Gutknecht, J., *Limnol. Oceanogr.*, **10**, 58–66 (1965).
Harley, J. H., Ed., "Manual of Standard Procedures," 2nd ed., New York, N.Y., USAEC (NYO-4700), 1967.
Jones, G. E., *Limnol. Oceanogr.*, **12**, 165–7 (1967).
Knauss, H. J., Porter, J. W., *Plant Physiol.*, **29**, 229–34 (1954).
Polikarpov, G. G., "Radioecology of Aquatic Organisms," North-Holland, Amsterdam, 314 pp, 1966.
Robertson, D. E., *Anal. Chim. Acta*, **42**, 533–6 (1968).
Schutz, D. F., Turekian, K. K., *Geochim. Cosmochim. Acta*, **29**, 259 (1965).
Strickland, J. D. H., Parsons, T. R., "A Manual of Sea Water Analysis," 2nd ed., Ottawa, 203 pp (Fish. Res. Bd. Can., Bull. No. 126), 1965.
Tomlinson, R. D., MS thesis, Oregon State University, Corvallis, Ore., 1970.
Townsley, S. J., Reid, D. F., Ego, W. T., "Uptake of Radioisotopes and Their Transfer Through Food Chains by Marine Organisms," 40 pp, Annu. rept. (1959–60), Univ. of Hawaii contract At(04-3)-56 with U.S. Atomic Energy Comm. (microfilm).

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Factors Affecting Plant Uptake and Phytotoxicity of Cadmium Added to Soils

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■ For a set of 30 surface soils, addition of 50 mg of cadmium, from $CdCl_2$, to 500 grams of soil reduced yields and sharply increased cadmium levels in analyzed portions of radish and lettuce plants when compared with those plants grown on control soils. For the treated soils, plant cadmium was significantly related to cadmium extracted from soil by neutral *N* ammonium acetate. The *N* HCl and *N* HNO_3 extractions did not indicate plant availability but removed most of the soil cadmium. From among 18 potential independent variables, stepwise linear regressions to predict cadmium found in plant parts harvested from treated soils included a measure of the relative ability of soils to adsorb cadmium, acetate-soluble cadmium in the soil, soil reaction, and organic matter as significantly contributing independent variables. Plant cadmium levels were significantly correlated with amounts of Ni, Fe, Zn, and Cu in the same plant portion.

Incrimination of cadmium accumulation as a factor in several health problems has catalyzed recent studies of cadmium in the environment. Accumulation of cadmium in man has been linked with hypertension (Schroeder, 1965), emphysema and chronic bronchitis (Lewis et al., 1969; Nandi et al., 1969), and "ouch-ouch" disease (Tsuchiya, 1969a,b). Recognition of this association has led to investigation of cadmium levels in plants, animals, foods, and the human body (Kropf and Geldmacher-v. Mallinckrodt, 1968; Schroeder et al., 1961, 1967). Smelting and electroplating of metals, motor oils, motor vehicle tires (Lagerwerff and Specht, 1970), and fungicide sprays (Ross and Stewart, 1969) have been implicated as sources of cadmium contamination of the environment. The cadmium pollution of soils and its uptake by oats were studied by John et al. (1972). They reported that a surface sample taken near a battery smelter contained 95 ppm of HNO_3-soluble cadmium.

Inasmuch as the mechanism of cadmium uptake by plants is largely unknown, the study of cadmium's entry into the food cycle is being continued. Absorption of essential and nonessential elements from the soil by plants is often related to soil factors such as acidity and organic matter. Estimation of cadmium availability to the plant by a soil test may also be useful. The present study attempts to relate cadmium uptake by radish and lettuce plants to soil factors.

Materials and Methods

Soils. The 30 surface samples used in this investigation were collected throughout southwestern British Columbia, Canada. They represent soils of varying texture, organic matter, acidity, and parent material (Table I). The samples were taken from virgin sites as well as cultivated areas.

Growth Chamber Studies. For each soil, two styrene pots were filled with 500 grams of air-dried soil. One set remained untreated while 50 mg of cadmium were added to the other by thorough mixing of $CdCl_2$ solution with the soil. Resulting soil cadmium concentrations of 100 ppm, added to the natural content, were similar to those found in proximity to an industrial smelting operation bordering on agricultural land (John et al., 1972). The soils were brought to field capacity with deionized distilled water and incubated for a month in a darkened growth chamber at 25° ± 3°C. Radish seeds (*Raphanus sativus* L., cv. "Early Scarlet Globe") were planted in the soils and, after emergence, the number of plants was reduced to eight per pot. Hoagland's solution (Hoagland and Arnon, 1950) and deionized distilled water were supplied to maintain vigorous growth. The growth chamber provided a 16-hr day length, a day temperature of 20° ± 2°C, a night temperature of 15° ± 2°C, and a relative humidity of 70%. Three weeks after planting, radish tops and roots were harvested, separated, washed, and dried at 80°C. Soils were dried, mixed, and repotted.

Using a modified Stanford-DeMent bioassay (Stanford and DeMent, 1957), lettuce seeds (*Lactuca sativa* L., cv. "Salad Bowl") were germinated in smaller styrene pots containing

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Table I. Assigned Variable Names and Description of the Methods Employed in Determination of Soil Properties

Assigned name of property	Description of method	Mean[a]	Std dev[a]
ADSCD	Cd adsorbed by soil when 500 ppm supplied, ppm[b,c]	490.00	8.64
CDAC	Cd in N NH_4Ac extractant, pH 7.0, treated soil, ppm[b,c]	61.25	13.44
CDHCL	Cd in N HCl extractant, treated soil, ppm[b,c]	99.93	32.18
$CDHNO_3$	Cd in N HNO_3 extractant, treated soil, ppm[b,c]	110.20	37.18
PHWA	pH in water, 1:1[d,e]	5.61	0.81
PHKCL	pH in N KCl[d,f]	4.70	0.81
OMAT	Organic matter, %[g]	12.92	15.74
Sand	Sand fraction, %[f,h]	33.95	27.67
Clay	Clay fraction, %[f,h]	19.33	14.42
EXCAP	Exchange capacity, m.e./100 grams[e]	32.79	25.18
BASAT	Base saturation, %[e]	51.29	30.06
ALCA	Al with 0.01M $CaCl_2$, ppm[c,f]	4.12	6.67
ALKCL	Al with N KCl, ppm[c,i]	57.45	64.91
ALTOT	Al, total, %[c,f]	0.67	0.20
FENC	Fe with 0.05N HCl, 0.025N H_2SO_4 (North Carolina), ppm[c,f]	80.25	79.77
FEDTPA	Fe with DTPA, ppm[c,j]	97.49	50.94
MNDTPA	Mn with DTPA, ppm[c,j]	14.93	13.71
ZNCA	Zn with 0.01M $CaCl_2$, ppm[c,f]	0.52	0.33

[a] Means and std dev calculated for 30 soils and expressed in the units of measure given in the description.
[b] Refer to text.
[c] Determined using atomic absorption spectrophotometer.
[d] pH determined using pH meter.
[e] Jackson (1958).
[f] Black (1965).
[g] Walkley and Black (1934).
[h] Determined by hydrometer method.
[i] Pionke and Corey (1967).
[j] Follett and Lindsay (1971).

Table II. Effect of Cadmium Treatment on Cadmium Content and Dry Weight Yields of Plant Parts

	Cadmium, ppm oven-dry basis				Dry wt yield			
	50 mg Cd added/pot		Control		Grams/pot control		Reduction, % by treatment[a]	
Plant part	Mean[b]	Std dev[b]	Mean	Std dev	Mean	Std dev	Mean	Std dev
Radish tops	528	311	6.9	2.8	2.1	0.6	47.3	31.9
Radish roots	387	737	7.4	2.9	2.4	1.1	67.2	32.0
Lettuce tops	138	57	2.3	1.2	3.8	0.8	13.6	20.5
Lettuce roots from quartz	114	47	5.7	1.6	1.0	0.3	10.6	41.3
Lettuce roots from soil	636	318	5.3	1.4	0.7	0.2	24.9	42.3

[a] Percentage yield reduction due to treatment = [(control − treated)/control)] × 100%.
[b] Means and std dev (S.D. were calculated for 30 soils).

Table III. Correlation Coefficients, r, Between Levels of Cadmium and of Other Elements in the Same Plant Part

Factors correlated	Zn	Ni	Cu	Fe	Mg	Ca	P	S
Cd in radish tops	0.15	0.77[b]	0.56[b]	0.73[b]	0.06	0.14	0.14	0.01
Cd in radish roots	0.79[b]	0.96[b]	0.74[b]	0.79[b]	0.86[b]	0.81[b]	0.25	0.13
Cd in lettuce tops	0.49[b]	0.58[b]	0.37[a]	0.20	0.10	0.37	0.04	0.45
Cd in lettuce roots from quartz	0.49[b]	0.31	−0.01	0.52[b]	−0.15	0.07	0.22	0.18
Cd in lettuce roots from soil	0.22	0.52[b]	0.28	0.09	0.12	0.25	0.16	0.26

[a] Significant at 5% level.
[b] Significant at 1% level.

100 grams of quartz sand. Bottoms of these smaller styrene pots were removed and the two-week-old lettuce plants, thinned to four per pot, were nested on the repotted soils to allow roots to come in contact with the soil. Nutrient and growth chamber conditions were similar to those maintained for growth of radish crop. After three weeks of growth on the soils, lettuce was harvested, and separated into three parts: the lettuce leaves, the root portion from the quartz sand in the uppermost pot, and the root portion from the soil in the lower pot.

Plant materials were digested with nitric–perchloric acid mixture and the levels of cadmium, zinc, nickel, magnesium, calcium, copper, and iron were determined by atomic absorption. Phosphorus content was determined colorimetrically with ascorbic acid (John, 1970b). Sulfur content was measured by the turbidimetric method described by Tabatabai and Bremner (1970).

Soil Analyses. Various soil properties used in developing regressions were determined (Table I). To estimate the relative abilities of differing soils to adsorb cadmium, 1-gram samples of each untreated soil were shaken for 16 hr with 50 ml of a $CdCl_2$ solution containing 10 ppm of cadmium [500 ppm of cadmium on a soil basis; (John, 1971)]. After centrifuging and filtering, the cadmium content of the filtrate was determined by atomic absorption and the amount adsorbed by the soil (ADSCD) was calculated. To assess soil cadmium availability, 1-gram samples, collected from the treated soils after cropping, were shaken for 30 min with 10 ml of three different extractants: *N* ammonium acetate (NH_4Ac), *N* HCl, and *N* HNO_3. Cadmium in each extractant was determined by atomic absorption. For these and other determinations of cadmium, a correction for background absorption and light scattering involved the use of a hydrogen lamp at the same wavelength setting as for cadmium. Other properties which further characterize the untreated soils are described in Table I.

Statistical Analyses. Computer methods for acquisition, reduction, and statistical analyses of data were employed as described by John (1970a). Only the observations for plant parts grown on 30 treated soils were included for calculation of simple correlations and for regression analyses. A linear stepwise regression program, used to relate cadmium in plants to soil properties, involved the insertion of independent variables in the regression in the order of importance for prediction of the dependent variable. Only those variables which contributed significantly at the 5% level were included.

Results and Discussions

Cadmium Absorption by Radish and Lettuce Plants. The cadmium concentrations found in plant parts analyzed are reported in Table II. The accumulation of cadmium in lettuce roots from the soil zone was probably due to assimilation of cadmium through the soil-root interface and some immobilization of the metal in this root portion. Lettuce roots from the quartz zone and radish storage roots (fibrous roots were discarded, and therefore soil-root interface was not involved) contained lower amounts of cadmium than the tops. These results indicated that cadmium, not immobilized in the root portion involved with absorption of cadmium from the soil, was accumulated in the aboveground parts of the plants.

Effect of Cadmium Treatment on Yield. Yields of radish tops and roots were reduced 47.3 ± 31.9% and 67.2 ± 32.0%, respectively, while the addition of 50 mg of cadmium per pot did not decrease lettuce yields as significantly (Table II). The treatment caused chlorosis of the leaves and stunted growth as shown in Figure 1. These results may be interpreted as the differential tolerance of these plant species to the cadmium treatment. Different growing practices may also explain some of this difference between radish and lettuce yield decreases. Radishes were germinated in the soil whereas lettuce plants were already established in quartz and were in contact with the soils for only half of their growth period.

Figure 1. Compared to control plants, radish plants on the left show stunted growth and chlorosis of leaves due to addition of cadmium to a silt loam soil

Table IV. Correlation Coefficients, *r*, Between Plant Cadmium Levels and Amounts Extracted and Adsorbed Cadmium

Factors correlated	Cadmium extracted from treated soils by *N* NH_4Ac	*N* HCl	*N* HNO_3	Cadmium adsorbed by soil (ADSCD)
Cd in radish tops	0.36[a]	−0.15	−0.22	−0.69[b]
Cd in radish roots	0.19	−0.09	−0.13	−0.80[b]
Cd in lettuce tops	0.54[b]	0.01	−0.14	−0.17
Cd in lettuce roots from quartz	0.41[a]	−0.05	−0.13	−0.29
Cd in lettuce roots from soil	0.30	−0.20	−0.21	−0.40[a]

[a] Significant at 5% level.
[b] Significant at 1% level.

Effect of Cadmium Treatment on Plant Elemental Composition. The effect of high cadmium absorption on the elemental composition of the plant parts was studied from correlation coefficients relating levels of cadmium and other elements (Table III). Cadmium concentrations in plants grown on the treated soils were related significantly with levels of Ni, Fe, Zn, and Cu in the same plant part. These findings suggested that cadmium availability is affected by soil properties such as acidity in a similar manner as availability of Ni, Fe, Zn, and Cu in the plant part.

Plant Uptake Related to Soil Cadmium. The relationship between plant cadmium and soil cadmium was studied by consideration of correlation coefficients (Table IV) calculated for the treated soils. The cadmium extracted from the 30 treated soils by *N* NH_4Ac averaged 57 ppm and was correlated significantly with cadmium in radish tops, lettuce tops, and lettuce roots from quartz. The *N* HCl and *N* HNO_3 ex-

Table V. Prediction of Cadmium in Plant from Soil Properties

Dependent variable	Model	Independent variables[a]	Coefficient of determination, R^2	Std error of prediction
Cd in radish tops, ppm	A-1	−ADSCD	0.48	228
	A-2	−ADSCD, −PHKCL	0.58	209
	A-3	−ADSCD, −PHKCL, −OMAT	0.70	180
	A-4	−ADSCD, −PHKCL, −OMAT, −ZNCA	0.78	157
	A-5	−ADSCD, −PHKCL, −OMAT, −ZNCA, FENC	0.88	119
Cd in radish roots, ppm	B-1	−ADSCD	0.65	446
	B-2	−ADSCD, FENC	0.70	420
Cd in lettuce tops, ppm	C-1	FENC	0.36	46
	C-2	FENC, MNDTPA	0.49	42
	C-3	FENC, MNDTPA, CDAC	0.57	40
Cd in lettuce roots from quartz, ppm	D-1	CDAC	0.17	44
	D-2	CDAC, ALTOT	0.33	40
Cd in lettuce roots from soil, ppm	E-1	FENC	0.32	267
	E-2	FENC, ALTOT	0.49	236

[a] Abbreviations are described in Table I. Those independent variables preceded by a negative sign (−) had negative regression coefficients.

tractions recovered most of the cadmium added but these measures of soil cadmium were not correlated with plant content. Cadmium levels in radish parts and lettuce roots from the soil were correlated inversely with relative amounts of cadmium adsorbed (averaging 490.0 ± 8.6 ppm cadmium) by the different soils (ADSCD). The inverse relation indicated that those soils able to adsorb more cadmium produced plants with lower cadmium levels.

Multiple Effect of Soil Cadmium and Other Soil Properties on Plant Cadmium. Prediction of plant cadmium on the basis of soil properties (18 potential independent variables from Table I) by the stepwise regression procedure provided a means of studying the factors which regulate cadmium absorption by radish and lettuce plants from treated soils (Table V). The significant inclusion of five terms in prediction of cadmium in radish tops explained 88% of the variation (Equation A-5). The increased relative ability of soils to adsorb cadmium was associated with decreased cadmium in radish tops, and, therefore, the term ADSCD (ppm cadmium adsorbed by soil when 500 ppm supplied) had a negative coefficient in the prediction equations. Similarly, increasing soil pH in *N* KCl (PHKCL) and oxidizable organic matter content (OMAT) adversely influenced the cadmium level in radish tops. Prediction of cadmium in radish roots from ADSCD accounted for most of the variation (65%, Equation B-1). Inclusion of FENC (Fe extracted by North Carolina extractant) improved the prediction so that 70% of the variation in cadmium content of radish roots was explained (Equation B-2). A possible explanation for the inclusion of FENC in the regression for radish roots and those for lettuce tops with a positive coefficient may be that FENC (abundant for the more acid soils) indirectly reflected the influence of soil reaction on plant cadmium uptake. Prediction of levels in lettuce tops also involved MNDTPA (Mn extracted by DTPA probably reflecting increased soil acidity) and CDAC (cadmium extracted by *N* NH_4Ac) as independent terms (Equation C-3) and explained 57% of the variation. Cadmium availability from soil, estimated by CDAC, and ALTOT (total aluminum) accounted for 33% of the variability in cadmium content of lettuce roots in the quartz zone. The two terms, FENC and ALTOT, used to predict cadmium content of roots from soil are possibly both indirect measures of soil acidity.

Summary and Conclusions

Among studies of factors influencing the assimilation o heavy metals by plants, investigation of cadmium uptake ma be most important. The cadmium content of treated soils i this study exceeded levels which occur in surface agricultura soils. John et al. (1972) found cadmium content of 33 suc soils averaged 0.88 ± 0.79 ppm HNO_3-soluble cadmium an ranged from undetectable amounts to 4.67 ppm. However localized contamination of soils attributed to agricultura chemicals or metallurgical and other industrial sources could and are shown to (John et al., 1972), attain the level of soi contamination studied. When 50 mg of cadmium was added t 500 grams of soil, the cadmium concentrations in the edibl portions of radishes and lettuce harvested from 30 differen soils averaged 387 ppm and 138 ppm in dry tissue, respec tively. The allowable level for foodstuffs, arbitrarily set a 0.5 ppm of cadmium on a wet-tissue basis, may be exceede easily when certain soils are contaminated. Results of thi study indicated that the cadmium pollutant may readily b taken up from the soil and may result in potentially hazardou accumulation of cadmium in plants. Besides its effect on th cadmium levels, the treatment produced toxicity symptom and reduced yields.

The cadmium content of plant parts was related to amount of exchangeable cadmium in the contaminated soil (measure by extraction with normal ammonium acetate) rather than t total amounts of cadmium added to the soil (estimated closel by *N* HCl and *N* HNO_3 extractions). The ability of the soils t adsorb cadmium was inversely correlated with plant cadmiu levels and was the most important single factor in explainin variations in cadmium in radish plant parts. Increased so acidity was associated with higher plant levels of cadmiu while increased organic matter content provided added ca pacity for adsorption of cadmium by the soil and was therefor related inversely to cadmium in the plant parts.

Literature Cited

Black, C. A., Ed., "Methods of Soil Analysis," Monograp No. 9, American Society of Agronomy, Madison, Wi (1965).

Follett, R. H., Lindsay, W. L., *Soil Sci. Soc. Amer. Proc* **35**, 600–2 (1971).

Hoagland, D. R., Arnon, D. I., "The Water-Culture Method for Growing Plants Without Soil," California Agr. Expt. Sta. Circ. 347 (revised) (1950).
Jackson, M. L., "Soil Chemical Analysis," Prentice Hall, New York, N.Y., 1958.
John, M. K., "Computerized Acquisition and Interpretation of Soils Data," *Agron. Abstr.*, **1970a**, p 138.
John, M. K., *Soil Sci.*, **109**, 214–20 (1970b).
John, M. K., *Environ. Lett.*, **2**, 173–9 (1971).
John, M. K., Chuah, H. H., VanLaerhoven, C. J., ENVIRON. SCI. TECHNOL., **6**, 555–7 (1972).
Kropf, R., Geldmacher-v. Mallinckrodt, M., *Arch. Hyg.*, **152**, 218–24 (1968).
Lagerwerff, J. V., Specht, A. W., ENVIRON. SCI. TECHNOL., **4**, 583–6 (1970).
Lewis, G. P., Lyle, H., Miller, S., *Lancet*, **II**, 1330–3 (1969).
Nandi, M., Jick, H., Slone, D., Shapiro, S., Lewis, G. P., *Lancet*, **II**, 1329–30 (1969).
Pionke, H. B., Corey, R. B., *Soil Sci. Soc. Amer. Proc.*, **31**, 749–52 (1967).
Ross, R. G., Stewart, D. K. R., *Can. J. Plant Sci.*, **49**, 49–52 (1969).
Schroeder, H. A., *J. Chronic Dis.*, **18**, 647–56 (1965).
Schroeder, H. A., Balassa, J. J., Hogencamp, J. C., *ibid.*, **14**, 236–58 (1961).
Schroeder, H. A., Nason, A. P., Tipton, I. H., Balassa, J. J., *ibid.*, **20**, 179–210 (1967).
Stanford, G., DeMent, J. D., *Soil Sci. Soc. Amer. Proc.*, **21**, 612–17 (1957).
Tabatabai, M. A., Bremner, J. M., *Agron. J.*, **62**, 805–6 (1970).
Tsuchiya, K., *Keio J. Med.*, **18**, 181–94 (1969a).
Tsuchiya, K., *ibid.*, **1969b**, pp 195–211.
Walkley, A., Black, C. A., *Soil Sci.*, **37**, 29–38 (1934).

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Desulfurization of Fuels with Half-Calcined Dolomite: First Kinetic Data

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■ Kinetic data are given for the first time for reaction of half-calcined dolomite with H_2S (550–800°C, 0.005–0.2 atm of H_2S in gas at 1 atm). The reaction can be used to remove H_2S from a fuel gas made by gasifying coal with air and steam at high pressure. Gas at 20 atm from a dilute-phase slagging gasifier can be desulfurized in an operation at about 920°C to reduce the SO_2 emission from power generation to roughly that expected from coal containing 0.15% sulfur. Gas at 20 atm from an ash-agglomerating fluidized-bed gasifier can be desulfurized to an even greater extent in an operation at about 760°C. In light of data given here for 700° and 800°C, the reaction can be expected to proceed to completion under these conditions at a faster rate than that afforded by the reaction of fully calcined dolomite, reported earlier. Data at lower temperatures reveal kinetic curiosities which may prove important to understanding of the reverse reaction, useful in regenerating half-calcined dolomite and releasing H_2S.

Squires (1967, 1968) proposed half-calcined dolomite as an agent to capture sulfur from a fuel gas at high pressure and at temperatures greater than about 750°C. At that time, no data were available for the reaction.

$$[CaCO_3+MgO] + H_2S = [CaS+MgO] + H_2O + CO_2 \quad (1)$$

but Squires reasoned that tiny crystallites of $CaCO_3$ embedded in a porous matrix along with tiny crystallites of MgO might display good reactivity toward H_2S. The present work has confirmed this expectation. Reaction 1 is livelier at 800°C than the reaction of fully calcined dolomite

$$[CaO+MgO] + H_2S = [CaS+MgO] + H_2O \quad (2)$$

reported on earlier (Squires et al., 1971; Pell et al., 1971). Reaction of pulverized limestone with H_2S is very slow at 800°C.

Equilibrium for Reaction 1 is a strong function of temperature, and the reverse reaction

$$[CaS+MgO] + H_2O + CO_2 = [CaCO_3+MgO] + H_2S \quad (3)$$

can be used at about 600°C to regenerate half-calcined dolomite and to release H_2S for conversion to elemental sulfur.

At 550° and 600°C, the rate of Reaction 1 drops sharply after partial conversion. A high partial pressure of CO_2 or H_2O cancels this effect and allows the reaction to proceed to completion at a good rate. A brief burst of oxygen restores reactivity. An understanding of these kinetic curiosities may prove important to the study of Reaction 3.

The City College is studying the kinetics of Reactions 1–3 with the object of contributing toward development of clean power systems in which coal or oil would be either gasified or pyrolyzed at high pressure in fuel-treating processes which are satellite to power generation by gas and steam turbines. In such processes, sulfur in the fuel would be converted to H_2S, which would then enter either Reaction 1 or 2.

A modification of the Du Pont 950 Thermogravimetric Analyzer has adapted this instrument for study of the reaction of a corrosive gas, H_2S.

The good reactivity of half-calcined dolomite makes it attractive for use in a panel bed filter (Squires et al., 1970) which removes both dust and sulfur from fuel gas produced by gasifying coal or oil at high pressure.

Reaction Conditions

Squires et al. (1971) gave the equilibrium for Reaction 1:

$$\log_{10} [H_2O]\,[CO_2]\,P/[H_2S] = 7.253 - 5280.5/T$$

where [. . .] signifies mole fraction; P is the pressure, atm: and T is temperature, °K. In a clean power process in which Reaction 1 is used to remove sulfur from a fuel gas at high pressure, the equilibrium is generally favorable for absorption of sulfur only at high temperatures, above about 750°C.

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