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 the bonding energy and melting point.	
F	

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

3. When the ion size in materials with ionic bonding increases the lattice energy decreases.	
T	

4. Materials with a strong atomic bonding present a low Young's modulus.	
F	

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.

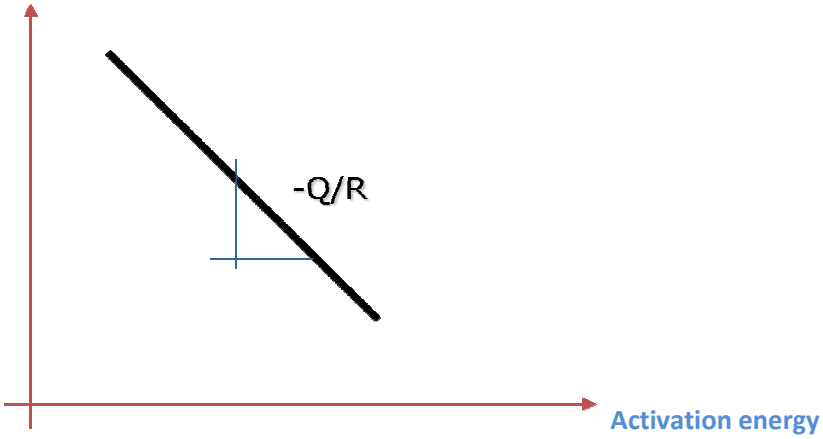
a) $1.157 \cdot 10^{20}\ vacancies/cm^3$
b) $0.532\ g/cm^3$

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

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

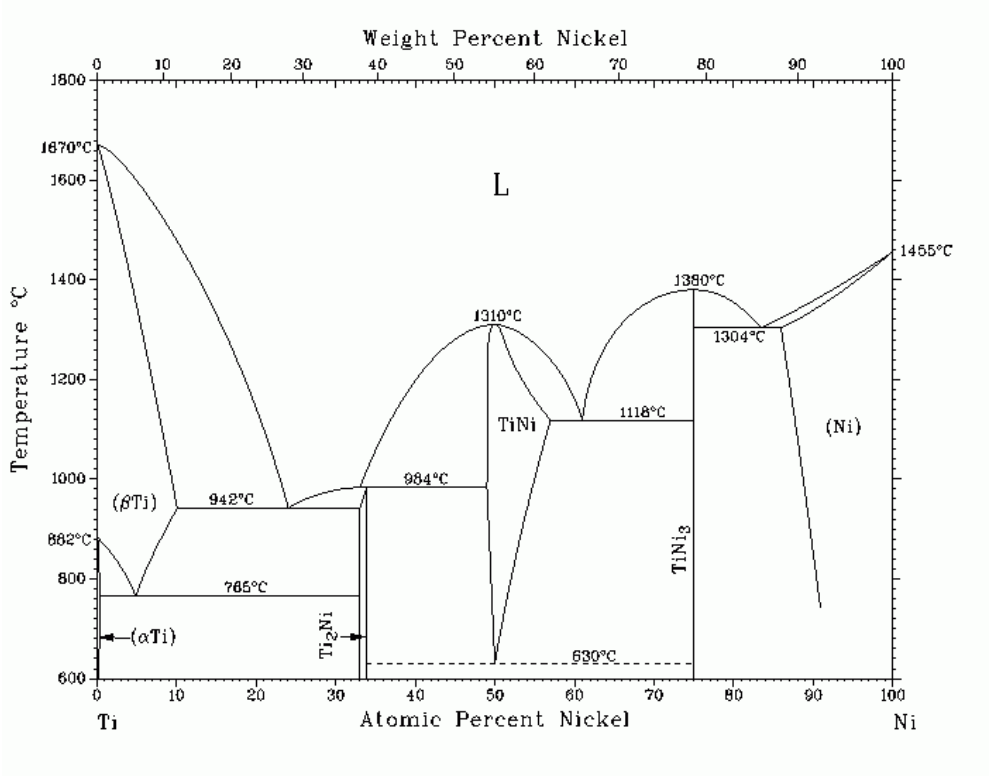
   a. (0.25p) What is the name of this type of equation? Apply it to diffusion and name the terms in equation.
   b. (0.25p) Draw a schematic plot of the natural logarithm of the rate *versus* 1/T. What does the slope of this curve represent?

a) Arrhenius type.
b)



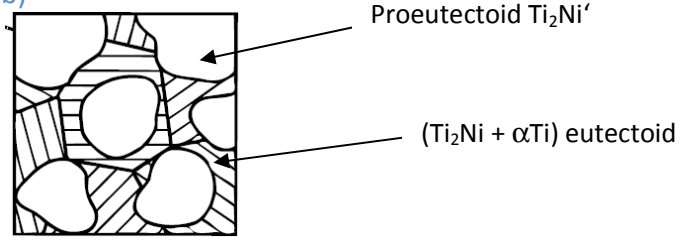
4. **(2 points)** Use the following Ni-Ti phase diagram to answer the questions.

   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?



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

and

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

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

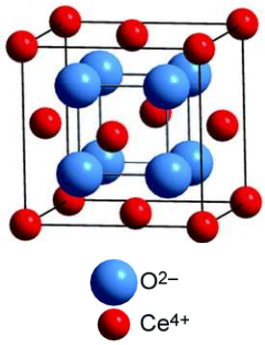
b) R = 6.1 x 10^{-3} Ω

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 $6Fe_2O_3$	450	4,000	2,400	2,500,000
Co_5Sm	725	9,500	9,500	25,000,000
Alnico 1	780	7,100	440	1,400,000
Alnico 5	900	13,100	640	6,000,000
Nanoperm	475	14,500	10,200	32,000,000

Co_5Sm is selected.

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) $PF = 0.602$

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

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

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

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

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.

$40\ vol\%\ of\ fibers\ in\ the\ composite$