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Review

A review on reduction of acetone to isopropanol with Ni nano superactive, heterogeneous catalysts as an environmentally benevolent approach

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A B S T R A C T

A review summarizes about the Ni nano catalysts have emerged as a superactive catalysts for reduction reactions particularly acetone reduction to isopropanol and its valued-added products in chemical industry and Ni catalysts is well informed for hydrogenation reactions for decades but reduction which forms an important area of catalytic process to produce fine chemicals in industries. Reduction of acetone has important applications in heat pumps, fuel cells or fulfilling the substantial demand for the production of 2-propanol. Hydrogenation of acetone is carried out with variety of catalysts notably homogeneous catalysts such as Iridium, Ru complexes etc and heterogeneous catalysts such as Raney Nickel, Raney Sponge, Ni/Al_2O_3, Ni/SiO_2, Ni or Ni, (or supported on SiO_2 or MgO) and r-NiMg Al layered double hydroxide. The major products are typically 2-propanol, methyl isobutyl ketone. Nano catalysts are being developed for actone reduction like Ni maleate, cobalt oxide prepared in organic solvents. These catalysts process can be applied for other commercial catalytic process replacing the old one to prepare hollow nanospheres of other materials for catalytic applications. The author summarizes a mini review on acetone hydrogenation under different conditions with various Ni nano heterogeneous catalysts studied so far in literature and new strategies to develop economic and environmentally friendly approach.

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1. Introduction

Catalysis is likely to become a key element in the conversion of liquid or gaseous fuel cell. Conversion of ketones to value added products is referred as fuel processing, most often involves either hydrocarbons like methane, ethane, propane/LPG or liquid higher hydrocarbons or alcohols, methanol and ethanol, however in principal any hydrocarbon containing may be applied, such as dimethyl ether and ammonia. It is even possible to convert other fuels than hydrogen directly or indirectly in the fuel cells. There is a continuous exploitation and exploration of nano-materials which have unusual properties that differ from either the bulk or single atom. Consequently nano-metals find applications in diverse fields, such as homogeneous and heterogeneous catalysis [1,2] fuel cell

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catalysis [3–7] electronic appliances, medical and biological sciences [8]. While the design of nano-materials endowed with size dependant functions is gaining much importance, the synthetic strategies have matched their application needs, making a "made to order" relationship possible. These newer tunable synthetic methodologies offer not only an option of preparing any desired bi- and multimetallic compositions, but it is also possible to control the size and the inner structure of the resulting nano-metals. The main objective of this mini review is reduction of acetone to isopropanol with Ni nano particles. In general briefly it is summarized about both heterogeneous and homogeneous catalysts used for the title reaction. Isopropanol is widely regarded as essential commodity in fine chemical synthesis which is used as a solvent in industry and academia. Isopropanol is a projected to grow at a global rate of 1% to 3% per year. The state of the art of reduction of carbonyl compound namely acetone dates back decades when simple metals and hydrides were used for the reduction of ketones. Ex: acetone to 2-propanol [9–11]. Despite the history of the industrial application of acetone hydrogenation catalysts, opportunities remain for further improvements in hydrogenation rates, selectivity, stability, and applicability in hydrogenation of a wider range of materials [12,13]. Increased fundamental understanding of hydrogenation catalysts would allow for rationally-directed improvements [14].

Table 1
List of Raney nickel catalayst used for acetone to isopropanol process Ref. [14].

Run	Catalyst	Promoter	Min	Conversion (%)
A	A400Sponge nickel	2.5% Cr	22	99.9
B	Raney cobalt 2724	2.15% Cr	28	99.9
C	A7000 Sponge nickel	2% Mo	35	99.93
D	A5000 Sponge nickel	None	45	99.92
E	Raney nickel 3300	1.1% Mo	46	99.94
F	Raney nickel 4200	None	62	99.92

Hydrogenation of acetone to isopropanol is regarded as a major commodity for industry and academics since it has wide applications in heat pumps and fuel cell's for hydrogen storage [15–23] (Tables 1 and 2).

2. Related chemical reaction

The commercial production of MIBK involves a three-step process.

1. Acetone is first converted to diacetone alcohol (DAA) by aldol condensation of acetone [24].
2. Dehydration of DAA to mesityl oxide.

Table 2
Previous work for one-step synthesis of methyl isobutyl ketone from acetone [31,37].

Catalyst	Pressure (atm)	*T* (K)	Conv (%)	Selectivity (%)
Pd-KUZ	20	393	50	94.5
Pd-CuO/Al_2O_3/SiO_2	1	423–503	30	60
Pd-CuO/MgO/SrO	20	433	38.5	93.6
Pd-Nb_2O_5-Al_2O_3	–	–	28	90
Pd-oxides of Ti, Zr, Cr	10	413	33.9	92.3
Pd-KUZFPP	30	353–388	–	–
Pd-C-Nb_2O_5	20	413	39.5	92.5
Pd-C-Nb_2O_5	10	413	30	91.7
Pd-oxides of Ce, Hf, Ta	10	413	33	90.2
Pd-IER	40	363–393	–	–
Pd-CS-H-ZSM-5	1	523	41.9	82.4
Pd-Nb_2O_5	–	–	41.8	93.5
Pd-oxides of Zr	–	–	27	94.9
Pd-KS-IER	50	373–403	–	90
Pd-ZSM-5	50	443	40.25	95.36
Pd-IER	–	–	–	–
Ni, Cu, Co-Ga-Al_2O_3	–	453	53.9	37.1
Ni-Al_2O_3	1	373	–	95
Pd-ZSM-5	–	–	–	–
$SiO_2/Al_2O_3 = 30$	6–60	433	41.24	90.98
Ni-CaO	–	473	70–80	60
Cu-MgO	1	653	60–80	60–75
Pt-HMF	1	433	–	–
Ni-CaO	–	–	60–80	50–60
Pd-$AIPO_4$-II, $SAPO_4$	–	–	–	–
Ni-Al phosphate	–	–	–	–
Pd-(Zn)-H-ZSM-5	5	408–483	55	83–94
Pd-Nb_2O_5-SiO_2	–	–	30–35	88–92
Ni-CaO	–	–	60–70	70
Pd-Al_2O_3	40–90	413–473	–	–
Pt-H-ZSM-5	1	433	–	–
Pt-NaX	–	713	–	70
Pd-H-ZSM-5	1	473	47.3	30.7
Pd-IER	40–70	353–373	–	–
Cu-MgO-Al_2O_3	–	–	65.26	57.49
Pd-zeolite	–	–	70	87.5
Pd-IER	–	403	43.2	98.2
Pt-Sn-H-ZSM-5	1	433	–	–
Pd-C	1-20	333	–	–
Pd-Ca-Al_2O_3	–	–	–	–
Amberlyst CH	28-30	403–423	25–50	70–90
Pd	35	300	15	60
Pd-IER	5–15	373–453	–	–
Pd-MCM-56	–	–	33.5	81.2
Pd-MCM-49	–	–	35.6	85
Cu-MgO-Al_2O_3	1	513	71.7	50.1