, the Russian fleet at Port Arthur and the British warships at Wei-Hai-Wei are readied for battle.[14] November 5 – Negros Revolution: Filipinos on the island of Negros revolt against Spanish rule and establish the short-lived Republic of Negros.[14] In China, an admiral of the Imperial Russian Navy and 40 sailors are denied permission by the Chinese government to proceed from Tientsin to Beijing. In the U.S., the collapse of a theater under construction in Detroit kills 11 workmen.[14] November 6 – The Japanese ambassador to China meets with the Emperor and the Empress Dowager at Beijing.[14] November 7 – The final meeting of the Cuban Assembly of the República de Cuba en Armas, which had been founded in 1895 during the Cuban War of Independence, is called to order by General Calixto García in the city of Santa Cruz del Sur. Domingo Méndez Capote is elected as president of the assembly. November 8 – Elections are held in the U.S. for all 357 seats in the House of Representatives, as well as for the governors and state legislature of 25 of the 45 states. With 179 needed for a majority, the Republican Party maintains control with 187 seats, despite losing 19; the Democratic party gains 37 to reach 124 seats; the Populist party losses all but five of its 22 seats, and the other 4 seats are controlled by smaller parties. Among Governors elected are Theodore Roosevelt as Governor of the state of New York.[14] Count Yamagata Aritomo forms a new government as Prime Minister of Japan.[14] November 9 – In the U.S., the racial violence in Phoenix, South Carolina, comes to an end after 12 African-Americans had been lynched.[14] November 10 – The Wilmington insurrection of 1898 begins as a coup d'état by the white Democratic Party of the U.S. state of North Carolina against the Republican Mayor of Wilmington. On the first day, a building housing a negro newspaper is burned and eight African Americans are killed.[14] The new United Central American States, a merger of El Salvador, Honduras and Nicaragua, places its capital in the Nicaraguan city of Chinandega.[14] Bartolomé Masó, the President of the República de Cuba en Armas that had been founded during the Cuban War of Independence, resigns.[14] November 11 – In Wilmington, negro leaders and white republicans are forced to leave the city by new government.[14] November 12 – The Earl of Minto takes office as the new Governor General of Canada.[14] November 17 – Fighting begins in Pana, Illinois, between striking white coal miners and black miners hired to replace them.[14] November 18 – The wreck of the ship Atalanta off the coast of the U.S. state of Oregon kills 28 of the 30 crew aboard.[14] November 19 – In U.S. college football, Harvard University defeats Yale University, 17 to 0, to close the season unbeaten.[14] November 21 – At the Paris conference to end the Spanish-American War, the U.S. commissioners offer $20,000,000 for purchase of the Philippines from Spain.[15] November 24 – Italy sends an ultimatum to the Sultan of Morocco concerning treatmen of Italian residents.[15] November 26 – General Ramón Blanco resigns as the spanish Governor-General of Cuba and is replaced by General Adolfo Jiménez Castellanos.[15] A two-day blizzard known as the Portland Gale piles snow in Boston, severely impacting the Massachusetts fishing industry and several coastal New England towns.[15] The U.S. Marines arrive on USS Boston at Tientsin in China in order to guard the American legation at Beijing.[15] November 27 – All 115 people aboard the American steamer SS Portland are killed when the ship founders off of the caost of Cape Cod.[15] November 28 –The Spanish peace commissioners in Paris announce that they accept the offer of the U.S. to purchase the Philippines.[15] November 30 – The United Central American States, a merger of Nicaragua, Honduras and El Salvador, is formally dissolved after the government was unable to suppress a revolution in San Salvador.[15] December 1 – President Alfaro of Ecuador suspends the govnerment and assumes a dictatorship over the South American nation.[15] The French government decrees a ban on imports of fruit and plants from the United States.[15] December 2 – The French Chamber of Deputies declines to endorse the policies of Prime Minister Depuy, with the vote failing 228 to 243.[15] President Alfaro of Ecuador suspends the govnerment and assumes a dictatorship over the South American nation.[15] December 3 – The Republic of Nicaragua issues a decree announcing its return to sovereignty as a separate nation after its union with El Salvador and Honduras collapses.[15] December 4 – President Zelaya of Nicaragua appoints a new cabinet free of ministers from El Salvador or Honduras.[15] The wreck of the British steamer SS Clan Drummond in the Bay of Biscay kills 37 people on board.[15] December 5 – A fire at a factory in the Russian city of Vilana (now Vilnius in Lithuania) kills 15 women and girls, most of whom die after jumping from the windows.[15] December 6 – The Chancellor of Germany opens the new session of the Reichstag and asks for an increase in the budget for the German Army.[15] December 9 – The first of the two Tsavo Man-Eaters is shot by John Henry Patterson; the second is killed 3 weeks later, after 135 railway construction workers have been killed by the lions. December 10 – The Treaty of Paris is signed, ending the Spanish–American War. December 12 – The French Chamber of Deputies voes 403 to 78 in favor of the Depuy government.[15] December 15 – A warrant issued in Paris for the arrest of Count Ferdinand Esterhazy in connection with the Dreyfus case.[15] A new President of the Swiss Confederation is elected.[15] The French Chamber of Deputies votes to extend a loan of 200,000,000 francs for the construction of railroads in French Indochina.[15] December 18 – Gaston de Chasseloup-Laubat sets the first official land speed record in an automobile, averaging 63.15 km/h (39.24 mph) over 1 km (0.62 mi) in France. December 21 – Prince George of Greece arrives in Crete as its High Commissioner, and is escorted by the flagships of four nations.[16] December 25 – Penny postage goes into effect throughout the British Empire, setting the cost of mailing a letter to most British colonies at one pence. Rates remain the same for mail to Australia, New Zealand and the Cape Colony.[16] December 26 – Marie and Pierre Curie announce the discovery of an element that they name radium.[16] December 27 – The French government delivers its secret dossier on the Dreyfus case to the Court of Cassation.[16] December 28 – The Swiss village of Airolo is buried in an avalanche.[16] December 29 – The Moscow Art Theatre production of The Seagull by Anton Chekhov opens.[17] King Umberto of Italy commutes the sentences of all prisoners who had been given the death penalty.[16] December 31 – Chief Justice Chambers of the Samoan Supreme Court rules that Malietoa Tanus is entitled to become King of Samoa, and holds that Mataafa is barred by the Treaty of Berlin.[16] French serial killer Joseph Vacher is executed at Bourg-en-Bresse.[18] The first volume of the Linguistic Survey of India is published in Calcutta. Gracie Fields Kaj Munk Sergei Eisenstein Randolph Scott Denjirō Ōkōchi Bertolt Brecht Leó Szilárd Enzo Ferrari Soong Mei-ling Eben Dönges January 1 – Viktor Ullmann, Austrian composer, conductor and pianist (d. 1944) January 3 – John Loder, British actor (d. 1988) January 6 – James Fitzmaurice, Irish aviation pioneer (d. 1965) January 7 – Art Baker, American actor (d. 1966) January 9 – Gracie Fields, British singer, actress and comedian (d. 1979) January 10 – Katharine Burr Blodgett, American physicist and chemist (d. 1979) January 13 – Kaj Munk, Danish playwright, Lutheran pastor and martyr (d. 1944) January 16 – Margaret Booth, American film editor (d. 2002) January 20 – Norma Varden, British-born American actress (d. 1989) January 21 Rudolph Maté, Polish-born American cinematographer (d. 1964) Shah Ahmad Shah Qajar of Persia (d. 1930) January 22 Sergei Eisenstein, Russian and Soviet film director (d. 1948) Elazar Shach, Lithuanian-born Israeli Haredi rabbi (d. 2001) January 23 – Randolph Scott, American film actor (d. 1987) January 24 – Karl Hermann Frank, German Nazi official, war criminal (d. 1946) January 25 – Hymie Weiss, Polish-American mob boss (d. 1926) January 28 – Milan Konjović, Serbian painter (d. 1993) January 31 – Hubert Renfro Knickerbocker, American journalist and author (d. 1949) February 1 – Leila Denmark, American pediatrician, supercentenarian (d. 2012) February 3 – Alvar Aalto, Finnish architect (d. 1976) February 5 Denjirō Ōkōchi, Japanese actor (d. 1962) Ralph McGill, American journalist and editorialist (d.1969) February 6 – Melvin B. Tolson, American poet, educator, columnist, and politician (d. 1966) February 10 Bertolt Brecht, German writer (d. 1956) Joseph Kessel, French journalist and author (d. 1979)[19] Margot Sponer, German philologist and resistance fighter (d. 1945) February 11 Henry de La Falaise, French film director, Croix de guerre recipient (d. 1972) Leó Szilárd, Hungarian-American physicist (d. 1964) February 12 Wallace Ford, British actor (d. 1966) Roy Harris, American composer (d. 1979) February 14 Eva Novak, American actress (d. 1988) Fritz Zwicky, Swiss physicist, astronomer (d. 1974) February 15 Totò, Italian comedian, actor, poet, and songwriter (d. 1967) Allen Woodring, American runner (d. 1982) February 18 Enzo Ferrari, Italian race car driver, automobile manufacturer (d. 1988) Luis Muñoz Marín, Puerto Rican poet, journalist and politician (d. 1980) February 24 – Kurt Tank, German aeronautical engineer (d. 1983) February 25 – William Astbury, English physicist, molecular biologist (d. 1961) February 28 Hugh O'Flaherty, Irish Catholic priest (d. 1963) Molly Picon, American actress, lyricist (d. 1992) March 2 – Amélia Rey Colaço, Portuguese actress and impresario (d. 1990) March 3 – Emil Artin, Austrian mathematician (d. 1962) March 4 – Georges Dumézil, French philologist (d. 1986) March 5 Zhou Enlai, Premier of the People's Republic of China (d. 1976) Soong Mei-ling, First Lady of China (d. 2003) March 6 – Therese Giehse, German actress (d. 1975) March 8 – Eben Dönges, acting Prime Minister of South Africa and elected President of South Africa (d. 1968) March 9 – Dudley Stamp, British geographer (d. 1966) March 11 – Dorothy Gish, American actress (d. 1968) March 13 – Henry Hathaway, American film director, producer (d. 1985) March 14 – Reginald Marsh, American painter (d. 1954) March 21 – Paul Alfred Weiss, Austrian biologist (d. 1989) March 23 Erich Bey, German admiral (d. 1943) Madeleine de Bourbon-Busset, Duchess of Parma (d. 1984) March 30 – Joyce Carey, English actress (d. 1993) Paul Robeson Jim Fouché April 1 – William James Sidis, American mathematician (d. 1944) April 2 – Harindranath Chattopadhyay, Indian poet, actor and politician (d. 1990) April 3 George Jessel, American comedian (d. 1981) Henry Luce, American magazine publisher (d. 1967) April 4 – Agnes Ayres, American actress (d. 1940) April 5 – Solange d'Ayen, French noblewoman, Duchess of Ayen and journalist (d. 1976)[20] April 9 Paul Robeson, African-American actor, singer and political activist (d. 1976) Atsushi Watanabe, Japanese film actor (d. 1977) Therese Neumann, German Catholic mystic and stigmatic (d. 1962). April 12 – Lily Pons, French-American opera singer, actress (d. 1976) April 14 Lee Tracy, American actor (d. 1968) Harold Stephen Black, American electrical engineer (d. 1983) April 19 – Constance Talmadge, American actress (d. 1973) April 26 Vicente Aleixandre, Spanish writer, Nobel Prize laureate (d. 1984) John Grierson, Scottish documentary filmmaker (d. 1972) Tomu Uchida, Japanese film director (d. 1970) April 27 – Ludwig Bemelmans, Austrian-American writer and illustrator (d. 1962) April 29 – E. J. Bowen, British chemist (d. 1980) May 2 – Henry Hall, British bandleader (d. 1989) May 3 Golda Meir, Prime Minister of Israel (d. 1978)[21] Septima Poinsette Clark, American educator and civil rights activist (d. 1987) May 5 Blind Willie McTell, American singer (d. 1959) Hans Heinrich von Twardowski, German actor (d. 1958) May 6 – Konrad Henlein, Sudeten German Nazi leader (d. 1945) May 13 – Hisamuddin of Selangor, King of Malaysia (d. 1960) May 15 Arletty, French model, actress (d. 1992) Tom Wintringham, British politician and historian (d. 1949) May 16 Tamara de Lempicka, Polish Art Deco painter (d. 1980) Kenji Mizoguchi, Japanese film director (d. 1956) May 17 Anagarika Govinda, German buddhist lama (d. 1985) A. J. Casson, Canadian painter (d. 1992) May 19 – Julius Evola, Italian philosopher (d. 1974) May 21 – Armand Hammer, American entrepreneur, art collector (d. 1990) May 23 – Frank McHugh, American actor (d. 1981) May 24 – Helen B. Taussig, American cardiologist (d. 1986) May 25 – Robert Aron, French historian and writer (d. 1975) May 28 – Andy Kirk, American jazz bandleader and saxophonist (d.1992) May 31 – Norman Vincent Peale, American clergyman (d. 1993) June 3 – Stuart H. Ingersoll, American admiral (d. 1983) June 4 – Harry Crosby, American publisher, poet (d. 1929) June 5 – Federico García Lorca, Spanish poet, playwright (d. 1936) June 6 Ninette de Valois, Irish dancer, founder of The Royal Ballet (d. 2001) Jim Fouché, 5th President of South Africa (d. 1980) June 10 – Michel Hollard, French Resistance hero (d. 1993) June 11 – Lionel Penrose, English geneticist (d. 1972) June 17 M. C. Escher, Dutch artist (d. 1972) Harry Patch, British World War I soldier, the last Tommy (d. 2009) June 22 Weeratunge Edward Perera, Malaysian educator, businessman and social entrepreneur (d. 1982) Erich Maria Remarque, German writer (d. 1970)[22] June 23 – Winifred Holtby, English novelist and journalist (d. 1935) June 26 Sa`id Al-Mufti, 3-time prime minister of Jordan (d. 1989) Willy Messerschmitt, German aircraft designer, manufacturer (d. 1978) June 30 George Chandler, American actor (d. 1985) Josef Jakobs, German spy (d.1941) Stefanos Stefanopoulos Isidor Isaac Rabi Regis Toomey Leopold Infeld Alfons Gorbach Howard Florey George Gershwin July 2 George J. Folsey, American cinematographer (d. 1988) Anthony McAuliffe, American general (d. 1975) July 3 Donald Healey, English motor engineer, race car driver (d. 1988) Stefanos Stefanopoulos, Prime Minister of Greece (d. 1982) July 4 Gulzarilal Nanda, Indian politician, economist (d. 1998) Gertrude Lawrence, English actress, singer (d. 1952) July 6 – Hanns Eisler, German composer (d. 1962) July 7 Teresa Hsu Chih, Chinese-born Singaporean social worker, supercentenarian (d. 2011) Arnold Horween, American Harvard Crimson, NFL football player (d. 1985) July 8 – Vic Oliver, Austrian-born British actor and radio comedian (d. 1964) July 14 Happy Chandler, American politician (d. 1991) Youssef Wahbi, Egyptian actor, film director (d. 1982) July 17 – Berenice Abbott, American photographer (d. 1991) July 18 – John Stuart, Scottish actor (d. 1979) July 22 Stephen Vincent Benét, American writer (d. 1943)[23] Alexander Calder, American artist (d. 1976) July 25 – Arthur Lubin, American film director (d. 1995) July 29 – Isidor Isaac Rabi, American physicist, Nobel Prize laureate (d. 1988) July 30 – Henry Moore, English sculptor (d. 1986) August 5 – Piero Sraffa, Italian political economist (d. 1983) August 11 – Peter Mohr Dam, 2-time prime minister of the Faroe Islands (d. 1968) August 12 Maria Klenova, Russian marine geologist (d. 1976) Oscar Homolka, Austrian actor (d. 1978) August 13 Mohamad Noah Omar, Malaysian politician (d. 1991) Regis Toomey, American actor (d. 1991) August 15 Jan Brzechwa, Polish poet (d. 1966) Mohan Singh Oberoi, Indian businessman and politician (d. 2002) August 18 Lance Sharkey, Australian Communist leader (d. 1967) Tsola Dragoycheva, Bulgarian politician (d. 1993) August 19 – Eleanor Boardman, American actress (d. 1991) August 20 Leopold Infeld, Polish physicist (d. 1968) Vilhelm Moberg, Swedish novelist, historian (d. 1973) August 21 – Herbert Mundin, English actor (d. 1939) August 26 – Peggy Guggenheim, American art collector (d. 1979) August 27 – John Hamilton, Canadian criminal, bank robber (d. 1934) August 29 – Preston Sturges, American director, writer (d. 1959) August 30 – Shirley Booth, American actress (d. 1992) September 1 Violet Carson, British actress (d. 1983) Marilyn Miller, American actress, singer, and dancer (d. 1936) September 2 – Alfons Gorbach, 15th Chancellor of Austria (d. 1972) September 9 – Walter B. Rea, American university administrator and basketball player (d. 1970) September 10 George Eldredge, American actor (d. 1977) Bessie Love, American actress (d. 1986) September 13 László Baky, Hungarian Nazi leader (d. 1946) Emilio Núñez Portuondo, Cuban diplomat, lawyer and politician, 13th Prime Minister of Cuba (d. 1978) September 19 – Giuseppe Saragat, President of Italy (d. 1988) September 24 – Howard Florey, Australian-born pharmacologist, recipient of the Nobel Prize in Physiology or Medicine (d. 1968) September 26 – George Gershwin, American composer (d. 1937) September 29 – Trofim Lysenko, Russian biologist (d. 1976) September 30 Renée Adorée, French actress (d. 1933) Princess Charlotte, Duchess of Valentinois (d. 1977), Monégasque princess William O. Douglas Peng Dehuai Karl Ziegler Gunnar Myrdal October 6 Arthur G. Jones-Williams, British aviator (d. 1929) Mitchell Leisen, American film director (d. 1972) Clarence Williams, American jazz pianist, composer (d. 1965) October 9 – Joe Sewell, American professional baseball player (d. 1990) October 10 Lilly Daché, French milliner (d. 1989) Marie-Pierre Kœnig, French general, politician (d. 1970) October 15 – Boughera El Ouafi, Algerian athlete (d. 1959) October 16 – William O. Douglas, Associate Justice of the Supreme Court of the United States (d. 1980) October 17 – Shinichi Suzuki, Japanese musician, educator (d. 1998) October 18 – Lotte Lenya, Austrian actress, singer (d. 1981) October 24 – Peng Dehuai, Chinese military leader (d. 1974) October 28 – Abdul Khalek Hassouna, Egyptian diplomat, 2nd Secretary-General of the Arab League (d. 1992) October 29 – Vera Stanley Alder, English painter and mystic (d. 1984) October 30 – Raphael Girard, Swiss-Guatemalan ethnographer (d. 1982) November 11 – René Clair, French filmmaker, novelist, and non-fiction writer (d. 1981) November 12 – Leon Štukelj, Slovene gymnast (d. 1999) November 13 – Walter Karig, American naval captain and author (d. 1956) November 14 – Benjamin Fondane, Romanian-French Symbolist poet, critic and existentialist philosopher (d. 1944) November 15 – Sylvan Goldman, American businessman and inventor (d. 1984) November 17 – Colleen Clifford, Australian actress (d. 1996) November 18 – Joris Ivens, Dutch director (d. 1989) November 21 – René Magritte, Belgian artist (d. 1967) November 22 – Gabriel González Videla, 24th president of Chile (d. 1980) November 23 – Bess Flowers, American actress (d. 1984) November 24 – Liu Shaoqi, President of the People's Republic of China (d. 1969) November 26 – Karl Ziegler, German chemist, Nobel Prize laureate (d. 1973) November 29 – C. S. Lewis, British author (d. 1963)[24] November 30 Firpo Marberry, American baseball pitcher (d. 1976) Link Lyman, American professional football player (d. 1972) December 2 – Indra Lal Roy, Indian World War I pilot (d. 1918) December 5 – Grace Moore, American opera singer, actress (d. 1947) December 6 Alfred Eisenstaedt, American photojournalist (d. 1995) Gunnar Myrdal, Swedish sociologist, economist and Nobel Prize laureate (d. 1987) December 9 – Emmett Kelly, American circus clown (d. 1979) December 10 – Howard Beale, Australian politician and diplomat (d. 1983) December 14 – Lillian Randolph, American actress, singer (d. 1980) December 19 – Zheng Zhenduo, Chinese author, translator (d. 1958) December 20 – Irene Dunne, American actress (d. 1990) December 24 – Baby Dodds, American jazz drummer (d. 1959) December 27 – Inejiro Asanuma, Japanese politician (d. 1960) December 28 – Shigematsu Sakaibara, Japanese admiral and war criminal (d. 1947) December 31 István Dobi, Hungarian prime minister (d. 1968) Ivan Miller, Canadian journalist and sportscaster (d. 1967)[25] Krishna Ballabh Sahay, Indian freedom fighter (d. 1974) Ernest Born, American architect, designer, and artist (b. 1992) Robert Piguet, Swiss-born, Paris-based fashion designer (d. 1953) Henryk Sucharski, Polish military officer (d. 1946) Piotr Triebler, Polish sculptor (d. 1952) Lewis Carroll Matilda Joslyn Gage William Ewart Gladstone January 3 – Lawrence Sullivan Ross, Confederate brigadier general, Texas governor, and president of Texas A&M University (b. 1838) January 14 – Lewis Carroll, British writer, mathematician (Alice in Wonderland) (b. 1832) January 16 – Charles Pelham Villiers, longest-serving MP in the British House of Commons (b. 1802) January 18 – Henry Liddell, English Dean of Christ Church, Oxford (b. 1811) January 26 – Cornelia J. M. Jordan, American lyricist (b. 1830) February 1 – Tsuboi Kōzō, Japanese admiral (b. 1843) February 6 – Abdul Samad of Selangor, Malaysian ruler, 4th Sultan of Selangor (b. 1804) February 16 – Thomas Bracken, author of the official national anthem of New Zealand (God Defend New Zealand) (b. 1843) March 1 – George Bruce Malleson, Indian officer, author (b. 1825) March 6 – Andrei Alexandrovich Popov, Russian admiral (b. 1821) March 10 Marie-Eugénie de Jésus, French religious (b. 1817) George Müller, Prussian evangelist, founder of the Ashley Down orphanage (b. 1805) March 11 – William Rosecrans, California congressman, Register of the U.S. Treasury (b. 1819) March 15 – Sir Henry Bessemer, British engineer, inventor (b. 1813) March 16 – Aubrey Beardsley, British artist (b. 1872)[26] March 18 – Matilda Joslyn Gage, American feminist (b. 1826) March 27 – Sir Syed Ahmad Khan, Indian university founder (b. 1817) March 28 – Anton Seidl, Hungarian conductor (b. 1850) April 13 – Aurilla Furber, American author (b. 1847) April 15 – Te Keepa Te Rangihiwinui, Maori military leader April 18 – Gustave Moreau, French painter (b. 1826) April 29 – Mary Towne Burt, American benefactor (b. 1842) May 19 – William Ewart Gladstone, Prime Minister of the United Kingdom (b. 1809) May 22 – Edward Bellamy, American author (b. 1850) May 29 – Theodor Eimer, German zoologist (b. 1843) June 4 – Rosalie Olivecrona, Swedish feminist activist (b. 1823) June 10 – Tuone Udaina, Croatian-Italian last speaker of the Dalmatian language (b. 1821) June 14 – Dewitt Clinton Senter, American politician, 18th Governor of Tennessee (b. 1830) June 25 – Ferdinand Cohn, German biologist, bacteriologist and microbiologist (b. 1828) Otto von Bismarck Theodor Fontane Saint Charbel Makhluf July 1 Siegfried Marcus, Austrian automobile pioneer (b. 1831) Joaquín Vara de Rey y Rubio, Spanish general (killed in action) (b. 1841) July 5 – Richard Pankhurst, English lawyer, radical and supporter of women's rights (b. 1834) July 8 – Soapy Smith, American con artist and gangster (b. 1860) July 14 – Louis-François Richer Laflèche, Roman Catholic Bishop of Trois-Rivières, Native American missionary (b. 1818) July 30 – Otto von Bismarck, German statesman (b. 1815)[27] August 8 – Eugène Boudin, French painter (b. 1824) August 11 – Sophia Braeunlich, American business manager (b. 1854) August 23 – Félicien Rops, Belgian artist (b. 1833) September 2 – Wilford Woodruff, fourth president of the Church of Jesus Christ of Latter-day Saints (b. 1807) September 5 – Sarah Emma Edmonds, Canadian nurse, spy (b. 1841) September 9 – Stéphane Mallarmé, French poet (b. 1842) September 10 – Empress Elisabeth of Austria, empress consort of Austria, queen consort of Hungary (assassinated) (b. 1837) September 16 – Ramón Emeterio Betances, Puerto Rican politician, medical doctor and diplomat (b. 1827) September 19 – Sir George Grey, 11th Premier of New Zealand (b. 1812) September 20 – Theodor Fontane, German writer (b. 1819)[28] September 26 – Fanny Davenport, American actress (b. 1850) September 28 – Tan Sitong, Chinese revolutionary (executed) (b. 1865) September 29 – Louise of Hesse-Kassel, German princess, queen consort of Christian IX of Denmark (b. 1817) October 24 – Pierre Puvis de Chavannes, French painter (b. 1824) November 2 – George Goyder, surveyor-general of South Australia (b. 1826) November 20 – Sir John Fowler, British civil engineer (b. 1817) December 24 – Charbel Makhluf, Lebanese Maronite, Roman Catholic and Eastern Catholic monk, priest and saint (b. 1828) December 25 – Laura Gundersen, Norwegian actress (b. 1832) December 29 – Ilia Solomonovich Abelman, Russian astronomer (b. 1866)[29] Sotirios Sotiropoulos, Greek economist, politician (b. 1831) ^ Penguin Pocket On This Day. 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Media related to 18th century at Wikimedia Commons Retrieved from " 4 The following pages link to 18th century External tools (link count transclusion count sorted list) · See help page for transcluding these entries Showing 50 items. View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)List of decades, centuries, and millennia (links | edit) Goths (links | edit) Industrial espionage (links | edit) Romania (links | edit) 20th century (links | edit) 15th century (links | edit) 16th century (links | edit) 17th century (links | edit) 1870s (links | edit) 1624 (links | edit) 1626 (links | edit) 1642 (links | edit) 1661 (links | edit) 1756 (links | edit) 1791 (links | edit) 1608 (links | edit) 1818 (links | edit) 1743 (links | edit) 1826 (links | edit) 1828 (links | edit) 14th century (links | edit) 1860s (links | edit) 1788 (links | edit) 1st century (links | edit) 13th century (links | edit) 1787 (links | edit) 1863 (links | edit) 4th century (links | edit) 12th century (links | edit) 11th century (links | edit) 1859 (links | edit) 1900 (links | edit) 1848 (links | edit) 1866 (links | edit) 1896 (links | edit) 1895 (links | edit) 1861 (links | edit) 1648 (links | edit) 1623 (links | edit) 1662 (links | edit) 1640s (links | edit) 1770s (links | edit) 1780s (links | edit) 1789 (links | edit) 1782 (links | edit) 1840 (links | edit) 1840s (links | edit) 1883 (links | edit) 1800s (decade) (links | edit) 1801 (links | edit) View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500) Retrieved from " WhatLinksHere/18th_century" Chemical reaction between a fuel and oxygen "Burning" redirects here. For the type of injury, see Burn. For combustion without external ignition, see spontaneous combustion. For the vehicle engine, see internal combustion engine. For other uses, see Burning (disambiguation), Combustion (disambiguation), and Firing (disambiguation). The flames caused as a result of a fuel undergoing combustion (burning) Air pollution abatement equipment provides combustion control for industrial processes. Combustion, or burning,[1] is a high-temperature exothermic redox chemical reaction between a fuel (the reductant) and an oxidant, usually atmospheric oxygen, that produces oxidized, often gaseous products, in a mixture termed as smoke. Combustion does not always result in fire, because a flame is only visible when substances undergoing combustion vaporize, but when it does, a flame is a characteristic indicator of the reaction. While activation energy must be supplied to initiate combustion (e.g., using a lit match to light a fire), the heat from a flame may provide enough energy to make the reaction self-sustaining. The study of combustion is known as combustion science. Combustion is often a complicated sequence of elementary radical reactions. Solid fuels, such as wood and coal, first undergo endothermic pyrolysis to produce gaseous fuels whose combustion then supplies the heat required to produce more of them. Combustion is often hot enough that incandescent light in the form of either glowing or a flame is produced. A simple example can be seen in the combustion of hydrogen and oxygen into water vapor, a reaction which is commonly used to fuel rocket engines. This reaction releases 242 kJ/mol of heat and reduces the enthalpy accordingly (at constant temperature and pressure): 2 H 2 (g) + O 2 (g) → 2 H 2 O ↑ {\displaystyle {\ce {2H_{2}(g){+}O_{2}(g)\rightarrow 2H_{2}O\uparrow }}} Uncatalyzed combustion in air requires relatively high temperatures. Complete combustion is stoichiometric concerning the fuel, where there is no remaining fuel, and ideally, no residual oxidant. Thermodynamically, the chemical equilibrium of combustion in air is overwhelmingly on the side of the products. However, complete combustion is almost impossible to achieve, since the chemical equilibrium is not necessarily reached, or may contain unburnt products such as carbon monoxide, hydrogen and even carbon (soot or ash). Thus, the produced smoke is usually toxic and contains unburned or partially oxidized products. Any combustion at high temperatures in atmospheric air, which is 78 percent nitrogen, will also create small amounts of several nitrogen oxides, commonly referred to as NOx, since the combustion of nitrogen is thermodynamically favored at high, but not low temperatures. Since burning is rarely clean, fuel gas cleaning or catalytic converters may be required by law. Fires occur naturally, ignited by lightning strikes or by volcanic products. Combustion (fire) was the first controlled chemical reaction discovered by humans, in the form of campfires and bonfires, and continues to be the main method to produce energy for humanity. Usually, the fuel is carbon, hydrocarbons, or more complicated mixtures such as wood that contain partially oxidized hydrocarbons. The thermal energy produced from the combustion of either fossil fuels such as coal or oil, or from renewable fuels such as firewood, is harvested for diverse uses such as cooking, production of electricity or industrial or domestic heating. Combustion is also currently the only reaction used to power rockets. Combustion is also used to destroy (incinerate) waste, both nonhazardous and hazardous. Oxidants for combustion have high oxidation potential and include atmospheric or pure oxygen, chlorine, fluorine, chlorine trifluoride, nitrous oxide and nitric acid. For instance, hydrogen burns in chlorine to form hydrogen chloride with the liberation of heat and light characteristic of combustion. Although usually not catalyzed, combustion can be catalyzed by platinum or vanadium, as in the contact process. See also: pyrolysis The combustion of methane, a hydrocarbon In complete combustion, the reactant burns in oxygen and produces a limited number of products. When a hydrocarbon burns in oxygen, the reaction will primarily yield carbon dioxide and water. When elements are burned, the products are primarily the most common oxides. Carbon will yield carbon dioxide, sulfur will yield sulfur dioxide, and iron will yield iron(III) oxide. Nitrogen is not considered to be a combustible substance when oxygen is the oxidant. Still, small amounts of various nitrogen oxides (commonly designated NOx species) form when the air is the oxidative. Combustion is not necessarily favorable to the maximum degree of oxidation, and it can be temperature-dependent. For example, sulfur trioxide is not produced quantitatively by the combustion of sulfur. NOx species appear in significant amounts above about 2,800 °F (1,540 °C), and more is produced at higher temperatures. The amount of NOx is also a function of oxygen excess.[2] In most industrial applications and in fires, air is the source of oxygen (O2). In the air, each mole of oxygen is mixed with approximately 3.71 mol of nitrogen. Nitrogen does not take part in combustion, but at high temperatures, some nitrogen will be converted to NOx (mostly NO, with much smaller amounts of NO2). On the other hand, when there is insufficient oxygen to combust the fuel completely, some fuel carbon is converted to carbon monoxide, and some of the hydrogens remain unreacted. A complete set of equations for the combustion of a hydrocarbon in the air, therefore, requires an additional calculation for the distribution of oxygen between the carbon and hydrogen in the fuel. The amount of air required for complete combustion is known as the "theoretical air" or "stoichiometric air".[3] The amount of air above this value actually needed for optimal combustion is known as the "excess air", and can vary from 5% for a natural gas boiler, to 40% for anthracite coal, to 300% for a gas turbine.[4] See also: Charring Incomplete combustion will occur when there is not enough oxygen to allow the fuel to react completely to produce carbon dioxide and water. It also happens when the combustion is quenched by a heat sink, such as a solid surface or flame trap. As is the case with complete combustion, water is produced by incomplete combustion; however, carbon and carbon monoxide are produced instead of carbon dioxide. For most fuels, such as diesel oil, coal, or wood, pyrolysis occurs before combustion. In incomplete combustion, products of pyrolysis remain unburnt and contaminate the smoke with noxious particulate matter and gases. Partially oxidized compounds are also a concern; partial oxidation of ethanol can produce harmful acetaldehyde, and carbon can produce toxic carbon monoxide. The designs of combustion devices can improve the quality of combustion, such as burners and internal combustion engines. Further improvements are achievable by catalytic after-burning devices (such as catalytic converters) or by the simple partial return of the exhaust gases into the combustion process. Such devices are required by environmental legislation for cars in most countries. They may be necessary to enable large combustion devices, such as thermal power stations, to reach legal emission standards. The degree of combustion can be measured and analyzed with test equipment. HVAC contractors, firefighters and engineers use combustion analyzers to test the efficiency of a burner during the combustion process. Also, the efficiency of an internal combustion engine can be measured in this way, and some U.S. states and local municipalities use combustion analysis to define and rate the efficiency of vehicles on the road today. Carbon monoxide is one of the products from incomplete combustion.[5] The formation of carbon monoxide produces less heat than formation of carbon dioxide so complete combustion is greatly preferred especially as carbon monoxide is a poisonous gas. When breathed, carbon monoxide takes the place of oxygen and combines with some of the hemoglobin in the blood, rendering it unable to transport oxygen.[6] These oxides combine with water and oxygen in the atmosphere, creating nitric acid and sulfuric acids, which return to Earth's surface as acid deposition, or "acid rain." Acid deposition harms aquatic organisms and kills trees. Due to its formation of certain nutrients that are less available to plants such as calcium and phosphorus, it reduces the productivity of the ecosystem and farms. An additional problem associated with nitrogen oxides is that they, along with hydrocarbon pollutants, contribute to the formation of ground level ozone, a major component of smog.[7] Breathing carbon monoxide causes headache, dizziness, vomiting, and nausea. If carbon monoxide levels are high enough, humans become unconscious or die. Exposure to moderate and high levels of carbon monoxide over long periods is positively correlated with the risk of heart disease. People who survive severe carbon monoxide poisoning may suffer long-term health problems.[8] Carbon monoxide from the air is absorbed in the lungs which then binds with hemoglobin in human's red blood cells. This reduces the capacity of red blood cells that carry oxygen throughout the body. Smoldering is the slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phase fuel. It is a typically incomplete combustion reaction. Solid materials that can sustain a smoldering reaction include coal, cellulose, wood, cotton, tobacco, peat, duff, humus, synthetic foams, charring polymers (including polyurethane foam) and dust. Common examples of smoldering phenomena are the initiation of residential fires on upholstered furniture by weak heat sources (e.g., a cigarette, a short-circuited wire) and the persistent combustion of biomass behind the flaming fronts of wildfires. Spontaneous combustion is a type of combustion that occurs by self-heating (increase in temperature due to exothermic internal reactions), followed by thermal runaway (self-heating which rapidly accelerates to high temperatures) and finally, ignition. For example, phosphorus self-ignites at room temperature without the application of heat. Organic materials undergoing bacterial composting can generate enough heat to reach the point of combustion.[9] Combustion resulting in a turbulent flame is the most used for industrial applications (e.g. gas turbines, gasoline engines, etc.) because the turbulence helps the mixing process between the fuel and oxidizer. Colourized gray-scale composite image of the individual frames from a video of a backlit fuel droplet burning in microgravity The term 'micro' gravity refers to a gravitational state that is 'low' (i.e., 'micro' in the sense of 'small' and not necessarily a millionth of Earth's normal gravity) such that the influence of buoyancy on physical processes may be considered small relative to other flow processes that would be present at normal gravity. In such an environment, the thermal and flow transport dynamics can behave quite differently than in normal gravity conditions (e.g., a candle's flame takes the shape of a sphere.[10]). Microgravity combustion research contributes to the understanding of a wide variety of aspects that are relevant to both the environment of a spacecraft (e.g., fire dynamics relevant to crew safety on the International Space Station) and terrestrial (Earth-based) conditions (e.g., droplet combustion dynamics to assist developing new fuel blends for improved combustion, materials fabrication processes, thermal management of electronic systems, multiphase flow boiling dynamics, and many others). Combustion processes that happen in very small volumes are considered micro-combustion. The high surface-to-volume ratio increases specific heat loss. Quenching distance plays a vital role in stabilizing the flame in such combustion chambers. Generally, the chemical equation for stoichiometric combustion of a hydrocarbon in oxygen is: C x H y + (x + y 4) O 2 ⟶ x CO 2 + y 2 H 2 O {\displaystyle {\ce {C}_{x}{\ce {H}}_{y}+\left(x+{y \over 4}\right){\ce {O2->}}x{\ce {CO2}}+{y \over 2}{\ce {H2O}}} For example, the stoichiometric combustion of methane in oxygen is: CH 4 methane + 2 O 2 ⟶ CO 2 + 2 H 2 O {\displaystyle {\ce {{\underset {methane}{CH4}}+ 2O2 -> CO2 + 2H2O}}} If the stoichiometric combustion takes place using air as the oxygen source, the nitrogen present in the air (Atmosphere of Earth) can be added to the equation (although it does not react) to show the stoichiometric composition of the fuel in air and the composition of the resultant flue gas. Treating all non-oxygen components in air as nitrogen gives a 'nitrogen' to oxygen ratio of 3.77, i.e. (100% − O2%) / O2% where O2% is 20.95% vol: C x H y + z O 2 + 3.77 z N 2 ⟶ x CO 2 + y 2 H 2 O + 3.77 z N 2 {\displaystyle {\ce {C}_{x}{\ce {H}}_{y}+z{\ce {O2}}+3.77z{\ce {N2 ->}}x{\ce {CO2}}+{y \over 2}{\ce {H2O}}+3.77z{\ce {N2}}} where z = x + y 4 {\displaystyle z=x+{y \over 4}} . For example, the stoichiometric combustion of methane in air is: CH 4 methane + 2 O 2 + 7.54 N 2 ⟶ CO 2 + 2 H 2 O + 7.54 N 2 {\displaystyle {\ce {{\underset {methane}{CH4}}+ 2O2}+7.54{\ce {N2-> CO2 + 2H2O}}+7.54{\ce {N2}}} The stoichiometric composition of methane in air is 1 / (1 + 2 + 7.54) = 9.49% vol. The stoichiometric combustion reaction for CαHβOγ in air: C α H β O γ + (α + β 4 − γ 2) (O 2 + 3.77 N 2) ⟶ α CO 2 + β 2 H 2 O + 3.77 (α + β 4 − γ 2) N 2 {\displaystyle {\ce {C_{\mathit {\alpha }}H_{\mathit {\beta }}O_{\mathit {\gamma }}}}+\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}\right)\left({\ce {O_{2}}}+3.77{\ce {N_{2}}}\right)\longrightarrow \alpha {\ce {CO_{2}}}+{\frac {\beta }{2}}{\ce {H_{2}O}}+3.77\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}\right){\ce {N_{2}}}} The stoichiometric combustion reaction for CαHβOγSδ: C α H β O γ S δ + (α + β 4 − γ 2 + δ) (O 2 + 3.77 N 2) ⟶ α CO 2 + β 2 H 2 O + δ SO 2 + 3.77 (α + β 4 − γ 2 + δ) N 2 {\displaystyle {\ce {C_{\mathit {\alpha }}H_{\mathit {\beta }}O_{\mathit {\gamma }}S_{\mathit {\delta }}}}+\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}+\delta \right)\left({\ce {O_{2}}}+3.77{\ce {N_{2}}}\right)\longrightarrow \alpha {\ce {CO_{2}}}+{\frac {\beta }{2}}{\ce {H_{2}O}}+\delta {\ce {SO_{2}}}+3.77\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}+\delta \right){\ce {N_{2}}}} The stoichiometric combustion reaction for CαHβOγN δSε: C α H β O γ N δ S ϵ + (α + β 4 − γ 2 + ϵ) (O 2 + 3.77 N 2) ⟶ α CO 2 + β 2 H 2 O + ϵ SO 2 + (3.77 (α + β 4 − γ 2 + ϵ) + δ 2) N 2 {\displaystyle {\ce {C_{\mathit {\alpha }}H_{\mathit {\beta }}O_{\mathit {\gamma }}N_{\mathit {\delta }}S_{\mathit {\epsilon }}}}+\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}+\epsilon \right)\left({\ce {O_{2}}}+3.77{\ce {N_{2}}}\right)\longrightarrow \alpha {\ce {CO_{2}}}+{\frac {\beta }{2}}{\ce {H_{2}O}}+\epsilon {\ce {SO_{2}}}+\left(3.77\left(\alpha +{\frac {\beta }{4}}-{\frac {\gamma }{2}}+\epsilon \right)+{\frac {\delta }{2}}\right){\ce {N_{2}}}} The stoichiometric combustion reaction for CαHβOγFδ: C α H β O γ F δ + (α + β − δ 4 − γ 2) (O 2 + 3.77 N 2) ⟶ α CO 2 + β − δ 2 H 2 O + δ HF + 3.77 (α + β − δ 4 − γ 2) N 2 {\displaystyle {\ce {C_{\mathit {\alpha }}H_{\mathit {\beta }}O_{\mathit {\gamma }}F_{\mathit {\delta }}}}+\left(\alpha +{\frac {\beta -\delta }{4}}-{\frac {\gamma }{2}}\right)\left({\ce {O_{2}}}+3.77{\ce {N_{2}}}\right)\longrightarrow \alpha {\ce {CO_{2}}}+{\frac {\beta -\delta }{2}}{\ce {H_{2}O}}+\delta {\ce {HF}}+3.77\left(\alpha +{\frac {\beta -\delta }{4}}-{\frac {\gamma }{2}}\right){\ce {N_{2}}}} Various other substances begin to appear in significant amounts in combustion products when the flame temperature is above about 1600 K. When excess air is used, nitrogen may oxidize to NO and, to a much lesser extent, to NO2. CO forms by disproportionation of CO2, and H2 and OH form by disproportionation of H2O. For example, when 1 mol of propane is burned with 28.6 mol of air (120% of the stoichiometric amount), the combustion products contain 3.3% O2. At 1400 K, the equilibrium combustion products contain 0.03% NO and 0.002% OH. At 1800 K, the combustion products contain 0.17% NO, 0.05% OH, 0.01% CO, and 0.004% H2.[11] Diesel engines are run with an excess of oxygen to combust small particles that tend to form with only a stoichiometric amount of oxygen, necessarily producing nitrogen oxide emissions. Both the United States and European Union enforce limits to vehicle nitrogen oxide emissions, which necessitate the use of special catalytic converters or treatment of the exhaust with urea (see Diesel exhaust fluid). The incomplete (partial) combustion of a hydrocarbon with oxygen produces a gas mixture containing mainly CO2, CO, H2O, and H2. Such gas mixtures are commonly prepared for use as protective atmospheres for the heat-treatment of metals and for gas carburizing.[12] The general reaction equation for incomplete combustion of one mole of a hydrocarbon in oxygen is: C x H y fuel + z O 2 oxygen ⟶ a CO 2 carbon dioxide + b CO carbon monoxide + c H 2 O water + d H 2 hydrogen {\displaystyle {\ce {{\underset {fuel}{C_{\mathit {x}}H_{\mathit {y}}}}}+{\underset {oxygen}{{\mathit {z}}O2}}->{\underset {carbon\ dioxide}{{\mathit {a}}CO2}}+{\underset {carbon\ monoxide}{{\mathit {b}}CO}}+{\underset {water}{{\mathit {c}}H2O}}+{\underset {hydrogen}{{\mathit {d}}H2}}}}} When z falls below roughly 50% of the stoichiometric value, CH4 can become an important combustion product; when z falls below roughly 35% of the stoichiometric value, elemental carbon may become stable. The products of incomplete combustion can be calculated with the aid of a material balance, together with the assumption that the combustion products reach equilibrium.[13][14] For example, in the combustion of one mole of propane (C3H8) with four moles of O2, seven moles of combustion gas are formed, and z is 80% of the stoichiometric value. The three elemental balance equations are: Carbon: a + b = 3 {\displaystyle a+b=3} Hydrogen: 2 c + 2 d = 8 {\displaystyle 2c+2d=8} Oxygen: 2 a + b + c = 8 {\displaystyle 2a+b+c=8} These three equations are insufficient in themselves to calculate the combustion gas composition. However, at the equilibrium position, the water-gas shift reaction gives another equation: CO + H 2 O ⟶ CO 2 + H 2 {\displaystyle {\ce {CO + H2O -> CO2 + H2}}} ; K e q = a × d b × c {\displaystyle K_{eq}={\frac {a\times d}{b\times c}}} For example, at 1200 K the value of Keq is 0.728.[15] Solving, the combustion gas consists of 42.4% H2O, 29.0% CO2, 14.7% H2, and 13.9% CO. Carbon becomes a stable phase at 1200 K and 1 atm pressure when z is less than 30% of the stoichiometric value, at which point the combustion products contain more than 98% H2 and CO and about 0.5% CH4. Substances or materials which undergo combustion are called fuels. The most common examples are natural gas, propane, kerosene, diesel, petrol, charcoal, coal, wood, etc. Combustion of a liquid fuel in an oxidizing atmosphere actually happens in the gas phase. It is the vapor that burns, not the liquid. Therefore, a liquid will normally catch fire only above a certain temperature: its flash point. The flash point of liquid fuel is the lowest temperature at which it can form an ignitable mix with air. It is the minimum temperature at which there is enough evaporated fuel in the air to start combustion. Combustion of gaseous fuels may occur through one of four distinctive types of burning: diffusion flame, premixed flame, autoignitive reaction front, or as a detonation.[16] The type of burning that actually occurs depends on the degree to which the fuel and oxidizer are mixed prior to heating: for example, a diffusion flame is formed if the fuel and oxidizer are separated initially, whereas a premixed flame is formed otherwise. Similarly, the type of burning also depends on the pressure: a detonation, for example, is an autoignitive reaction front coupled to a strong shock wave giving it its characteristic high-pressure peak and high detonation velocity.[16] A general scheme of polymer combustion The act of combustion consists of three relatively distinct but overlapping phases: Preheating phase, when the unburned fuel is heated up to its flash point and then fire point. Flammable gases start being evolved in a process similar to dry distillation. Distillation phase or gaseous phase, when the mix of evolved flammable gases with oxygen is ignited. Energy is produced in the form of heat and light. Flames are often visible. Heat transfer from the combustion to the solid maintains the evolution of flammable vapours. Charcoal phase or solid phase, when the output of flammable gases from the material is too low for the persistent presence of flame and the charred fuel does not burn rapidly and just glows and later only smoulders. Efficient process heating requires recovery of the largest possible part of a fuel's heat of combustion into the material being processed.[17][18] There are many avenues of loss in the operation of a heating process. Typically, the dominant loss is sensible heat leaving with the offgas (i.e., the flue gas). The temperature and quantity of offgas indicates its heat content (enthalpy), so keeping its quantity low minimizes heat loss. In a perfect furnace, the combustion air flow would be matched to the fuel flow to give each fuel molecule the exact amount of oxygen needed to cause complete combustion. However, in the real world, combustion does not proceed in a perfect manner. Unburned fuel (usually CO and H2) discharged from the system represents a heating value loss (as well as a safety hazard). Since combustibles are undesirable in the offgas, while the presence of unreacted oxygen there presents minimal safety and environmental concerns, the first principle of combustion management is to provide more oxygen than is theoretically needed to ensure that all the fuel burns. For methane (CH4) combustion, for example, slightly more than two molecules of oxygen are required. The second principle of combustion management, however, is to not use too much oxygen. The correct amount of oxygen requires three types of measurement: first, active control of air and fuel flow; second, offgas oxygen measurement; and third, measurement of offgas combustibles. For each heating process, there exists an optimum condition of minimal offgas heat loss with acceptable levels of combustibles concentration. Minimizing excess oxygen pays an additional benefit: for a given offgas temperature, the NOx level is lowest when excess oxygen is kept lowest.[2] Adherence to these two principles is furthered by making material and heat balances on the combustion process.[19][20][21][22] The material balance directly relates the air/fuel ratio to the percentage of O2 in the combustion gas. The heat balance relates the heat available for the charge to the overall net heat produced by fuel combustion.[23][24] Additional material and heat balances can be made to quantify the thermal advantage from preheating the combustion air,[25][26] or enriching it in oxygen.[27][28] This section needs additional citations for verification. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed. (January 2017) (Learn how and when to remove this message) Combustion in oxygen is a chain reaction in which many distinct radical intermediates participate. The high energy required for initiation is explained by the unusual structure of the dioxygen molecule. The lowest-energy configuration of the dioxygen molecule is a stable, relatively unreactive diradical in a triplet spin state. Bonding can be described with three bonding electron pairs and two antibonding electrons, with spins aligned, such that the molecule has nonzero total angular momentum. Most fuels, on the other hand, are in a singlet state, with paired spins and zero total angular momentum. Interaction between the two is quantum mechanically a "forbidden transition", i.e. possible with a very low probability. To initiate combustion, energy is required to force dioxygen into a spin-paired state, or singlet oxygen. This intermediate is extremely reactive. The energy is supplied as heat, and the reaction then produces additional heat, which allows it to continue. Combustion of hydrocarbons is thought to be initiated by hydrogen atom abstraction (not proton abstraction) from the fuel to oxygen, to give a hydroperoxide radical (HOO). This reacts further to give hydroperoxides, which break up to give hydroxyl radicals. There are a great variety of these processes that produce fuel radicals and oxidizing radicals. Oxidizing species include singlet oxygen, hydroxyl, monatomic oxygen, and hydroperoxyl. Such intermediates are short-lived and cannot be isolated. However, non-radical intermediates are stable and are produced in incomplete combustion. An example is acetaldehyde produced in the combustion of ethanol. An intermediate in the combustion of carbon and hydrocarbons, carbon monoxide, is of special importance because it is a poisonous gas, but also economically useful for the production of syngas. Solid and heavy liquid fuels also undergo a great number of pyrolysis reactions that give more easily oxidized, gaseous fuels. These reactions are endothermic and require constant energy input from the ongoing combustion reactions. A lack of oxygen or other improperly designed conditions result in these noxious and carcinogenic pyrolysis products being emitted as thick, black smoke. The rate of combustion is the amount of a material that undergoes combustion over a period of time. It can be expressed in grams per second (g/s) or kilograms per second (kg/s). Detailed descriptions of combustion processes, from the chemical kinetics perspective, require the formulation of large and intricate webs of elementary reactions.[29] For instance, combustion of hydrocarbon fuels typically involve hundreds of chemical species reacting according to thousands of reactions. The inclusion of such mechanisms within computational flow solvers still represents a pretty challenging task mainly in two aspects. First, the number of degrees of freedom (proportional to the number of chemical species) can be dramatically large; second, the source term due to reactions introduces a disparate number of time scales which makes the whole dynamical system stiff. As a result, the direct numerical simulation of turbulent reactive flows with heavy fuels soon becomes intractable even for modern supercomputers.[30] Therefore, a plethora of methodologies have been devised for reducing the complexity of combustion mechanisms without resorting to high detail levels. Examples are provided by: The Relaxation Redistribution Method (RRM)[31][32][33][34] The Intrinsic Low-Dimensional Manifold (ILDM) approach and further developments[35][36][37] The invariant-constrained equilibrium edge preimage curve method.[38] A few variational approaches[39][40] The Computational Singular perturbation (CSP) method and further developments.[41][42] The Rate Controlled Constrained Equilibrium (RCCE) and Quasi Equilibrium Manifold (QEM) approach.[43][44] The G-Scheme.[45] The Method of Invariant Grids (MIG).[46][47][48] The kinetic modelling may be explored for insight into the reaction mechanisms of thermal decomposition in the combustion of different materials by using for instance Thermogravimetric analysis.[49] Antoine Lavoisier conducting an experiment related to combustion generated by amplified sunlight Assuming perfect combustion conditions, such as complete combustion under adiabatic conditions (i.e., no heat loss or gain), the adiabatic combustion temperature can be determined. The formula that yields this temperature is based on the first law of thermodynamics and takes note of the fact that the heat of combustion is used entirely for heating the fuel, the combustion air or oxygen, and the combustion product gases (commonly referred to as the flue gas). In the case of fossil fuels burnt in air, the combustion temperature depends on all of the following: the heating value; the stoichiometric air to fuel ratio λ {\displaystyle {\lambda }} ; the specific heat capacity of fuel and air; the air and fuel inlet temperatures. The adiabatic combustion temperature (also known as the adiabatic flame temperature) increases for higher heating values and inlet air and fuel temperatures and for stoichiometric air ratios approaching one. Most commonly, the adiabatic combustion temperatures for coals are around 2,200 °C (3,992 °F) (for inlet air and fuel at ambient temperatures and for λ = 1.0 {\displaystyle \lambda =1.0}), around 2,150 °C (3,902 °F) for oil and 2,000 °C (3,632 °F) for natural gas.[50][51] In industrial fired heaters, power station steam generators, and large gas-fired turbines, the more common way of expressing the usage of more than the stoichiometric combustion air is percent excess combustion air. For example, excess combustion air of 15 percent means that 15 percent more than the required stoichiometric air is being used. Combustion instabilities are typically violent pressure oscillations in a combustion chamber. These pressure oscillations can be as high as 180 dB, and long-term exposure to these cyclic pressure and thermal loads reduces the life of engine components. In rockets, such as the F1 used in the Saturn V program, instabilities led to massive damage to the combustion chamber and surrounding components. This problem was solved by re-designing the fuel injector. In liquid jet engines, the droplet size and distribution can be used to attenuate the instabilities. Combustion instabilities are a major concern in ground-based gas turbine engines because of NOx emissions. The tendency is to run lean, an equivalence ratio less than 1, to reduce the combustion temperature and thus reduce the NOx emissions; however, running the combustion lean makes it very susceptible to combustion instability. The Rayleigh Criterion is the basis for analysis of thermoacoustic combustion instability and is evaluated using the Rayleigh Index over one cycle of instability[52] G (x) = 1 T ∫ T q ′ (x , t) p ′ (x , t) d t {\displaystyle G(x)={\frac {1}{T}}\int _{T}q'(x,t)p'(x,t)dt} where q' is the heat release rate perturbation and p' is the pressure fluctuation.[53][54] When the heat release oscillations are in phase with the pressure oscillations, the Rayleigh Index is positive and the magnitude of the thermoacoustic instability is maximised. On the other hand, if the Rayleigh Index is negative, then thermoacoustic damping occurs. The Rayleigh Criterion implies that thermoacoustic instability can be optimally controlled by having heat release oscillations 180 degrees out of phase with pressure oscillations at the same frequency.[55][56] This minimizes the Rayleigh Index. Related concepts Air–fuel ratio Autoignition temperature Chemical looping combustion Deflagration Detonation Dust explosion Explosion Fire Flame Global warming Heterogeneous combustion Markstein number Phlogiston theory (historical) Spontaneous combustion Machines and equipment Boiler Bunsen burner External combustion engine Furnace Gas turbine Internal combustion engine Rocket engine Scientific and engineering societies International Flame Research Foundation The Combustion Institute Other Combustible dust Biomass burning List of light sources Open burning of waste Stubble burning ^ colloquial meaning of burning is combustion accompanied by flames ^ a b The formation of NOx. Alentecinc.com. Retrieved on 2010-09-28. ^ Central Boiler Plants (Report). US Department of the Army. 1989. p. Glossary 26. TM 5-650. ^ "Engineering Toolbox: Optimal Combustion Processes - Fuel vs. Excess Air". 2003. 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