

Large-Type Edition

The University of the State of New York
REGENTS HIGH SCHOOL EXAMINATION

PHYSICAL SCIENCE: CHEMISTRY (NYSP12SLS)

Wednesday, August 19, 2026 — 8:30 to 11:30 a.m., only

Student Name _____

School Name _____

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

Print your name and the name of your school on the lines above.

Use your knowledge of **Physical Science: Chemistry** to answer all questions in this examination. Before you begin this examination, you must be provided with the **2025 Edition Reference Tables for Physical Science: Chemistry**. You may need to use these reference tables to answer some of the questions.

You are to answer all questions in this examination. You may use scrap paper to work out the answers to the questions, but be sure to record your answers on your answer sheet and in your test booklet. A separate answer sheet for multiple-choice questions has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers for the constructed-response questions in your test booklet.

All answers in your test booklet should be written in pen, except for graphs and drawings, which should be done in pencil.

When you have completed the examination, you must sign the declaration printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and test booklet cannot be accepted if you fail to sign this declaration.

NOTICE ...

A scientific calculator or graphing calculator and a copy of the **2025 Edition Reference Tables for Physical Science: Chemistry** must be available for you to use while taking this examination.

Note that diagrams are not drawn to scale unless otherwise noted.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Base your answers to questions 1 through 5 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**. Be sure to record your answers for multiple-choice questions on the separate answer sheet provided. Record your answers for constructed-response questions in your test booklet.

Electricity Generation in New York State

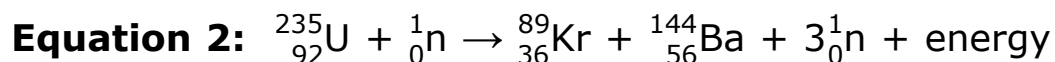
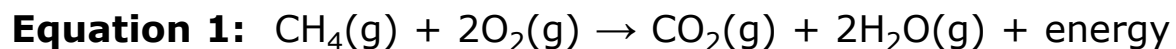
New York State uses several types of energy sources to generate electricity. Data from 2021 indicate a large percentage of electrical energy in New York State is generated by natural gas plants and nuclear power plants. Burning natural gas primarily composed of methane (CH_4) produces carbon dioxide, which is a major contributor to climate change.

Figure 1 represents a distribution of energy sources of electricity in New York State. Equations 1 and 2 represent reactions that produce energy, which are used to generate electricity.

Figure 1: Sources of Electricity Generation in New York (2021)

Energy Sources	Percentage of Electricity Generation* (%)
Natural gas (CH_4)	45.6
Nuclear (U-235)	24.9
Hydropower	22
Wind	3.6
Biomass, solar, and other	4

*The percentages do not add up to 100, due to rounding.



- 1 Which row correctly compares the relative amount of energy released to the changes that occur at the atomic level in Equations 1 and 2 when an equal number of moles of the fuel source are used?

Row	Equation 1	Equation 2
(1)	Small magnitude of energy released; involves formation of different atoms	Large magnitude of energy released; involves rearrangement of atoms
(2)	Small magnitude of energy released; involves rearrangement of atoms	Large magnitude of energy released; involves formation of different atoms
(3)	Large magnitude of energy released; involves formation of different atoms	Small magnitude of energy released; involves rearrangement of atoms
(4)	Large magnitude of energy released; involves rearrangement of atoms	Small magnitude of energy released; involves formation of different atoms

2 Which statement describes the flow of energy in *Equation 1*?

- (1) The energy enters the system from the surroundings, and the temperature of the surroundings decreases.
- (2) The energy enters the system from the surroundings, and the temperature of the surroundings increases.
- (3) The energy exits the system to the surroundings, and the temperature of the surroundings decreases.
- (4) The energy exits the system to the surroundings, and the temperature of the surroundings increases.

3 Calculate the volume in liters of the gas produced in *Equation 1*, which is a major contributor to climate change, when 25.0 g of methane has completely reacted at STP. [1]

_____ **L**

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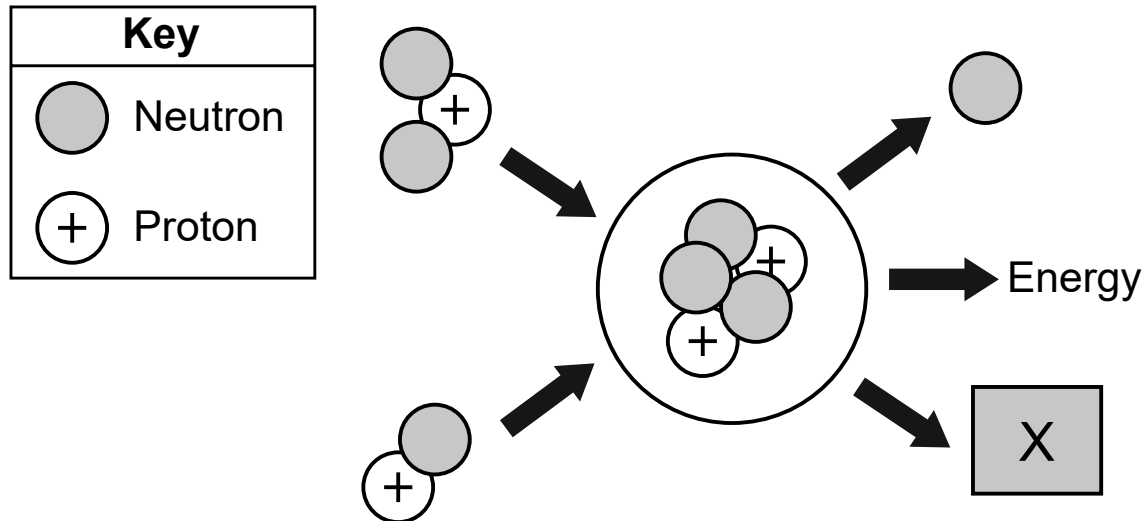
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Uranium-235 naturally decays by several steps, known as a decay series. In the first step, U-235 emits an alpha particle, producing Th-231. In the next step, Th-231 undergoes beta decay. Nuclear fission and the products of the decay series can pose serious health risks.

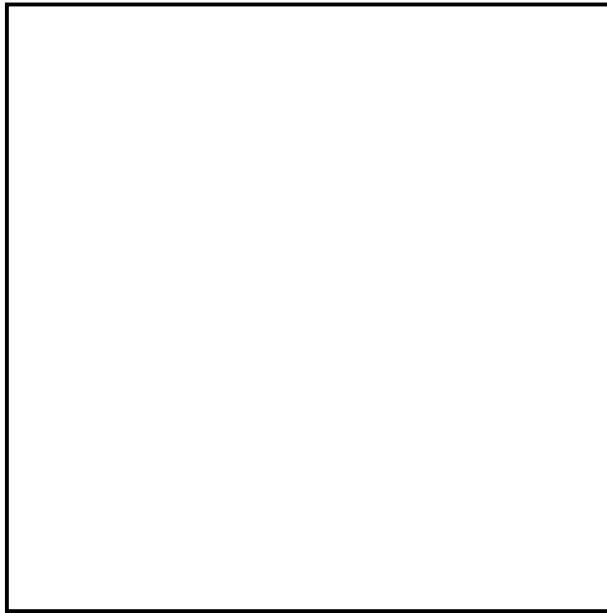
A nuclear power plant on the Hudson River, Indian Point, was closed by New York State on April 30, 2021, as a result of ongoing safety issues. With the loss of electricity generated by this power plant, production from other energy sources had to be increased.

Scientists are researching methods to utilize a controlled nuclear fusion reaction, as illustrated by Figure 2. This could be a useful alternative to generate electricity in the future, addressing both environmental and health concerns.

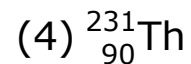
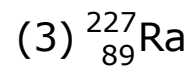
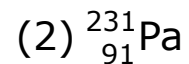
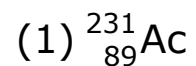
Figure 2: Model of Nuclear Fusion



4 Using the key provided in Figure 2, draw a model of the nucleus, labeled X. [1]



5 Which isotopic notation represents the product of the nuclear decay of the ^{231}Th ?



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Base your answers to questions 6 through 9 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

The Fruit Industry in New York State

New York State is the third largest producer of grapes and the second largest producer of apples in the United States. Factors that affect the growth of grapes include temperature, soil pH, humidity, rainfall, and wind. The optimal conditions for growing grapes include a soil pH of 5.5 to 6.5 and a temperature range between 25°C and 32°C. Apples grow in a wide variety of soil types, but do best in well-drained soil at a pH of 6.0 to 7.0.

- 6** Make a claim that compares the hydronium ion concentration of the optimal soil conditions to grow grapes to the hydronium ion concentration of the optimal soil conditions to grow apples. [1]

The sugars produced by grape plants and apple trees include glucose, fructose ($C_6H_{12}O_6$), and sucrose ($C_{12}H_{22}O_{11}$). Glucose is first produced, which can transform to fructose, a molecule with the same molecular formula but a different structure. These two simple sugars chemically combine to produce water and sucrose, which are transported to the other parts of the plant.

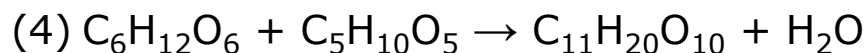
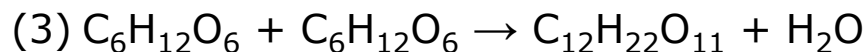
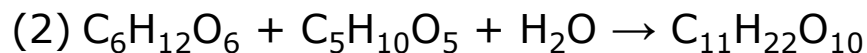
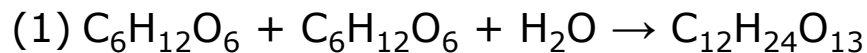
- 7 Select components from the options provided and complete the model, including energy, to correctly demonstrate the production of glucose in grapes and apples. [1]

Components for Model			
H_2O_2	C_6H_{12}	CO_2	Light
O_2	H_2O	$C_6H_{12}O_6$	Nuclear

Model:

_____ + _____ + _____ → _____ + _____

8 Which equation best demonstrates the conservation of matter in the synthesis of sucrose in apples?



Grapes and apples can be made into jellies. Grape jelly can be made from grape juice in a process that involves boiling and dissolving additional sugars. During heating, soluble substances called pectins are released and help thicken the jelly.

9 Which claim identifies the relationship between the boiling points of grape juice and jelly?

(1) The jelly has the same boiling point as the juice because they both contain the same concentration of dissolved particles.

(2) The juice has a lower boiling point than the jelly because the juice contains a lower concentration of dissolved particles.

(3) The jelly has a higher boiling point than the juice because the jelly contains a lower concentration of dissolved particles.

(4) The juice has a higher boiling point than the jelly because the juice contains a greater concentration of dissolved particles.

Base your answers to questions 10 through 13 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

The Great American Solar Eclipse

On April 8, 2024, most people in New York State were able to see some portion of a total solar eclipse. During a solar eclipse the moon passes between the Sun and Earth, blocking the Sun's rays.

The Sun's energy is emitted as electromagnetic radiation produced by fusion. More than half the energy from the Sun that reaches Earth's surface is in the infrared range. Nearly as much energy is in the visible range and less than 5% is in the ultraviolet (UV) range, which is damaging when absorbed by the human body.

When the Sun's energy is blocked by the moon, the outer layer of hot magnetized plasma, called the corona, becomes visible. The corona is always present, but is only visible in daylight during an eclipse. During the brief time of total Sun blockage in an eclipse, scientists can study the emission spectra of the corona. In 2019 during a solar eclipse, scientists in Chile recorded spectral lines associated with iron at wavelengths 530.3 nm, 637.4 nm, and 789.2 nm.

- 10** Which types of electromagnetic radiation correspond to the spectral lines of iron reported in the Sun's corona during a solar eclipse?
- (1) visible light, infrared, and ultraviolet
 - (2) visible light and infrared
 - (3) ultraviolet and visible light
 - (4) ultraviolet and infrared

- 11** Which row completes the claim describing how the absorption of radiation with a wavelength of 10^{-4} m would affect a living cell?

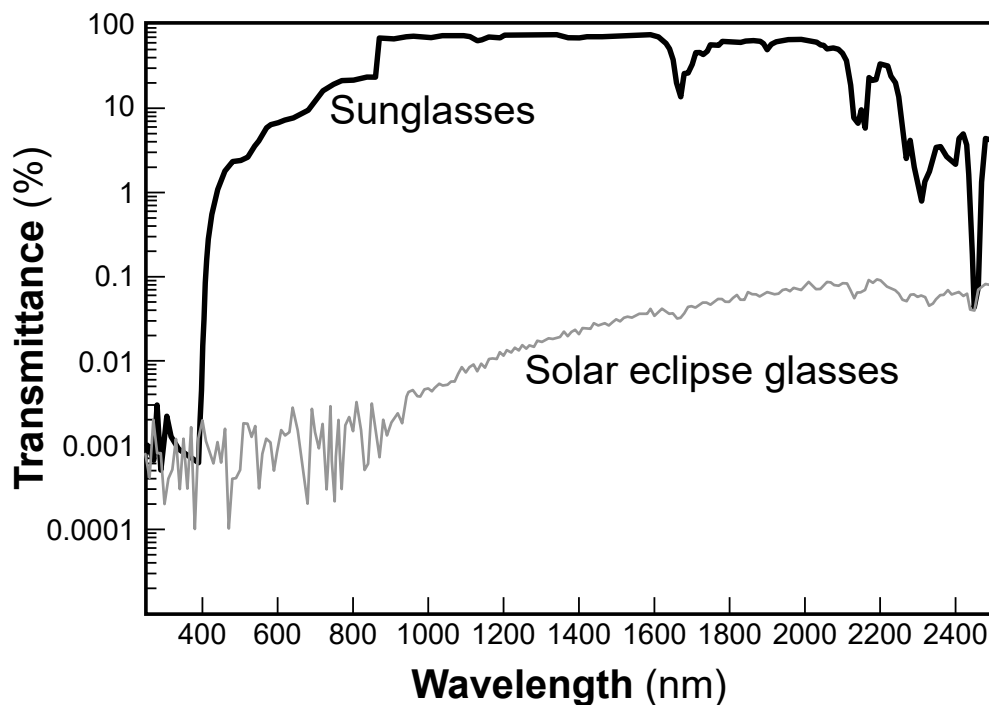
When compared to UV, this radiation is **A** and has **B** .

Row	A	B
(1)	less damaging	a longer wavelength
(2)	less damaging	a shorter wavelength
(3)	more damaging	a longer wavelength
(4)	more damaging	a shorter wavelength

Sunglasses and eclipse glasses were designed by engineers using materials that block an amount of light transmitted to the eyes. Everyday sunglasses typically block between 75% and 95% of visible light and must block at least 99% of UV light to be safe. Solar glasses block 99.9997% of all light from reaching the eyes.

Figure 1 shows a transmittance spectrum for two types of glasses. Transmittance is an indication of the amount of light that is not blocked at a specific wavelength. Prior to the eclipse, counterfeit eclipse glasses were manufactured and sold to unsuspecting consumers. These counterfeit glasses allowed transmittance similar to ordinary sunglasses and could damage the eyes if used to view the sun.

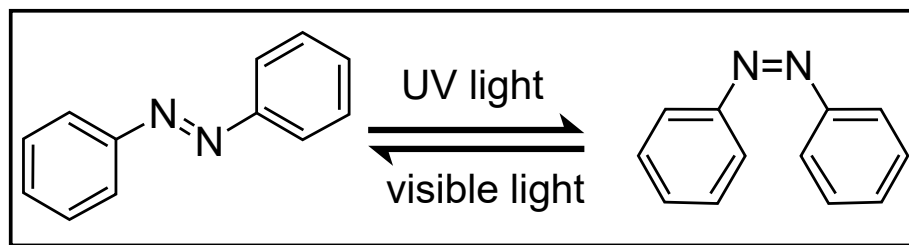
Figure 1: Transmittance of Sunglasses vs. Eclipse Glasses



- 12** Identify a solution by proposing a safe, at-home test *and* the expected results to determine if eclipse glasses are counterfeit. [1]

Exposure to UV radiation should be minimized to prevent harm to the skin. Sunscreen is a consumer product that protects the human body from this damaging portion of solar energy. Inorganic chemicals in sunscreen, such as iron(II) oxide (FeO), protect by absorbing, scattering, and reflecting UV light. Organic molecules are also used in sunscreen. When applied to skin, the chemical bonds in these organic molecules absorb energy, converting the UV light to heat and protecting the skin. Figure 2 represents this process.

Figure 2: Organic Molecule Transformation in Light



(Not drawn to scale)

13 Describe how the structure of the organic molecule in sunscreen supports its function. [1]

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Base your answers to questions 14 through 17 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Semiconductors

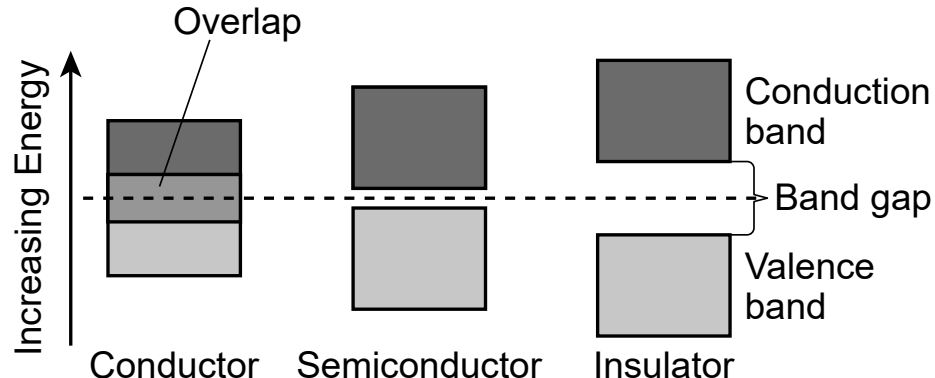
Semiconductors are used in many aspects of daily life, including computers, mobile devices, and medical imaging. They can be made from elements as well as from some compounds and mixtures. Many semiconductors involve Group 14 elements.

One measure of the ability to conduct is called band gap energy, which is the energy needed to excite an electron of an atom in a crystal so the electron becomes mobile and can conduct electricity. Materials that are considered insulators have band gap energies greater than three electron volts (eV). Figures 1 and 2 each provide some information about band gap energies.

Figure 1: Band Gap Energies of Selected Crystalline Forms of Group 14 Elements

Selected Group 14 Element	Band Gap Energy at 300 K (eV)
C (diamond)	5.47
Si	1.12
Ge	0.66
Sn	0.00

Figure 2: Band Gap Energies of Conductors, Semiconductors, and Insulators



- 14** Which statement identifies a relationship between conductivity and another property of the selected Group 14 elements at 300 K?
- (1) As the number of outermost electrons increases, the elements are better conductors.
 - (2) The element with the greatest atomic mass is the best insulator.
 - (3) Carbon is a good semiconductor because it has a band gap energy greater than three eV.
 - (4) Tin is a good conductor and has the largest atomic radius.

- 15** Make a claim that describes the relationship between first ionization energy and conductivity of the selected Group 14 elements. Cite evidence to support this claim. [1]

Claim: _____

Evidence: _____

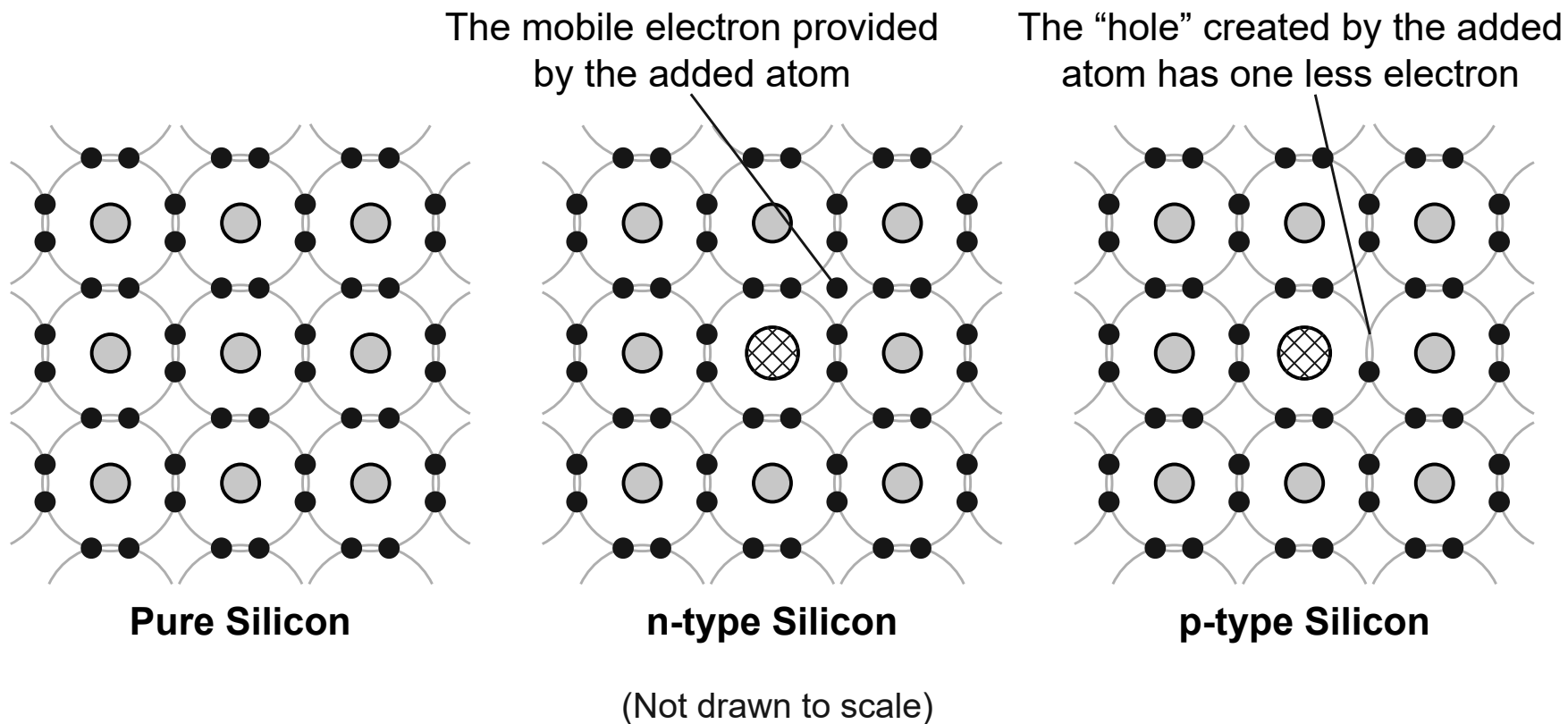
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Some compounds that can be used for semiconductors include silicon carbide (SiC), lead telluride (PbTe), bismuth selenide (Bi₂Se₃) and gallium arsenide (GaAs). Silicon is often used as a material for semiconductors, but its low electrical conductivity at room temperature is often enhanced by adding atoms of other elements into the silicon crystal lattice. This creates either an n-type semiconductor or a p-type semiconductor. Figure 3 shows the structure of pure silicon and two types of semiconductors.

Figure 3: Electrons in Silicon Atoms, n-type, and p-type Semiconductors

Key	
	Silicon
	Added Atom
	Electron



16 Based on the patterns of electrons in the outermost energy level, which element identifies the atoms in the given semiconductor compounds that have an oxidation state of +3?

- (1) arsenic
- (2) gallium
- (3) lead
- (4) selenium

- 17** Which row identifies elements that could be added to the silicon lattice to allow the material to function as each type of semiconductor?

Row	n-type	p-type
(1)	Sb	B
(2)	B	Al
(3)	Sb	P
(4)	Al	P

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Base your answers to questions 18 through 21 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Go With the Flow

Insulated containers were invented in the 1890s by Sir James Dewar. His container had a glass inner bottle for heat insulation, but it was heavy and fragile. Today's insulated containers are designed to improve temperature maintenance using a sealed layer of partial vacuum inside a glass layer, in an outer layer of metal, as shown in Figure 1. The partial vacuum layer is designed to be at a low pressure and contains almost no gas particles.

Engineers are also considering several other materials for use as insulating components in beverage containers, based on their specific heats and thermal conductivity. Figure 2 lists some of these components.

Figure 1: Insulated Container

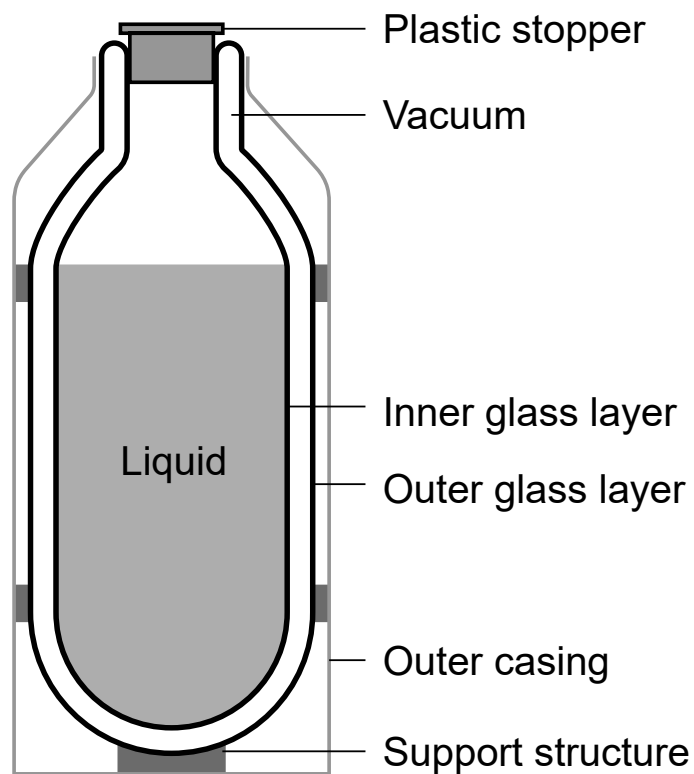


Figure 2: Thermal Properties of Selected Insulating Components

Component	Specific Heat (J/g•°C)	Thermal Conductivity (W/m•°C)
Air	1.005	0.024
Aluminum	0.897	205
Glass (borosilicate)	0.830	1.12
Plastic (polypropylene)	1.92	0.28
Steel (stainless 304)	0.500	16.2
Styrofoam (polystyrene)	1.13	0.033
Vacuum	≈ 0	0.006
Water	4.184	0.606

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18 Eventually, a hot liquid slowly begins to cool in an insulated container. Which claim explains how this happens?

- (1) Some heat is transferred from the glass layer to the liquid.
- (2) Some heat is transferred from the plastic stopper to the few atoms in the partial vacuum layer.
- (3) The few atoms in the partial vacuum layer gain heat energy and release it to the metal outer casing.
- (4) The few atoms in the partial vacuum layer transfer heat energy into the liquid.

19 Which claim identifies two components potentially used as insulation in a container and the properties of these components that minimize the transfer of heat energy?

- (1) Glass and plastic provide good insulating properties due to high specific heats.
- (2) Partial vacuum and water provide good insulating properties due to low specific heats.
- (3) Aluminum and stainless steel provide good insulating properties due to high thermal conductivity.
- (4) Air and Styrofoam provide good insulating properties due to low thermal conductivity.

Not all consumer products are designed to conserve energy by insulating the material inside. Some products are designed to generate or consume heat and allow heat transfer.

Hot and cold packs often contain a substance that, when dissolved, results in a heat transfer. The combination of specific components, with the safe use of the substances considered, creates a temperature change in a plastic package that can be applied to the surface of the skin.

Students were asked to research four potential compounds to be used in heat packs. Figure 3 provides published data for the heats of solution, ΔH .

Figure 3: Selected Compounds with Heats of Solution

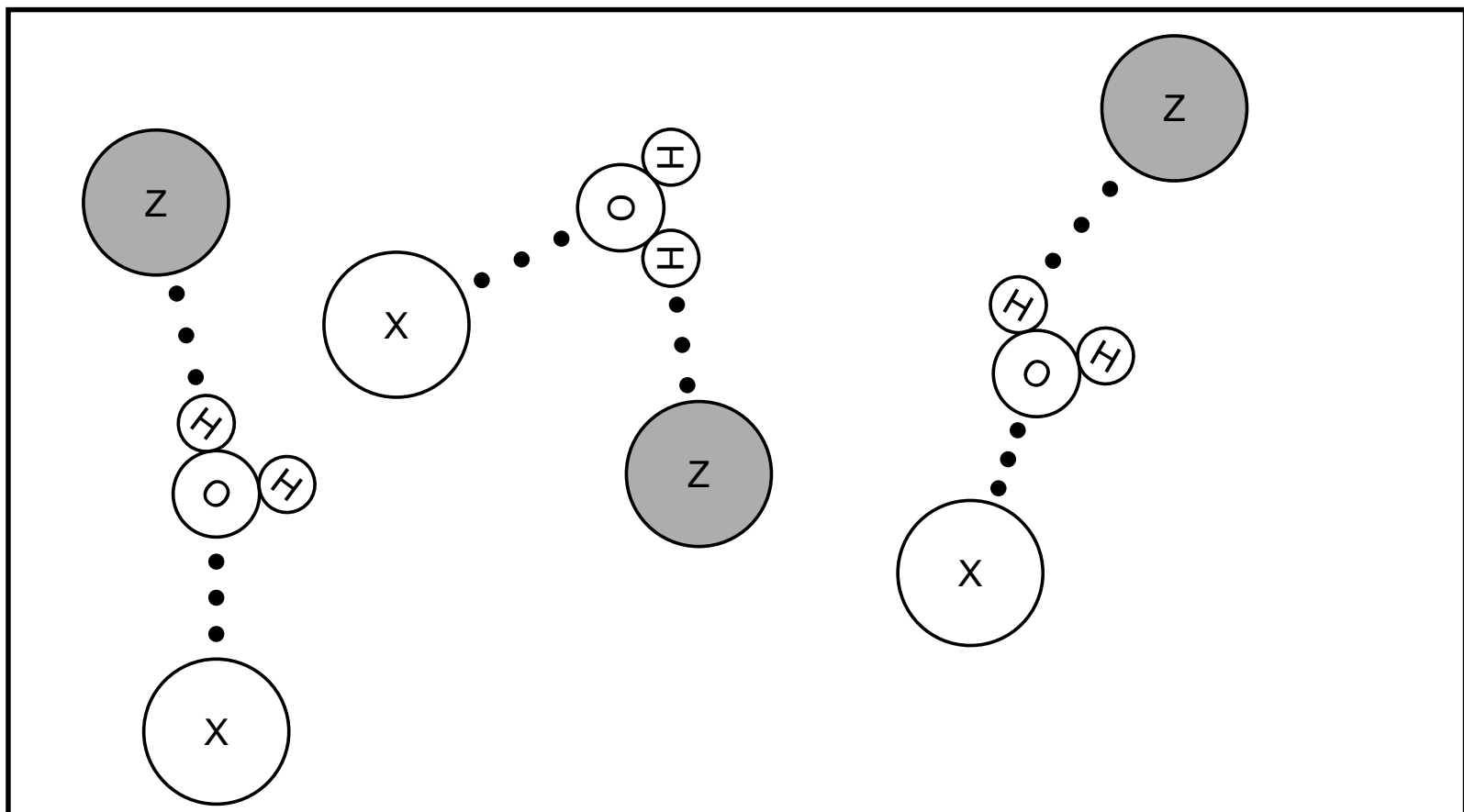
Compounds	Heats of Solution, ΔH (kJ/mol)
Sodium acetate ($\text{NaC}_2\text{H}_3\text{O}_2$)	-17.3
Ammonium nitrate (NH_4NO_3)	+25.7
Sodium carbonate (Na_2CO_3)	-26.7
Potassium nitrate (KNO_3)	+34.9

- 20** Make a claim about which compound would result in the highest solution temperature and justify this claim using evidence. (Assume equal molar concentrations and initial temperatures.) [1]

Claim: _____

Evidence: _____

- 21** Based on the information provided and the model below, which row in the table below correctly identifies the attractive forces between the ions and water in a solution?



(Not drawn to scale)

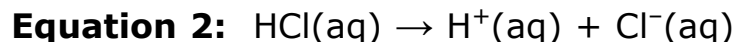
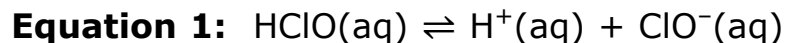
Row	X	Z
(1)	Nitrate ion	Potassium ion
(2)	Sodium ion	Acetate ion
(3)	Chloride ion	Carbonate ion
(4)	Ammonium ion	Sodium ion

Base your answers to questions 22 through 25 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Pool Water Chemistry

The quality of pool water is not always optimal after being covered for the winter. High levels of phosphate ions, PO_4^{3-} , increase algal growth. Phosphates form insoluble compounds with most metals. High concentrations of ions, such as calcium and magnesium, may combine with carbonate ions, CO_3^{2-} , in the water. This process forms precipitates that can lead to cloudiness in pool water. An increase in pH above the optimal range can also cause precipitates to form, resulting in cloudy water.

Aqueous chlorine compounds, including hypochlorous acid, $\text{HClO}(\text{aq})$, help to sanitize pools. Equation 1 represents the ionization of $\text{HClO}(\text{aq})$ in pool water. Diluted hydrochloric acid, $\text{HCl}(\text{aq})$, is sometimes added to pool water to stabilize the concentration of $\text{HClO}(\text{aq})$. Equation 2 represents the ionization of $\text{HCl}(\text{aq})$.



- 22** Which claim predicts how phosphates would affect the aqueous metallic ions present in pool water?
- (1) Calcium, magnesium, and sodium ions would form precipitates.
 - (2) Calcium and sodium ions would form precipitates, and magnesium ions remain dissolved.
 - (3) Calcium and magnesium ions would form precipitates, and sodium ions remain dissolved.
 - (4) Magnesium and sodium ions would form precipitates, and calcium ions remain dissolved.

23 To reduce cloudiness in a sample of pool water, the concentration of which ion should be increased?

- (1) calcium ion
- (2) magnesium ion
- (3) hydroxide ion
- (4) hydronium ion

24 Which claim explains how the addition of HCl(aq) will help to sanitize the pool?

- (1) The addition of the $\text{H}^+(\text{aq})$ will shift the equilibrium in Equation 1 to the right.
- (2) The addition of the $\text{H}^+(\text{aq})$ will shift the equilibrium in Equation 1 to the left.
- (3) The addition of the $\text{H}^+(\text{aq})$ will shift the equilibrium in Equation 2 to the right.
- (4) The addition of the $\text{H}^+(\text{aq})$ will shift the equilibrium in Equation 2 to the left.

Figure 1 provides the results of a water-quality test performed on pool water. Samples of the pool water were tested using four different indicators. Figure 2 provides information about each indicator used.

Figure 1: Results of Water Quality Test

Aspects of Pool Chemistry Tested	Results
pH	5.5
Calcium Hardness	500 ppm
Free Chlorine	0.5 ppm
Phosphates	0.01 ppm

Figure 2: Selected Acid-Base Indicators

Indicator	Color Change	pH Range
Methyl orange	red to yellow	3.1–4.4
Bromothymol blue	yellow to blue	6.0–7.6
Phenol red	yellow to pink	6.8–8.2
Bromocresol green	yellow to blue	3.8–5.4

- 25** Identify the color of the solution in each of the four samples after the indicators were added. [1]

Methyl Orange	Bromothymol Blue	Phenol Red	Bromocresol Green

Base your answers to questions 26 through 29 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

The ABCs of Ultraviolet Radiation

Ultraviolet (UV) radiation is one component of solar radiation. UV radiation exists in three forms: UVA, UVB, and UVC. Published research describes how UV radiation poses risks to both skin and eyes. UVA, which accounts for about 95% of ultraviolet radiation reaching Earth, increases melanin production and plays a major role in skin aging and wrinkling. UVB accounts for the remaining 5% of ultraviolet radiation reaching Earth. UVB causes damage to skin, including sunburns, and has a strong link to skin cancer. UVC has the greatest health risks but is mostly absorbed by the ozone layer. Figure 1 shows the characteristics of UV radiation.

Figure 1: Characteristics of UV Radiation

Type of UV Radiation	Wavelength (nm)
UVA	315–400
UVB	280–315
UVC	100–280

26 Which range of wavelengths identifies the solar radiation that is associated with sunburns?

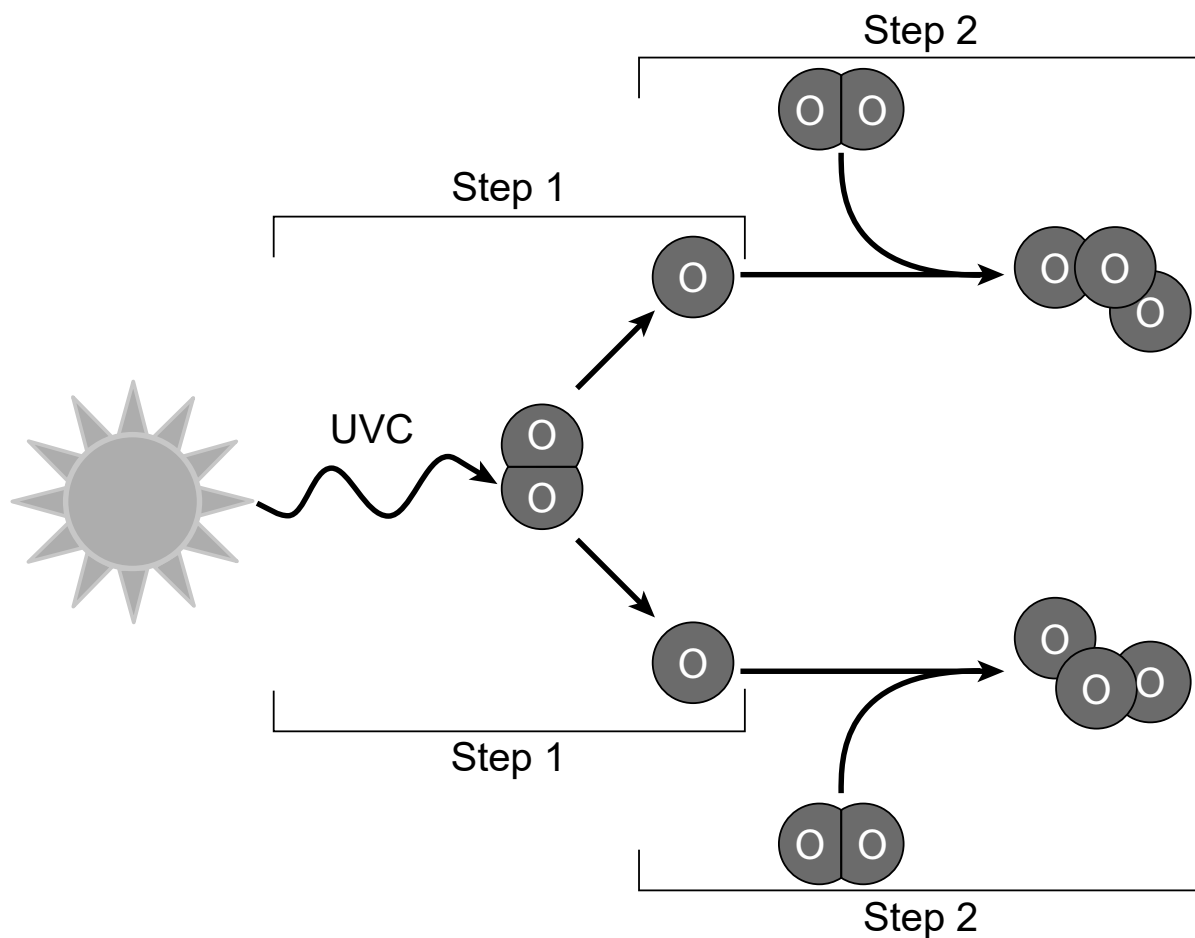
- (1) 325 nm–345 nm
- (2) 290 nm–310 nm
- (3) 255 nm–275 nm
- (4) 160 nm–180 nm

27 When comparing UVA and UVC, which statement describes how increased frequency of ultraviolet radiation affects human health?

- (1) UVA has a higher frequency with greater health risks.
- (2) UVA has a lower frequency with greater health risks.
- (3) UVC has a higher frequency with greater health risks.
- (4) UVC has a lower frequency with greater health risks.

Most UVC radiation is absorbed by the ozone layer in the stratosphere. However, high levels of ozone in the lower atmosphere may cause problems for individuals with health conditions that make breathing difficult. Air quality alerts are issued when ozone concentrations reach an unsafe level of 0.070 ppm. On June 26, 2019, a health alert was issued on Long Island when the ozone concentration exceeded the unsafe level by 0.003 ppm. Figure 2 illustrates the production of ozone in a multistep reaction in the stratosphere.

Figure 2: Stratospheric Ozone Production



(Not drawn to scale)

28 Which mathematical representation is used to determine the total mass of ozone contained in a 90.0 L sample of air (density = 1.29 g/L) that resulted in a health alert on June 26, 2019, on Long Island?

(1) $0.003 \text{ ppm} = \left(\frac{x}{70 \text{ g}} \right) \times 10^6$

(2) $0.003 \text{ ppm} = \left(\frac{x}{116 \text{ g}} \right) \times 10^6$

(3) $0.073 \text{ ppm} = \left(\frac{x}{70 \text{ g}} \right) \times 10^6$

(4) $0.073 \text{ ppm} = \left(\frac{x}{116 \text{ g}} \right) \times 10^6$

29 Use the model in Figure 2 to write a balanced equation to represent the reaction that results in the production of ozone. [1]

Balanced Equation: _____ $\rightarrow$ _____

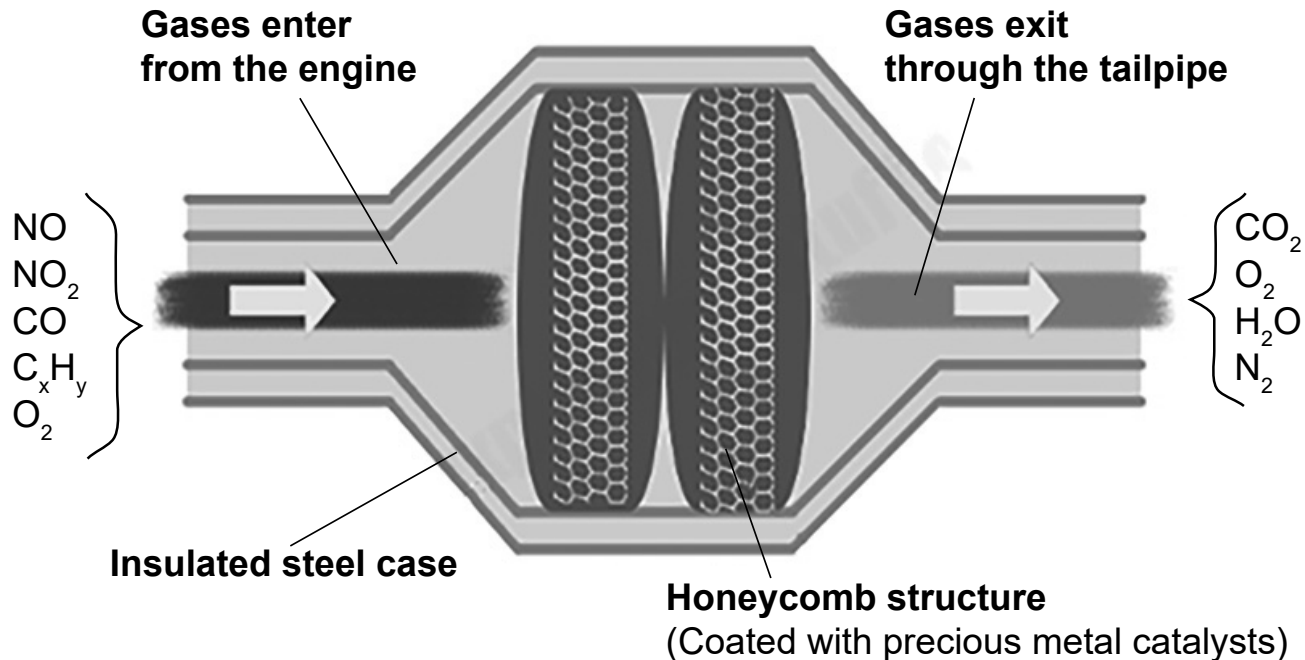
Base your answers to questions 30 through 33 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Catalytic Converter in Cars

In 1970, the Clean Air Act was passed to initiate requirements to lower emissions of pollutants. These pollutants include nitrogen monoxide (NO), nitrogen dioxide (NO_2), hydrocarbons (C_xH_y), and carbon monoxide (CO) from gasoline-powered cars. Catalytic converters were added to the exhaust system of cars to meet the global challenge of improving air quality.

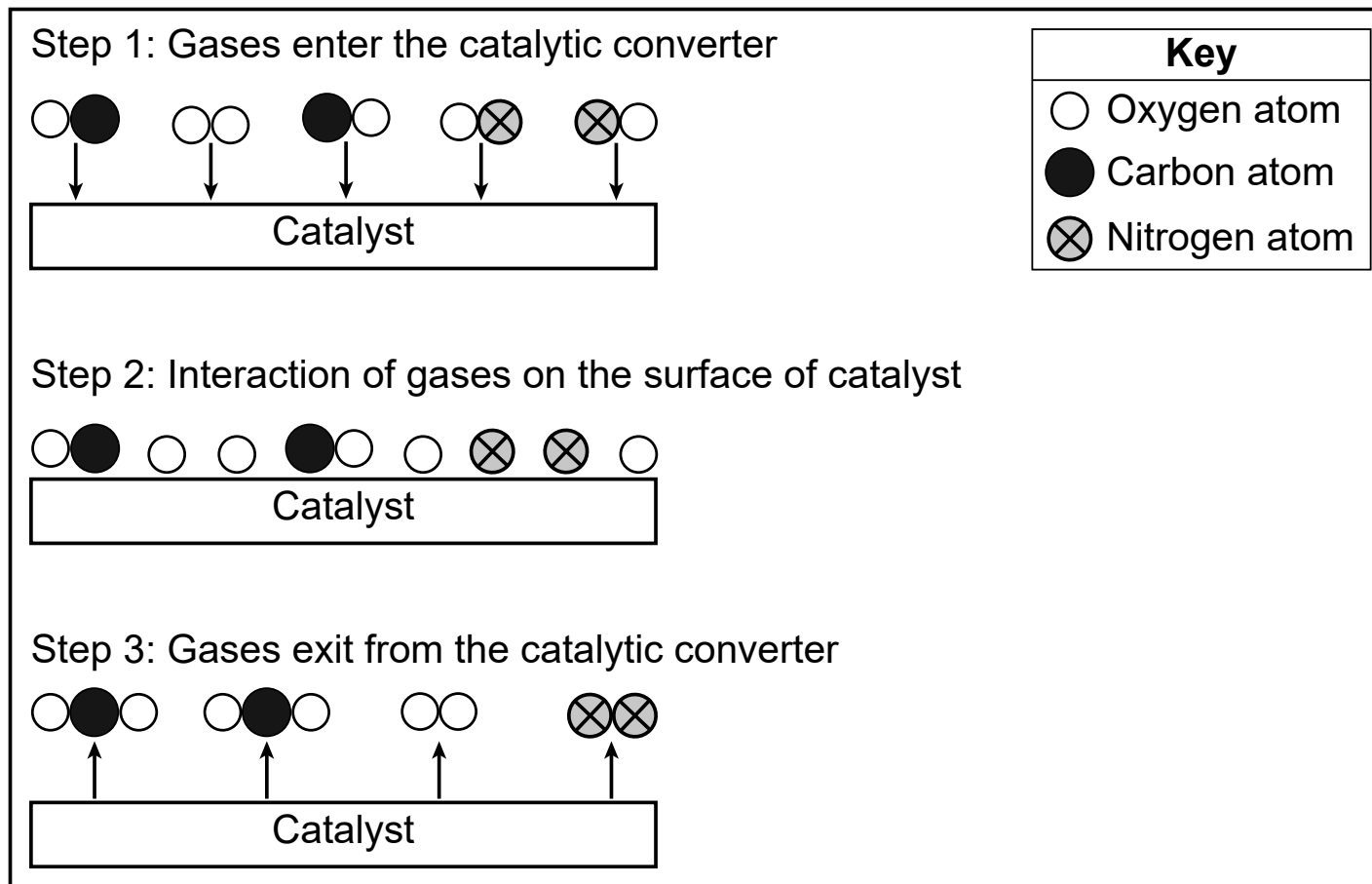
Figure 1 represents one type of catalytic converter. The precious metal catalysts are recycled at the end of their use due to their high economic value. On average, the operation of a typical passenger car releases 52.3 moles of $\text{CO}_2(\text{g})$ from the complete combustion of 1.0 liter of gasoline (C_8H_{18}) after the initial exhaust products have passed through the catalytic converter. Figure 2 represents the catalytic conversion of pollutants as shown on the next page.

Figure 1: Catalytic Converters



(Not drawn to scale)

Figure 2: Conversion of Catalytic Pollutants



(Not drawn to scale)

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30 Which description predicts how the rate of conversion of the exhaust gases is affected by the presence of a catalyst in a catalytic converter?

- (1) The rate of reaction decreases because the catalyst inhibits breaking the bonds in NO and in O₂ molecules.
- (2) The rate of reaction decreases because the catalyst inhibits breaking the bonds in O₂ and in N₂ molecules.
- (3) The rate of reaction increases because the catalyst promotes breaking the bonds in NO and in O₂ molecules.
- (4) The rate of reaction increases because the catalyst promotes breaking the bonds in O₂ and in N₂ molecules.

31 Use a mathematical representation to determine the mass of CO₂ gas product for the complete combustion of 1.0 liter of gasoline. [1]

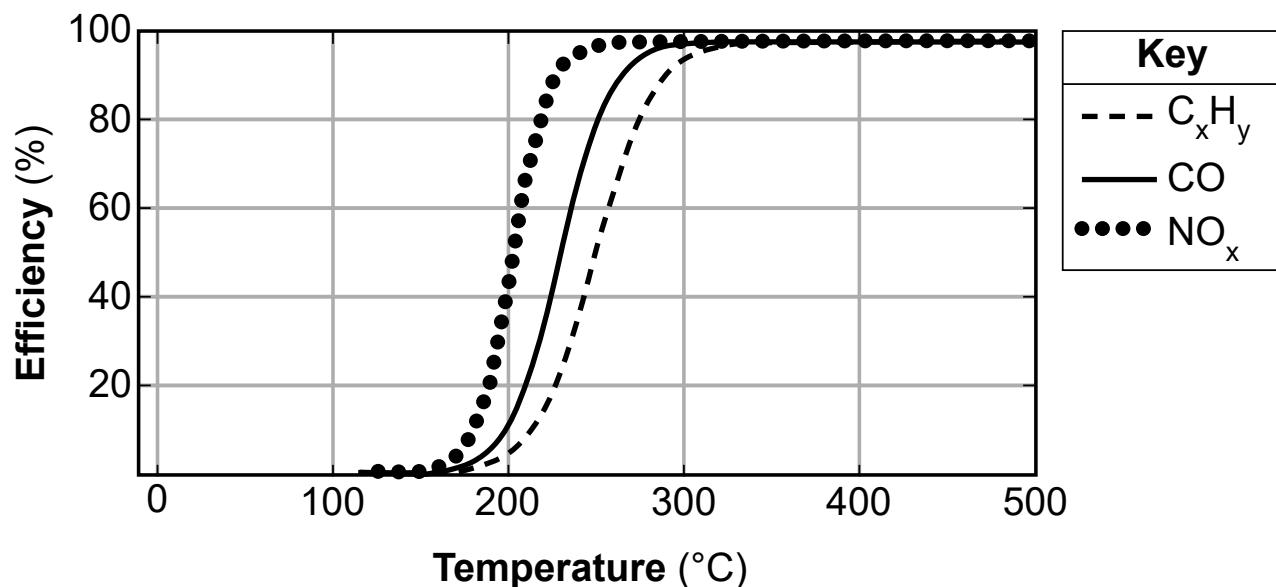
_____ **g CO₂**

Two of the reactions that occur in a catalytic converter involve decomposition of nitrogen oxides (NO_x), as represented in Equations 1 and 2.



Most pollution from an engine occurs right after starting. When the engine starts, the catalytic converter is still cold. Both the materials used and the temperature play an important role in the efficiency of the catalytic converter. Figure 3 represents this relationship.

Figure 3: The Conversion Efficiency of a Catalytic Converter



32 Which row represents how potential energy changes are modeled for Equation 1 and Equation 2?

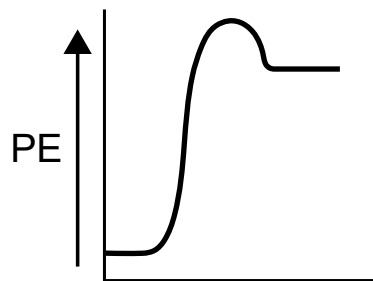


Diagram 1

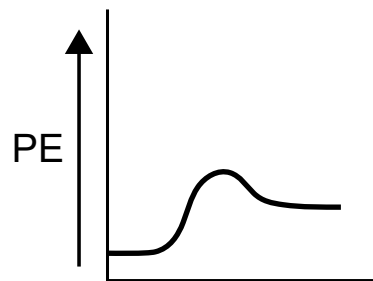


Diagram 2

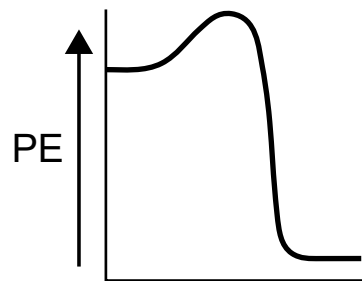


Diagram 3

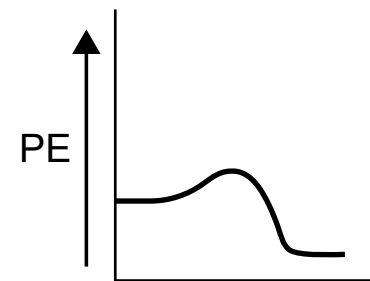


Diagram 4

Row	Equation 1	Equation 2
(1)	Diagram 1	Diagram 2
(2)	Diagram 2	Diagram 1
(3)	Diagram 3	Diagram 4
(4)	Diagram 4	Diagram 3

33 Which row predicts and describes how a change in temperature affects the rate of reactions and efficiency in a catalytic converter?

Row	Temperature Change (°C)	Efficiency	Effective Collisions	Rate of Reaction
(1)	250 to 350	Decrease	Decrease	Decrease
(2)	250 to 350	Increase	Increase	Increase
(3)	400 to 500	Increase	Increase	Increase
(4)	400 to 500	Decrease	Decrease	Decrease

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Base your answers to questions 34 through 38 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Get a Whiff of That!

Some people like wearing perfumes for a desirable scent. Perfumes are mixtures of natural or synthetic compounds, stabilizers, and solvents. Natural perfumes come from essential oils that are often extracted from plants and flowers. Different extraction methods are used depending on the desired product.

Steam extraction requires gaseous water to be passed through a container of the plant material. Essential oils with low mass in the material are carried by the steam and condensed in a separate container. Figure 1 represents how the mixture enters into a separator where the essential oil settles on top of the cooled water and can be collected.

Figure 1: Steam Extraction of Essential Oils

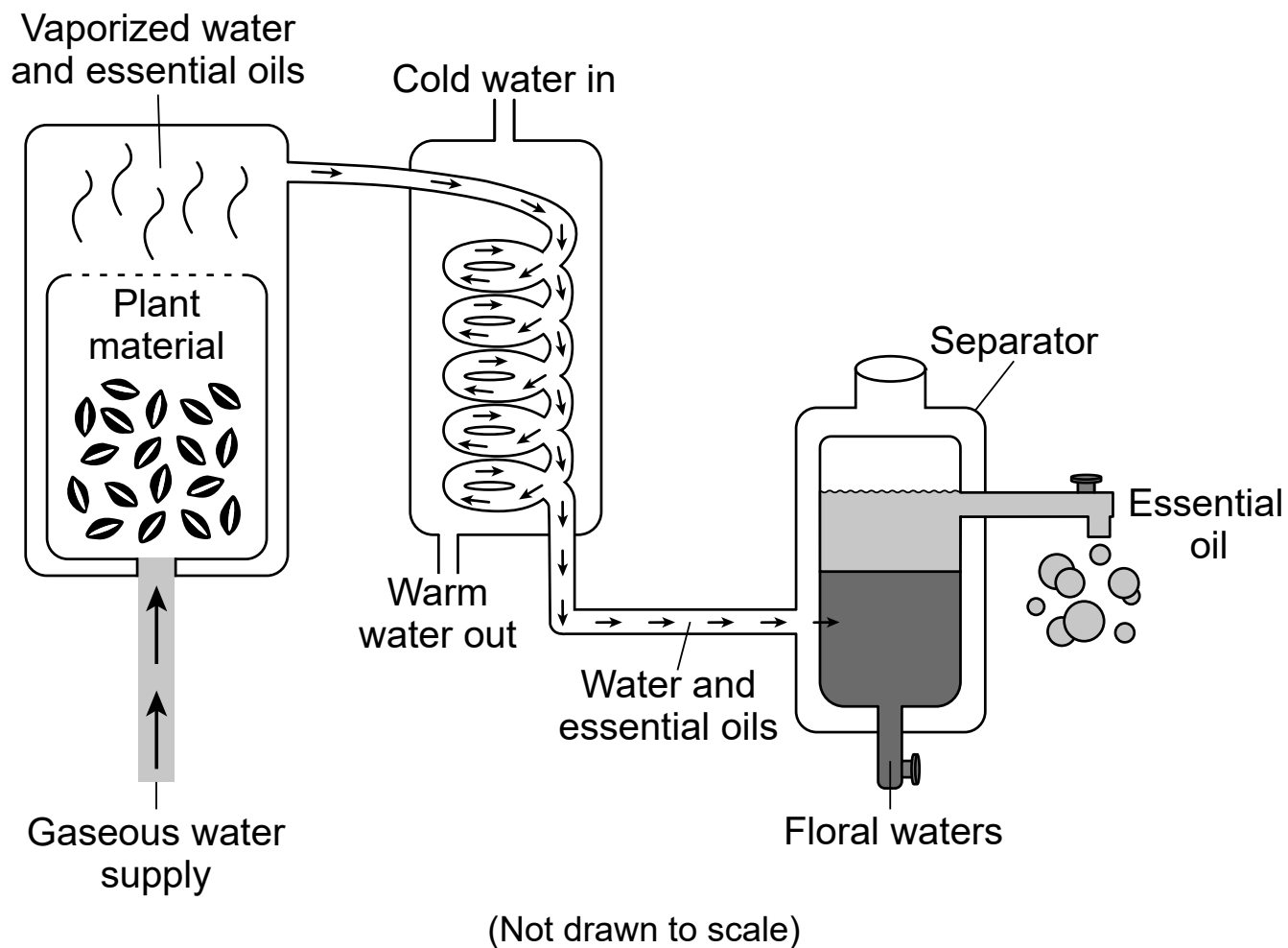


Figure 2: Selected Properties of Essential Oils

Essential Oil	Boiling Point (°C)	Density at 25°C (g/mL)	Odor
Rose	176	0.964	Floral
Lavender	204	0.882	Sweet herbal
Peppermint	215	0.898	Minty

- 34** Identify the polarity of the compounds in essential oils extracted from flowers and plants. Support your answer with evidence. [1]

Polarity of Compounds: _____

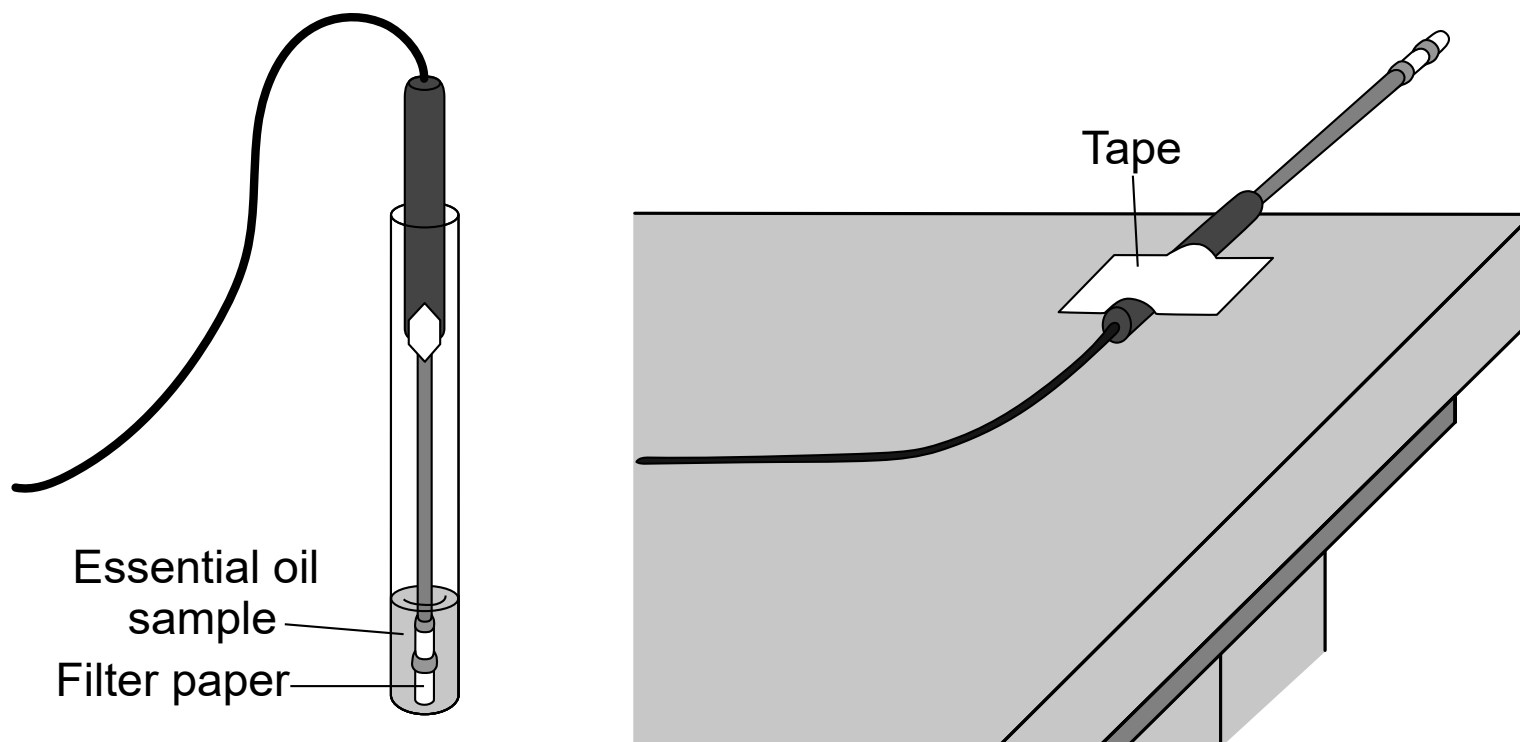
Evidence: _____

35 Which claim provides supporting evidence about the strength of the intermolecular forces in essential oils?

- (1) The peppermint oil has the strongest intermolecular forces and the highest boiling point at 215°C.
- (2) The peppermint oil has the weakest intermolecular forces of attraction and the weakest odor of mint.
- (3) The rose oil has the strongest intermolecular forces and the lowest density at 0.964 g/mL.
- (4) The rose oil has the weakest intermolecular forces of attraction and the weakest odor of floral.

A teacher demonstrated several differences between two essential oils by performing three demonstrations. First, the teacher wrapped a piece of filter paper around a temperature probe and dipped it into a test tube containing one of the essential oils and taped it to the lab bench. The temperature for each sample decreased. The relative size of the change in temperature was recorded.

Figure 3: Measuring Change in Temperature During Evaporation



Next, equal volumes of each essential oil were placed in similar containers. Over time, the volume of the samples decreased, but not equally. The relative rates were recorded.

Finally, the teacher dipped a temperature probe into a test tube containing Essential Oil A, left it there for three seconds, and then waved the probe through the air. The students measured the time it took for them to first notice the odor. The demonstration was then repeated with Essential Oil B. Table 1 provides a summary of all observations made during the demonstrations.

Table 1: Summary of Observations

	Essential Oil A	Essential Oil B
Change in Temperature	Small	Large
Rate of Evaporation	Slow	Fast
Time to Detect Odor	Long	Short

- 36** Place a check mark (✓) in the box to indicate the essential oil that has stronger intermolecular forces and provide evidence to support this choice. [1]

☐

Essential Oil *A*

☐

Essential Oil *B*

Evidence: _____

- 37** Which change describes what would occur if the demonstration was repeated with warmer samples of the essential oils?

- (1) The change in temperature would be greater and the rate of evaporation would increase.
- (2) The change in temperature would be greater and the rate of evaporation would decrease.
- (3) The change in temperature would be less and the rate of evaporation would increase.
- (4) The change in temperature would be less and the rate of evaporation would decrease.

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The fragrance of a perfume is related to the concentration of perfume oils in alcohol. The higher the concentration of the oil, the higher the purity of the fragrance. As the concentration increases, the scent of perfume will last longer.

Making perfume requires dissolving the essential oils into a carrier. The carrier is a solvent that holds the scent without interference. Ethyl alcohol is the preferred carrier used to dissolve the essential oils and create the perfumes. Figure 4 provides information about perfumes.

Figure 4: Perfume Concentrations

Classification	Perfume Number	Concentration of Essential Oils (percent by mass)	Lasting Power (hours)
Parfum	1	20–40	six to eight
Eau de Parfum	2	15–20	four to six
Eau de Toilette	3	5–15	three to four
Eau de Cologne	4	2–5	two

- 38** Construct a mathematical representation, using appropriate calculations, and determine the percent composition by mass of a perfume sample when 5.0 g of essential oil is combined with 25.0 g of alcohol. Show all work. Use this calculated value as evidence to place a check mark (✓) in the box to indicate the perfume number of the sample. [1]

Mathematical Representation

_____ %

Perfume
Number

1

☐

Perfume
Number

2

☐

Perfume
Number

3

☐

Perfume
Number

4

☐

Base your answers to questions 39 through 43 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Parade of Balloons

Balloons will float when filled with a gas less dense than air, like hydrogen or helium. Helium is preferred, due to safety considerations.

Parades often occur throughout the United States to celebrate holidays. These parades sometimes feature large balloons of various shapes. Parade balloons are filled early in the morning with helium and must stay afloat for many hours. The cost of balloons varies depending on the material from which the balloon is made and the ability to be reused. Parade balloons have been made of both vinyl and materials coated with urethane. Figure 1 provides information on balloon fabric types.

Figure 1: Information on Balloon Fabric Types

Fabric Type	Cost	Weight	Elasticity	Cold Weather Cracking	Valves Leaking
Vinyl	Low	Light	High	High probability	High probability
Urethane coated	High	Heavy	High	Low probability	Low probability

- 39** Describe how the pattern of electrons in the outermost energy level makes the preferred gas safer to use in filling balloons. [1]

- 40** Which statement identifies a criterion that supports using urethane-coated materials instead of vinyl in the production of parade balloons?

- (1) Urethane-coated balloons are heavy.
- (2) Urethane-coated balloons are highly elastic.
- (3) Urethane-coated balloons have a high probability of valves leaking.
- (4) Urethane-coated balloons have a low probability of cracking in the cold.

In the past 150 years, the lowest recorded Thanksgiving Day temperature in New York City was in 2018, while the highest was in 2007. The large balloons that are seen in the Thanksgiving Day parade can only fly if the weather conditions are appropriate.

A weather balloon rises through the atmosphere and collects data until it bursts and falls to Earth. A weather balloon containing 155 L of gas is released into the atmosphere from sea level at a standard pressure of 101.3 kPa where the temperature is 25°C. The balloon climbs to an altitude where the atmospheric pressure is 11.6 kPa, and reaches a maximum volume of 1172 L before bursting.

- 41** Which claim compares the relationship between the volume of a specific parade balloon and the temperature during the Thanksgiving Day parades in 2007 and 2018, assuming the same amount of helium gas was used both years?
- (1) In 2007, the volume was lower because the temperature was lower.
 - (2) In 2007, the volume was lower because the temperature was higher.
 - (3) In 2018, the volume was lower because the temperature was lower.
 - (4) In 2018, the volume was lower because the temperature was higher.

- 42** Construct a mathematical representation, using appropriate calculations, that could be used to determine the temperature at the point where the weather balloon bursts. Show all work. [1]

Mathematical Representation

Parade balloons require a large amount of helium to fill them. Helium formed from fusion in the Sun cannot be captured for use on Earth. Helium-4 is produced as a result of the first step of the nuclear decay of Uranium-238, which is found in rocks deep below Earth's surface.

- 43** Write an equation to model the first step of the nuclear decay of uranium that occurs in rocks deep below Earth's surface. Your answer must include a symbol and a mass number of each element. [1]
-

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Base your answers to questions 44 through 48 on the information below, on your knowledge of chemistry, and on the **2025 Edition Reference Tables for Physical Science: Chemistry**.

Safe Transport of Drinking Water

Water is delivered to homes for human consumption by way of pipes. Early civilizations constructed water-carrying pipes from lead due to its malleability and durability. Lead is susceptible to corrosion, forming lead(II) ions. The ions formed can enter drinking water and cause lead poisoning with serious health consequences when ingested.

In recent years, pipes carrying drinking water have been constructed from other materials in order to reduce this hazard. Figure 1 lists materials commonly used to construct pipes.

Figure 1: Pipe Material Information

Material	Characteristics	Composition
Lead	Very malleable; can cause health problems when ingested	Pb
Copper	Corrosion resistant; malleable; difficult to install	Cu
Stainless Steel	Heat and corrosion resistant; durable	Mixture of Fe, C, and other elements
PVC (polyvinyl chloride)	Corrosion resistant; lightweight; weakens in very hot water	Plastic (long chained molecules of C, H, and Cl)

44 Which evidence supports selection of the most ideal material for construction of pipes that carry drinking water?

- (1) Lead is more malleable than copper.
- (2) Copper is easier to install than PVC.
- (3) Stainless steel is more corrosion resistant than lead.
- (4) PVC is more heat resistant than stainless steel.

45 Write a balanced half-reaction to provide evidence that electrons are transferred during the formation of the ion from the metal used by early civilizations to construct water pipes. [1]

Half-reaction: _____

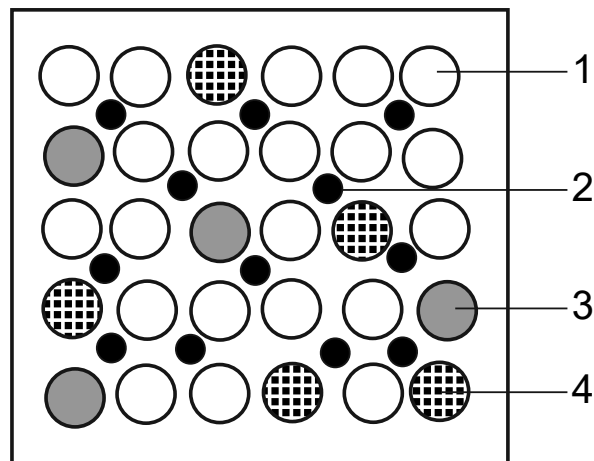
Pure iron is a malleable and reactive metal that has been used in pipes carrying water. The properties of iron can be improved when mixed with other elements to create an alloy. Alloys may be formed by the substitution of an atom, the trapping of atoms within a crystal, or a combination of both. Stainless steel is an alloy composed of iron, other metals, and carbon. Figure 2 provides information about some elements found in stainless steel.

Figure 2: Components of Stainless Steel

Component	Purpose	Atomic Radius (pm)	Ionization Energy (kJ/mol)
Carbon	Increases hardness and strength	75	1086
Chromium	Resists corrosion	130.	653
Copper	Resists corrosion in seawater or acidic environment	122	745
Iron	Abundant, inexpensive	124	762
Nickel	Resists corrosion, increases flexibility	117	737

Figure 3 illustrates the relative atomic radii of the components of one type of stainless steel, which are carbon, chromium, iron, and nickel.

Figure 3: Representation of Stainless Steel Composition



- 46** Place a check mark (✓) in the box to indicate the particle number that represents carbon. Cite evidence to describe how this particle changes the structure and, therefore, the function of the stainless steel. [1]

Particle Number: ☐ 1 ☐ 2 ☐ 3 ☐ 4

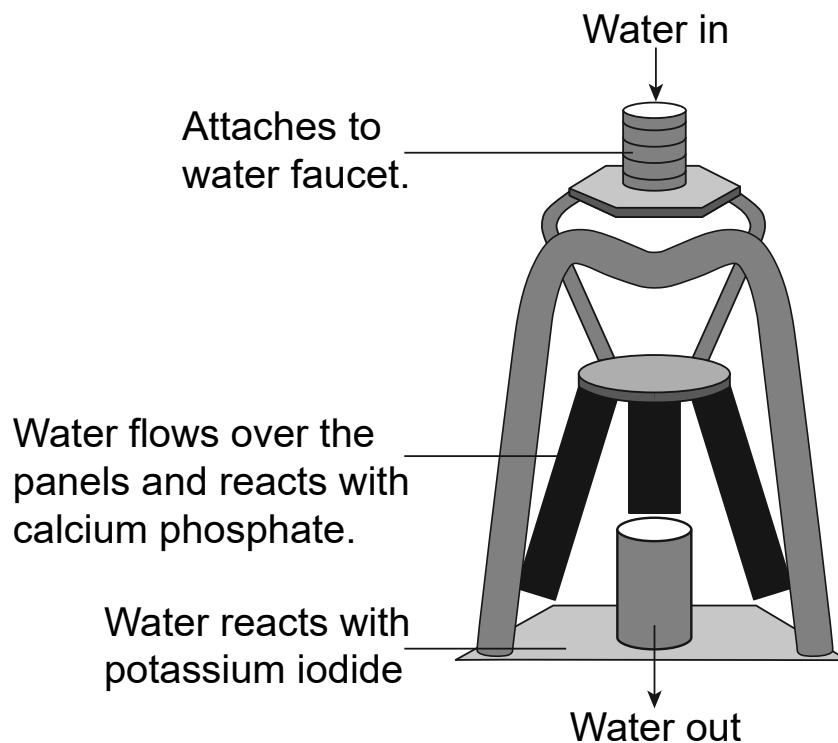
Structure: _____

Function: _____

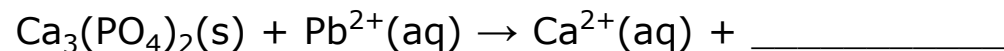
Precipitation is the most common method to remove lead(II) ions from water. A high-school chemistry class in Maryland developed a 3D-printed filter that attaches to a household water faucet to remove lead(II) ions. Figure 4 models this filter containing calcium phosphate, $\text{Ca}_3(\text{PO}_4)_2$ and potassium iodide, KI. The lead(II) ions react with calcium phosphate to produce a lead compound and calcium ions. Once the reaction capacity of the calcium phosphate is reached, lead(II) ions react with the potassium iodide. This produces a yellow precipitate of lead(II) iodide, PbI_2 , and the color change indicates to the homeowner that lead is present in the water.

Adjustments to the original design of the filter had to be made because calcium phosphate has a tendency to form large clumps, and this affected the rate of the reaction to remove lead ions from the water.

Figure 4: Cross Sectional Sketch of Water Filter



- 47** Given the incomplete unbalanced equation representing the reaction to remove the lead ions from the water, which chemical formula identifies the missing product?



- (1) $\text{PbPO}_4(\text{s})$
 - (2) $\text{Pb}_2\text{PO}_4(\text{s})$
 - (3) $\text{Pb}_2(\text{PO}_4)_3(\text{s})$
 - (4) $\text{Pb}_3(\text{PO}_4)_2(\text{s})$
- 48** Which statement predicts why the original design had to be modified?
- (1) The rate of the reaction decreased due to the decreased surface area.
 - (2) The rate of the reaction decreased due to the increased surface area.
 - (3) The rate of the reaction increased due to the increased surface area.
 - (4) The rate of the reaction increased due to the decreased surface area.

