APPENDIX G

Experimental Data For Runs 5, 6 and 7

TERTIARY LEACH RUN 5

The objective of Run 5 is to determine whether the ferrous (Fe3+) in solution will have any effect on the solubilisation of the PGMs, particularly rhodium, ruthenium and palladium. This is achieved by performing a leach under the same conditions as those employed in Run 2 but at the point where the intermediate acid addition will occur, a 2 g/l ferric sulphate solution in sulphuric acid is injected into the system in place of the acid. The leach is continued for a further one and a half hours to allow observation of any effects of solubility with regards to the PGM component. The leach is terminated and it must therefore be noted that it is prevented from reaching completion. This fact is indicated by the redox and acidity profiles displayed in Figure G 1.1, where it is evident that the slurry redox does not exceed 488 mV at any one time. No intermediate acid addition is employed for this investigation.

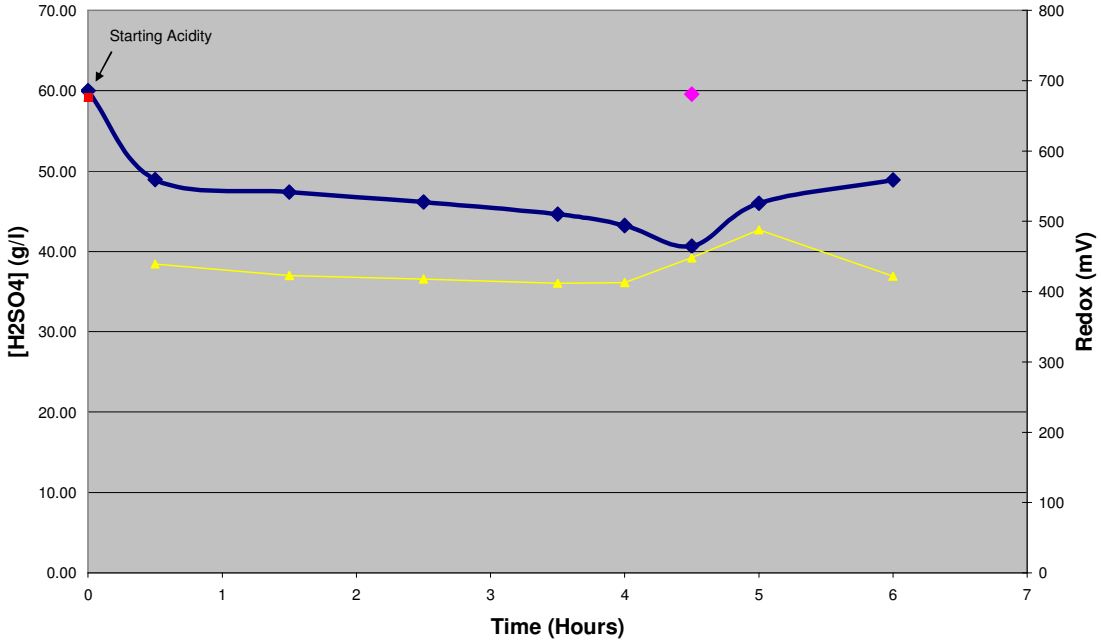

Figure G 1.1 Profiles of acidity of leach solution and redox of slurry for Run 5

The starting acidity is indicated by the red data point on the graph and it can be seen that there is a decrease in the acidity from the start of the leach up until the point at which the ferric sulphate solution with a redox of 681 mV is added, indicated by the pink data point, this appears to halt the acid consumption and effectively results in the acidity levelling out. The graph shows that once the ferric is added there is an initial response from the redox of the system, an increase of slurry redox from

448 mV to 488 mV is observed at this point but it is short lived as the redox then stabilises back to similar levels (422 mV) recorded prior to the ferric solution addition. The leaching kinetics up until the point of ferric sulphate addition is as expected, this is displayed in Figure G 1.2. Sulphur profile gives the usual initial decrease and 2 step cycle before an increase in the soluble content which may be coincidental in that it appears to occur at the same time as the addition of the ferric solution, this may be due to the ferric or due to the generation of acid which may also be influenced by the addition of the ferric. The copper and nickel leaching profiles appear to be very similar to those seen for Run 2 and nothing out of the norm is observed. It is once again evident from the profile that an acid consuming reaction is taking place from the start of the leach but the decrease in acidity is not as drastic as previously seen, it only decreases down from 60 g/l to ~40 g/l equating to ~33 % of the available acid being consumed. Unlike in Run 2, where a total of ~83 % of the available acid is consumed in the reactions taking place at this time.

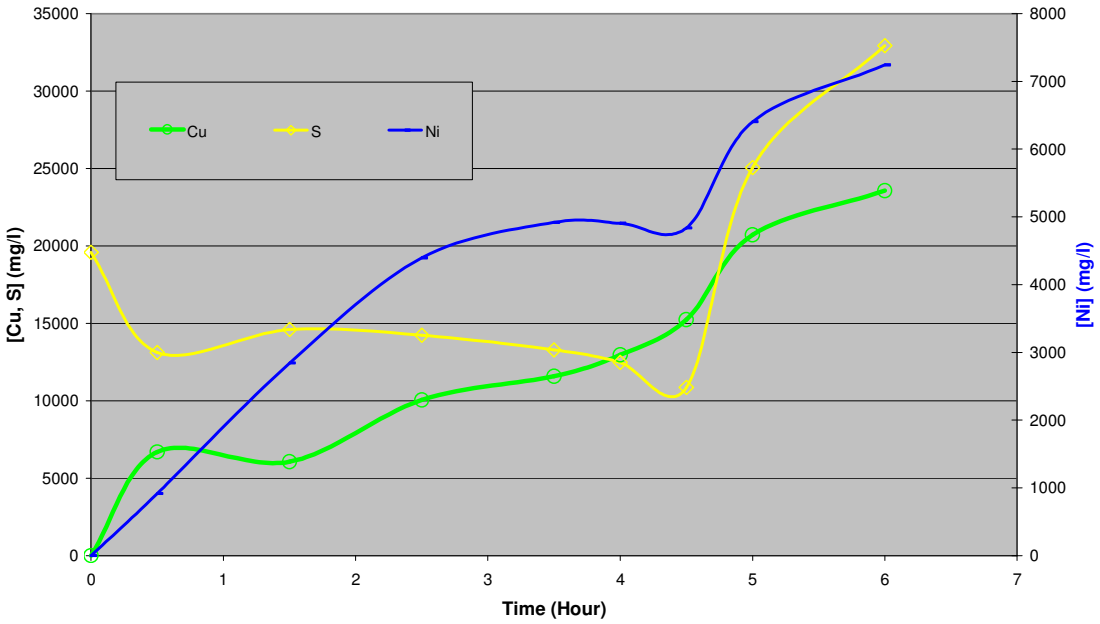

Figure G 1.2 Soluble base metal concentration profiles for Run 5

The iron and cobalt base metals have not been included in this profile as they are leached to insignificant levels. The nickel is displayed on a different axis to that of copper and sulphur to illustrate the similarities and comparisons of the trends. However, the point of this exercise is to establish whether or not the precious metals

are influenced by manipulating the redox of the slurry with the addition of a ferric solution. The amount of soluble PGMs detected in solution before and after the addition is negligible and therefore it is logical to conclude that the amount of ferric added cannot be considered a significant factor in this experiment. The profile of the precious metals is given in Figure G 1.3. Once again platinum, gold and iridium are below detection levels. The log sheet providing all the conditions and recorded measurements during the leach is given in Appendix B, while a full mass balance of 10 elements can be viewed in Appendix C. No mineralogical analyses are requested for the samples taken during this run since the solution analyses did not indicate significant solubilisation of any of the PGM components.

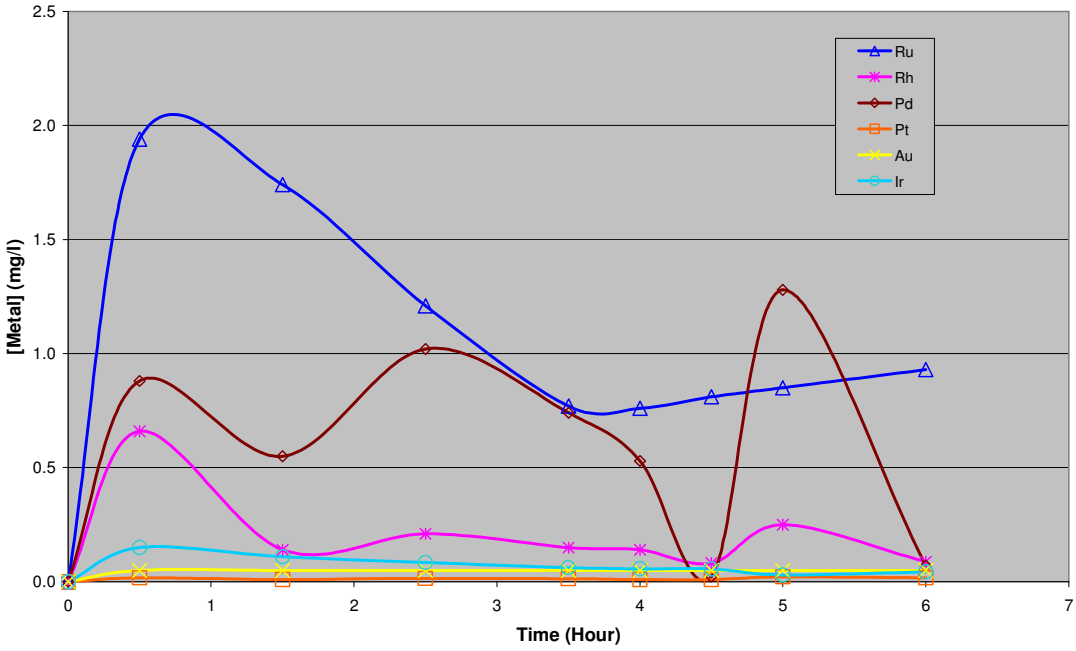

Figure G 1.3 Soluble precious metal concentration profiles for Run 5

TERTIARY LEACH RUN 6

There is a concern that in the previous experiment, the amount of ferric solution added is diluted by the leachate and therefore insufficient to cause a substantial increase in the redox measurements of the slurry. This will result in a lack of influence on the PGM solubilities and thereby prevent sufficient amounts to deport to the liquor. It is therefore logical to perform the next experiment under the same conditions as that of Run 5 except, several portions of ferric sulphate solutions (5 g/l) will be added at various time intervals to establish whether these amounts are able to influence the redox enough to effect solubilisation of the PGMs. The graph, Figure G 1.4, depicts the profiles of the acidity of the solution and redox of the slurry and also indicates the points at which different quantities of 5 g/l ferric sulphate solutions are added. The first addition of 50 ml is added at 5 hours, the second addition of 100 ml is added at 5.5 hours, thereby attempting to add a large amount of ferric into the system compared to what the usual iron concentration will normally be in the slurry. Then an interval where no additions of ferric occur to allow reaction time and assess whether any effects can be observed. After a total of 10.5 hours of leaching, the third amount of 100ml ferric solution is added and again another 100 ml is added at 11.5 hour interval. This made a total addition of 350 ml of 5 g/l ferric solution to the system, equating to ~0.5 g of ferric. This amount of iron, even though the iron solution measured a redox of 660 mV, does not significantly affect the slurry redox at each addition as seen from the graph. The ability to add a large excess of iron (as a solution of ferric sulphate) is limited by the volume in the pressure vessel, the low redox may have also resulted due to the considerable dilution of the ferric solution by the volume already present in the vessel. The lack of redox manipulation has therefore indicated the necessity to explore one more possibility that can rule out any dilution effects. This is achieved by the addition of larger excesses of Fe^{3+} to the system, and based on the volume constraints, this will therefore need to be added in a solid form upfront prior to pressurisation and heating of the reactor.

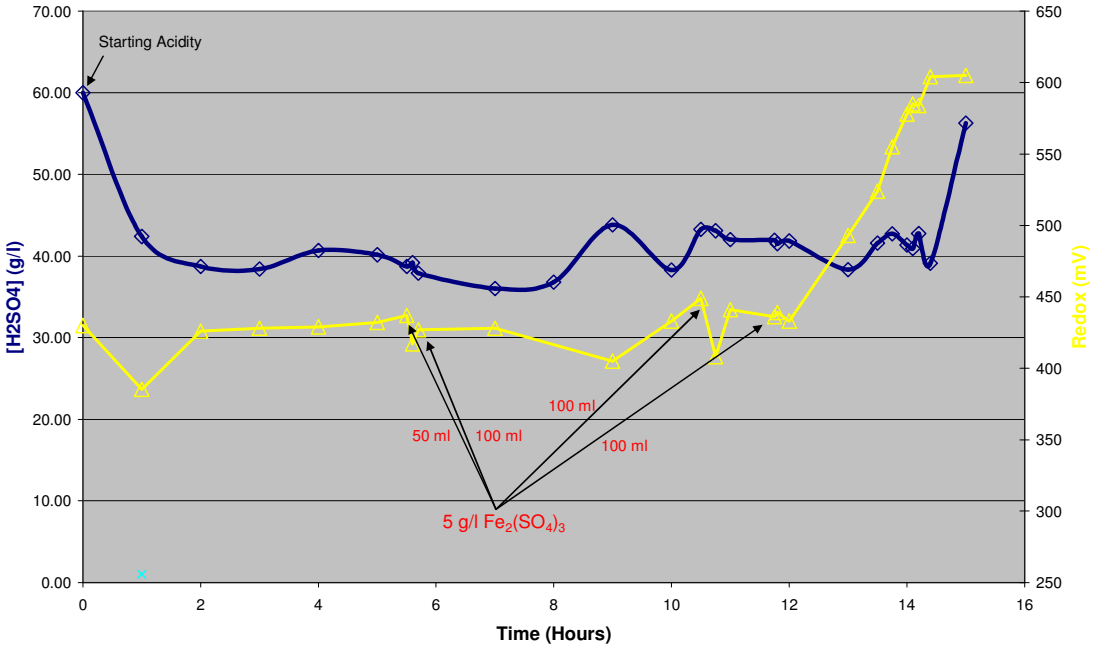

Figure G 1.4 Profiles of acidity of leach solution and redox of slurry for Run 6

The question of whether the addition of the ferric sulphate solution influences the solubility of the precious metals is indicated in Figures G 1.5 and G 1.6. The first graph shows the profile of ruthenium and rhodium throughout the entire leach, while the second graph indicates the first 14 hours of the leach, to expand the scale of the concentration levels so that the smaller changes can be viewed before the sudden increase in the soluble values of rhodium and ruthenium that occurs in the final stages of the leach.

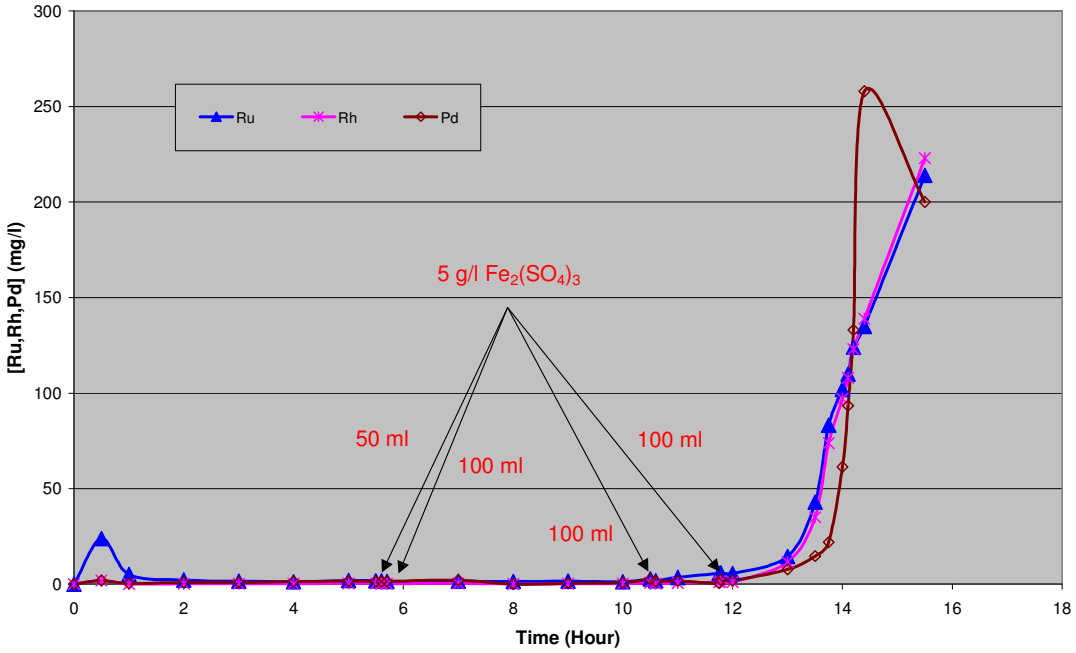

Figure G 1.5 Soluble precious metal concentration profiles for Run 6

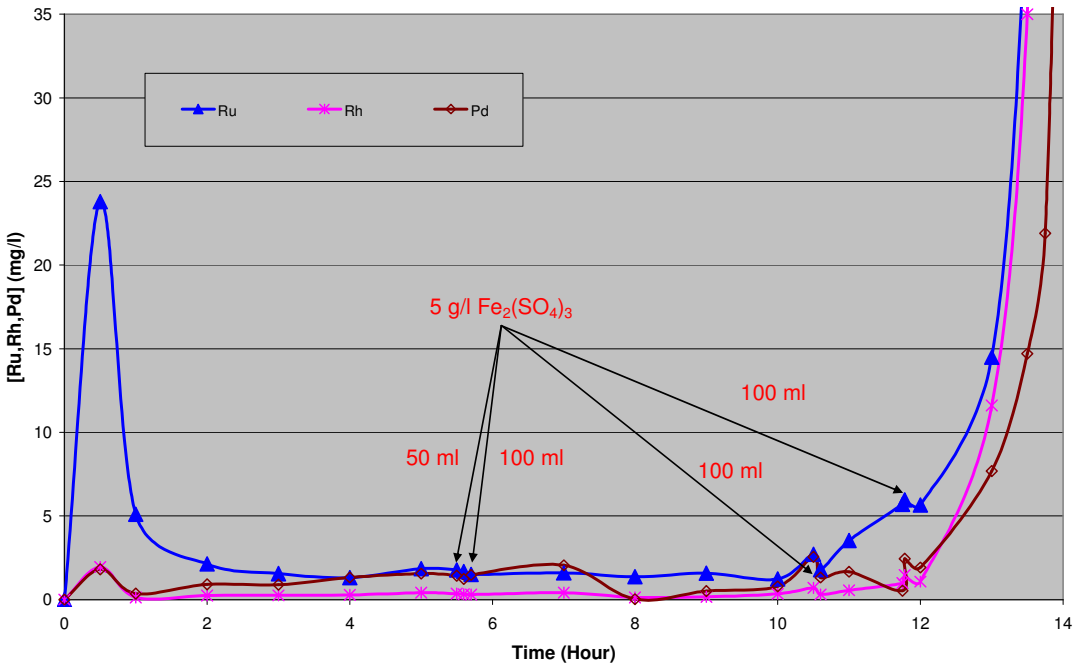

Figure G 1.6 Soluble precious metal concentration profiles for a section of the leach for Run 6

It is evident that there is some degree of rhodium, ruthenium and palladium that dissolves from the start of the leach and that the amount of ferric sulphate solution added does not appear to influence the PGM solubilities. Similar concentration

profiles are obtained in experiments where no ferric is added to the system. Again, the platinum, gold and iridium concentration profiles are not included as these are below levels of detection thereby indicating no significant dissolution.

For completeness sake the profiles of the base metals are also displayed in Figure G 1.7, these are very similar to those obtained for Run 2, confirming reproducibility.

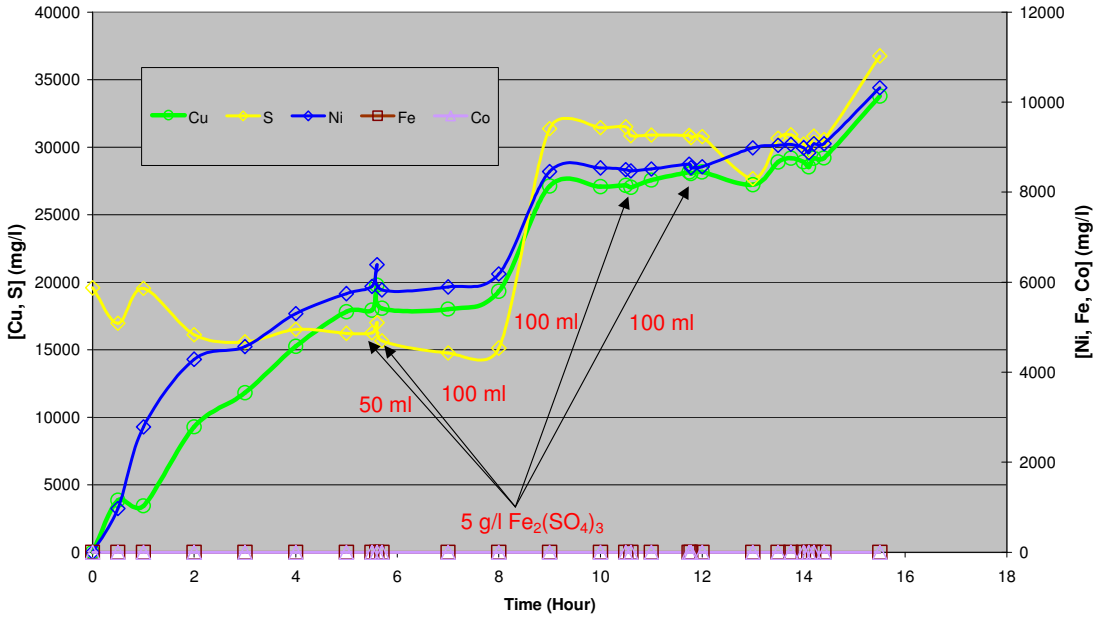

Figure G 1.7 Soluble base metal concentration profiles for Run 6

The log sheet providing all the conditions and recorded measurements during the leach is given in Appendix B, while a full mass balance of 10 elements can be viewed in Appendix C.

The modal abundance of all compositionally distinct phases in the eight samples submitted for mineralogical evaluation is determined by MLA technique. Comprehensive results in terms of volume percent abundances are listed in Appendix D, while a more condensed set of results is given in Table G 1.1.

Table G 1.1 Modal abundance of compositionally distinct phases for Run 6

Mineral	ALR	5.5 Hrs Before Fe^{3+} Addn	5.7 Hrs After Fe^{3+} Addn	10 Hrs	10.6 Hrs After Fe^{3+} Addn	12 Hrs	13.5 Hrs	Final ($15^{1}/_{2}$ Hrs)
Refractory	1.8	1.5	1.3	2.4	2.6	9.0	15.6	3.3
BMSulphides	61.9	25.0	20.1	23.1	16.7	3.1	0.4	9.1
BMSulphates	3.0	0.7	0.5	1.2	1.3	0.4	0.3	0.1
PGE BM Sulphoxides	24.9	55.7	55.7	35.5	37.3	6.7	0.2	6.1
Pd oxide type 1	0.4	5.4	8.6	18.6	22.7	44.8	42.1	14.9
Pd oxide type 2	0.0	0.0	0.0	0.1	0.1	0.2	1.3	0.3
Pd oxide (compact)	0.9	3.2	3.7	4.4	5.0	4.7	6.5	9.0
PGE oxide (compact)	1.2	2.8	3.5	5.6	5.9	18.8	20.6	22.6
Ru oxide (compact	0.5	1.6	1.9	3.0	3.1	5.0	3.7	7.0
Pt cores	2.2	0.5	0.9	1.0	0.8	0.8	0.6	6.9
Pt rims	2.8	2.4	3.3	4.7	4.1	5.9	7.2	20.3
Other alloy Unknown	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4
Total	100.0	99.2	99.9	100.0	100.0	99.8	99.0	100.0

TERTIARY LEACH RUN 7

As observed in Run 6, addition of several portions of ferric sulphate solution (5 g/l) to the leach slurry has no significant effect on the redox of the solution and the solubility of the PGMs. The limited response may be the result of significant dilution of the ferric solution upon addition to the leach slurry. Consequently, a pressure leach is carried out with upfront addition of a large excess of Fe^{3+}, in the form of solid ferric sulphate, to the leach acid prior to addition of the ALR. The concentration of ferric ions is 0.08 M and this gives a measured redox of 625 mV prior to the addition of the ALR. Figure G 1.8 indicates that at the start of the leach, before heating and pressurising, the redox of the slurry containing the ferric sulphate is higher than that of the slurry that does not have any ferric added, indicated by the solid and fragmented blue lines. However, the solution redox is lower for the leach liquor to which the ferric sulphate is added and continues to remain lower throughout the duration of the leach.

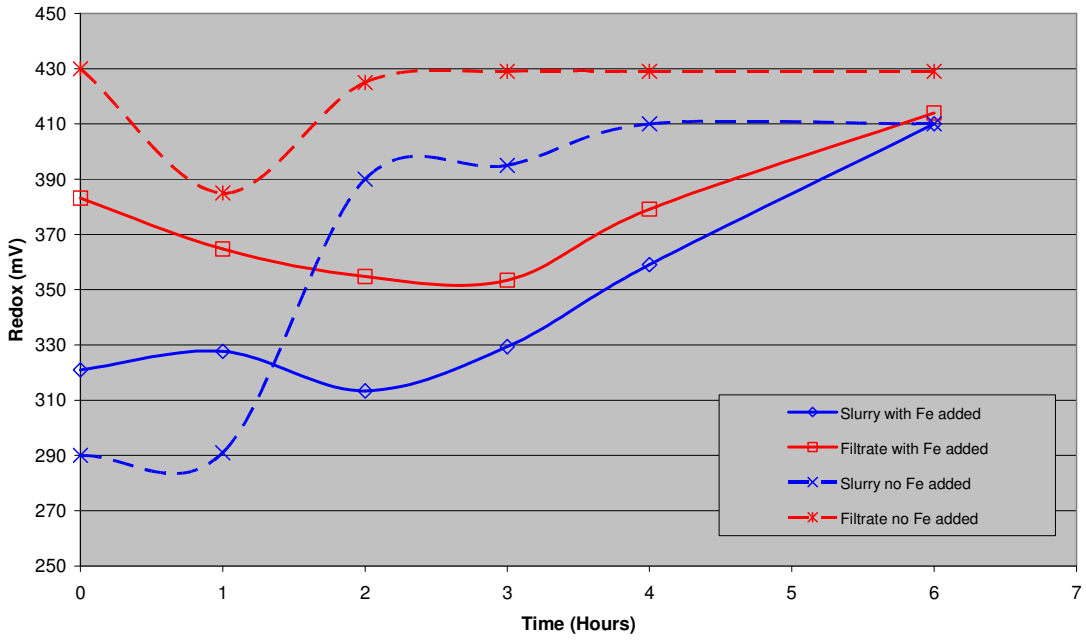

Figure G 1.8 Profiles of redox of slurry and filtrates with and without the addition of Fe^{3+} up front for Run 7

Since this experiment is performed to ascertain whether or not the up front addition of a ferric solution will manipulate the redox and influence the PGM solubilities, the

leach is not continued to completion and is terminated after leaching for 6 hours. This is seen in Figure G 1.9 where the redox of the slurry does not exceed 450 mV, the acidity profile is also displayed in this figure and the redox measurement of the slurry straight after the solid ferric addition measured 625 mV. The redox profile does not appear to be influenced by the significant ferric sulphate solid addition as the redox of the slurry at the start is similar to that measured when no ferric is added to the system.

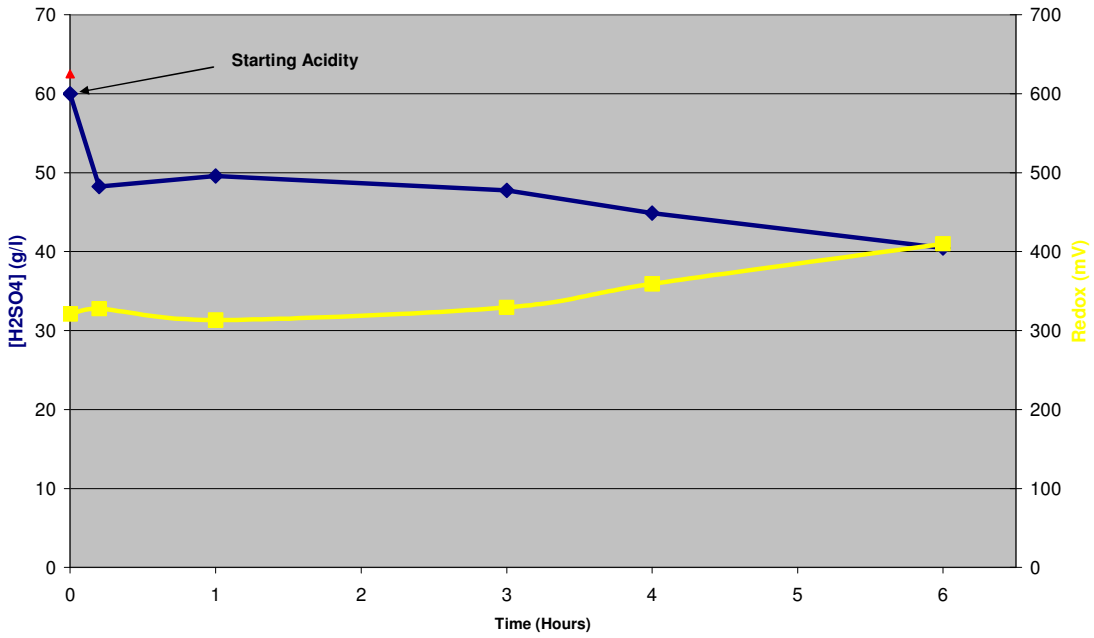

Figure G1.9 Profiles of acidity of leach solution and redox of slurry for Run 7

Once again the question arises as to whether the addition of a significant amount of ferric sulphate will influenced the solubility of the precious metals. This is indicated in Figures G 1.10, G 1.11 and G 1.12 which shows profiles of palladium, rhodium and ruthenium respectively. As a reference to what can be expected if no addition of ferric is added, Run 2 profiles are included in the graphical representations. The palladium profile shows no significant difference in solubility with the addition of a large amount of ferric. The slight variation in the two traces can be attributed to analytical fluctuations. The profile of rhodium however, appears to display a difference of 10 mg/l which cannot be an analytical variation and therefore has to be attributed to the presence of the ferric in solution, the effect is small but apparent. The presence of ferric in solution has a more profound effect on solubilising ruthenium, the difference observed due to the presence of ferric equated to 22 mg/l

additional soluble ruthenium, which again cannot be attributed to analytical variation, it must be a consequence of the effect of ferric. The platinum, iridium and gold in solution are below detection levels and therefore not displayed on the graphs.

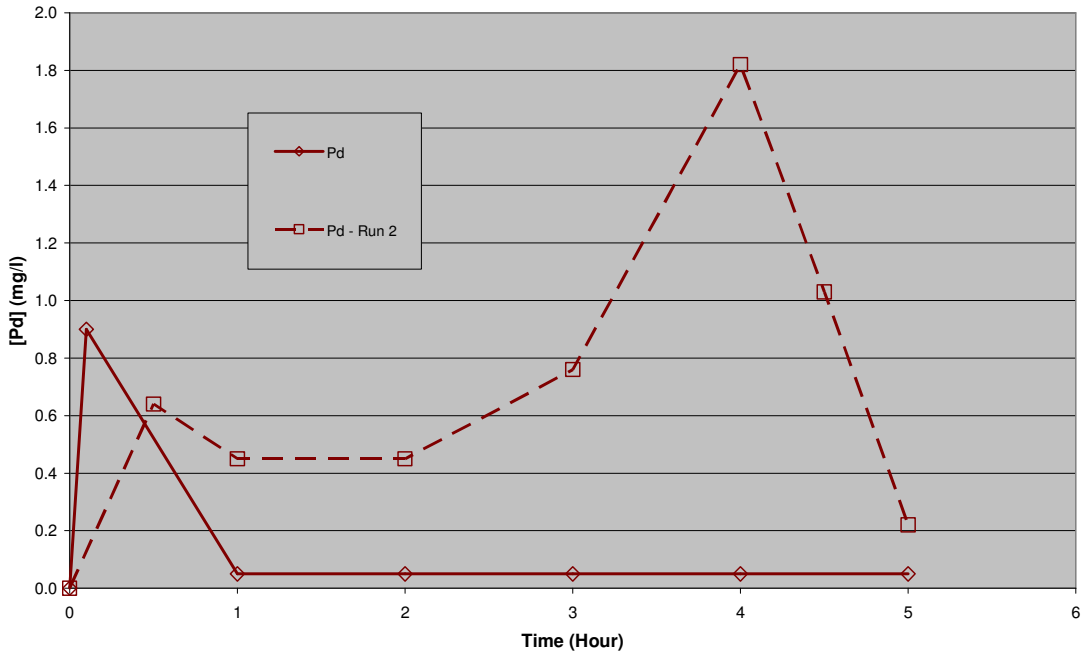

Figure G 1.10 Soluble palladium concentration profiles for the leach liquors with and without (Run 2) the addition of Fe^{3+} for Run 7

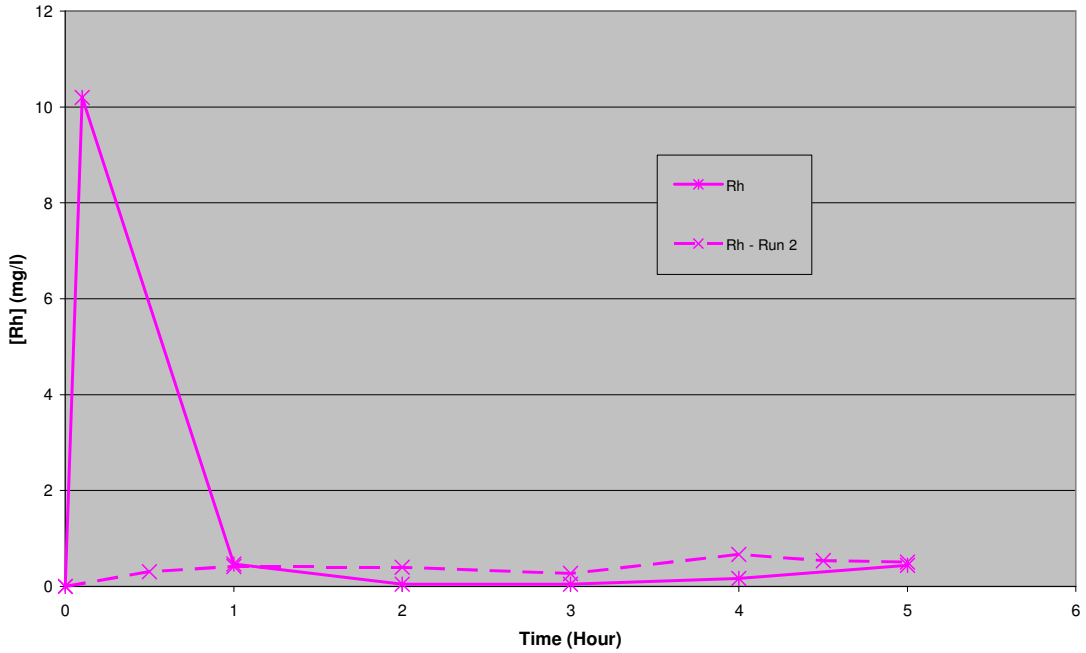

Figure G 1.11 Soluble rhodium concentration profiles for the leach liquors with and without (Run 2) the addition of Fe^{3+} for Run 7

What is interesting however, is the fact that both the rhodium and ruthenium that solubilise is re-precipitated within 2 hours of the leach being underway.

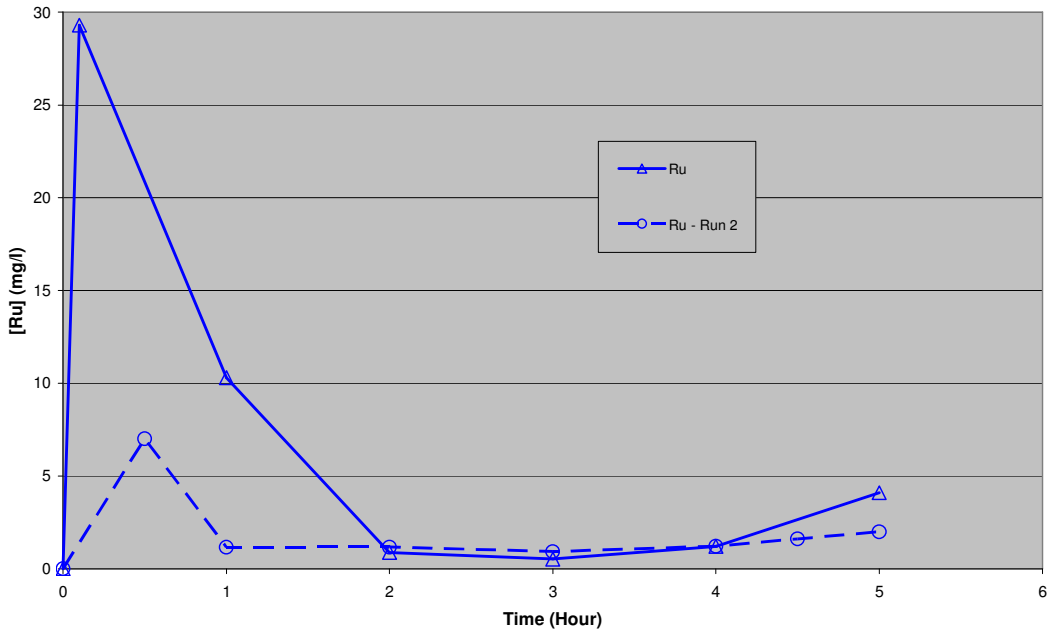

Figure G 1.12Soluble ruthenium concentration profiles for the leach liquors with and without (Run 2) the addition of Fe^{3+} for Run 7

The only base metal that shows a deviation from the normal behaviour is iron. Figure G 1.13 indicates that iron is being almost quantitatively removed from solution to concentrations well below the solubility limits of either ferric or ferrous sulphate, which suggests that iron is being precipitated by another mechanism.

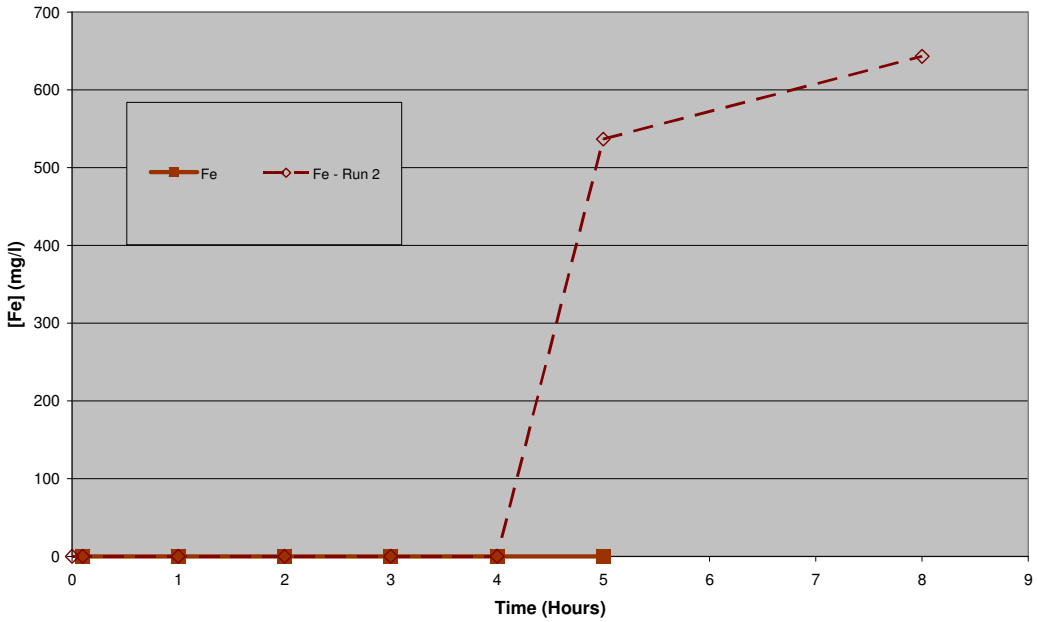

Figure G1.13 Soluble iron concentration profiles for the leach liquors with and without (Run 2) the addition of Fe^{3+} for Run 7

The log sheet providing all the conditions and recorded measurements during the leach is given in Appendix B, while a full mass balance of 10 elements can be viewed in Appendix C.

The modal abundance of all compositionally distinct phases in the six samples submitted for mineralogical evaluation is determined by MLA technique. Comprehensive results in terms of volume percent abundances are listed in Appendix D, while a more condensed set of results is given in Table G 1.2.

Table G 1.2 Modal abundance of compositionally distinct phases for Run 7

Mineral	ALR	1 Hour	2 Hour	3 Hour	4 Hour	5 Hour
Refractory	1.0	1.1	1.5	1.3	1.1	1.6
BMSulphides	66.4	59.0	48.1	48.3	58.5	32.3
BMSulphates	3.4	3.3	1.0	0.8	3.1	4.4
PGE BM Sulphoxides	20.2	29.5	40.4	38.4	30.8	32.8
Pd oxide type 1	0.6	0.6	2.0	2.3	0.5	13.2
Pd oxide type 2	0.0	0.0	0.0	0.0	0.0	0.0
Pd oxide (compact)	0.8	0.9	1.5	1.7	0.7	1.6
PGE oxide (compact)	1.3	0.9	1.7	1.7	0.8	1.0
Ru oxide (compact	0.5	0.3	0.6	0.9	0.3	2.0
Pt cores	2.1	0.6	0.3	0.6	0.4	2.5
Pt rims	2.7	1.5	1.7	2.6	1.7	5.4
Other alloy	0.6	0.8	0.5	0.4	0.7	0.9
Unknown	0.5	1.6	0.7	0.9	1.4	2.4
Total	100.1	100.1	100.0	99.9	100.0	100.1