Journal of Engineering Physics and Thermophysics, Vol. 68, No. 5, 1995

TEMPERATURE-DEPENDENT EFFECTIVE THERMAL CONDUCTIVITY AND THERMAL DIFFUSIVITY OF CATALYSTS AND THEIR SUPPORTS IN VARIOUS GAS MEDIA AND IN VACUUM.

1. THERMAL CONDUCTIVITY AND THERMAL DIFFUSIVITY OF GRANULAR POROUS SUPPORTS AND CATALYSTS

Kh. Madzhidov

UDC 536.21

The basic characteristics of catalysts and their supports and the results of experimental studies of the thermal conductivity and thermal diffusivity of some supports and catalysts in the temperature range of 293–1073 K in vacuum ($P = 1.07$ Pa) and in an atmosphere of air, argon, nitrogen, helium, hydrogen and in a gas mixture ($0.2NH_3 + 0.3N_2 + 0.5H_2$) are reported. It is established that as the temperature rises in the all gas media and in vacuum the thermal conductivity and thermal diffusivity of a burden of the catalysts and their supports increase according to a linear law and depend on the size and shape of the granules rather than on their specific surface.

Numerous works, which are reviewed in [1-5], are devoted to theoretical and experimental studies of heat transfer in granular systems.

Up to now, the thermophysical properties of granular aluminum oxide-based catalysts containing various metal fillers have not been studied, although they find wide application. We performed experimental studies of the thermophysical properties of granular porous catalysts and their supports as functions of the temperature, sizes, and shape of the granules, porosity, and specific surface in various gas media and in vacuum.

As a catalyst support, we used activated aluminum oxide, mainly of φ-modification, which consisted of porous granules of different sizes (from 0.8 to 4.0 mm diameter) and geometries (tablets, beads, cylindrical granules, granules of irregular shape).

To promote the catalytic activity of the porous granular aluminum oxide, its developed surface was coated with different metals whose nature is determined by the chemical reaction in which the catalysts are used. The latter in the form of porous grains with a specific surface of from tens to hundreds of m^2/g are employed in industrial processes, including the complete combustion of the exhaust gases of internal combustion engines of motor transport. Depending on the concentration and nature of the metal, the porous structure of supports, granule size, and the gas medium, the physical parameters of the catalysts vary widely.

To determine the influence of the structural parameters of the granules (free pore volume, surface area, pore distribution, pore size distribution) on the thermophysical characteristics, which are mainly determined in supported catalysts by the support as well as by the nature and concentration of the active component, i.e., the metal, we investigated supports and catalysts on their basis separately.

In the investigations, we used alumina supports synthesized from different source materials and differing in their granulometric composition, surface area, total voidage, and phase composition. The basic characteristics of the investigated supports are given in Table 1.

Support H-1 was prepared from the reprecipitated aluminium hydroxide of the pseudoboehmite structure and anhydrous alumina. It had a polydisperse structure with uniform pore size distribution within 1–100,000 nm in volume.

K. Dzhuraev Pedagogical University, Dyushambe, Uzbekistan. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 68, No. 5, pp. 799-809, September-October, 1995. Original article submitted October 7, 1993; revision submitted October 25, 1994.

TABLE 1. Basic Characteristics of the Investigated Supports

Support	Granule shape	Granule size d, mm	Specific surface S, m^2/g	Total voidage V, cm^3/g	Bulk density r, g/cm^3
H-1	Cylindrical	0.8–1.25	123	0.35	1.00
H-1	"	2–3	130	0.35	1.07
H-1	"	3–40	130	0.38	0.99
H-2	"	0.8–1.25	212	0.35	0.99
H-2	"	0.8–1.25	148	0.40	1.01
H-2	"	0.8–1.25	116	0.40	0.99
H-2	"	2–3	315	0.40	0.98
H-2	"	2–3	207	0.38	1.01
H-2	"	2–3	197	0.39	1.01
H-2	"	2–3	117	0.36	1.02
H-2	"	3–4	183	0.43	0.95
H-2	Tubular	1.5–2	250	0.37	0.77
H-3	Spherical	1–2	90	0.35	0.91
H-3	"	2–3	100	0.34	0.85
H-3	"	3–4	80	0.32	0.90
H-4	Cylindrical	2–3	190	0.75	0.69

Support H-2 was prepared from reprecipitated aluminum hydroxide of pseudoboehmite structure and technical-grade aluminum hydroxide of hydroargillite structure. It is characterized by uniform pore size distribution with micropores predominating (from 1 to 10 nm). As compared with H-1, H-2 has the advantage of a specific surface and resistance to destruction in the composition of catalysts under operation conditions.

Unlike alumina supports H-1 and H-2, H-3 is a two-component composite consisting of aluminum nitride and aluminum oxide with a uniform pore size distribution.

Support H-4 was prepared from reprecipitated aluminum hydroxide of pseudoboehmite structure and aluminum oxide obtained by calcination of this hydroxide at 400°C. In comparison with the above supports, H-4 had a considerably larger total voidage: 0.65–0.80 cm^3/g and, correspondingly, a smaller bulk weight, i.e., 0.8–0.65 g/cm^3. The size pore distribution was uniform.

The general method of preparation of the investigated supported catalysts (independently of the metal nature) consists in single or multiple impregnation of porous supports by an aqueous solution of salts containing the active component, i.e., the metal. To decompose the salts, the impregnated supports are subjected to heat treatment in air or in an inert gas and then in hydrogen, during which the decomposed salts are reduced to metals [6]. The final temperatures of decomposition and reduction of such salts are usually 523–773 K. One of the main stages in catalyst preparation is passivation of the reduced catalyst, at temperatures of from 323 K to room temperature, which contains no more than 1% of oxygen by volume. A passivation stage is necessary for removal of the adsorbed hydrogen from the metal surface and prevention of its uncontrollable oxidation upon discharging from the air reduction reactor.

Thus, catalysts represent a dispersed metal distributed over the support surfaces. The structure of the catalysts is mainly a replica of the porous structure of the supports with the exception of the micropores wherein the metal resides. The mechanical strength of the catalysts is also determined by that of supports.

Catalysts are used in the catalytic reactors of various engines. The main characteristics of the investigated catalysts are given in Tables 2 and 3.

TABLE 2. Basic Characteristics of the H-1-Supported Catalysts with 0.8–1.25 mm Sizes of Cylindrical Granules

Metal concentration n, %	Specific surface S, m^2/g	Total voidage V, cm^3/g	Bulk density ρ, g/cm^3
Iridium catalysts			
5	108	0.31	1.159
10	106	0.28	1.252
15	102	0.26	1.295
20	90	0.25	1.407
25	87	0.22	1.522
31.6	79	0.20	1.556
Nickel catalysts			
6.4	121	0.29	1.096
9.3	117	0.28	1.148
14.2	107	0.24	1.213
20.4	95	0.21	1.338
25.1	75	0.18	1.430
30.0	70	0.15	1.561
Copper catalysts			
4.5	119	0.31	1.013
12.0	112	0.27	1.022
15.5	105	0.26	1.148
18.6	100	0.25	1.186
23.4	99	0.22	1.277
28.8	84	0.20	1.344
Cobalt catalysts			
6.5	117	0.28	1.073
11.4	105	0.26	1.162
15.7	85	0.24	1.277
19.4	83	0.21	1.376
25.0	72	0.15	1.459
30.0	49	0.11	1.671
Ruthenium catalysts			
7	92	0.246	1.146
11	92	0.224	1.178
15	93	0.213	1.258

The physicochemical properties of the investigated catalysts were determined by the following methods [7]: specific surface – chromatographically with accuracy to 20% by the method of thermal desorption of argon; total voidage – in terms of the moisture content by the filtration method with an accuracy to 10%; bulk density – by measuring a volume of known weight after material compaction in a vibrator as well as with the aid of a pycnometer with an error of 1.5%.

The thermal conductivity and the thermal diffusivity of the investigated catalysts and supports in different gas media and in vacuum were determined in experimental setups using a cylindrical bicalorimeter and an acalorimeter of a regular thermal regime [8, 9].

TABLE 3. Basic Characteristics of the Catalysts

Support	Granule size	Active metal concentration, %	Specific surface S, m^2/g	Total voidage V, m^3/g	Bulk density ρ, g/cm^3	Mechanical strength, kg/granule
H-1	2–3	Ir, 31.2	89	0.20	1.557	6.0
H-1	3–4	Ir, 31	87	0.20	1.615	9.0
H-1	2–3	Ir, 10	122	0.29	1.271	5.0
H-1	2–3	Ir, 20	105	0.24	1.458	7.0
H-1	2–3	Ru, 20	90	0.22	1.393	6.0
H-1	0.8–2	Ru, 20	80	0.20	1.359	–
H-1	2–3	Co, 12	100	0.24	1.250	7
H-1	2–3	Ni, 12	110	0.28	1.314	–
H-1	2–3	Ni, 20	100	0.24	1.491	–
H-1	2–3	Ni, 30	80	0.20	1.671	–
H-2	1.25–1.5	Ir, 31.7	150	0.20	1.500	–
H-2	2–3	Ir, 31.9	160	0.20	1.480	5
H-3	1–2	Ir, 10	82	0.29	1.064	7
H-3	1–2	Ir, 20	73	0.26	1.189	8
H-3	1–2	Ir, 30	62	0.22	1.298	9
H-3	2–3	Ir, 10	85	0.32	0.958	11
H-3	2–3	Ir, 20	76	0.27	1.111	13
H-4	0.8–1.25	Cu, 50	70	0.20	1.366	7
H-4	2–3	Cu, 50	70	0.20	1.440	7
H-4	2–4	Pt+Ir, 0.5+0.5	90	0.20	0.800	8
H-4	2–4	Pt+Ir, 4+16	90	0.20	0.98	6

TABLE 4. Thermal Conductivity and Thermal Diffusivity of the Supports versus Granule Size in Air ($\lambda \cdot 10^3$, W/(m·K) and $a \cdot 10^7$, m^2/sec)

Support	Thermal conductivity and thermal diffusivity	Granule size, mm			
		0.8–1.25	2–3	3–4	1.5–2
H-1	λ	168	174	188	
	a	1.58	1.65	1.76	
	λ	184	208	222	190^{t}
	a	1.83	2.06	2.35	2.44^{t}
	λ	241	251	268	
	a	2.43	2.63	2.85	
	λ		163		
	a		2.20		

Note: t, tubular granules.

TABLE 5. Thermal Conductivity ($\lambda \cdot 10^3$, W/(m·K)) of Support H-2 versus Temperature and Granule Size in Different Gas Media and Vacuum

T, K	Vacuum (P = 1.07 Pa)	Argon	Nitrogen	Helium	Hydrogen	Nitrous oxide
			0.8–1.25 mm			
295.1	58	180	186	400	450	182
386.3	64	188	200	426	478	193
489.4	70	205	222	446	511	213
593.7	74	217	236	486	548	228
682.6	81	224	260	505	570	237
780.9	84	237	270	530	600	252
891.2	91	251	288	565	642	270
			2–3 mm			
292.6	64	189	202	417	470	295
390.2	69	202	224	441	497	213
503.7	76	217	240	473	543	229
663.5	83	232	268	512	576	250
776.6	89	250	280	542	625	265
904.7	95	272	306	579	670	289
			3–4 mm			
292.6	65	195	218	426	482	209
384.6	69	209	237	452	514	225
478.3	74	224	257	478	537	241
586.7	82	233	270	500	580	252
696.8	89	252	292	537	610	274
792.9	94	260	315	560	650	284
904.9	97	277	328	586	678	300
			1.5–2 mm with tubular granules			
292.7	57	177	185	385	453	181
283.4	61	186	200	410	480	193
490.3	67	200	218	440	521	209
594.9	72	212	232	464	555	222
680.6	78	226	245	494	575	236
784.2	84	238	267	514	617	252
896.8	89	248	280	540	642	246

An analysis of the possible errors in thermal conductivity and diffusivity measurements has shown that the general relative error does not exceed 5.4 and 5.2%, respectively, at a confidence coefficient of $\alpha = 0.95$.

To determine the influence of the support's nature on the thermophysical properties of the catalysts with an extended specific surface, we investigated the thermal conductivity λ and the thermal diffusivity a of some supports as functions of their fractions in the different gas media (argon, nitrogen, helium, and hydrogen) at atmospheric pressure and in vacuum (P = 1.07 Pa) in the temperature range of 293–1073 K.

Table 4 contains experimental data on the thermal conductivity and the thermal diffusivity of the investigated supports in air. As is seen, for the all investigated supports the thermal conductivity and the thermal diffusivity increase with granule size.

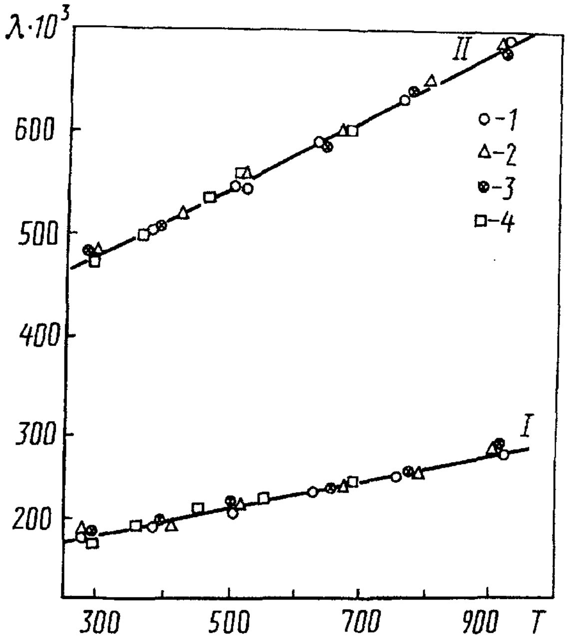

Fig. 1. Thermal conductivity of burden of support H-2 as a function of temperature in atmospheres of argon (I) and hydrogen (II) with different specific surfaces (m^2/g): 1) 117; 2) 197; 3) 209; 4) 315. $\lambda \cdot 10^3$, W/(m·K); T, K.

Of the supports with the same granule shape and size, H-4 has the lowest thermal conductivity, while H-1 has the lowest thermal diffusivity and H-4 has the highest thermal diffusivity and H-2 has the highest thermal conductivity. The thermal conductivity and diffusivity of H-3 with spherical granules are much higher than λ and a of the other supports.

Experimental data obtained on the thermal conductivity of the investigated supports versus temperature in the various gases and in vacuum are presented in Table 5.

An increase in the temperature in all gas media and in vacuum causes a linear increase in the thermal conductivity and the thermal diffusivity. The smallest rise is observed in vacuum.

A linear increase in the thermal conductivity with a temperature rise has been also established by V. S. Nikitin in experimental studies of different fractions of cast iron and slag beads in vacuum ($P = 1 \cdot 10^{-4}$ mm Hg) and in different gas media (air, carbon dioxide, helium) in the temperature range of 293–1273 K by the stationary method of coaxial cylinders [5].

The thermal conductivity and the thermal diffusivity of H-3 is higher in all the gas media and in vacuum over the entire investigated temperature range than λ and a of H-1, H-2, and H-4 with the same granule size.

To determine the influence of granule shape on thermal conductivity and thermal diffusivity, we investigated λ and a of support H-2 with grains that are 1.5-2-mm hollow cylindrical granules (tubes). The investigations revealed that H-2 with hollow cylindrical granules has the same thermal conductivity as the same support but with solid cylindrical granules of the same size. The thermal diffusivity of the support with hollow cylindrical granules is much higher than that of the support with solid granules.

To establish the dependence of the thermal conductivity and diffusivity of the supports on the specific surface, we investigated λ and a of H-2 having the same granule size but the different specific surfaces. The specific surface of the supports varied from 315 to 116 m^2/g.

As the investigations have revealed, the thermal conductivity and the thermal diffusivity of supports with the same granule size are independent of their specific surface. To illustrate this, Fig. 1 shows the thermal conductivity of H-2 supports with different specific surfaces as a function of temperature in atmospheres of argon and hydrogen. As is seen, the departure of experimental data for supports with different specific surfaces from a general straight line is within the limits of experimental error.

TABLE 6. Thermal Diffusivity ($a \cdot 10^7$, m^2) of Iridium Catalysts versus Temperature, Weight Concentration of the Metal, and Granule Size in Different Gas Media and Vacuum

T, K	Vacuum (P = 1.07 Pa)	Argon	Nitrogen	Helium	Hydrogen
0,8–1,25 mm; H-1 + 10% Ir					
292,9	0,56	1,67	1,79	3,75	4,37
363,8	0,58	1,71	1,84	3,80	4,44
513,6	0,60	1,79	1,93	3,92	4,59
686,5	0,64	1,87	2,05	4,08	4,77
796,8	0,66	1,93	2,13	4,17	4,89
903,7	0,68	1,99	2,21	4,26	5,01
1011,8	0,71	2,05	2,28	4,36	5,12
0,8–1,25 mm; H-1 + 20% Ir					
296,4	0,65	1,74	1,93	4,08	4,81
357,4	0,66	1,79	1,97	4,12	4,86
458,5	0,68	1,85	2,04	4,20	4,94
557,5	0,71	1,92	2,10	4,27	5,03
787,4	0,76	2,09	2,26	4,42	5,21
835,5	0,78	2,13	2,30	4,46	5,25
960,8	0,81	2,22	2,38	4,54	5,35
1039,0	0,83	2,28	2,43	4,59	5,42
2–3 mm; H-1 + 10% Ir					
298,0	0,61	1,72	1,84	3,84	4,50
350,4	0,62	1,75	1,88	3,88	4,55
429,8	0,63	1,79	1,94	3,96	4,66
562,4	0,66	1,87	2,02	4,05	4,76
663,2	0,68	1,93	2,10	4,16	4,87
765,8	0,71	1,98	2,18	4,25	4,99
833,0	0,73	2,02	2,23	4,30	5,04
964,4	0,75	2,09	2,30	4,40	5,18
1070,4	0,77	2,15	2,39	4,50	5,30
2–3 mm; H-1 + 20% Ir					
293,0	0,67	1,85	2,08	4,24	4,95
434,8	0,71	1,97	2,19	4,36	5,06
515,0	0,73	2,05	2,23	4,40	5,15
688,5	0,78	2,16	2,33	4,55	5,28
793,0	0,80	2,26	2,42	4,60	5,39
871,5	0,83	2,31	2,97	4,66	5,43
968,7	0,86	2,39	2,54	4,74	5,52
1068,2	0,88	2,48	2,60	4,81	5,60
2–3 mm; H-1 + 31,2% Ir					
298,0	0,78	2,20	2,24	4,50	5,16
411,2	0,81	2,10	2,35	4,57	5,25
606,3	0,86	2,23	2,48	4,70	5,41
705,5	0,88	2,35	2,56	4,75	5,50
818,1	0,91	2,42	2,67	4,82	5,62
929,2	0,94	2,54	2,75	4,92	5,71
1030,0	0,97	2,60	2,86	4,99	5,79
3–4 mm; H-1 + 31% Ir					
295,5	0,80	2,12	2,35	4,61	5,31
411,0	0,83	2,21	2,44	4,69	5,40
495,5	0,85	2,30	2,51	4,73	5,48
585,9	0,88	2,36	2,60	4,84	5,58
703,0	0,91	2,45	2,70	4,89	5,69
818,8	0,94	2,58	2,78	4,98	5,80
925,1	0,97	2,65	2,88	5,03	5,88
1043,5	1,00	2,76	3,00	5,13	6,00

Thus, the thermal conductivity and the thermal diffusivity of the supports depend on their grade, granule size, and temperature rather than on their specific surface.

Moreover, with an increase in the metal content and the granule size, the thermal conductivity and the thermal diffusivity of the all catalysts increase. It is pertinent to note that the addition of metallic fillers changes the thermal conductivity and diffusivity of the catalysts insignificantly. According to [10, 11], at a temperature of 300 K the thermal conductivity of copper, iridium, ruthenium, nickel, and cobalt is greater by a factor of 2339, 875, 696, 517, and 548 and their thermal diffusivity is greater by a factor of 708, 318, 255, 161, and 145 higher than λ and a of a burden of support H-1, but adding 12% copper, 10% iridium, 10.7% ruthenium, 9.3% nickel,

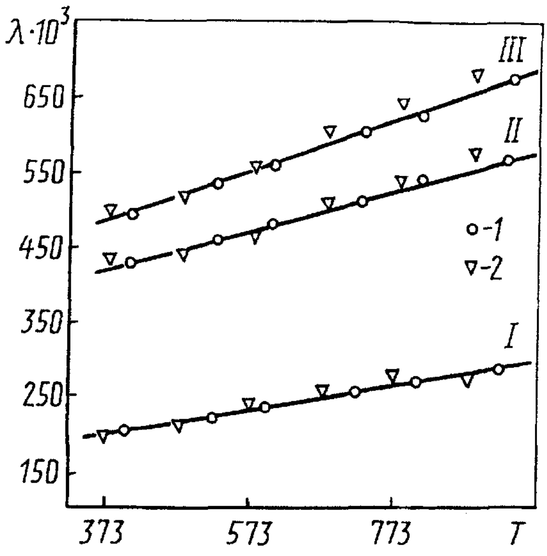

Fig. 2. Comparison of experimental data on the thermal conductivity of a cobalt catalyst containing 15.7 wt. % cobalt with granule sizes of 0.8 to 1.25 mm versus temperature in gas media obtained by the methods of a regular thermal regime (1) and momotonic heating (2): I, nitrogen; II, helium; III, hydrogen.

and 11.4% cobalt causes an increase in the thermal conductivity of support H-1 with 0.8–1.25 mm granules by only 14.9%, 10.7, 5.71, 5.95, and 3%, respectively, and its thermal diffusivity by 16.5%; 1.5.2; 5.7; 3.2, and 2.5%. Apparently, this is due to the fact that the metal precipitated on the H-1 surface forms separate crystal clusters (with sizes of 30 to 60 Å) that are separated from each other by a granular substance with poor thermal conductivity. Even in a more concentrated sample containing 31.6% metal, approximately 40–45% of the support surface is coated with the metal.

Naturally, such metallic impurities cannot make an appreciable contribution to the effective thermal conductivity. This explains the insignificant contribution of the metal distributed over the support surface to the thermal conductivity and to the thermal diffusivity. Moreover, it should be noted that the higher the thermal conductivity and thermal diffusivity of the metal admixtures, the stronger their effect on changing λ and a of the catalyst burden. For instance, the addition of 28.8% copper yields an increase in the thermal conductivity and the thermal diffusivity of a burden of support H-1 with 0.8–1.25 mm granules by 47 and 44.3%, respectively, while the addition of 30% cobalt causes their increase by 28 and 7%, respectively.

Experimental data obtained on the thermal diffusivity of some H-1-supported catalysts in different gas media and in vacuum are given in Table 6. With a temperature rise, the thermal conductivity and the thermal diffusivity of the catalysts increase linearily in all the gas media and in vacuum. The lowest rise in thermal conductivity with temperature is observed for all the catalysts in vacuum.

According to the results obtained, the thermal conductivity of the investigated catalysts and supports is far in excess of that of the gas that fills the pores and the space between granules.

Figure 2 shows data on the thermal conductivity of a copper catalyst containing 15.7 wt. % metal as a function of the temperature in different gas media that were obtained by the methods of a regular thermal regime [8] and monotonic heating [12]. The results obtained by different methods are seen to coincide, thus pointing to the reliability of the experimental data.

To reveal the support's effect on the thermophysical properties of the catalyst, we investigated the thermal conductivity and the thermal diffusivity of H-2-supported iridium catalysts in the temperature range of 293.7–898.2 K in vacuum ($P = 1.07$ Pa) and in atmospheres of air, argon, nitrogen, helium, hydrogen, nitrous oxide, and a gas mixture ($0.2NH_3 + 0.3N_2 + 0.5H_2$) at atmospheric pressure.

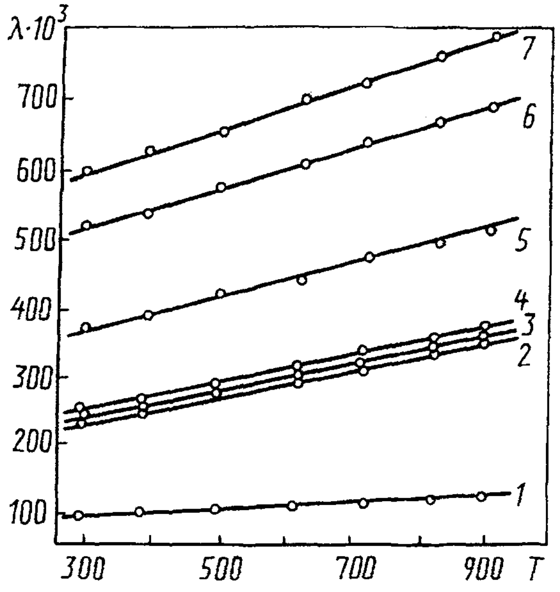

Fig. 3. Thermal conductivity of burden of H-2-supported iridium catalyst with a granule size of 1.5 to 2 mm containing 31.7% of the metal versus temperature in different gas media and vacuum: 1) vacuum (P = 1.07 Pa); 2) argon; 3) nitrous oxide; 4) nitrogen; 5) gas mixtures ($0.2NH_3 + 0.3N_2 + 0.5H_2$); 6) helium; 7) hydrogen.

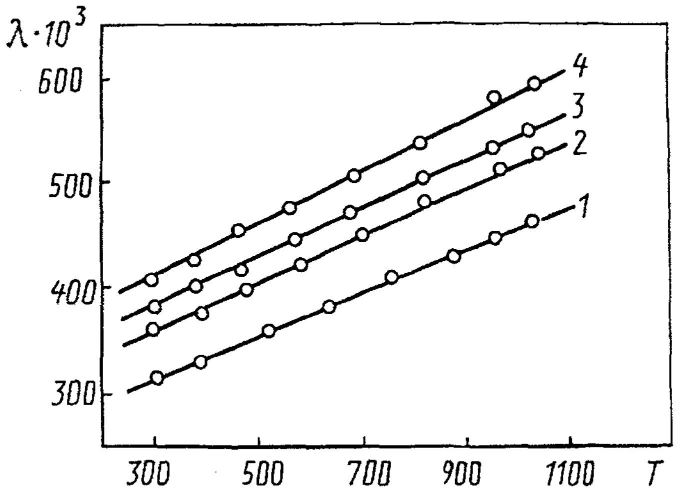

Fig. 4. Thermal conductivity of burden of iridium catalysts and support H-3 with a granule size of 1–2 mm versus temperature in the gas mixture ($0.2NH_3 + 0.3N_2 + 0.5H_2$): 1) H-3; 2) H-3 + 10% Ir; 3) H-3 +20% Ir; 4) H-3 + 30% Ir.

Figure 3 shows the thermal conductivity of H-2-supported iridium catalyst as a function of temperature. It is seen that with a temperature rise λ increases linearily in all the gas media and in vacuum. The lowest λ and a of the catalysts are found in vacuum, while the highest values pertain to a hydrogen atmosphere.

The investigations demonstrated that the growth of the thermal conductivity of the catalysts with a temperature increases as λ of the gas-filler becomes higher. For instance, with an increase in temperature by 1 deg, the thermal conductivity of the catalyst with 1.5–2-mm granules increases in different media as follows: in vacuum by $6.65\cdot10^{-5}$; in argon by $19.5\cdot10^{-5}$; in nitrous oxide by $19.7\cdot10^{-5}$; in nitrogen by $20.9\cdot10^{-5}$; and in hydrogen by $32.1\cdot10^{-5}$ W/(m·K).

A comparison of the experimental data on λ and a of the H-2-supported catalysts with those of the H-1-supported catalysts containing the same amount of metallic admixtures and on granule sizes has shown that the thermal conductivity and the thermal diffusivity of the H-2-supported catalysts are higher in all the gas media and in vacuum in the investigated temperature range than λ and a of those based on support H-1.

It has been found that an increase in the thermal conductivity of the gas-filler causes an increase in λ and a of these catalysts with temperature. For instance, for the catalyst with 1–2-mm granules based on the H-3 support containing 20% iridium a 1-deg temperature increase makes the thermal conductivity (thermal diffusivity) in the various gas media increase as follows: in vacuum by $7.18 \cdot 10^{-5}$ W/(m·K) ($3.6 \cdot 10^{-11}$ m^2/sec); in argon by $13.2 \cdot 10^{-5}$ ($5.1 \cdot 10^{-11}$); in nitrous oxide by $16.8 \cdot 10^{-5}$ ($6.9 \cdot 10^{-11}$); in nitrogen by $24.4 \cdot 10^{-5}$ ($8.9 \cdot 10^{-11}$); in helium by $28.8 \cdot 10^{-5}$ ($10.9 \cdot 10^{-11}$); and in hydrogen by $33.6 \cdot 10^{-5}$ W/(m·K) ($11 \cdot 10^{-11}$ m^2/sec).

With an increase in the amount of metallic admixtures, the increase in the thermal conductivity and the thermal diffusivity of the investigated samples with temperature becomes somewhat pronounced. For instance, with a temperature increase by 1 deg, λ and a of the H-3 with 1–2-mm granules increase, respectively, in vacuum by $5.8 \cdot 10^{-5}$ W/(m·K) and $2.56 \cdot 10^{-11}$ m^2/sec but in helium by $27.6 \cdot 10^{-5}$ W/(m·K) and $7.32 \cdot 10^{-11}$ m^2/sec; for the catalyst containing 10% metal and having granules of the same size this change in vacuum and in helium is as follows: $6.5 \cdot 10^{-5}$ W/(m·K) ($3.2 \cdot 10^{-11}$ m^2/sec) and $28.2 \cdot 10^{-5}$ W/(m·K) ($10.5 \cdot 10^{-11}$ m^2/sec), for the catalyst with 1–2 mm granules containing 30% of the metal: $7.69 \cdot 10^{-5}$ W/(m·K) ($3.9 \cdot 10^{-11}$ m^2/sec) and $29.2 \cdot 10^{-5}$ W/(m·K) ($14 \cdot 10^{-11}$ m^2/sec).

Figure 4 shows λ of the iridium catalysts and support H-3 as a function of temperature. As is seen, H-3 has the lowest λ values, but with an increase in the metallic admixture concentration the thermal conductivity increases.

Thus, with an increase in the content of metallic impurities, λ and a of the H-3-supported catalysts increase in all the gas media and in vacuum. The thermal conductivity and the thermal diffusivity of the H-4-supported catalysts were investigated in the temperature range of 293.5–1054.6 K in air, argon, nitrogen, helium, hydrogen, and nitrous oxide at atmospheric pressure and in vacuum ($P = 1.07$ Pa). The thermal conductivity and the thermal diffusivity of these catalysts based on support H-4 are higher than λ and a of the other investigated catalysts in an atmosphere of gas-fillers and in vacuum.

REFERENCES

1. G. N. Dul'nev and Yu. P. Zarichnyak, Thermal Conductivity of Mixtures and Composites [in Russian], Leningrad (1974).
2. L. L. Vasil'ev and Yu. E. Fraiman, Thermophysical Properties of Poor Heat Conductors [in Russian], Minsk (1967).
3. G. N. Dul'nev, Inzh.-Fiz. Zh., 19, No. 3, 562-577 (1970).
4. A.F. Chudnovskii, Thermophysical Characteristics of Dispersed Materials [in Russian], Moscow (1962).
5. V. S. Nikitin, Investigation of the Effective Thermal Conductivity of a Burden of the Dispersed-Material at Elevated Temperatures [in Russian], Candidate's Thesis, Minsk (1969).
6. I. P. Mukhlenov, E. I. Drobkina, V. I. Deryukina, and V. E. Soloko, Production of Catalysts [in Russian], Leningrad (1979).
7. Zh. D. Galimov, G. G. Dubinina, and R. M. Masagutov, Methods of Analysis of Oil Refining Catalysts [in Russian], Moscow (1973).
8. Kh. Madzhidov, M. M. Safarov, and T. P. Gaidei, Zh. Fiz. Khim., 58, No. 1, 75-79 (1984).
9. Kh. Madzhidov and M. M. Safarov, Teplofiz. Vys. Temp., 21, No. 4, 693-696 (1983).
10. A. I. Pekhovich and V. M. Zhidkikh, Calculations of the Thermal Regime of Solids [in Russian], Leningrad (1968).
11. V. E. Zinov'ev, Kinetic Properties of Metals at High Temperatures [in Russian], Moscow (1984).
12. Kh. Madzhidov, S. Zubaidov, M. M. Safarov, et al., Priborostroenie, No. 12, 82-85 (1989).