



REFERENCES

- Audeh, C.A. Process for removing residual mercury from liquid hydrocarbons with aqueous polysulfide solution. U.S Patent 4.880.527 (1989).
- Audeh, C.A. Use of polysulfide treated molecular sieves to remove mercury from liquefied hydrocarbon. U.S Patent 4.877.515 (1989).
- Bond, G.C. Heterogeneous catalysis: Principle and applications. Great Britain: Clarendon Press. (1982).
- Cameron, C. Method of eliminating mercury or arsenic from a fluid in the presence of a mercury and/or arsenic recovery mass. U.S Patent 5.245.106 (1993).
- Chao, C.C. Adsorbent compositions. U.S Patent 4.474.896 (1984).
- Courty, P.H. et al. Process for eliminating mercury and possibly arsenic in hydrocarbons. U.S Patent 5.401.392 (1984).
- Furuta, A. Removal of mercury from a liquid hydrocarbon. Eur. Pat. Appl. EP 3352.420 (1988)
- Furuta, et al. Method for removing mercury from a liquid hydrocarbon. U.S. Patent number 4.946.596 (1990).
- Leeper, J.E. Mercury -LNG plant's problem. Hydrocarbon processing 59 (1980):237-240
- McNamara, James D. Product/Process/Application for removal of mercury from liquid hydrocarbon, U.S. Patent number 5.336.835 (1994).
- Morales, A. et al. Poisoning effect on kinetic of the cyclopentane hydrogenolysis reaction on platinum-alumina catalysts. Act.Cient.Venez.4:373-376, of Chemical Abstract no. 93 (1979):185,450a.
- Ou , J.D.Y., Mercury removing Compound by dispersed-metal adsorbents, PCT Int. Appl. WO 91 15.559 (1990)
- Pongsiri, N. Initiatives on Mercury, Society of Petroleum Engineers. SPE 54523 (February 1999).
- Sokol'skii, D.V. et al. Study of palladium catalyst poisoning in the liquid-phase hydrogenation of phenylacetylene. Dokl.Akad.Nauk SSSR3: 674-678, of Chemical Abstract no. 97 (1982).

- Soontaranurak, K. Removal of mercury compounds from liquid hydrocarbon by hydrodemetallation. Master thesis of Engineering faculty, Chulalongkorn University (1998).
- Tantichaipakorn, P. Removal of mercury and arsenic compounds from liquid hydrocarbon by adsorption on Ni-Cu adsorbents. Master thesis of Engineering faculty, Chulalongkorn University (1998)
- Torihata, T.K. Method of removing mercury from hydrocarbon oils. Eur.Pat.Appl.EP 325.486 (1988).
- Torihata, T. and Kawashimura, E. Method of removing mercury from hydrocarbon oils. Eur.Pat.Appl.EP 342.898 (1989).
- Torihata, T. and Kawashima, E. Method of removing mercury from hydrocarbon oils. Eur.Pat.Appl EP 325.486 (1989).
- Wilhelm, S.M. and Bloom, N. Mercury in petroleum, Fuel processing technology 63 (2000) :1-27.
- Yan, T.Y. Process for removing mercury from water or hydrocarbon Condensate. U.S. Patent 4.962.276 (1990).
- Yan, Reaction of trace mercury in natural gas with dilute polysulfide solution in a packed bed column, Ind. Eng. Chem. Res. 30,12 (1991).

APPENDICES

APPENDIX A

Details and results of each experiment

Exp.no.	Type of mercury	Type of adsorbent	Temp (°C)	Ini. Conc. ppb	Product Conc. ppb	mercury deposition 10^{-6} g of Hg/g ads
1	HgCl ₂	SiO	30	1006.9	894.9	11.2
2	HgCl ₂	SiO	30	952.2	840.2	11.2
3	HgCl ₂	SiO	30	950.4	845.4	10.5
4	HgCl ₂	SiO	50	1006.9	871.9	13.5
5	HgCl ₂	SiO	50	952.2	826.2	12.6
6	HgCl ₂	SiO	50	950.4	819.4	13.1
7	HgCl ₂	SiO	70	1006.9	863.9	14.3
8	HgCl ₂	SiO	70	952.2	814.2	13.8
9	HgCl ₂	SiO	70	950.4	810.4	14.0
10	HgCl ₂	SiO	70 (desorbed)	0	61	6.1
11	DPM	SiO	30	1018.7	966.7	5.2
12	DPM	SiO	30	946.5	895.5	5.1
13	DPM	SiO	30	987.4	939.4	4.8
14	DPM	SiO	50	1018.7	937.7	8.1
15	DPM	SiO	50	946.5	862.5	8.4
16	DPM	SiO	50	987.4	912.4	7.5
17	DPM	SiO	70	1018.7	907.7	11.1
18	DPM	SiO	70	946.5	839.5	10.7
19	DPM	SiO	70	987.4	874.4	11.3
20	DPM	SiO	70 (desorbed)	0	29	2.9
21	HgCl ₂	NiO	30	1006.9	843.9	16.3
22	HgCl ₂	NiO	30	952.2	788.2	16.4
23	HgCl ₂	NiO	30	950.4	798.4	15.2
24	HgCl ₂	NiO	50	1006.9	775.9	23.1
25	HgCl ₂	NiO	50	952.2	718.2	23.4
26	HgCl ₂	NiO	50	950.4	724.4	22.6

Details and results of each experiment (continued)

Exp.no.	Type of mercury	Type of adsorbent	Temp (°C)	Ini. Conc. ppb	Product Conc. ppb	mercury deposition 10^{-6} g of Hg/g ads
27	HgCl ₂	NiO	70	1006.9	721.9	28.5
28	HgCl ₂	NiO	70	952.2	661.2	29.1
29	HgCl ₂	NiO	70	950.4	657.4	29.3
30	HgCl ₂	NiO	70 (desorbed)	0	58	5.8
31	DPM	NiO	30	1018.7	882.7	13.6
32	DPM	NiO	30	946.5	804.5	14.2
33	DPM	NiO	30	987.4	846.4	14.1
34	DPM	NiO	50	1018.7	822.7	19.6
35	DPM	NiO	50	946.5	757.5	18.9
36	DPM	NiO	50	987.4	799.4	18.8
37	DPM	NiO	70	1018.7	787.7	23.1
38	DPM	NiO	70	946.5	719.5	22.7
39	DPM	NiO	70	987.4	755.4	23.2
40	DPM	NiO	70 (desorbed)	0	28	2.8
41	HgCl ₂	CrO	30	1052.6	928.6	12.4
42	HgCl ₂	CrO	30	1050.9	935.9	11.5
43	HgCl ₂	CrO	30	964.3	844.3	12.0
44	HgCl ₂	CrO	50	1052.6	906.6	14.6
45	HgCl ₂	CrO	50	1050.9	909.9	14.1
46	HgCl ₂	CrO	50	964.3	829.3	13.5
47	HgCl ₂	CrO	70	1052.6	900.6	15.2
48	HgCl ₂	CrO	70	1050.9	903.9	14.7
49	HgCl ₂	CrO	70	964.3	813.3	15.1
50	HgCl ₂	CrO	70 (desorbed)	0	67	6.7
51	DPM	CrO	30	1024.3	213.3	81.1
52	DPM	CrO	30	968.2	156.2	81.2
53	DPM	CrO	30	977.6	100.6	87.7
54	DPM	CrO	50	1024.3	198.3	82.6
55	DPM	CrO	50	968.2	153.2	81.5

Details and results of each experiment (continued)

Exp.no.	Type of mercury	Type of adsorbent	Temp (°C)	Ini. Conc. ppb	Product Conc. ppb	mercury deposition 10^{-6} g of Hg/g ads
56	DPM	CrO	50	977.6	158.6	81.9
57	DPM	CrO	70	1024.3	150.3	87.4
58	DPM	CrO	70	968.2	97.2	87.1
59	DPM	CrO	70	977.6	109.6	86.8
60	DPM	CrO	70 (desorbed)	0	38	3.8
61	HgCl ₂	FeO	30	1052.6	901.6	15.1
62	HgCl ₂	FeO	30	1050.9	897.9	15.3
63	HgCl ₂	FeO	30	964.3	817.3	14.7
64	HgCl ₂	FeO	50	1052.6	880.6	17.2
65	HgCl ₂	FeO	50	1050.9	886.9	16.4
66	HgCl ₂	FeO	50	964.3	790.3	17.4
67	HgCl ₂	FeO	70	1052.6	857.6	19.5
68	HgCl ₂	FeO	70	1050.9	859.9	19.1
69	HgCl ₂	FeO	70	964.3	776.3	18.8
70	HgCl ₂	FeO	70 (desorbed)	0	64	6.4
71	DPM	FeO	30	1024.3	613.3	41.1
72	DPM	FeO	30	968.2	555.2	41.3
73	DPM	FeO	30	977.6	571.6	40.6
74	DPM	FeO	50	1024.3	585.3	43.9
75	DPM	FeO	50	968.2	532.2	43.6
76	DPM	FeO	50	977.6	532.6	44.5
77	DPM	FeO	70	1024.3	516.3	50.8
78	DPM	FeO	70	968.2	456.2	51.2
79	DPM	FeO	70	977.6	466.6	51.1
80	DPM	FeO	70 (desorbed)	0	36	3.6
81	HgCl ₂	MoO	30	1036.2	772.2	26.4
82	HgCl ₂	MoO	30	997.8	736.8	26.1
83	HgCl ₂	MoO	30	956.5	698.6	25.8
84	HgCl ₂	MoO	50	1036.2	745.2	29.1

Details and results of each experiment (continued)

Exp.no.	Type of mercury	Type of adsorbent	Temp (°C)	Ini. Conc. ppb	Product Conc. ppb	mercury deposition 10^{-6} g of Hg/g ads
85	HgCl ₂	MoO	50	997.8	707.8	29.0
86	HgCl ₂	MoO	50	956.6	670.6	28.6
87	HgCl ₂	MoO	70	1036.2	684.2	35.2
88	HgCl ₂	MoO	70	997.8	644.8	35.3
89	HgCl ₂	MoO	70	956.6	612.6	34.4
90	HgCl ₂	MoO	70 (desorbed)	0	63	6.3
91	DPM	MoO	30	1044.2	552.2	49.2
92	DPM	MoO	30	1011.6	522.6	48.9
93	DPM	MoO	30	967.4	479.4	48.8
94	DPM	MoO	50	1044.2	423.2	62.1
95	DPM	MoO	50	1011.6	389.6	62.2
96	DPM	MoO	50	967.4	351.4	61.6
97	DPM	MoO	70	1044.2	242.2	80.2
98	DPM	MoO	70	1011.6	215.6	79.6
99	DPM	MoO	70	967.4	166.4	80.1
100	DPM	MoO	70 (desorbed)	0	41	4.1
101	HgCl ₂	MnO	30	1036.2	772.2	26.4
102	HgCl ₂	MnO	30	997.8	742.8	25.5
103	HgCl ₂	MnO	30	956.6	695.6	26.1
104	HgCl ₂	MnO	50	1036.2	743.2	29.3
105	HgCl ₂	MnO	50	997.8	706.8	29.1
106	HgCl ₂	MnO	50	956.6	670.6	28.6
107	HgCl ₂	MnO	70	1036.2	681.2	35.5
108	HgCl ₂	MnO	70	997.8	635.8	36.2
109	HgCl ₂	MnO	70	956.6	594.6	36.2
110	HgCl ₂	MnO	70 (desorbed)	0	58	5.8
111	DPM	MnO	30	1044.2	693.2	35.1
112	DPM	MnO	30	1011.6	661.6	35.1
113	DPM	MnO	30	967.4	#REF!	35.0

Details and results of each experiment (continued)

Exp.no.	Type of mercury	Type of adsorbent	Temp (°C)	Ini. Conc. ppb	Product Conc. ppb	mercury deposition 10^{-6} g of Hg/g ads
114	DPM	MnO	50	1044.2	621.2	42.3
115	DPM	MnO	50	1011.6	595.6	41.6
116	DPM	MnO	50	967.4	546.4	42.1
117	DPM	MnO	70	1044.2	545.2	49.9
118	DPM	MnO	70	1011.6	514.6	49.7
119	DPM	MnO	70	967.4	465.4	50.2
120	DPM	MnO	70 (desorbed)	0	32	3.2
121	HgCl ₂	Mixed	30	1008.3	712.3	29.6
122	HgCl ₂	Mixed	30	957.2	672.2	28.5
123	HgCl ₂	Mixed	30	1019.5	731.5	28.8
124	HgCl ₂	Mixed	50	1008.3	627.3	38.1
125	HgCl ₂	Mixed	50	957.2	580.2	37.7
126	HgCl ₂	Mixed	50	1019.5	639.5	38.0
127	HgCl ₂	Mixed	70	1008.3	585.3	42.3
128	HgCl ₂	Mixed	70	957.2	536.2	42.1
129	HgCl ₂	Mixed	70	1019.5	603.5	41.6
130	HgCl ₂	Mixed	70 (desorbed)	0	62	6.2
131	DPM	Mixed	30	985.3	390.3	59.5
132	DPM	Mixed	30	994.6	391.6	60.3
133	DPM	Mixed	30	1033.4	430.4	60.3
134	DPM	Mixed	50	985.3	215.3	77.0
135	DPM	Mixed	50	994.6	226.6	76.8
136	DPM	Mixed	50	1033.4	260.4	77.3
137	DPM	Mixed	70	985.3	103.3	88.2
138	DPM	Mixed	70	994.6	113.6	88.1
139	DPM	Mixed	70	1033.4	157.4	87.6
140	DPM	Mixed	70 (desorbed)	0	34	3.4

APPENDIX B

Results of digestion of spent adsorbent

Type of adsorbent	Type of Mercury compound	mercury deposition 10^{-6} g of Hg/g ads
NiO	Mercuric chloride	23
NiO	Diphenylmercury	19
CrO	Mercuric chloride	9.7
CrO	Diphenylmercury	81.4
FeO	Mercuric chloride	12.8
FeO	Diphenylmercury	46.5
MoO	Mercuric chloride	29.1
MoO	Diphenylmercury	78.5
MnO	Mercuric chloride	30.6
MnO	Diphenylmercury	45.3
Mixed	Mercuric chloride	36.4
Mixed	Diphenylmercury	83.5

Appendix C

Table 1C Properties of Toluene*

Formula	C ₇ H ₈
Chemical Name	Toluene
Physical properties	
Molecular Weight	92.13
Form	liquid
Color	colorless
Boiling point (° C)	110.8
Melting Point (°C)	-95
Specific Gravity	0.866
Solubility	soluble in ether and alcohol
Purity	>99%
Supplier	Merck

* From Encyclopedia of Chemical Engineering

Table 2C Properties of Mercuric chloride *

Formula	HgCl ₂
Chemical Name	Mercuric chloride
Physical properties	
Molecular Weight	271.52
Form	liquid
Color	white
Boiling point (° C)	302
Melting Point (°C)	277
Specific Gravity	5.44
Solubility	soluble in water
Purity	>99%
Supplier	Carlo Erba

* From Merck Index

Table 3C Properties of Diphenylmercury *

Formula	$C_{12}H_{10}Hg$
Chemical Name	Diphenylmercury
Physical properties	
Molecular Weight	354.8
Form	solid
Color	white
Boiling point (° C)	-
Melting Point (°C)	121-124
Specific Gravity	2.32
Solubility	moderately soluble in toluene
Purity	>97%
Supplier	Fluka

* From Supplier

Table 4C Properties of Silicodioxide*

Formula	SiO ₂
Chemical Name	Silicodioxide
Physical properties	
Form	solid
Color	white
Standard grade	325 mesh
Surface area	400 m ² /g
PH of aqueous suspension	7.0+/-0.5

* From Catalogue Handbook's Aldrich

Table 5C Properties of Nickel nitrate *

Formula	$\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$
Chemical Name	nickelous nitrate
Physical properties	
Molecular Weight	290.83
Form	solid
Color	green
Boiling point (° C)	137
Melting Point (°C)	56.7
Specific Gravity	2.05
Solubility	238.5g/100cc water at 0 °C
Purity	>99%

* From Merck Index

Table 6C Properties of Chromium nitrate *

Formula	$\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$
Chemical Name	Chromium nitrate
Physical properties	
Molecular Weight	400.21
Form	solid
Color	purple
Boiling point (° C)	100
Melting Point (°C)	60
Specific Gravity	1.8
Solubility	soluble in water
Purity	>99%

* From Merck Index

Table 7C Properties of Ferric nitrate *

Formula	$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$
Chemical Name	Ferric nitrate
Physical properties	
Molecular Weight	404.00
Form	solid
Color	violet
Boiling point (° C)	100
Melting Point (°C)	47.2
Specific Gravity	1.684
Solubility	freely soluble
Purity	>99%

* From Merck Index

Table 8C Properties of Ammoniummolybdate tetrahydrate *

Formula	$(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$
Chemical Name	ammonium molybdate tetrahydrate
Physical properties	
Molecular Weight	1235.86
Form	solid
Color	white to yellow-green
Boiling point (° C)	190
Melting Point (°C)	90
Specific Gravity	2.498
Solubility	43 g / 100 cc cold water
Purity	>99%

* From Merck Index

Table 9C Properties of Manganese nitrate *

Formula	Mn(NO ₃) ₂
Chemical Name	Manganese nitrate
Physical properties	
Molecular Weight	241.6
Form	solution
Color	pink
Boiling point (° C)	116
Melting Point (°C)	-
Specific Gravity	1.54
Solubility	infinitely soluble
Purity	>99%

* From Merck Index

Table 10C Properties of Nitric Acid *

Formula	HNO ₃
Chemical Name	Nitric Acid
Physical properties	
Molecular Weight	63.02
Form	liquid
Color	colorless
Boiling point (° C)	86
Melting Point (°C)	-41.59
Specific Gravity	1.502
Solubility	soluble in water
Purity	69.0-70.597%

* From Merck Index

Table 11C Properties of Hydrochloric Acid *

Formula	HCl
Chemical Name	Hydrochloric
Physical properties	
Molecular Weight	36.47
Form	liquid
Color	colorless
Melting Point (°C)	-15.35
Specific Gravity	1.05
Solubility	soluble in water and alcohol
Purity	37%

* From Encyclopedia of Chemical Engineer

Table 12C Properties of Sulfuric Acid *

Formula	H ₂ SO ₄
Chemical Name	Sulfuric Acid
Physical properties	
Molecular Weight	97.09
Form	liquid
Color	colorless
Melting Point (°C)	-
Specific Gravity	2.03
Solubility	soluble in water
Purity	95.7%

* From Merck Index

Table 13C Properties of Hydrogen Peroxide *

Formula	H ₂ O ₂
Chemical Name	Hydrogen Peroxide
Physical properties	
Molecular Weight	34.02
Form	liquid
Color	colorless
Melting Point (°C)	151.4
Specific Gravity	1.13
Solubility	soluble in water, acid and ether
Purity	35-35.6 %

* From Encyclopedia of Chemical Engineering

Table 14C Properties of Potassium Permanganate *

Formula	KMnO_4
Chemical Name	Potassium Permanganate
Physical properties	
Molecular Weight	158.03
Form	solid
Color	dark purple
Specific Gravity	2.71
Solubility	soluble in water,
Purity	>99 %

* From Merck Index

Table 15C Properties of Potassium Persulfate *

Formula	K_2SO_8
Chemical Name	Potassium Persulfate
Physical properties	
Molecular Weight	270.32
Form	solid
Color	white
Specific Gravity	-
Solubility	soluble in water,
Purity	>99 %

* From Merck Index

Table 16C Properties of Hydroxylamine Hydrochloride *

Formula	$\text{NH}_2\text{OH}\cdot\text{HCl}$
Chemical Name	Hydroxylamine Hydrochloride
Physical properties	
Molecular Weight	69.49
Form	solid
Color	white
Boiling Point (°C)	58
Melting Point (°C)	33
Specific Gravity	1.20
Solubility	soluble in water
Purity	>99 %

* From Merck Index

Table 17C Properties of Aluminum oxide, activated, neutral Brockmann *

Formula	Al_2O_3
Chemical Name	Neutral Alumina
Physical properties	
Form	solid
Color	white
Standard grade	150 mesh
Surface area	155 m ² /g
pH of aqueous suspension	7.0+/-0.5

* From Catalogue Handbook's Aldrich

Table 18C Properties of Copper nitrate *

Formula	$\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$
Chemical Name	Copper nitrate trihydrate
Physical properties	
Molecular Weight	241.6
Form	solid
Color	blue
Boiling point (° C)	-
Melting Point (°C)	114.5
Specific Gravity	2.32
Solubility	soluble in ether and alcohol
Purity	>99%

* From Merck Index

Table 19C Properties of Hydrofluoric acid *

Formula	HF
Chemical Name	Hydrofluoric acid
Physical properties	
Molecular weight	20.01
Form	aqueous solution
Color	colourless
Melting point (°C)	-83
Boiling point (°C)	19.4
Solubility	soluble in water
Purity	48 - 51%

* From Encyclopedia of Chemical Engineering

Table 20C Properties of Sodium Chloride *

Formula	NaCl
Chemical Name	Sodium Chloride
Physical properties	
Molecular Weight	58.54
Form	solid
Color	white
Boiling Point (°C)	58.54
Melting Point (°C)	-
Specific Gravity	2.17
Solubility	soluble in water
Purity	>99 %

* From Merck Index

VITA



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