Donald P. Shiley School of Engineering
EGR 221 Materials Science
Assignment 4, Fall 2015
SOLUTIONS

1) Who was Linus Pauling and why "should" someone studying science or engineering in Portland know who he is?

Ans: Linus Pauling was born and raised in Portland. He graduated from Oregon Agricultural College (now, OSU). From http://lpi.oregonstate.edu/linus-pauling-biography:

> He is the only person ever to receive two unshared Nobel Prizes — for Chemistry (1954) and for Peace (1962). In addition to the **general recognition as one of the two greatest scientists of the 20th century**, he was usually acknowledged by his colleagues as **the most influential chemist since Lavoisier,** the 18th-century founder of the modern science of chemistry. His introductory textbook General Chemistry, revised three times since its first printing in 1947 and translated into 13 languages, has been used by generations of undergraduates.

Why should someone at UP know who he is? That should be self-explanatory – if one of the greatest scientists of the 20th century is from Portland, Portlanders should know who he is.

2) In Greek, what does the word "*plasma*" mean? In physics, what is *plasma*?

ANS: "Plasma" in Greek: "anything formed" (Wikipedia). It is one of the four naturally occurring states of matter (solid, liquid, gas – being the other three … just in case you wondering). A common way it is created is by heating a gas sufficiently to "strip" electrons away from the elements. It is the least common form of matter on earth, but it is by far the most common in the universe. Stars are mostly plasma.

3) What is brass? What is bronze? When were they each first used? How are they each used in modern industry?

ANS: both brass and bronze are copper alloys. Brass is copper alloyed with zinc and bronze is copper alloyed with tin; although other elements may be added to either of them. Brass is used in acoustical applications such as musical instruments and for aesthetic reasons (decorative). Bronze is good corrosion resistance in marine environments and has good wear properties – so it finds applications in shipping (such as propellers) and "friction" bearings (not roller bearings). Brass dates back to around 300BC, but bronze is older. The ancient period from around 3000BC is known as "the bronze age." --- information from various web resources including Wikipedia, http://www.diffen.com/difference/Brass_vs_Bronze, and "ancient history encyclopedia".

4) Information for various elements is shown in the table below. Which of the elements in table would you expect to form with *copper*:
   a) A substitutional solid solution with complete solubility
   b) A substitutional solid solution with partial (incomplete) solubility
   c) An interstitial solid solution (which is never complete solubility)

Element	**Atomic Radii (nm)**	**Crystal Structure**	**Atomic Weight (amu)**	***% Difference, atomic radii***
Cu	***0.128***	***FCC***	***63.55***	***0***
C	0.071	Not BCC, HCP, FCC	12.011	***-45***
Fe	0.124	BCC	55.85	***-3***
Ni	0.125	FCC	58.69	***-2***
O	0.060		16.00	***-53***
Pb	0.137	FCC	207.2	***7***
Zn	0.1332	HCP	65.41	***4***

Solution: for complete substitutional solubility, the two elements must have the same crystal structure and similar atomic radii (within about 15% of each other). For interstitial solid solutions to form, the atomic radii of the solute must be much smaller than the solvent (Cu). The last column in the table above was created to show the percentage difference of atomic radii compared to copper.

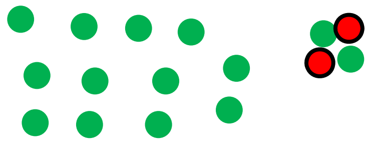
a) Elements within 15% atomic radii of copper and have FCC: Ni, Pb
b) Elements similar is size to copper, but not FCC: Fe, Zn
c) Elements much smaller than copper: C, O

In materials science, we often discuss the “composition” of an alloy. Usually we express this in terms of “mass percentage” or “weight percentage” (effectively, the same thing). For example, alpha brass has a composition of 65%Cu and 35% Zn – so if I have 100kg of alpha brass it contains 65kg of copper and 35 kg of zinc. On occasion, we express composition as atomic percentage. Since no two elements have the same atomic weight, atomic percentage is different than mass percentage. Here’s a simple problem to help you develop the ability to convert between these two different methods of expressing composition:

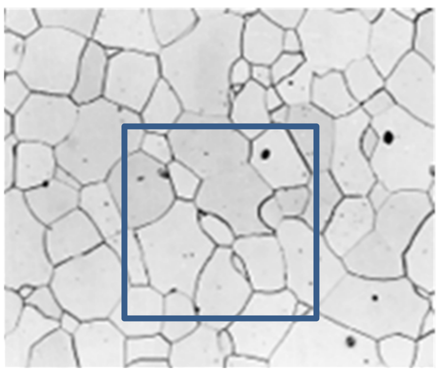
5) According to modern cosmology, after about 1 second “post-big bang” (in other words, when the universe was a mere 1 second old) all of the protons and neutrons to ever exist, existed. For the next 3 minutes, the universe was too hot for them to join in the formation of nuclei (if they joined, their bonds were quickly broken). However, the “Goldilock” minutes were about to occur; minutes 3 to 20. Those minutes provided just enough energy to allow protons and neutrons to form – and stay joined. Only two elements were formed – hydrogen and helium (and they were too hot to hold onto electrons so they were completely ionized plasma). ---*where did the other elements come from? That’s another story*…. But in the beginning, for every 12 ionized hydrogen nuclei (aka “free protons”) there was one ionized helium nucleus (2N+2P). Therefore, the composition of the universe was (and largely remains today) 92.3% (12/13) hydrogen and 7.7% (1/13) helium – by atomic percentage. If

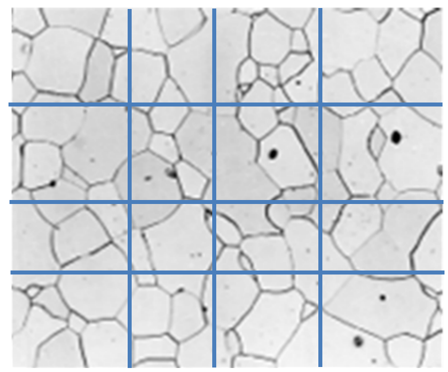
ionized helium is four times more massive than a single hydrogen ion, calculate the composition of the universe by mass. Include a sketch (this will help you visualize your answer). (No, don't worry about dark matter, etc.).

ANS: the sketch below shows 12 hydrogen ions and 1 helium ion (92.3% hydrogen, atomic percentage). By mass, there is a total of 14 protons and 2 neutrons (all of equivalent mass) - so there is a total of 16 unified atomic mass units (1 u ~ mass of a proton or neutron). The hydrogen accounts for 12/16 of the total mass, and the helium accounts for 4/16. Therefore, the hydrogen is 75% and helium 25% of the total mass.



6) A) Determine the ASTM grain size number in the micrograph below. B) Also determine the average grain diameter for this same sample. The image was taken at 100X magnification.





a) *The number of grains in the 1 inch by 1 inch square is approximately 21. The ASTM grain size number, n, is given by:*
   $n = 3.32 \log (N) + 1$, where N was determined to be 21. Therefore, ***<u>n = 5.4</u>***
b) *Six lines have been drawn, and the approximate number of grains each cross is as follows (top horizontal line, middle, bottom, left vertical line, middle, right): 12, 12, 10, 10, 7, 7 (58 total). Total length of all lines (3 at 2.25" and 3 at 1.9") is 12.45 inches. Ave diameter = $l_{tot}/(n_{gb})(mx)$. From above: l_{tot} = 12.45", n_{gb} = 58, mx = 100 (magnification).* ***<u>Ave diameter is 0.002 inch.</u>***

7) For an FCC single crystal, would you expect the surface energy for a (100) plane to be greater or less than that for a (111) plane? Why?

ANS: (1 1 1) plane has the highest planar density in FCC which means the atoms are "tightly packed." If the atoms are tightly packed, their bond energy is more satisfied than less tightly packed. ***Therefore, (1 0 0) would have greater surface energy*** *(more active, less "satisfied")*

8) Briefly explain the difference between self-diffusion and interdiffusion.

ANS: self-diffusion is the result of random movement of atoms with in a pure material. For example, if titanium atoms move through a titanium matrix (i.e. if titanium moves through *titanium) it is self-diffusion. Interdiffusion is when what material moves through another – for example if a carbon atom moves through iron.*

9) Briefly explain the concepts of "steady state" and "transient" (aka non-steady state) as they apply to diffusion.

ANS: Steady state diffusion means that the composition (aka concentration) at every point in the material does not change over time.

Transient diffusion means that the composition at a point in the material does change over time.

10) What is the diffusion coefficient (D) and what does its magnitude tell you about diffusion?

ANS: It relates the flux to the concentration gradient. For a given concentration gradient, the larger the magnitude of D, the more mass will diffuse in a given amount of time.

~~11) a) Compute the diffusion coefficient (D) of nitrogen in FCC iron at 950°C (iron is FCC above 912°C and BCC below that temperature).~~

~~b) Compute the diffusion coefficient (D) of nitrogen in BCC iron at100°C.~~

~~c) Compare these two answers - how much greater is the diffusion rate at 950°C than 100°C?~~

12) a) What is nitriding? Very briefly, describe the process and explain its benefits (why is it done). Is nitriding commonly performed on non-ferrous materials?

Nitriding is the process of diffusing nitrogen into the near-surface of a material. This usually increases hardness and fatigue life. It is used on many different alloys (ferrous and non-ferrous).

b) What is carburization (aka carburizing) and explain its benefits. Is carburizing commonly performed on non-ferrous materials?

Carburization is similar to nitriding except it diffuses carbon into the material. It is not common to carburize non-ferrous materials (carbon and iron have a special relationship). Increasing carbon content increases hardness of steel (up to about 1% carbon – beyond that, the hardness does not increase further).

c) Are either of these process (nitriding, carburizing) performed at room temperature?

No, both are done at high temperatures – diffusion is very very slow at room temperature.

d) Could either of these processes be used to enhance the performance of a knife?

Yes, both processes increase the hardness of steel. For a knife, this means increased retention of a sharp edge.