國立高雄大學九十六學年度研究所碩士班招生考試試題

科目：輸送現象與單元操作　　系所：化學工程及材料工程學系甲組　　是否使用計算機：是
考試時間：100 分鐘　　本科原始成績：100 分

1. Please illustrate or explain the meaning the following questions:

(a) (10%) Please proof the five dimensionless numbers in fluid transport by Buckingham method as Eu=f(Re, Fr, We, Ma).

(b) (10%) Please explain what are LMTD, Fourier number, shell-and-tube exchanger, Stefan-Boltzmann law, and forced convection in Heat Transfer.

(c) (10%) What are humidity, relative humidity, humid volume, dew point and humid heat in the humidification operations?

(d) (5%) Please indicate what is the difference between flash, continuous and batch distillations?

2. (15%) A source of strength 6.5 m^2/s at the origin is combined with a uniform stream moving at 8 m/s in the x direction. For the half-body which results, find

(a) The stagnation point.
(b) The body height as it crosses the y axis.
(c) The body height at large x.
(d) The maximum surface velocity and its position (x, y).

3. (20%) A catalytic tubular reactor is shown in Fig. Q3. A dilute solution of solute A in a solvent S is in fully developed, laminar flow in the region Z<0. When it encounters the catalytic wall in the region $0 \leqq z \leqq L$, solutes A is instantaneously and irreversibly rearranged to an isomer B. Write the diffusion equation appropriate for this problem, and find the solution for short distances into the reactor. Assume that the flow is isothermal and neglect the presence of B.

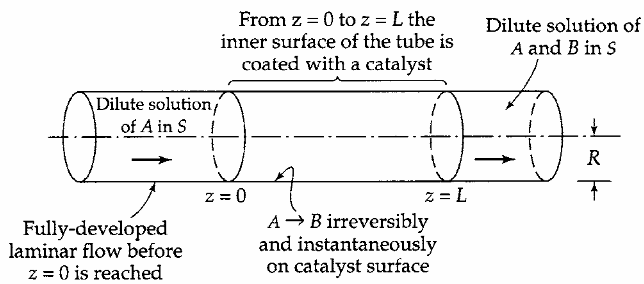

Figure Q3. Boundary conditions for a tubular reactor.

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4. (15%) A packed column is used to remove toluene from water by stripping with air. The water contain 60 ppm toluene (weight basis), and the concentration must be reduced to 2 ppm. The column will operate at 20°C and an average pressure of 1.5 atm. The equilibrium relationship is

$$P_{tot} = 300x$$

where P_{tot} is partial pressure of toluene, atm, in the gas phase, and x is mole fraction of toluene in the liquid. (a) Determine the minimum air rate in gram moles per minutes for a water rate of 100L/min. (b) Calculate N_{ox} for an air rate twice the minimum. (c) Determine the packed height required if H_y= 0.7m and H_x= 0.6m.

5. (15%) Shown in the Figure Q5 is the case of a fluid flowing parallel to a flat plate, where, for a distance X from the leading edge, the plate and fluid are at the same temperature. For values of x > X the plate is maintained at a constant temperature, T_s, were $T_s > T_\infty$. Assuming a cubic profile for both the hydrodynamic and thermal boundary layers, (a) show that the ratio of the thickness, x, is expressed as

$$\xi = \frac{\delta_t}{\delta} @ \frac{1}{Pr^{1/3}}\left[1-\left(\frac{X}{x}\right)^{3/4}\right]^{1/3}$$

Also (b) show that the local Nusselt number can be expressed as

$$Nu_x @ 0.33\left(\frac{Pr}{1-(X/x)^{3/4}}\right)^{1/3} Re_x^{\ 1/2}$$

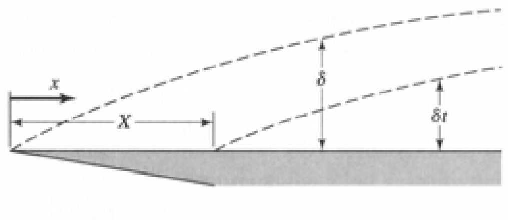

Figure Q5. A fluid flowing parallel to a flat plate

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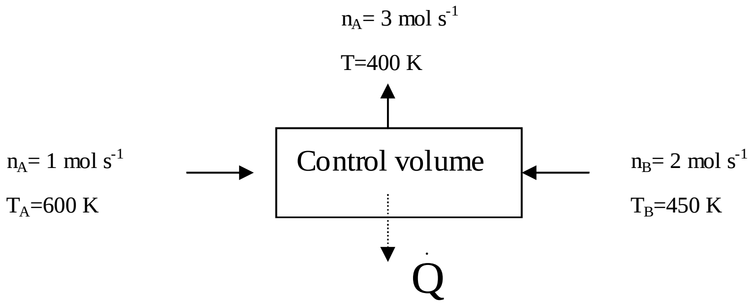
1. In a steady state flow process, 1 mol s^{-1} of air at 600 K and 1 atm is continuously mixed with 2 mol.s^{-1} of air at 450 K and 1 atm. The product stream is at 400 K and 1 atm. A schematic representation of the process is shown in the following figure. Determine the rate of heat transfer (Js^{-1}) and the rate of entropy ($JK^{-1}s^{-1}$) generation for the process. Assume that air is an ideal gas with $C_p = (7/2)R$, that the surroundings are at 300 K, and that kinetic and potential energy changes are negligible. (ps. values of the universal gas constant are listed in the last page)（14%）



2. The excess Gibbs energy of a binary liquid mixture at T and P is given by:

$$G^E / RT = (-2.6x_1 - 1.8x_2)x_1x_2$$

(a) Find expression for $\ln\gamma_1$ and $\ln\gamma_2$ at T and P. （10%）

(b) Show that these expression satisfy the Gibbs/Duhem equation. （5%）

(c) Plot G^E / RT, $\ln\gamma_1$ and $\ln\gamma_2$ as calculated by the given equation for G^E / RT and by the equations developed in (a) vs. x_1. Label points $\ln\gamma_1^\infty$ and $\ln\gamma_2^\infty$ and show their values. （9%）

3. Determine the enthalpy and entropy changes of liquid water for a change of state from 1 bar and 25℃ to 1000 bar and 50℃. Data for water are given in the following state table.（12%）

t/℃	P/bar	C_p/J $mol^{-1}K^{-1}$	V/cm^3 mol^{-1}	b/K^{-1}
25	1	75.305	18.071	256×10^{-6}
25	1000	……..	18.012	366×10^{-6}
50	1	75.314	18.234	458×10^{-6}
50	1000	……..	18.174	568×10^{-6}

* b : volume expansivity; C_p: heat capacity at constant pressure

4. For the elementary reactions

$$A \xrightarrow{k_1} R \xrightarrow{k_2} S \qquad A \xrightarrow{k_3} T \qquad k_2 = k_1 + k_3$$

find $C_{R,max}/C_{AO}$ and t_{opt} in a plug flow reactor. Where t is the space time in the reactor.（14%）

5. The liquid phase reaction

$$A + B \longrightarrow C$$

follows an elementary rate law and is carried out isothermally in a flow system. The concentrations of the A and B feed streams are 2M before mixing. The volumetric flow rate of each stream is 5 dm^3/min, and the entering temperature is 300 K. The streams are mixed immediately before entering. Two reactors are available. One is a gray 200 dm^3 continuous-stirred tank reactor (CSTR) that can be heated to 77℃, and the other is a white 800 dm^3 plug-flow reactor (PFR) operated at 300 K that cannot be heated or cooled but can be painted red or black. Note k = 0.07 dm^3/mol.min at 300 K and E = 20 kcal/mol.

(a) Which reactor and what conditions do you recommend? Explain the reason for your choice. Back up your reasoning with the appropriate calculations. （5%）

(b) How long would it take to achieve 90 % conversion in a 200 dm^3 batch reactor with $C_{A0} = C_{B0}$ = 1M after mixing at a temperature of 77℃? （5%）

(c) What conversion would be obtained if the CSTR and PFR were operated at 300 K and connected in series? In parallel with 5 mol/min to each? （8%）

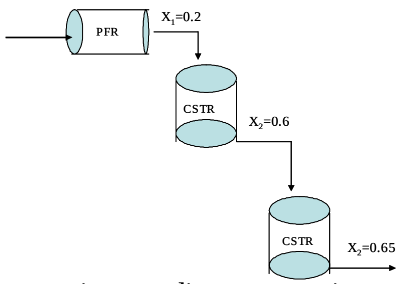
6. The isomerization of butane

$$n\text{-}C_4H_{10} \rightleftharpoons i\text{-}C_4H_{10}$$

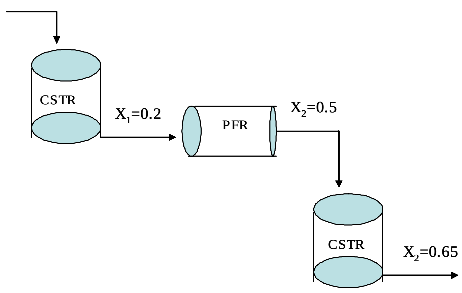
was carried out adibatically in the liquid phase and the data in the following table was obtained. The reaction was happened in reactors in series, and an entering molar flow rate of n-butane was 50 kmol/hr.

X	0.0	0.2	0.4	0.6	0.65
$-r_A$(kmol/m^3.h)	39	53	59	38	25

(a) What would be the reactor volumes if the two intermediate conversions were 20% and 60%, respectively.（6%）



(b) What would be the reactor volumes if the two intermediate conversions were 20% and 50%, respectively.（6%）



(c) What is the worst possible way to arrange the two CSTRs and one PFR and what is the volume for the three reactors? (X_1=0.2, X_2=0.6, and X_3=0.65)（6%）

Table: Values of the universal gas constant

$R = 8.314\ J\ mol^{-1}\ K^{-1} = 8.314\ m^3\ Pa\ mol^{-1}K^{-1}$
$= 83.14\ cm^3\ bar\ mol^{-1}\ K^{-1} = 8314\ cm^3\ kPa\ mol^{-1}\ K^{-1}$
$= 82.06\ cm^3\ (atm)\ mol^{-1}\ K^{-1} = 62356\ cm^3\ (torr)\ mol^{-1}\ K^{-1}$
$= 1.987\ (cal)\ mol^{-1}\ K^{-1} = 1.986\ (Btu)(lb\ mole)^{-1}\ (R)^{-1}$
$= 0.7302\ (ft)^3\ (atm)\ (lb\ mol)^{-1}\ (R)^{-1} = 10.73\ (ft)^3\ (psia)(lb\ mol)^{-1}\ (R)^{-1}$
$=1545\ (ft)(lb_f)(lb\ mol)^{-1}(R)^{-1}$

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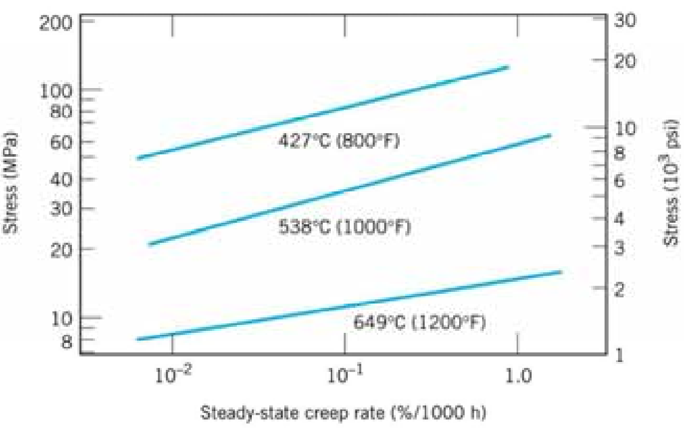
(10%) 1. The thermal expansion coefficient of graphite along the C axis is more than 25 times greater than that in the basal plane. Draw a bond energy curve to explain why.

(15%) 2. What are the planes of highest density in FCC? What are the directions of highest density within these planes?
How many slip systems does a FCC crystal have? Draw schematically to show these slip systems.

(10%) 3. A specimen 1015mm (40 in.) long of a low carbon-nickel alloy is to be exposed to a tensile stress of 70 MPa (10,000psi) at 427℃ (800 ^{o}F).Determine its elongation after 10,000 h. Assume that the total of both instantaneous and primary creep elongations is 1.3mm (0.05 in.).

Stress (logarithmic scale) versus steady-state creep rate (logarithmic scale) for a low carbon–nickel alloy at three temperatures. [From *Metals Handbook: Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals*, Vol. 3, 9th edition, D. Benjamin (Senior Editor), American Society for Metals, 1980, p. 131.]



(15%) 4. For a 76 wt% Pb-24 wt% Mg alloy, make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 575℃ (1070 ^{o}F), 500℃(930 ^{o}F), 450℃(840 ^{o}F) and 300℃(570 ^{o}F). Label all phases and indicate their approximate compositions.

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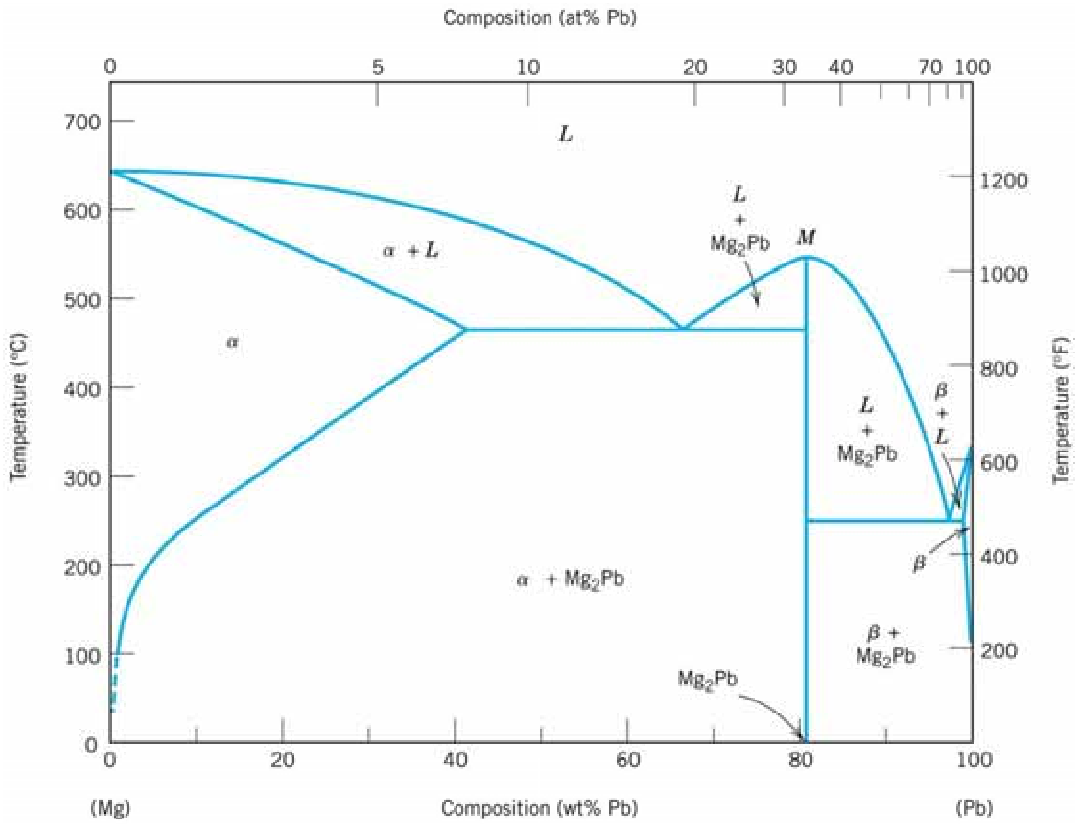

The magnesium–lead phase diagram. [Adapted from *Phase Diagrams of Binary Magnesium Alloys*, A. A. Nayeb-Hashemi and J. B. Clark (Editors), 1988. Reprinted by permission of ASM International, Materials Park, OH.]

(15%) 5. (a) Plot the energy band structures to explain the electrical properties of metals, semiconductors, and insulators. (b) Provide a method to measure the value of energy gap. (c) Explain the influence of energy band gap on optical properties of materials.

(10%) 6. (a) Describe the phenomenon of magnetic hysteresis, and why it occurs for ferromagnetic and ferrimagnetic materials.

(b) Explain why the magnitude of the saturation magnetization decreases with increasing temperature for ferromagnetic materials, and why ferromagnetic behavior ceases above the Curie temperature.

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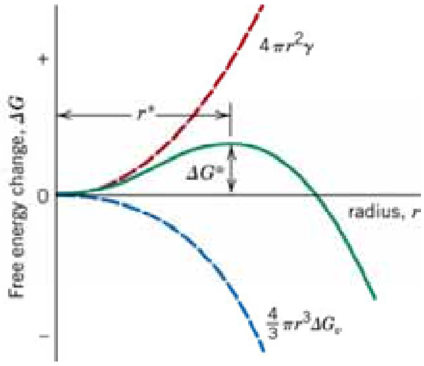
(15%) 7. Considering the solidification of a pure material, the total free energy change for homogeneous nucleation is equal to the sum of volume free energy change and surface free energy,

$$DG = \frac{4}{3} p\, r^3\, DG_v + 4pr^2 g$$



The volume, surface, and total free energy contributions are plotted schematically as a function of nucleus radius in the figure.

In a physical sense, this means that as a solid particle begins to form as atoms in the liquid cluster together, its free energy first increase. If this cluster reaches a size corresponding to the critical radius r^*, then growth will continue with the accompaniment of a decrease in free energy. On the other hand, a cluster of radius less than the critical will shrink and redissolve. The subcritical particle is an embryo, whereas the particle of radius greater than r^* is termed a nucleus. A critical free energy, DG^*, occurs at the critical radius and, consequently, at the maximum of the curve in the figure. The DG^* corresponds to an activation free energy, which is the free energy required for the formation of a stable nucleus.

(a) Translate the above underlined paragraph to Chinese. (英翻中)

(b) Derive the expression for r^* and DG^*, respectively.

(c) The volume free energy change DG_v is a function of temperature as

$$DG_v = \frac{DH_f\,(T_m - T)}{T_m}$$

where ΔH_f is latent heat of fusion and T_m is melting point.

For the solidification of Nickle, calculate the critical radius r^* and activation free energy DG^* if nucleation is homogeneous. The values for the latent heat of fusion, surface free energy, melting temperature, and supercooling value are -2.53×10^9 J/m^3, 0.255 J/m^2, 1455°C, and 319°C, respectively.

(10%) 8. If you find a mineral interesting, explain how would you study the crystallography and composition of the mineral.

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1. The solid-state electrochemical cell

   (Pt), O_2 (gas at p_{O_2}) |CaO-ZrO_2 |Fe |FeO,(Pt)

   is built to measure the partial pressure of oxygen in gases. Write an equation relating the oxygen pressure and temperature of the gas to the EMF of the cell. ($Fe_{(s)}$ + ½ $O_{2\,(eq)}$= $FeO_{(s)}$, ΔG^o = -263700 + 64.35T J,) (10%)

2. Calculate the work done by the system for one mole of mercury when the external pressure is changed from 0 to 5×10^8 N/m^2 at 300K. the molar volume, isothermal compressibility, and isobaric thermal expansivity of mercury are 1.47×10^{-5} m^3/mole, 3.84×10^{-11} m^2/N, and 158×10^{-6} K^{-1}, respectively. Neglect the pressure dependence of molar volume, compressibility, and isobaric thermal expansivity. (10%)

3. Please explain the following terms:

   (1). configuration entropy (3%)

   (2). intensive properties (3%)

   (3). partial molar quantities (4%)

4. The molar volumes of solid and liquid lead at the normal melting temperature of lead are, respectively, 18.92 cm^3 and 19.47 cm^3. Calculate the pressure, which must be applied to lead in order to increase its melting temperature by 20-centigrade degrees. ($\Delta H_{m,\,Pb}$ = 4810 J, $T_{m,\,Pb}$ = 600K) (10%)

5. Using the virial equation ($PV = RT(1 + 6.4\times10^{-4}P)$) of state for hydrogen at 298K, calculate
   a. the fugacity of hydrogen at 200 atm and 298K, (5%)
   b. the pressure at which the fugacity is twice the pressure, (5%)
   c. the change in the Gibbs free energy caused by a compression of one mole of hydrogen at 298K from 1 atm to 200 atm. (5%)

6. A CO-CO_2-H_2-H_2O gas mixture at a total pressure of 1 atm exerts a partial pressure of oxygen of 10^{-7} atm at 1600℃. In what ratio were the CO_2 and H_2 mixed to produce the gas with this oxygen pressure? (½ O_2 + H_2 = H_2O, $\Delta G^o_{,\,1873K}$ = -142892 J; CO + ½ O_2 = CO_2, $\Delta G^o_{,\,1873K}$ = -119805 J) (10%)

7. a. Explain the application of the Ellingham diagram. (5%)
   b. Using attached Ellingham diagram (figure 1), for Cu and Ni at a temperature range of 500 to 800℃, which is more likely to react with oxygen? Explain your answer. (5%)
   c. Which of Al, Mg, Fe and Cr will likely to have significant reaction with a quartz (SiO_2) crucible at high temperatures? Explain your answer. (5%)

8. Determine the heat of vaporization of zinc. The vapor pressure of zinc is 0.013 atm, 0.052 atm, and 0.13 atm at 593℃, 673℃, and 736℃, respectively. The boiling point of zinc is 1580 K. (10%)

9. The activity coefficient of Zn in liquid Zn-Cd alloys at 435℃ can be represented as

$$\ln\gamma_{Zn} = 0.875X^2_{Cd} - 0.30\,X^3_{Cd}$$

Derive the corresponding expression for the dependence of $\ln\gamma_{Cd}$ on composition and calculate the activity of cadmium in the alloy of $X_{Cd} = 0.5$ at 435℃. (10%)

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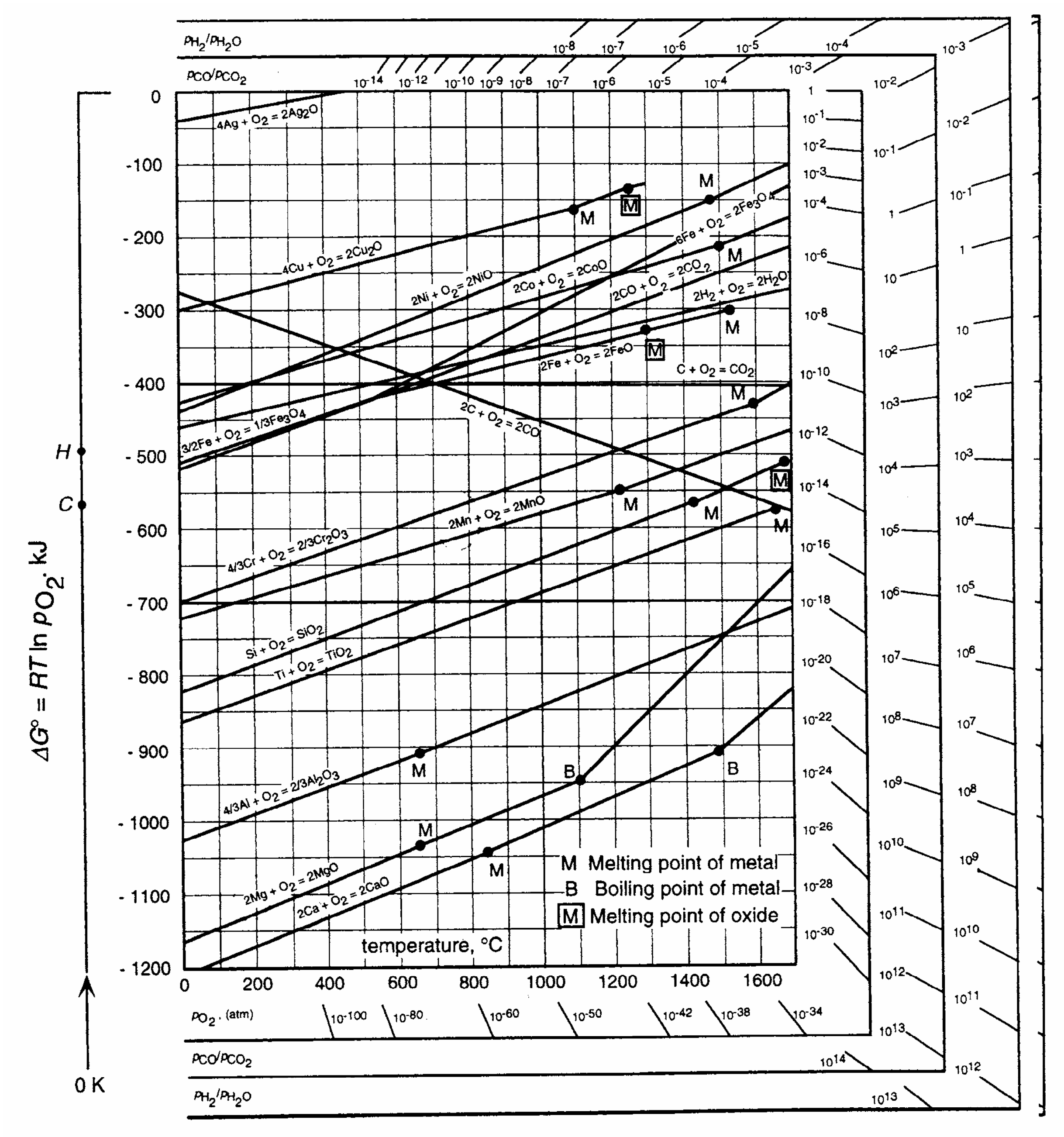

Figure 1. The Ellingham diagram for selected oxides.