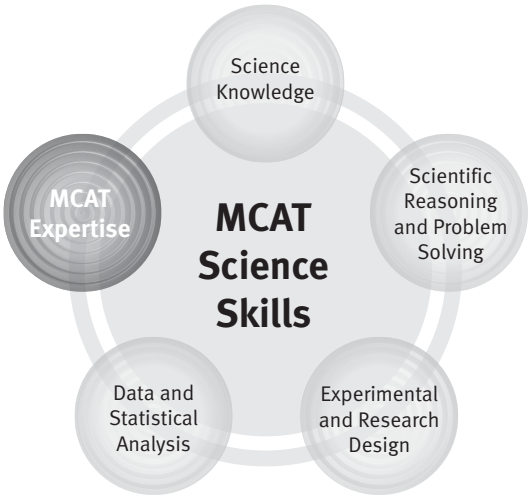
Science Passage Strategy

In this lesson, you'll learn to:

- Preview a science passage at a glance, determining likely topics and difficulty
- Identify the most question-relevant information in a science passage
- Create efficient and useful passage outlines



Science Topics:

- Intermolecular Forces
- Organic Chemistry Reaction Analysis
- Translational Motion

MCAT STRATEGY—SCIENCE PASSAGES

SCAN FOR STRUCTURE
Determine your "gut feeling" about the passage with a quick preview

READ STRATEGICALLY
Read the passage, focusing your attention on the more test-worthy details

LABEL EACH COMPONENT
Write down a short label or summary for each passage as you read

REFLECT ON YOUR OUTLINE
Make a full passage summary for yourself before moving to the questions

LESSON 5.1, LEARNING GOAL 1:

- Preview a science passage at a glance, determining likely topics and difficulty

The Previewing Process

Practice Passage I

The cell's cytoplasm includes all the liquid and solutes in the cell as well as all the organelles, excluding the nucleus. Also included are sodium, calcium, potassium, and all other ions as well as all the proteins in the cell. This "cell soup" provides the basis for cellular micro-processes that eventually lead to the macro-processes that we see as organismal activity. Many of these processes are derived from intermolecular forces between different parts of the cytoplasm.

The water basis of the cytoplasm helps to dissolve these solutes in the substrate. Around larger solutes, water forms solvation layers. These layers have water arranged in specific ways that use the partial charges of water to stabilize the ions and dipoles of the solutes. Depending on the species, water can hydrogen bond to the solutes for a stronger bond.

Intermolecular forces can often cause problems. Important molecules, such as ATP, use intermolecular forces to make sure proper reactions occur. ATP, when binding to proteins, also binds to a divalent cation, usually magnesium. Without magnesium, the dissociation constant between the ATP and protein is increased.

A biochemist performs an experiment to determine the effects of Mg on hexokinase enzyme activity and ATP-Mg dissociation, where $K_{ATP\text{-}Mg}$ is the dissociation constant for ATP-Mg and k_{cat} is proportional to V_{max} of the enzyme. The results are displayed in Table 1.

What do you notice in the first sentence?

What stands out in the rest of the passage text?

What kinds of figures are present?

Free [Mg^{++}]	[Mg-ATP]	[Peptide]	$K_{ATP\text{-}Mg}$	k_{cat}
0.5 mM	0.3 mM	1 mM	3.50	12.9 s^{-1}
3 mM	0.3 mM	1 mM	2.50	13.3 s^{-1}
7 mM	0.3 mM	1 mM	0.95	13.3 s^{-1}
10 mM	0.3 mM	1 mM	0.20	13.3 s^{-1}

Table 1. Effect of free magnesium on various quantities.

Practice Passage II

Van der Waals forces are also important in the cell membrane. Although hydrophobic interactions bring a cell membrane together, the membrane is stabilized by van der Waals forces. These are usually transient, but in certain cases, as with cholesterol and sphingolipids such as sphingomyelin, they form lipid rafts that are thicker than the cell membrane and a stable place for certain membrane proteins to accumulate. Sphingomyelin's structure is shown in Figure 1.

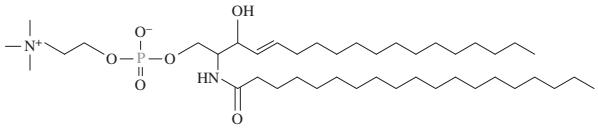


Figure 1. Structure of sphingomyelin.

What science topic is being tested in the passage?

How hard do you think this passage (and its questions) will be for you?

Would you skip this passage on Test Day?

KAPLAN TIP

The grayed-out text on this page is meant to represent that during preview, only certain parts of a passage—figures, numbers, formulas, and the like—will stand out to you. The blocked-out text *doesn't* mean that you should be "skimming" passages when you decide to dive in; once you've committed to reading a passage, it's important to read every word.

The Previewing Process

Practice Passage III

When evaluating automobile safety, there are three major factors to consider: the vehicle, the operator, and the driving conditions.

What do you notice in the first sentence?

Vehicles have become much safer over the last few decades due to innovations in passenger safety. The seatbelt restrains the wearer against sharp forward motion and distributes the force of impact over the rider's chest and pelvis. Riders wearing a seatbelt have a good chance of surviving a collision, as long as their deceleration doesn't exceed 30 g. Airbags, installed in the center of the steering wheel, inflate quickly after impact, forming a cushion for the driver. Crumple zones in the front and rear of a car are designed to absorb a large fraction of the energy during a collision.

What stands out in the rest of the passage text?

Human factors—such as the driver's behavior, visual and auditory acuity, decision-making ability, and reaction time—also contribute to the incidence of accidents. A driver's reaction time, t_{reaction}, is the time elapsed between observing a dangerous situation and acting on it. For a car traveling at speed v, the minimum safe distance, d, between the car and the hazard is:

$$d = vt_{\text{reaction}} + \frac{v^2}{2a},$$

where a is the maximum rate of deceleration of the car, which is largely dependent upon the frictional force between the tires and the roadway.

What kinds of figures are present?

Crash tests are routinely conducted by manufacturers and regulating government agencies in order to assess the safety of automobiles. Sophisticated anthropomorphic test devices (ATDs) are often employed to replace human passengers. These mannequins are constructed from materials with properties similar to those of the human body. Accelerometers, force transducers, and displacement sensors within ATDs collect data during a crash. Figure 1 shows data from two head-on collisions at 40 km/hr.

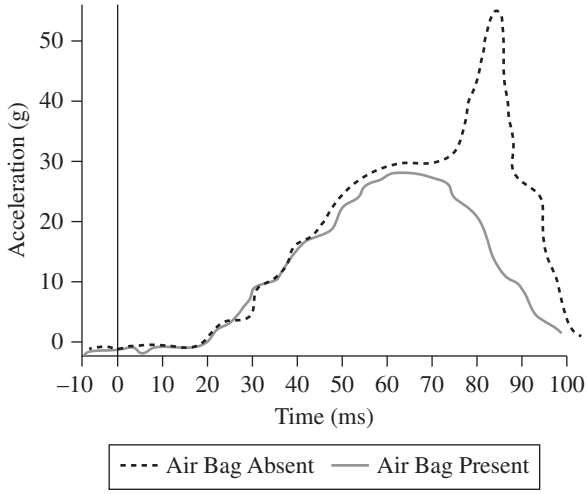


Figure 1. Acceleration of ATD head with and without an air bag.

What science topic is being tested in the passage?

How hard do you think this passage (and its questions) will be for you?

Would you skip this passage on Test Day?

KAPLAN TIP

Don't overcomplicate the preview process; it's supposed to be very quick and lead to snap decisions. As long as previewing isn't taking you more than 5–10 seconds per passage and you're answering the main Takeaway questions, then you're doing it right!

LESSON 5.1, LEARNING GOAL 2:

- Identify the most question-relevant information in a science passage

Biochemistry Passage Sample

The water basis of the cytoplasm helps to dissolve these solutes in the substrate. Around larger solutes, water forms solvation layers. These layers have water arranged in specific ways that use the partial charges of water to stabilize the ions and dipoles of the solutes. Depending on the species, water can hydrogen bond to the solutes for a stronger bond.

What outside science knowledge will most likely be required to answer questions based on this passage?

Intermolecular forces can often cause problems. Important molecules, such as ATP, use intermolecular forces to make sure proper reactions occur. ATP, when binding to proteins, also binds to a divalent cation, usually magnesium. Without magnesium, the dissociation constant between the ATP and protein is increased.

What information in this sample would be *likely* material for MCAT-style questions?

A biochemist performs an experiment to determine the effects of Mg on hexokinase enzyme activity and ATP-Mg dissociation, where $K_{ATP\text{-}Mg}$ is the dissociation constant for ATP-Mg and k_{cat} is proportional to V_{max} of the enzyme. The results are displayed in Table 1.

What information in this sample would be *unlikely* material for MCAT-style questions?

Free [Mg^{++}]	[Mg-ATP]	[Peptide]	$K_{ATP\text{-}Mg}$	k_{cat}
0.5 mM	0.3 mM	1 mM	3.50	12.9 s^{-1}
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Table 1. Effect of free magnesium on various quantities.

Organic Chemistry Passage Sample

Styrene is used extensively in the manufacture of plastics, rubber, and resins. It is a colorless liquid with a sweet, aromatic odor at low concentrations and a sharp, penetrating, disagreeable odor at high concentrations.

Because of the reactivity of its metabolite, styrene is classified as a mutagen. Studies have not yet definitively proven that exposure leads to cancer, but a causal link is strongly suspected and the U.S. National Toxicology Program describes styrene as "reasonably accepted to be a human carcinogen."

Styrene can be synthesized in the lab either by reacting sulfuric acid with compound **A** ($C_8H_{10}O$) or using zinc metal with compound **B** ($C_8H_8Br_2$) in ethanol. Compound **B** can be made from compound **C** (C_8H_9Br) by generating Br_2 gas *in situ* from the reaction of potassium bromate and hydrobromic acid and irradiation with a lamp. Compound **A** is characterized by its mild hyacinth odor and the ester, **D** ($C_{10}H_{12}O_2$), formed by the reaction of **A** with acetic acid and sulfuric acid, has a fruity smell.

What outside science knowledge will most likely be required to answer questions based on this passage?

What information in this sample would be *likely* material for MCAT-style questions?

What information in this sample would be *unlikely* material for MCAT-style questions?

KAPLAN TIP

Don't let yourself get stressed about "non-science" material in science passages. In fact, you should see it as good news: more non-science information in the passage means less space for question-worthy material, making your job easier!

LESSON 5.1, LEARNING GOAL 3:

- Create efficient and useful passage outlines

Practice Passage I

When evaluating automobile safety, there are three major factors to consider: the vehicle, the operator, and the driving conditions.

Vehicles have become much safer over the last few decades due to innovations in passenger safety. The seatbelt restrains the wearer against sharp forward motion and distributes the force of impact over the rider's chest and pelvis. Riders wearing a seatbelt have a good chance of surviving a collision, as long as their deceleration doesn't exceed 30 g. Airbags, installed in the center of the steering wheel, inflate quickly after impact, forming a cushion for the driver. Crumple zones in the front and rear of a car are designed to absorb a large fraction of the energy during a collision.

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Crash tests are routinely conducted by manufacturers and regulating government agencies in order to assess the safety of automobiles. Sophisticated anthropomorphic test devices (ATDs) are often employed to replace human passengers. These mannequins are constructed from materials with properties similar to those of the human body. Accelerometers, force transducers, and displacement sensors within ATDs collect data during a crash. Figure 1 shows data from two head-on collisions at 40 km/hr.

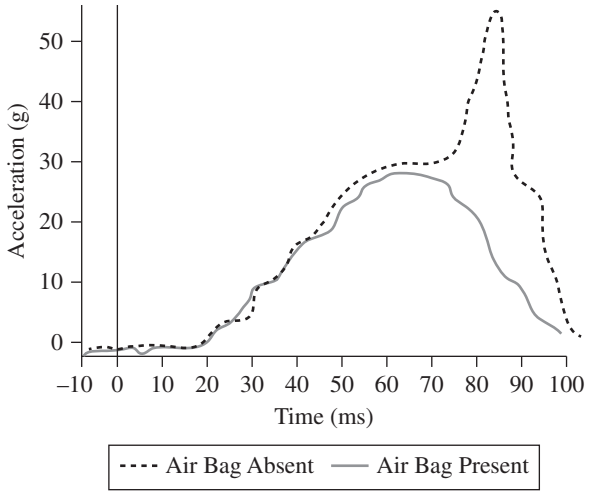


Figure 1. Acceleration of ATD head with and without an air bag.

Passage Outline Framework:

P1. (A summary or label of Paragraph 1)

P2. (A summary or label of Paragraph 2)

P3. (A summary or label of Paragraph 3)

Eq. 1. (A label that says what Equation 1 tells us)

P4. (A summary or label of Paragraph 4)

Fig. 1. (A label that says what Figure 1 represents)

Write Your Passage Outline Here:

P1.

P2.

P3.

Eq. 1.

P4.

Fig. 1.

KAPLAN TIP

Passage outlining, which you'll be doing a lot of between now and Test Day, is writing down what you notice about a passage as you read so you can store the important information more efficiently and return to it more easily when you need it for the questions.

Sample Passage Outlines for Passage I

Example 1

P1. Automobile safety factors

P2. Seatbelts and airbags

P3. Driver reaction time and stopping distance

Eq. 1. Minimum safe distance from hazard

P4. ATDs test crashes in cars

Fig. 1. Graph of acceleration of ATD head

Example 2:

P1. Car safety

P2. Vehicle safety innovations

P3. Contributors to accidents

Eq. 1. Distance to stop car

P4. Crash tests

Fig. 1. Air bag crash test

Example 3:

P1. Auto safety: three factors

P2. Seatbelts, airbags, crumple zones; forces, acceleration and energy

P3. Factors influence safe distance: velocity, reaction time, max deceleration

Eq. 1. Equation bringing together P3's variables

P4. Crash tests use ATDs (crash-test dummies) with different sensors

Fig. 1. ATDs in crash test with and without airbags

Please turn to the next page. ▶ ▶ ▶

Practice Passage II

Styrene is used extensively in the manufacture of plastics, rubber, and resins. It is a colorless liquid with a sweet, aromatic odor at low concentrations, but with a sharp, penetrating, disagreeable odor at high concentrations.

In humans, the liver metabolizes styrene into styrene oxide via the cytochrome P450 system. Both enantiomers are toxic, although (*R)*-styrene oxide has more pronounced health effects in mice. Long-term human exposure to styrene via inhalation, ingestion, or skin contact can lead to lethargy, memory loss, and headaches. Because of the reactivity of its metabolite, styrene is classified as a mutagen. Studies have not yet definitively proven that exposure leads to cancer, but a causal link is strongly suspected and the U.S. National Toxicology Program describes styrene as "reasonably accepted to be a human carcinogen."

Styrene can be synthesized in the lab by either reacting sulfuric acid with compound **A** ($C_8H_{10}O$) or using zinc metal with compound **B** ($C_8H_8Br_2$) in ethanol. Compound **B** can be made from compound **C** (C_8H_9Br) by generating Br_2 gas *in situ* from the reaction of potassium bromate and hydrobromic acid and irradiation with a lamp. Compound **A** is characterized by its mild hyacinth odor and the ester, compound **D** ($C_{10}H_{12}O_2$), formed by the reaction of **A** with acetic acid and sulfuric acid, has a fruity smell.

Compound **A** will undergo oxidation to **E** (C_8H_8O) in the presence of bleach and acetic acid. Compound **E**, which is characterized by its floral aroma, has a boiling point of 202°C and a refractive index of 1.5372. The semicarbazone derivative of **E** has a melting point of 198°C.

For styrene production on an industrial scale, the preferred method of synthesis involves taking compound F (C_8H_{10}) through a dehydrogenation reaction catalyzed by an amalgam of iron(III) oxide and potassium carbonate.

Figure 1 shows selected synthesis and derivatives of styrene.

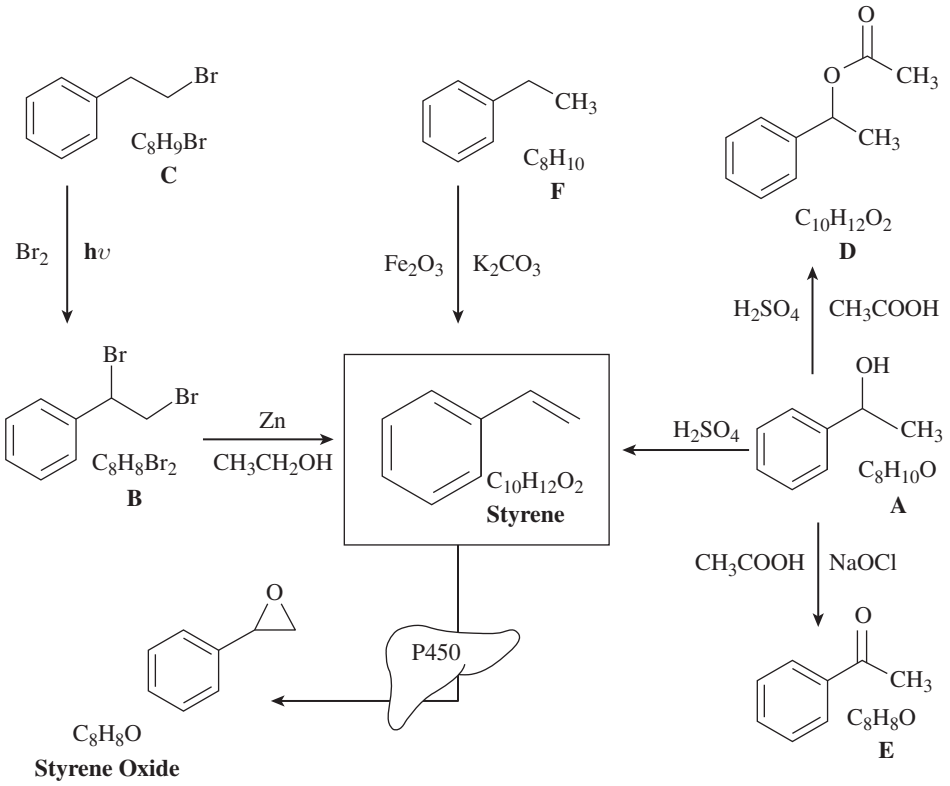


Figure 1. Selected synthesis and derivatives of styrene.

Write Your Passage Outline Here:

P1.

P2.

P3.

P4.

Fig. 1.

KAPLAN TIP
To see all the questions for this passage, and the others in this chapter, check out the homework for this session.

LESSON 5.1 REVIEW

MCAT Strategy—Science Passages

SCAN FOR STRUCTURE
Determine your "gut feeling" about the passage with a quick preview

READ STRATEGICALLY
Read the passage, focusing your attention on more test-worthy details

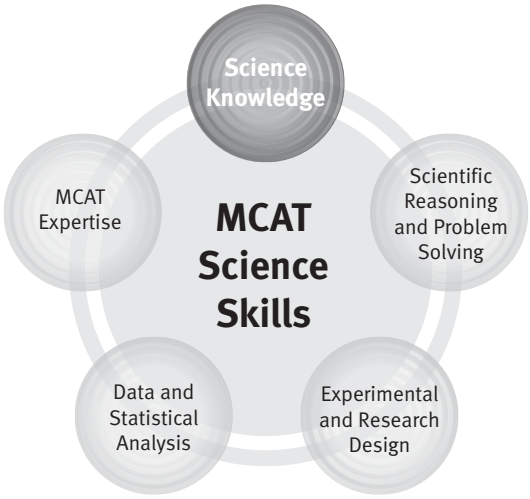
LABEL EACH COMPONENT
Write down a short label or summary for each passage as you read

REFLECT ON YOUR OUTLINE
Make a full passage summary to yourself before moving to the questions

Skill 1 (Knowledge) Basics

In this lesson, you'll learn to:

- Recognize and recall scientific principles when mentioned in a question
- Recognize and recall scientific principles when given a specific example in a question
- Recognize and recall correct scientific principles when a question seems to be indicating another topic



Science Topics:

- Stoichiometry
- Organic Chemistry Nomenclature
- Thermodynamics
- Fluids

MCAT STRATEGY—SCIENCE QUESTIONS

ASSESS THE QUESTION
Read the question, looking for clues to the science topic.

PLAN YOUR ATTACK
Recall what you know about the topic being tested.

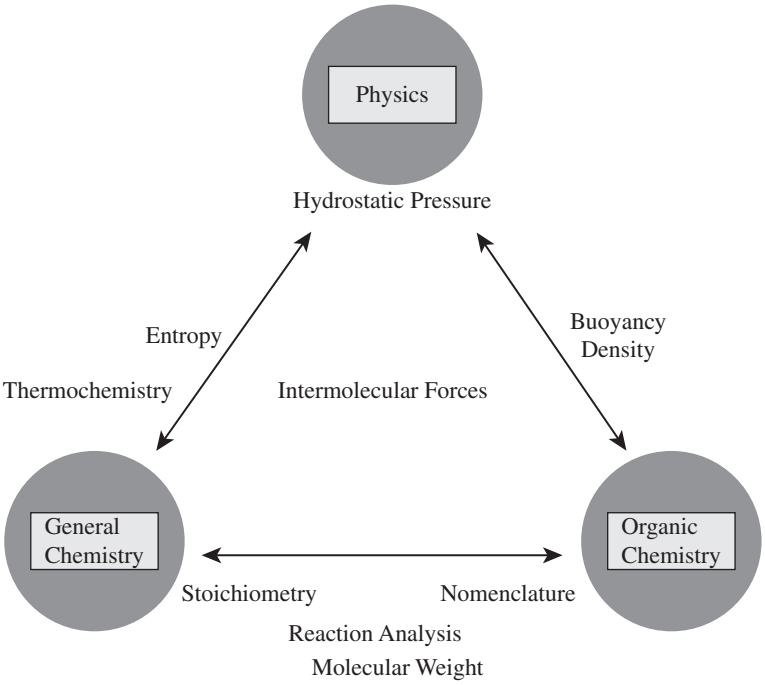
EXECUTE THE PLAN
Figure out the correct answer.

ANSWER BY MATCHING, ELIMINATING, OR GUESSING
Find the right answer in the answer choices.

LESSON 1.1, LEARNING GOAL 1:

- Recognize and recall scientific principles when mentioned in a question

CHEM/PHYS CONCEPT MAP



*Biochemistry is also a subject within the Chem/Phys section on the MCAT.

Sample Questions

1. What type of heat transfer is the primary way the sun's heat reaches Earth?

What do you know about heat transfer?

2. What is the correct IUPAC name for the following compound?

$$CH_3CHCHCOOCHCl_2$$

What factors influence the name of an organic compound?

3. Which of the following is true of liquids, but NOT true of gases?

What are the general properties of fluids (liquids and gases)?

4. How would the plot of hydrostatic pressure versus depth change for a vessel filled with liquid and exposed to the environment if it were transported to the moon?

What do you know about hydrostatic pressure?

KAPLAN TIP

The MCAT will demand that you recall science knowledge to solve Skill 1 questions. If you quickly and confidently bring your knowledge of the content to these questions, you can pick up points.

Answer the Questions:

1. What type of heat transfer is the primary way the sun's heat reaches Earth?

A. Convection
B. Radioactivity
C. Conduction
D. Radiation

2. What is the correct IUPAC name for the following compound?

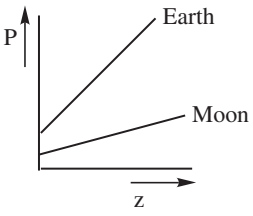
$$CH_3CHCHCOOCHCl_2$$

A. Chloromethyl-2-butenoate
B. Dichloromethyl-2-butenoate
C. 2-Butene-chloromethanoate
D. 2-Butene-dicholoromethanoate

3. Which of the following is true of liquids, but NOT true of gases?

A. They will conform to fit the shape of their container.
B. They are essentially incompressible.
C. Larger constituent molecules will move at lower velocities, given equal temperatures.
D. They exert pressure on objects contained within them.

4. How would the plot of hydrostatic pressure versus depth change for a vessel filled with liquid and exposed to the environment if it were transported to the moon?

A.


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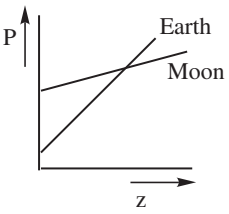
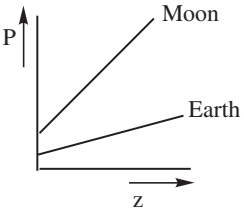
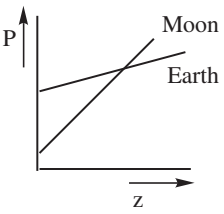


C.


D.


LESSON 1.1, LEARNING GOAL 2:

- Recognize and recall scientific principles when given a specific example in a question

Sample Questions

5. A sample of monatomic ideal gas is taken through an adiabatic expansion and is then isothermally compressed until the gas returns to its original pressure. Which of the following is true of this process?

What topic is being tested?

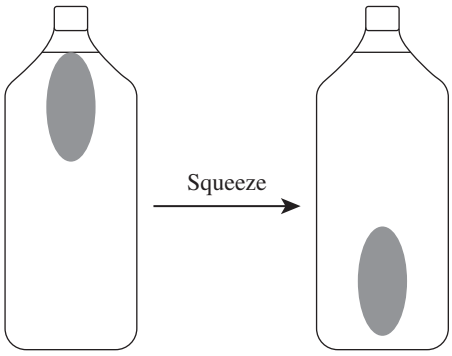
What do you know about this topic?

6. A student reacts 28 grams of iron with 24 grams of sulfur to produce iron(II) sulfide (FeS), but has some unreacted chemicals left over at the end of the reaction. How much of which chemicals are left over and why?

What topic is being tested?

What do you know about this topic?

7. A child plays with a toy in which a small, air-filled balloon floats within a bottle that is closed and completely filled with water (see diagram below). The bottle is flexible such that when the child squeezes it, the bottle can just slightly compress. Upon squeezing the bottle, the balloon sinks. Why does this happen?



What topic is being tested?

What do you know about this topic?

KAPLAN TIP

Remember that Skill 1 questions will appear on all the science sections, not just on the Chemical and Physical Science section. Don't worry—you will have many chances to practice this skill between now and Test Day.

Answer the Questions:

5. A sample of monatomic ideal gas is taken through an adiabatic expansion and is then isothermally compressed until the gas returns to its original pressure. Which of the following is true of this process?

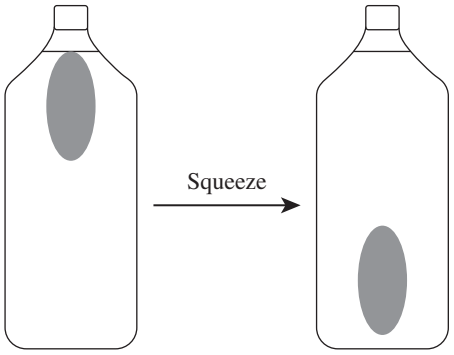
A. The net heat input into the gas is zero.
B. The net work done by the gas is zero.
C. The final state of the gas has a lower total internal energy than the initial state.
D. The final state of the gas has a higher average temperature than the initial state.

Process	Definition
Isothermal	no change in temperature
Isobaric	no change in pressure
Isovolumetric	no change in volume
Adiabatic	no heat in or out of system

6. A student reacts 26 grams of iron with 24 grams of sulfur to produce iron(II) sulfide (FeS), but has some unreacted chemicals left over at the end of the reaction. How much of which chemicals are left over and why?

A. Iron is left over because there are fewer moles of it present initially. There are 8 grams of it left.
B. Sulfur is left over because there are more moles of it present initially. There are 8 grams of it left.
C. Sulfur is left over because there is less mass of it present initially. There are 8 grams of it left.
D. Both chemicals are left over because neither is the limiting reagent. There are 8 grams of each left.

7. A child plays with a toy in which a small, air-filled balloon floats within a bottle that is closed and completely filled with water (see diagram below). The bottle is flexible such that when the child squeezes it, the bottle can just slightly compress. Upon squeezing the bottle, the balloon sinks. Why does this happen?



A. The balloon is compressed upon squeezing, thus increasing its density.
B. The water in the bottle is compressed, increasing its density and, thus, the buoyant force on the balloon.
C. Atmospheric pressure increases upon squeezing, forcing the balloon to sink.
D. As the balloon sinks, the depth decreases the hydrostatic pressure, causing the balloon to sink further.

LESSON 1.1, LEARNING GOAL 3:

- Recognize and recall correct scientific principles when a question seems to be indicating another topic

Sample Questions

8. A cube of solid ice is floating in a glass of water. After the ice melts into the liquid phase, the level of water in the glass:

A. is higher.
B. is lower.
C. remains the same.
D. cannot be determined with the information provided.

What topic is directly mentioned?

What topic is related and necessary to answer the question?

What do you already know about this related topic?

9. A student reads that mixing a strong acid and a strong base is a neutralization reaction and should produce a solution with a neutral pH. So the student mixes equal volumes of equally concentrated sulfuric acid and sodium hydroxide. Rather than a neutral pH, however, the pH of the resulting solution is acidic. Why is this? (Assume the neutralization reaction goes to completion.)

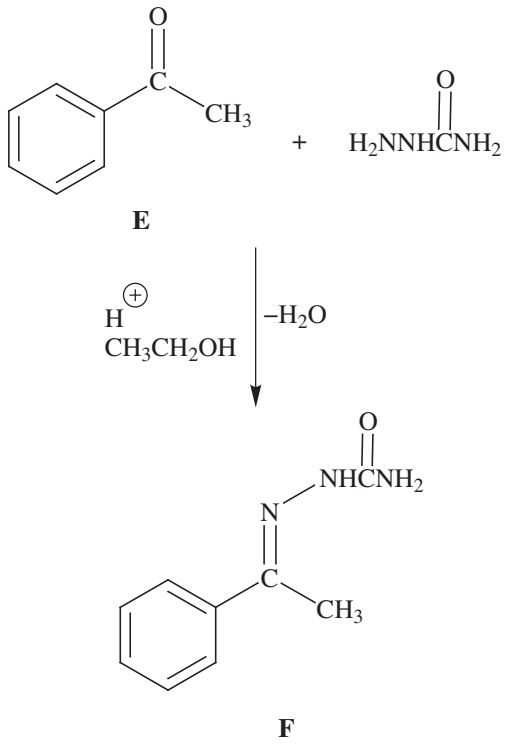
A. Sulfuric acid is sufficiently strong as an acid so as not to react at all but still neutralize the sodium hydroxide.
B. There are more moles of sulfuric acid than sodium hydroxide, so there is sulfuric acid left over at the end of the reaction.
C. There are more hydrogen ions from the sulfuric acid than there are hydroxide ions from the sodium hydroxide, so there are hydrogen ions left over at the end of the reaction.
D. There are fewer hydrogen ions from the sulfuric acid than there are hydroxide ions from the sodium hydroxide, so there are hydroxide ions left over at the end of the reaction.

What topic is directly mentioned?

What topic is related and necessary to answer the question?

What do you already know about this related topic?

10. Compound E reacts with semicarbazide to form the semicarbazone F according to the following equation:



Compound F contains what functional groups?

A. Imine, amine, amide
B. Imine, amine, carbonyl
C. Amine, amide, hydroxyl
D. Phenyl, amide, imine

What topic is directly mentioned?

What topic is related and necessary to answer the question?

What do you already know about this related topic?

KAPLAN TIP

The questions here can be some of the hardest Skill 1 questions the MCAT will have. You'll answer these questions correctly, though, if you're careful to identify exactly what each one is asking.

LESSON 1.1 REVIEW

MCAT Strategy—Science Questions

Assess the question by reading it and looking for clues to the science topic.

Recall what you know about scientific principles when you read them in a question:

- When the scientific principle is directly mentioned
- When given a specific example of a scientific principle in a question

Recall correct scientific principles when a question seems to be indicating another topic.

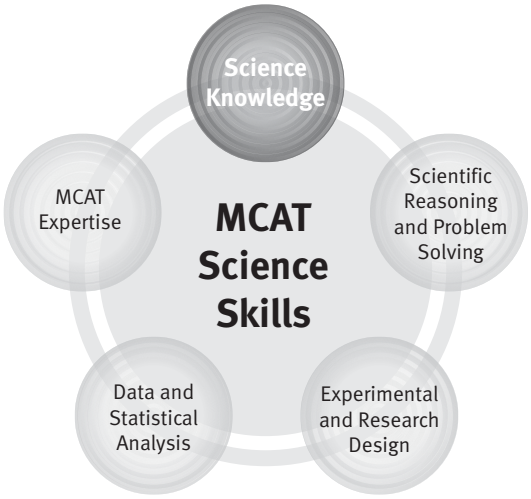
Math on the MCAT

In this lesson, you'll learn to:

- Solve MCAT math problems using minimal calculation
- Identify when math is needed to solve a problem

Science Topics:

- Fluids
- Translational Motion
- Energy
- Intermolecular Forces



MCAT STRATEGY—SCIENCE QUESTIONS WITH CALCULATIONS

ASSESS THE QUESTION
Read the question and decide if calculations are necessary to solve it.

PLAN YOUR ATTACK
Recall what formulas you need and plan how to set up the math.

EXECUTE THE PLAN
Implement the plan to figure out the correct answer.

ANSWER BY MATCHING, ELIMINATING, OR GUESSING
Find the right answer using the choices to guide you if necessary.

LESSON 1.2, LEARNING GOAL 1:

- Solve MCAT problems using minimal calculation

Sample Questions:

1. Decelerating uniformly, a car traveling north at 25 m/s takes 10 seconds to come to a complete stop. What is the magnitude and direction of the car's acceleration as it slows down?

A. North, at 2.5 m/s^2
B. South, at 2.5 m/s^2
C. North, at 9.8 m/s^2
D. South, at 25 m/s^2

2. In a head-on collision, a car moving at 10 m/s is uniformly brought to a halt over a distance of 0.5 m, the size of the car's crumple zone. How much time does it take for the car to come to a complete stop?

A. 0.05 s
B. 0.1 s
C. 0.2 s
D. 0.5 s

3. Blood moves toward a dialysis machine according to the equation Flow = 100^x, where x is the pressure at which the filtration system is set. To what pressure must the filtration system be set to ensure that blood flows evenly through the filtration system with no backup or vacuum created, if flow must equal 1,000 upon exiting the filtration system?

A. 0.66
B. 1.33
C. 1.5
D. 2.5

KAPLAN TIP
Doing the least amount of calculation necessary helps avoid time traps on the MCAT.

LESSON 1.2, LEARNING GOAL 2:

- Identify when math is needed to solve a problem

Sample Questions:

4. If a car moving at 15 m/s suffers a collision, causing it to decelerate uniformly at 2 m/s^2, approximately how far does the car travel during time t?

A. $15t + t^2$ m
B. $15\left(\frac{t}{3}\right) - \left(\frac{t}{3}\right)^2$ m
C. $15t$ m
D. $15t - t^2$ m

Is it necessary to use calculations to solve this problem?

If so, what calculations are necessary?

5. What is the distance a 75 kg patient can be pushed upward using a downward force of 20 N over 15 m (accomplished through several foot pumps) on a hydraulically powered surgical bed?

A. 0.4 m
B. 0.8 m
C. 2 m
D. 4 m

Is it necessary to use calculations to solve this problem?

If so, what calculations are necessary?

6. When an external uniform electric field, E, is applied to an atom, the nucleus and the electron cloud shift, moving in opposite directions and forming an induced dipole moment $p = qd$. The induced dipole moment is directly proportional to the external field $p = \alpha E$, where α is the atomic polarizability. The atomic polarizability has the SI units:

A. $\frac{C^2 \cdot s^2 \cdot m^3}{kg}$

B. $\frac{C^2 \cdot s^2}{kg}$

C. $\frac{C^2 \cdot s^2}{kg \cdot m^3}$

D. $\frac{kg \cdot s^2}{C^2}$

Is it necessary to use calculations to solve this problem?

If so, what calculations are necessary?

KAPLAN TIP

Knowing when to actually perform calculations, and especially when not to, can save you time on Test Day!

LESSON 1.2 REVIEW

MCAT Strategy—Science Questions with Calculations

ASSESS THE QUESTION

Read the question and decide if calculations are necessary to solve it.

PLAN YOUR ATTACK

Recall what formulas you need and plan how to set up the math.

EXECUTE THE PLAN

Implement the plan to figure out the correct answer.

ANSWER BY MATCHING, ELIMINATING, OR GUESSING

Find the right answer using the choices to guide you if necessary.

Chemistry and Physics 1: Science Passages and Science Knowledge Questions

PASSAGE I (QUESTIONS 1–4)

A physics class is attempting to measure the acceleration due to gravity g by throwing balls out of classroom windows. They performed the following two experiments:

Experiment 1
Two class members lean out of different windows at the same height, $h = 5.2$ m, above the ground and drop two different balls. One ball is made out of lead and has a mass of 5 kg. The other ball is made out of plastic and has a mass of 1 kg. The students measure the velocity of the lead ball just before impact with the ground and find it to be 10 m/s. They also find that when the plastic ball hits the ground it bounces, and its momentum changes by 18 kg · m/s.

Experiment 2
Instead of dropping the plastic ball, a student throws the ball out of a higher window and observes its projectile motion. The ball is thrown from a height of 10 m above the ground with a velocity of 4 m/s directed at an angle of 30° above the horizontal.

(Note: Assume that the air resistance is negligible unless otherwise stated.)

1. Which of the following would change the measured value of g in Experiment 1?

I. Increasing the mass of the Earth
II. Using balls having a different mass but the same volume
III. Throwing the balls horizontally instead of dropping them vertically

A. I only
B. III only
C. I and II only
D. II and III only

2. In Experiment 1, the change in momentum that the plastic ball experiences when it bounces off the ground does NOT depend on: (Note: Assume that the collision is perfectly elastic.)

A. the velocity of the ball just before impact.
B. the mass of the ball.
C. the mass of the Earth.
D. the volume of the ball.

3. The students did not account for air resistance in their measurement of g in Experiment 1. How does the value of g they obtained compare to the actual value of g?

A. The value of g obtained in Experiment 1 is greater than the actual value of g because air resistance increases the time it takes the balls to fall from the windows to the ground.
B. The value of g obtained in Experiment 1 is greater than the actual value of g because air resistance decreases the kinetic energy of the balls just before impact.
C. The value of g obtained in Experiment 1 is less than the actual value of g because air resistance decreases the velocity of the balls just before impact.
D. The value of g obtained in Experiment 1 is less than the actual value of g because air resistance decreases the time it takes the balls to fall from the windows to the ground.

4. In Experiment 2, what was the maximum height above the window reached by the plastic ball? (Note: The acceleration due to gravity is $g = 9.8\ m/s^2$, $\sin 30° = 0.50$, and $\cos 30° = 0.866$.)

A. 10.2 cm
B. 20.4 cm
C. 30.6 cm
D. 61.2 cm

PASSAGE II (QUESTIONS 1–8)

Serous otitis media (SOM) is a condition characterized by a buildup of fluid in the middle ear. Typically, SOM follows a bacterial or viral infection and usually clears up without direct treatment. However, sometimes fluid accumulation persists or the fluid itself becomes infected. If left untreated, chronic otitis media (COM) can develop, potentially leading to hearing loss, deep ear pain, and continued ear drainage.

Hearing occurs as mechanical vibrations are transduced into electrical impulses that are transmitted to the brain. Sound waves are funneled into the pinna and travel through the ear canal to the tympanic membrane. The ossicles amplify the incoming signal and transmit it to the inner ear at the cochlea, a fluid-filled tube. The sound waves pass through the cochlear fluid to the basilar membrane, which is lined with hair cells. These hair cells are depolarized, indirectly stimulating the auditory nerve. Figure 1 shows the anatomy of the ear.

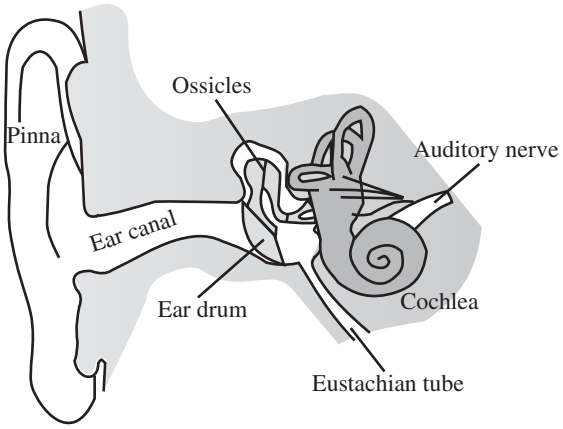


Figure 1. Anatomy of the ear.

The middle ear is lined with mucus and is connected to the nasopharynx by the Eustachian tube. The Eustachian tube remains closed except during swallowing, when it temporarily opens, equalizing external pressure and the pressure in the middle ear. Congestion and swelling due to illness may cause the Eustachian tube to become completely blocked, preventing air pressure equalization. Over time, a negative pressure develops in the middle ear, which draws liquid from the mucosal cells. Eventually, the fluid thickens and the middle ear membranes become inflamed. Pressure builds on the tympanic membrane until it grows distorted or perforated. At this stage, an individual is diagnosed with COM.

Preventative measures can limit the probability of developing COM. One such approach is a myringotomy (incision in the ear drum) to drain fluid followed by the insertion of a grommet. By aerating the middle ear, fluid accumulation is remediated. The structure of a grommet is illustrated in Figure 2.

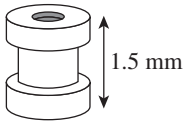


Figure 2. Structure of a grommet.

1. If a grommet with a larger hollow inner tube were inserted in a patient with COM, how would this affect the velocity of fluid initially exiting the middle ear?

A. Velocity would increase.
B. Velocity would decrease.
C. Velocity would remain the same.
D. Effect on velocity cannot be determined from the information given.

2. A patient with COM experiences significant hearing loss and is provided with a hearing aid. If the hearing aid amplifies sound intensity by 100 times, by how much is the decibel level increased?

A. 10 dB
B. 20 dB
C. 40 dB
D. 100 dB

3. How does the speed of sound waves moving through the ear canal compare to the speed of sound waves moving through the cochlear fluid?

A. Sound waves travel faster in the ear canal.
B. Sound waves travel slower in the ear canal.
C. Sound waves travel at the same speed in both the ear canal and the cochlear fluid.
D. Sound waves do not travel in the ear canal at all.

4. Which of the following accurately describes the purpose of the third paragraph?

A. To describe the significance of the Eustachian tube in proper ear function
B. To explain the mechanism of air pressure equalization that occurs during swallowing
C. To identify one potential cause of ear drum perforation
D. To offer a mechanism for COM development

5. A patient hears a beeping sound from ten meters away and decides to go closer to examine the source. If the patient is now one meter away, what is the ratio of the original intensity of the sound to the new intensity of the sound?

A. 1:1
B. 1:10
C. 1:100
D. 1:1,000

6. Which of the following best explains why a patient with a middle ear volume of 1.7 mL experiences a dramatic increase in pressure in her middle ear when fluid accumulation reaches 1.8 mL?

A. The Eustachian tube is typically closed, so fluid cannot escape the middle ear.
B. The mucosal cells cannot take up more water.
C. The ratio of fluid mass to volume is nearly immutable.
D. The tympanic membrane is inflexible.

7. Which of the following describes the main idea of the fourth paragraph?

A. Aerating the middle ear will eliminate the possibility of COM.
B. Failure to take preventative measures will likely cause COM.
C. One treatment of COM is myringotomy followed by insertion of a grommet.
D. The chance of acquiring COM is lessened with insertion of a grommet.

8. A man is on an airplane and notices that his ears keep "popping." What is the cause of this phenomenon?

A. His Eustachian tube is blocked and pressure is building in his middle ear.
B. His Eustachian tube is blocked and pressure is decreasing in his middle ear.
C. External pressure is lower at a high altitude and air is rushing out of his middle ear.
D. External pressure is greater at a high altitude and air is rushing into his middle ear.

PASSAGE III (QUESTIONS 1–7)

Styrene is used extensively in the manufacture of plastics, rubber, and resins. It is a colorless liquid with a sweet, aromatic odor at low concentrations, but with a sharp, penetrating, disagreeable odor at high concentrations.

In humans, the liver metabolizes styrene into styrene oxide via the cytochrome P450 system. Both enantiomers are toxic, although (*R*)-styrene oxide has more pronounced health effects in mice. Long-term human exposure to styrene via inhalation, ingestion, or skin contact can lead to lethargy, memory loss, and headaches. Because of the reactivity of its metabolite, styrene is further classified as a mutagen. Studies have not yet definitively proven that exposure leads to cancer, but a causal link is strongly suspected and the U.S. National Toxicology Program describes styrene as "reasonably accepted to be a human carcinogen."

Styrene can be synthesized in the lab by either reacting sulfuric acid with compound A ($C_8H_{10}O$) or using zinc metal with compound B ($C_8H_8Br_2$) in ethanol. Compound B can be made from compound C (C_8H_9Br) by generating Br_2 gas *in situ* from the reaction of potassium bromate and hydrobromic acid and irradiation with a lamp. Compound A is characterized by its mild hyacinth odor and the ester, compound D ($C_{10}H_{12}O_2$), formed by the reaction of A with acetic acid and sulfuric acid, has a fruity smell.

Compound A will undergo oxidation to E (C_8H_8O) in the presence of bleach and acetic acid. Compound E, which is characterized by its floral aroma, has a boiling point of 202°C and a refractive index of 1.5372. The semicarbazone derivative of E has a melting point of 198°C.

For styrene production on an industrial scale, the preferred method of synthesis involves taking compound F (C_8H_{10}) through a dehydrogenation reaction catalyzed by an amalgam of iron(III) oxide and potassium carbonate. Figure 1 shows selected synthesis and derivatives of styrene.

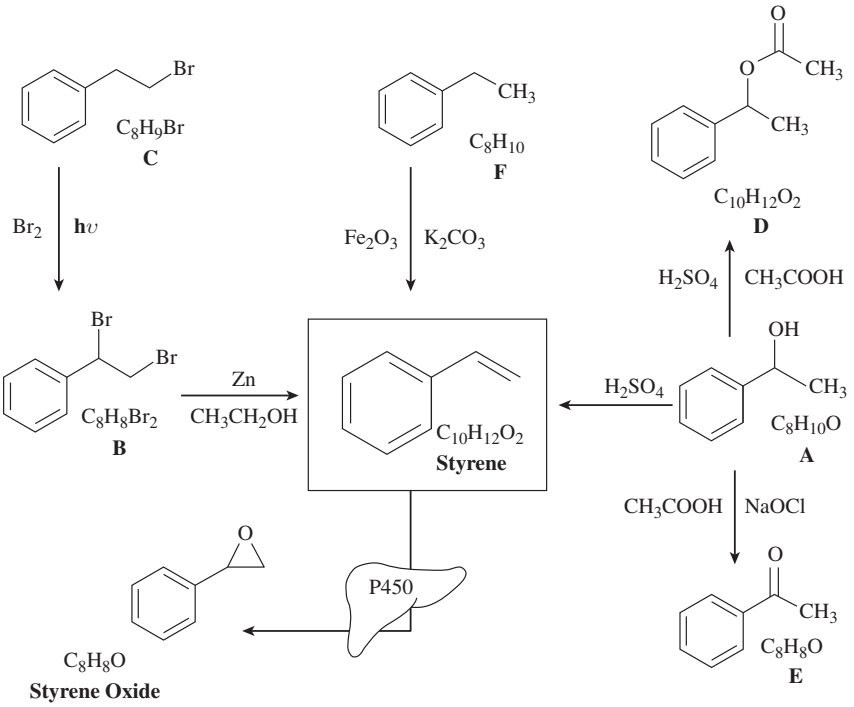


Figure 1. Selected synthesis and derivatives of styrene.

1. Which of the following compounds illustrated in the passage will have the lowest melting point?

A. Compound A
B. Compound D
C. Compound E
D. Compound F

2. What is the likely intermediate in the conversion of compound C to compound B?

A. A carbene
B. A carbocation
C. A cyclic bromonium ion
D. A radical

3. What is the likely first step in the conversion of compound A to compound D?

A. Nucleophilic attack of acetic acid on the carbon bound to the –OH group
B. Nucleophilic attack of compound A on the carbonyl carbon of acetic acid
C. Protonation of the hydroxyl group of compound A
D. Protonation of the carbonyl oxygen of acetic acid

4. Which of the following reagents would NOT also convert compound A to compound E?

A. CrO_3
B. $K_2Cr_2O_7$
C. PCC
D. Tollen's reagent

5. CH_3CH_2OH, H_2SO_4, and CH_3COOH are all reagents illustrated in Figure 1. Which of the following is true?

A. CH_3CH_2OH has a higher K_a than CH_3COOH.
B. CH_3COOH has the lowest pK_a.
C. CH_3COOH has a lower pK_a than CH_3CH_2OH.
D. H_2SO_4 has the highest pK_a.

6. Which of the following correctly identifies the main idea of the second paragraph?

A. (*R*)-Styrene oxide is more dangerous than (*S*)-styrene oxide.
B. Further medical research is needed to effectively treat those poisoned by styrene.
C. Styrene usage should be reduced to limit health risks.
D. Styrene is likely a carcinogen with known health impacts.

7. Which of the following contains the correct content for a map of the third paragraph?

A. Compounds A and B can be used to synthesize styrene in the lab.
B. Compound A, compound B, compound C, and compound D are all effective means by which to synthesize styrene.
C. Compounds A and B each have a unique associated smell.
D. Synthesis of styrene requires either ethanol or a zinc catalyst.

DISCRETE PRACTICE QUESTIONS (QUESTIONS 1–6)

1. How much work is done by the force of gravity to maintain the orbit of a satellite that moves in a circular orbit if the satellite has a mass of 1×10^5 g, a velocity of 4×10^3 m/s, and a radius of orbit of 2×10^8 m from the center of the earth?

A. 0 J
B. 800 J
C. 8×10^5 J
D. 16×10^5 J

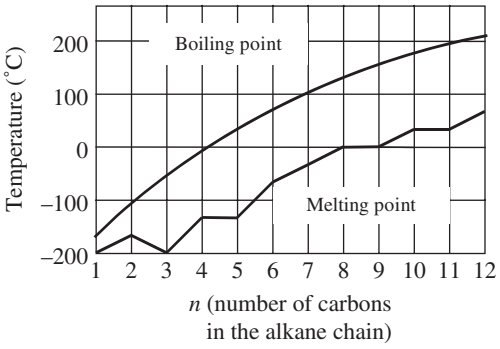
2. In backscattering spectrometry, a beam of helium ions is directed at a sample and energy from the collision is measured. If the source aperture from which a beam of 2-MeV helium ions emerge is at a distance of 15 cm from the sample, how long does it take for one of these incident particles (each with mass 4 amu) to reach the sample? (1 amu = 1.66×10^{-27} kg; 1 eV = 1.60×10^{-19} J)

A. 1.5×10^{-8} s
B. 1.0×10^{-7} s
C. 1.5×10^{-6} s
D. 1.0×10^{-5} s

3. The most reactive functional group on the molecule 6,6-dichlorohexanal is a(n):

A. alcohol group.
B. carbonyl group.
C. carboxyl group.
D. chlorine.

4. According to the graph below, which straight-chain hydrocarbons exist in the liquid state at –50°C? (*n* is the number of carbons)



A. Ethane, butane, pentane
B. Pentane, hexane, octane
C. Propane, butane, hexane
D. Pentane, octane, urethane

5. An object in free fall first accelerates at 9.8 m/s^2 and after a few seconds has an acceleration of 0. Why?

A. The object hits the ground.
B. Air resistance counters gravity completely at a certain speed.
C. The object continues falling at a faster and faster rate for the whole fall.
D. The object falls at a constant rate for the whole fall.

6. Which one of the following has the highest boiling point?

A. water
B. methane
C. acetic acid
D. acetone