Materials Science

March 1st, 2014
Menomonie Regional Tournament
Menomonie High School

Wisconsin Science Olympiad

STOUT
UNIVERSITY OF WISCONSIN
WISCONSIN'S POLYTECHNIC UNIVERSITY

Team #

_____

School Name and Color

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Student Names

_____

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Lab Section: Identification of Recyclable Plastics

Introduction

In this experiment, we will examine some common plastics and perform several tests to identify them. The most common plastics are easily identified using recycling code symbols as shown in **Figure 1**.

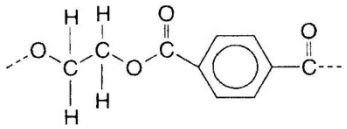
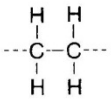
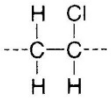
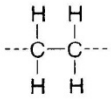
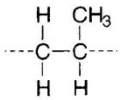
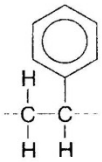
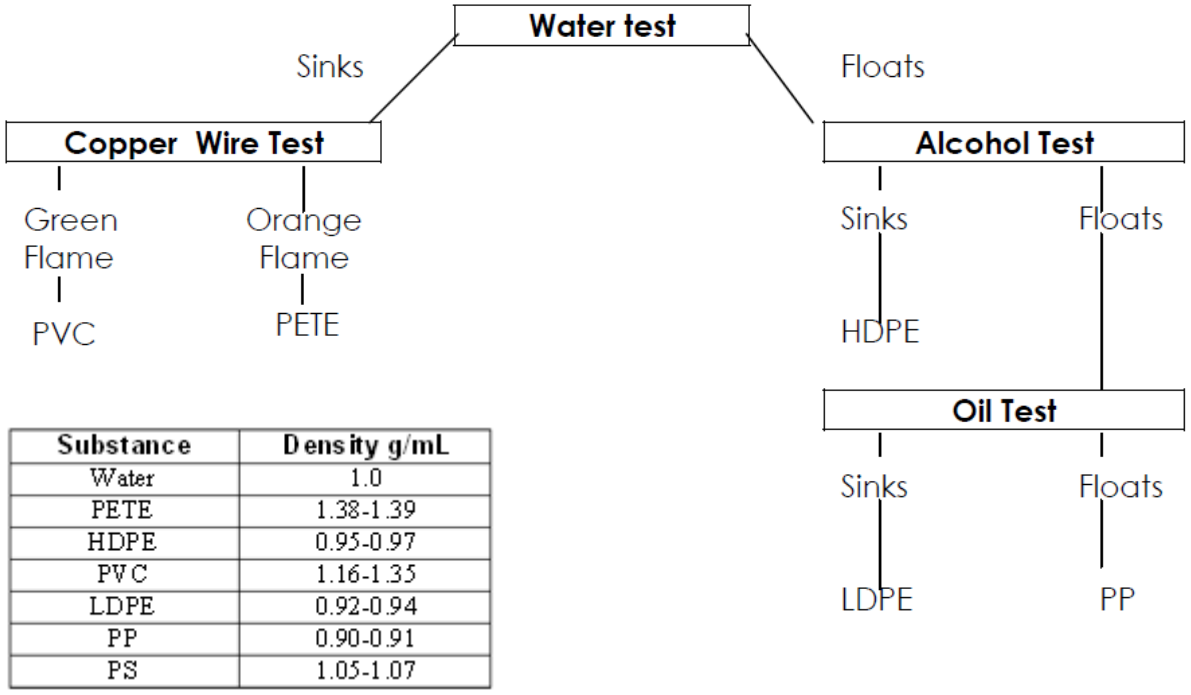
Symbol	Chemical Structure	Applications
1 PETE	 Polyethylene Terephthalate	Soft drink bottles, mouthwash bottles, peanut butter and salad dressing containers
2 HDPE	 High Density Polyethylene	Milk, water and juice containers, grocery bags, toys, liquid detergent bottles
3 V	 Polyvinyl Chloride	Clear food packaging, shampoo bottles
4 LDPE	 Low Density Polyethylene	Bread bags, frozen food bags, grocery bags
5 PP	 Polypropylene	Ketchup bottles, yogurt containers, margarine tubs, and medicine bottles
6 PS	 Polystyrene	Videocassette cases, compact disc jackets, coffee cups, tableware (knives, spoons and forks), cafeteria trays, grocery store meat trays, and fast-food sandwich containers.

Figure 1. Common polymers, their structures and packaging applications.

Experimental Procedure

Recycling operations rely on differences in physical properties such as density to separate mixed plastics. This experiment will use a similar procedure to identify a set of five unknown plastics.

A flow chart for the test procedures is given below:



Substance	Density g/mL
Water	1.0
PETE	1.38-1.39
HDPE	0.95-0.97
PVC	1.16-1.35
LDPE	0.92-0.94
PP	0.90-0.91
PS	1.05-1.07

Obtain a set of samples of the seven unknown plastics (A through G). Note that each type of resin is a different shape or color. This allows for visual identification in this experiment. Actual resins may be almost any color depending on colorants added during its initial formulation.

The Water Test

Place approximately 20 mL of water in a medicine cup.

Start with one of the samples. Using a pair of forceps, hold the sample in the middle of the water and release. Make sure there are no bubbles attached to the sample. Note whether the sample sinks or floats. Remove the sample, dry, and save for later use.

Repeat the water test with each of the remaining samples.

Save the samples that sank in the water for the copper wire test. Use the samples that floated for the isopropyl alcohol test.

The Isopropyl Alcohol Test

Place 20 mL of isopropyl alcohol solution in a medicine cup.

Select one of the samples that floated in water. Using a pair of forceps, hold the sample in the middle of the isopropyl alcohol solution and release. Make sure there are no bubbles attached to the sample. Note whether the sample sinks or floats. Remove the sample, dry, and save for later use.

Repeat the isopropyl alcohol test with each of the remaining samples that floated in the water. Samples that sink test positive for **High Density Polyethylene (HDPE)**. Samples that float should advance on to the oil test.

The Oil Test

Place 20 mL of Mazola corn oil in a medicine cup.

Select one of the samples that floated in the isopropyl alcohol solution. Using a pair of forceps, hold the sample in the middle of the oil and release. Make sure there are no bubbles attached to the sample. Note whether the sample sinks or floats. Remove the sample, dry, and save for later use.

Repeat the oil test with each of the remaining samples. Samples that sink test positive for **Low Density Polyethylene (LDPE)** and samples that float test positive for **Polypropylene (PP)**.

Copper Wire Test

This test is used only for the plastic samples that sank in the <u>water</u>. (They were more dense than water.)

Obtain a piece of copper wire about 5 cm long. Push one end of the wire into a small cork. (The cork is used as a handle so you are not touching a hot wire.)

Hold the free end of the copper wire in the burner flame until it is red hot and the flame no longer has any green or bright yellow color.

Remove the wire from the flame and touch the hot wire to the edge of the sample you are testing. A small amount of the plastic should melt onto the wire. You do **not** need to dig a noticeable amount of plastic onto the wire, the slight residue that clings after swiping the hot wire along the edge will suffice.

Place the end of the wire, with the small amount of plastic on it, into the flame. You should see a slight flash of a luminous flame (a yellow-orange color). If the flame turns green in color, then the sample contains chlorine and therefore tests positive for **Polyvinyl Chloride (PVC)**. If the flame remains yellow the entire time, then the sample (by default) tests positive for **Polyethylene Terephthalate (PETE)**.

Repeat this test for each of the remaining plastic samples that sank in the water.

Clean Up

Return all plastic samples to the “Used Plastic Samples” beaker at the front. Return the corn oil to the “Used Corn Oil” beaker. Return the Isopropyl Alcohol solution to the “Used Alcohol Solution” Beaker. Return the used medicine cups to the gray bin at the front.

Experimental Results

Identify the following samples by writing the correct abbreviation in the blank provided.

Sample A (White Pellet):_____

Sample B (Red Triangle):_____

Sample C (White Square):_____

Sample D (Clear Square):_____

Sample E (Red Square):_____

Sample F (Clear Orange Square): _____

Sample G (Opaque Orange Square):_____

Written Exam
Please CLEARLY indicate answers

Match the following materials to the type of bond(s) that is most associated with the properties of the material
A. Faraday Interactions B. Metallic Bonds C. Covalent Bonds D. Ionic Bonds

1.) W (Tungsten) = _____

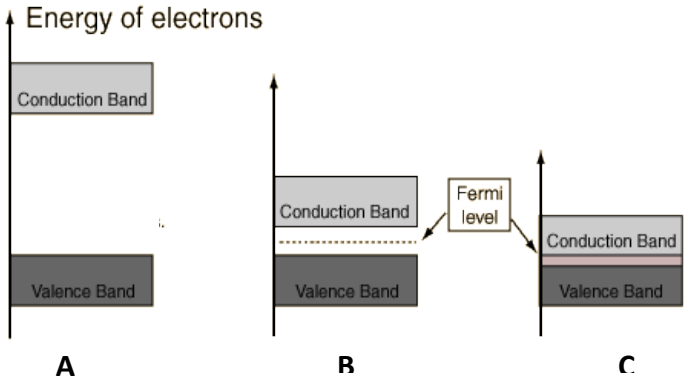
2.) CH_4 = _____

3.) $CaCO_3$ = _____

4.) Select the correct electron configuration for a Ca^{2+} ion.
A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^0$
C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$
D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^4$
E. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4\ 4s^4$

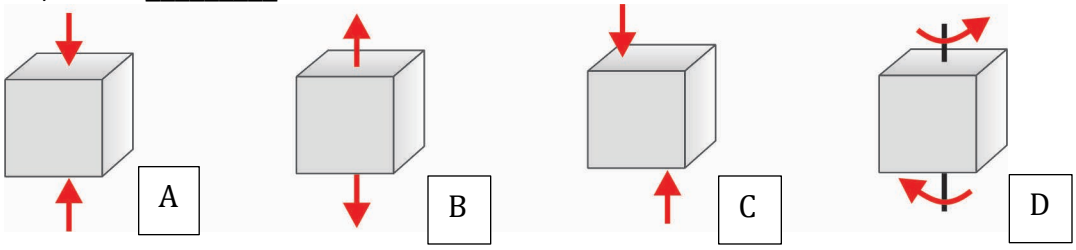
Below are images of the band gaps for 3 different materials, Ge, Au, and SiO_2. Match each image to the correct material.

5.) Ge=_____
6.) Au=_____
7.) SiO_2=_____



8.) The perceived shininess of metals is due to:
A. the delocalized "sea" of valence band electrons interaction and reflection of incident light
B. the ability of metals to form cations
C. the conduction of current
D. someone polishing the metal

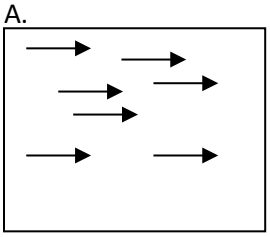
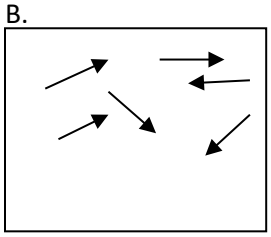
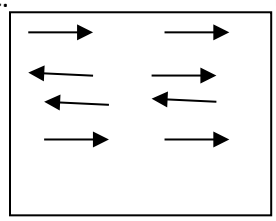
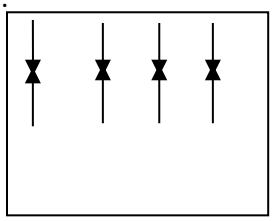
In the diagrams below, the red arrows represent a force applied to the box. Match the type of stress/strain with the depiction below.
9.) Compression = _____
10.) Torsional= _____
11.) Tensile = _____
12.) Shear =_____



13.) Lightweight bulletproof vests more comfortable than standard ceramic vests can be fabricated using fluids inside the vest. To the touch, the bulletproof material feels soft and squishy, but when a high-speed projectile hits the fluid, it becomes rigid and stops the projectile. What is the relationship between the viscosity and shear rate?

A) Dynamic
B) Newtonian
C) Non-Newtonian
D) Constant
E) Inverse Logarithmic

14.) Electromagnets can be created by coiling copper wire around a piece of iron and passing a DC current through it. This creates a net magnetic moment in the material, or a magnetic field. Which of the following diagrams would represent the alignment of the electrons in iron with the direction of the magnetic field?

A. 
B. 
C. 
D. 

15.) As a quantum dot becomes smaller, the energy of photos emitted when it is irradiated increases. A 5.5nm quantum dot emits red light when irradiated. Will a 2nm quantum dot…?

A. Emit a longer wavelength than the 5.5nm dot
B. Emit a shorter wavelength than the 5.5nm dot
C. Not emit at all
D. Emit at the same wavelength as the 5.5nm dot

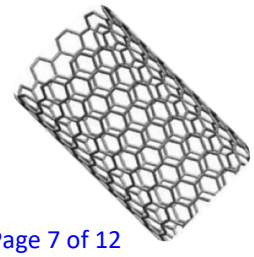
16.) Chromium (mass 51.99amu) has a BCC structure with a cell edge distance of 0.1383nm. Calculate the theoretical density of Chromium. $\rho = \frac{n*A}{Vc*Na}$

17.) In which of the following types of materials is the band gap the greatest?

A. Insulators
B. Allotropes
C. Conductors
D. Semiconductors

18.) The image to the right shows a model of a carbon nanotube, where carbon atoms are arranged in a hexagon. What type of hybridization occurs in these carbon atoms?

A. Single Bond
B. sp^2
C. RF
D. sp^3



19.) Finely powdered dusts in enclosed spaces can present the hazard of explosion in many industries. Flour, coal, aluminum and sawdust particles can ignite under the right conditions, causing large explosions, so processing these materials requires special ventilation measures. Why are these dusts more dangerous than the bulk material? Think of where and how combustion occurs.

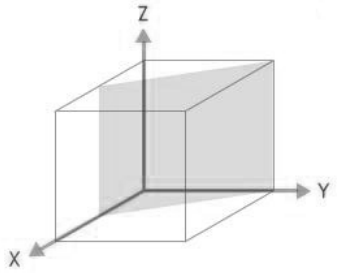
A. The dusts have less surface area so the combustion is more confined
B. The dusts have more surface area so more of the material can combust
C. Dusts less mass so there is a lower activation energy
D. The dusts have a unique crystalline structure that is more combustible

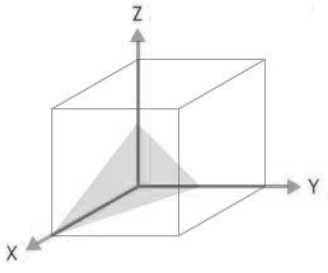
20.) At the nanoscale, the properties of the _____ are overshadowed by _____ properties.

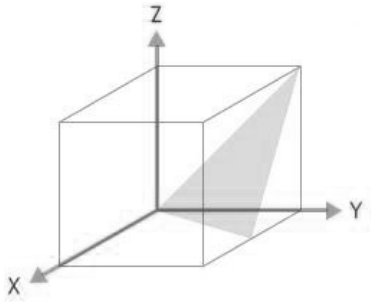
A. nanoparticle, crystal-dependent
B. atoms, bulk material
C. bulk material, physical
D. molecule, mass-dependent
E. bulk material, size-dependent

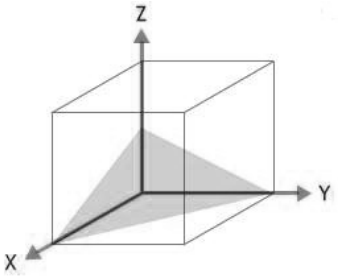
For questions 21-24, match the following planes with their Miller Indicies

A. (210) B. (122) C. (2-12) D. (112) E. (200) F. (3-10)

21) 

22) 

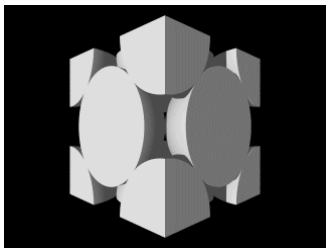
23) 

24) 

25.) The speed of sound in a metal is the square root of the Young's modulus over the density, $c_1 = \sqrt{\frac{Y}{\rho}}$ How does doubling the mass of the metal change the speed of sound in a metal?

A. Increases by a factor of $\sqrt{2}/2$
B. Decreases by a factor of 1/2
C. Decreases by a factor of $\sqrt{2}/2$
D. Increases by a factor of 4
E. Does not change

26.) A space-filling model of a body centered cubic structure is pictured to the right. If the lattice constant of a BCC crystal is 35pm, what is the atomic radius?



27.) Which of the following colors of visible light has the highest frequency?
a) green b) orange c) red d) yellow e) blue

28.) Which of the following regions of the electromagnetic spectrum has the longest wavelength?
a) ultraviolet b) x-ray c) infrared d) visible e) gamma ray

29.) An argon ion laser emits light at 457.9 nm. What is the frequency of this radiation?
a) $4.338 \times 10^{-19}\ s^{-1}$
b) $1.527 \times 10^{-15}\ s^{-1}$
c) $1.373 \times 10^{11}\ s^{-1}$
d) $6.547 \times 10^{14}\ s^{-1}$
e) $2.305 \times 10^{18}\ s^{-1}$

30.) When heated in a flame, sodium atoms emit light with a frequency of $5.09 \times 10^{14}\ s^{-1}$. What is the wavelength of this radiation?
a) 153 nm b) 170 nm c) 589 nm d) 1.70×10^{6} nm e) 1.53×10^{14} nm

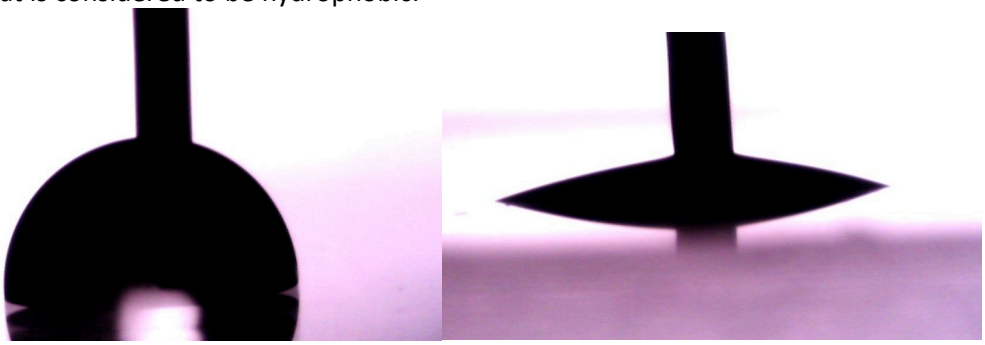
31.) The _____ of a photon of light is _____ proportional to its frequency and _____ proportional to its wavelength.
a) energy, directly, inversely
b) energy, inversely, directly
c) velocity, directly, inversely
d) intensity, inversely, directly
e) amplitude, directly, inversely

32.) What is the surface area of a cubic centimeter of copper?
a) 153 nm b) 170 nm c) 589 nm d) 1.70×10^{6} nm e) 1.53×10^{14} nm

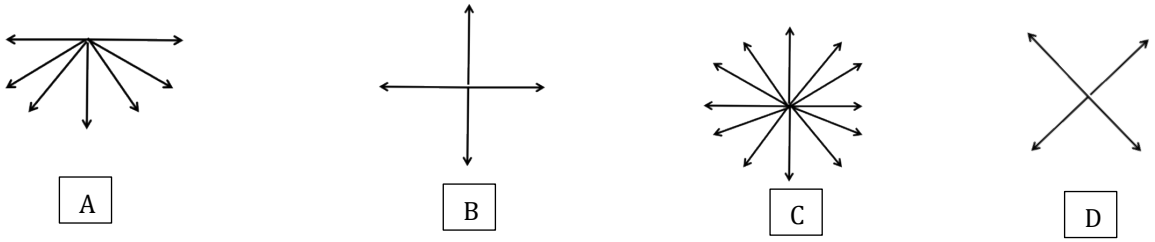
33.) What is the surface area of a cubic centimeter of copper that has been made from cubes of copper with 10 nm edges?
a) 153 nm b) 170 nm c) 589 nm d) 1.70×10^{6} nm e) 1.53×10^{14} nm

34.) Which of the following molecules always has a molecular dipole moment?
a) SiO_2 b) CH_4 c) H_2O d) CO_2

35.) A drop of water is pipetted onto the two surfaces shown in pictures A and B below. Circle the droplet on the surface that is considered to be hydrophobic.



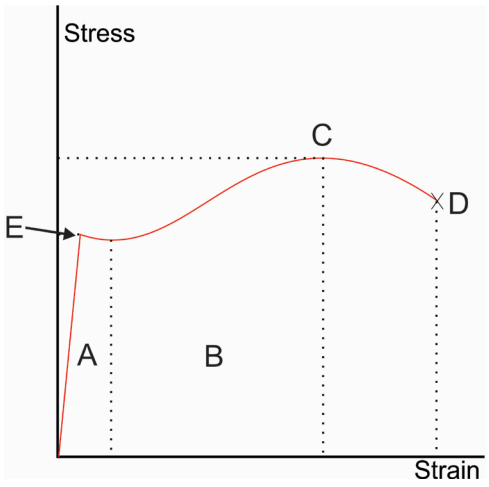
36.) Which of the following images correctly corresponds to the force vectors at the liquid/water interface of a water droplet on a surface, such as the images above.



37.) As the radius of a droplet of water decreases the surface-area to volume ratio also decreases. Based on this information, if a water droplet had a radius of 5 mm and then it decreased to 1mm, would you expect the internal pressure of the droplet to:

a. Remain unchanged
b. Increase
c. Decrease
d. There is no internal pressure in the droplet. The cohesive forces hold it together.

In the stress-strain to the right,



38.) Identify the elastic region= _____

39.) The ultimate strength = _____

40.) The plastic region =_____

41.) The yield point = _____

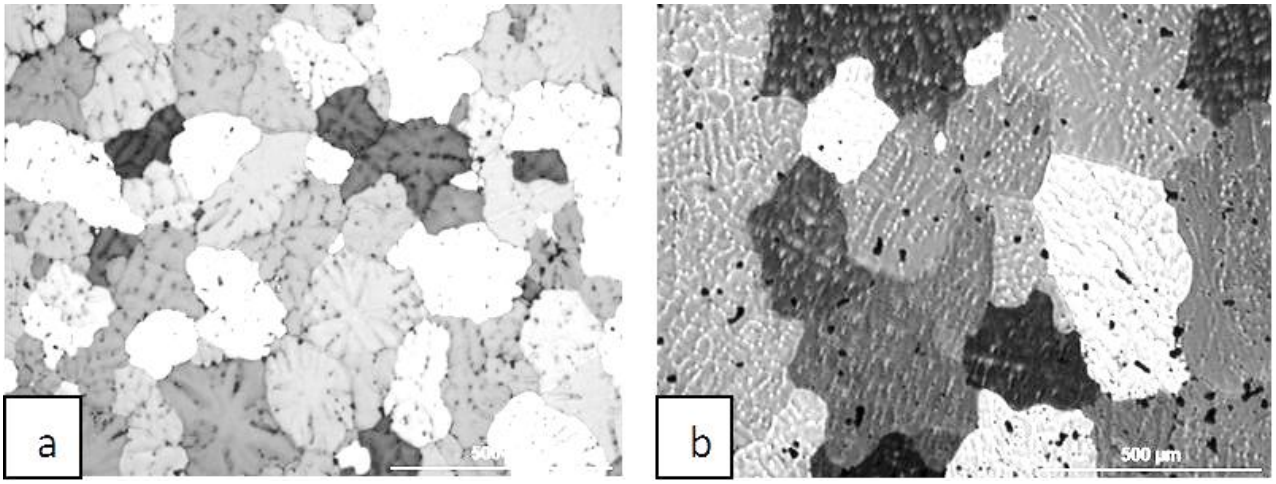
42.) The rupture point= _____

43.) Which of the following materials is a composite?

A) Benzene
B) Polystyrene
C) Fiberglass
D) Stainless Steel
E) Graphite

44.) You and your teammate are looking out the window of an old house and notice ripples in the glass. Your friend suggests this is due to a mechanical property called creep. Why is this not a feasible explanation?

A. There are no intermolecular forces in glass, since it is amorphous
B. The covalent bonds of glass are strong and rigid
C. The degree of bonding exceeds the normal force
D. The strength of Van der Waals forces in glass is very high
E. Your teammate is correct, glass exhibits creep



The micrographs above depict the metallic grain structure of samples of an aluminum alloy with identical chemical composition at the same magnification. Aluminum crystallizes into a BCC crystal lattice

45.) What is the difference between a particular grain in the micrograph and the one adjacent to it? In other words, what gives rise to the grain structure of metals?

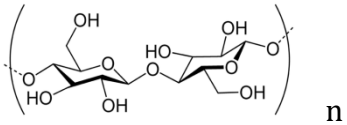
A. They have the same crystal structure
B. Different crystal structure
C. Different orientation of crystal structure
D. They have the same orientation
E. There is no difference

46.) What is the likely cause of the difference in the grain structure of samples a and b?

A. Glass transition temperature
B. Quenching rate
C. Hexagonal close packing
D. Atomic packing factor
E. There is no difference

47.)Short answer: Which sample, a or b, would be stronger and why?

48.) Pictured right is a repeating unit on a chain of cellulose, an organic polymer present in many textiles and woods. What are the strongest intermolecular forces occur between chains of cellulose?



A. Keesom Forces
B. London Dispersion Forces
C. Ionic bonding
D. Hydrogen bonding

49.) What property does Young's Modulus quantify?
A. Crystallinity
B. Shear modulus
C. Stiffness
D. Internal stress
E. Stress versus strain