B132584

The effects of temperature, chloride concentration, pH and sulfide concentration on zinc ore transport and precipitation.

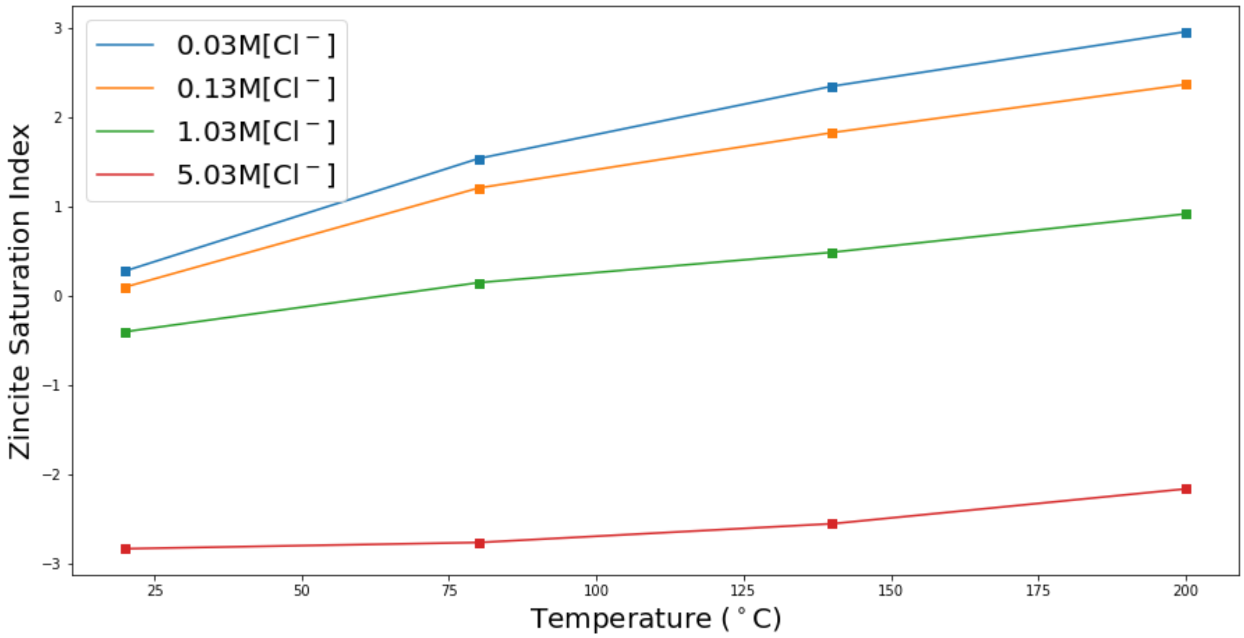


Fig. 1. The effects of temperature on zinc saturation, in solutions with different chloride concentrations.

1.a With rising temperature, the zinc saturation rises, indicating that its solubility decreases. Given that metal-transporting fluids are usually hot, this is unexpected. It's possible that hydrothermal fluids generally have a high Cl- concentration, where, as shown here, zinc is still quite soluble at high temperatures. It's also possible that this effect is due only to the higher-than-usual zinc concentration used in this example.

1.b Zinc saturation decreases with increasing [Cl-], making the zinc more soluble. This suggests that a high [Cl-] makes metals easier to transport.

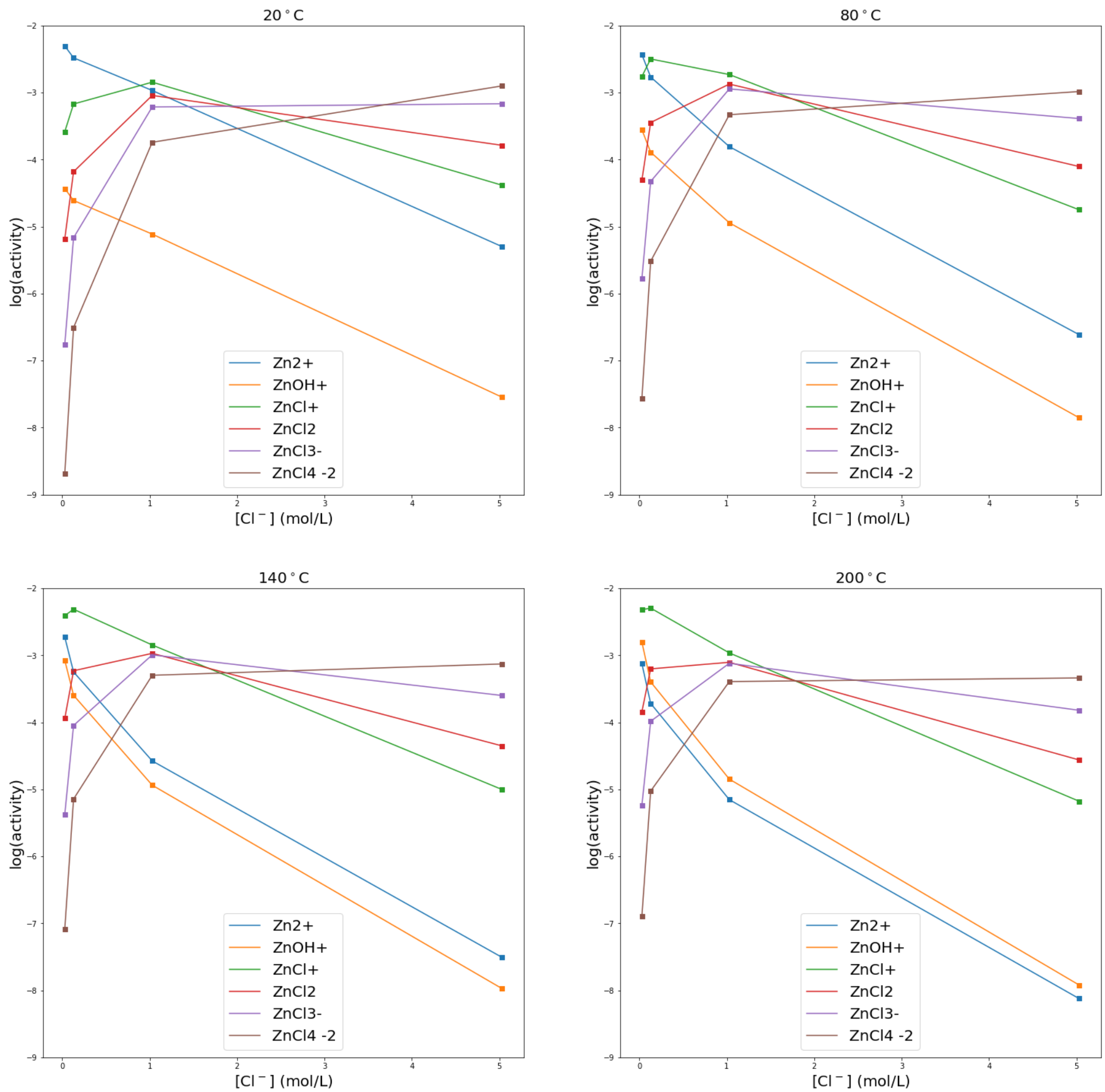


Fig. 2. Logarithm of dissolved zinc species activity given chloride concentration, at different temperatures.

2.a The activities of Zn^{2+} and $ZnOH^{+}$ fall with increasing Cl^{-} concentration. All zinc-chloride complexes increase in activity and then decrease, with the exception of $ZnCl_4^{2-}$, which continues to increase. The relative activities of the zinc-chloride complexes reverse with increasing concentration of Cl^{-}, from $ZnCl^{+}$ having the highest activity to $ZnCl_4^{2-}$ having the highest.

2.b Complexes with many chloride ions are most common at high Cl^{-} concentrations, while complexes with the fewest chloride ions are most common at low Cl^{-} concentrations.

2.c The proportion of zinc present as Zn^{2+} decreases with temperature. At high temperatures, the proportion present as $ZnOH^{+}$ increases at low chloride concentrations, but otherwise does not change with temperature.

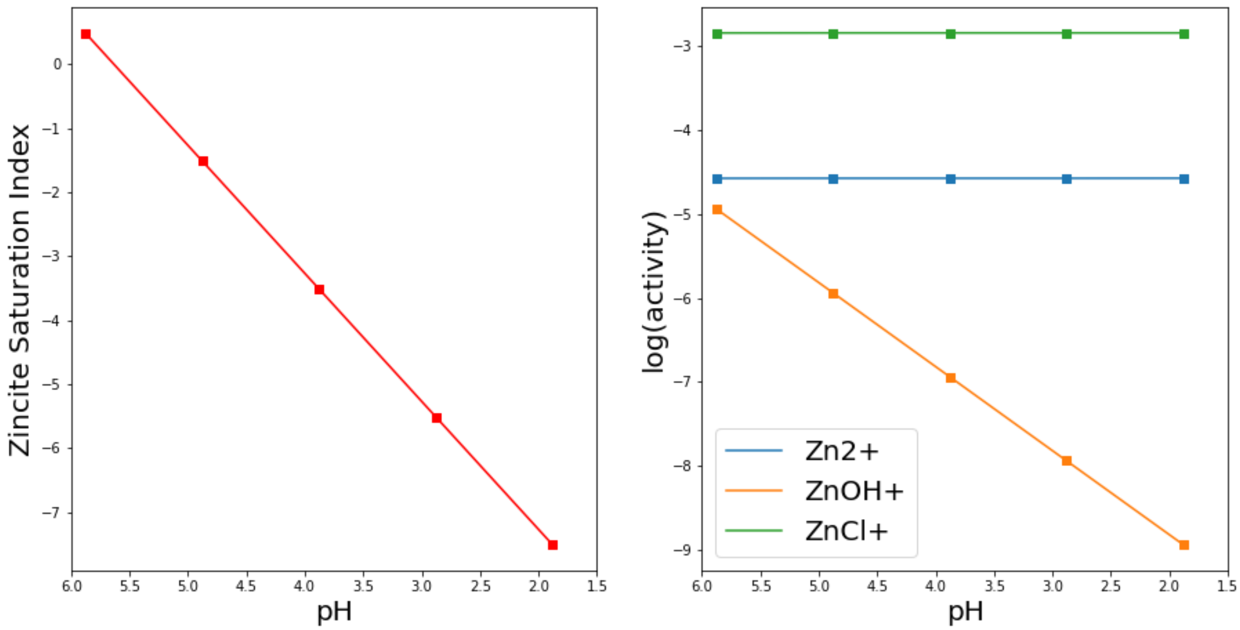


Fig. 3 Effects of decreasing pH at 140℃ with 1.01 molar [Cl^-].

3.a Zinc solubility increases with decreasing pH.

3.b pH has no effect on zinc species, with the exception of $ZnOH^+$. Lower pH reduces the activity of $ZnOH^+$ because lower pH reduces the concentration of OH^-, making it less available to form a complex with Zn.

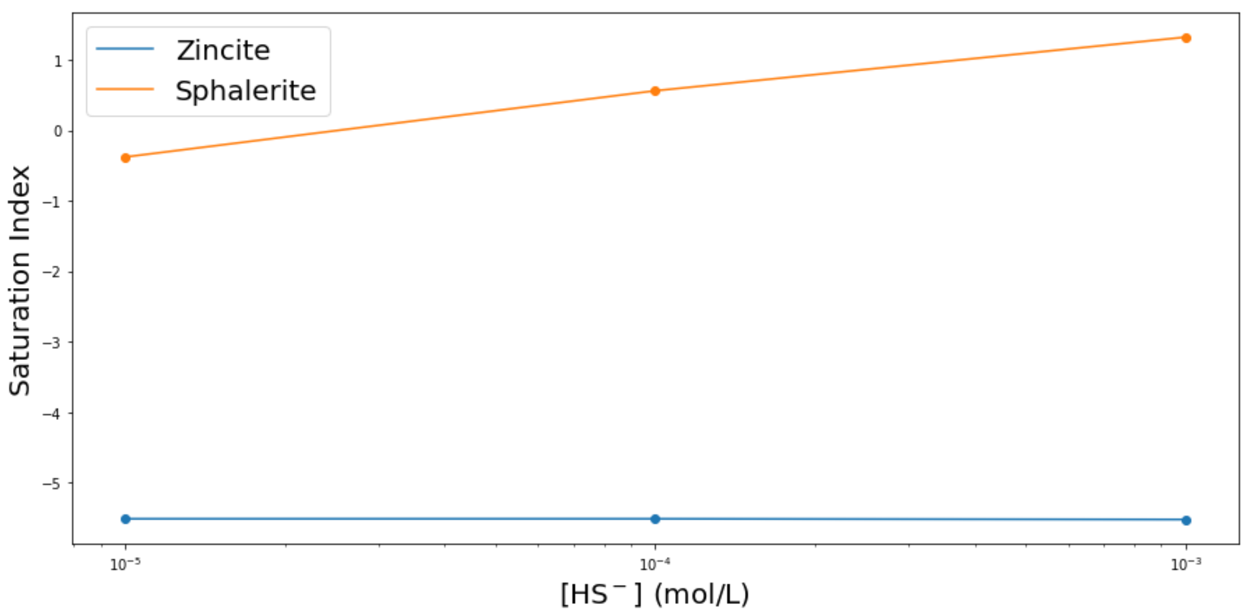


Fig. 4. Zincite and sphalerite saturation indices at varying concentrations of HS^-, at pH 2.88 and 140℃.

4. Sphalerite solubility decreases in the presence of HS^-, while zincite solubility remains unchanged.

5. Zinc is more soluble with higher chloride concentration, lower temperature, and lower pH. With high chloride concentrations, $ZnCl_4^{2-}$ becomes the most common species and Zn^{2+} one of the least common, while at low chloride concentrations the opposite is true. Low pH has little effect on zinc speciation, except that it lowers the activity of $ZnOH^+$ significantly. In the presence of HS^-, sphalerite quickly becomes oversaturated.

Data:

						Activity					
Zn	pH	T (C)	Na+	Cl-	SI Zincite	Zn2+	ZnOH+	ZnCl+	ZnCl2	ZnCl3-	ZnCl4 -2
0.01M	7	20	0.01	0.03	0.28	0.00495	3.69E-05	2.61E-04	6.57E-06	1.75E-07	2.06E-09
0.01M	7	20	0.11	0.13	0.1	3.30E-03	2.45E-05	6.74E-04	6.57E-05	6.79E-06	3.10E-07
0.01M	7	20	1.01	1.03	-0.4	1.07E-03	7.70E-06	1.43E-03	9.05E-04	6.09E-04	1.81E-04
0.01M	7	20	5.01	5.03	-2.83	5.01E-06	2.84E-08	4.14E-05	1.63E-04	6.81E-04	1.26E-03
0.01M	6.31	80	0.01	0.03	1.54	3.67E-03	2.78E-04	1.74E-03	4.96E-05	1.67E-06	2.73E-08
0.01M	6.31	80	0.11	0.13	1.21	1.70E-03	1.29E-04	3.17E-03	3.57E-04	4.71E-05	3.03E-06
0.01M	6.31	80	1.01	1.03	0.15	1.56E-04	1.14E-05	1.86E-03	1.34E-03	1.13E-03	4.67E-04
0.01M	6.31	80	5.01	5.03	-2.76	2.43E-07	1.40E-08	1.78E-05	7.87E-05	4.09E-04	1.04E-03
0.01M	5.88	140	0.01	0.03	2.35	1.87E-03	8.40E-04	3.91E-03	1.15E-04	4.24E-06	8.20E-08
0.01M	5.88	140	0.11	0.13	1.83	5.65E-04	2.53E-04	4.87E-03	5.88E-04	8.96E-05	7.14E-06
0.01M	5.88	140	1.01	1.03	0.49	2.65E-05	1.15E-05	1.43E-03	1.07E-03	1.02E-03	5.03E-04
0.01M	5.88	140	5.01	5.03	-2.55	3.10E-08	1.06E-08	9.93E-06	4.45E-05	2.51E-04	7.43E-04
0.01M	5.65	200	0.01	0.03	2.96	7.47E-04	1.57E-03	4.80E-03	1.44E-04	5.79E-06	1.28E-07
0.01M	5.65	200	0.11	0.13	2.37	1.92E-04	4.01E-04	5.07E-03	6.27E-04	1.04E-04	9.42E-06
0.01M	5.65	200	1.01	1.03	0.92	7.00E-06	1.42E-05	1.09E-03	7.87E-04	7.61E-04	4.06E-04
0.01M	5.65	200	5.01	5.03	-2.16	7.52E-09	1.20E-08	6.64E-06	2.74E-05	1.51E-04	4.59E-04

Table 1. Zincite saturation index and species activity with varying temperature and chloride concentration.

Zn	pH	T (C)	Na+	Cl-	SI Zincite	Zn2+	ZnOH+	ZnCl+	ZnCl2	ZnCl3-	ZnCl4 -2
0.01M	5.88	140	1.01	1.03	0.49	2.65E-05	1.15E-05	1.43E-03	1.07E-03	1.02E-03	5.03E-04
0.01M	4.88	140	1.01	1.03	-1.51	2.66E-05	1.15E-06	1.43E-03	1.07E-03	1.02E-03	5.04E-04
0.01M	3.88	140	1.01	1.03	-3.51	2.66E-05	1.15E-07	1.43E-03	1.07E-03	1.02E-03	5.04E-04
0.01M	2.88	140	1.01	1.03	-5.51	2.66E-05	1.15E-08	1.43E-03	1.07E-03	1.02E-03	5.04E-04
0.01M	1.88	140	1.01	1.03	-7.51	2.66E-05	1.16E-09	1.43E-03	1.07E-03	1.01E-03	5.02E-04

Table 2. Zincite saturation index and species activity with varying pH.

Zn	pH	T (C)	Eh (volts)	Na+	Cl-	HS-	SI Zincite	SI Sphalerit
0.01	2.88	140	-0.25	1.01	1.03	0.001	-5.52	1.32
0.01	2.88	140	-0.25	1.01	1.03	0.0001	-5.51	0.56
0.01	2.88	140	-0.25	1.01	1.03	0.00001	-5.51	-0.38

Table 3. Zincite and sphalerite saturation indices with varying HS^- concentration.

Appendix 1: Python code used.

```python
#Import relevant packages

import pandas as pd

import numpy as np

import matplotlib.pyplot as plt

import seaborn as sns

from scipy import stats
```

In [8]:

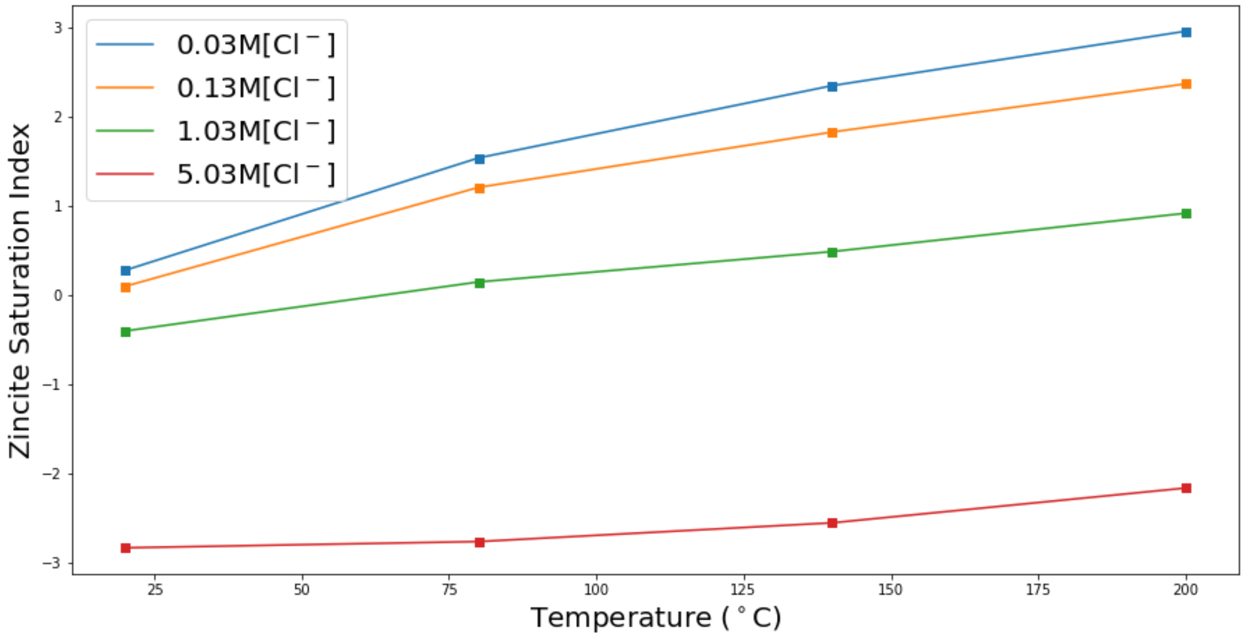
```python
#Load main data set

data=pd.read_excel("IMOP Ores Practical.xlsx",header=3,skiprows=[15,16,17,18,24,25,26,27,28,29,30],usecols='A:L')
```

In [9]:

```python
#Effects on zincite saturation index

plt.figure(figsize=(15,7.5))

for i in data['Cl-'].unique():

    cl=data[data['Cl-']==i]

    plt.plot(cl['T'],cl['SI Zincite'],label=str(i)+'M[Cl$^-$]')

    plt.scatter(cl['T'],cl['SI Zincite'],marker='s')

plt.ylabel('Zincite Saturation Index',fontsize=20)

plt.xlabel('Temperature ($^\circ$C)',fontsize=20)

plt.legend(fontsize=20)
```

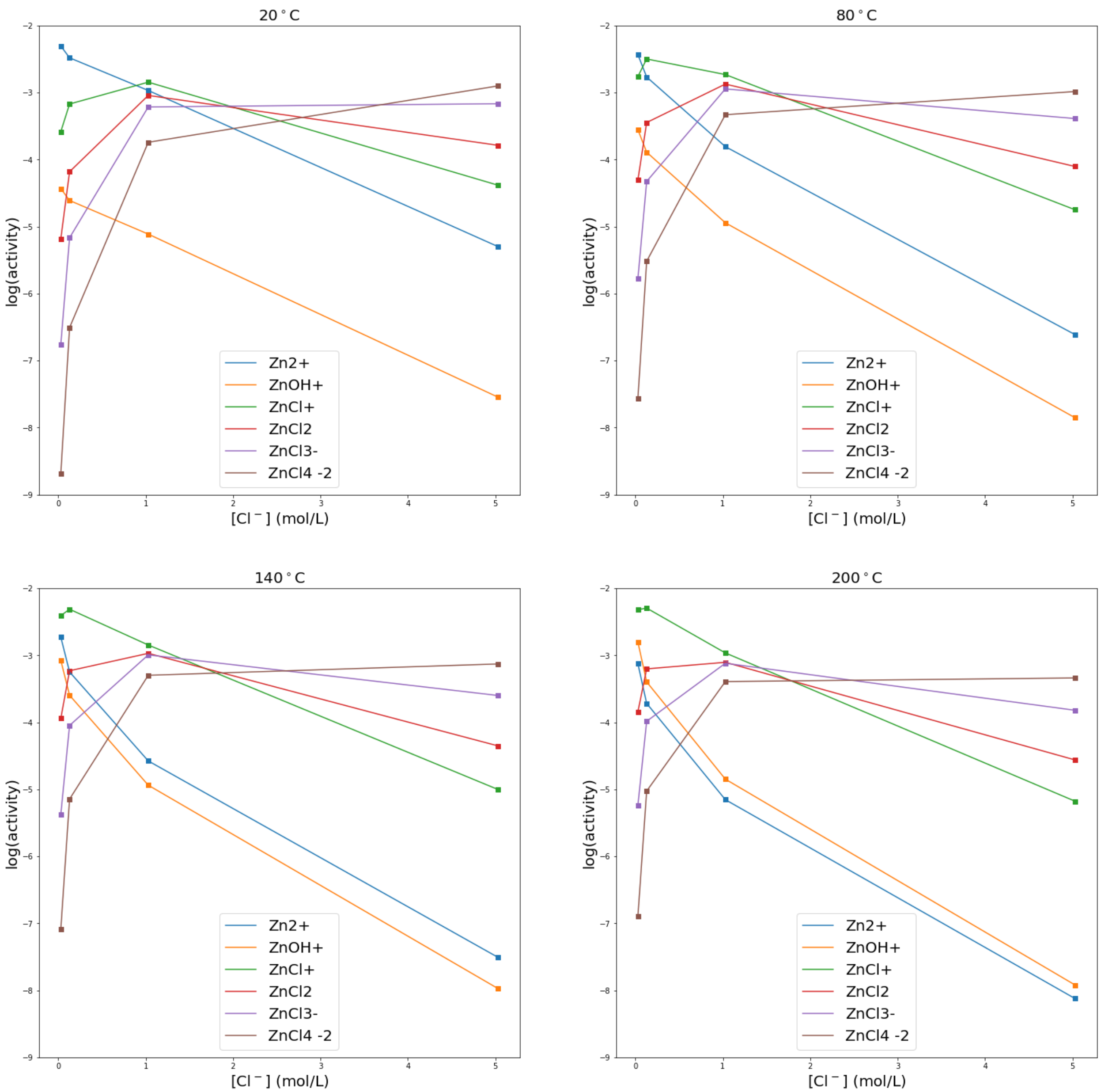
Out[9]:

```
<matplotlib.legend.Legend at 0x1caead0b820>
```



In [23]:

```
#Effects on Zn speciation
index=1
plt.figure(figsize=(25,25))
for j in data['T'].unique():
    T=data[data['T']==j]
    plt.subplot(2,2,index)
    for i in data.columns[6:]:
        plt.plot(T['Cl-'],np.log10(T[i]),label=i)
        plt.scatter(T['Cl-'],np.log10(T[i]),marker='s')
    plt.legend(loc=8,fontsize=20)
    plt.xlabel('[Cl$^-$] (mol/L)',fontsize=20)
    plt.ylabel('log(activity)',fontsize=20)
    plt.ylim(-9,-2)
    plt.title(str(j)+'$^\circ$C',fontsize=20)
    index+=1
```



In [18]:

```
#Load pH data

ph=pd.read_excel("IMOP Ores Practical.xlsx",sheet_name='pH')
```

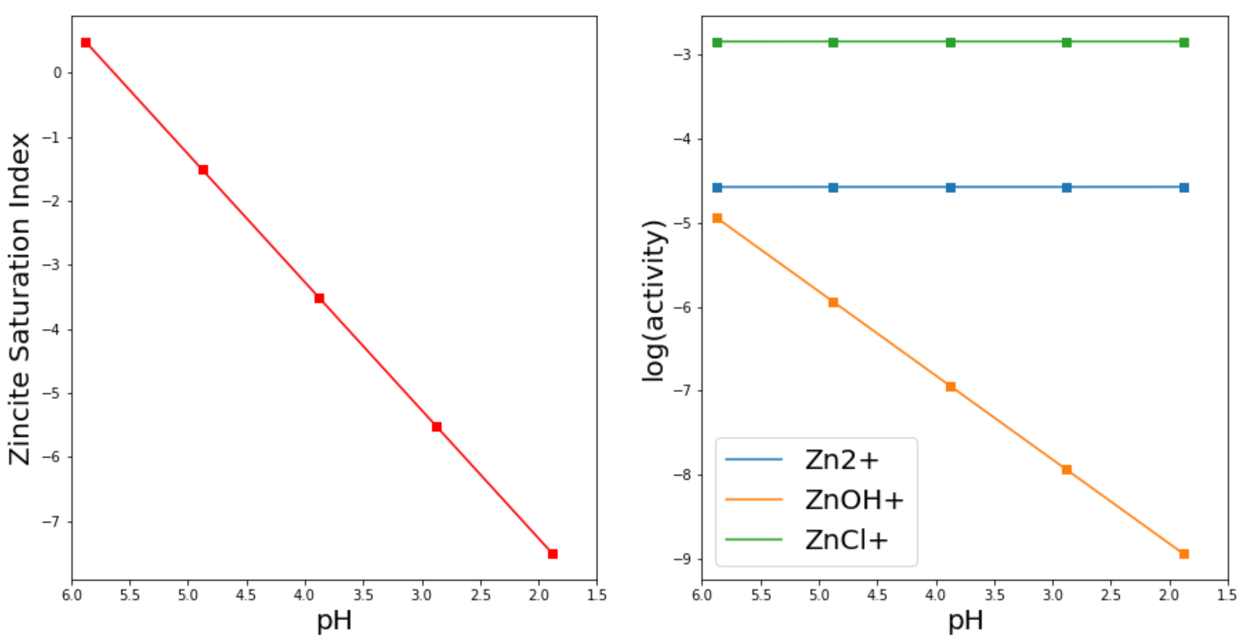
In [22]:

```
#Effects of pH

plt.figure(figsize=(15,7.5))

plt.subplot(121)

plt.plot(ph['pH'],ph['SI Zincite'],c='r')
```

```
plt.scatter(ph['pH'],ph['SI Zincite'],c='r',marker='s')
plt.xlabel('pH',fontsize=20)
plt.xlim(6,1.5)
plt.ylabel('Zincite Saturation Index',fontsize=20)
plt.subplot(122)
for i in ['Zn2+', 'ZnOH+', 'ZnCl+']:
    plt.plot(ph['pH'],np.log10(ph[i]),label=i)
    plt.scatter(ph['pH'],np.log10(ph[i]),marker='s')
plt.legend(fontsize=20)
plt.xlabel('pH',fontsize=20)
plt.xlim(6,1.5)
plt.ylabel('log(activity)',fontsize=20)
```

Out[22]:

Text(0, 0.5, 'log(activity)')



In [3]:

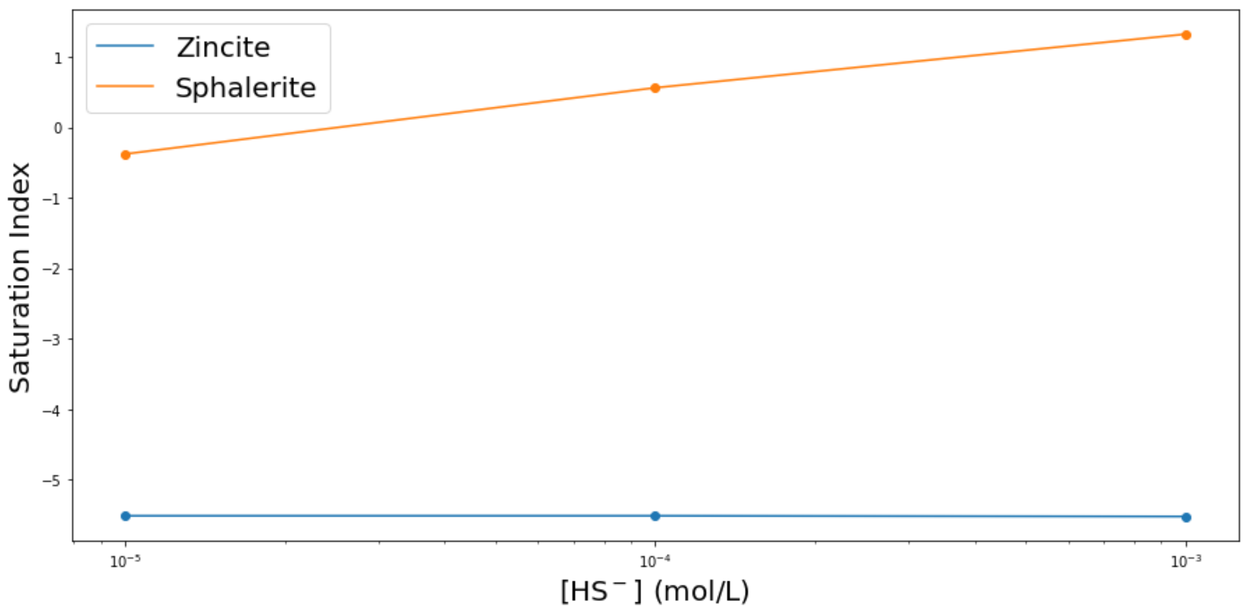
```
#Load sulfur data
sulf=pd.read_excel("IMOP Ores Practical.xlsx",sheet_name='Sulfur')
```

In [25]:

```
#Effects of sulfur
plt.figure(figsize=(15,7))
plt.plot(sulf['HS-'],sulf['SI Zincite'],label='Zincite')
plt.scatter(sulf['HS-'],sulf['SI Zincite'])
plt.plot(sulf['HS-'],sulf['SI Sphalerite'],label='Sphalerite')
plt.scatter(sulf['HS-'],sulf['SI Sphalerite'])
plt.xscale('log')
plt.xlabel('[HS$^-$] (mol/L)',fontsize=20)
plt.ylabel('Saturation Index',fontsize=20)
plt.legend(fontsize=20)
```

Out[25]:

```
<matplotlib.legend.Legend at 0x1caeb6e6640>
```



In [ ]: