THE PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

THIRD YEAR MINERAL PROCESSING ENGINEERING

MP344 - PYROMETALLURGY

FIRST SEMESTER EXAMINATION

TUESDAY 15th JUNE 2021 – 12:50 PM

TIME ALLOWED – 3 HOURS

INFORMATION FOR STUDENTS

1. You have 10 minutes to read the paper. You **MUST NOT** begin writing during that time.
2. **Attempt ALL questions.** Write all answers in the answer booklet provided.
3. Write your **NAME** and **STUDENT NUMBER** clearly on the **ANSWER BOOKLET.** Do this **NOW.**
4. **NO MOBILE PHONES AND LAPTOPS ARE ALLOWED IN THE EXAMINATION ROOM.**

Marking Scheme:

All question carry equal marks. Total mark is 100.

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Question 1

(a) Determine the feasibility of reducing NiO by vanadium at 1000 °C. Show equations for the process. Refer to Figure 1.0 to answer this question.

(b) Show by aid of a diagram the shaft furnace operation. Discuss the processes in each zone.

(c) Discuss with an aid of a diagram the temperature of gas and solid during calcination of limestone in a coke-fired shaft furnace.

(d) Show by equations the following processes:

i. magnetizing roasting

ii. sintering roasting

Question 2

(a) Discuss with the aid of a diagram the Blast Furnace operation for pig iron production. Explain the processes within the Blast Furnace.

(b) A Blast Furnace burden contains 160 kg Fe_2O_3, 54 kg SiO_2, 20 kg Al_2O_3, 100 kg $CaCO_3$ and 78 kg C. For the smelting of the above burden 266 Nm^3 of air is used. The hot metal produced contains 4 % C and 1 % Si, the balance being iron, and it is assumed that all the iron in the burden enters the hot metal. The remaining oxides form a slag, whereas CO_2 from the limestone is expelled and mixes with the furnace gas. Carbon in the gas is partly as CO_2 and CO and there is no free oxygen.

i. Calculate the weight of the hot metal as well as the weight and composition of the slag.

ii. Calculate the volume and composition of the furnace gas, all for the above basis.

Note: Refer to Figure 2.0 for calculations.

Question 3

(a) Design a flow sheet to produce 99.9 % Cu from Ok Tedi deposit of copper grade 1 – 2 % Cu. Assays of the tails report 0.1 -0.2 % Cu whilst the Cu concentrate reported 20 – 30 % Cu. Slag to the waste is 0.3 – 1 % Cu with the Cu matte records 50 – 70 % Cu. Hence, slag from the refinery is re - circulated back to the matte smelting. Blister copper assayed 98 % Cu and at the cathodes with 99.5 % Cu. Finally, the waste electrolyte contains Ni, Cr, Co etc. and the noble metals (Au, Ag and Pt) are collected at the anode.

Note: Indicate flow of material, addition of fluxes and air, exit of volatile substances and wastes. Show all unit processes involved in the flow sheet.

(b) A copper concentrate contains 20 %Cu and 40 % S. The ore minerals are $CuFeS_2$ and FeS_2, the remaining gangue is SiO_2.

i. Calculate the number of moles of Fe, Cu, S, and SiO_2 in 1 kg of concentrate.

ii. The concentrate (25 °C) is flash smelted with oxygen enriched air (25 °C) to give a matte with 40 % Cu. All the oxygen in the blast is consumed. The matte is assumed to be a mixture of stoichiometric Cu_2S and FeS. The slag is stoichiometric Fe_2SiO_4. Calculate the number of moles of Cu_2S and FeS in the matte and of FeO and SiO_2 in the slag.

iii. Calculate the necessary addition of SiO_2 as well as the total O_2 in the blast, all per kilogram of concentrate.

Question 4

(a) Which furnace smelt the copper concentrates to produce copper matte? Explain the operation of this furnace.

(b) Discuss the process in (a) by a chemical equation.

(c) Study Figure 3.0 and answer the following questions:-

i. Discuss the composition of an acid slag and explain how it produces high viscous melt.

ii. Give the properties of the Blast furnace slag and discuss its formation with regards to temperature and chemical composition.

iii. Why are the following properties important in valuing refractory materials?

- Melting point.
- Resistance towards molten slags and metals.
- Resistance to oxidation and reduction.

(d) Study Figure 4.0 and answer the following questions:-

i. Which substance is independent of temperature?

ii. Which substances are less stable at higher temperatures?

iii. Give reasons why coke & coal are not viable on industrial scale.

iv. Which product of carbon is more stable at a higher temperature?

v. Explain why most of the organic compounds are not reducible by carbon.

END OF PAPER

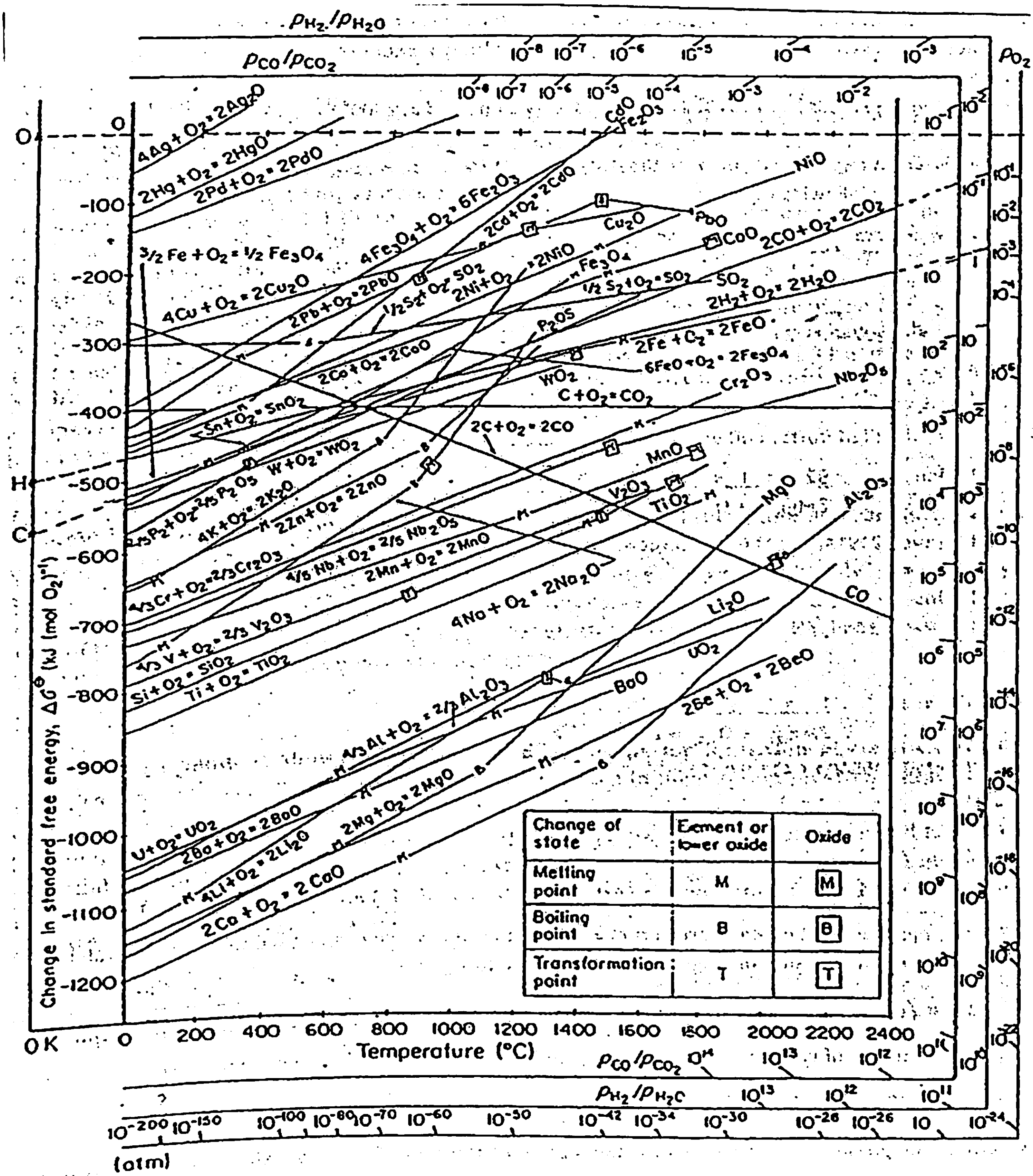

Figure 1.0 ΔG° - T diagram for the formation of oxides. For equilibrium P_{O_2}, P_{CO}/P_{CO_2} and P_{H_2}/P_{H_2O} values use points O, C and H respectively on the ΔG° axis at 0 K.

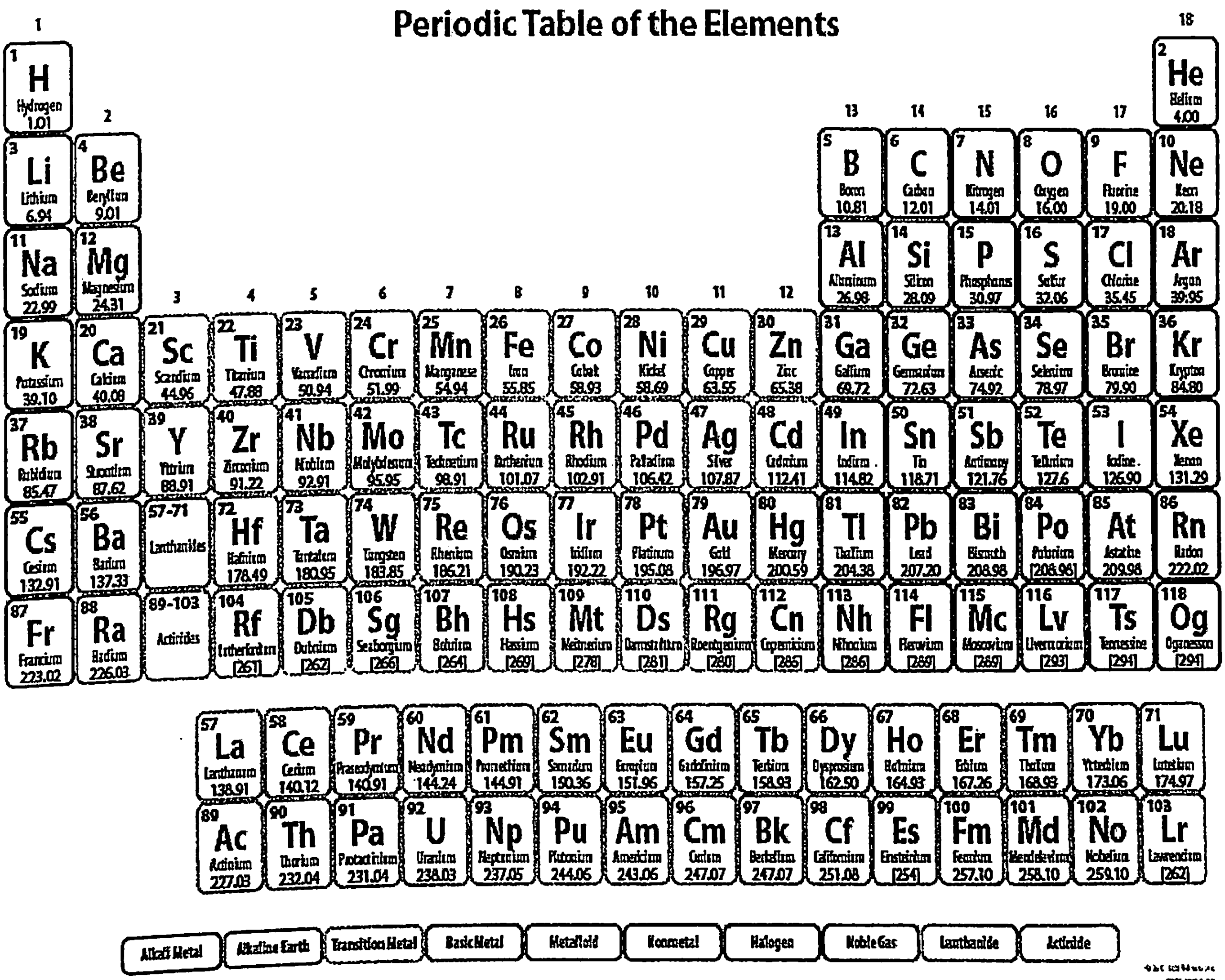

Figure 2.0 Periodic Table of Elements

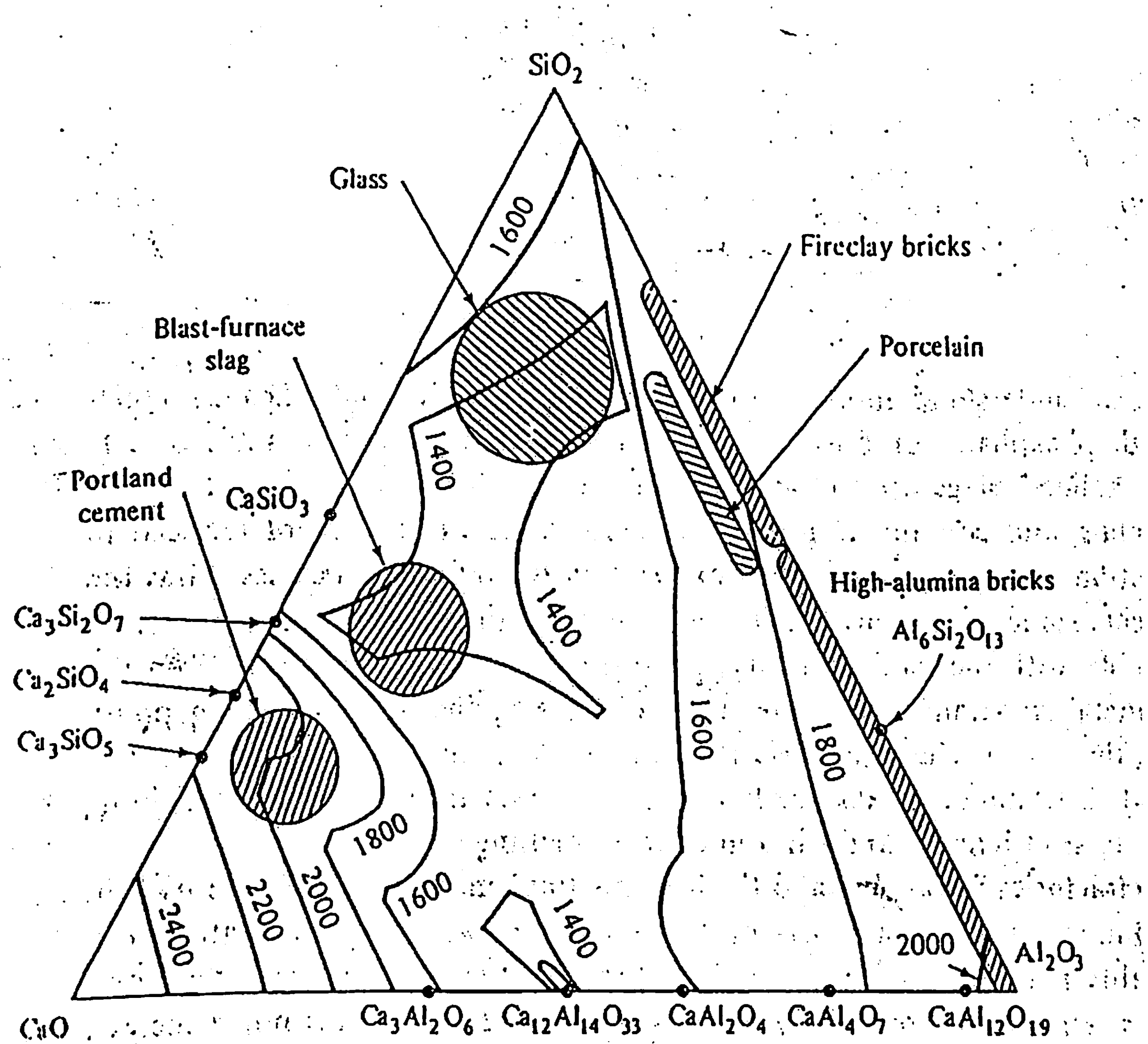

Figure 3.0 **Liquidus isotherms in the $SiO_2 - CaO - Al_2O_3$ system**

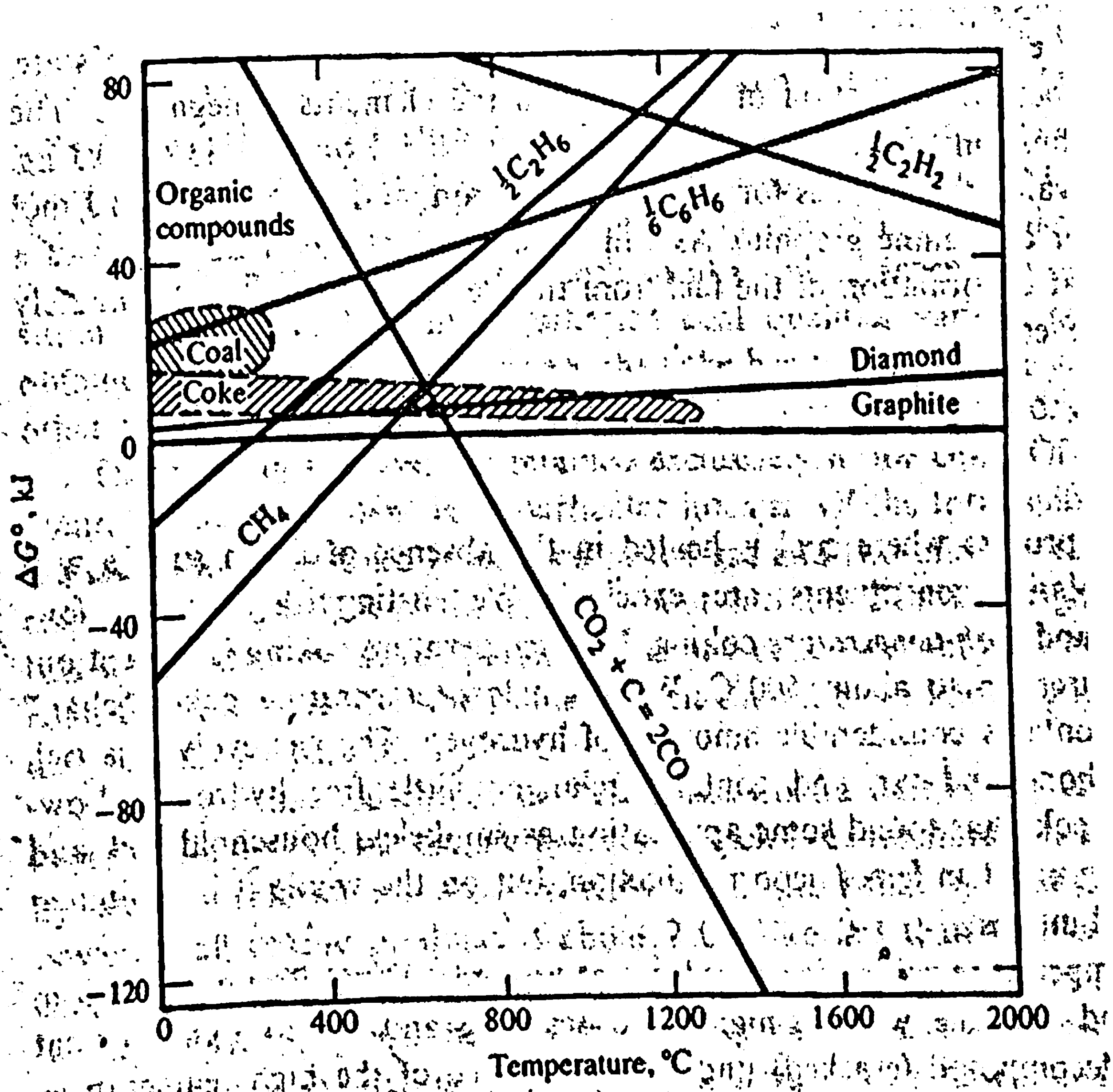

Figure 4.0 Standard Gibbs energy of formation, per mole of carbon, of various carbon compounds relative to graphite.