$$CH4+H2O \leftrightarrow 3H2+CO-206\ kJ$$

b) conversion of methane by oxygen:

$$CH_4+1/2\ O_2 \leftrightarrow 2H_2+CO+35\ kJ$$

c) *CO* steam reforming:

$$CO+H_2O \leftrightarrow H_2+CO_2+41\ kJ$$

The total conversion process of CH_4 with water vapor:

$$CH_4+2H_2O \leftrightarrow CO_2+4H_2-165\ kJ$$

Methods of separation of CO_2, CO, H_2S, O_2, Ar, CH_4 from nitric mixture:

Wet method:

a) *chemisorption by alkaline solutions*: CO_2 and H_2S (ethanolamine, diethanolamine, K_2CO_3 solution); *CO* (copper acetate ammonia solution);

b) *hydrogenation*:

$$CO+3H_2 \leftrightarrow CH_4+H_2O+Q$$

$$CO_2+4H_2 \leftrightarrow CH_4+2H_2O+Q$$

$$O_2+2H_2 \leftrightarrow 2H_2O+Q$$

The dry method - adsorption by solid adsorbents

The process is carried out at T = 420-500ºC, P = 32 MPa, on the catalysts - Fe_{porous}/Al_2O_3, K_2O, *CaO*, SiO_2, with a ratio of $N_2:H_2$ =1:3 and the reverse process speed V = 15,000-25,000 h^{-1}. The productivity of the process is P = 20-40 tons per day with 1 m^3 of catalyst, the degree of ammonia conversion is X_{NH3} = 15-20%.

c) *washing with liquid nitrogen* at -190 ºC (*CO*, CH_4, *Ar*).

Industrial methods of ammonia production depending on the pressure are divided into:

- under low pressure up to 10 (10-15) MPa;

- under average pressure 20-30 (25-60) MPa;

- high pressure 75-100 (60-100) MPa.

Physical and chemical bases of ammonia synthesis process

The exothermic, reversible; ratio of $N_2:H_2$=1:3; because the process is by reducing the amount necessary to reduce T and increase R (much lower T disadvantageous because it decreases the speed of the process and the performance of $T_{optimal}$ =400-500°C).

The maximum conversion reaches 97% at T=400°C is achieved at P >350 MPa. Lowering the pressure increases the equilibrium yield of ammonia, so apply very high pressure is disadvantageous (P_{optim} = 32 MPa). Industrial ammonia synthesis catalyst-GIAP:

$$|Fe|_{cat} + |Al_2O_3 + K_2O + CaO + SiO_2|_{promotor}$$

Also as catalysts of process apply: *Mn, Rh, W, Re, U, Os, Pt*.