Base your answers to questions 1 through 5 on the information below and on your knowledge of chemistry.

Smartphone Chemistry

Smartphones have become a part of our everyday lives and there is a significant amount of chemistry involved in their production.

Most smartphone display screens are made of aluminosilicate glass. This electrically conductive glass is composed of an oxide of silicon and aluminum with sodium ions dispersed throughout the surface. Some aluminosilicate glass is made stronger by immersing the glass in a bath of molten potassium salt at 400°C. This causes some sodium ions to be replaced by potassium ions. The potassium ions are compressed in the spaces between molecules in the glass. This makes the glass harder and more resistant to breakage, but less conductive.

Since glass is an insulator, the glass screen is coated with a layer of transparent indium tin oxide This layer is highly conductive and allows the screen to act as a conductive touch screen.

1 Which statement describes why positive ions in the molten salt replace ions in the aluminosilicate glass, resulting in the strengthening of the glass?

(1) Sodium and potassium have similar patterns of electrons in the outermost energy level and have the same number of occupied energy levels.
(2) Sodium and potassium have similar patterns of electrons in the outermost energy level and potassium is larger than sodium.
(3) Aluminum and silicon have similar patterns of electrons in the outermost energy level and have the same number of occupied energy levels.
(4) Aluminum and silicon have similar patterns of electrons in the outermost energy level and aluminum is larger than silicon.

2 Explain why the particulate-level structure of the glass prevents the potassium ions in the glass from functioning as a conductor. [1]

_____

_____

_____

A popular smartphone has a mass of 172 g and requires 10.32 g of aluminum to manufacture. Equation 1 represents a model of the overall chemical process used to obtain aluminum from the purified aluminum oxide.

Equation 1: $2Al_2O_3 + 3C \rightarrow 4Al + 3CO_2$

Some states are studying ways to require tech companies to build phones that follow clear repair and recycling standards. Recycling smartphones prevents contamination of land, water, and air, which could occur when smartphones are disposed of in a landfill. Recycling can also reduce the amount of raw materials mined and the energy used to manufacture new phones. Recycling is not always cost-effective because there are not enough valuable recyclable materials within a single smartphone. Although consumers prefer thinner smartphones, they are more challenging for recyclers to take apart. Larger phones tend to have longer battery life.

3 Construct a mathematical representation *and* calculate the number of grams of aluminum oxide required to produce the aluminum necessary to manufacture one smartphone. [1]

Mathematical Representation:
_____ **g**

4 A criterion that should be considered when designing smartphones to be more easily recyclable is to reduce the

(1) battery life
(2) size of the phone
(3) amount of valuable materials in the phone
(4) disposal of hazardous components in landfills

Most smartphones use rechargeable lithium ion batteries. The anode contains lithium embedded in a carbon matrix.

Figure 2 shows the equations representing the half-reactions and overall reaction that occur during the discharge of this type of battery.

Figure 2: Chemical Reactions During the Discharge of a Lithium Battery

Equations	
half-reaction 1	$CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$
half-reaction 2	$Li \rightarrow Li^+ + e^-$
overall-reaction	$Li + CoO_2 \rightarrow LiCoO_2$

5 Cite evidence from half-reaction 1 to demonstrate that there is a transfer of electrons. [1]

_____

_____

_____

Base your answers to questions 1 through 5 on the information below and on your knowledge of chemistry.

A Profitable Blueberry Field

Optimal blueberry growth occurs within a soil pH of 4.5 to 5.0. A blueberry farmer had the soil from a field tested. The results indicated that the soil had a hydronium ion concentration of 1.0×10^{-8} M. Figure 1 shows indicators that could be used to test soil pH.

One way farmers can optimize the soil for blueberry growth is by adding elemental sulfur. Equation 1 shows the process when bacteria in the soil oxidizes the sulfur.

Equation 1: $2S(s) + 3O_2(g) + 6H_2O(\ell) \rightarrow 4H_3O^+(aq) + 2SO_4^{2-}(aq)$

Figure 1: Indicators

Indicator	pH Range for Color Change	Color Change
alizarine yellow	10.2 – 12.0	yellow to red
bromcresol purple	5.2 – 6.8	yellow to purple
bromphenol blue	3.0 – 4.6	yellow to purple
congo red	3.0 – 5.0	blue-violet to red
methyl red	4.4 – 6.2	red to yellow

1 Which two indicators, when used independently, would provide results that, together, are suitable for evaluating soil pH to ensure optimal blueberry growth?

(1) alizarine yellow and bromcresol purple
(2) bromcresol purple and bromphenol blue
(3) bromphenol blue and congo red
(4) methyl red and alizarine yellow

2 Which row in the table completes the claim describing a possible cause and effect of adding elemental sulfur to the soil?

Adding elemental sulfur to the soil ___cause___, resulting in the ___effect___.

	Cause	Effect
(1)	increases the pH by 3	hydronium ion concentration decreasing by 1000
(2)	decreases the hydronium ion concentration by 1000	pH increasing by 3
(3)	decreases the pH by 3	hydronium ion concentration increasing by 1000
(4)	increases the hydronium ion concentration by 1000	pH decreasing by 3

The use of elemental sulfur can result in over-acidifying the soil. Using ammonium fertilizers such as ammonium sulfate ($(NH_4)_2SO_4$) as an alternative reduces this risk. The equations below demonstrate two ways in which ammonium ions contribute to soil acidification.

Equation 2: $NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

Equation 3: $NH_4^+(aq) + 2O_2(g) \rightarrow NO_3^-(aq) + H_2O(\ell) + 2H^+(aq)$

3 Identify the acid and the base when both water and ammonium fertilizer are added to soil. Compare the pattern of behaviors to explain why each substance is classified as an acid or a base. [1]

Acid: _____ Base: _____

Comparison of Behaviors: _____

_____

_____

4 How many grams of nitrogen are added to the soil when 100. grams of the substance that acidifies soil with reduced risk is applied?

(1) 10.6 g
(2) 12.3 g
(3) 21.2 g
(4) 24.6 g

5 Cite numerical evidence from Equation 3 to demonstrate the claim that atoms, and therefore mass, are conserved. [1]

Evidence: _____

_____

_____

Base your answers to questions 1 through 5 on the information below and on your knowledge of chemistry.

Evaluating Gas Stoves

New York State is the first state to institute a ban on stoves and furnaces that are powered by methane gas (CH_4) in new residential construction. Methane is a greenhouse gas that contributes to climate change.

Leaks from gas stoves and pipelines can be significant. Studies suggest that the warming potential from gas stoves is equivalent to the carbon emissions from 500,000 cars annually. Escaping gas from pipelines can release 6.5 million tons of methane a year. Repairing or replacing pipelines can cost millions of dollars.

1 A student incorrectly identifies the products of the combustion of methane as oxygen and water. Based on patterns of chemical properties, revise the student's explanation. [1]

2 Which gas has similar properties to the fuel being banned in new residential stoves and furnaces?

	Gas	Number of Bonds	Type of Bond
(1)	SiH_4	4	polar covalent, single
(2)	CO_2	4	nonpolar covalent, double
(3)	SF_6	6	polar covalent, single
(4)	N_2H_4	6	nonpolar covalent, double

Greenhouse gases have different global warming potentials (GWPs) due to the amount of each gas present, their ability to absorb energy, and the length of time each gas remains in the atmosphere. The difference between the amount of energy entering Earth's atmosphere and the amount of energy leaving is defined as Radiative Forcing. This represents the effect of a greenhouse gas on Earth's temperature over time.

Natural chemical processes occurring in the soil and air help to remove methane. This reduces the amount of time methane remains in the atmosphere relative to carbon dioxide.

Figures 1 and 2 provide information on selected greenhouse gases, GWP, and Radiative Forcing.

Figure 1: GWP of Various Greenhouse Gases Relative to CO_2 Over 100 Years

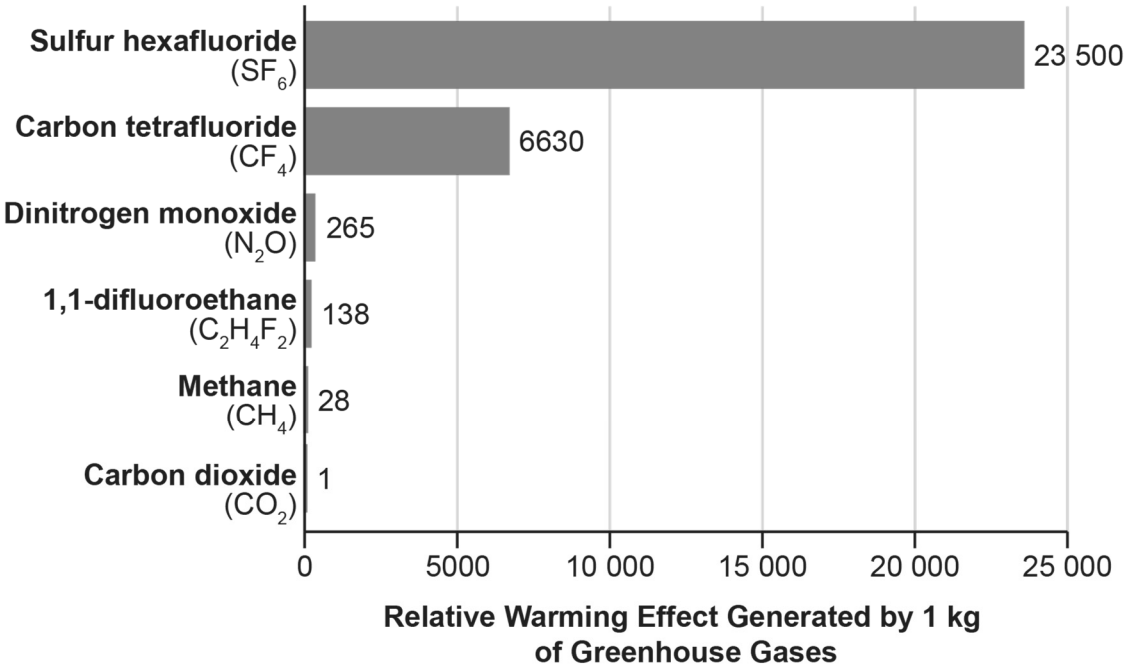
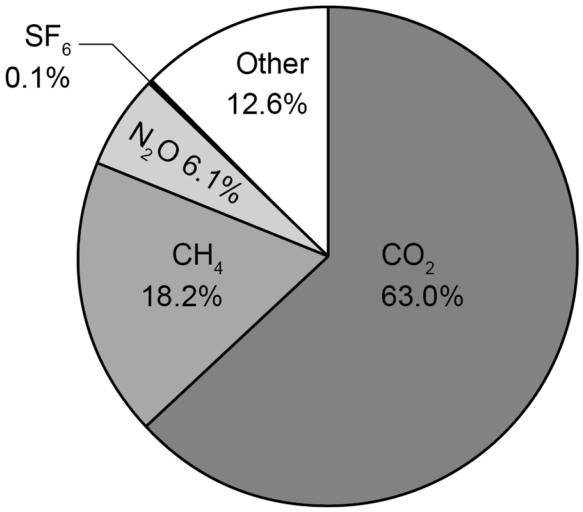


Figure 2: Radiative Forcing Since 1750



3 Choose and support a claim, citing *both* qualitative *and* quantitative evidence, to either promote or oppose limiting the use of methane as a way to reduce global warming. [1]

Circle your claim:

Methane use should not be limited

Methane use should be limited

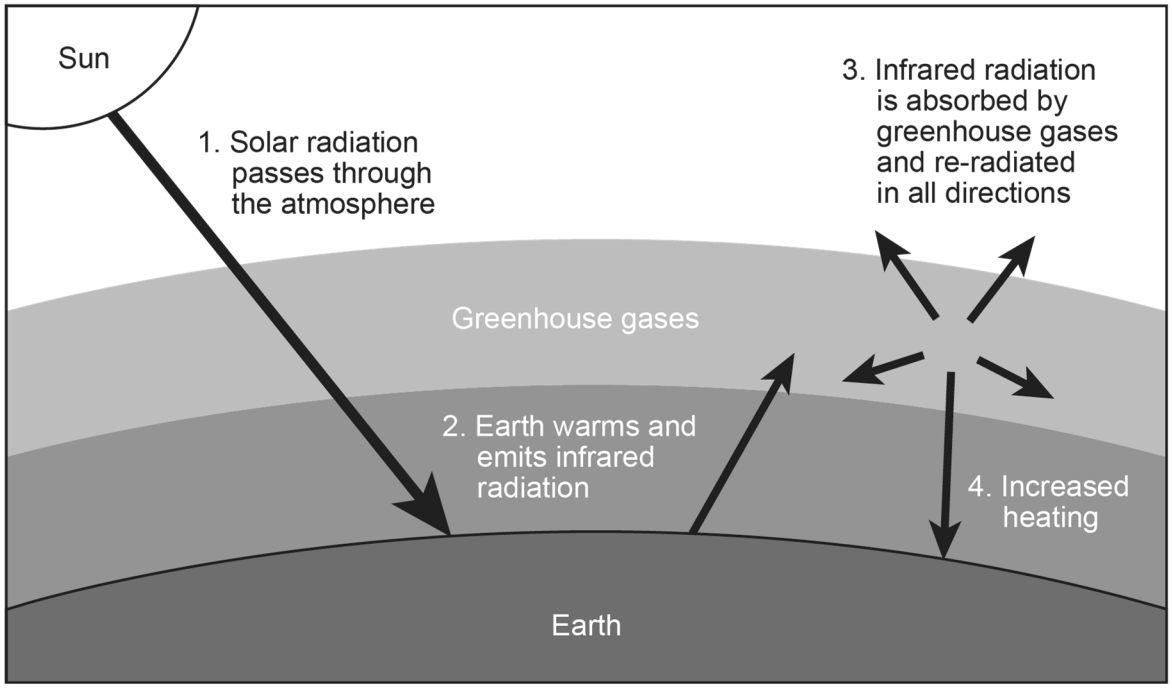
Evidence: _____

_____

_____

The greenhouse effect is the process that traps heat, which contributes to global warming. One method of addressing global warming is through reforestation. As trees grow, the chlorophyll in leaves helps to remove carbon from the atmosphere. Chlorophyll absorbs electromagnetic radiation that is mostly in the visible part of the spectrum.

Figure 3: Greenhouse Effect



4 Which statement compares the frequency and resulting energy of a photon absorbed by chlorophyll to the frequency and resulting energy of a photon emitted by greenhouse gases?

(1) A photon absorbed by chlorophyll has a higher frequency, resulting in more energy than a photon re-radiated by greenhouse gases.
(2) A photon absorbed by chlorophyll has a higher frequency, resulting in less energy than a photon re-radiated by greenhouse gases.
(3) A photon absorbed by chlorophyll has a lower frequency, resulting in more energy than a photon re-radiated by greenhouse gases.
(4) A photon absorbed by chlorophyll has a lower frequency, resulting in less energy than a photon re-radiated by greenhouse gases.

5 Select the components from each list to complete the equation that models the chemical reaction that addresses global warming through reforestation. [1]

Select Two Reactants

- ☐ CO_2
- ☐ CH_4
- ☐ $C_6H_{12}O_6$
- ☐ H_2O
- ☐ O_2

Select One Energy

- ☐ $\xrightarrow{\text{chemical energy}}$
- ☐ $\xrightarrow{\text{electromagnetic energy}}$
- ☐ $\xrightarrow{\text{nuclear energy}}$
- ☐ $\xrightarrow{\text{thermal energy}}$

Select Two Products

- ☐ CO_2
- ☐ CH_4
- ☐ $C_6H_{12}O_6$
- ☐ H_2O
- ☐ O_2