

# LESSON CHEM 3.3 – ENGINEERING MATERIALS

## EVIDENCE NOTEBOOK

### KEY IDEAS

1. \_\_\_\_\_ scientists design and discover new materials.
2. Illustrate the four steps in the engineering design:

Engineers are trying to harvest water from fog. Use the engineering design process to evaluate the material selection.

- a. What kind of questions could be asked when defining and delimiting the problem?
- b. How does the Namib Beetle (*Stenocara*) catch fog water?
- c. Based on the following data, which material (1, 2, or 3) would be the best solution?

DECISION MATRIX FOR FOG-COLLECTING MATERIAL				
Design Criteria	Weight	Material 1	Material 2	Material 3
Durability	4	5	1	4
Water collected	3	2	3	4
Cost	2	1	2	1
Algae Resistance	1	1	4	0
<b>Total Points</b>				

d. What factors outside of the engineer’s control affect the implementation of a project?

3. Life cycle of a cell phone

a. Label the stages in the life cycle of a cell phone:

Stage #	Description
1	
2	
3	
4	
5	



b. What stage in the material life cycle would the following criteria be applied:

Engineering Criteria	Life Cycle Stage
Reduce the energy consumption of an appliance	
Develop more efficient natural gas drilling techniques	
Design a material that can be easily separated into recyclable components	
Automate the assembly process for putting car parts together	
Develop software systems to improve warehouse operations	

4. Metals

a. Metal have \_\_\_\_\_ electronegativity and are cations surrounded by a sea of

\_\_\_\_\_.

b. Metals are ideal for:

1	
2	
3	
4	
5	
6	

5. Ceramics

a. Ceramics have electrons that are \_\_\_\_\_ or \_\_\_\_\_ between atoms.

b. List four properties of ceramic materials:

c. Ceramics are ideal for:

1	
2	
3	
4	
5	
6	

6. Semiconductors

- a. Semiconductors are poor conductors of electricity at \_\_\_\_\_ temperatures but start to conduct electricity as the temperature \_\_\_\_\_.
- b. Where on the periodic table are the metalloids located? *Circle them.*

PERIODIC TABLE OF THE ELEMENTS																					
1 H 1.008																	2 He 4.003				
3 Li 6.941	4 Be 9.012															5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305															13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.69	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.64	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798				
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98.906	44 Ru 101.07	45 Rh 101.07	46 Pd 106.36	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.6	53 I 126.905	54 Xe 131.29				
55 Cs 132.905	56 Ba 137.327	57 La 138.905	58 Ce 140.12	59 Pr 140.908	60 Nd 144.24	61 Pm 144.913	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.925	66 Dy 162.50	67 Ho 164.930	68 Er 167.259	69 Tm 168.930	70 Yb 173.054	71 Lu 174.967	72 Hf 178.49				
73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.222	78 Pt 195.084	79 Au 196.967	80 Hg 200.59	81 Tl 204.384	82 Pb 207.2	83 Bi 208.980	84 Po 209	85 At 210	86 Rn 222	87 Fr 223	88 Ra 226	89 Ac 227	90 Th 232.038				
91 Pa 231.036	92 U 238.029	93 Np 237.048	94 Pu 244.064	95 Am 243.061	96 Cm 247.070	97 Bk 247.070	98 Cf 251.08	99 Es 252.083	100 Fm 257.10	101 Md 258.10	102 Lv 260.10	103 Ts 261.10	104 Og 264.10	105 Nh 265.10	106 Fl 269.10	107 Mc 270.10	108 Lr 260.10				
97 Bk 247.070	98 Cf 251.08	99 Es 252.083	100 Fm 257.10	101 Md 258.10	102 Lv 260.10	103 Ts 261.10	104 Og 264.10	105 Nh 265.10	106 Fl 269.10	107 Mc 270.10	108 Lr 260.10	Lanthanide and Actinide Series									
89 La 138.905	90 Ce 140.12	91 Pr 140.908	92 Nd 144.24	93 Pm 144.913	94 Sm 150.36	95 Eu 151.964	96 Gd 157.25	97 Tb 158.925	98 Dy 162.50	99 Ho 164.930	100 Er 167.259	101 Tm 168.930	102 Yb 173.054	103 Lu 174.967	Lanthanide Series						
89 La 138.905	90 Ce 140.12	91 Pr 140.908	92 Nd 144.24	93 Pm 144.913	94 Sm 150.36	95 Eu 151.964	96 Gd 157.25	97 Tb 158.925	98 Dy 162.50	99 Ho 164.930	100 Er 167.259	101 Tm 168.930	102 Yb 173.054	103 Lu 174.967	Actinide Series						

- c. Adding impurities to a metalloid crystal is called \_\_\_\_\_. How does this increase the electrical conductivity of a semiconductor?

7. Polymers

- a. Polymers are chains of \_\_\_\_\_.

b. Complete the polymer table below:

Shape	Shape Illustration	Example	Properties
Linear			
Branched			
Cross-linked			
Networked			

c. The greater the attractive forces are between molecules in a thermoplastic, the \_\_\_\_\_ the material will be. Greater intermolecular forces between chains also means the plastic will melt at a \_\_\_\_\_ temperature. The bottle with stronger intermolecular forces between its molecules is most likely the \_\_\_\_\_ bottle. The bottle what would be easier to recycle is most likely the \_\_\_\_\_ bottle.



8. Composites

a. Composites are \_\_\_\_\_ materials \_\_\_\_\_ to form a \_\_\_\_\_ material with unique properties.

NAME: \_\_\_\_\_ DATE: \_\_\_\_\_ PERIOD: \_\_\_\_\_

- b. Fiber glass is a combination of:
  
- c. Laminate floors are made by combining a \_\_\_\_\_, a \_\_\_\_\_, and a \_\_\_\_\_ to make it strong.
  
- d. Adding different materials together to create a new material with unique properties is a composite. Give your own example of a composite:

9. Shape memory alloy (SMA)

- a. How was SMA discovered?
  
  
  
  
  
  
  
  
  
  
- b. The \_\_\_\_\_ was the first vehicle to incorporate SMA materials into its design.
  
- c. SMA have both \_\_\_\_\_ and \_\_\_\_\_ properties.
  
- d. The alloy atoms in a SMA are in the \_\_\_\_\_ phase at low temperatures and the \_\_\_\_\_ phase at high temperatures.
  
- e. *Label and illustrate* these SMA two phases:

- f. Explain how to shape a SMA and what are its properties after it is formed: *Your answer should include austenite and twinned/detwinned martensite*

### CHECKPOINTS

10. Why are metals generally ductile, or able to be pulled into wires?
- Metal ions form strong, rigid three-dimensional networks.
  - Ions within the metal structure easily slide past one another.
  - The bonds between metal atoms are very strong and they stick tightly together.
  - Valence electrons can flow freely through the material when there is an electric potential.
11. How does the addition of an element that can donate electrons, such as phosphorus, into a silicon crystal change the electrical properties of the crystal?
- Conductivity is not affected by an increase in electrons.
  - The donor atoms bond with all free electrons, increasing conductivity.
  - The unbonded electrons from the donor atoms are mobile, increasing conductivity.
  - Conductivity is lower at high concentrations of the donor atoms than at low concentrations of the donor atoms.
12. *Select the correct terms to complete the statement about thermoplastic polymers.*
- The strength of intermolecular forces between polymer chains affects the properties of the material. The greater the intermolecular forces between adjacent molecules, the more | less rigid one would expect the material to be. As the strength of attractive forces between molecules increases, more | less energy is required to melt the material. Therefore, it would be easier to recycle a plastic with relatively strong | weak intermolecular forces between its molecules as compared to other types of plastics.

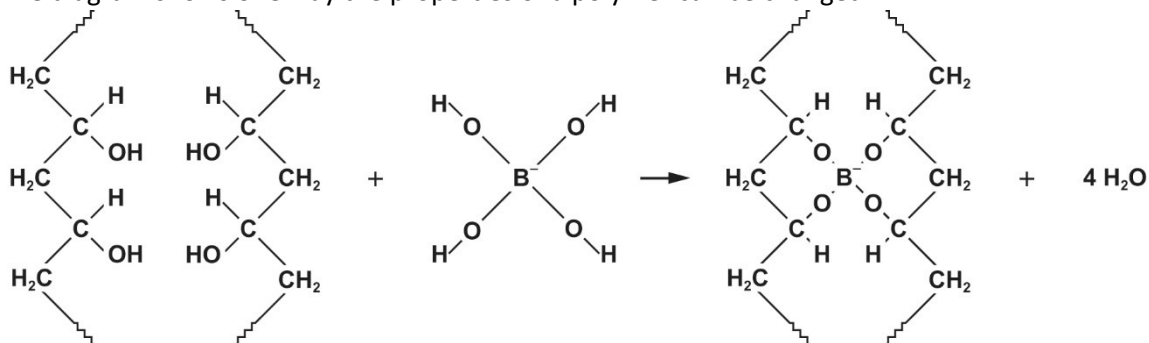
13. Which statements best describe a composite material? *Select all correct answers.*
- Composites all contain carbon, which makes them lightweight.
  - A composite may have more desirable properties than its components.
  - Composites form hydrogen bonds, which makes them stronger than their components.
  - A brick made of mud and straw is an example of a composite; a brick made of mud is not.
14. *Select the correct terms to complete the statement about how molecular patterns affect a shape memory alloy valve.*
- A temperature-sensitive valve is manufactured from a shape memory alloy in its austenite | twinned martensite | detwinned martensite phase. When the device is cooled, a phase change occurs, and the material's plasticity decreases | increases | remains stable. After being deformed, the material holds its new shape until it is bent | cooled | heated | stressed, which causes another phase change. The phase change from the deformed state to the original state is an example of the conductivity | elasticity | plasticity of shape memory alloys
15. Given the constraint of metal fatigue, for which of these problems might SMA materials be a suitable solution? *Select all correct answers.*
- wires that hold teeth in place for a long time during orthodontic procedures
  - automated pistons that move up and down in an automobile engine
  - connectors between bones in a replacement knee joint
  - sensors to open a sprinkler head during a fire
  - landing gear on a robotic Mars lander.
16. How does defining an engineering problem and identifying criteria and constraints help engineers determine the types of materials that are likely to be suitable for use in a device?
17. How do the electrical interactions of attraction and repulsion determine the properties of a material and how it can be applied to an engineering solution?



18. Describe a material that has had unintended consequences on society or the environment. What constraints could be considered when evaluating solutions that use this material?
19. Which type of material includes examples such as porcelain, cement, and pottery?
- Metals
  - Ceramics
  - Composites
  - Semiconductors
20. A company needs a substance for a new product that is a good electrical insulator, is lightweight, and can withstand high pressures. Which type of scientist should the company contact for help?
- Geophysicist
  - Organic chemist
  - Material scientist
  - Analytical chemist
21. Which statement describes the electrical conductivity of metals and semiconductors?
- Metals are poor conductors at low temperatures.
  - The conductivity of metals changes with changing pressure.
  - The conductivity of semiconductors changes with changing pressure.
  - Semiconductors are poor conductors at low temperatures, but their resistance decreases with increasing temperature.
22. Which polymer structure should be used if a strong and heat-resistant adhesive is required?
- Linear
  - Branched
  - Networked
  - Cross-linked
23. Which type of material incorporates a variety of substances to enhance desired properties such as strength and flexibility?
- Metals
  - Polymers
  - Composites
  - Semiconductors

24. Which statement best describes why shape memory alloys bend without breaking?
- The atoms are weakly attracted to one another.
  - The atoms are arranged in a crystalline structure that cannot change.
  - When a force is applied, the layers in the crystal shift and the material deforms.
  - They are composed of long molecules and when a force is applied, they can stretch and pull apart.
25. An engineer is designing a shape memory alloy. Which of the following is a limitation of these types of materials?
- They are composed of rare metals.
  - They can wear out after repeated use.
  - They are difficult to manufacture on a large scale.
  - They are hazardous when placed in the human body.
26. School administrators need to revise the emergency exit routes because construction at the school will block one exit for several weeks. They use a floor plan of the school to model the exit route from each room of the school. What is the next step in the process?
- Design and test solutions.
  - Optimize design solutions.
  - Define and delimit the problem.
  - Implement and communicate results.

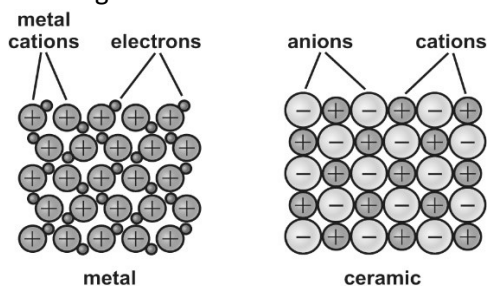
27. The diagram shows one way the properties of a polymer can be changed.



What does the diagram show?

- making polymer chains shorter
- adding polymer chains to water
- linking polymer chains together
- making a net out of polymer chains

28. The diagram shows the structures of a metal and a ceramic.



What makes metals better conductors of electric current than ceramics?

- Metals have ionic bonds.
  - Metals contain metal cations.
  - Electrons in metals can move around easily.
  - The anions in metals are smaller than those in ceramics.
29. Explain how a material scientist and an engineer would collaborate to create effective fog collectors.

30. Explain why an organic chemist is likely to work with polymers.

31. Two plastic containers are washed in a dishwasher. One keeps its shape and the other becomes deformed.

- Identify and compare the property of the plastic containers demonstrated in this example.
- Describe the structure of the polymers that affect this property.

32. Many major grocery stores in the United States replaced paper bags with plastic bags in the 1980s. The plastic bags are made from petroleum products that do not degrade in the environment. Many communities have now restricted the use of these bags due to environmental concerns. Explain, in terms of the life cycle of designed materials, why reducing the use of plastic grocery store bags is better for the environment than reusing or recycling them.

33. Engineers are designing a backpacking tent. They consider three materials for the tent and construct a decision matrix to evaluate the materials.

**Decision Matrix for Tent Material**

Design Criteria	Weight	Material 1	Material 2	Material 3
Lightweight	3	5	3	3
Durable	2	3	2	4
Waterproof	1	3	4	3
<b>Total points</b>				

Calculate the total points. Which material would the engineers pick based on this matrix?