

SURFACE VEHICLE RECOMMENDED PRACTICE

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(R) Stoichiometric Air-Fuel Ratios of Automotive Fuels

RATIONALE

A recent SAE paper has been added to the references and its use discussed. For clarity, the references have been numbered and footnotes modified. IUPAC atomic weights were updated and equations and tables were modified to reflect the latest atomic weights.

1. SCOPE

The mass of air required to burn a unit mass of fuel with no excess of oxygen or fuel left over is known as the stoichiometric air-fuel ratio. This ratio varies appreciably over the wide range of fuels - gasolines, diesel fuels, and alternative fuels - that might be considered for use in automotive engines.

Although performance of engines operating on different fuels may be compared at the same air-fuel ratio or same fuel-air ratio, it is more appropriate to compare operation at the same equivalence ratio, for which a knowledge of stoichiometric air-fuel ratio is a prerequisite.

This SAE Recommended Practice summarizes the computation of stoichiometric air-fuel ratios from a knowledge of a composition of air and the elemental composition of the fuel without a need for any information on the molecular weight of the fuel.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

1. M. E. Wieser and T. B. Coplen, "Pure and Applied Chemistry," 83, 393 (2009).
2. U.S. Standard Atmosphere, 1976, National Oceanic and Atmospheric Administration; National Aeronautics and Space Administration; United States Air Force, Washington, DC, October 1976.
3. P. Geng, L. R. Melkvik, and R. L. Furey, "Elemental Composition Determination and Stoichiometric Air-Fuel Ratios of Gasoline Containing Ethanol," SAE Paper 2010-01-2112.
4. W.R. Pierson, Chemtech, May 1976, p. 332.

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Documents

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5. L.M. Horsley, "Azeotropic Data III," Advances in Chemistry Series 116, American Chemical Society, Washington.
6. O.T. Zimmerman and I. Lavine, "Industrial Research Services Psychrometric Tables and Charts," 1945.
7. A. Wexler, "Humidity and Moisture—Measurement and Control in Science and Industry," Vol. 1, p. 97, Reinhold Publishing Corp., New York, NY, 1965

3. EQUIVALENCE RATIOS

When the actual air-fuel ratio supplied to the engine is higher than the stoichiometric air-fuel ratio, there is excess air and the engine is operating "lean." Conversely, when the air-fuel ratio is lower than stoichiometric, fuel combustion will be incomplete and engine operation is "rich."

The ratio of the actual fuel-air ratio to the stoichiometric fuel-air ratio is the fuel-air equivalence ratio. (See Equation 1.)

$$\frac{(\text{Fuel} / \text{Air})_{\text{actual}}}{(\text{Fuel} / \text{Air})_{\text{stoichiometric}}} = \text{fuel-air equivalence ratio} = (\phi = \Phi) \quad (\text{Eq. 1})$$

The inverse of the fuel-air ratio is the air-fuel ratio. The ratio of the actual air-fuel ratio to the stoichiometric air-fuel ratio is the air-fuel equivalence ratio. (See Equation 2.)

$$\frac{(\text{Air} / \text{Fuel})_{\text{actual}}}{(\text{Air} / \text{Fuel})_{\text{stoichiometric}}} = \text{air-fuel equivalence ratio} = \lambda = \lambda \quad (\text{Eq. 2})$$

When the term "equivalence ratio" is used, it is necessary to indicate whether the fuel-air equivalence ratio (Equation 1) or the air-fuel equivalence ratio (Equation 2) is intended. The air-fuel equivalence ratio has frequently been labeled as "excess air ratio."

4. ATOMIC WEIGHTS AND COMPOSITION OF FUELS AND AIR

The following atomic weights of elements present in many fuels are:

Carbon - 12.011
Hydrogen - 1.008
Oxygen - 15.999
Nitrogen - 14.007
Sulfur - 32.06

These atomic weights have been adopted by the Commission on Atomic Weights and Isotopic Abundances of the International Union of Pure and Applied Chemistry.¹

The composition of air is shown in Table 1.

In the computations as follows, the atomic weights and mass of air containing one mass unit of oxygen are rounded to five significant digits. Measured values of actual air-fuel ratios and elemental analyses are seldom more precise than four significant digits.

¹ See Reference 1 in Section 2.

TABLE 1 - MOLECULAR WEIGHTS AND ASSUMED FRACTIONAL VOLUME -
COMPOSITION OF SEA LEVEL DRY AIR

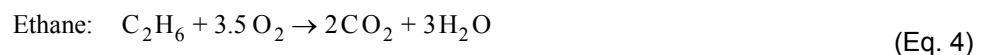
Gas Species	Fractional Volume ⁽¹⁾	Molecular Weight g/mole	Relative Mass ⁽²⁾
N ₂	0.78084	28.014	21.874452
O ₂	0.209476	31.998	6.702813
Ar	0.00934	39.948	0.373114
CO ₂	0.000314	44.009	0.013819
Ne	0.00001818	20.1797	0.000367
He	0.00000524	4.002602	0.000021
Kr	0.00000114	83.798	0.000096
Xe	0.000000087	131.293	0.000011
CH ₄	0.000002	16.043	0.000032
H ₂	0.0000005	2.016	0.000001
			28.964726
			(3)

$$\text{Thus, } \frac{\text{Mass of}}{\text{Mass of Oxygen}} = \frac{28.964726}{6.702813} = 4.3213$$

1. Data from Table 3 of Reference 2 in Section 2.
2. Relative mass = fractional volume x molecular weight.
3. Calculated from 1983 IUPAC Atomic Weights, Reference 1 in Section 2.

5. CALCULATION OF STOICHIOMETRIC AIR-FUEL RATIOS OF HYDROCARBONS

The stoichiometric oxidation of pure compounds such as methane and ethane can be expressed by balanced chemical equations, (see Equations 3 and 4):



Thus, the stoichiometric oxygen/methane mass ratio is shown in Equation 5:

$$(\text{oxygen / methane})_{\text{stoich}} = \frac{15.999 \times 2 \times 2}{(12.011 \times 1) + (1.008 \times 4)} = \frac{63.996}{16.043} = 3.9890 \quad (\text{Eq. 5})$$

Similarly, the stoichiometric oxygen/ethane mass ratio is shown in Equation 6:

$$(\text{oxygen / ethane})_{\text{stoich}} = \frac{15.999 \times 3.5 \times 2}{(12.011 \times 2) + (1.008 \times 6)} = \frac{111.99}{30.07} = 3.7244 \quad (\text{Eq. 6})$$