Molecular Property Spectrometer™ (MPS™) Flammable Gas Sensor

Measuring Flammable Gas Mixtures

Measuring the %LEL of flammable gas mixtures

The MPS™ Flammable Gas Sensor classifies flammable gases into one of six categories: (1) hydrogen; (2) hydrogen-containing mixtures; (3) methane (or natural gas); (4) light gas or gas mixture; (5) medium gas or gas mixture; and (6) heavy gas or gas mixture. This first-of-its-kind capability is made possible by a molecular-property-based analysis. The sensor assesses, among other properties, the molecular weight range of the gas—or, in the case of a flammable gas mixture, the *average* molecular weight range.

Figure 1 shows the relationship between the lower explosive limit (LEL) concentration of a flammable gas and its molecular weight. This relationship generally applies for *average* molecular weight as well; that is, a gas mixture with an average molecular weight equal to that of pentane will have a composite %LEL concentration similar to that of pentane. For this reason, the %LEL reported by the MPS is more accurate than competitive sensor technologies when presented mixtures of multiple flammable gases.

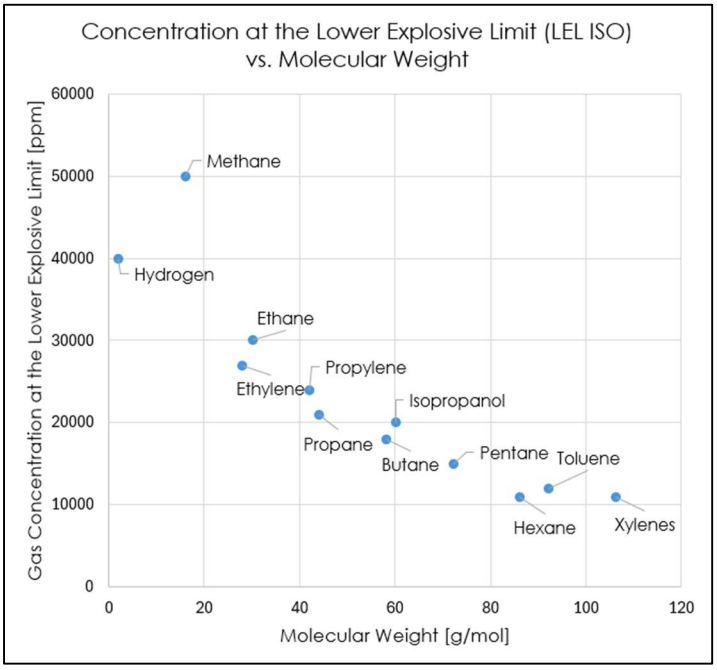


Figure 1: LEL concentration in parts-per-million by volume (ppm) vs. molecular weight (grams/mol).

Le Chatelier's mixing rule is commonly used for estimating the %LEL of mixtures of flammable gases in air. It states that the composite %LEL of a mixture depends on the mole fraction, *x*, of each gas present and each gas' current percentage of its respective lower-explosive-limit concentration:

$$\%LEL_{mix} = \frac{1}{\sum \frac{x_i}{\%LEL_i}}$$

Let's look at an example: in a given volume of air, three-quarters of the total volume (x=0.75) is 50 %LEL methane, and the remaining quarter of the volume (x=0.25) is 30 %LEL hexane. (This condition might be created in a laboratory setting by flowing 375 mL/min of 50 %LEL methane in air and 125 mL/min of 30 %LEL hexane in air, for a total flow of 500 ml/min.) The %LEL of this particular mixture according to the rule is:

$$\%LEL_{mix} = \frac{1}{\left(\frac{0.75}{50\ \%LEL} + \frac{0.25}{30\ \%LEL}\right)} = \frac{1}{(0.015 + 0.0083)} = 42.9\ \%LEL$$

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NevadaNano has conducted tests of representative flammable gas mixtures. In one such test, three different mixture ratios of methane, ethane and propane were created inside Tedlar bags using flammable gas from compressed gas cylinders. The calculated and reported %LEL concentrations of these mixtures from this test are provided below:

Case 1:
0.2 volume fraction of 50.4 %LEL methane (600 ml of 50.4 %LEL CH_4 gas into a 3-liter total gas volume)
0.5 volume fraction of 47.0 %LEL ethane
0.3 volume fraction of 49.5 %LEL propane

The expected %LEL of this mixture is:

$$\%LEL_{mix} = \frac{1}{\left(\frac{0.2}{50.4\ \%LEL} + \frac{0.5}{47.0\ \%LEL} + \frac{0.3}{49.5\ \%LEL}\right)} = 48.4\ \%LEL$$

The %LEL reported by the MPS™ Flammable Gas Sensor was 51.9 %LEL.

Case 2:
0.5 volume fraction of 50.4 %LEL methane
0.25 volume fraction of 47.0 %LEL ethane
0.25 volume fraction of 49.5 %LEL propane

The expected %LEL of this mixture is:

$$\%LEL_{mix} = \frac{1}{\left(\frac{0.5}{50.4\ \%LEL} + \frac{0.25}{47.0\ \%LEL} + \frac{0.25}{49.5\ \%LEL}\right)} = 49.3\ \%LEL$$

The %LEL reported by the MPS™ Flammable Gas Sensor was 52.4 %LEL.

Case 3:
0.8 volume fraction of 50.4 %LEL methane
0.2 volume fraction of 47.0 %LEL ethane
(no propane)
The expected %LEL of this mixture is:

$$\%LEL_{mix} = \frac{1}{\left(\frac{0.8}{50.4\ \%LEL} + \frac{0.2}{47.0\ \%LEL}\right)} = 49.7\ \%LEL$$

The %LEL reported by the MPS™ Flammable Gas Sensor was 47.6 %LEL.