UNIVERSITY OF JOHANNESBURG

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| **PROGRAM** | : | NATIONAL DIPLOMA<br>*EXTRATION and PHYSICAL METALLURGY* |
| **SUBJECT** | : | **METALLURGICAL THERMODYNAMICS II** |
| **CODE** | : | **THM 21-1** |
| **DATE** | : | WINTER EXAM 2018<br>28 MAY 2018 |
| **DURATION** | : | (X-PAPER) 12:30 - 15:30 |
| **WEIGHT** | : | 40 : 60 |
| **TOTAL MARKS** | : | 100 |

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| **EXAMINER** | : | MR MK KALENGA<br>Ms N. TSHIONGO | 5128 |
| **MODERATOR** | : | MR KALEMBA | |
| **NUMBER OF PAGES** | : | 3 PAGES AND 3 ANNEXURES | |

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| **INSTRUCTIONS** | : | QUESTION PAPERS MUST BE HANDED IN. |
| **REQUIREMENTS** | : | CALCULATORS. |

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## QUESTION 1 [16]

1.1 Suppose you have 1 $m^3$ of air at 1 atm (101 kPa) pressure; what would the volume be if you doubled the pressure and keep the temperature the same? (4)

1.2 Suppose you have 1 $m^3$ of air at 1 atm (101 kPa) pressure and 25°C; what would the volume be if you increased the temperature to 150°C but keep the pressure the same? (4)

1.3 Calculate the mass of 2.1 $m^3$ of oxygen (in kg). (4)

1.4 Show that the difference of two temperatures is the same, irrespective whether you express them in °C or K; however, also show that the ratio of two temperatures depend very much on whether you express them in °C or K.
(4)

## QUESTION 2 [20]

2.1 What is the enthalpy change for the following reaction? (6)

$$SiCl_{4(\ell)} + H_{2(g)} \text{ ---> } Si_{(s)} + HCl_{(g)}$$

Given:

$SiCl_{4(\ell)}$; -687 kJ $mol^{-1}$

$HCl_{(g)}$; -92 kJ $mol^{-1}$

2.2 Determine the enthalpy of the following reaction: (8)

$$Fe_2O_{3(s)} + CO_{(g)} \text{ ---> } Fe_3O_{4(s)} + CO_{2(g)}$$

Given:

$Fe_2O_{3(s)} + 3CO_{(g)} \text{ ---> } 2Fe_{(s)} + 3CO_{2(g)}$ $\Delta H = -23.44$ kJ

$Fe_3O_4 + CO_{(g)} \text{ ---> } 3FeO_{(s)} + CO_{2(g)}$ $\Delta H = +21.79$ kJ

$Fe_{(s)} + CO_{2(g)} \text{ ---> } FeO_{(s)} + CO_{(g)}$ $\Delta H = -10.94$ kJ

2.3 What is the ΔH at 373 K for the reaction? (8)

$$O_{3(g)} + OH_{(g)} \rightarrow H_{(g)} + O_{2(g)}$$

Given: $\Delta H^{\circ}_{(298K)} = 36.3$ kJ

## QUESTION 3 [12]

Consider two equal copper ingots in contact with each other, the temperature of the one being 300°C, that of the other 500°C; heat transfer shall only be allowed between the two ingots, but not with the surroundings. It is expected that the temperature will equalize and reach 400°C,

3.1 Calculate the entropy change of the system (7)

3.2 State whether the process is reversible or irreversible (5)

## QUESTION 4 [12]

Using the equilibrium constant, discuss which between the two reactions below take place first at 600°C:

a) $Si + O_2 = SiO_2$
b) $Ti + O_2 = TiO_2$

## QUESTION 5 [14]

You are given the following reaction:

$2\ CuO + Fe \quad = \quad Cu_2O + FeO$

4.1 Determine whether this reaction feasible at 25°C (6)

4.2 If the answer in 4.1 is no, determine the temperature from which the reaction can be expected to start taking place (8)

## QUESTION 5 [12]

Based on the Ellingham diagram:

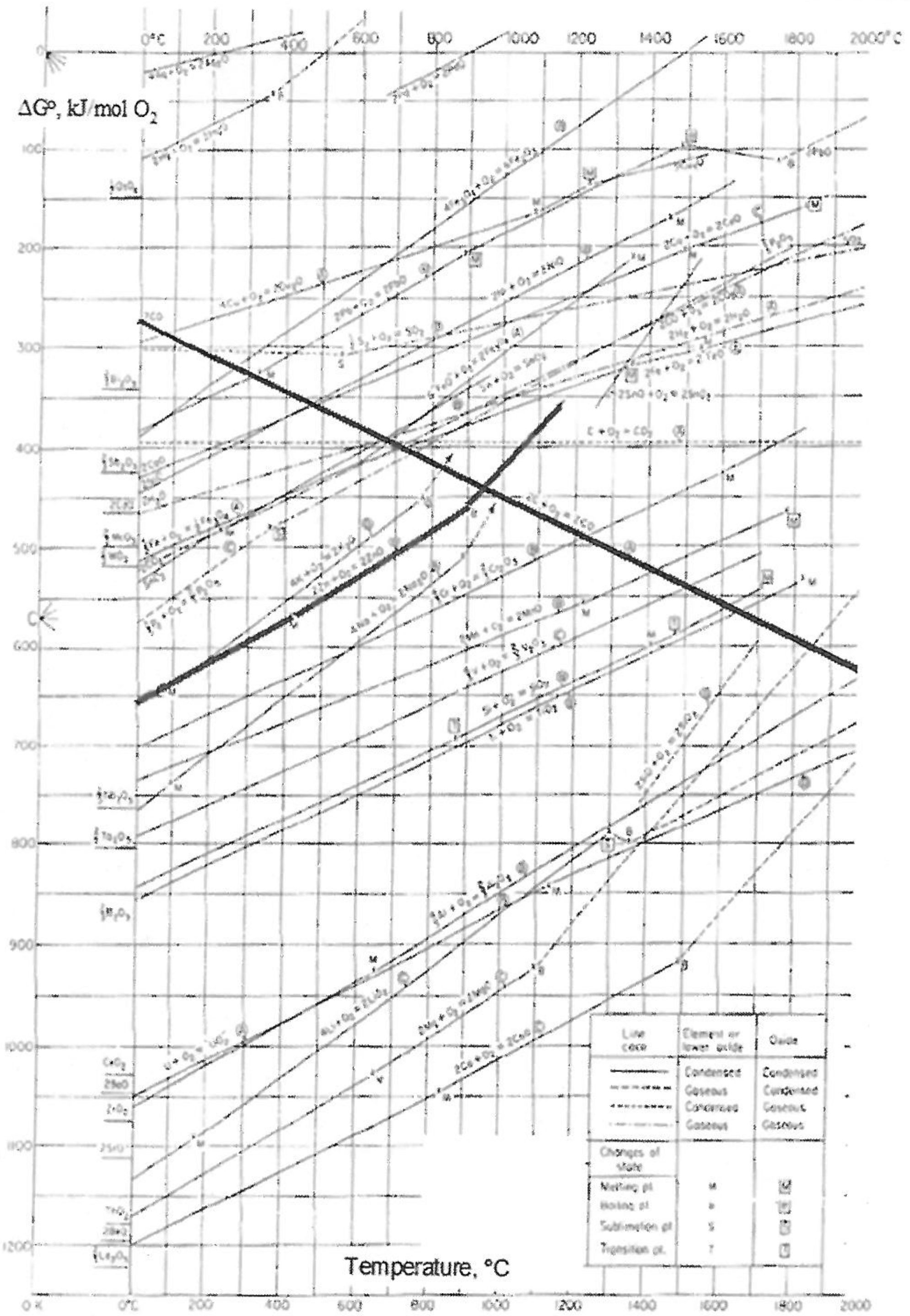
5.1 Discuss whether you can thermodynamically reduce $Cu_2O$ using Fe. Discuss the temperature range where it is possible to have the reduction taking place. (7)

5.2 Discuss by estimating, not calculate, the minimum temperature from which it becomes possible to reduce $Cr_2O_3$ using carbon. (7)

*Please, make use of the diagram and draw wherever needed to show your estimations*

## QUESTION 6 [14]

You are pre-heating a furnace and wish to reach a temperature above 1400°C. You are provided with methane as fuel and air containing 50% oxygen is at your disposal for the combustion reaction. Calculate the temperature of the adiabatic flame.


ΔG°, kJ/mol $O_2$
0°C
200
400
600
800
1000
1200
1400
1600
1800
2000°C
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
C + $O_2$ = $CO_2$
2CO
Line code
Element or lower oxide
Oxide
Condensed
Gaseous
Changes of state
Melting pt
Boiling pt
Sublimation pt
Transition pt
Temperature, °C
0 K

| Ttab | Substance Name | Formula (1) | State (2) | Mol Mass g/mol (3) | Enthalpy $H^o_{298}$ J/mol (4) | Entropy $S^o_{298}$ J/(mol K) (5) | Temperature Range K (6) | (7) | (8) | Heat Capacity $C = a + b\,10^{-3}\,T$ J/(mol K) a (9) | b (10) | Mean $C_{mean}$ (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Acetylene | $C_2H_2$ | gas | 26.0 | 226 731 | 201.0 | 298 | - | 3000 | 50.2 | 14.2 | |
| 2 | Aluminium | Al | sol | 27.0 | | 28.3 | 298 | - | 933 | 33.0 | -20.7 | 28.5 |
| 3 | | Alliq | liq | | 10 711 | 11.5 | 933 | - | 2790 | 31.7 | | |
| 4 | Aluminium oxide, *alumina* | $Al_2O_3$ | sol | 102.0 | -1 675 274 | 50.9 | 298 | - | 800 | 58.2 | 83.5 | |
| 5 | Cadmium | Cd | sol | 112.4 | | 51.8 | 298 | - | 594 | 22.3 | 12.2 | |
| 6 | | Cdliq | liq | | 6 192 | 10.4 | 594 | - | 1038 | 29.7 | | |
| 7 | | Cdgas | gas | | 111 796 | 167.7 | 1038 | - | 2000 | 20.8 | | |
| 8 | Cadmium carbonate | $CdCO_3$ | sol | 172.4 | - 751 865 | 92.5 | 298 | - | 600 | 43.1 | 131.8 | |
| 9 | Cadmium oxide | CdO | sol | 128.4 | - 258 990 | 54.8 | 298 | - | 1500 | 42.5 | 10.1 | |
| 10 | Calcium oxide, *lime* | CaO | sol | 56.1 | - 635 089 | 38.1 | 298 | - | 3200 | 46.0 | 6.0 | 56.3 |
| 11 | Ca-carbonate, *calcite* | $CaCO_3$ | sol | 100.1 | -1 206 921 | 92.9 | 298 | - | 1200 | 74.8 | 50.2 | 110.4 |
| 12 | Carbon, *graphite* | C | sol | 12.0 | | 5.7 | 298 | - | 1100 | 4.9 | 17.2 | 16.3 |
| 13 | Carbon monoxide | CO | gas | 28.0 | - 110 541 | 197.7 | 298 | - | 3000 | 28.7 | 2.6 | 29.7 |
| 14 | Carbon dioxide | $CO_2$ | gas | 44.0 | - 393 505 | 213.8 | 298 | - | 5000 | 51.9 | 3.0 | 60.9 |
| 15 | Chromium | Cr | sol | 52.0 | | 23.6 | 298 | - | 2130 | 20.3 | 12.1 | 30.0 |
| 16 | | Crliq | liq | | 16 900 | 8.0 | 2130 | - | 2945 | 39.3 | | |
| 17 | Chromium(III)-oxide | $Cr_2O_3$ | sol | 152.0 | -1 139 701 | 81.2 | 298 | - | 2603 | 114.8 | 11.2 | |
| 18 | Copper | Cu | sol | 63.5 | | 33.2 | 298 | - | 1358 | 22.0 | 7.4 | 28.0 |
| 19 | | Culiq | liq | | 13 138 | 9.7 | 1358 | - | 2843 | 32.8 | | |
| 20 | Copper(I)-oxide, *cuprite* | $Cu_2O$ | sol | 143.1 | - 170 707 | 92.3 | 298 | - | 1517 | 56.4 | 25.8 | 79.7 |
| 21 | | Cu2Oliq | liq | | 64 768 | 42.7 | 1517 | - | 2000 | 99.9 | | |
| 22 | Copper(II)-oxide, *tenorite* | CuO | sol | 79.5 | - 156 063 | 42.6 | 298 | - | 1397 | 40.8 | 13.9 | 48.6 |
| 23 | *Chalcopyrite* | $CuFeS_2$ | sol | 183.5 | - 190 372 | 125.0 | 298 | - | 830 | 78.6 | 63.6 | 114.0 |
| 24 | Cu(I)-sulfide, *chalcocite* | $Cu_2S$ | sol | 159.1 | - 81 170 | 116.2 | 298 | - | 1400 | 47.9 | 97.2 | 85.7 |
| 25 | Matte | Cu2Sliq | liq | | 12 845 | 9.2 | 1400 | - | 2000 | 89.7 | | |
| 26 | Cu(II)-sulfide, *covellite* | CuS | sol | 95.6 | - 53 095 | 66.5 | 298 | - | 1300 | 44.4 | 11.0 | |
| 27 | Hydrogen | $H_2$ | gas | 2.0 | | 130.7 | 298 | - | 5000 | 28.2 | 2.7 | 35.0 |
| 28 | Iron | Fe | sol | 55.8 | | 27.3 | 298 | - | 1809 | 17.4 | 25.0 | 40.0 |
| 29 | | Feliq | liq | | 13 807 | 7.6 | 1809 | - | 3158 | 40.9 | 1.7 | 45.0 |
| 30 | Iron(II)-oxide, *wüstite* | FeO | sol | 71.8 | - 267 270 | 57.6 | 298 | - | 1650 | 47.9 | 10.7 | 58.0 |
| 31 | | | liq | | 24 058 | 14.6 | 1650 | - | 3687 | 68.2 | | |
| 32 | Iron(II)(III)-oxide, *magnetite* | $Fe_3O_4$ | sol | 231.5 | -1 118 383 | 146.1 | 298 | - | 1870 | 75.5 | 240.1 | 207.0 |
| 33 | | Fe3O4liq | liq | | 138 072 | 73.8 | 1870 | - | 2000 | 213.4 | | |
| 34 | Iron(III)-oxide, *hematite* | $Fe_2O_3$ | sol | 159.7 | - 824 248 | 87.4 | 298 | - | 1700 | 78.1 | 99.8 | 142.0 |
| 35 | Iron carbonate, *siderite* | $FeCO_3$ | sol | 115.9 | - 740 568 | 92.9 | 298 | - | 800 | 48.7 | 112.1 | |
| 36 | Iron sulfide, *pyrrhotite* | FeS | sol | 87.9 | - 105 441 | 60.8 | 298 | - | 1465 | 31.0 | 63.0 | 68.0 |
| 37 | Matte *(troilite)* | FeSliq | liq | | 32 464 | 21.5 | 1465 | - | 3000 | 62.6 | | |
| 38 | Iron sulfide, *pyrite* | $FeS_2$ | sol | 120.0 | - 171 544 | 52.9 | 298 | - | 1000 | 56.0 | 27.8 | |
| 39 | Lead | Pb | sol | 207.2 | | 64.8 | 298 | - | 600 | 24.2 | 8.7 | 28.1 |
| 40 | | Pbliq | liq | | 4 770 | 7.9 | 600 | - | 1200 | 32.5 | -3.1 | |
| 41 | Lead oxide, *litharge* | PbO | sol | 223.2 | - 218 062 | 68.7 | 298 | - | 1159 | 41.8 | 16.1 | |
| 42 | | PbOliq | liq | | 25 522 | 22.0 | 1159 | - | 2000 | 65.0 | | |
| 43 | Lead sulfide, *galena* | PbS | sol | 239.3 | - 98 634 | 91.3 | 298 | - | 1386 | 46.6 | 9.5 | |
| 44 | | PbSliq | liq | | 18 828 | 13.6 | 1386 | - | 2000 | 66.9 | | |
| 45 | Lead sulfate, *anglesite* | $PbSO_4$ | sol | 303.3 | - 923 137 | 149.5 | 298 | - | 1139 | 66.5 | 110.0 | |
| 46 | Magnesium | Mg | sol | 24.3 | | 32.7 | 298 | - | 922 | 21.4 | 11.8 | 28.5 |
| 47 | | Mgliq | liq | | 8 954 | 9.7 | 922 | - | 1361 | 32.6 | | |
| 48 | | Mggas | gas | | 146 440 | 148.6 | 1361 | - | 2000 | 20.8 | | |
| 49 | Mg-carbonate, *magnesite* | $MgCO_3$ | sol | 84.3 | -1 095 798 | 65.7 | 298 | - | 700 | 47.8 | 99.0 | |
| 50 | Mg-oxide, *periklase* | MgO | sol | 40.3 | - 601 241 | 26.9 | 298 | - | 3105 | 42.8 | 6.0 | |
| 51 | Manganese | Mn | sol | 54.9 | | 32.0 | 298 | - | 1360 | 20.7 | 18.7 | |
| 52 | Manganese carbonate | $MnCO_3$ | sol | 114.9 | - 894 100 | 85.8 | 298 | - | 700 | 58.1 | 85.4 | |
| 53 | Manganese oxide | MnO | sol | 70.9 | - 385 221 | 59.7 | 298 | - | 1500 | 42.9 | 10.9 | 52.3 |
| 54 | Mn-dioxide, *pyrolusite* | $MnO_2$ | sol | 86.9 | - 520 029 | 53.0 | 298 | - | 523 | 35.1 | 66.0 | 61.8 |
| 55 | Mercury (quicksilver) | Hg | liq | 200.6 | | 75.9 | 298 | - | 630 | 28.4 | -2.1 | |
| 56 | | Hggas | gas | | 61 291 | 174.8 | 630 | - | 3000 | 20.8 | | |
| 57 | Mercury oxide, *red mercury* | HgO | sol | 216.6 | - 90 789 | 70.3 | 298 | - | 800 | 36.6 | 27.6 | |
| 58 | Mercury sulfide, *cinnabar* | HgS | sol | 232.7 | - 53 346 | 82.4 | 298 | - | 1096 | 43.8 | 15.6 | |
| 59 | | HgSgas | gas | | 127 194 | 254.2 | 1096 | - | 2000 | 36.6 | 0.5 | |
| 60 | Methane | $CH_4$ | gas | 16.0 | - 74 873 | 186.2 | 298 | - | 1000 | 19.6 | 54.1 | |
| 61 | Nickel | Ni | sol | 58.7 | | 29.9 | 298 | - | 500 | 19.1 | 23.5 | 33.0 |
| 62 | Nickel carbonate | $NiCO_3$ | sol | 118.7 | - 694 544 | 86.2 | 298 | - | 700 | 67.1 | 68.1 | |
| 63 | Nickel carbonyl | $Ni(CO)_4$ | gas | 170.8 | - 602 910 | 410.6 | 298 | - | 2000 | 152.7 | 29.1 | |
| 64 | Nickel oxide | NiO | sol | 74.7 | - 239 701 | 38.0 | 298 | - | 2228 | | | 58.0 |
| 65 | Nickel sulfide, *millerite* | NiS | sol | 90.8 | - 87 864 | 53.0 | 298 | - | 1249 | 36.5 | 27.4 | |
| 66 | Ni-sulfide, *heazlewoodite* | $Ni_3S_2$ | sol | 208.1 | - 216 313 | 133.9 | 298 | - | 1062 | | | 150.0 |
| 67 | Nitrogen | $N_2$ | gas | 28.0 | | 191.6 | 298 | - | 1600 | 28.0 | 3.1 | 30.8 |
| 68 | Oxygen | $O_2$ | gas | 32.0 | | 205.1 | 298 | - | 5000 | 31.9 | 2.5 | 38.3 |
| 69 | Palladium | Pd | sol | 106.4 | | 37.8 | 298 | - | 1400 | 24.2 | 6.4 | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 69 | Palladium | Pd | sol | 106.4 | | 37.8 | 298 | - | 1400 | 24.2 | 6.4 | |
| 70 | Palladium oxide | PdO | sol | 122.4 | - 115 478 | 38.9 | 298 | - | 1200 | 21.0 | 34.7 | |
| 71 | Platinum | Pt | sol | 195.1 | | 41.6 | 298 | - | 2045 | 24.3 | 5.4 | |
| 72 | | Ptliq | liq | | 19 665 | 9.6 | 2045 | - | 4096 | 34.7 | | |
| 73 | Silicon | Si | sol | 28.1 | | 18.8 | 298 | - | 1687 | 22.8 | 3.9 | |
| 74 | | Siliq | liq | | 50 208 | 29.8 | 1687 | - | 3504 | 27.2 | | |
| 75 | Silica | $SiO_2$ | sol | 60.1 | - 910 857 | 41.5 | 298 | - | 1996 | 29.2 | 56.8 | 65.0 |
| 76 | | SiO2liq | liq | | 9 565 | 7.8 | 1996 | - | 3000 | 85.8 | | |
| 77 | Silver | Ag | sol | 107.9 | | 42.7 | 298 | - | 1234 | 24.3 | 2.5 | 28.0 |
| 78 | | Agliq | liq | | 11 297 | 9.2 | 1234 | - | 2433 | 33.5 | | |
| 79 | Slag, *calcium ortho silicate* | $Ca_2SiO_4$ | sol | 172.2 | -2 315 216 | 120.8 | 298 | - | 1121 | 145.9 | 40.8 | |
| 80 | | Ca2SiO4liq | liq | | 71 100 | 29.6 | 2403 | - | 2800 | 209.2 | | |
| 81 | Slag, *fayalite* | $Fe_2SiO_4$ | sol | 203.8 | -1 479 902 | 145.2 | 298 | - | 1490 | 125.5 | 60.6 | 153.0 |
| 82 | | Fe2SiO4liq | liq | | 92 174 | 61.9 | 1490 | - | 1700 | 240.6 | | |
| 83 | Sulfur | S | sol | 32.1 | | 32.1 | 298 | - | 368 | 16.8 | 20.1 | |
| 84 | | Sliq | liq | | 1 720 | 4.4 | 368 | - | 882 | 30.0 | 6.8 | |
| 85 | | Sgas | gas | | 128 599 | 228.2 | 882 | - | 5000 | 35.2 | 1.9 | |
| 86 | Sulfur dioxide | $SO_2$ | gas | 64.1 | - 296 813 | 248.2 | 50 | - | 500 | 30.8 | 31.9 | 39.0 |
| 87 | | SO2hi | hi | | | 0.0 | 500 | - | 5000 | 52.5 | 3.0 | 60.7 |
| 88 | Tin, *white* | Sn | sol | 150.7 | | 51.2 | 298 | - | 505 | 21.6 | 18.1 | 28.8 |
| 89 | | Snliq | liq | | 7 029 | 13.9 | 505 | - | 2873 | 28.5 | | |
| 90 | Tin dioxide, *cassiterite* | $SnO_2$ | sol | 150.7 | - 577 631 | 49.0 | 298 | - | 1903 | 58.7 | 18.2 | |
| 91 | *Heat of Fusion* | Ice | sol | | *5 980* | | 273 | | | | | |
| 92 | Water | $H_2O$ | liq | 18.0 | - 285 830 | 69.9 | 298 | - | 373 | 59.7 | 23.0 | 75.5 |
| 93 | | H2Ogas | gas | | - 241 827 | 188.8 | 373 | - | 1600 | 30.1 | 10.4 | 38.5 |
| 94 | Zinc | Zn | sol | 65.4 | | 41.6 | 298 | - | 693 | 22.2 | 10.5 | 27.1 |
| 95 | | Znliq | liq | | 7 322 | 10.6 | 693 | - | 1 180 | 31.4 | | |
| 96 | | Zngas | gas | | 130 415 | 161.0 | 1 180 | - | 2 000 | 20.8 | | |
| 97 | Zinc carbonate | $ZnCO_3$ | sol | 125.4 | - 812 780 | 82.4 | 298 | - | 500 | 38.9 | 138.1 | |
| 98 | Zinc oxide, *zincite* | ZnO | sol | 81.4 | - 350 460 | 43.6 | 298 | - | 2248 | 41.4 | 9.5 | 53.3 |
| 99 | Zinc sulfide, *sphalerite* | ZnS | sol | 97.4 | - 201 669 | 57.7 | 298 | - | 1293 | 44.7 | 10.6 | 52.8 |

| *Variable, constant or function* | | | | *Unit of measurement* | | | |
|---|---|---|---|---|---|---|---|
| t | time | | | s | second | = | 1 / 60 min |
| | | | also measured in | 1 h | hour | = | 3600 s |
| | | | also measured in | 1 d | day | = | 24 h |
| m | mass | | SI | 1 kg | | = | 1000 g |
| | | | also | 1 t | | = | 1000 kg |
| n | mole | | for chemical calculations | mol | | = | m / M mol |
| M | Mole mass | | *tabulated* | g / mol | | | |
| V | volume | | | 1 $m^3$ | cubicmeter | = | 1000 L *liter* |
| $V_{mol}$ | mol volume | | volume occupied by 1 mol of *an ideal gas* at 273 K | | | = | **22.4** L / mol |
| d | density | = | m / V mass / volume | t / $m^3$ | | or | kg / L |
| | | | density of water at 4°C | | | = | 1 kg / L |
| p | pressure | | SI | 1 Pa | Pascal | ≈ | 1 N / $m^2$ |
| | | | old but useful | 1 atm | atmosphere | = | 101 325 Pa |
| T | temperature | | also measured in °C | K | Kelvin | = | **273** + °C |
| E | energy | $E_{me}$ | *mechanical* | 1 Nm | Newtonmeter | = | 1 J |
| | | $E_{me}$ | *volume work* pV | 1 atm x L | Literatmosphere | = | 101.3 J = Pa $m^3$ |
| | | $E_{th}$ or Q | *thermal* | 1 J | Joule | = | 1 Ws |
| | | $E_{el}$ | *electrical* | 1 Ws | Wattsecond | = | 1 J |
| P | power | = | energy / time | 1 J/s | | = | 1 W *Watt* |
| $H_T$ | enthalpy | heat content at constant pressure | | J / mol | | = | U + pV |
| $S_T$ | entropy | = | $Q_{rev}$ / T | J / (mol K) | | | |
| $G^\circ_T$ | Gibbs free energy | = | $H^\circ_T - T S^\circ_T$ | J / mol | under standard conditions | | |
| $G_T$ | | = | $G^\circ_T + RT \ln K$ | J / mol | under *non-standard* conditions | | |
| $H^\circ_{298}$ $S^\circ_{298}$ $G^\circ_{298}$ | | enthalpy, entropy or free energy values under standard conditions at room temperature | | | | | |
| $\Delta H$ $\Delta S$ $\Delta G$ | | change of enthalpy, entropy or Gibbs free energy in reactions | | | | | $\Sigma$ products – $\Sigma$ reactants |
| $\Delta H^\circ_T$ $\Delta S^\circ_T$ $\Delta G^\circ_T$ | | change of enthalpy, entropy or Gibbs free energy under standard condtions at temp. T | | | | | |
| $\Delta G_T$ | | = | $\Delta G^\circ_T + R\,T \ln K = \Delta H^\circ_T - T\Delta S^\circ_T + RT \ln K$ | | *General reaction isotherm* | | |
| K | equilibrium constant | | | no units | | | $\Pi$ products / $\Pi$ reactants |
| $C \equiv C_p$ | heat capacity | | at constant pressure | J / (mol K) | | | |
| $C_T$ | molar h.c. at T | = | $\int (a + b10^{-3}\,T)\,dT$ | J / (mol K) | to be integrated from $T_{lo}$ to $T_{hi}$ | | |
| $C_{mean}$ | mean h.c. | = | Q / $\Delta$T | J / (mol K) | valid over entire temperature interval | | |
| R | universal gas constant | | | **8.314** J / (mol K) | | | |
| F | Faraday constant | | | 96 484 Cb / mol = As / mol | | = | **26.8** Ah/mol |
| $N_A$ | Avogadro Number | | number of particles or molecules *per mole* of matter | | | = | 6E+23 / mol |
| Oxygen in air | | oav = | **21.0%** by volume | | oam | = | **23.2%** by mass |
| Water | | M = | 18.0 g / mol | | 1 L = 1 kg | = | 55.5 mol |
| Consumption of electrical energy | | | 1 kWh | = | 1000 x 3600 Ws = J | = | 3.6 MJ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| μ | $10^{-6}$ | *micro* | e.g. | 1 μL | microliter | = | $10^{-6}$ L | | |
| m | $10^{-3}$ | *milli* | | 1 ms | millisecond | = | $10^{-3}$ s | | |
| | $10^0 = 1$ | unit | | | | | | | |
| k | $10^3$ | *kilo* | | 1 km | kilometer | = | $10^3$ m | | |
| M | $10^6$ | *mega* | | 1 Mg | megagram | = | $10^6$ g | = | 1 t |
| G | $10^9$ | *giga* | | 1 GJ | gigajoule | = | $10^9$ J | | |