

Chemistry Chapter 7 – Chemical Reactions and the Periodic Table

1. Give an explanation for each of the following observations:

- a) Many complex ions of zinc, such as $\text{Zn}(\text{CN})_4^{2-}$, exhibit a coordination number of four.
 - b) Complex ions of Fe(III), such as $\text{Fe}(\text{CN})_6^{3-}$, are paramagnetic.
-

2. (a) What is the pH of a 2.0 molar solution of acetic acid. K_a of acetic acid = 1.8×10^{-5}

(b) A buffer solution is prepared by adding 0.10 liter of 2.0 molar acetic acid solution to 0.1 liter of a 1.0 molar sodium hydroxide solution. Compute the hydrogen ion concentration of the buffer solution.

(c) Suppose that 0.10 liter of 0.50 molar hydrochloric acid is added to 0.040 liter of the buffer prepared in (b). Compute the hydrogen ion concentration of the resulting solution.

3. H_3PO_2 , H_3PO_3 , and H_3PO_4 are monoprotic, diprotic and triprotic acids, respectively, and they are about equal strong acids. HClO_2 , HClO_3 , and HClO_4 are all monoprotic acids, but HClO_2 is a weaker acid than HClO_3 which is weaker than HClO_4 .

Account for:

(a) The fact that the molecules of the three phosphorus acids can provide different numbers of protons

(b) The fact that the three chlorine acids differ in strengths.

4. A comparison of the theories Arrhenius, Brønsted and Lewis shows a progressive generalization of the acid base concept. Outline the essential ideas in each of these theories and select three reactions, one that can be interpreted by all three theories, one that can be interpreted by two of them, and one that can be interpreted by only one of the theories. Provide these six interpretations.

5. Give the formulas to show the reactants and the products for FIVE of the following chemical reactions.

Example: A strip of magnesium is added to a solution of silver nitrate.



a) a mixture of solid calcium oxide and solid tetraphosphorus decaoxide is heated.

b) solid barium peroxide is added to cold dilute sulfuric acid.

c) dilute acetic acid solution is added to solid magnesium carbonate.

d) the hydrocarbon hexane is burned in excess oxygen.

e) solid magnesium nitride is added to excess deuterium oxide.

f) gaseous hydrofluoric acid reacts with solid silicon dioxide

g) potassium dichromate solution is added to an acidified solution of sodium sulfite.

h) dilute hydrochloric acid is added to a solution of diamminesilver(I) nitrate

6. Explain why in aqueous solution,

- (a) Ti^{3+} is colored but Sc^{3+} is not.
 - (b) Ti^{2+} is a reducing agent but Ca^{2+} is not.
-

7. An excess of $AgNO_3$ solution was added to a solution that contained 1.65 grams of a chloride salt of an unknown element M. The $AgCl$ precipitate was filtered, dried, and found to weigh 2.49 grams. Further experiments showed that the ion of element M had a +3 oxidation state in the chloride salt.

- (a) Write a balanced equation for the reaction of $AgNO_3$ with MCl_3 .
 - (b) Calculate the percent of chlorine in MCl_3 .
 - (c) Calculate the atomic weight of the unknown element M.
-

4. A solution containing tin(II) ions is added to an acidified solution of potassium dichromate.

5. Liquid bromine is added to a solution of potassium iodide.

6. An excess of ammonia gas is bubbled through a solution saturated with silver chloride.

7. Water is added to a sample of pure sodium hydride.

8. An excess of chlorine gas is added to pure acetylene.

9. A dilute solution of sulfuric acid is electrolyzed between platinum electrodes.

10. Excess oxygen gas is mixed with ammonia gas in the presence of platinum.

11. Dilute nitric acid is added to crystals of pure calcium oxide.

12. A solution of sodium hydroxide is added to a solution of calcium hydrogen carbonate until the number of moles of sodium hydroxide added is twice the number of moles of the calcium salt.

9. Reactions requiring either an extremely strong acid or an extremely strong base are carried out in solvents other than water. Explain why this is necessary for both cases.

10. Answer FIVE of the eight options in this part. (Answer to more than five options will not be scored.)

(a) Solutions of sodium fluoride and dilute hydrochloric acid are mixed.

(b) A saturated solution of barium hydroxide is mixed with a solution of iron(III) sulfate.

- (c) A solution of ammonium sulfate is added to a potassium hydroxide solution.
- (d) Carbon dioxide gas is bubbled through a concentrated solution of sodium hydroxide.
- (e) Solid copper is added to a dilute nitric acid solution.
- (f) Chlorine gas is bubbled into a cold solution of dilute sodium hydroxide.
- (g) A solution of potassium permanganate is mixed with an alkaline solution of sodium sulfite.
- (h) Methyl iodine is heated with a solution of sodium hydroxide.

ANSWERS

- (a) $F^- + H^+ (H_3O^+) \rightarrow HF (+ H_2O)$
- (b) $Ba^{2+} + OH^- + Fe^{3+} + SO_4^{2-} \rightarrow BaSO_4 + Fe(OH)_3$
- (c) $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$
- (d) $CO_2 + OH^- \rightarrow CO_3^{2-} + H_2O$
- (e) $Cu + NO_3^- + H^+ \rightarrow Cu^{2+} + NO + H_2O$ (NO_2 , or other valid reduction product)
- (f) $Cl_2 + OH^- \rightarrow Cl^- + ClO^- (ClO_3^-) + H_2O$
- (g) $MnO_4^- + SO_3^{2-} + OH^- \rightarrow MnO_2 (MnO_4^{2-}) + SO_4^{2-}$
- (h) $CH_3I + OH^- \rightarrow CH_3OH + I^-$

11. Account for the difference in solubility described in each of the following experimental observations:

- (a) $BaCO_3$, $BaSO_3$, and $BaSO_4$ are only slightly soluble in water, but the first two dissolve in HCl solution whereas $BaSO_4$ does not.
- (b) CuS cannot be dissolved by warm, dilute HCl but it does dissolve in warm, dilute HNO_3
- (c) $AgCl$, Hg_2Cl_2 , and $PbCl_2$ are only slightly soluble in water, but $AgCl$ does dissolve in ammonia solution whereas the other two do not.
- (d) $Fe(OH)_3$ and $Al(OH)_3$ are only slightly soluble in water, but $Al(OH)_3$ dissolves in concentrated NaOH whereas $Fe(OH)_3$ does not.

ANSWERS

a) 3 points

Recognition that dissolution is favored by shift to right of equilibrium,
 $BaX(s) \rightleftharpoons Ba^{2+} + X^{2-}$

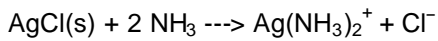
Recognition that conversions, $CO_3^{2-} \rightarrow HCO_3^-$ and $SO_3^{2-} \rightarrow HSO_3^-$ caused by H^+ , result in greater solubility of the carbonate and sulfite

Recognition that H^+ does not react appreciably with SO_4^{2-} , so as to increase the solubility of the sulfate, since SO_4^{2-} is a poor base (or equivalent)

b) 1 point

The sulfide ion is oxidized by warm nitric acid, shifting $CuS(s) \rightleftharpoons Cu^{2+} + S^{2-}$ to the right.

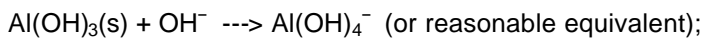
c) 2 points



Recognition that NH_3 complexes Ag

Recognition of $Ag(NH_3)_2^+$ complex and that Hg_2^{2+} and Pb^{2+} do not form soluble ammine complexes

d) 2 points



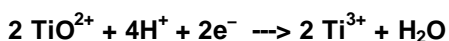
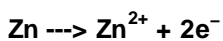
$Fe(OH)_3$ does not react in this way.

Recognition of amphoterism of $Al(OH)_3$

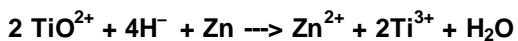
12. Titanium can be reduced in acid solution from TiO^{2+} to Ti^{3+} with zinc metal. Write a balanced equation for the reaction of TiO^{2+} with zinc in acid solution.

ANSWER: (Another highly probable one. MEMORIZE)

a) one point



The sum of the equations above is:



13. (a) Sodium metal is added to water.

(b) Dilute sulfuric acid is added to a solution of lithium hydrogen carbonate.

(c) Ethanol and formic acid (methanoic acid) are mixed and warmed.

(d) Excess concentrated potassium hydroxide solution is added to a precipitate of zinc hydroxide.

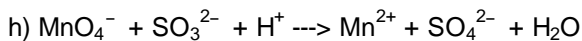
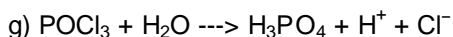
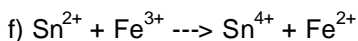
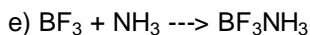
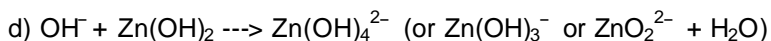
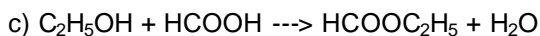
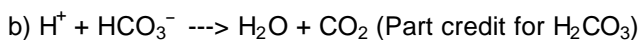
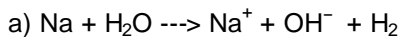
(e) The gases boron trifluoride and ammonia are mixed.

(f) A solution of tin(II) chloride is added to a solution of iron(III) sulfite.

(g) Phosphorus(V) oxytrichloride is added to water.

(h) An acidified solution of sodium permanganate is added to a solution of sodium sulfite.

ANSWER:



HSO_3^- and HSO_4^- were accepted.

14. Properties of the chemical elements often show regular variations with respect to their positions in the periodic table.

(a) Describe the general trend in acid-base character of the oxides of the elements in the third period (Na to Ar). Give examples of one acidic oxide and one basic oxide and show with equations how these oxides react with water.

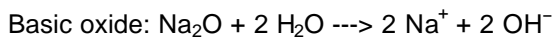
(b) How does the oxidizing strength of the halogen elements vary down the group? Account for this trend.

(c) How does the reducing strength of the alkali metals vary down the group? Account for this trend.

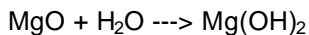
ANSWER

a) three points

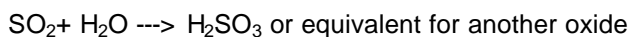
Oxides at left are basic and become less basic: more acidic as one moves to the right.



or



Acidic oxide: any one of the oxides of Cl, S, or P



(Both examples with no equations 1 point)

b) two points

Oxidizing strengths of halogen elements decrease down the group.

Since atoms get larger down the group, the attraction for e^- decreases and oxidizing strength increases

c) two points

Reducing strengths of alkali metals increases down the group.

Since atoms get larger down the group, loss of outer electrons is easier and reducing strength increases.

15. (a) Solutions of sodium iodide and lead nitrate are mixed.

(b) A solution of ammonia is added to a solution of ferric chloride.

(c) A solution of hydrogen peroxide is heated.

(d) Solutions of silver nitrate and sodium chromate are mixed.

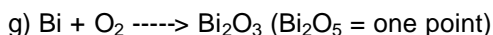
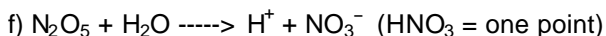
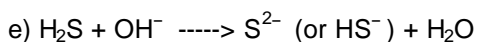
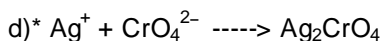
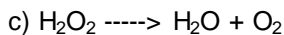
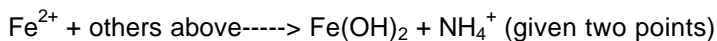
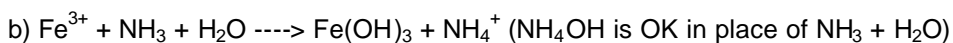
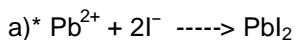
(e) Hydrogen sulfide gas is bubbled through a solution of potassium hydroxide.

(f) Solid dinitrogen pentoxide is added to water.

(g) A piece of solid bismuth is heated

(h) A strip of copper metal is added to a concentrated solution of sulfuric acid.

ANSWERS:



h) $\text{Cu} + \text{H}^+ + \text{HSO}_4^-$ (or SO_4^{2-}) $\rightarrow \text{Cu}^{2+} + \text{SO}_2 + \text{H}_2\text{O}$ (any two products is given one point; all three must be there for 3 points; omitting H^+ and/or H_2O is minus one point)

16. (a) For the diprotic acid H_2S , the first dissociation constant is larger than the second dissociation constant by about 10^5 ($K_1 = 10^5 K_2$).

(b) In water, NaOH is a base, but HOCl is an acid.

(c) HCl and HI are equally strong acids in water but, in pure acetic acid, HI is a stronger acid than HCl .

(d) When each is dissolved in water, HCl is a much stronger acid than HF .

ANSWER:

a) two points

After the first H^+ is lost from H_2S , the remaining species, HS^- , has a negative charge. This increases the attraction of the S atom for the bonding electrons in HS^- . The bond is therefore stronger, H^+ is harder to remove, and K_2 is lower.

b) two points

Polar H_2O can separate ionic NaOH into Na^+ (aq) and OH^- (aq) giving a basic solution. In HOCl , chlorine has a high attraction for electrons due to its greater charge density. This draws electrons in the HO bond towards it and weakens the bond. H^+ can be removed, making an acid solution.

c) two points

Water is a more basic solvent (greater attraction for H^+) and removes H^+ from Cl^- and I^- equally.

Acetic acid has little attraction for H^+ but the H^+ separates from the larger I^- easier than from the smaller Cl^- .

d) two points

The bond between H and Cl is weaker than the bond between H and F. HCl is therefore a stronger acid.

17. (a) Ethanol is burned in oxygen.

(b) Solid barium oxide is added to distilled water.

(c) Chlorine gas is bubbled into a cold, dilute solution of potassium hydroxide.

(d) A solution of iron(II) nitrate is exposed to air for an extended period of time.

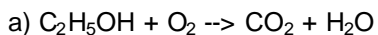
(e) Excess concentrated sulfuric acid is added to solid calcium phosphate.

(f) Hydrogen sulfide gas is bubbled into a solution of mercury(II) chloride.

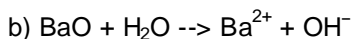
(g) Solid calcium hydride is added to distilled water.

(h) A bar of zinc metal is immersed in a solution of copper(II) sulfate.

ANSWER



CO acceptable as oxidized form of carbon
C acceptable as product if accompanied by CO or CO_2



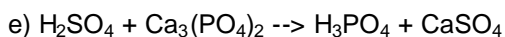
Only 1 product point awarded for $Ba(OH)_2$



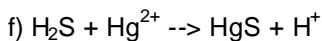
both an oxidized and a reduced form of Cl necessary for 2 product points
 H_2O not necessary as product
both ClO^- and ClO_2^- acceptable as oxidized forms of Cl 1 point deducted if acidic products shown (e.g., H^+ , $HClO$, HCl)



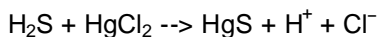
Fe^{3+} , $Fe^{3+} + OH^-$, and FeO_2 or Fe_3O_4 awarded only 1 product point



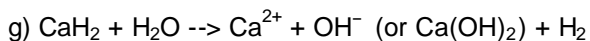
no ionized form of H_3PO_4 acceptable
 $CaSO_4$ may appear as $Ca^{2+} + SO_4^{2-}$, or $Ca^{2+} + HSO_4^-$, or $Ca(HSO_4)_2$



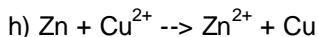
OR



If reactant is $HgCl_2$, products must include Cl^-



no ionized form of CaH_2 is acceptable; no H^- as a reactant



18. Define oxidation and reduction in terms of electron transfer. Illustrate your answer by reference to the reactions which take place between the following pairs of substances in aqueous solutions:

(a) Iodine and hydrogen sulfide

(b) Bromine and iron(II) sulfate

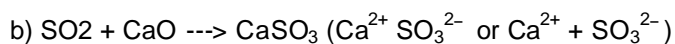
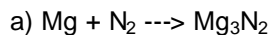
1. equimolar amounts of trisodium phosphate and hydrogen chloride, both in solution, are mixed.

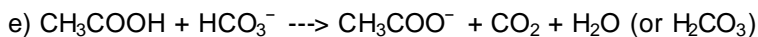
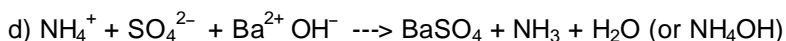
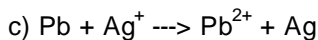
2. propene gas is mixed with bromine vapor.
3. solid aluminum nitrate is dissolved in water.
4. solutions of potassium iodide, potassium iodate, and dilute sulfuric acid are mixed.
5. a solution of tin(II) sulfate is added to a solution of iron(III) sulfate.
6. a suspension of copper(II) hydroxide is treated with an excess of ammonia water.
7. a saturated solution of calcium hydroxide is added to a solution of magnesium chloride.
8. solid silver sulfide is warmed with dilute nitric acid.

-
- (a) Solid calcium oxide is exposed to a stream of carbon dioxide gas.
 - (b) Dinitrogen trioxide gas is bubbled into water.
 - (c) Sodium hydrogen carbonate is dissolved in water.
 - (d) Pellets of lead are dropped into hot sulfuric acid.
 - (e) Potassium permanganate solution is added to a solution of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, acidified with a few drops of sulfuric acid.
 - (f) Magnesium turnings are added to a solution of iron(III) chloride.
 - (g) Ethyl acetate is treated with a solution of sodium hydroxide.
 - (h) A suspension of zinc hydroxide is treated with concentrated sodium hydroxide solution.

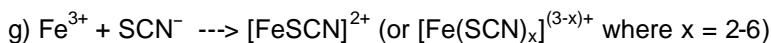
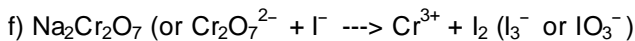
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- a) Magnesium metal is burned in nitrogen gas.**
 - (b) Sulfur dioxide gas is passed over solid calcium oxide.**
 - (c) Lead foil is immersed in silver nitrate solution.**
 - (d) A solution of ammonium sulfate is added to a saturated solution of barium hydroxide.**
 - (e) Acetic acid solution is added to a solution of sodium hydrogen carbonate.**
 - (f) Solid sodium dichromate is added to an acidified solution of sodium iodide.**
 - (g) A drop of potassium thiocyanate is added to a solution of iron(III) chloride.**
 - (h) Ethanol is completely burned in air.**

ANSWER:

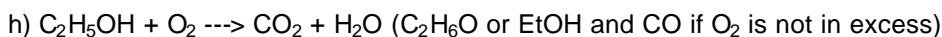
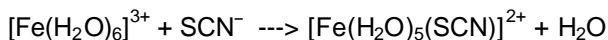




(Somewhat suprising to the ChemTeam, the answer sheet indicated that HAc or HOAc were accepted for acetic acid and Ac^- : or OAc^- for acetate. Hmmmmm.)



or



(a) A piece of lithium metal is dropped into a container of nitrogen gas.

(b) Dilute hydrochloric acid is added to a solution of potassium sulfite.

(c) Solid sodium oxide is added to water.

(d) A solution of sodium sulfide is added to a solution of zinc nitrate.

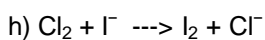
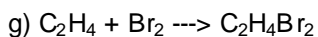
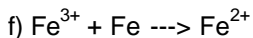
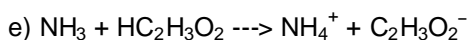
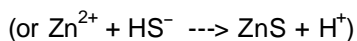
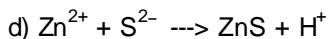
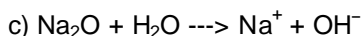
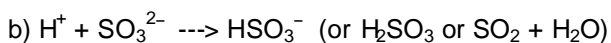
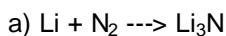
(e) A solution of ammonia is added to a dilute solution of acetic acid.

(f) A piece of iron is added to a solution of iron(III) sulfate.

(g) Ethene (ethylene) gas is bubbled through a solution of bromine.

(h) Chlorine gas is bubbled into a solution of potassium iodide.

ANSWER:



Notes:

- 1) 3 points; one for reactants and 2 for products
- 2) 2 of 3 points for correct responses in inappropriate form, e.g. molecular when it should be ionic
- 3) 1 point penalty for spurious product, e.g. redox products in acid-base reaction
- 4) 1 point penalty for inclusion of spectator ions (only once per paper)



Oxyacids, such as those above, contain an atom bonded to one or more oxygen atoms; one or more of these oxygen atoms may also be bonded to hydrogen.

(a) Discuss the factors that are often used to predict correctly the strengths of the oxyacids listed above.

(b) Arrange the examples above in the order of increasing acid strength.

ANSWER:

a) four points

1. As effective nuclear charge on central atom increases, acid strength increases.

OR

As number of lone oxygen atoms (oxygen atoms not bonded to hydrogen) increases, acid strength increases.

OR

As electronegativity of central atom increases, acid strength increases.

2. Loss H^+ by neutral acid molecules reduces acid strength.

OR

K_a of $\text{H}_2\text{SO}_3 > K_a$ of HSO_3^-

b) four points

$\text{H}_3\text{BO}_3 < \text{HSO}_3^- < \text{H}_2\text{SO}_3 < \text{HClO}_3 < \text{HClO}_4$

H_3BO_3 or HSO_3^- weakest (must be together)

HClO_3 weaker than HClO_4

HSO_3^- weaker than H_2SO_3

Both S acid weaker than both Cl acids

Note: if acids in exactly in exactly reverse, one point

9) (a) Describe what you would see if you added

1. a piece of zinc metal to a test tube that contains 6-molar hydrochloric acid;
2. a piece of copper metal to another test tube that contains 6-molar hydrochloric acid.

(b) Write balanced equations for any reactions that occur.

(c) Explain how you could use the table of standard reduction potentials on page 4 to predict the observed results.

(d) In a separate experiment, concentrated nitric acid is added to a test tube containing a piece of copper metal.

1. Describe what you would see.
2. Explain any differences between the results obtained in this experiment and those obtained with copper metal in part (a).

ANSWER:

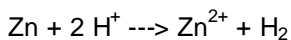
9)

a) two points

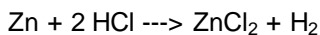
1. Bubbling or dissolving of Zn

2. No reaction

b) two points

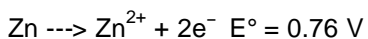
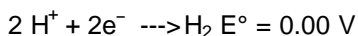


OR



Note: these last two answers are not off the official AP scoring standards, however the ChemTeam believes they are very representative of how the standards might look.

c) two points



The E° of the overall reaction is positive, demonstrating that the forward reaction is spontaneous.

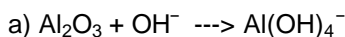
d) two points

1) The Cu dissolves with the evolution of a brown gas.

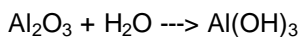
2) The Cu was non-reactive toward the HCl and reacted spontaneously with the HNO_3

-
- (a) Solid aluminum oxide is added to a solution of sodium hydroxide.
- (b) Solid calcium oxide is heated in the presence of sulfur trioxide gas.
- (c) Equal volumes of 0.1-molar sulfuric acid and 0.1-molar potassium hydroxide are mixed.
- (d) Calcium metal is heated strongly in nitrogen gas.
- (e) Solid copper(II) sulfide is heated strongly in oxygen gas.
- (f) A concentrated solution of hydrochloric acid is added to powdered manganese dioxide and gently heated.
- (g) A concentrated solution of ammonia is added to a solution of zinc iodide.
- (h) A solution of copper(II) sulfate is added to a solution of barium hydroxide.

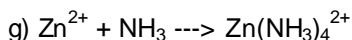
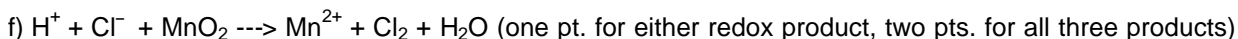
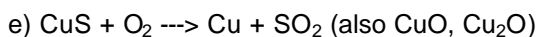
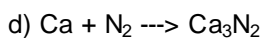
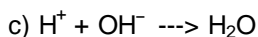
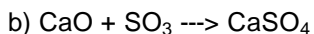
ANSWER:



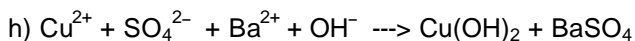
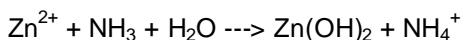
OR



(Personal note by John Park: I think the H_2O in the second equation above comes from the fact that the NaOH concentration was not specified in the original problem. For example, suppose $[\text{OH}^-]$ were 10^{-12} M. Then the second equation becomes the predominate one.)

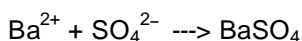
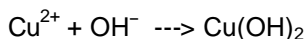


OR



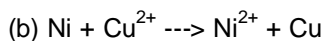
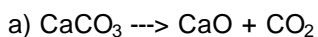
A rare double precipitation.

Partial credit was allowed for some alternate solutions, e.g.



- (a) Solid calcium carbonate is strongly heated.
- (b) A piece of nickel metal is immersed in a solution of copper(II) sulfate.
- (c) Equal volumes of equimolar solutions of disodium hydrogen phosphate and hydrochloric acid are mixed.
- (d) Chlorine gas is bubbled into a solution of sodium bromide.
- (e) Ammonia gas is bubbled into a solution of ethanoic (acetic) acid.
- (f) Solid ammonium carbonate is added to a saturated solution of barium hydroxide.
- (g) Drops of liquid dinitrogen trioxide are added to distilled water.
- (h) Solutions of potassium permanganate and sodium oxalate are mixed.

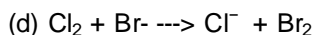
ANSWER:



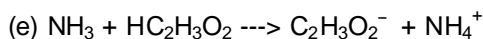
hydrated ions acceptable with correct charge
1 point for $\text{Ni}(\text{OH})_2$ as product



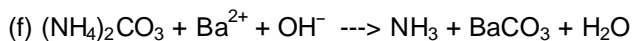
incorrect charge on H_2PO_4^- when only one product occurs, 1 point only
1 product point for transfer if H^+ from an ionic reactant to product when a phosphate species is incorrectly but consistently written.



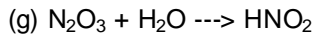
no credit for monatomic Cl as reactant or Br as product



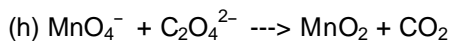
1 product point for $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2$
1 point for $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$



1 product point for either NH_3 or BaCO_3
2 product points for all three species correct

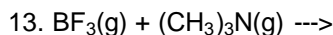
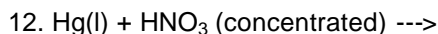
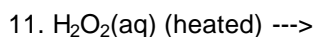
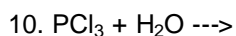
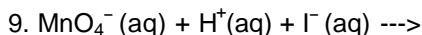
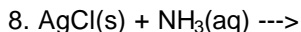


1 product point for $\text{H}^+ + \text{NO}_2^-$



no penalty for OH^- or H_2O in equation
no point earned for Mn^{2+} as product

- 5) Chlorine gas is bubbled through a cold solution of sodium hydroxide.
 - 6) Acidified potassium permanganate solution is added to a dilute solution of potassium sulfite.
 - 7) Sodium hydroxide solution in excess is added to a solution of magnesium nitrate.
 - 8) A mixture of 1-molar hydrochloric acid and 1-molar sodium bromide is warmed.
 - 9) Ammonia gas is dissolved in 6-molar sodium hydroxide solution.
 - 10) Solid radium oxide is added to water.
 - 11) Tetraborane, B_4H_{10} , is burned completely in an excess of oxygen.
 - 12) Solid silver chloride is treated with concentrated (15-molar) ammonia solution.
-



1. hydrogen gas is passed over hot copper(II) oxide.
 2. solid zinc sulfide is heated in an excess of oxygen.
 3. a limited amount of liquid bromine is added to an excess of benzene.
 4. a solution of diammine silver(I) chloride is treated with dilute nitric acid.
 5. metallic copper is heated with concentrated sulfuric acid.
 6. sulfur dioxide gas is bubbled into an excess of a saturated solution of calcium hydroxide.
 7. manganese(IV) oxide is added to warm, concentrated hydrobromic acid.
8. hydrogen sulfide gas is added to a solution of cadmium nitrate.
-

Given a solution of ammonium chloride. What additional reagent or reagents are needed to prepare a buffer from the ammonium chloride solution?

Explain how this buffer solution resists a change in pH when:

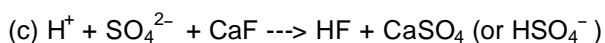
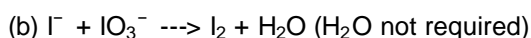
- (a) Moderate amounts of strong acid are added.
 - (b) Moderate amounts of strong base are added.
 - (c) A portion of the buffer solution is diluted with an equal volume of water.
-

- (a) Dilute sulfuric acid is added to a solution of barium acetate.
- (b) Ammonium chloride crystals are added to a solution of sodium hydroxide.

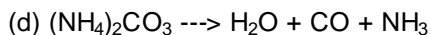
- (c) Solid phosphorus pentachloride is added to excess water.
 - (d) A solution of hydrogen peroxide is catalytically decomposed.
 - (e) Powdered iron is added to a solution of iron(III) sulfate.
 - (f) Chloride gas is bubbled into a solution of sodium bromide.
 - (g) A precipitate is formed when solutions of trisodium phosphate and calcium chloride are mixed.
 - (h) Benzene is treated with bromine in the presence of a catalyst.
-

- (a) Hydrogen gas is passed over hot iron(III) oxide.**
- (b) Solution of potassium iodide and potassium iodate are mixed in acid solution.**
- (c) Dilute sulfuric acid is added to solid calcium fluoride.**
- (d) Solid ammonium carbonate is heated.**
- (e) Methane gas is mixed with an excess of chlorine gas.**
- (f) A concentrated solution of ammonia is added to a suspension of zinc hydroxide.**
- (g) Hydrogen peroxide is added to an acidified solution of sodium bromide.**
- (h) Dilute hydrochloric acid is added to a dilute solution of mercury(I) nitrate.**

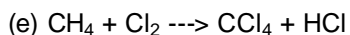
ANSWER:



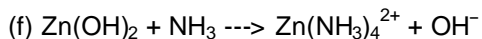
If $\text{H}^+ + \text{F}^- \rightarrow \text{HF}$ or $\text{Ca} + \text{SO}_4^{2-} \rightarrow \text{CaSO}_4$, a maximum of two points was awarded.



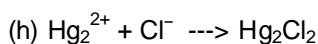
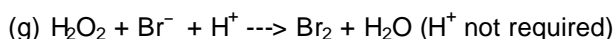
One point for any correct product and 2 points for all three products.



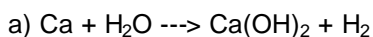
(CH_3Cl , CH_2Cl_2 , CHCl_3 , also accepted)



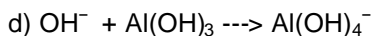
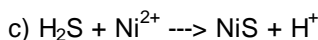
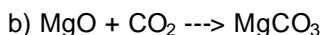
(2 points were awarded for $\text{Zn}^{2+} + \text{NH}_3 \rightarrow \text{Zn}(\text{NH}_3)_4^{2+}$)



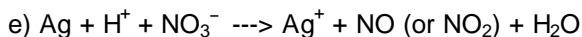
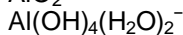
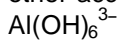
-
- a) Solid calcium is added to warm water.
 - b) Powdered magnesium oxide is added to a container of carbon dioxide gas.
 - c) Gaseous hydrogen sulfide is bubbled through a solution of nickel(II) nitrate.
 - d) Excess concentrated sodium hydroxide solution is added to solid aluminum hydroxide.
 - e) Solid silver is added to a dilute nitric acid (6M) solution.
 - f) Excess potassium hydroxide solution is added to a solution of potassium dihydrogen phosphate.
 - g) Hydrogen peroxide solution is added to a solution of iron(II) sulfate.
 - h) Propanol is burned completely in air.



$\text{Ca}^{2+} + \text{OH}^-$ earns one point



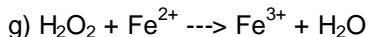
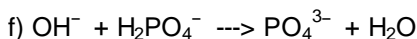
other acceptable answers:



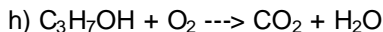
1 product = 1 pt

2 products = 1 pt

3 products = 2 pts



Fe(OH)_3 only as a product earns one point (Note: the scoring standard on this question has a two next to the formula, but in context of below, a one seems more appropriate)



spurious products: minus 1 pt.

2 pts for correct molecular equation where ionic equation is appropriate

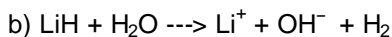
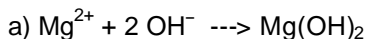
(a) An excess of sodium hydroxide solution is added to a solution of magnesium nitrate.

(b) Solid lithium hydride is added to water.

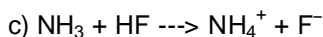
- (c) Solutions of ammonia and hydrofluoric acid are mixed.
- (d) A piece of aluminum metal is added to a solution of silver nitrate.
- (e) A solution of potassium iodide is electrolyzed.
- (f) Solid potassium oxide is added to water.
- (g) An excess of nitric acid solution is added to a solution of tetraamminecopper(II) sulfate.
- (h) Carbon dioxide gas is bubbled through water containing a suspension of calcium carbonate.

ANSWER:

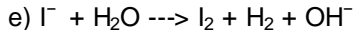
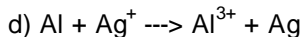
Count positive credit; single concept mistake = minus one point; products = first allowable is one point; all correct are two points. Spurious product if all other right is minus one point.



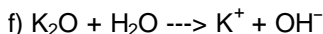
OH^- or H_2 earns one point, all three for two points.



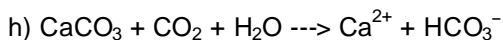
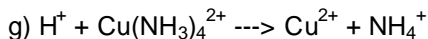
$\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ earns two points



I_2 or H_2 (one point); all three products for two points

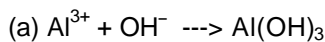


KOH product alone is one point.

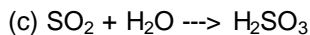
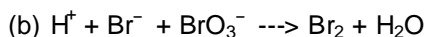


- (a) Excess potassium hydroxide solution is added to a solution of aluminum nitrate.
- (b) A solution of sodium bromide is added to an acidified solution of potassium bromate.
- (c) Sulfur dioxide gas is bubbled into distilled water.
- (d) Phosphine (phosphorus trihydride) gas is bubbled into liquid boron trichloride.
- (e) Hydrogen gas is passed over hot iron(II) oxide powder.
- (f) Solid potassium amide is added to distilled water.
- (g) A strip of magnesium metal is heated strongly in pure nitrogen gas.
- (h) A solution of nickel chloride is added to a solution of sodium sulfide.

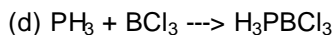
ANSWER:



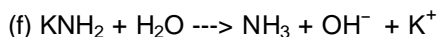
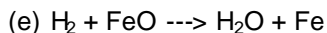
Other acceptable products: $\text{Al}(\text{OH})_4^-$; $\text{Al}(\text{OH})_4(\text{H}_2\text{O})_2^-$; Al_2O_3 ; $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$; AlO_2^-



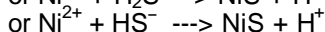
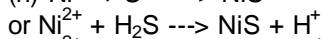
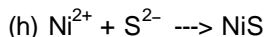
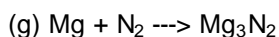
other acceptable products: $\text{H}^+ + \text{HSO}_3^-$ or $\text{H}^+ + \text{HSO}_3^- + \text{SO}_3^{2-}$



other acceptable products: PH_3BCl_3



other acceptable products: $\text{NH}_4\text{OH} + \text{OH}^- + \text{K}^+$



14) Give the definition of a base according to EITHER the Bronsted-Lowry OR the Lewis concept. Which of the following substances are bases according to the definition you have given?

O^{2-} , HSO_4^- , Ar, HF, H^- , $\text{Cu}(\text{NH}_3)_4^{2+}$

For one of the above substances which you have classified as a base, write an equation illustrating its basic character according to the definition you have given.

a) chlorine gas is bubbled into cold dilute sodium hydroxide.

b) solid iron(III) oxide is heated in excess carbon monoxide.

c) solid magnesium carbonate is heated.

d) trisodium phosphate crystals are added to water.

e) gaseous diborane, B_2H_6 , is burned in excess oxygen.

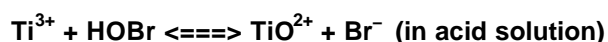
f) small chunks of solid sodium are added to water.

g) hydrogen peroxide solution is added to acidified potassium iodide solution.

h) pure methyl alcohol and pure acetic acid are mixed.

i) an excess of concentrated ammonia solution is added to freshly precipitated copper(II) hydroxide.

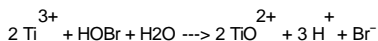
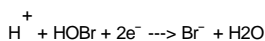
- (a) Gaseous silane, SiH₄, is burned in oxygen.
- (b) Equal volumes of 0.1-molar hydrochloric acid and 0.1-molar disodium monohydrogen phosphate are mixed.
- (c) Hydrogen sulfide gas is bubbled through a solution of lead(II) nitrate.
- (d) Solid zinc strips are added to a solution of copper sulfate.
- (e) Solid lithium oxide is added to excess water.
- (f) Copper(II) sulfide is oxidized by dilute nitric acid.
- (g) Silver chloride is dissolved in excess ammonia solution.
- (h) Propene reacts with water in the presence of a catalyst.



- (a) Write the correctly balanced half-reaction and net ionic equation for the skeletal equation shown above.
- (b) Identify the oxidizing agent and the reducing agent in this reaction.
- (c) A galvanic cell is constructed that utilizes the reaction above. The concentration of each species is 0.10-molar. Compare the cell voltage that will be observed with the standard cell potential. Explain your reasoning.
- (d) Give one example of a property of this reaction, other than the cell voltage, that can be calculated from the standard cell potential, E°. State the relationship between E° and the property you have specified.

ANSWER:

(a) three points



The third point was available for the correct addition of two half-reactions even if the half-reaction(s) were incorrect.

(b) one point

HOBr is the oxidizing agent and Ti³⁺ is the reducing agent.

(c) two points

The observed voltage will be greater than E° since $E = E^\circ - 0.059/2 (\log [0.1]^3)$.

Or 2 points for correctly discussing the relationships between cell potential and concentration for the balanced net equation that the student gave in part (a). One point could be achieved for discussing the cell potential and concentration relationship but omitting H⁺ or the exponents.

(d) two points

Identification of the property, ΔG , K or pH.

Statement of the relationship $\Delta G^\circ = -n F E^\circ$ or $E^\circ = 0.059/n (\log K)$.

Or 1 point was given if the student stated that reaction is spontaneous if $E > 0$.

(a) A solution of potassium iodide is added to an acidified solution of potassium dichromate.

(b) A solution of sodium hydroxide is added to a solution of ammonium chloride.

(c) A strip of magnesium is added to a solution of silver nitrate.

(d) Solid potassium chlorate is heated in the presence of manganese dioxide as a catalyst.

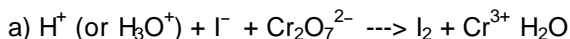
(e) Dilute hydrochloric acid is added to a solution of potassium carbonate.

(f) Sulfur trioxide gas is added to excess water.

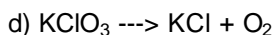
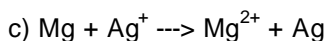
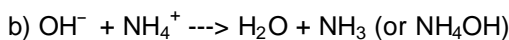
(g) Dilute sulfuric acid is added to a solution of barium chloride.

(h) A concentrated solution of ammonia is added to a solution of copper(II) chloride.

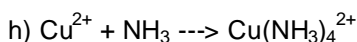
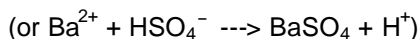
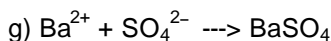
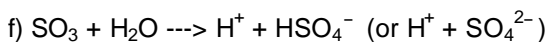
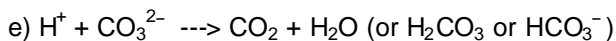
ANSWER



(Any reasonable I^- oxidation product accepted.)



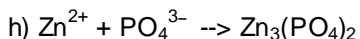
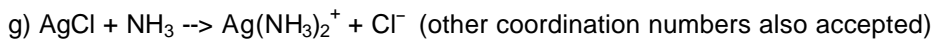
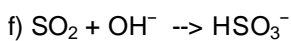
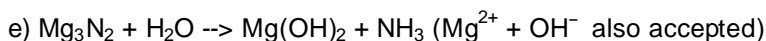
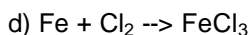
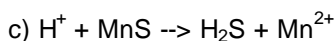
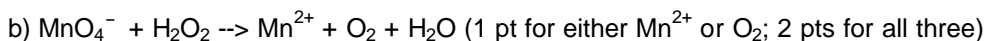
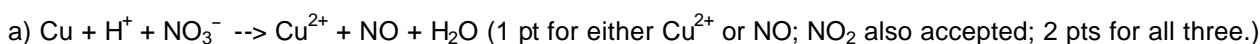
(MnO_2 is also shown over the reaction arrow in the original.)



(Partial credit for other logical Cu(II) ammonia complexes and for $\text{Cu}(\text{OH})_2$)

- (a) A strip of copper is immersed in dilute nitric acid.
- (b) Potassium permanganate solution is added to an acidic solution of hydrogen peroxide.
- (c) Concentrated hydrochloric acid is added to solid manganese(II) sulfide.
- (d) Excess chlorine gas is passed over hot iron filings.
- (e) Water is added to a sample of solid magnesium nitride.
- (f) Excess sulfur dioxide gas is bubbled through a dilute solution of potassium hydroxide.
- (g) Excess concentrated ammonia solution is added to a suspension of silver chloride.
- (h) Solutions of tri-potassium phosphate and zinc nitrate are mixed.

ANSWER:

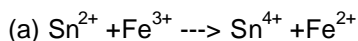


1 pt for reactants

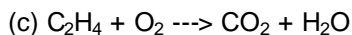
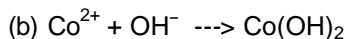
2 pts for products; 1 pt per product where two occur; 2 pts for single product

- (a) Solutions of tin(II) chloride and iron(III) chloride are mixed.
- (b) Solutions of cobalt(II) nitrate and sodium hydroxide are mixed.
- (c) Ethene gas is burned in air.
- (d) Equal volumes of equimolar solutions of phosphoric acid and potassium hydroxide are mixed.
- (e) Solid calcium sulfite is heated in a vacuum.
- (f) Excess hydrochloric acid is added to a solution of diamminesilver(I) nitrate.
- (g) Solid sodium oxide is added to distilled water.
- (h) A strip of zinc is added to a solution of 6.0-molar hydrobromic acid.

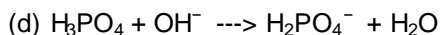
ANSWER>:



Two points earned if only error is wrong symbol for tin (e.g., Ti)

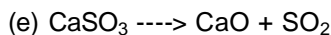


No penalty for other oxidized forms of carbon as products (e.g., C, CO)

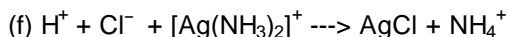


One point earned for $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$

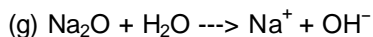
Two points earned for removal of H^+ from any $\text{H}_x\text{P}_y\text{O}_z$ species and H_2O as product



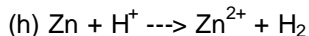
Two points earned for $\text{CaSO}_4 \rightarrow \text{CaO} + \text{SO}_3$



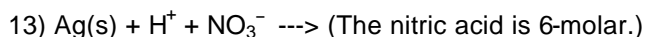
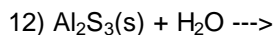
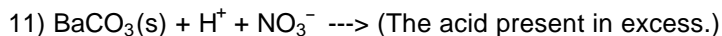
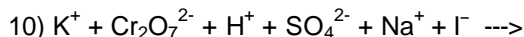
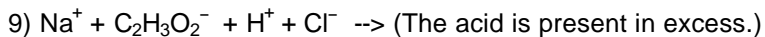
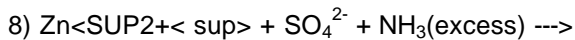
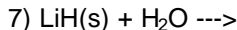
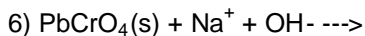
$\text{Cl}^- + [\text{Ag}(\text{NH}_3)_2]^+ \rightarrow \text{AgCl} + \text{NH}_3$ (or NH_4^+) earns two points
 $\text{H}^+ + [\text{Ag}(\text{NH}_3)_2]^+ \rightarrow \text{Ag}^+ + \text{NH}_4^+$ earns two points



Two points earned if reactants correct but only product is NaOH



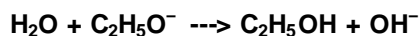
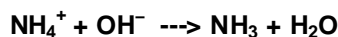
Two points earned for $\text{Zn} + \text{H}^+ + \text{Br}^- \rightarrow \text{ZnBr}_2 + \text{H}_2$
Two points earned for $\text{Zn} + \text{HBr} \rightarrow \text{Zn}^{2+} + \text{Br}^- + \text{H}_2$



18) Explain why H_3O^+ is the strongest Bronsted acid that can exist in aqueous solution and why OH^- is the strongest base. On the basis of your explanation, what species would be the strongest acid and what species would be the strongest base in liquid ammonia?

-
- 4) A sample of pure 2-butene is treated with hydrogen bromide gas.
 - 5) Water is added to a sample of pure phosphorus tribromide.
 - 6) Hydrogen peroxide is added to an acidified solution of potassium dichromate.
 - 7) Calcium metal is added to a dilute solution of hydrochloric acid.
 - 8) A solution of sulfuric acid is added to a solution of barium hydroxide until the same number of moles of each compound has been added.
 - 9) Excess dilute nitric acid is added to a solution containing the tetramminecadmium(II) ion.
 - 10) Sulfur dioxide gas is bubbled through an acidified solution of potassium permanganate.
 - 11) Pellets of aluminum metal are added to a solution containing an excess of sodium hydroxide.
 - 12) A solution of sodium hydroxide is added to a solution of sodium dihydrogen phosphate until the same number of moles of each compound has been added.

-
- (a) A solution of copper(II) sulfate is electrolyzed using inert electrodes.
 - (b) Hydrogen sulfide gas is bubbled through excess potassium hydroxide solution.
 - (c) Solutions of silver nitrate and sodium chromate are mixed.
 - (d) Sodium hydroxide solution is added to a precipitate of aluminum hydroxide in water.
 - (e) Solid sodium sulfite is added to water.
 - (f) A solution of formic acid, HCOOH, is oxidized by an acidified solution of potassium dichromate.
 - (g) Ammonia gas and carbon dioxide gas are bubbled into water.
 - (h) Concentrated hydrochloric acid solution is added to solid manganese(IV) oxide and the reactants are heated.



The equations for two acid-base reactions are given above. Each of these reactions proceeds essentially to completion to the right when carried out in aqueous solution.

- (a) Give the Brönsted-Lowry definition of an acid and a base.
 - (b) List each acid and its conjugate base for each of the reactions above.
 - (c) Which is the stronger base, ammonia or the ethoxide ion, $\text{C}_2\text{H}_5\text{O}^-$? Explain your answer.
-

5) Discuss the roles of indicators in the titration of acids and bases. Explain the basis of their operation and the factors to be considered in selecting an appropriate indicator for a particular titration.

ANSWER:

An indicator signals the endpoint of a titration by changing color. (2)

An indicator is a weak acid or a weak base where the acid form and the basic form of the indicator are different colors. (2)

An indicator usually changes color when the concentrations of the acid form and the basic form are about equal; that is, when the pH is near the pK for the indicator. (1)

When an indicator is selected, the pH at which the indicator changes color should bracket the pH of the titration solution at the equivalence point. (2)

For example, when a strong acid is titrated with a strong base, the pH at the equivalence point is 7, so an indicator that changes color at a pH of 7 should be used. (1)

(a) Solutions of zinc sulfate and sodium phosphate are mixed.

(b) Solutions of silver nitrate and lithium bromide are mixed.

(c) A stream of chlorine gas is passed through a solution of cold, dilute sodium hydroxide.

(d) Excess hydrochloric acid solution is added to a solution of potassium sulfite.

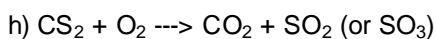
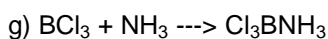
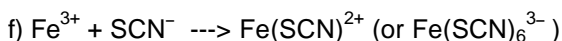
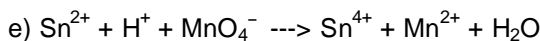
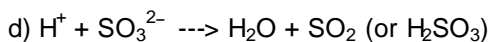
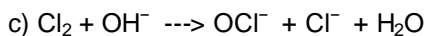
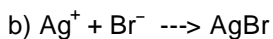
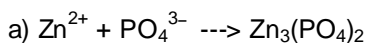
(e) A solution of tin(II) chloride is added to an acidified solution of potassium permanganate.

(f) A solution of ammonium thiocyanate is added to a solution of iron(III) chloride.

(g) Samples of boron trichloride gas and ammonia gas are mixed.

(h) Carbon disulfide vapor is burned in excess oxygen.

ANSWER:



7) Consider three unlabeled bottles, each containing small pieces of one of the following metals.

- Magnesium
- Sodium
- Silver

The following reagents are used for identifying the metals.

- Pure water
- A solution of 1.0-molar HCl
- A solution of concentrated HNO₃

(a) Which metal can be easily identified because it is much softer than the other two? Describe a chemical test that distinguishes this metal from the other two, using only one of the reagents above. Write a balanced chemical equation for the reaction that occurs.

(b) One of the other two metals reacts readily with the HCl solution. Identify the metal and write the balanced chemical equation for the reaction that occurs when this metal is added to the HCl solution. Use a table of standard reduction potentials to account for the fact that this metal reacts with HCl while the other does not.

(c) The one remaining metal reacts with the concentrated HNO₃ solution. Write a balanced chemical equation for the reaction that occurs.

(d) The solution obtained in (c) is diluted and a few drops of 1 M HCl is added. Describe what would be observed. Write a balanced chemical equation for the reaction that occurs.

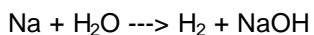
Note: This is an extremely good question!!!!!!

ANSWER:

a) any two parts = 1 point; all three parts = 2 points

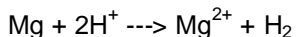
Sodium is softest of the three.

Na added to H₂O leads to gas and base.



b) any two parts = 1 point; all three parts = 2 points

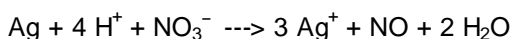
Magnesium reacts with HCl



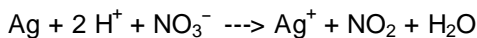
Redn. potentials: Mg = - 2.37 V; Ag = 0.80 V

Mg, but not Ag, reacts with HCl.

c) unbalanced equation = 1 point; balancing adds another point

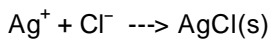


OR



d) two points

A white precipitaion forms.



(a) Excess sodium cyanide is added to a solution of silver nitrate.

(b) Solutions of manganese(II) sulfate and ammonium sulfide are mixed.

(c) Phosphorous(V) oxide powder is sprinkled over distilled water.

(d) Solid ammonium carbonate is heated.

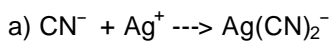
(e) Carbon dioxide gas is bubbled through a concentrated solution of potassium hydroxide.

(f) A concentrated solution of hydrochloric acid is added to solid potassium permanganate.

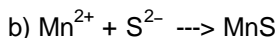
(g) A small piece of sodium metal is added to distilled water.

(h) A solution of potassium dichromate is added to an acidified solution of iron(II) chloride.

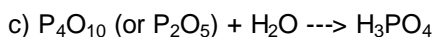
ANSWER



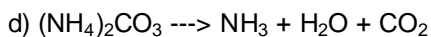
Note: any complex ion of Ag^+ with cyanide with consistent charge earns 3 points; AgCN given as product earns one product point.



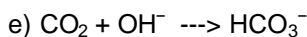
Note: If Mg is used instead of Mn , maximum possible score is two points.



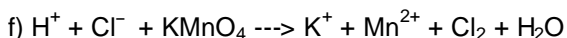
Note: Acidic species (H^+ or oxyacid of phosphorous) earns one product point; P in +5 oxidation state in oxyanion earns one product point; anions of oxyacids of phosphorous require H^+ for full credit for products.



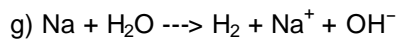
Note: any one product earns one point; all three earn two points. $\text{NH}_4\text{OH} + \text{CO}_2$ earns one product point. $\text{NH}_3 + \text{H}_2\text{CO}_3$ earns one product point.



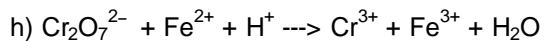
Note: $\text{CO}_3^{2-} + \text{H}_2\text{O}$ as products earns two product points. CO_3^{2-} alone as product earns one product point. $\text{HCO}_3^- + \text{H}_2\text{O}$ earns one product point.



Note: HCl and MnO_4^- acceptable as reactants. Any valid redox product earns one point. All four product earns two points. K^+ and/or H_2O only as products earns no credit. If both H^+ and H_2O omitted, then maximum of two points possible.



Note: all three products earn two product points. Any valid redox product earns one product point.



Note: All three products earn two product points. Any valid redox product earns one product point. H_2O only earns no credit. If $\text{Cl}^- \rightarrow \text{Cl}_2$ instead of $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+}$, then maximum of two points possible.

- a. Calcium oxide powder is added to distilled water.
- b. Solid ammonium nitrate is heated to temperatures above 300°C.
- c. Liquid bromine is shaken with a 0.5 M sodium iodide solution.
- d. Solid lead(II) carbonate is added to a 0.5 M sulfuric acid solution.
- e. A mixture of powdered iron(III) oxide and powdered aluminum metal is heated strongly.
- f. Methylamine gas is bubbled into distilled water.
- g. Carbon dioxide gas is passed over hot, solid sodium oxide.
- h. A 0.2 M barium nitrate solution is added to an alkaline 0.2 M potassium chromate solution.