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Figure 3 I.r. spectra of a typical fraction from t.l.c. of FAm

and 1384 cm^{-1} (CH_2 and CH_3), and also a broad band with defined peaks around 1245 , 1210 , 1175 , 1110 and 1030 cm^{-1} ($\text{C}-\text{O}$ bonds in methyl esters and ethers). No marked differences in chemical nature could be inferred from the i.r. spectra of the fractions, which differed only in the relative intensity of the bands. This low selectivity can be attributed to small

differences in polarity, strongly reduced by the methylation process.

The results obtained agree with those reported previously from column chromatography or pyrolysis-gas chromatography¹⁸⁻²¹, which indicated that the main components of FA are polysaccharide-like substances, and showed the use of a technique as simple as t.l.c. in adequately fractionating FA on the basis of the functional groups present. This fractionation is better carried out on FA rather than FAm, which has a reduced polarity that impedes good separation of the components.

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Mineralogy of heavy mineral concentrates from oil sands†

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The distribution of heavy minerals in concentrates, obtained from Alberta oil sand tailings using acid demineralization and oil phase agglomeration, was determined by X-ray diffractometry. The data have demonstrated the effectiveness of oil phase agglomeration techniques in rejecting gangue and other unwanted minerals such as pyrite during the concentration of heavy minerals. The results also suggest that titanium minerals could possibly be separated from zircon in the mineral concentrate by acid dissolution. Due to the different modes of agitation during collection, the mineralogical components of the two samples obtained from Suncor sludge differ considerably.

(Keywords: oil sand; demineralization; X-ray diffractometry)

Oil sand solids are known to contain small quantities of 'heavy metal' minerals, notably those of titanium and zirconium¹. These minerals occur in low concentrations, but in amounts which are significant considering the large volume of material processed ($\approx$ two tons of oil sand per barrel of synthetic crude oil). These minerals are concentrated along with the bitumen froth in the hot water separation process^{1,2}. In particular, solids removed from the bitumen froth in the centrifuge stage contain significant amounts of heavy minerals of titanium, zirconium and iron. The minerals present in the waste stream of the hot water extraction process are often associated

Table 1 Sample description and elemental composition of the mineral portion of the heavy mineral concentrates

Sample No.	Source	Ash ^a (wt %)	Elemental analyses (wt % of ash)							
			SiO ₂	Al ₂ O ₃	Ti	Zr	Fe	V	Ni	Mn
1	Heavy mineral concentrate obtained from Suncor sludge ^b	74	39.8	6.7	18.6	1.4	11.5	0.1	0.1	0.2
2	As above	68.0	31.8	14.0	20.1	2.55	6.5	N.D.	0.05	0.2
3	Heavy mineral concentrate obtained from Syncrude tailings ^b	32.0	21.4	7.6	30.0	6.0	10.0	0.6	0.1	0.2
4	Acid demineralized Syncrude centrifuge tailings (8)	3.1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

^a The incombustible portions of these samples consist mainly of humic matter (Ref. 8)

^b Obtained using oil phase agglomeration technique (6)

N.D. = not determined due to insufficient sample

† Issued as NRCC 28413

with the bitumen. This paper reports an investigation into the feasibility of selectively concentrating heavy metals, particularly titanium and zirconium, from oil sand tailings by the oil phase agglomeration method³⁻⁶. The distribution of heavy minerals in the concentrates so obtained was determined by X-ray diffractometry (SCINTAG unit with a graphite crystal monochromator and CoK_α radiation; λ = 1.7902 Å).

RESULTS AND DISCUSSION

Table 1 lists the elemental analyses of ashes from heavy mineral concentrates and an acid-demineralized (HCl/HF) Syncrude centrifuge tailings sample. The elemental analyses were determined using the quantitative inductively coupled plasma atomic emission spectroscopic method (ICP-AES)⁷. X-ray diffraction analyses (Table 2) reveal that gangue rejection is most effective for the sample (No. 3) from Syncrude centrifuge tailings, which consists mainly of zircon, anatase, rutile and quartz. Considering that a portion of the silica is associated with zircon, the amount of quartz in this sample is small. The X-ray diffraction study of the acid-demineralized Syncrude centrifuge tailings sample (No. 4) shows zircon, quartz and pyrite as the major minerals. This result is consistent with the

Table 2 Mineral composition of various samples as determined from X-ray diffraction

Sample	Minerals
1	Major: quartz, anatase, rutile, ilmenite Minor: mica, apatite, pyrite, diaspore (?)
2	Major: quartz, siderite, kaolinite, anatase, calcite, pyrite Minor: rutile
3	Major: zircon, anatase, rutile, quartz
4	Major: zircon, quartz, pyrite

zircon being most resistant to acid attack. Pyrite was also detected in sample No. 2, but not in samples Nos. 1 and 3. These results demonstrate the advantage of oil phase agglomeration techniques⁶ in rejecting gangue and other unwanted minerals such as pyrite. They also suggest that titanium minerals could possibly be removed from zircon in the mineral concentrate by acid dissolution. The mineralogical components of the two samples obtained from Suncor sludge pond tailings differ considerably, as shown in Table 2. Since two different modes of agitation were used in collecting these concentrates, these results support the previous observation⁵ that the mode of agitation plays a significant role in the

beneficiation of heavy metal minerals using oil phase agglomeration techniques. The differences between the mineralogical compositions of the samples obtained from sludge pond tailings and those from centrifuge tailings are representative of the compositions of the feed materials.

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Book Review

Combustion, Flame and Explosion of Gases
Bernard Lewis and Guenther von Elbe
Academic Press (3rd edn), 1987, pp. xxiv + 739, £52

A book of this title was first published by the authors in 1938. Major revision led to the first edition proper of this famous work, published in 1951, which helped establish the authors as the undoubted leading figures in Combustion Science. The second edition appeared in 1961, with the recognition that the subject was growing at a remarkable pace. The rate of growth during the intervening 26 years between second and third editions has been perhaps even more dramatic, fuelled by biennial Combustion Institute conferences and by journals such as *Combustion and Flame* (and *Fuel*, although this was omitted from the authors' list). One probably cannot expect a complete treatise in a single volume. Similarly, it is no longer possible for one or two specialists, even with the eminence of Lewis and von Elbe, to cover the whole of the field in full comprehension and awareness.

The aim of this work, as stated in the preface, continues to be to provide 'the chemist, physicist and engineer with the scientific basis for understanding combustion phenomena'. There is a huge amount of information captured within the text and every combustion scientist should spend some time in its pages. Since the publication of the second edition, however, a growing number of introductory works on the subject have appeared, notably that by Barnard and Bradley, which perhaps make easier teaching texts. For the third edition the authors have steered a middle course between correction of minor changes and a full rewriting. Some parts of the second edition remain virtually verbatim, perhaps augmented only by the addition of a few modern references with a throw-away line in the main text. There has, however, been a major revision of some

chapters and the inclusion of new topics, such as wrinkled flames. The book remains divided into four main sections: part I, Chemistry and Kinetics of the Reaction between Gaseous Fuels and Oxidants; part II, Flame Propagation; part III, State of the Burned Gas; part IV, Technical Combustion Processes. There are also a number of useful appendices, including a short tabulation of some important rate constants (although without any indication of the temperature range over which these may be used). The new edition sees a more attractive typeface and layout, in particular many of the diagrams are larger than before. The authors continue to mix units, for example, kcal or even ft³ h⁻¹; true SI units are the hardest to find. Part I contains the major revisions. I am disappointed that Thermal Explosion Theory, which has received much attention and interest in the past 30 years, still gets only a cursory mention here and no discussion elsewhere. Chapter II discusses the classic behaviour of the hydrogen-oxygen reaction in great mechanistic detail. The elementary steps