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OLLSCOIL NA hÉIREANN
GAILLIMH

NATIONAL UNIVERSITY OF IRELAND
GALWAY

SPRING EXAMINATIONS 2001

M.Sc. in BIOMEDICAL SCIENCE

EP513: Materials and Biomaterials

Dr. Michael Ball
Prof. T.J. Glynn

Time allowed : **Three** hours.

Answer two questions from Section A

Answer two questions from Section B

Answer one question from Section C.

Q.1 Sodium. Atomic Number 11, Ionic radius 0.102nm
Chlorine. Atomic Number 17, Ionic radius 0.181 nm

(a) What is the reason for the disparity in sizes of the two ions?

(b) The NaCl ionic bond has a bonding energy of 640 kJ mol^{-1}. However, the forces between Cl atoms in the Cl_2 molecule are only 31kJ mol^{-1}. What forces operate here, and why is there a difference between the two forces?

(c) Carbon (atomic number 6) bonds differently. Ethylene (C_2H_4) has a double bond between the carbon atoms.

Sketch how the structure resolves itself in three dimensions, indicating the positions of the orbitals and the bonding involved.

(d) Describe the main forms (allotropes) of carbon. How do the bonds between the atoms dictate shape and bond strength?

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Q.2 (a) Describe the fundamental differences between a crystalline and an amorphous state in ceramics.

(b) One example of a solid amorphous structure is a glass. Indicate, using a sketch graph, how the solid amorphous state arises by cooling from a gas to a solid. Indicate on your diagram the relationship between temperature and volume, glass transition temperature, the melting point and how the crystalline state differs from the amorphous state.

(c) Although possessing crystalline and amorphous states, polymers act in different ways. Sketch a similar graph for a polymer as in (b), indicating the points at which polymers differ from glasses.

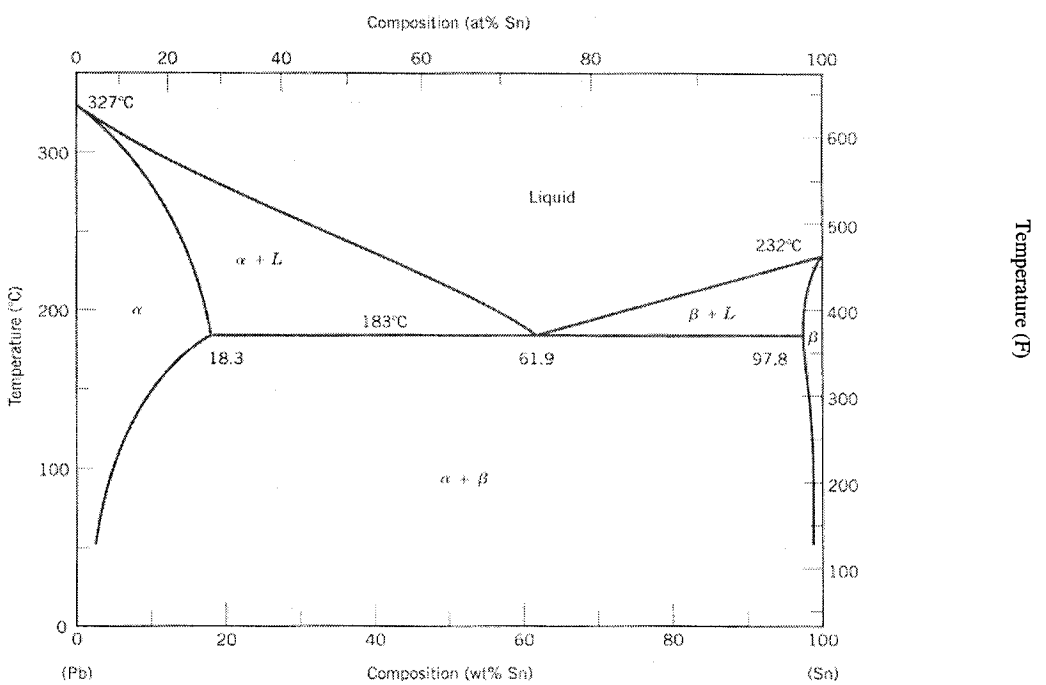
(d) Describe (briefly), for a glass,
either the strengthening of a glass by tempering

or

the formation of a polycrystalline glass ceramic.

(e) Briefly describe, for a polymer, how crystallinity influences the polymer behaviour under tensile stress. Mention the feature of 'necking'.

Q.3



Above is the lead-tin phase diagram.

(a) Explain the significance of the α and the β sections.

(b) What phases are present for a 20:80 lead/tin alloy(wt%) at 200 °C? What are the compositions of those phases?

(c) Describe the transformations which occur as an alloy of 40 wt% Pb, 60 wt% Sn is cooled from liquid at 400 °C to 0 °C. What is the nature of the final structure?

(d) Citing a specific example, briefly describe the effect of including another ion into the crystal lattice of a material. How does the inclusion affect the physical and/or chemical properties of the material? Sketch a diagram showing the position of the inclusion relative to the native ions/atoms.

(e) Composite materials are mixtures of two separate materials. Describe the main features of a fibre composite. Give an example.

(f) What is a shape memory alloy?

Section B.

Q.1 (a) Describe the main points of Donald Ingber's tensegrity model.

(b) How does the cell act as a tensegrity structure?

(c) Hence use this model to describe how a cells activity can change once it adheres to a substrate.

(d) Surface topography can be used to influence cell activity. Suggest how the surface topography of a specific type of device could be altered to enhance the device interactions with a specific cell type. How would the change in topography change the activity of the cell?

Q.2 (a) The concept of 'biocompatibility' is central to the study of biomaterials. Briefly discuss what is meant by it. Can the term be applied to any material? If not, why not?

(b) How could these ideas influence the planning of a series of *in vitro* assays on a biomaterial?

(c) Describe <u>one</u> assay that you could carry out to assess cell interactions with a material surface.

(d) What further experiment would you perform? How would it complement the assay you have already performed?

(e) Describe <u>two</u> ways in which the use of immortalised cell lines for *in vitro* assays differs from the normal implantation situation. Suggest how these problems can be reduced.

Q.3.) (a) Describe the main features of <u>one</u> tissue engineered device. Mention the cells or tissues involved and the applications it is (or might be) put to.

(b) What are the advantages of pre-coating a device with cells?

(c) How does the surface energy of a material influence protein adhesion to it? How does this subsequently influence cell adhesion?

(d) This feature of cell adhesion can be exploited by functionalising polymer surfaces. Briefly describe how the polymer might be altered to have specific biological activity and the protein structures that might be involved. What problems might such a structure encounter *in vivo*?

(e) What is the Vroman Effect?

Section C.

Q.1 Hydroxyapatite (HA) has been successfully used as a bone-bonding material.

(a) Why is HA suitable as a bone-bonding material?

(b) What is the main cell type involved in bone formation?

(c) HA is generally coated onto a metal substrate for hip implants.
(i) Why is this coating performed?
(ii) Name one coating method used.
(iii) Give an example of a metal used for the substrate.

(d) How might the presence of grain boundaries in an HA surface affect cell adhesion.

(e) Bioglass has also been used successfully as a bone-bonding material. What is the characteristic composition of Bioglass? What is 45S5 Bioglass?

(f) What general reactions must occur at the Bioglass surface for a successful bond with bone form?

(g) What will occur around the implant if it does not successfully bone with bone? What are the consequences for the efficacy of the implant?

Q.2 (a) Define the following terms:

(i) Hardness
(ii) Toughness
(iii) Brittleness
(iv) Elasticity

(b) Describe the concept of 'plastic deformation'. Explain in your answer the relevance of the slip plane.

(c) Describe one method of hardening a material.

(d) Mechanical failure of a material can also occur *in situ*. Briefly describe two ways an implanted material can undergo mechanical failure.

(e) One consequence of *in vivo* device failure is the formation of wear particles. Describe how the body will respond to particulate debris, and the result.