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4.1 Review Questions

1. State two examples of chemical change from everyday life. What evidence indicates that these are chemical changes?

2. What chemical law requires us to balance chemical equations?

   Who was responsible for formulating this law?

3. Write a word equation for each formula equation below:

   (a) $C(s) + O_2(g) \rightarrow CO_2(g)$

   (b) $CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(g)$

   (c) $Cl_2(g) + 2\,KI(s) \rightarrow I_2(s) + 2\,KCl(s)$

   (d) $HCl(aq) + NaOH(s) \rightarrow NaCl(aq) + H_2O(l)$

   (e) $KF(s) \rightarrow K(s) + F_2(g)$

4. Balance each of the following equations. (State indicators are not required.)
   (a) $CdF_2 + NaBr \rightarrow CdBr_2 + NaF$
   (b) $Cr + F_2 \rightarrow CrF_3$
   (c) $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$
   (d) $Bi(NO_3)_3 + Na_2S \rightarrow Bi_2S_3 + NaNO_3$
   (e) $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$
   (f) $V + S_8 \rightarrow V_2S_5$
   (g) $LiNO_3 + Li \rightarrow Li_2O + N_2$
   (h) $Ca_3(PO_4)_2 + H_2SO_4 \rightarrow CaSO_4 + H_3PO_4$
   (i) $PH_3 + O_2 \rightarrow P_2O_5 + H_2O$
   (j) $Ba + Ag_3PO_4 \rightarrow Ba_3(PO_4)_2 + Ag$
   (k) $Ca(ClO_3)_2 \rightarrow CaCl_2 + O_2$
   (l) $C_{12}H_{22}O_{11} + O_2 \rightarrow CO_2 + H_2O$
   (m) $Ca_2C + H_2O \rightarrow Ca(OH)_2 + CH_4$
   (n) $NH_4Br + BaO \rightarrow NH_3 + BaBr_2 + H_2O$
   (o) $LiAlH_4 + BF_3 \rightarrow LiF + AlF_3 + B_2H_6$

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5. Write a balanced formula equation for each of the following (phase indicators should be included if possible):

   (a) Titanium metal reacts with selenium to produce crystals of titanium(III) selenide.

   (b) Phosphoric acid is neutralized with barium hydroxide to produce a precipitate of barium phosphate in water.

   (c) Nitrogen gas reacts with lead(II) oxide powder to yield lead(II) nitride and oxygen gas.

   (d) Xenon hexafluoride crystals react with water to produce xenon trioxide powder and hydrofluoric acid.

   (e) Aluminum carbide is reacted with water in the synthesis of methane gas. Aluminum hydroxide precipitate is also formed.

   (f) Plants produce the simple sugar $C_6H_{12}O_6$ and oxygen gas from carbon dioxide and water during photosynthesis.

   (g) Ammonia gas (NH_3) is formed along with a precipitate of magnesium hydroxide from the reaction of magnesium nitride powder with water.

   (h) Strong heating of copper(II) nitrate trihydrate produces copper(II) oxide, nitrogen dioxide, oxygen gas, and water.

6. Balancing Bonkers: Some equations are extremely difficult to balance even with the application of the balancing hints! Later on in your chemistry career, you will learn to balance some equations using the concepts of oxidation and reduction. This will be a major stress reducer when it comes to balancing. In the meantime, try to balance a few of these exhauster equations:

   (a) $Ag + HNO_3 \rightarrow NO + AgNO_3 + H_2O$
   (b) $Al + NaOH + H_2O \rightarrow NaAl(OH)_4 + H_2$
   (c) $HNO_3 + Zn \rightarrow Zn(NO_3)_2 + H_2O + NH_4NO_3$
   (d) $H_2O + As + HClO_3 \rightarrow H_3AsO_3 + HClO$
   (e) $H_2SO_4 + H_2O_2 + KMnO_4 \rightarrow MnSO_4 + O_2 + H_2O + K_2SO_4$

   Hint: You may want to come back to these once you've finished section 4.3.

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4.2 Review Questions

1. Balance each of the following reactions:
   (a) $CdF_2 + NaBr \rightarrow CdBr_2 + NaF$
   (b) $Na_2SO_4 + Cu \rightarrow Cu_2SO_4 + Na$
   (c) $Cr + F_2 \rightarrow CrF_3$
   (d) $Fe(OH)_3 \rightarrow Fe_2O_3 + H_2O$
   (e) $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$
   (f) $Bi(NO_3)_3 + Na_2S \rightarrow Bi_2S_3 + NaNO_3$
   (g) $C_{25}H_{52} + O_2 \rightarrow CO_2 + H_2O$
   (h) $Al + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2$
   (i) $LiClO_3 \rightarrow LiCl + O_2$
   (j) $K + Cl_2 \rightarrow KCl$
   (k) $Au + H_2S \rightarrow Au_2S_3 + H_2$
   (l) $Nb + S_8 \rightarrow Nb_2S_5$
   (m) $P_4O_{10} + H_2O \rightarrow H_3PO_4$
   (n) $HClO \rightarrow Cl_2O + H_2O$
   o) $H_3PO_4 + KOH \rightarrow K_3PO_4 + H_2O$
   (p) $Rb + Sc_2(CrO_4)_3 \rightarrow Rb_2CrO_4 + Sc$
   (q) $V(OH)_5 \rightarrow V_2O_5 + H_2O$
   (r) $Ba_3P_2 \rightarrow Ba + P_4$
   (s) $K_2C_2O_4 + Ca(NO_3)_2 \rightarrow CaC_2O_4 + KNO_3$
   (t) $BaCO_3 + HCl \rightarrow BaCl_2 + CO_2 + H_2O$

2. (a) Classify each of the reactions in question 1 as synthesis, decomposition, combustion, single replacement, double replacement, or neutralization.

   (b) Which of the single replacement reactions would *not* proceed spontaneously?

   (c) Which of the double replacement reactions involve precipitate formation?

   (d) Indicate the precipitates with an *(s)*.

3. Classify each of the following reactions, using the following key: **S** = Synthesis, **D** = Decomposition, **C** = Combustion, **SR** = Single Replacement, **DR** = Double Replacement, **N** = Neutralization. Complete the equations and balance them. Indicate any precipitates that form with an *(s)*.
   ____(a) $Rb + ZnF_2 \rightarrow$
   ____(b) $Sc_2O_3 + H_2O \rightarrow$
   ____(c) $Pb(NO_3)_2 + NaCl \rightarrow$
   ____(d) $H_2CO_3 \rightarrow$
   ____(e) $GeO_2 + SO_2 \rightarrow$

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   ____(f) $SrCO_3 + H_2S \rightarrow$
   ____(g) $C_2H_6 + O_2 \rightarrow$
   ____(h) $Cs + NiCl_2 \rightarrow$
   ____(i) $Zr(OH)_4 \rightarrow$
   ____(j) $Br_2 + InI_3 \rightarrow$
   ____(k) $H_3PO_4 + Ba(OH)_2 \rightarrow$
   ____(l) $AgNO_3 + Ca(CH_3COO)_2 \rightarrow$
   ____(m) $C_3H_7OH + O_2 \rightarrow$
   ____(n) $N_2O_5 + H_2O \rightarrow$
   ____(o) $AlCl_3 + Na_2CO_3 \rightarrow$
   ____(p) $NH_4F + LiOH \rightarrow$
   ____(q) $HNO_3 + Sr(OH)_2 \rightarrow$
   ____(r) $F_2 + K_2S \rightarrow$
   ____(s) $Mg(OH)_2 \rightarrow$
   ____(t) $Na + N_2 \rightarrow$

4. Classify each of the following chemical changes using the key from question 3. Write balanced formula equations for each, including state indicators.
   ____(a) A piece of magnesium ribbon on a stock shelf reacts over time with nitrogen gas in the air to form a black coating.

   ____(b) Phosphoric acid solution removes iron(III) hydroxide stains from an old bath tub.

   ____(c) Butane gas is combusted in a disposable lighter.

   ____(d) A zinc strip placed in a solution of copper (II) sulphate becomes coated with brownish solid.

   ____(e) Sulphur dioxide emitted from industrial plants combines with water vapour to form acid rain.

   ____(f) Calcium carbonate in marble structures is eroded over time by nitric acid in acid rain.

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____(g) Nickel(III) hydroxide reacts with a cadmium anode in a prototype rechargeable battery.

____(h) Solutions of gold(III) nitrate and sodium carbonate are combined.

____(i) Potassium chromate solution indicates the endpoint in a potato chip analysis with a standard silver nitrate solution.

____(j) Methanol (CH_3OH) is combusted in race car engines.

____(k) Baking soda (sodium hydrogen carbonate) is used to neutralize a spill of hydrochloric acid.

____(l) A bright yellow pigment once used in paints is formed from the reaction of lead(II) nitrate and sodium iodide solutions.

____(m) Iron(III) oxide and water combine to form a basic compound often called rust.

____(n) Dark silver sulphide tarnish may be removed from knives and forks by placing them in contact with a piece of aluminum foil in a dilute ionic solution.

____(o) A precipitate of barium oxalate forms in a solution of sodium nitrate following the combination of two solutions.

____(p) A precipitate of barium sulphate and hydrogen gas are formed from the combination of a metal and an acid.

____(q) Diphosphorus pentoxide gas and water are produced from the decomposition of an acid.

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4.4 Review Questions

1. Indicate whether each of the following changes is endothermic or exothermic:
   (a) Barbecuing a steak

   (b) Freezing a tray full of water to make ice

   (c) Neutralizing an acid spill with baking soda

   (d) Making a grilled cheese sandwich

   (e) Lighting a barbecue igniter

   (f) Condensing water on a mirror

2. Convert the following ΔH notation equations into thermochemical equations using the smallest whole number coefficients possible:
   (a) $\frac{1}{2}\ C_3H_8(g) \rightarrow \frac{1}{2}\ C_3H_8(l) \quad \Delta H = -175$ kJ/mol

   (b) $Li(s) + \frac{1}{2}\ CaCl_2(aq) \rightarrow LiCl(aq) + \frac{1}{2}\ Ca(s) \quad \Delta H = -362$ kJ/mol

   (c) $2\ B(s) + 3\ H_2O(g) \rightarrow B_2H_6(g) + 3/2\ O_2(g) \quad \Delta H = 762$ kJ/mol

   (d) $\frac{1}{2}\ P_4(s) + 3\ Cl_2(g) \rightarrow 2\ PCl_3(s) \quad \Delta H = -613$ kJ/mol

   (e) $NH_3(g) + 3/2\ N_2O(g) \rightarrow 2\ N_2(g) + 3/2\ H_2O(l) \quad \Delta H = -505$ kJ/mol

   (f) $\frac{1}{2}\ Fe_3O_4(s) + \frac{1}{2}\ CO(g) \rightarrow 3/2\ FeO(s) + \frac{1}{2}\ CO_2(g) \quad \Delta H = 9$ kJ/mol

3. Convert the following thermochemical equations into ΔH notation using the smallest whole number coefficients possible.
   (a) $C(s) + 2\ H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow CH_3OH(l) + 201$ kJ/mol

   (b) $\frac{1}{2}\ Cu(s) + \frac{1}{2}\ H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow \frac{1}{2}\ Cu(OH)_2(s) + 225$ kJ/mol

   (c) 389 kJ/mol $+ \frac{1}{2}\ Sb_4O_5(s) + 3\ C(s) \rightarrow 2\ Sb(s) + 3\ CO(g)$

   (d) 56 kJ/mol $+ NO_2(g) \rightarrow NO(g) + \frac{1}{2}\ O_2(g)$

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(e) $PCl_3(g) + \frac{1}{2} O_2(g) \rightarrow Cl_3PO(g) + 286$ kJ/mol

(f) $F_2(s) + \frac{1}{2} O_2(g) \rightarrow OF_2(g) + 22$ kJ/mol

4. Use the equations in question 3 to answer the following questions:
   (a) How much energy would be released during the formation of 4 mol of methanol?

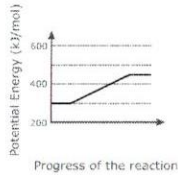
   (b) How many moles of nitrogen dioxide could be decomposed through the use of 168 kJ of energy?

   (c) Is more energy absorbed or released during the formation of Cl_3PO gas from PCl_3 and O_2 gas?

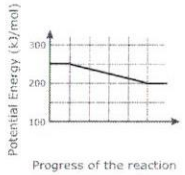
   (d) What is the ΔH value for the decomposition of OF_2 gas into its elements?

   (e) How much energy is required to decompose 1 mol of copper(II) hydroxide?

5. Does the following potential energy diagram represent an endothermic or an exothermic reaction? What is ΔH for this reaction?



6. What is ΔH for this reaction?



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4.5 Review Questions

1. Malachite is a beautiful green mineral often sculpted into jewellery. It decomposes as follows:
   $Cu(OH)_2 \cdot CuCO_3(s) \rightarrow 2\,CuO(s) + CO_2(g) + H_2O(l)$
   (a) How many moles of CuO are formed from the decomposition of 1.26 mol of malachite?

   (b) If a 1.5 kg piece of malachite is completely decomposed, how many grams of copper(II) oxide are formed?

   (c) If 706 g of copper(II) oxide are formed from the decomposition of a piece of malachite, how many litres of carbon dioxide gas would form at STP?

2. Nitromethane, a fuel occasionally used in drag racers, burns according to the reaction:
   $4\,CH_3NO_2(l) + 3\,O_2(g) \rightarrow 4\,CO_2(g) + 6\,H_2O(g) + 2\,N_2(g)$
   (a) What is the volume of nitrogen gas produced at STP if 3160 g of CH_3NO_2 is burned?

   (b) What is the mass of nitromethane burned if 955 g of nitrogen gas are produced in the exhaust of the drag racer?

   (c) What mass of water vapour is produced in the exhaust along with 3.5×10^{25} molecules of nitrogen gas?

3. What mass of zinc would completely react with 10.0 mL of 0.45 M hydrochloric acid solution?
   $Zn(s) + 2\,HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

4. How much energy will be required to complete the reaction of 12.2 g of sodium to produce sodium oxide?
   $4\,Na(s) + O_2(g) + 124.7\text{ kJ} \rightarrow 2\,Na_2O(s)$

5. Potassium permanganate reacts with oxalic acid in aqueous sulphuric acid according to the equation:
   $2\,KMnO_4 + 5\,H_2C_2O_4 + 3\,H_2SO_4 \rightarrow 2\,MnSO_4 + 10\,CO_2 + 8\,H_2O + K_2SO_4$
   How many millilitres of a 0.250 M $KMnO_4$ solution are needed to react with 3.225 g of oxalic acid?

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Begin the following calculations with a balanced equation.

6. The reaction of scrap aluminum with chlorine gas forms aluminum chloride. What mass of chlorine in the presence of excess aluminum is required to make 4.56 kg of aluminum chloride?

7. How many moles of sulphuric acid could neutralize 0.034 mol of potassium hydroxide solution?

8. What mass of water vapour would be formed from the complete combustion of 35.00 g of ethanol ($C_2H_5OH(l)$)?

9. Dihydrogen monosulphide gas may be prepared in a laboratory by the action of hydrochloric acid on iron(II) sulphide. How many grams of iron(II) sulphide would be needed to prepare 21.7 L of the gas at STP?

10. Carbon dioxide gas is produced in the reaction between calcium carbonate and hydrochloric acid. If 15.0 g of calcium carbonate reacted with an excess of hydrochloric acid, how many grams of carbon dioxide gas would be produced?

11. The Haber process for making ammonia gas from its elements was developed by Fritz Haber during World War I. Haber hoped to use the ammonia as fertilizer to grow food for Germany during the Allies' blockade. How many litres of hydrogen would be required to produce 40.0 L of ammonia at STP?

12. $PbI_2(s) \rightarrow Pb^{2+}(aq) + 2\,I^-(aq) \quad \Delta H = 46.5$ kJ/mol
How much energy would be required to dissolve 5.00 g of lead (II) iodide?

13. A piece of zinc metal was dropped into a solution of tin(IV) nitrate. If 27.5 g of tin metal was displaced, how many grams of reducing agent were used?

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14. Solutions of barium nitrate and potassium sulfate were poured together. If this reaction required 6.5 mol of barium nitrate, how many grams of precipitate were formed?

15. Calcium carbonate (marble chips) is dissolved by hydrochloric acid. If 12.2 L of carbon dioxide gas forms at STP, what mass of marble chips was used?

16. When dinitrogen tetroxide decomposes into nitrogen dioxide, 56 kJ of energy is required for each mole of reactant decomposed. How much heat is absorbed if 1.25 g of product is formed?

17. A flask containing 450 mL of 0.500 M HBr was accidentally knocked to the floor. How many grams of K_2CO_3 would you need to put on the spill to completely neutralize the acid?

18. The acetic acid in a 2.5 mol/L sample of a solution of a kettle scale remover is reacted with an excess of a lead(II) nitrate solution to form a precipitate, which is then filtered and dried. The mass of the precipitate is 8.64 g. What volume of the solution was required to produce that mass?

19. How many milliliters of a 0.610 M NaOH solution are needed to completely neutralize 25.0 mL of a 0.356 M phosphoric acid solution?

20. What volume of hydrogen gas is formed at STP by the reaction of excess zinc metal with 150 mL of 0.185 mol/L hydroiodic acid?

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4.6 Review Questions

1. Do all reactions between two chemicals result in a complete reaction in such a way that all the reactants are consumed and turn in to products? Explain.

2. What do we call the chemicals that remain unreacted following a chemical change?

3. What is the percentage yield of a reaction?

4. Are all reactants in a chemical reaction completely pure? How might this affect a stoichiometry calculation?

5. A saturated solution of lithium fluoride, which is sometimes used as a rinse to prevent tooth decay, contains 0.132 g of LiF in 100.0 g of water. Calculate the percentage purity by mass of the LiF.

6. Automotive air bags inflate when solid sodium azide (NaN_3) decomposes explosively into its constituent elements. What volume of nitrogen gas is formed if 120 g of 85% pure sodium azide decomposes? Assume STP conditions.

7. Silver nitrate and aluminum chloride react with each other by exchanging anions:

   $3\ AgNO_3(aq) + AlCl_3(aq) \rightarrow Al(NO_3)_3(aq) + 3\ AgCl(s)$

   What mass of precipitate is produced when 4.22 g of silver nitrate react with 7.73 g of aluminum chloride in solution?

8. GeF_3H is synthesized in the reaction: $GeH_4 + 3\ GeF_4 \rightarrow 4\ GeF_3H$. If the reaction yield is 91.5%, how many moles of GeH_4 are needed to produce 8.00 mol of GeF_3H?

9. What is the maximum mass of sulphur trioxide gas that can be formed from the combination of 5.00 g each of S_8 solid with O_2 gas? Begin with a balanced equation.

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10. In the reaction in question 9, 63.2 g of sulphur trioxide are produced using 40.0 g of oxygen and 48.0 g of sulphur. What is the percentage yield?

11. What volume of 0.105 mol/ L silver nitrate solution would be required to react completely with an excess of magnesium chloride solution to produce 8.95 g of precipitate? Assume the precipitate is only 75.0% pure, as it is still damp following filtration. Begin with a balanced equation.

12. What mass of silver could be formed if a large zinc wire is placed in a beaker containing 145.0 mL of 0.095 mol/L silver nitrate and allowed to react overnight? Assume the reaction has a 97% yield.

13. 8.92 g of indium oxide is reacted with an excess of water and forms 10.1 g of base. What is the percent yield?

14. What volume of chlorine gas could be produced under STP conditions if 39.8 g of 84.0% pure potassium chloride were reacted with an excess of fluorine gas?

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15. An aqueous solution containing 46.7 g of copper(I) nitrate is placed into an aqueous solution containing 30.8 g of strontium bromide. The resulting mixture was filtered to remove the copper(I) bromide precipitate. Assuming a 100% yield:
(a) What is the mass of solid collected on the filter paper?

(b) Which reactant is in excess?

(c) How many grams of the excess reactant remains when the reaction has gone to completion?

16. A 20.0 g piece of calcium metal reacts with 18.0 mL of water over time. If 10.0 L of hydrogen gas is formed under STP conditions, what is the percentage yield of the reaction? (Recall the density of water is 1.00 g/mL.)

17. Excess silver nitrate is dissolved in a total volume of 250 mL of 0.103 mol/L calcium chloride solution. The resulting reaction produces 4.41 g of silver chloride precipitate. What was the percentage purity of the calcium chloride?

18. A sample of impure silver with a mass of 0.7294 g was dissolved in excess concentrated nitric acid according to the following *unbalanced* equation:
$Ag(s) + HNO_3(aq) \rightarrow AgNO_3(aq) + NO(g) + H_2O(l)$
Once the nitrogen monoxide gas was vented off in a fume hood, the resulting silver nitrate solution was reacted with a slight excess of hydrochloric acid to form a precipitate of silver chloride. The dried precipitate's mass was 0.3295 g. What was the percentage purity of the silver sample?

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