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THE INFLUENCE OF GAMMA RADIATION ON THE FLOTATION OF MINERALS

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THE INFLUENCE OF GAMMA RADIATION ON THE FLOTATION OF MINERALS

by

H.P. Dibbs* and R.A. Fortin**

SYNOPSIS

The effect of gamma radiation on the flotation and the collector-adsorption properties of quartz has been studied for radiation doses between 1.1×10^4 and 7×10^7 rads. No difference in behaviour was found between the irradiated and the non-irradiated samples. Flotation studies were also made on irradiated and non-irradiated galena and chalcopyrite; here again, no radiation-induced effects were observed.

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Direction des mines

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L'INFLUENCE DE LA RADIATION GAMMA SUR LA FLOTTATION DES MINÉRAUX

par

H.P. Dibbs* et R.A. Fortin**

RÉSUMÉ

Les auteurs ont fait une étude sur l'effet de la radiation gamma sur la flottation et sur les propriétés d'absorption par collecteur pour les doses d'irradiation entre les rads de 1.1×10^4 et 7×10^7. Ils n'ont pas trouvé de différence dans le comportement entre les échantillons irradiés et non irradiés. Ils ont aussi fait des études de flottation sur la galène et la chalcopyrite irradiées et non irradiées, ici encore ils ont observé qu'il n'y avait pas d'effets d'irradiation induite.

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INTRODUCTION

The froth-flotation process for the separation of valuable minerals from gangue materials has been widely investigated, and much effort has been devoted to develop an understanding of the factors that influence flotation and to the empirical development of collectors, modifiers, and depressants for the selective separation of specific minerals (1-4). However, relatively little attention has been given to the effect of physical (i. e., non-chemical) variables on flotation, although it is known, for example, that magnetic and electromagnetic fields can influence the rates of chemical reactions (5). The present study arose from reports in the literature (6-10) that the irradiation of certain minerals with neutrons, with beta particles, or with gamma radiation changed some of the surface properties of the minerals that are significant in flotation, and also produced changes in flotation yields by comparison with systems that had not been irradiated. Thus, O'Connor (6) found that the zeta potential and the ion-adsorption properties of thoria were altered by thermal-neutron irradiation at an integrated thermal-neutron flux of 3.73×10^{18} neutrons/cm^2. This behaviour was qualitatively attributed to modifications in the surface structure of thoria as a result of energy deposition in the solid phase during neutron irradiation. Although the magnitude of the zeta potential at the oxide-solution interface is known to influence the adsorption of surface-active agents, and to be important in the flotation behaviour of oxides (11), neutron irradiation is not practical in the industrial flotation process because of the radio-activity that is induced in the target elements. Irradiation with beta particles or with gamma radiation does not lead to the formation of induced activity and is, therefore, a potentially attractive method to produce modifications in the physico-chemical properties of the solid-solution interface. As large amounts of long-lived beta and/or gamma-emitting fission products and other reactor-produced isotopes are readily available at moderate cost, the commercial application of radiation sources to flotation systems would be practical.

The wetting angle at the mineral/solution interface is an important parameter in flotation studies (1), and changes in the wetting angles of several oxide minerals have been observed following gamma irradiation at doses as low as 1,000 rads, using a cobalt-60 source (7). Reports have also been published that the irradiation of minerals or of a flotation pulp with beta and/or gamma radiation can lead to changes in flotation recovery by comparison with parallel measurements on non-irradiated systems (8, 9, 12, 13), and that these radiation-induced changes decayed slowly over a period of hours or days. To investigate these effects in more detail, the present study was made of the flotation behaviour and the collector-adsorption properties of irradiated quartz, and of the flotation behaviour of some irradiated sulphide minerals, using a cobalt-60 (gamma) irradiation facility. Because radiation-induced effects depend upon the total radiation dose and also upon the dose-rate (9), two widely different dose-rates were used in the flotation measurements with quartz. To delineate unambiguously the influence of irradiation, flotation and adsorption measurements were made under identical experimental conditions with irradiated and non-irradiated minerals.

EXPERIMENTAL

Preliminary flotation measurements with quartz were made in a Hallimond cell (14). The cell contained a medium-porosity frit and a constant volume of gas was used in all the tests. It was found, however, that replicate flotation measurements were not sufficiently precise (±10%) to determine accurately small changes in flotation recovery. This lack of precision could be due to the relatively large bubble size from the frit and to the gradual abrasion of the frit by the quartz leading to changes in the bubble characteristics. A flotation cell (Figure 1) was therefore developed in which the frit was replaced, as a bubble source, by a 60-μm-diameter capillary tube. The end of the capillary tube was positioned about one centimetre above the bottom of the cell to allow sufficient space for the unhindered rotation of the magnetic stirrer bar. High-purity nitrogen was displaced through the cell by admitting water from a five-gallon header tank into a 400-ml cylinder connected to the 60-μm capillary tube. An accurate and reproducible measurement of the gas volume was obtained from a graduated side-arm on the cylinder. At the end of a run, the water was returned to the header tank by admitting nitrogen through the three-way stopcock (A) at the top of the cylinder.

For the flotation measurements, two grams of cleaned quartz were placed in the flotation cell and 165 ml of 6×10^{-6} M dodecylamine hydrochloride (DDAHCl) at pH 10.5 was added. The quartz was conditioned for five minutes with gentle stirring, and a fixed volume of nitrogen was then passed through the cell. At the end of a run, the non-floated quartz was collected, dried, and weighed. The flotation recovery was dependent on the volume of nitrogen passed through the cell (Figure 2); this volume was standardized at 325 ml. A flotation run with irradiated quartz was made immediately before or after a comparable run with non-irradiated quartz. Usually, at least five pairs of flotation runs were made for each irradiation dose. The irradiations prior to flotation were made in either a low-dose-rate (3.75×10^{3} rads/hr) or a high-dose-rate (1.12×10^{6} rads/hr) cobalt-60 irradiation facility at Commercial Products Division, Atomic Energy of Canada Ltd., Ottawa. About thirty minutes elapsed between the end of the irradiation and the first flotation measurement. Integral doses between 1.1×10^{4} and 7×10^{7} rads were used.

The quartz was prepared from selected crystals of Brazilian quartz. These were crushed; the -65 + 100 -mesh fraction was retained and leached with constant-boiling hydrochloric acid to remove iron in an all-glass Soxhlet extractor for twenty-four hours. The cleaned quartz was then elutriated with distilled water until the effluent was free from chloride ions. The cleaned and washed quartz was stored until required under triple-distilled water.

1. 5-gal reservoir
2. 400-ml cylinder
3. Teflon-coated magnetic bar
4. Magnetic stirrer
5. 60μ capillary
6. 29/42 standard taper joint (Teflon sleeve)
7. Collector solution level
8. Rubber stopper

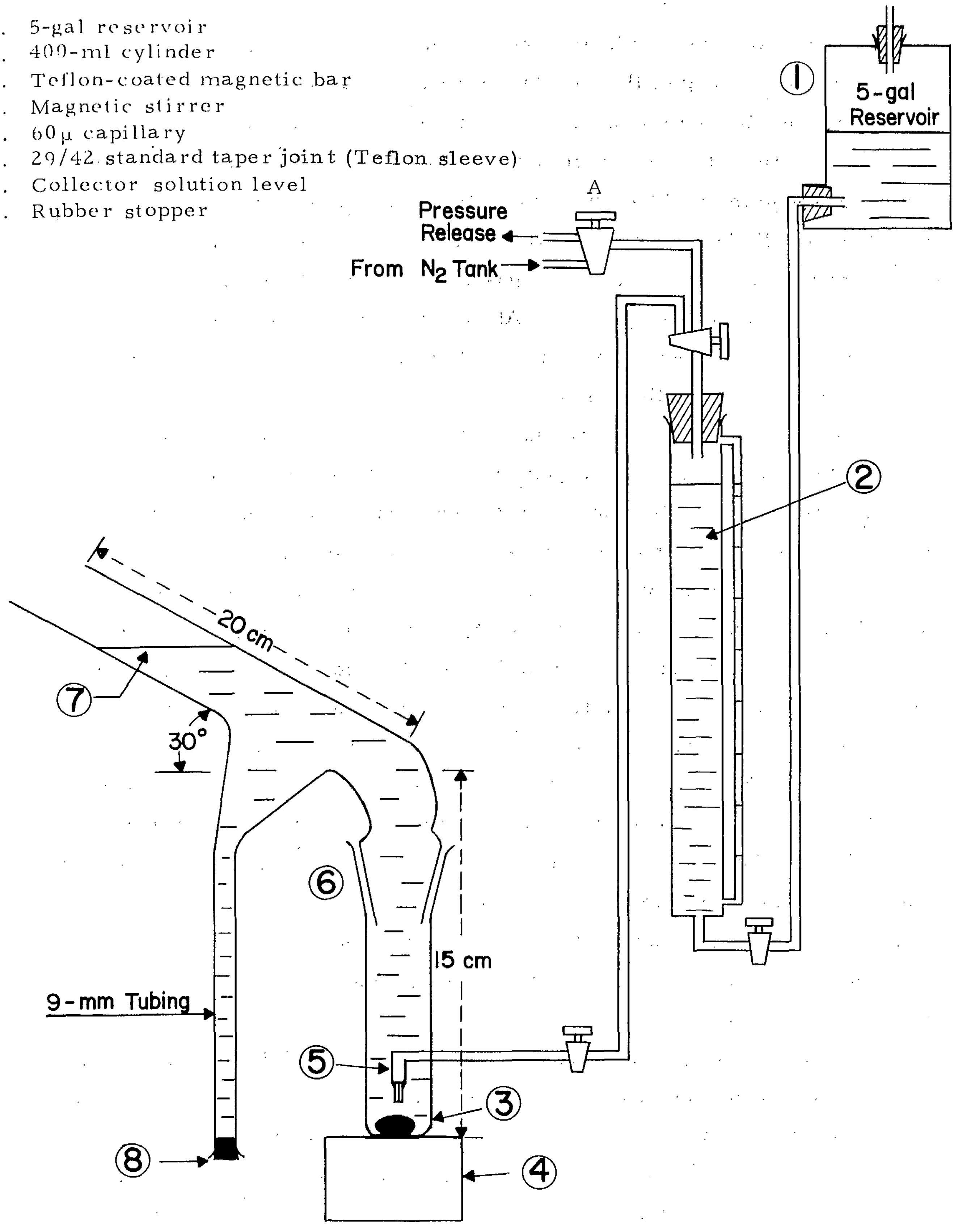

Figure 1. Flotation Cell and Gas System.

Some flotation measurements were also made with samples of -65 + 100 -mesh chalcopyrite and galena, prepared from natural crystals. The samples were elutriated with distilled water for twenty-four hours and then dried before use. The flotation procedure was similar to that employed with quartz, except that potassium ethyl xanthate was used as a collector at pH 10.

It was felt that, if the irradiation of minerals was to influence their flotation behaviour, it should also affect the amount of collector adsorbed at the mineral solution interface. Therefore, measurements were made, using DDAHCl labelled with carbon-14, of the amount of DDAHCl adsorbed on irradiated and non-irradiated quartz. A stock solution, containing 8.8 mg of the labelled DDAHCl (specific activity, 0.92 mCi/ mM) in a 1,000 ml of water at pH 10.5, was prepared. A 250-μl aliquot of this solution was added to 10 ml of a scintillator (Type 'PCM', Amersham-Searly Corporation, Toronto) in a low-background vial and counted in a liquid-scintillation counter to give the initial concentration (in terms of counts per minute) of the stock solution. For the adsorption measurements, 20 ml of the stock solution was added to a pre-weighed sample of quartz in a screw-top vial which was then rotated in a mechanical shaker for fifteen minutes. Preliminary measurements (Figure 3) had indicated that this time was adequate for equilibrium to be established between the collector and the quartz and that the amount of DDAHCl adsorbed depended on the weight of quartz (Figure 4). Following shaking, a further 250-μl aliquot of the supernatant solution was taken and counted. The difference in the count-rates between the stock solution and the adsorption solution then gave a measure of the amount of DDAHCl adsorbed on the quartz.

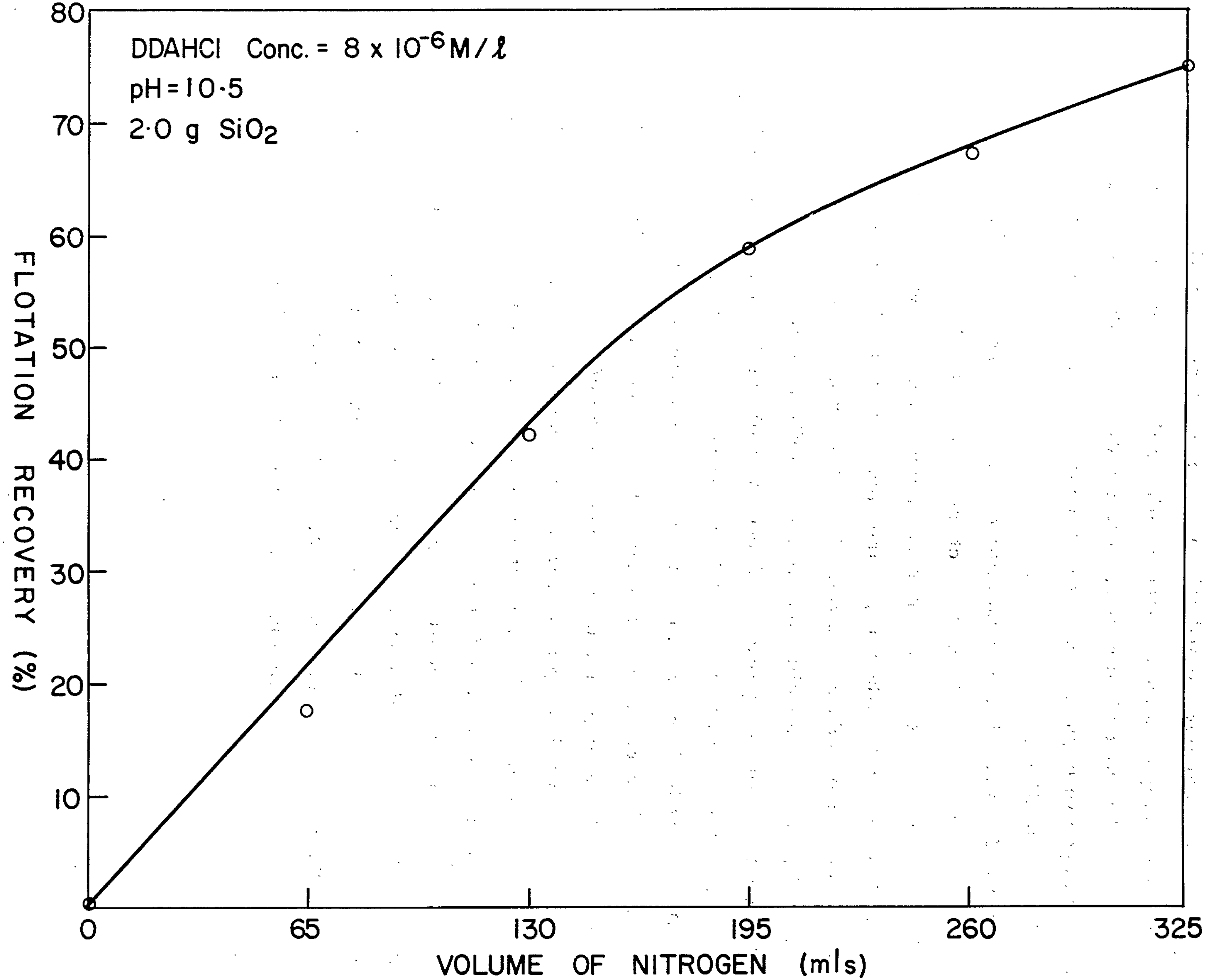

Figure 2. Flotation Recovery of Quartz as a Function of Volume of Nitrogen.

RESULTS

The flotation recoveries of quartz, irradiated for doses between 1.1×10^4 and 7×10^7 rads, together with the results of parallel flotation measurements on non-irradiated quartz, are given in Tables 1 to 5. The close agreement between the two sets of results shows that gamma irradiation has a negligible effect on the flotation recovery of quartz. Similarly, quadruplicate measurements indicated that the adsorption of DDAHCl on 2-and 8-gram samples of irradiated and non-irradiated quartz was unaffected by the radiation treatment (Table 6).

It was also found that the flotation recovery of chalcopyrite was unaffected by radiation treatment (Table 7). The results for the flotation recovery of galena (Table 8) were somewhat more scattered than those for quartz and chalcopyrite. This could be due to the relatively friable nature of the galena, but no evidence of radiation-induced effect was found.

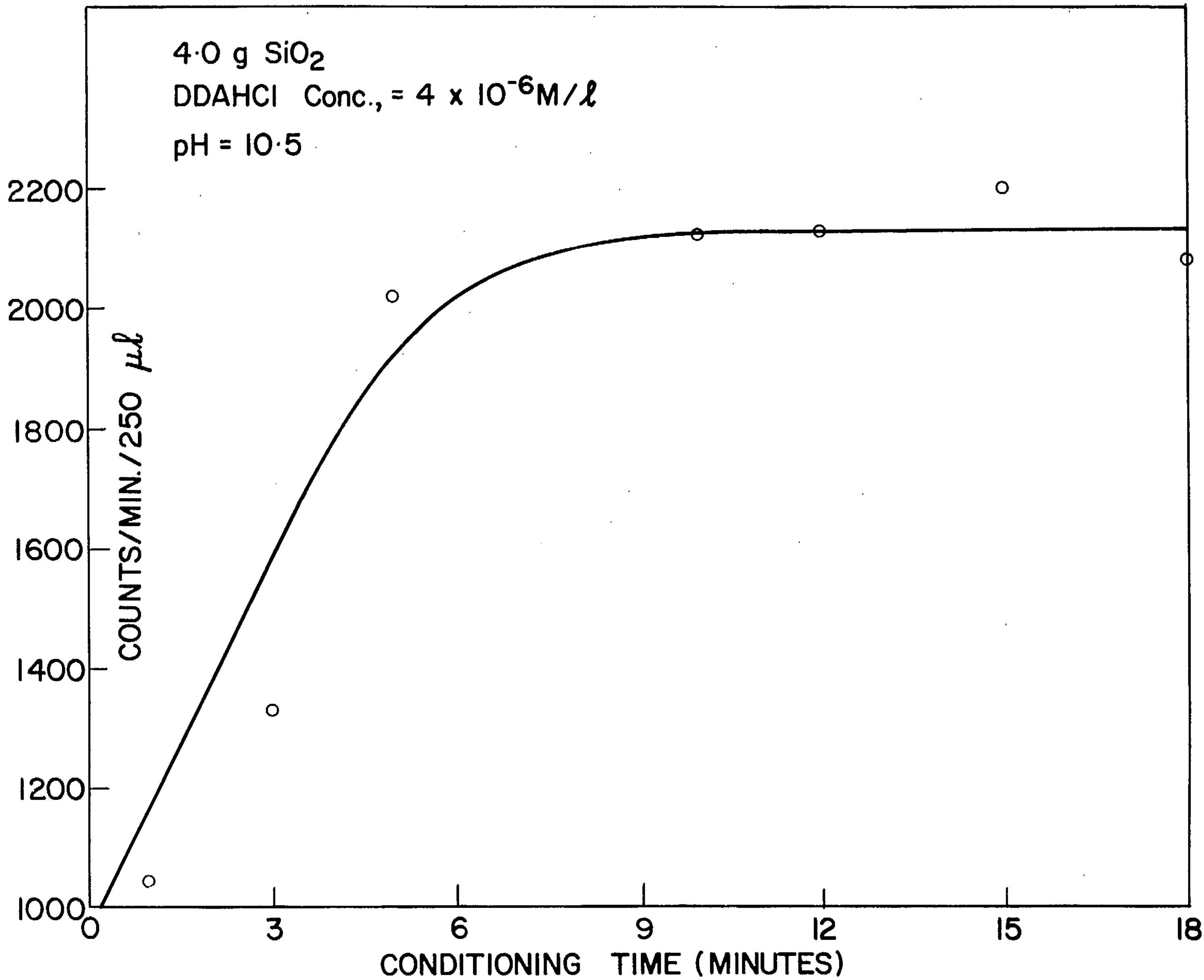

Figure 3. Adsorption of DDAHCl on Quartz as a Function of Conditioning Time.

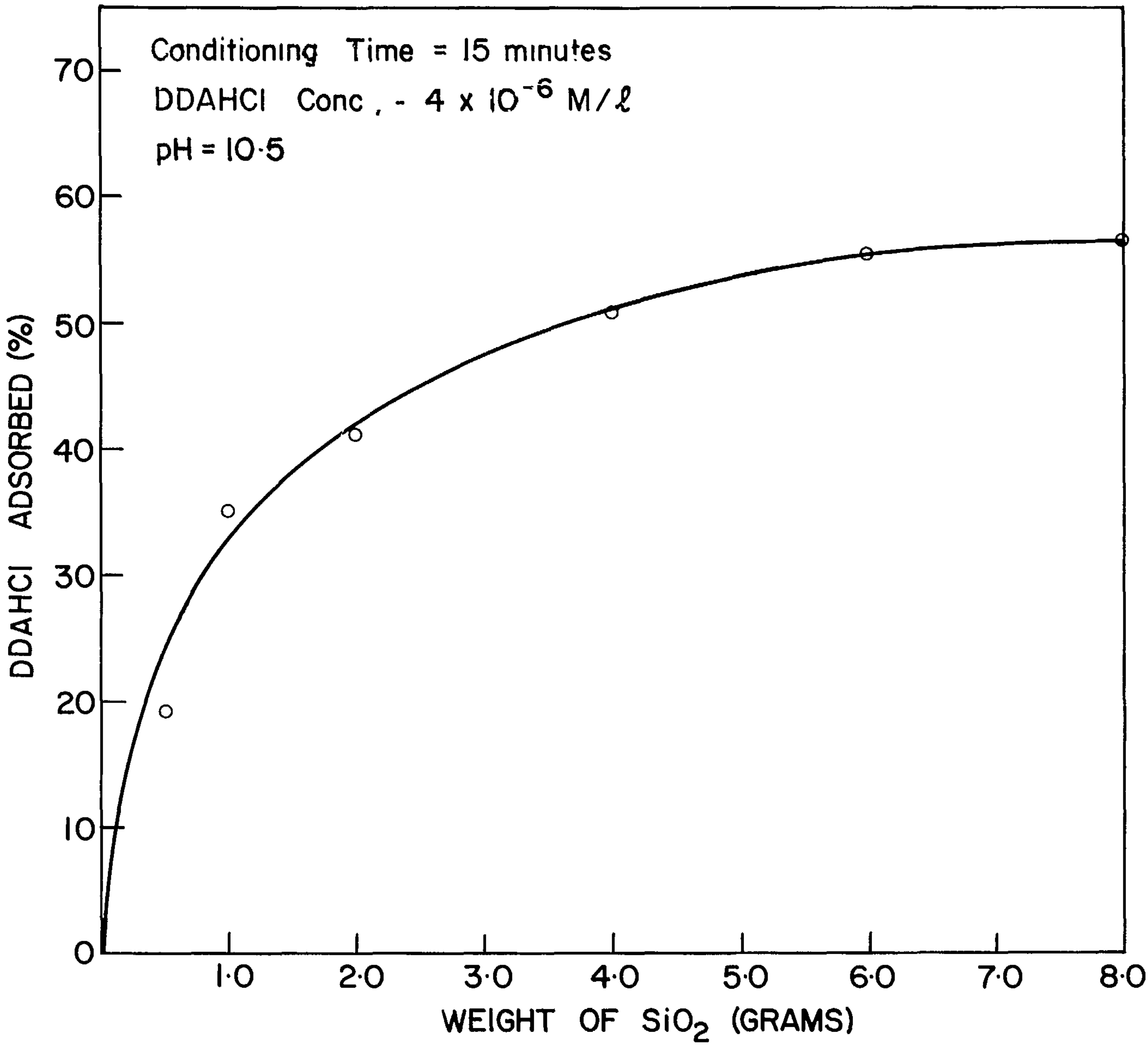

Figure 4. Percentage of DDAHCl Adsorbed on Quartz as a Function of the Weight of Quartz.

TABLE 1

Flotation Recovery of Quartz
Radiation dose = 11,000 rads (at 1.12×10^6 rads/hr)

% Recovery SiO_2, Non-irradiated	% Recovery SiO_2, at 11,000 rads
39.6	31.1
34.5	34.0
29.8	31.5
30.0	33.3
28.1	27.5
27.0	27.4
Average 31.5	Average 30.8

TABLE 2

Flotation Recovery of Quartz
Radiation dose = 15,000 rads (at 3750 rads/hr)

% Recovery SiO_2, Non-irradiated	% Recovery SiO_2, at 15,000 rads
37.9	29.4
32.6	30.1
34.9	29.5
Average 35.1	Average 29.7
28.4	27.9
27.6	28.5
26.8	28.3
	26.9
Average 27.6	Average 27.9

TABLE 3

Flotation Recovery of Quartz
Radiation dose = 22,000 rads (at 1.12 x 10^6 rads/hr)

% Recovery SiO_2, Non-irradiated	% Recovery SiO_2, at 22,000 rads
36.7	38.6
37.0	37.3
36.2	39.0
37.3	36.7
30.2	37.9
28.4	30.7
34.4	31.6
Average 34.3	Average 36.0

TABLE 4

Flotation Recovery of Quartz
Radiation dose = 220,000 rads (at 1.12 x 10^6 rads/hr)

% Recovery SiO_2, Non-irradiated	% Recovery SiO_2, at 220,000 rads
15.7	15.1
14.4	14.2
14.4	14.1
18.0	18.1
16.6	14.8
14.5	14.2
Average 15.6	Average 15.1

TABLE 5

Flotation Recovery of Quartz
Radiation dose = 7.0×10^7 rads (at 1.12×10^6 rads/hr)

% Recovery SiO_2, Non-irradiated	% Recovery SiO_2, at 7.0×10^7 rads
31.7	30.0
33.4	30.1
33.6	29.0
32.3	30.9
29.0	32.7
	33.1
Average 32.0	Average 31.0

TABLE 6

Adsorption of DDAHCl on Quartz
Radiation Dose = 22,000 rads (at 1.12×10^6 rads/hr)

Wt. of SiO_2 (g)	SiO_2, Non-Irradiated, Average counts/min	SiO_2, 22,000 Rads, Average counts/min
2.0	3070	3074
8.0	4032	4014

TABLE 7

Flotation Recovery of Chalcopyrite
Radiation dose = 22,000 rads (at 1.12 x 10^6 rads/hr)

% Recovery $CuFeS_2$, Non-irradiated	% Recovery $CuFeS_2$, at 22,000 rads
57.3	57.9
49.9	48.8
52.4	52.4
51.6	45.7
61.6	48.7
43.6	43.6
Average 52.7	Average 49.5

TABLE 8

Flotation Recovery of Galena
Radiation dose = 22,000 rads (at 1.12 x 10^6 rads/hr)

% Recovery PbS, Non-irradiated	% Recovery PbS, at 22,000 rads
66.0	63.0
73.0	54.0
60.2	74.1
86.3	74.2
81.2	73.4
82.4	78.3
Average 74.9	Average 69.5
45.2	82.6
60.1	46.3
74.1	58.2
74.5	61.7
64.5	85.0
Average 63.7	Average 66.8

SUMMARY

The results obtained in this study of the effect of gamma radiation on the flotation recovery of quartz, galena, and chalcopyrite show no evidence that the radiation treatment modifies their flotation behaviour. Thus, the Student's "t" test detects no significant difference (at 95% level of significance) between the results for non-irradiated and for irradiated minerals, except for the first set of data on quartz recovery in Table 2. This experiment was repeated and gave a negative result so little weight can be given to the result of this single experiment which is at variance with the results of all the other experiments. These results may perhaps be expected for quartz which is a very stable insulator; however, from other studies (8, 12) it might be expected that galena and chalcopyrite, which are low band-gap semiconductors (15), would show some evidence of radiation-induced effects. It would, therefore, be interesting to extend the study of these and other sulphide minerals, to cover a greater range of radiation doses and dose rates, and to examine the influence on the flotation recovery of in-situ radiation during flotation. This latter treatment will produce highly reactive short-lived species in the aqueous and solid phases that could have a marked effect on solute-solid interactions.

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