Replace r_1 with $2r_1 + r_2$:

CH_4	H_2O	CO	CO_2	H_2
0	0	0	0	0
0	1	1	−1	−1
−1	0	2	−1	2
0	−1	−1	1	1

Replace r_2 with $r_2 + r_3$:

CH_4	H_2O	CO	CO_2	H_2
0	0	0	0	0
0	0	0	0	0
0	1	1	−1	−1
−1	0	2	−1	2

No additional eliminations can be done past this point. We are left with two rows of nonzero coefficients; therefore, the number of independent reactions is 2.

Comments The elimination process can be done in many different ways and the surviving rows may contain different coefficients from ones obtained above, but the *number* of nonzero rows will be the same. This method comes from linear algebra and amounts to the determination of the *rank* of the matrix of the stoichiometric coefficients.

The reactions that correspond to the last table of stoichiometric coefficients are

$$CO_2 + H_2 = CO + H_2O \qquad [R5]$$

2 H2

$$CH_4 + CO_2 = 2CO + 2H_2\cancel{O} \qquad [R5]$$

However, *any two independent* reactions between the five components may be used to calculate the equilibrium composition.

Example 14.20: Equilibrium Composition with Multiple Reactions

Methane is reformed by reaction with steam according to reactions R1 − R4 on page 632. Determine the equilibrium composition at 600 K, 2 bar, of a reaction mixture whose feed consists of a methane-water mixture at molar ratio 1:2.

Solution We determined that only two of the four reactions are independent. We may choose any two independent reactions to describe the system, namely, any two of the four in R1–R6, or any linear combination of these, such as reactions R5 and R6 in Example 14.19. We choose reactions R1 and R2 and build the stoichiometric table shown below using the gas standard state for all components.