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Oxidative Dehydrogenation of Ethane to Ethylene Over Mo-V-Nb Catalysts: Effect of Calcination Temperature and Type of Support

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Abstract. The development and implementation of a suitably active and selective Mo-V-Nb catalyst in ethane oxidative dehydrogenation was desirable and carried out in a micro-reactor system for the present study. Impregnation method was used to prepare the catalysts. The study established the effect of the parameters, namely, calcination temperatures and supports on the performance of Mo-V-Nb with Pd promoter catalysts. Catalyst samples were tested under reaction condition of temperatures 250, 280, 300 and 325°C, pressure 14.7 psi, flow rate 30 ml/min.gm (F/W) and the oxygen/ethane feed ratio of 1/3. Different supports, namely, alumina (SA-5239), silica (S151-10) and activated carbon were used. Palladium promoter was employed. Sensitivity analysis for the catalysts was carried out at different reaction temperatures. It was found that catalyst supported with silica S151-10 gave better performance than catalyst supported with alumina SA-5239 and activated carbon. On the other hand it was noted that ethylene selectivity decreases by increasing the reaction temperature, while the selectivity of COx products increases with the increase of reaction temperature. Moreover, higher calcination temperatures were not favorable not only due to low C_2H_6 and O_2 conversion, but also low C_2H_4 selectivity and yield and high CO_X selectivity and yield.

Introduction

Saudi Arabia is one of the leading countries in production and reserve of natural gas. Natural gas used to be burnt. But presently it is collected in a master gas system where it is separated into methane, ethane and others. The methane and ethane have been successfully used as raw materials for most of industries and converted into many petrochemical products such as ethylene, ethanol amine, ethanol, plastic materials and acetic acid. Ethylene is produced by thermal steam cracking of hydrocarbons which may be ethane contained in natural gas, ethane-propane mixtures originating from refinery processes and naphtha [Kniel, *et al.* 1980]. The highly endothermic thermal cracking processes consumes a large amount of energy and involve significant formation of coke which requires frequent process shut-downs for its removing from the reactor. Moreover, coke deposits on the inner walls of the tubular cracking reactor reduce heat transfer requiring higher wall temperature (up to 1100^0C) and therefore, more energy and resulting in reduction of the life time of the reactor tubes. To overcome the energy and coke problems associated with thermal cracking, recent technologies employ direct oxidative-dehydrogenation of ethane. The oxidative dehydrogenation is to overcome thermodynamic limitations by operation at low temperature of 200-400^0C and atmospheric pressure with an exothermic reaction, and avoiding frequent regeneration. This entails development and implementation of a suitably active and selective catalyst [James, *et al.* 2002]. In fact, in ethane oxidative dehydrogenation, a surface-initiated, homogeneous mechanism leads to high selectivity to ethylene. The possibility of development of a process competitive to the steam-cracking of ethane depends on the development of stable catalytic system able to operate in the absence of corrosive or toxic gas promoters, giving the olefin with high selectivity and acceptable productivity. However, it is obvious that severe operating conditions (more favorable to the selectivity) might render the Paraffin Oxidative dehydrogenation

(ODH) less competitive with other conventional processes. The minimization of CO_2, the most difficult by-product to separate, is also an important task. Current catalytic system characteristically encounters an apparent selectivity/conversion barrier that limit single pass process yield to less than about 35%[Kung, 1994]. The decrease in selectivity with conversion is primarily due to secondary combustion reactions of the primary product, ethylene. High reaction temperature is generally used in the selective oxidation of short chain alkanes, especially ethane, as a consequence of their low reactivity [Blasco, *et al.*. 1997]. For this reason, more active catalysts are required in order to decrease the reaction temperatures. The main challenge for ODH is, therefore to identify a catalyst with the ability to activate the less reactant alkane, while avoiding over oxidation of the olefin products [James, *et al.* 2002]. V-containing catalysts have been widely used in the oxidative dehydrogenation (ODH) of alkanes [Bañares,1999]. Mo–V–Nb mixed oxides have been proposed to be the most active and selective catalysts in the ODH of ethane at relatively low reaction temperatures (300–400 °C) [Desponds, *et al.*. 1993, Ruth, K., *et al.* 1998]. The influence of both the composition and the calcination conditions of Mo–V–Nb mixed oxides catalysts on their catalytic behavior in the ODH of ethane have been studied in the last years [Botella, *et al.* 2003- Thorsteinson, *et al.* 1978].

Different catalyst such as Pt-Rh and Pd-coated monoliths [Huff, M., *et al.* 1993, Yokoyama, *et al.* 1996], Li/La/CaO [Ji, and Liu 1996], Sr $Ce_{0.5}$ $Yb_{0.5}$ $O_{2.75}$[Velle, *et al.* 1990], BaO/Y_2O_3 [Dai,. *et al.* 1999], SrO/La_2O_3 [Choudhary, *et al.*, 1996], $SmNa_{0.028}P_{0.014}O_x$ [Buyerskaya, *et al.* 1998], Sr-Nd-La-Ox [Mulla, *et al.* 2001] as well as halide containing catalysts [Conway, *et al.* 1991, Dai, *et al.* 1999, Wang, *et al.*, 1999] have been reported to achieve ethylene yields above 40%. Most of the high ethylene yields catalysts reported for mixed oxides [Velle, *et al.* 1990, Dai,. *et al.* 1999, Choudary, *et al.* 1995, Buyerskaya, *et al.* 1998, Mulla, *et al.* 2001] and noble metal containing systems [Kung, 1994, Huff, M., *et al.* 1993]. The high ethylene yields were obtained at temperature > 600^0 C at which the homogeneous gas phase reaction may contribute significantly [Burch, and Crabb 1993, Wanzek, 1991].

Casaletto *et al.*., 2002, investigated γ-Al_2O_3 supported vanadyl and iron vanadyl phosphates ($VOPO_4$ and $Fe_{0.23}$ $(VO)_{0.77}PO_4$) calcined at 550 or 650^0C as catalysts for the ODH of ethane to ethylene in the temperature range 450-650^0C in a fixed bed reactor operating under atmospheric pressure. Supported vanadyl phosphates catalysts are more active than iron modified samples and catalysts calcined at 650^0C give better catalytic performances than those calcined at 550^0C.

Franscesco *et al.* 2002, studied the ODH of ethane in a short contact time reactor consisting of a $LaMnO_3$ bases monolithic catalyst with a honey comb morphology. Using an ethane/air mixture with C_2H_6/O_2 ratio = 1.5 and a preheat temperature ranging from 250 to 400^0C results in a 55% ethylene yield. Mo-V-Nb catalyst has been investigated, that Mo-V-Nb oxides were active at temperature as low as 200^0C. Furthermore, these catalysts were found to give selectivity's to ethylene of 100% at 10% conversion. These data, however, have not been confirmed by later studies [Burch, and Swarnakar, 1991, Desponds, *et al.* 1993] on the same system.

High reaction temperature is generally used in the selective oxidation of short chain alkanes, especially ethane, as a consequence of their low reactivity [Casaletto, *et al.* 2002, Franscesco *et al.* 2002, Burch, and Swarnakar, 1991]. For this reason, more active catalysts are required in order to decrease the reactor temperatures. The effect of catalyst composition and catalytic activity and selectivity can be achieved by calcinations at about 400^0C of the corresponding mixed metal oxides.

The oxidative dehydrogenation of ethane into ethylene by CO_2 over a series of Silica–supported chromium oxide catalysts was investigated. The result showed that the catalysts were effective for the reaction and CO_2 in the feed promoted the catalytic activity. The 5% Cr/SiO_2 catalyst exhibited the excellent performance with 30.7% ethane conversion and 96.5% ethylene selectivity at 700^0C [Xin *et al.* 2002].

Oxidative dehydrogenation of ethane with carbon dioxide to ethylene was investigated in a fixed-bed flow micro-reactor under ambient pressure. Chromium oxide was found to be the best catalyst among activated carbon (AC) supported Fe-, Mn-, W- and Cr-oxide catalysts. Coke deposition and changes in the surface state of the catalyst are believed to be the reasons for catalyst deactivation [Hong, *et al.* 2001].

Mo-V-M(=Al, Ga, Bi, Sb and Te)-O mixed oxide catalysts were synthesized hydrothermally, characterized structurally, and tested for ethane and propane oxidation after activation. The resulting catalysts were very active for an oxidative dehydrogenation of ethane with 80% of the ethylene selectivity in the reaction temperature range of 300 to 400^0C and also showed about 50% selectivity to acrylic acid in the propane oxidation [Ueda, *et al.* 2002].

Dai *et al*., 2001, have studied the catalytic performance and characterization of A $CuO_{2-\gamma}$ ($A=Sr_{0.63}Ca_{0.27}$) and $ACuO_{2-\gamma}X_\sigma$ (X=F, Cl) catalysts for ODE to ethane. The results of X-ray diffraction

indicated that the three catalysts are single-phase and tetragonal infinite-layer in structure. The incorporation of fluoride or chloride ions in the $ACuO_{2-\gamma}$ lattice can significantly enhance C_2H_6 conversion and C_2H_4 selectivity.

Lui *et al.*. prepared and screened niobium and tantalum containing mixed metal oxide libraries of V-Al-Nb, Cr-Al-Nb and Cr-Al-Ta for ethane ODH. Their results suggest that a fine composition mapping is necessary for discovery of new heterogeneous catalysts in the ternary systems [Liu, *et al.* 1998].

In this work, different Mo-V-Nb catalysts were prepared using Pd as a promoter over different supports. These catalysts are tested under various conditions of temperatures, flow rates. The study encompasses the effect of calcinations temperatures and supports on the catalyst performance. The final target is to develop oxidative dehydrogenation (Mo-V-Nb) catalyst, for oxidative dehydrogenation of ethane in order to maximize the activity and selectivity to ethylene.

Thermodynamics

The main reaction equations describing the oxidative dehydrogenation process are summarized:

$$C_2H_6 + 1/2\ O_2 \rightarrow C_2H_4 + H_2O \quad (1)$$

$\Delta H\ 600\ ^0K$ = - 24.59 kcal/gmole C_2H_4

$$C_2H_6 + 3/2\ O_2 \rightarrow CH_3COOH + H_2O \quad (2)$$

$\Delta H\ 600\ ^0K$ = - 116.54 kcal/gmole

$$C_2H_6 + 5/2O_2 \rightarrow 2CO + 3H_2O \quad (3)$$

$\Delta H\ 600^0K$=- 90.13 kcal/gmole CO

$$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O \quad (4)$$

$\Delta H\ 600\ ^0K$ = -157.92 Kcal /gmole CO_2

Thus all the reactions are highly exothermic and mainly irreversible. Therefore, the kinetics of the reactions, which mainly depends on the reaction conditions and the catalyst, mainly influence the composition of the product.

Experimental

Preparation method

Impregnation method was used to prepare the catalysts in this study. 1.43 gm ammonium m-vanadate is dissolved in 75 ml distilled water while stirring and heating at 87^0C. Similarly, 2.394 gm niobium oxalate (21.5% Nb_2O_5) is dissolved in 75 ml distilled water while stirring and heating at 63^0C. The two solutions are mixed together while stirring and heating at 87^0C. After that, 3.69 gm oxalic acid powder is added to the final solution while stirring and heating at 88^0C. At this point, 5.38 gm ammonium p-molybdate is dissolved in to 75 ml distilled water stirring and heating at 60^0C. Then it is added to the former solution while stirring and heating at 85^0C. Now 0.1 gm of promoter (Pd) is added to the above solution. After this, 10 gm of support (activated carbon, silica, or alumina) is added to the Mo-solution while stirring and heating at 70° C for 45 min until water evaporate, then calcinations take place for 4 hr at 700° C. In the study of the effect of calcination furnace temperature is raise to 325^0C (1^0C/min) for 1.5 hr, two temperatures are tested (325,400 °C).

Experimental Set-Up

The experimental equipment used in this study is micro-reactor system as shown schematically in Fig. 1. The feed section contains three gas cylinders for oxygen, nitrogen and ethane. Gases coming from regulators pass through in-line filters (molecular sieves, 5A, to remove moisture and oil) are then introduced to the Mass Flow Controllers (MFC), obtained from Bronkhurst. The gases are mixed and passed to the reaction section. On line samples (reactor By-Pass) from the feed gas mixture are directed to gas chromatograph for analysis. The micro-reactor, overall length is 300 mm with inside diameter of 8 mm, is made of stainless steel and surrounded by heater. Surrounding temperature can be controlled. The temperature in the reactor is measured by a thermocouple located in the catalyst bed. The outlet from the reactor (bottom end) is passed through a back pressure regulator (BPR) to control the pressure in the reactor and the product gases from the BPR were sent to analysis section. Reaction products as well as feed mixture are analyzed on-line using Varian system model CP-3800 RGA gas chromatograph. Thermal conductivity detector (TCD) is used for analysis using Haysepe A Columns.

Evaluation

Catalyst is evaluated using a micro reactor with on-line gas chromatograph system. The conversion of the component i was calculated by dividing the number of moles of the component i reacted by the number of mole of the component i inlet to the reactor by using the following equation:

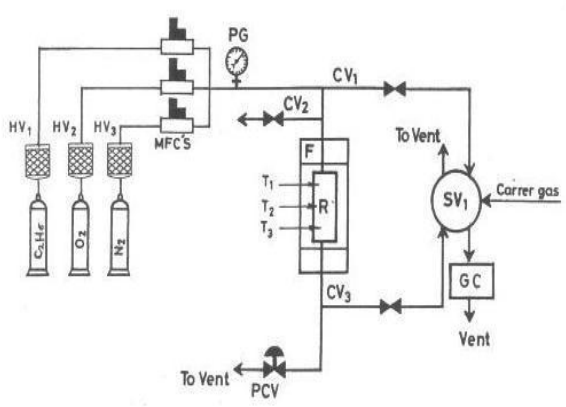

Fig. 1. Schematic experimental setup:
HV1, HV2 and HV3 = Filters, MFC'S = Mass flow controller, PG = Pressure guage;
CV1, CV2, CV3 = Shut-off vlaves, SV1 = Sampling valve, F = Furnace, R = Reactpr;
T1, T2, T3 = Temperature measurement thermocouple, GC = Gas chromatograph

$$Conversion = \frac{ni\,(in) - ni(out)}{ni\,(in)} \quad (5)$$

Where i = Ethane or Oxygen

The selectivity of the products is calculated by dividing the number of mole of the component (p) produced by the number of reacted ethane by using the following equation

$$\text{Selectivity} = \frac{np}{n_{C_2H_6}(\text{in}) - n_{C_2H_6}(\text{out})} \times 100 \quad (6)$$

Where $p = C_2H_4$, CH_3COOH, CO, CO_2

The yield of the products was calculated by multiplying the selectivity of the product by the conversion of ethane:

$$Yield\ p = Conversion\ C_2H_6\ \text{X}\ \ Selectivity\ P$$

$$Yield\ p = \frac{np}{n_{C_2H_6}(in)} \text{X}100 \quad (7)$$

Results and Discussion

The results for preparation and testing of promoted catalyst for ethane oxidative dehydrogenation to ethylene are presented. The study establishes the effect of the parameters, namely, calcination temperatures and supports on the performance of the Mo16V6.26Nb2.01Pd0.1 metal oxide catalyst.

Catalyst samples were tested under reaction condition at temperatures of 250, 280, 300 and 325°C, 14.7 psi of pressure, 30 ml/min.gm (F/W) and the oxygen/ethane feed ratio of 1/3.

Effect of Calcination Temperatures

Different catalysts (Mo-V-Nb), prepared with Pd promoter, were dried at 100 °C for 16 hrs and calcined at two different temperatures 325 °C and 400 °C for 1.5 hr. Testing the prepared catalysts, at four different temperatures (250, 280, 300 and 325 °C), atmospheric pressure, and feed flow rate of 15 ml/min, provided the results given in the following figures and tables. The purpose of calcination is to eliminate extraneous materials such as binders and un-wanted hydrocarbon as well as volatile and unstable anions and cations that have been previously introduced, but is not desired in the final catalysts. Furthermore, the degrees of removal of un-wanted materials also affect the performance of the catalyst. Removal of these un-wanted hydrocarbons depends on the procedure of the calcination such as temperature, duration and atmosphere [Desponds, *et al.* 1993]. Batches of mixed metal oxide catalysts with a composition of Mo16V6.26Nb2.01Pd0.1 were prepared at different calcination temperatures (325 and 400 °C). It is found that with increasing calcination temperatures: decreases (i) both C_2H_6 and O_2 conversions particularly at lower reaction temperatures. (ii) decreases C_2H_4 selectivity and yield. (iii) increases CO_x selectivity and yield. The conversion of C_2H_6 and O_2 obtained, for the catalyst Mo V Nb Pd calcined at the above selected temperatures and tested at 280 °C, are (0.89%, 0.46% and 99.9%, 99.6%) respectively as can be seen in Table 1. The results showed that increasing the calcination temperatures is not favorable. It is reported that the XRD pattern for catalyst Mo16V6.4Mn4W1 calcined above 360°C showed crystalline phases corresponding to V_2O_5, V_9O_4, and MoO_3 [Karim, *et al.*]. These phases seem to be crystallized out from the amorphous material of the catalyst at the higher temperature. Catalytic evaluation data shows that these crystalline phases have a negative impact on the activity of the catalyst. Ethane conversion drops significantly for catalyst calcined above 360°C. For ethane oxidation, the activity of the Mo Nb V type of mixed metal oxide catalyst depends on vanadium-containing defect molybdenum structure. , possibly a precursor of $Mo_4V_6O_{25}$ or $Mo_6V_9O_4$ or an amorphous phase It is reported in the literature that mixed metal oxide catalyst with high amount of defects or amorphous

Table 1. Summary of Experimental Runs - Calcination Temperature Effect on Mo16V6.26Nb2.01Pd0.1 catalyst (Drying Temperature: 100 °C for 16 hr, F/W: 30 ml/min.gm. Cat., P = 1 atm)

Catalyst	CalcinationTemp, °C	Rxn Temp. °C	C_2H_6 Conv.%	O2 Conv.%	C_2H_4 Selec.%	CO Yield	CH_4 Selec.%
T10	325	325	2.43	99.65	61.12	0.87	3.00
T10	325	300	1.56	99.71	72.87	0.42	0.00
T10	325	280	0.89	99.93	100.0	0.00	0.00
T10	325	250	0.23	73.36	58.91	0.09	0.00
T11	400	325	23.13	99.79	0.95	22.86	0.21
T11	400	300	0.77	100.0	30.66	0.45	10.65
T11	400	280	0.46	99.68	39.27	0.22	13.9
T11	400	250	0.23	44.81	89.32	0.02	0.00

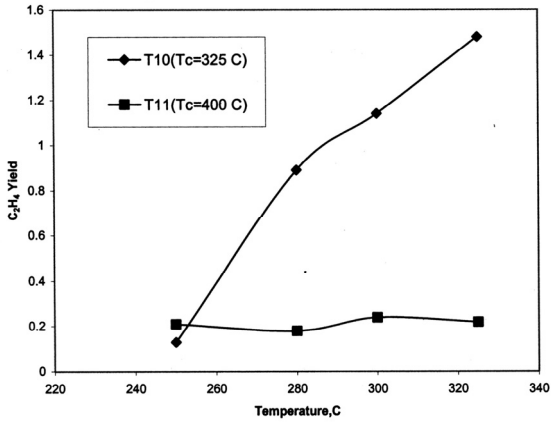

Fig. 2. Effect of Calcination temperature on C_2H_4 yield.

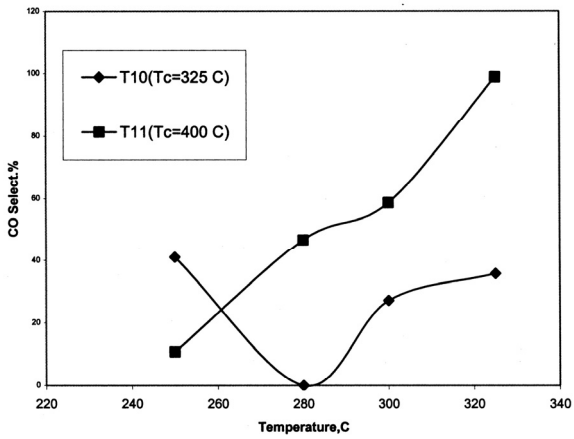

Fig. 3. Effect of Calcination Temperature on CO Selectivity.

phase are reported to have a high activity and selectivity to oxygenated products [Thorsteinson, *et al.* 1978, Ruth, *et al.* 1983]. Further, it is also known that transformation of phase from amorphous to crystalline cause a decrease in activity of the Mo V mixed oxide catalyst. From the results of Table 1 it is observed that increasing the calcination temperatures, decrease the catalyst activity. Figure3 shows clearly that yield of C_2H_4 reduces with the increase of calcination temperature. While Fig. 4 depicts that selectivity of undesired product CO increase with the increase of the calcination temperatures.

Effect of Supports ON Mo-V-Nb-Pd Catalyst

Different supports have been used in the preparation of Mo16V6.26Nb2.01Pd0.1 catalysts (alumina SA-5239, silica S151-10, and activated carbon). The catalysts were dried out at 100 °C for 16 hrs and calcined at 400 °C for 1.5 hrs. The catalytic activity was evaluated at 250, 280, 300, 325 °C using flow rate of 15 ml/min and atmospheric pressure. The results are presented in table 2. and shown in figures 4-6. Table 2 shows that catalyst T11 provides low C_2H_6 conversion except at 325 °C where the conversion shoots up. The unsupported T11 catalyst gives also higher O_2 conversion compared to all other catalysts as shown in Fig. 4. On the other way, T11 catalyst gives very low C_2H_4 selectivity therefore the C_2H_4 yield drops down. This decrease in C_2H_4 selectivity is accounted by an increase in CO selectivity which rends T11 catalyst quite undesirable at 325 °C. At lower temperature such as at 250°C, T11 catalyst has a very high selectivity towards C_2H_4 however this is accompanied by a very low C_2H_6 conversion which brings again very low yield in ethylene production. The Catalyst T21 shows very low conversion of C_2H_6 and O_2 compared to other catalyst. While it gives high C_2H_4 selectivity. The low C_2H_4 yield (maximum 0.3% at 325 °C) of catalyst T21 is due to low C_2H_6 conversion. In addition the catalyst T21 provides low CO_2 selectivity as well as CO_2 yield compared with other catalysts. The catalyst T22 provides low C_2H_6 conversion and higher O_2 conversion compared to other catalysts except T11. Moreover it shows higher C_2H_4 selectivity compared

Table 2. Summary of Experimental Runs - Support Effect on Catalyst Mo16V6.26Nb2.01Pd0.1 (Drying Temperature: 100 °C for 16 hr,Calcination Temp : 400 C for 1.5 hr, F/W: 30 ml/min.gm. Cat., P = 1 atm)

Catalyst	Support Used	Rxn Temp. C	C_2H_6 Conv.%	CO Selec.%	CO Yield
T11	No Support	325	23.13	98.83	22.86
T11	No Support	300	0.77	58.7	0.45
T11	No Support	280	0.46	46.83	0.22
T11	No Support	250	0.23	10.68	0.02
T21	SA-5239	325	0.31	5.51	0.02
T21	SA-5239	300	0.25	0.00	0.00
T21	SA-5239	280	0.06	0.00	0.00
T21	SA-5239	250	0.00	0.00	0.00
T22	SISI-10	325	0.99	26.7	0.26
T22	SISI-10	300	0.7	2.4	0.02
T22	SISI-10	280	0.09	0.00	0.00
T22	SISI-10	250	0.00	0.00	0.00
T23	Activated Carbon	325	1.42	42.5	0.60
T23	Activated Carbon	300	0.04	100	0.04
T23	Activated Carbon	280	0.02	100	0.02
T23	Activated Carbon	250	0.02	100	0.02

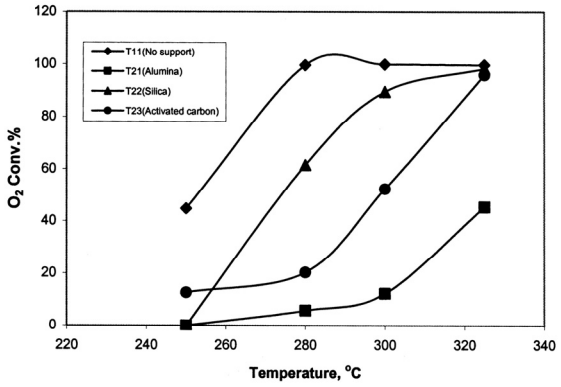

Fig. 4. Effect of support on O_2 conversion.

to other catalysts except at 325°C, where catalyst T21 gives higher C_2H_4 selectivity. The catalyst T22 also manifests very low CO_2 selectivity and yield. Catalyst T23, activated carbon support, shows low C_2H_6 and O_2 conversions, low C_2H_4 selectivity/yield and high CO_2 selectivity which make it undesirable for performance selection. The catalyst T22 of silica S151-10 improves the reaction selectivity to ethylene

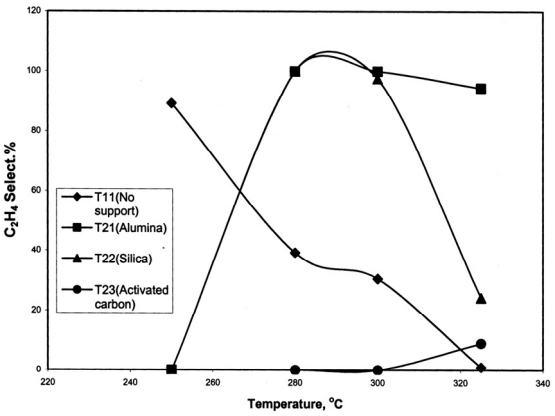

Fig. 5. Effect of support on C2H4 selectivity.

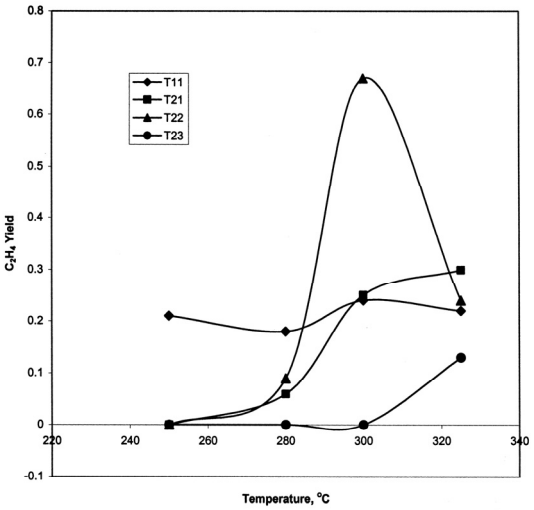

Fig. 6. Effect of support on C_2H_4 yield.

compared with unsupported catalyst that gives higher COx selectivity. Therefore, the catalyst T22 offer much better results (C_2H_4 yield as 0.67% at 300°C) compared to other catalysts

Conclusions

Different types Mo-V-Nb supported and unsupported catalysts for oxidative dehydrogenation of ethane reaction were prepared. The Palladium promoter was empolyed. The catalyst Mo-V-Nb-Pd was investigated using different supports, alumina (SA-5239), silica (S151-10) and activated carbon. Sensitivity analyses for the catalysts were carried out at different reaction temperatures. The results of the work lead to the following conclusions:

- ❖ It was found that, ethylene selectivity decreases by increasing the reaction temperature, while the selectivity of COx products increases with the increase of reaction temperature.

- ❖ It was found that higher calcination temperatures were not favorable not only due to low C_2H_6 and O_2 conversion, but also low C_2H_4 selectivity and yield and high CO_X selectivity and yield.
- ❖ Catalyst support with silica S151-10 gave better performance than catalyst supported with alumina SA-5239 and activated carbon

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دراسة حرارة الكلسنة والداعم على أداء حافز Mo-V-Nb لنزع الهيدروجين بالأكسدة في تحويل الإيثان للاثيلين

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الكلمات المفتاحية: الكلسنة، Mo-V-Nb، الدواعم، الأكسدة النازعة للهيدروجين، بلاديوم.

ملخص البحث. إن تطوير وتنفيذ حافز Mo-V-Nb المناسب والنشط الانتقائي في الإيثان المؤكسد لنزع الهيدروجين قد استخدم نظام مفاعل صغير لهذه الدراسة. وقد استخدم نظام الترطيب لتحضير المحفزات. وأظهرت الدراسة تأثير اثنين من المعاملات هي حرارة الكلسنة والمدعمات وقد تم اختبارها في حالة تفاعل عند درجات الحرارة الاتية٣٢٥,٢٨٠,٢٥٠و ٣٠٠ مئوية وعند ضغط ١٤,٧رطلا في البوصة المربعة وكانت نسبة تغذية الأوكسجين والايثين١ : ٣ . كذلك استخدمت مدعمات مختلفة وهي الالومينا (SA-5239) والسيلكا,(S151-10) والكربون المنشط .كذلك تمت إضافة البلاديم كعامل تنشيط. وقد أجريت اختبارات الحساسية للمحفزات في درجات حرارة مختلفة. ذات الشق)وقد أعطت المحفزات المدعومة بالسلكا أداء أفضل من المحفزات المدعومة بالألومينا والكاربون المنشط. ومن جهة أخري فقد لوحظ ان إختيارية الاثلين تتدني بزيادة درجة حرارة التفاعل بينما تزداد منتجات الCOx مع زيادة درجة حرارة التفاعل .بالإضافة إلي ذلك أن درجة الكلسنة العالية غير مرغوبة ليس فقط بسبب انخفاض تحول الإيثان و الاؤكسجين بل أيضا بسبب انخفاض اختيارية الإيثلين وارتفاع تكون (Cox).