21.E: The p-Block Elements (Exercises)

Application Problems

1. Borax ($Na_2B_4O_5(OH)_4{\cdot}8H_2O$) is used as a flux during welding operations. As brass is heated during welding, for example, borax cleans the surface of Cu_2O and prevents further oxidation of the fused metal. Explain why borax is effective at cleaning the surface and preventing surface oxidation.
2. Extensive research is being conducted into using GaAs as a material for computer memory chips. It has been found, for example, that chips made from GaAs are up to 10 times faster than those made from silicon. Propose an explanation for this increase in speed.
3. Cement that has a high content of alumina (Al_2O_3) is particularly resistant to corrosion, so it is used for structures that must be resistant to seawater and acidic conditions. Why is this material so effective under these service conditions? Failure occurs under prolonged exposure to a hot, wet environment. Why?
4. Aluminum is light and ductile. If you were considering using aluminum rather than steel as a structural material for building a high-speed ferry, what disadvantages would you need to consider in using aluminum for these service conditions?
5. Life on Earth is based on carbon. A possible explanation is that no other element in the periodic table forms compounds that are so diverse in their chemistry and physical properties. Discuss the chemistry of carbon with regard to

    a. types of bonding.
    b. the states of matter of carbon compounds.
    c. the properties of elemental C.
    d. the reactivity of elemental C and its compounds.

    Then compare B, Al, Si, N, and P with C in terms of these properties.

6. After a traffic accident in which a tanker truck carrying liquid nitrogen overturned, a reporter at the scene warned of a danger to residents in the vicinity of the accident because nitrogen would react with hydrocarbons in the asphalt to produce ammonia gas. Comment on the credibility of this statement.
7. Nitrogen forms a hydride called hydrazoic acid (HN_3), which is a colorless, highly toxic, explosive substance that boils at 37°C. The thermal decomposition of one of its salts—NaN_3—is used to inflate automotive air bags. The N_3^- ion is isoelectronic with CO_2.

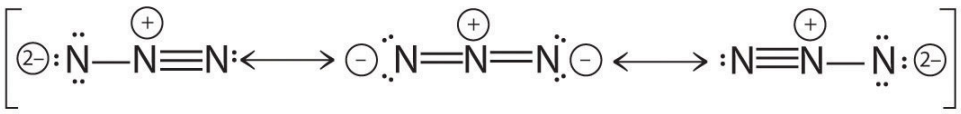
    a. Draw the Lewis electron structure of the N_3^- anion.
    b. Write a balanced chemical equation for the thermal decomposition of NaN_3.
    c. Based on your answer to part (b), propose an explanation for why many people have suffered skin burns when their air bags exploded.

8. Hydrazine (N_2H_4), a rocket fuel, is a colorless, oily liquid with a melting point of 1.4°C, and it is a powerful reducing agent. The physical properties of hydrazine presumably reflect the presence of multiple hydrogen-bond acceptors and donors within a single molecule. Explain the basis for this statement.
9. Because the N–C bond is almost as strong as the N–H bond, organic analogues of ammonia, hydrazine, and hydroxylamine are stable and numerous. Conceptually at least, they are formed by the successive replacement of H atoms by alkyl or aryl groups. Methylhydrazine and dimethylhydrazine, for example, were used as fuels in the US Apollo space program. They react spontaneously and vigorously with liquid N_2O_4, thus eliminating the need for an ignition source. Write balanced chemical equations for these reactions and calculate $\Delta G°$ for each reaction.
10. In an effort to remove a troublesome stain from a sink, a member of the cleaning staff of a commercial building first used bleach on the stain and then decided to neutralize the bleach with ammonia. What happened? Why?
11. A slow reaction that occurs on the ocean floor is the conversion of carbonate to bicarbonate, which absorbs CO_2. Write a balanced chemical equation for this reaction. Silicate sediments play an important role in controlling the pH of seawater. Given the reaction, propose a chemical explanation for this.
12. Marketing surveys have shown that customers prefer to buy a bright red steak rather than a dull gray one. It is known that NO combines with myoglobin to form a bright red NO complex. What would you add to beef during processing to ensure that this reaction occurs and yields the desired appearance?
13. Covalent azides are used as detonators and explosives. Ionic azides, in contrast, are usually much more stable and are used in dyestuffs. Why is there such a difference between these two types of compounds? The N_3^- ion is considered a pseudohalide. Why?

14. The heads of modern “strike anywhere” matches contain a mixture of a nonvolatile phosphorus sulfide (P_4S_3) and an oxidizing agent ($KClO_3$), which is ignited by friction when the match is struck against a rough object. Safety matches separate the oxidant and the reductant by putting $KClO_3$ in the head and a paste containing nonvolatile red phosphorus on the match box or cover. Write a balanced chemical equation for the reaction that occurs when a match is rubbed against the abrasive end of a matchbox.
15. Paris green was a common pigment in paints and wallpaper of the Napoleonic era. It is a mixed acetate/arsenite salt of copper with the formula $Cu_2(OAc)_2(AsO_3)$. In damp conditions, certain fungi are able to convert arsenite salts to volatile, toxic organoarsenic compounds. Shortly after his exile in 1815 to the remote island of St. Helena in the southern Atlantic Ocean, Napoleon died. As a forensic scientist investigating the cause of Napoleon’s mysterious death, you notice that the walls of his enclosed bedchamber are covered in green wallpaper. What chemical clues would you look for to determine the cause of his death?
16. Selenium, an element essential to humans, appears to function biologically in an enzyme that destroys peroxides. Why is selenium especially suited for this purpose? Would sulfur or tellurium be as effective? Why or why not?
17. One way to distinguish between fool’s gold (FeS_2, or iron pyrite) and real gold is to heat the sample over a fire. If your sample of “gold” were actually fool’s gold, what would happen?
18. Calcium hypochlorite is sold as swimming pool bleach. It is formed by the hydrolysis of Cl_2O, which gives only one product, followed by neutralization with lime [$Ca(OH)_2$]. Write balanced chemical equations for these reactions.
19. There is much interest in the superheavy elements beyond Z = 111 because of their potentially unique properties. Predict the valence electron configurations, preferred oxidation states, and products of the reaction with aqueous acid for elements 113 and 115.
20. Zeolites have become increasingly important in chemical engineering. They can be used as desiccants because the dehydrated zeolite absorbs small molecules, such as water. To be retained by the zeolite frame, a molecule must satisfy two conditions. What are they? Why can linear CO_2 and tetrahedral CH_4 not be held by a typical zeolite, even though they can penetrate it easily?

Answers

7. a. Three resonance structures for the azide ion may be reasonably drawn:



b. $2NaN_3(s) \xrightarrow{\Delta} 2Na(s) + 3N_2(g)$

c. One of the products of the decomposition of sodium azide is elemental sodium, which is highly reactive and can ignite in the presence of water and air.

15. Examine samples of Napoleon’s hair and/or fingernails from museums or collections to determine arsenic concentrations.

17. Upon heating, pyrite will react with oxygen to form $SO_2(g)$, which has a pungent smell.

19. Element 113: $5f^{14}6d^{10}7s^27p^1$, +1, $E^+(aq)$; element 115: $5f^{14}6d^{10}7s^27p^3$, +3, $E^{3+}(aq)$

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