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Exámenes resueltos 2012-2016

2° Materiales Aeroespaciales I

Grado en Ingeniería Aeroespacial

Escuela Politécnica Superior
Universidad Carlos III de Madrid



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Universidad Carlos III de Madrid

DEGREE IN AEROSPACE ENGINEERING
AEROSPACE MATERIALS I

January 7th, 2016

Surnames: **Name:** **Group:**

Information:
- Read the questions carefully before answering. Use the space given for answering each question.
- You have 2h 30min to complete the exam.
- The marks assigned to each of the questions are given at the beginning of the question.
- To pass the exam you need a minimum mark of 5 over 10.

1. (0.5 points) Justify if the following statements are True or False:

1. In materials with metallic bonding the higher the number of valence electrons involved, the ~~lower~~ higher the bonding energy and melting point.
F — more electrons → more attraction

2. Acetylene (HC≡CH) presents a higher C-C bond energy than that of the ethylene ($H_2C=CH_2$).
T — triple bond > single bond

3. When the ion size in materials with ionic bonding increases the lattice energy decreases.
T — the lattice energy is inversely related to the intermolecular distance → inversely proportional to ion size

4. Materials with a strong atomic bonding present a low Young's modulus.
F — Young's Modulus is a measurement of the ability of a material to withstand changes in length when under lengthwise tension or compression. Material with strong atomic bonding are more stiff → high Young's modulus (we need a great force to strech the bonds)

2. (1 point) BCC lithium has a lattice parameter of 3.5089 Å and contains one vacancy per 200 unit cells. Calculate:

a. (0.5p) The number of vacancies per cubic centimeter.
b. (0.5p) The density of Li.

Data: $M_{Li} = 6.94$ g/mol; $N_A = 6.023 \cdot 10^{23}$ atoms/mol.

a) $1.157 \cdot 10^{20}\ vacancies/cm^3$
b) $0.532\ g/cm^3$

a) $V_c = a^3 = (3.5089 \cdot 10^{-8}\ cm)^3 = 4.32 \cdot 10^{-23}\ \frac{cm^3}{cell}$

$n_v = \frac{1\ vac}{200\ cell} \cdot \frac{1\ cell}{4.32 \cdot 10^{-23}\ cm^3} = 1.159 \cdot 10^{20}\ vac/cm^3$

b) $\rho = \frac{nM}{N_A V_c} = \frac{(8 \cdot \frac{1}{8} \cdot 1 - \frac{1}{200}) \cdot 6.94}{6.023 \cdot 10^{23} \cdot 4.32 \cdot 10^{-23}} =$

$= 0.532\ g/cm^3$

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3. **(0.5 points)** Thermal activated processes can be described by the following equation:

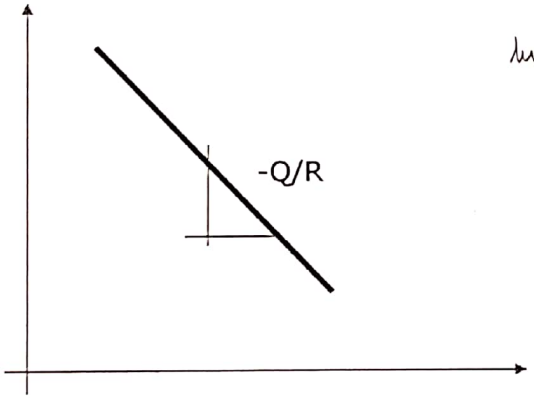
$$\text{Rate of reaction} = C\, e^{-Q/RT}$$

a. (0.25p) What is the name of this type of equation? Apply it to diffusion and name the terms in equation.

b. (0.25p) Draw a schematic plot of the natural logarithm of the rate *versus* 1/T. What does the slope of this curve represent?

a) Arrhenius type. $D = D_0\, e^{-E_D/RT}$

b)



$\ln(D) = \ln(D_0) - \frac{E_D}{RT}$

slope $= -\frac{E_D}{R}$ activation energy

4. **(2 points)** Use the following Ni-Ti phase diagram to answer the questions.

a. (0.5p) Determine the invariant reactions that take place at the following temperatures: 765 °C, 984 °C and 1118 °C. For each reaction state, specify its name, temperature, and composition (in at% of Ni) of all phases involved in the reaction.

b. (0.5p) For an alloy that has 8 at% of Ni, draw a schematic sketch of the microstructure that would be observed at 765 - ΔT °C.

c. (0.5p) For an alloy with 80 at% Ni, indicate the quantity and composition of the microconstituents present at 1304 - ΔT °C.

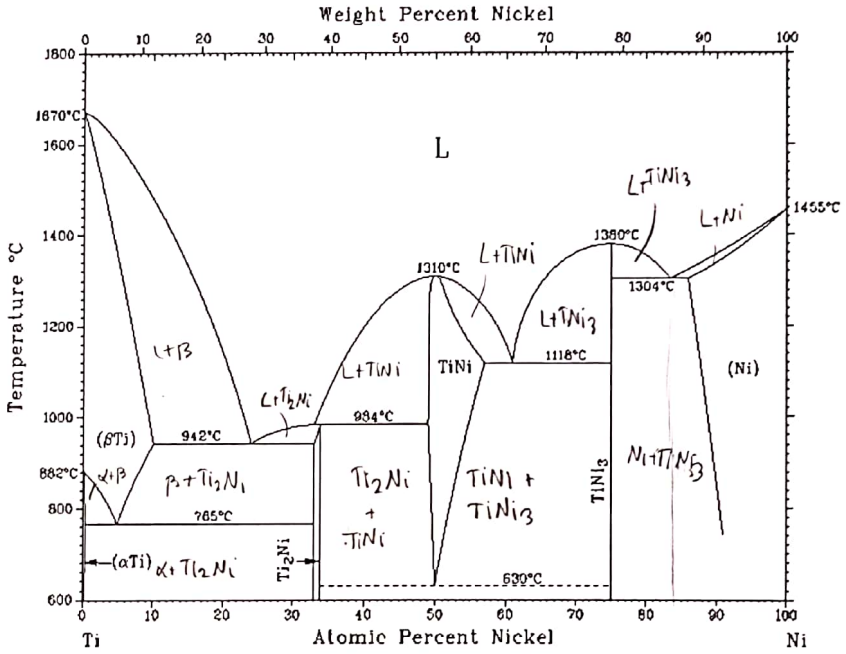
d. (0.5p) Indicate which intermetallic compounds melt congruently. Which is the maximum solubility of Titanium in Nickel and at which temperature is it observed?

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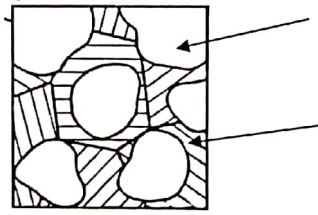
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Pídele a los reyes: Quiero el mejor proyector calidad/precio



a) 765: eutectoid: ßTi (5at%Ni) ⇒ αTi (0%ni) + Ti_2Ni (33%Ni)
964ºC: Peritectic: L (33%Ni) + TiNi (50%Ni) ⇒ Ti_2Ni (34%Ni)
1118ºC: Eutectic: L (61%Ni) ⇒ TiNi (57%Ni) + $TiNi_3$ (75%Ni)

b)



c) Primary and eutectic → micro: $TiNi_3$' and eutectic ($Ni + TiNi_3$)

and $C_{TiNi_3'} = 75\%Ni$ $W_{TiNi_3'} = \frac{84-80}{84-75} = 0.44$

$C_E = 84\%Ni$ $W_E = 0.56$

d) $TiNi_3$ and TiNi. Maximum solubility of Ti in Ni is 14at% Ti at 1304ºC

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Pídele a los reyes:
El **mejor proyector**
relación calidad/precio
Los recomendados de amazon y WUOLAH



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5. **(1 point)** A 120 mm long cylindrical rod of 14 mm in diameter should support a load of 30 kN without undergoing plastic deformation and its diameter cannot be reduced by more than 10 µm. Determine the possible candidates from the materials listed in the table. The mass of the rod should not exceed 100 g. Justify your answer.

Materials	*E (GPa)*	σ_y *(MPa)*	*ν*	ρ *(g/cm^3)*
Al alloy	70	250	0.33	2.7
~~Mg alloy~~	45	170	0.35	1.8
~~Steel~~	205	550	0.30	7.8
Ti alloy	105	850	0.34	4.5

The selected material is Ti alloy because it achieves all the requirements.

6. **(0.5 points)** The resistivity of pure copper is 2.42 x 10^{-8} Ω m at 132 °C and 1.6 x 10^{-8} Ω m at 0 °C.

   a. Calculate the temperature resistivity coefficient (α) for copper.
   b. If a copper wire is 5 mm in diameter and 5.0 m in length, what will be total resistance (R) in ohms of the wire at 132 °C?

a) α=3.88 x 10^{-3} Ωm/°C a) $\rho = \rho_0 (1 + \alpha T) \rightarrow \frac{\rho}{\rho_0} = 1 + \alpha T \rightarrow \alpha = \frac{\frac{\rho}{\rho_0} - 1}{T} = \frac{\frac{2.42}{1.6} - 1}{132} = 3.88 \cdot 10^{-3}$

b) R = 6.1 x 10^{-3} Ω b) $R = \rho \frac{l}{A} = 2.42 \cdot 10^{-8} \frac{5}{\frac{\pi}{4}(5 \cdot 10^{-3})^2} = 6.16 \cdot 10^{-3}\ \Omega$ (at 132 °C)

7. **(0.5 points)** Select the most adequate material from the table below to manufacture a permanent magnet for a magnetic energy storage application, able to work at magnetic fields higher than 600 Oersted and temperature of 500 °C. Justify your answer.

	Curie Temperature (°C)	*Remanence (Gauss)*	H_c *(Oersted)*	$(BH)_{max}$ *(gauss×Oersted)*
~~$BaO \cdot 6Fe_2O_3$~~	~~450~~ <500	4,000	2,400	2,500,000
→ Co_5Sm	725	9,500	9,500	25,000,000
~~Alnico 1~~	780	7,100	~~440~~ <600	1,400,000
Alnico 5	900	13,100	640	6,000,000
~~Nanoperm~~	~~475~~ <500	14,500	10,200	32,000,000

Co_5Sm is selected. Why Co_5Sm instead of Alnico 5?

$T_{operation} < T_{curie}$ → because above T_{curie} are not magnetic

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(5) $\sigma_s = \frac{30000N}{\frac{\pi}{4}(14\cdot10^{-3}m)^2}\cdot10^{-6} = 194.88\,MPa$

(6) It must fulfill $\sigma_{alloy} > \sigma_y$ → no plastic deformation → $\sigma_{My} = 170MPa$ ~~NO~~

mass $m_{max} = 100g$

$\rho = \frac{m}{V}$ ⟹ $V = \frac{\pi}{4}d^2h = \frac{\pi}{4}(1.4cm)^2\cdot 12cm = 18.47\,cm^3$

$m_{Al} = \rho_{Al}V = 2.7\cdot18.47 = 49.869g < 100g$ ✓

$m_{steel} = \rho_s V = 7.8\cdot18.47 = 144g > 100g$ ✗ ~~Steel~~

$m_{Ti} = \rho_{Ti}V = 4.5\cdot18.47 = 83.115g < 100$ ✓

reduction diameter $-\Delta\phi_{max} = 10\mu m = 10\cdot10^{-3}mm = 0.01mm$

$\nu = \frac{-\frac{\Delta\phi}{\phi_0}}{\frac{\Delta l}{l_0}} = \frac{-\Delta\phi}{\phi_0}\cdot\frac{1}{\varepsilon}$

Al: $\sigma = E\varepsilon \rightarrow \varepsilon = \frac{\sigma}{E} = \frac{250MPa}{70000MPa} = 3.57\cdot10^{-3}$

$\frac{\frac{-\Delta\phi}{14}}{3.57\cdot10^{-3}} = 0.33 \rightarrow -\Delta\phi = 0.016mm > 0.01mm$ ✗

Ti: $\varepsilon = \frac{\sigma}{E} = \frac{850MPa}{105000MPa} = 0.008$ (?)

$\frac{\frac{-\Delta\phi}{14}}{0.008} = 0.34 \rightarrow -\Delta\phi = 0.03_{mm} > 0.01mm$ ✗

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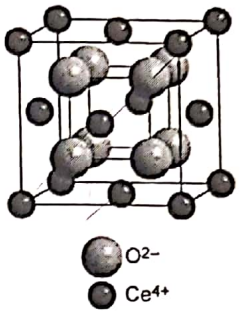
Pídele a los reyes: Quiero el mejor proyector calidad/precio

④ magnetic flow the temperature because above are not

⑦ 1) $T_{operation} < T_{curie}$ because above T_{curie} are not magnetic

2) Choose Anion 1 Sradjan

8. (2 points) Cerium oxide (Ce_xO_y) presents a structure according to the figure.



a. (0.5p) Determine and describe its crystalline structure.
b. (0.5p) Indicate the stoichiometry and coordination index of the ions.
c. (0.5p) Calculate the packing factor and the density (g/cm^3).
d. (0.5p) Determine the linear density (ions/nm) in the direction [110] and the planar density (ions/nm^2) in the plane (110).

Data: M(Ce) = 140 g/mol; M(O) = 16 g/mol; R(Ce^{4+}) =0.102 nm; R(O^{2-}) = 0.132 nm.

a) Structure type Fluorite
Ions Ce^{4+}: FCC: 8×(1/8) + 6×(1/2) = 4.

Ions O^{2-}: all tetrahedral interstitial sites: 8

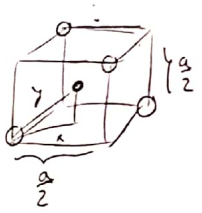
b) Stoichiometry: Ce_4O_8 <> 2 CeO_2; CI (O) = 4; CI (Ce) =8

c) $PF = 0.602$ $= PF = \frac{4 \cdot \frac{4}{3}\pi 0.102^3 + 8 \cdot \frac{4}{3}\pi \cdot 0.132^3}{0.543}$

$\rho = 7.25\ g/cm^3$

c) $\rho_{[110]} = 2.62\ ion/nm$

$\rho_{(110)} = 14.55\ ion/nm^2$



$\rho = \frac{ZM_iM_i}{N_A V_C} = \frac{4 \cdot 140 + 8 \cdot 16}{6.023 \cdot 10^{23} \cdot (0.54 \cdot 10^{-7})^3} = 7.25\ g/cm^3$

[110) $\rho_{(110)} = \frac{1 + 2 \cdot \frac{1}{2}}{r2\,a} = 2.62\ ion/nm$

(110) $\rho_{(110)} = \frac{4 \cdot \frac{1}{4} + 2 \cdot \frac{1}{2} + 4}{a\,r2\,a} = 14.55\ ion/nm^2$

9. (1 point) Answer and explain briefly the following questions:

a. (0.5p) What is the difference between thermoplastics and thermosets regarding the bond of the chain? Crosslinking

b. (0.5p) Explain the polymer extrusion process.

1. Raw material (thermoplastic pellets, granules, powder) are placed into a hopper and fed to a barrel of a screw extruder
2. Screw extruder blends and melts raw material (by viscous shearing and external heating) and conveys it toward the die
3. Pressure builds up 4. Molten plastic is forced through a die

10. (1 point) An epoxy matrix is reinforced with E-glass fibers to produce a 2-cm-diameter composite that is to withstand a load of 25,000 N that is applied parallel to the fiber length. Determine the volume fraction (in %) of fibers in the composite if the stress acting on each fiber is 188 MPa. The elastic modulus of the epoxy and the glass fibers is 2.76 GPa and 72 GPa, respectively.

$\sigma_c \cdot \frac{E_f V_f}{E_c V_c} = 188$ → A Marina no le da así

40 vol% of fibers in the composite

$\sigma_c = \frac{25000\ N}{\frac{\pi}{4}(2 \cdot 10^{-2}\ m)^2} \cdot 10^{-6} = 79.58\ MPa$

$\frac{\sigma_f}{\sigma_m} = \frac{E_f \varepsilon_f}{E_m \varepsilon_m} = \frac{72}{2.76} = 26.087 \rightarrow \sigma_m = \frac{\sigma_f}{26.087} = \frac{188\ MPa}{26.087} = 7.2\ MPa$

$\sigma_c = v_f \sigma_f + (1 - v_f)\sigma_m \rightarrow 79.58 = v_f 188 + 7.2 - v_f 7.2 \rightarrow v_f = 0.4 \rightarrow 40\%$

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