

Bożena POPIEL, Mieczysław ŻYŁA *

SORPTION OF NON-POLAR SUBSTANCES BY TRANSITION METAL CATIONS MODIFIED MONTMORILLONITE

UKD 541.183.26:549.623.08 montmorillonit:54—128:546.3

Abstract. The adsorption investigations of argon, *n*-hexane and benzene vapours were carried out to find out the influence of exchangeable cations of specific chemical properties (Cr^{3+} , Fe^{3+} , Zn^{2+} , Cu^{2+} , Co^{2+} , Ni^{2+} , Fe^{2+} and Cd^{2+}) on the sorption capacity of montmorillonite in relation to non-polar substance vapours. The results have shown that saturation of montmorillonite with Cr^{3+} cation increases remarkably the sorption of non-polar substance vapours. The polarizing power of cation determines the sorption capacity of *n*-hexane vapours. Benzene sorption depends on the kind of cation. Cu^{2+} , Cr^{3+} , Ni^{2+} and Fe^{2+} cations take presumably active part in the formation of benzene-montmorillonite complexes through π -electrons from benzene aromatic rings.

INTRODUCTION

In recent years great has been attention drawn to investigations of montmorillonite containing transition metal cations in interlayer spaces (Tarasevich *et al.* 1970, Tarasevich *et al.* 1972; Masar, Gregor 1972; Mocik *et al.* 1972; Sung, Condrate 1972a, b; Yamanaka *et al.* 1974). Because of their specific structure of electronic shell, the atoms of transition elements tend to attach to atoms having free electron pairs (Pauling 1959; Lejaren, Herber 1965). Thanks to this tendency, very strong coordination bonds are formed between a cation and the molecules which are donors of binding electron pairs (ligands). The most important ions which are able to form such complexes, are Cu^{2+} , Cu^{+} , Zn^{2+} , Cd^{2+} , Ni^{2+} , Cr^{3+} , Cr^{2+} , Fe^{2+} , Fe^{3+} , Co^{2+} and Co^{3+} . More important ligands are the following groups: NH_3 (ammine), H_2O (aquo), ROH (alkano), CO (carbonyl), NO (nitroso), CN^- (cyano) and OH^- (hydroxy). In addition, transition metal cations are able to form very stable chelated complexes (Pauling 1959; Lejaren, Herber 1965) and coordination bonds with π -electrons (Amiel 1975). The latter are

* Institute of Energochemistry of Coal and Physicochemistry of Sorbents, Academy of Mining and Metallurgy (Kraków, al. Mickiewicza 30).

formed by hydrocarbons containing one or more double bonds, conjugated or unconjugated.

In this connexion, the intercalation of transition metal cations in interlayer spaces of montmorillonite considerably affects the sorption of organic compounds, mainly by forming stable complexes in interlayer spaces (Mortland 1966; Bodenheimer, Heller 1967; Sung, Condrate 1972a, b).

Montmorillonite adsorption properties are, to a great extent, due to the degree of polarity of the used adsorbate (Żyła 1971). Polar substances like water, alcohols, acids and other organic substances are sorbed by intercalation into the interlayer spaces to a considerably greater extent than in the case with non-polar substances.

Previous papers have very seldom dealt with the influence of transition metal cations on non-polar substances' sorption e.g. argon, *n*-hexane, benzene or other hydrocarbons. Therefore it seems useful to carry out an investigation of the influence of montmorillonite surface modification by transition metal cations on the sorption process of non-polar substances.

EXPERIMENTAL

The investigation was carried out on montmorillonite samples collected by sedimentation from water suspension of bentonite from Milowice. Montmorillonite with particle sizes of less than $1 \mu\text{m}$ was considered as a relatively pure sample, and used as basic material for the intercalation of cations: Cr^{3+} , Fe^{3+} , Ni^{2+} , Co^{2+} , Zn^{2+} , Fe^{2+} , Cd^{2+} and Cu^{2+} , into the interlayer spaces.

The saturation with these cations was followed using the Jackson method (1958). The binding of cations in the interlayer spaces takes place through their electrostatic interaction with negatively charged oxygen layers of montmorillonite. The strength of the binding depends on cation valency and their ionic radius. It appears from previously published data (Stoch 1974) that multivalent ions are considerably more strongly bound between montmorillonite layers. The purity grade of the samples was tested using X-ray and thermogravimetric analysis (Popiel, Żyła 1976). Sorption experiments were carried out with samples thus prepared. As non-polar substances the following were used: argon, *n*-hexane and benzene. Before the measurement was made, the sample was heated in a temperature of $110\text{--}120^\circ\text{C}$, and simultaneously evacuated up to 10^{-5} mm Hg. Such conditions enable the full determination of a sorption capacity since all of the water has been removed from the interlayer spaces.

Sorption and desorption isotherms were measured for *n*-hexane and benzene vapours in 298K in a liquid microburette apparatus (Lasoń, Żyła 1963) while low temperature argon adsorption was measured using sorption manostats (Ciembroniewicz, Lasoń 1972). Sorption equilibration time for C_6H_{14} and C_6H_6 was found experimentally to be 4–5 hours and in case of argon, 1 hour.

RESULTS

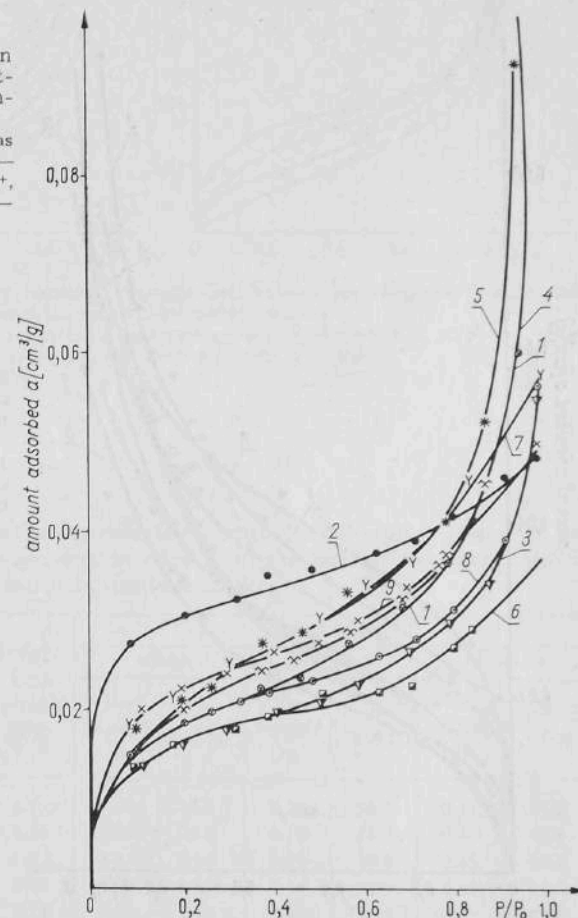
The results of non-polar vapours sorption in investigated montmorillonite samples were set up as isotherms (Fig. 1, 2, 3), to show the dependence of sorbed amount (in cm^3) of liquid sorbate/g on relative pressure.

Specific areas, which were treated as an indication of a sorption capacity in the range of the low relative pressure, were calculated from the part of an isotherm due to relative pressure of 0.05 to 0.35 using BET equation. Calculated area values are summarised in Table 1, where ionic radii and values of cation polarizing powers are also collected.

Isotherms determined in the liquid nitrogen temperature for argon vapours (Fig. 1) form the pencil of curves, which all belong to the type II by BET theory (Ościągła 1973). They are characterised by a great shape

Fig. 1. Argon vapours sorption isotherms determined for montmorillonite modified with transition metal cations

1 — montmorillonite containing as exchangeable cation Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+



regularity and a steep increase in relative pressure range of 0.7 to 0.97 which is likely caused by capillary condensation in the intergranular spaces. One notices major differences in the sorption capacity according to the type of a cation. Among the investigated samples, Cr^{3+} -montmo-

rillonite has the highest capacity, while the saturation of the montmorillonite with Co^{2+} , Ni^{2+} , Fe^{3+} and Cd^{2+} cations markedly lowers the sorption capacity in comparison with Na-montmorillonite (initial sample). Differences are also visible in the specific area values determined from the isotherms of the argon vapours adsorption (Table 1).

Figure 2 shows *n*-hexane sorption isotherms in the same samples. In the relative pressure range of 0.05 to 0.30 they show a lower sorption capacity than the adsorption isotherms determined using argon and in the pressure

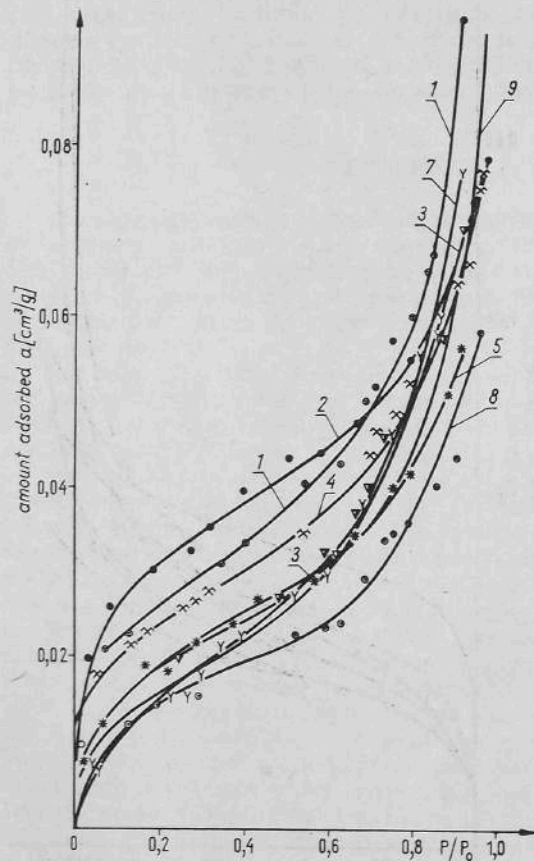


Fig. 2. Sorption isotherms for *n*-hexane determined for montmorillonite modified with the transition metal cations
1 — montmorillonite containing as exchangeable cation Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+

range of 0.3 to 0.9 — the higher sorption capacity. The highest sorption capacity in comparison with *n*-hexane vapours is shown by Cr^{3+} , Fe^{3+} and Zn^{2+} -montmorillonite. The specific surface area values calculated from the *n*-hexane adsorption isotherms (Table 1) are markedly lower than the argon area values. The differences can be explained by the varying availa-

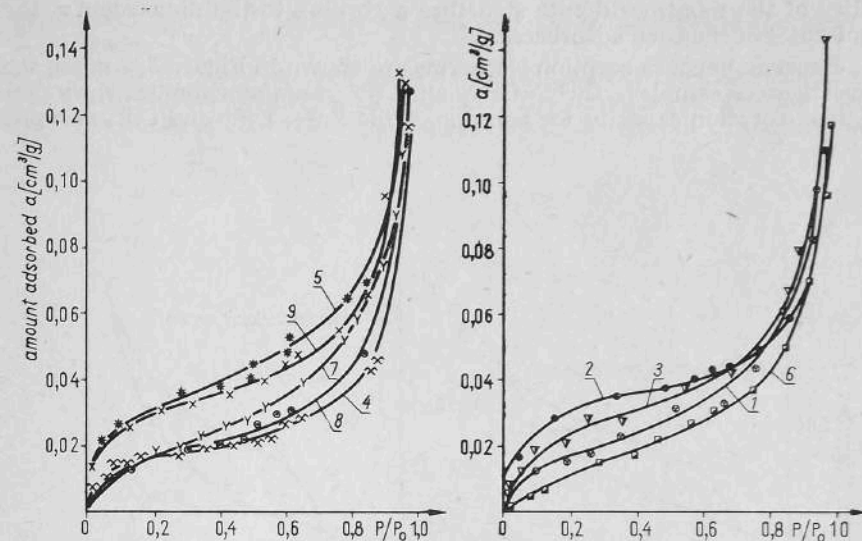


Fig. 3. Sorption isotherms for benzene vapours determined for montmorillonite modified with transition metal cations
1 — montmorillonite containing as exchangeable cation Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+

Table 1

V_m and specific surface area values calculated from the adsorption isotherm for argon, *n*-hexane and benzene vapours in relation to the kind of the exchangeable cation in montmorillonite

Sample	Ionic radius <i>R</i> Å	Polarizing power <i>Z/R</i>	Adsorbate					
			argon		<i>n</i> -hexane		benzene	
			<i>V_m</i> mmol/ /g	<i>S</i> m ² /g	<i>V_m</i> mmol/ /g	<i>S</i> m ² /g	<i>V_m</i> mmol/ /g	<i>S</i> m ² /g
Fe^{3+} —	0.64	4.7	0.49	46.6	0.15	36.1	0.14	26.2
Cr^{3+} —	0.69	4.34	0.79	79.7	0.18	44.0	0.26	49.5
Ni^{2+} —	0.69	2.8	0.43	43.8	0.11	26.5	0.25	46.6
Zn^{2+} —	0.69	2.8	0.56	56.45	0.14	34.7	0.13	41.1
Cu^{2+} —	0.72	2.77	0.56	56.9	0.11	28.4	0.29	54.8
Co^{2+} —	0.74	2.7	0.43	43.4	0.11	26.2	0.22	25.0
Fe^{2+} —	0.76	2.6	0.59	58.9	0.10	25.9	0.19	35.3
Cd^{2+} —	0.97	2.0	0.48	48.9	0.08	20.4	0.15	27.5
Na^+ —	0.98	1.0	0.59	59.7	0.11	26.6	0.25	47.3

bility of the montmorillonite structure according to the dimension of the molecules of the used adsorbates.

Benzene vapours sorption isotherms are shown in Figure 3. Among the investigated samples, Cu^{2+} , Cr^{3+} and Ni^{2+} -montmorillonite show the highest sorption capacity for benzene, while Zn^{2+} , Fe^{3+} and Cd^{2+} -samples

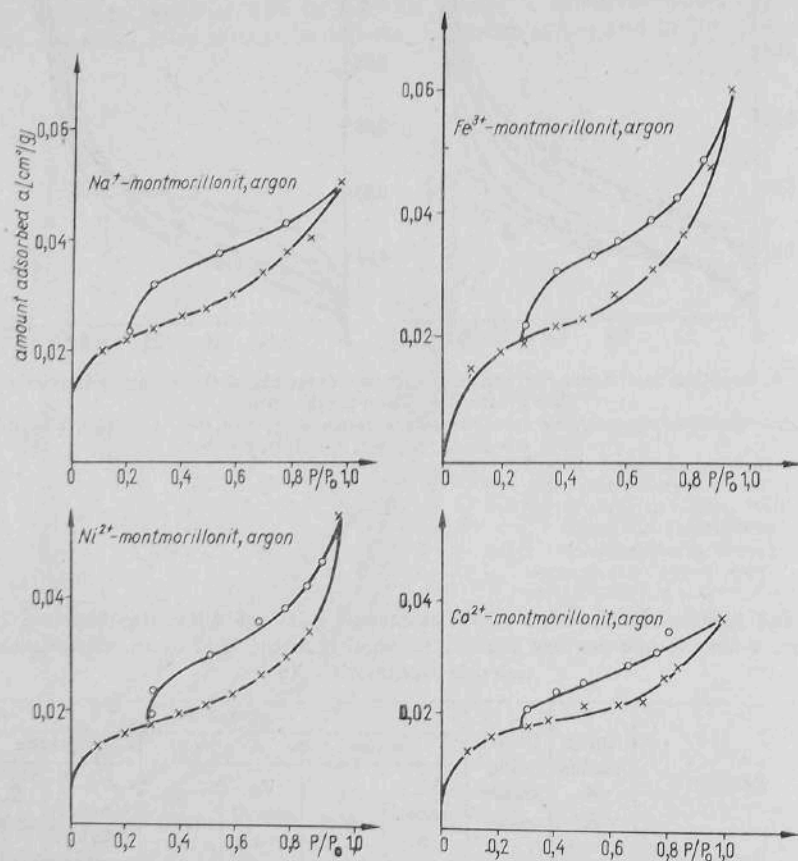


Fig. 4. Sorption and desorption isotherms for argon vapours determined for Na^+ , Fe^{3+} , Ni^{2+} and Co^{2+} -montmorillonite

have much lower capacity in comparison with Na^+ -montmorillonite. The specific surface area values collected in Table 1 corroborate the foregoing observations.

Together with the sorption investigations, desorption isotherms were measured. The curves obtained are, as an example, shown in Figure 4—7. The desorption isotherms of argon vapours (Fig. 4) lie higher than the adsorption isotherms forming a distinct, closed by pressure of 0.25 to 0.30,

hysteresis loop, which includes an area between an adsorption and desorption branch.

Analysis of the *n*-hexane vapours desorption curves allow us to see that the hysteresis loop remains opened i.e. the desorption isotherms do not meet the adsorption ones even under very low relative pressure. Only

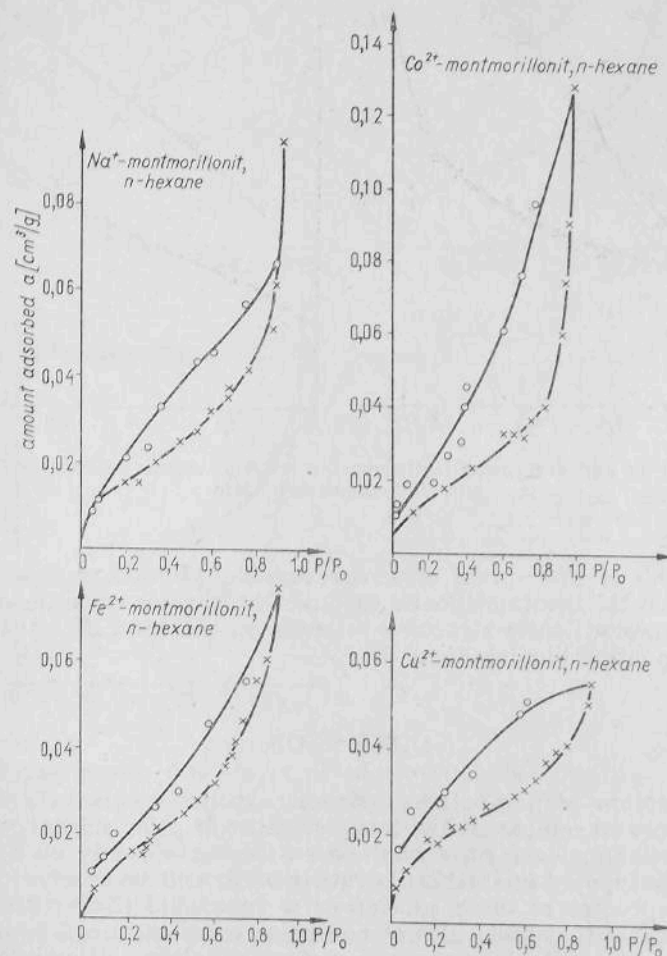


Fig. 5. Sorption and desorption isotherms for *n*-hexane vapours determined for Na^+ , Co^{2+} , Fe^{2+} and Cu^{2+} -montmorillonite

in the case of Na^+ -montmorillonite a closed hysteresis loop is observed, which is evidence for the reversible character of the *n*-hexane sorption on this adsorbent. Desorption curves for benzene vapours form an opened hysteresis loop in the case of Cu^{2+} , Cr^{3+} , Ni^{2+} and Fe^{2+} -montmorillo-

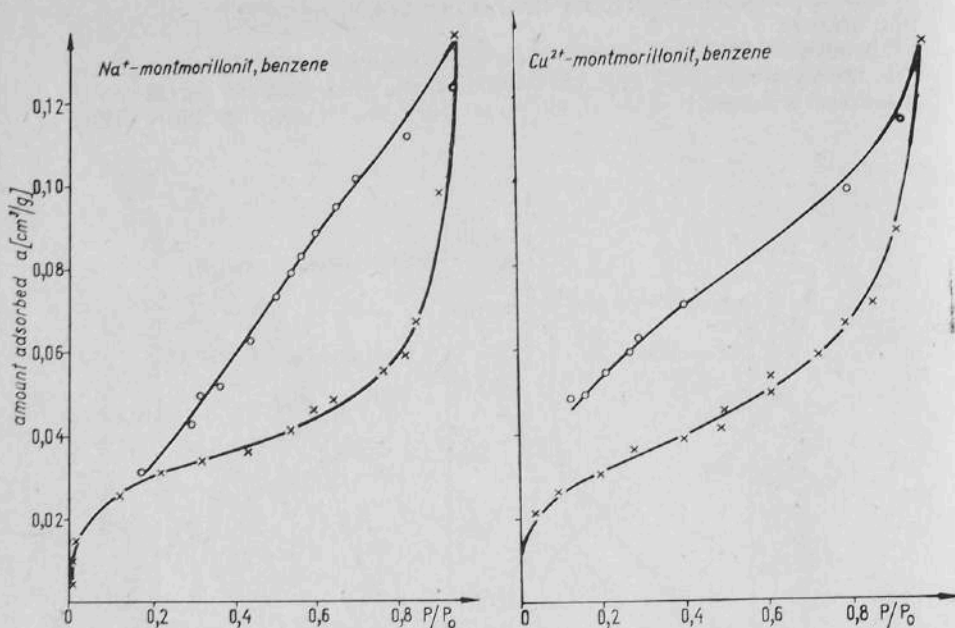


Fig. 6. Sorption and desorption isotherms for benzene vapours determined for Na^+ and Cu^{2+} -montmorillonite

nite and this is clear proof of an irreversible sorption process for this adsorbate on the montmorillonite surface. The amount of benzene contained in montmorillonite structure depends on the kind of cation which saturates montmorillonite (Fig. 6, 7).

DISCUSSION

The sorption of non-polar substances vapours occurs in a radically different way in comparison with the sorption of polar substances' vapours. Non-polar molecules are retained on the surface only by dispersion forces. This type of interaction is rather weak and because of that, the adsorption process of these substances is reversible (Żyła 1971). Many authors suggest that molecules of non-polar compounds can be adsorbed only on montmorillonite external surfaces (Nelson, Heindricks 1944). However, it was suggested in the paper of Żyła (1971), that montmorillonite heated in vacuum in $120\text{--}150^\circ$ lets, to a great extent, non-polar adsorbate molecules go into the interlayer spaces. In this connexion, it seems useful to consider the relation between the non-polar substances sorption and the kind of interlayer cation in heated montmorillonite. It is noticeable that the sorption of non-polar substances may occur as a result of the formation of dipoles induced by electrostatic field of montmorillonite surface (Kłapyta 1974).

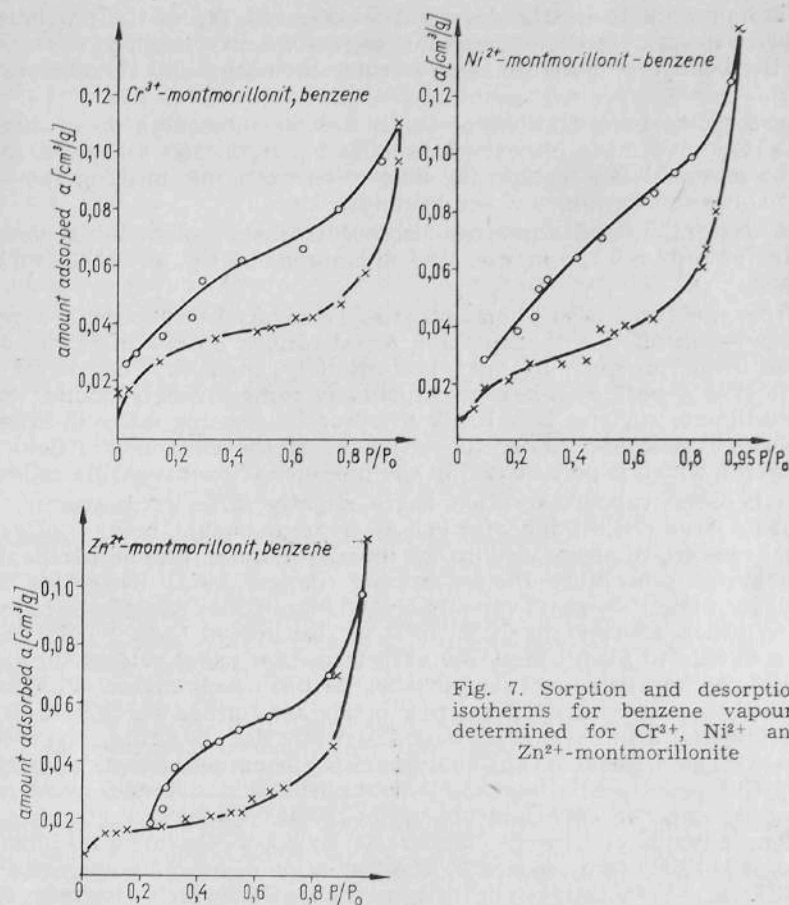


Fig. 7. Sorption and desorption isotherms for benzene vapours determined for Cr^{3+} , Ni^{2+} and Zn^{2+} -montmorillonite

It is also known (Sheinberg, Kemper 1966) that interlayer cations of montmorillonite bring about some changes in the electronic structure of oxygen atoms in the tetrahedral layer, which causes a perturbation in surface charge distribution. This suggests that we should look for a correlation between the existence of cations in the interlayer spaces and the sorption of non-polar substances.

In the case of the argon sorption, only a remarkable increase of the sorption capacity of the Cr^{3+} -montmorillonite is noticeable, which may be explained by the great polarizing power of Cr^{3+} -cation (the little radius and the large charge). However, a comparison between the sorption isotherms of *n*-hexane and the analysis of the values of the specific surface areas enable us to relate the sorption capacities of the investigated samples and the kind of cation.

The Cr^{3+} and Fe^{3+} cations, characterised by a large polarizing power (Table 1) cause a remarkable increase in the sorption capacity of montmorillonite which is saturated with these cations.

It is important to fix the degree of the reversibility of the previously adsorbed vapours. On the basis of this degree we may make a conclusion about the bond type between the adsorbate molecules and the adsorbent surface.

The sorption investigations of the non-polar substances on montmorillonite we have made hitherto, especially for argon and *n*-hexane, showed the reversible adsorption, the desorption isotherms meeting the adsorption ones and forming a closed hysteresis loop.

The desorption and adsorption isotherms share points by a steady pressure of $p/p_0 = 0.3$, whatever the dimensions of the adsorbate molecules are.

In this study, the desorption isotherms for *n*-hexane vapours on montmorillonite saturated with transition metal cations do not meet the adsorption isotherms even by very low relative pressures. This seems to indicate that a part of *n*-hexane vapours is being strongly bound with montmorillonite surface. It is likely to occur by forming induced dipoles in adsorbate molecules under the influence of the electrostatic field of the mineral, which is perturbed in the presence of exchangeable cations.

The benzene vapours sorption has a slightly different character. In spite of its large critical diameter (6,8 Å), benzene is able, because of geometrical reasons, to penetrate into the interlayer space of montmorillonite with a larger probability than *n*-hexane (Badger 1971). Therefore the over-all sorption of benzene vapours on the investigated samples is higher than the *n*-hexane vapours sorption. It is also known (Amiel 1975) that benzene is able to form complexes with transition metal cations through π -bond. The characteristic example may be dibenzochromium with formula $\text{Cr}(\text{C}_6\text{H}_6)_2$, in which the existing bonds are formed through π -electrons originating from aromatic rings. Important data regarding the sorption mechanism arises from the analysis of the benzene desorption. In the case of Cu^{2+} , Cr^{3+} , Ni^{2+} and Fe^{2+} -montmorillonite, a broad hysteresis loop becomes opened even under very low relative pressures. It suggests that some amount of benzene vapours is bound to the montmorillonite surface. It is likely to be caused by the formation of bonds between Cu^{2+} , Cr^{3+} , Ni^{2+} and Fe^{2+} cations and benzene molecules, which results in the formation of benzene—montmorillonite complexes. The same suggestions have been put forward in the paper of Pinnavaia and Mortland (1971), in which, it was shown, that simultaneously with the physical adsorption of toluene and other benzene derivatives, a chemical adsorption (chemisorption) occurs on Cu-montmorillonite resulting in the formation of complexes which are bound with Cu^{2+} ions through π -electrons. The benzene ring remains flat and its aromatic character is preserved.

CONCLUSION

The modification of montmorillonite surface with transition metal cations causes the sorption capacity change for the mineral in relation to argon, *n*-hexane and benzene vapours.

It is very profitable to introduce the Cr^{3+} cation into the interlayer space because it increases argon, *n*-hexane and benzene sorption in comparison with the pure (sodium) montmorillonite.

In case of *n*-hexane sorption a visible correlation is to be noticed between the polarizing power of the montmorillonite saturating cation and the amount of *n*-hexane sorption. Montmorillonite with exchangeable Cr^{3+} , Fe^{3+} and Zn^{2+} cations has the highest sorption capacity for *n*-hexane vapours among the investigated samples and it decreases with the lowering of the cation polarizing power. Moreover the transition metal cations cause the strong binding of *n*-hexane vapours with the montmorillonite surface.

On the other hand the montmorillonite saturation with cations able to form complexes with benzene through π -electrons affects the benzene vapours sorption. In the range of the investigated samples Cu^{2+} , Cr^{3+} and Ni^{2+} -montmorillonite is characterised by the high sorption capacity for benzene vapours and the existence of the broad opened hysteresis loop indicates the presence of chemisorption, by which the benzene-montmorillonite complexes are formed with Cu^{2+} , Cr^{3+} and Ni^{2+} cations.

REFERENCES

- AMIEL J., 1975: *Chemia Ogólna*, vol. 1. WNT, Warszawa.
- BADGER G. M., 1971: *Aromatyczność związków organicznych*. PWN, Warszawa.
- BODENHEIMER W., HELLER L., 1967: Sorption of α -amino-acids by copper montmorillonite. *Clay Miner.* 7, 167—176.
- CIEMBRONIEWICZ A., LASOŃ M., 1972: Manostat sorpcyjny półautomatyczny aparat do badań sorpcyjnych. *Roczniki Chemii*, 46, 703—710.
- JACKSON H. L., 1958: *Soil chemical analysis*.
- KLAPYTA Z., 1974: *Studia nad kompleksami sorpcyjnymi montmorylonitu*. *Pr. miner.* 36.
- LASOŃ M., ŻYŁA M., 1963: Aparatura do wyznaczania izoterm sorpcji i desorpcji par metodą mikrobiuretek. *Chem. Anal.* 8, 279—286.
- LEJAREN A. H., HERBER R. H., 1965: *Podstawy Chemii*. WNT, Warszawa.
- MASAR J., GREGOR M., 1972: Differentialthermoanalyse und Infrarot — Spektren von Zn, Cd- und Hg-Montmorillonit. *Silikat J.* 11, 258—259.
- MOCIK S., SLOSIARIKOVA H., KONVALINOVA M., 1972: Untersuchung der Sorption von Anilin auf Montmorillonit. *Chem. zvesti.* 27, 344—347.
- MORTLAND M. M., 1966: Urea complexes with montmorillonite — an infrared absorption study. *Clay Miner.* 6, 143—156.
- NELSON R. A., HEINDRICKS S. B., 1944: Specific surface of some clay minerals, soils and colloids. *Soil. Sci.* 56, 285—296.
- OSCIK J., 1973: *Adsorpcja*. PWN, Warszawa.
- PAULING L., 1959: *Chemia Ogólna*. PWN, Warszawa.
- PINNAVAIA J., MORTLAND M. M., 1971: Interlamellar metal complexes on layer silicates I. Copper II — arene complexes on montmorillonite. *J. Phys. Chem.* 7, 3957—3962.
- POPIEL B., ŻYŁA M., 1976: Z badań nad fizykochemicznymi własnościami montmorylonitu z kationami metali przejściowych. *Przemysł Chemiczny* (in press).
- SHEINBERG J., KEMPER W. D., 1966: Hydration status of adsorbed cations. *Soil. Sci. Soc. Am. Proc.* 30, 5, 707.
- STOCH L., 1974: *Minerały ilaste*. Wyd. Geol., Warszawa.
- SUNG DO JANG, CONDORATE R. A., 1972a: The infrared spectra of glycine adsorbed on various cationsubstituted montmorillonites. *J. Inorg. Nucl. Chem.* 34, 1503—1509.
- SUNG DO JANG, CONDORATE R. A., 1972b: The I.R. spectra of lysine adsorbed on several cationsubstituted montmorillonites. *Clays and Clay Miner.* 20, 79—82.
- TARASEVICH Y. I., RUDENKO V. M., SHARKINA, OVCHARENKO F. D., 1970: Methanol and ethanol adsorption on cationsubstituted montmorillonite and vermiculite. *Kolloid. Z.* 32, 266—272.
- TARASEVICH Y. I., TELICHKUN V. P., OVCHARENKO F. D., 1972: Influence of the exchange cations on the adsorption of acetonitrile and pyridine by montmorillonite. *Kolloid. Z.* 34, 412—418.

- YAMANAKA S., KANAMARU F., KOIZUMI M., 1974: Role of interlayer cations in the formation of acrylonitrile-montmorillonite complexes. *J. Phys. Chem.* 78, 42-44.
- Żyła M., 1971: Sorpcyjne własności termicznie modyfikowanych bentonitów i montmorillonitu z kopalni „Chmielnik”. *Zeszyty Naukowe AGH*, 376.

Bożena POPIEL, Mieczysław ŻYŁA

SORPCJA SUBSTANCJI APOLARNYCH NA MONTMORILLONICIE MODYFIKOWANYM KATIONAMI METALI PRZEJŚCIOWYCH

Streszczenie

Przeprowadzone badania adsorpcyjne par argonu, *n*-heksanu i benzenu miały na celu określenie wpływu modyfikacji montmorillonitu kationami Cr^{3+} , Fe^{3+} , Zn^{2+} , Cu^{2+} , Co^{2+} , Ni^{2+} , Fe^{2+} , Cd^{2+} o specyficznych właściwościach chemicznych, na chłonność sorpcyjną w stosunku do par substancji apolarnych. Uzyskane wyniki wykazały, że nasycenie montmorillonitu kationem Cr^{3+} wyraźnie zwiększa sorpcję par substancji apolarnych. O chłonności sorpcyjnej par *n*-heksanu decyduje siła polaryzacyjna kationu, a sorpcja benzenu zależy od rodzaju kationu. Prawdopodobnie kationy Cu^{2+} , Cr^{3+} , Ni^{2+} i Fe^{2+} biorą aktywny udział w tworzeniu się kompleksów montmorillonitowo-benzenowych za pomocą π -elektronów pochodzących z pierścieni aromatycznych benzenu.

OBJAŚNIENIA FIGUR

- Fig. 1. Izotermy sorpcji par argonu wyznaczone na montmorillonicie modyfikowanym kationami metali przejściowych
1 — montmorillonit zawierający jako kation wymienny Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Fig. 2. Izotermy sorpcji par *n*-heksanu wyznaczone na montmorillonicie modyfikowanym kationami metali przejściowych
1 — montmorillonit zawierający jako kation wymienny Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Fig. 3. Izotermy sorpcji par benzenu wyznaczone na montmorillonicie modyfikowanym kationami metali przejściowych
1 — montmorillonit zawierający jako kation wymienny Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Fig. 4. Izotermy sorpcji i desorpcji par argonu wyznaczone na Na^+ , Fe^{3+} , Ni^{2+} , Co^{2+} -montmorillonicie
- Fig. 5. Izotermy sorpcji i desorpcji par *n*-heksanu wyznaczone na Na^+ , Co^{2+} , Fe^{2+} , Cu^{2+} -montmorillonicie
- Fig. 6. Izotermy sorpcji i desorpcji par benzenu wyznaczone na Na^+ i Cu^{2+} -montmorillonicie
- Fig. 7. Izotermy sorpcji i desorpcji par benzenu wyznaczone na Cr^{3+} , Ni^{2+} i Zn^{2+} -montmorillonicie

Bożена ПОПЕЛЬ, Мечислав ЖИЛА

СОРБЦИЯ НЕПОЛЯРНЫХ ВЕЩЕСТВ НА МОНТМОРИЛЛОНИТЕ ВИДОИЗМЕНЕННЫМ КАТИОНАМИ ПЕРЕХОДНЫХ МЕТАЛЛОВ

Резюме

Целью адсорбционных исследований паров аргона, *n*-гексана и бензена было определение влияния модификации монтмориллонита катионами Cr^{3+} , Fe^{3+} , Zn^{2+} , Cu^{2+} , Co^{2+} , Ni^{2+} , Fe^{2+} , Cd^{2+} о специфических химических свойствах на сорбционную способность по отношению к парам неполярных веществ. Полученные результаты показали, что насыщение монтмориллонита катионом Cr^{3+} явно увеличивает сорбцию паров неполярных веществ. На сорбционную способность паров *n*-гексана основным образом влияет поляризационная сила катиона, а сорбция бензена зависит от типа катиона. По-видимому, катионы Cu^{2+} , Cr^{3+} , Ni^{2+} и Fe^{2+} принимают активное участие в образовании бензен-монтмориллонитовых комплексов с помощью π -электронов происходящих из ароматических колец бензена.

ОБЪЯСНЕНИЯ К ФИГУРАМ

- Фиг. 1. Изотермы сорбции паров аргона определенные на монтмориллоните модифицированным катионами переходных металлов
1 — монтмориллонит содержащий в качестве обменного катиона Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Фиг. 2. Изотермы сорбции паров *n*-гексана определенные на монтмориллоните модифицированным катионами переходных металлов
1 — монтмориллонит содержащий как обменный катион Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Фиг. 3. Изотермы сорбции паров бензена определенные на монтмориллоните модифицированным катионами переходных металлов
1 — монтмориллонит содержащий как обменный катион Fe^{3+} , 2 — Cr^{3+} , 3 — Ni^{2+} , 4 — Zn^{2+} , 5 — Cu^{2+} , 6 — Co^{2+} , 7 — Fe^{2+} , 8 — Cd^{2+} , 9 — Na^+
- Фиг. 4. Изотермы сорбции и десорбции паров аргона определенные на Na^+ , Fe^{3+} , Ni^{2+} , Co^{2+} -монтмориллоните
- Фиг. 5. Изотермы сорбции и десорбции паров *n*-гексана определенные на Na^+ , Co^{2+} , Fe^{2+} , Cu^{2+} -монтмориллоните
- Фиг. 6. Изотермы сорбции и десорбции паров бензена определенные на Na^+ и Cu^{2+} -монтмориллоните
- Фиг. 7. Изотермы сорбции и десорбции паров бензена определенные на Cr^{3+} , Ni^{2+} и Zn^{2+} -монтмориллоните