This law has been tested by Coward, Carpenter, and Payman[1] and proved to hold for hydrogen, carbon monoxide, and methane containing no inert gases in normal air. Subsequent tests made with paraffin hydrocarbons in air[3] showed that the law could also be applied to these mixtures. Exceptions have been found in tests made with some flammable gases. White[22] found that the law does not hold strictly for hydrogen-ethylene-air mixtures, acetylene-hydrogen-air mixtures, hydrogen sulfide–methane–air mixtures, and mixtures containing carbon disulfide. In tests on some chlorinated hydrocarbons, Coward and Jones[60] found that the law did not hold for methane-dichloroethylene-air mixtures. It was also found[32] to be only approximately correct for mixtures of methyl and ethyl chlorides. It is therefore apparent that the mixture law, useful when its applicability has been proved, cannot be applied indiscriminately, but must first be proved to hold for the combination of gases under investigation.

Many industrial processes require the use of mixtures of various solvents and although the limits of flammability of the various individual constituents in the mixture may be known, it is not at all certain what the limits of flammability will be for the various mixtures. Investigations of the lower limits of flammability of various solvent mixtures have shown[36] that where the ratios of lower limits of the individual constituents to the amount of oxygen required for theoretical complete combustion are about the same, the limits of mixtures of the constituents may be determined accurately by calculation. For example, limits may be calculated[26] for mixtures of benzene, furfural, and acetone, which have ratios ranging from 0.50 to 0.53; and mixtures of ethyl acetate, ethyl alcohol, and toluene, whose ratios vary from 0.50 to 0.56, also have been found[36] to give calculated results agreeing closely with experimental results.

To date, the accuracy of the above prediction has been proved only for a limited number of mixtures. As information on the subject is accumulated, the classification of compounds according to the ratios should be of considerable value in predicting and calculating the limits of flammability of mixtures of combustible gases and vapors.

3. *Complex Gas Mixtures*

It is possible to calculate closely the limits of flammability not only of mixtures of combustible gases and vapors in air but also mixtures containing varying amounts of inert gases and air. The limits of flammability of natural, manufactured, producer, blast-furnace, automobile, and sewage gases when mixed with various proportions of the inert gases present may be calculated from a knowledge of the composition of the gas and the flammability of the various constituents present. The actual procedure is rather long and complicated and tables or graphs are required for ascertaining the limits of the combustible–inert gas components. The reader who wishes to make such calculations is referred to published reports on the subject.[2,33,55,61]

[58] M. J. Burgess and R. V. Wheeler, *J. Chem. Soc.*, **99**, 2013 (1911).
[59] W. M. Thornton, *Phil. Mag.*, **33**, 190 (1917).
[60] H. F. Coward and G. W. Jones, *Ind. Eng. Chem.*, **22**, 963 (1930).

D. LIMITS OF FLAMMABILITY OF GASES AND VAPORS IN OXYGEN

In some instances, for example, the compressed-gas industry and in hospitals, the flammability of combustible gases in oxygen is of real importance. Published information on this phase of the subject is limited, and in many cases the values appear to be unreliable. A compilation of the best available information on the limits in oxygen is given in Table 2.

TABLE 2

Limits of Flammability of Gases and Vapors in Oxygen

Name	Formula	Limits of flammability (per cent by volume)			
		Lower	Ref. no.	Upper	Ref. no.
Acetaldehyde	C_2H_4O	4.00	2	93.0	2
Acetylene	C_2H_2	2.80	62	93.0	63
Ammonia	NH_3	14.80	44	79.0	44
Benzene	C_6H_6	2.80	64	29.9	64
Butane	C_4H_{10}	1.85	2	49.0	2
Isobutane	C_4H_{10}	1.80	2	48.0	2
Butene-1	C_4H_8	1.75	10	58.3	10
Butene-2	C_4H_8	1.75	10	55.0	10
Carbon monoxide	CO	15.50	65	93.9	65
2-Chloropropene	C_3H_5Cl	4.50	28	54.0	28
Isocrotyl bromide	C_4H_7Br	6.40	28	50.0	28
Isocrotyl chloride	C_4H_7Cl	2.80	28	66.0	28
Cyclopropane	C_3H_6	2.48	19	60.0	19
Deuterium	De	4.90	35	94.7	35
Dichloroethylene	$C_2H_2Cl_2$	10.00	28	26.0	28
Diethyl ether	$C_4H_{10}O$	2.10	66	82.0	12
Dimethyl ether	C_2H_6O	3.90	67	61.4	67
Divinyl ether	C_4H_6O	1.85	29	85.5	29
Ethane	C_2H_6	3.05	2	66.0	2
Ethyl bromide	C_2H_5Br	6.70	28	44.0	28
Ethyl chloride	C_2H_5Cl	4.05	68	67.2	68
Ethylene	C_2H_4	2.90	68	79.9	68
Ethyl-*n*-propyl ether	$C_5H_{10}O$	2.00	28	78.0	28
Hydrogen	H_2	4.65	2	93.9	2
Methane	CH_4	5.15	2	60.5	2
Methyl bromide	CH_3Br	14.00	28	19.0	28
Methyl chloride	CH_3Cl	8.20	69	65.8	69
Methylene chloride	CH_2Cl_2	15.50	70	66.4	70
Propane	C_3H_8	2.25	2	52.0	2
Propylene	C_3H_6	2.10	71	52.8	71
Isopropyl ether	$C_6H_{12}O$	2.20	28	69.0	28
Trichloroethylene	C_2HCl_3	10.30*	72	64.5*	72
Vinyl chloride	C_2H_3Cl	4.00	28	70.0	28

*Determinations made at elevated temperatures.