Chemistry Reference Tables Workbook

2nd Edition

About This Workbook –

Many questions on the New York State Physical Setting/CHEMISTRY Regents Exam may be answered simply by using information given on the Reference Tables. Other questions may require information from the Reference Tables to set up calculations in order to determine the answer. Knowing what information is on the Reference Tables and where to find it are very important steps towards being successful on the Regents exam.

The Introduction – Overview, The Chart and Additional Information –

In these sections, you will find an explanation of the information given on that table. Read each section carefully to fully understand the information given on that table.

Set 1 – Questions and Answers –

After careful reading of the Introduction, Set 1 questions will test your understanding of that particular table. Do all questions in Set 1, and then correct your work by going to the answers for Set 1, which are at the end of the section. The explanation given will help you to understand any mistakes you may have made. If you need additional explanation, ask your teacher for help.

Set 2 – Questions –

The answers to these questions are in a separate answer key. Correctly answering these questions will show yourself and your teacher that you understand the subject matter for that particular table.

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All of us at Topical Review Book Company hope that by gaining a complete understanding of the Chemistry Reference Tables, it will help you to increase your knowledge of chemistry and that your grades will improve.

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Physical Setting/Chemistry Reference Tables Workbook

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Table E Selected Polyatomic Ions

Formula	Name
H_3O^+	hydronium
Hg_2^{2+}	mercury(I)
NH_4^+	ammonium
$C_2H_3O_2^-$ / CH_3COO^-	acetate
CN^-	cyanide
CO_3^{2-}	carbonate
HCO_3^-	hydrogen carbonate
$C_2O_4^{2-}$	oxalate
ClO^-	hypochlorite
ClO_2^-	chlorite
ClO_3^-	chlorate
ClO_4^-	perchlorate

Formula	Name
CrO_4^{2-}	chromate
$Cr_2O_7^{2-}$	dichromate
MnO_4^-	permanganate
NO_2^-	nitrite
NO_3^-	nitrate
O_2^{2-}	peroxide
OH^-	hydroxide
PO_4^{3-}	phosphate
SCN^-	thiocyanate
SO_3^{2-}	sulfite
SO_4^{2-}	sulfate
HSO_4^-	hydrogen sulfate
$S_2O_3^{2-}$	thiosulfate

Overview:

Polyatomic ions are charged particles composed of two or more atoms. Most are composed of nonmetallic atoms combined with oxygen. Polyatomic ions are quite stable. Thus, in many chemical reactions, the polyatomic ion remains intact and is therefore written the same on the reactant and product side of a chemical equation. These ions are the negative component of many common compounds.

The Table:

The Formula, Name and charge of the ion are given in this table. This information is used in determining the name of a given compound or in writing the formula for a given compound involving a polyatomic ion. The name of these ions usually indicates the element present other than oxygen. For example, the polyatomic ion CrO_4^{2-} is chromate, containing the metal chromium.

Additional Information:

- The formula for a compound must represent a neutral group of atoms. The total positive oxidation state or number and the total negative oxidation state or number must be equal, leaving a net charge of zero for the group of atoms.

  Example 1: What is the formula for sodium sulfate?
  Answer: Na_2SO_4
  Explanation: From the Periodic Table, the oxidation number of Na is +1 (Na^+) and from Table E, sulfate is SO_4^{2-}. The correct formula must be Na_2SO_4.

  Example 2: What is the formula for calcium phosphate?
  Answer: $Ca_3(PO_4)_2$
  Explanation: From the Periodic Table the oxidation number of Ca is +2 (Ca^{2+}) and from Table E, phosphate is PO_4^{3-}. The correct formula must be $Ca_3(PO_4)_2$.

- In most compounds involving a polyatomic ion, there exist both covalent and ionic bonds. For example, in the compound Na_3PO_4, the phosphate ion (PO_4^{3-}) is formed by the covalent bonding between the nonmetals P and O, while the sodium ion (Na^+) and the phosphate ion are held together by an ionic bond.

- Most of the ions on this table are derived from ternary or oxo acids (acids composed of three elements, two of which are hydrogen and oxygen). If the acid name ends in –ic, it is modified to end in –ate to name the ion. Hence, sulfuric acid (H_2SO_4) gives rise to the sulfate ion (SO_4^{2-}). If the acid name ends in –ous, it is modified to end in –ite to name the ion. Sulfurous acid (H_2SO_3) therefore gives rise to the sulfite ion (SO_3^{2-}).

- In compounds between metals and nonmetals in which the metal shows more than one positive oxidation state, the *Stock System of Nomenclature* is used. In this system, the oxidation state of the metal in the compound is placed in Roman numerals in parentheses immediately following the name of the metal. For example, $CuSO_4$ is copper(II) sulfate since copper has a +2 oxidation state (Cu^{2+}) in this compound.

Specific uses of compounds containing a polyatomic ion:

- Sodium hydrogen carbonate ($NaHCO_3$), also known as sodium bicarbonate, is baking soda or bicarbonate of soda.
- Sodium hypochlorite (NaClO) is the substance in Clorox type bleaching solutions and the chlorinating agent used for swimming pools.
- Sodium nitrite ($NaNO_2$) is used in prepared meats to preserve freshness and color.
- Sodium sulfite (Na_2SO_3) is used in salad bars to preserve the freshness of greens.
- Phosphates (PO_4^{3-}) are found in soft drinks.
- Ammonium nitrate (NH_4NO_3) is used in agriculture as a high nitrogen fertilizer.

Set 1 — Selected Polyatomic Ions

1. Which polyatomic ion contains the greatest number of oxygen atoms?

   (1) acetate (3) hydroxide
   (2) carbonate (4) peroxide 1 _____

2. Which formula represents a hydronium ion?

   (1) H_3O^+ (3) OH^-
   (2) NH_4^+ (4) HCO_3^- 2 _____

3. What is the name of the polyatomic ion in the compound Na_2O_2?

   (1) hydroxide (3) oxide
   (2) oxalate (4) peroxide 3 _____

4. The name of the compound $KClO_2$ is potassium

   (1) hypochlorite (3) chlorate
   (2) chlorite (4) perchlorate 4 _____

5. Which element is found in both potassium chlorate and zinc nitrate?

   (1) hydrogen (3) potassium
   (2) oxygen (4) zinc 5 _____

6. What is the chemical formula for sodium sulfate?

   (1) Na_2SO_3 (3) $NaSO_3$
   (2) Na_2SO_4 (4) $NaSO_4$ 6 _____

7. What is the oxidation state of sodium in $NaNO_2$?

   (1) +1 (3) +2
   (2) –1 (4) –2 7 _____

8. What is the chemical formula for copper(II) hydroxide?

   (1) CuOH (3) $Cu_2(OH)$
   (2) $CuOH_2$ (4) $Cu(OH)_2$ 8 _____

Base your answers to question 9 using the passage below and your knowledge of chemistry.

Acid rain lowers the pH in ponds and lakes and over time can cause the death of some aquatic life. Acid rain is caused in large part by the burning of fossil fuels in power plants and by gasoline-powered vehicles. The acids commonly associated with acid rain are sulfurous acid, sulfuric acid, and nitric acid.

9. *a*) Write the chemical formula of a negative ion present in an aqueous nitric acid solution. _____

   b) Write the chemical formula of a negative ion present in aqueous sulfurous acid. _____

10. A 2.0-liter aqueous solution contains a total of 3.0 moles of dissolved NH_4Cl at 25°C and standard pressure.

    Identify the two ions present in the solute. _____

Set 2 — Selected Polyatomic Ions

11. Which formula is correct for ammonium sulfate?

(1) NH_4SO_4 (3) $NH_4(SO_4)_2$
(2) $(NH_4)_2SO_4$ (4) $(NH_4)_2(SO_4)_2$ 11 ____

12. Which formula represents a nitrate ion?

(1) NO^- (3) NO_3^-
(2) NO_2^- (4) NO_4^- 12 ____

13. Which formula represents lead(II) phosphate?

(1) $PbPO_4$ (3) $Pb_3(PO_4)_2$
(2) Pb_4PO_4 (4) $Pb_2(PO_4)_3$ 13 ____

14. Which compound has both ionic and covalent bonds?

(1) CO_2 (3) NaI
(2) CH_3OH (4) Na_2CO_3 14 ____

15. The name of the compound $Na_2S_2O_3$ is

(1) potassium sulfate
(2) potassium thiosulfate
(3) sodium sulfate
(4) sodium thiosulfate 15 ____

16. What is the oxidation state of Ca in $CaSO_4$?

(1) –1 (3) –2
(2) +1 (4) +2 16 ____

17. Which formula represents strontium phosphate?

(1) $SrPO_4$ (3) $Sr_2(PO_4)_3$
(2) Sr_3PO_8 (4) $Sr_3(PO_4)_2$ 17 ____

18. The chemical bonding in sodium phosphate, Na_3PO_4, is classified as

(1) ionic, only
(2) metallic, only
(3) both covalent and ionic
(4) both covalent and metallic 18 ____

19. An antacid contains the acid-neutralizing agent sodium hydrogen carbonate. Write the chemical formula for sodium hydrogen carbonate. _____

20. Write the correct formula for hydrogen sulfate. _____

21. In terms of their formulas, what is the difference between the chlorate and perchlorate ions?

_____

22. Write the chemical formula for the most abundant negative ion in an aqueous sodium phosphate solution._____

23. Write the chemical formula for copper(I) sulfite._____

Table E – Selected Polyatomic Ions

Answers

Set 1

1. 2 From Table E, the carbonate ion has the formula CO_3^{2-}. The formula shows three oxygen atoms are present in this ion. The other choices have one or two oxygen atoms.

2. 1 The hydrogen ion (a proton) combines with a water molecule to form the hydronium ion. This polyatomic ion is the first one given in Table E.

3. 4 Sodium peroxide, Na_2O_2, contains the peroxide ion, having the formula O_2^{2-}.

4. 2 Using Table E, the chlorite ion is ClO_2^-. Potassium, having an oxidation number +1, would join with the chlorite ion, forming the compound $KClO_2$, potassium chlorite.

5. 2 Using Table E, potassium chlorate is $KClO_3$, and zinc nitrate is $Zn(NO_3)_2$. Both of these compounds contain oxygen.

6. 2 As shown in the Periodic Table, sodium has an oxidation state of +1 (Na^+). Shown in Table E, the formula for the sulfate ion is SO_4^{2-}. To maintain a neutral compound, two sodium ions are needed to form sodium sulfate, Na_2SO_4.

7. 1 The formula of a compound must represent a neutral group of atoms. The nitrate ion (NO_3^-) has a charge of –1. Thus Na must have an oxidation state of +1 in the formula of $NaNO_3$. This is the oxidation state of sodium as shown in the Periodic Table.

8. 4 In the *Stock System of Nomenclature*, the oxidation state of the metal is shown by Roman numerals. Copper(II) has an oxidation state of +2. From Table E, the hydroxide ion (OH^-) has a charge of –1. For the compound to be neutral, two hydroxide ions are needed. The formula for copper(II) hydroxide would be $Cu(OH)_2$.

9. *a*) NO_3^- If the acid name ends in –ic, it is modified to end in –ate to name the ion. Thus, nitric acid would produce the nitrate ion, NO_3^-.

   b) SO_3^{2-} Sulfurous acid produces the sulfite ion. Remember, if the acid name ends in –ous, it is modified to end in –ite to name the ion.

10. Answer: NH_4^+ and Cl^- *or* ammonium and chloride

    Explanation: When this compound dissolves in water, it dissociates into the polyatomic ion NH_4^+ and the Cl^- ion.

Table I Heats of Reaction

Heats of Reaction at 101.3 kPa and 298 K

Reaction	ΔH (kJ)*
$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$	–890.4
$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(\ell)$	–2219.2
$2C_8H_{18}(\ell) + 25O_2(g) \longrightarrow 16CO_2(g) + 18H_2O(\ell)$	–10943
$2CH_3OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(\ell)$	–1452
$C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$	–1367
$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(\ell)$	–2804
$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$	–566.0
$C(s) + O_2(g) \longrightarrow CO_2(g)$	–393.5
$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$	–3351
$N_2(g) + O_2(g) \longrightarrow 2NO(g)$	+182.6
$N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$	+66.4
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$	–483.6
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$	–571.6
$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$	–91.8
$2C(s) + 3H_2(g) \longrightarrow C_2H_6(g)$	–84.0
$2C(s) + 2H_2(g) \longrightarrow C_2H_4(g)$	+52.4
$2C(s) + H_2(g) \longrightarrow C_2H_2(g)$	+227.4
$H_2(g) + I_2(g) \longrightarrow 2HI(g)$	+53.0
$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$	+34.89
$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$	–44.51
$NH_4Cl(s) \xrightarrow{H_2O} NH_4^+(aq) + Cl^-(aq)$	+14.78
$NH_4NO_3(s) \xrightarrow{H_2O} NH_4^+(aq) + NO_3^-(aq)$	+25.69
$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$	+3.88
$LiBr(s) \xrightarrow{H_2O} Li^+(aq) + Br^-(aq)$	–48.83
$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$	–55.8

*The ΔH values are based on molar quantities represented in the equations. A minus sign indicates an exothermic reaction.

Overview:

Any reaction, chemical or physical, involves either the absorption or release of energy. This energy is usually measured in the form of heat, expressed in kJ, and is called the enthalpy or simply the heat of reaction. The symbol for heat of reaction is ΔH. The conditions of 101.3 kPa and 298 K are the standard conditions for the measurement of heats of reaction.

The Table:

The chemical equations for many reactions are given on this table. Notice that the phases of the reactants and products are given in each reaction. The heats of reaction (ΔH) are given at the right hand side of the table. As indicated at the bottom of the table by the asterisk, a minus sign indicates an exothermic reaction. An exothermic reaction is one that produces or releases energy. This is indicated by a negative heat of reaction. When included in the chemical equation, the heat is included on the product side.

For example: The first reaction on the chart is an exothermic reaction since it has a negative heat of reaction (–890.4 kJ). Expressed as a chemical equation, it would be written as:

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4 \text{ kJ}$$

An endothermic reaction is one that absorbs energy. This is indicated by a positive heat of reaction. When included in the chemical equation, the heat is included on the reactant side.

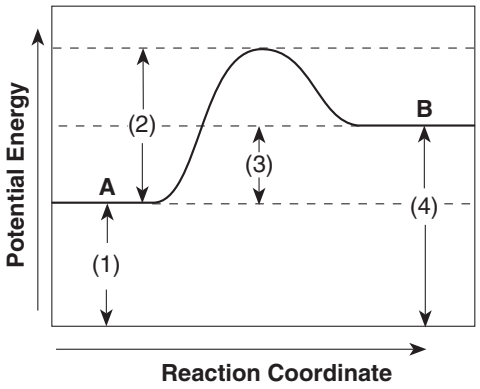
For example: The first endothermic reaction given on the chart is $N_2(g) + O_2(g) \rightarrow 2NO(g)$ as shown by the positive heat of reaction (182.6 kJ). This reaction would absorb 182.6 kJ. Expressed as a chemical equation, it would be written as:

$$N_2(g) + O_2(g) + 182.6 \text{ kJ} \rightarrow 2NO(g)$$

Potential Energy Diagrams: Chemical reactions can be shown by a potential energy diagram. Below is a potential energy diagram of an endothermic reaction.

Endothermic Reaction

In endothermic reactions, the potential energy of the products is greater than the potential energy of the reactants. Endothermic reactions absorb heat from the surroundings.



$$2\ C(s) + H_2(g) + 227.4 \text{ kJ} \rightarrow C_2H_2(g)$$

Explanation of the Arrows:

Arrow (1) represents the potential energy of the reactants, $2C(s) + H_2(g)$. This potential energy is illustrated by plateau A.

Arrow (2) is the activation energy. This is the minimum amount of energy needed to start the reaction.

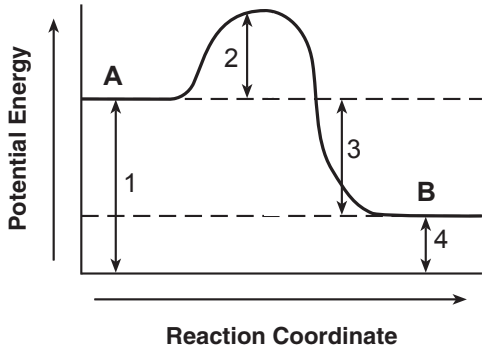
Arrow (3) is the heat of reaction (ΔH). The heat of reaction is the potential energy of the product minus the potential energy of the reactant. Since B is greater than A, the ΔH for an endothermic reaction is positive ($\Delta H = 227.4$ kJ).

Notice that, in the chemical equation, the heat is included on the reactant side of the equation since it is absorbed. This is true for all endothermic reactions.

Arrow (4) represents the potential energy of the product, $C_2H_2(g)$, plateau B.

Exothermic Reaction

In exothermic reactions, the potential energy of the products is lower than the potential energy of the reactants. Exothermic reactions release heat into the surroundings.



$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4\ kJ$

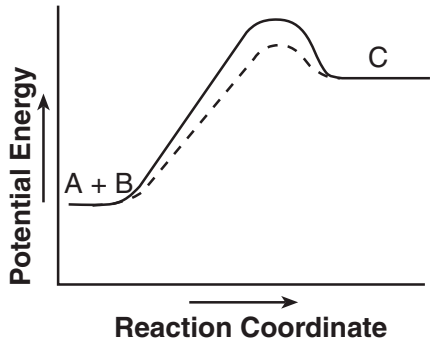
Arrow (1) represents the potential energy of the reactants, $CH_4(g) + 2O_2(g)$.

Arrow (2) represents the activation energy.

Arrow (3) is the heat of reaction (ΔH). Since 4 is less than 1, the ΔH for an exothermic reaction is negative ($\Delta H = -890.4$ kJ). Notice that, in the chemical equation, the heat is included on the product side of the equation since it is released. This is true for all exothermic reactions.

Arrow (4) represents the potential energy of the products, $CO_2(g) + 2H_2O(\ell)$, plateau B.

Catalyst



A catalyst is a substance that increases the speed at which a reaction takes place or equilibrium is reached. The catalyst accomplishes this by lowering the activation energy needed for the forward and reverse reaction. In the diagram to the left, the solid line represents the change in potential energy that occurs during the given reaction: A + B → C. The dotted line represents the pathway of the same reaction when a catalyst is added. Notice that a different reaction pathway occurs with the peak of the potential energy graph (the top of the curve) being lowered. Thus the activation energy is decreased, without changing the positions of the potential energy of the plateaus (reactants and products).

Additional Information:

- Melting and evaporation are endothermic phase changes.
  Condensation and freezing are exothermic phase changes.
- The greater the negative ΔH, the more stable the products of the reaction.
- The greater the positive ΔH, the more unstable the products of the reaction.
- Entropy is a measure of the randomness or disorder in a system. As a system becomes more random (less ordered), the entropy increases. As the temperature of a system increases, the entropy increases. As a substance changes from a solid to a liquid to a gas, the entropy increases.

Set 1 — Heats of Reaction

1. Which statement best describes a chemical reaction in which energy is released?

   (1) It is exothermic and has a negative ΔH.
   (2) It is exothermic and has a positive ΔH.
   (3) It is endothermic and has a negative ΔH.
   (4) It is endothermic and has a positive ΔH.

   1 _____

2. Which change of phase is exothermic?

   (1) solid to liquid (3) solid to gas
   (2) gas to liquid (4) liquid to gas 2 _____

3. Which equation represents an exothermic reaction at 298 K?

   (1) $N_2(g) + O_2(g) \rightarrow 2NO(g)$
   (2) $C(s) + O_2(g) \rightarrow CO_2(g)$
   (3) $KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq)$
   (4) $NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$ 3 _____

4. Based on Reference Table I, which change occurs when pellets of solid NaOH are added to water and stirred?

   (1) The water temperature increases as chemical energy is converted to heat energy.
   (2) The water temperature increases as heat energy is stored as chemical energy.
   (3) The water temperature decreases as chemical energy is converted to heat energy.
   (4) The water temperature decreases as heat energy is stored as chemical energy. 4 _____

5. Which reaction releases the greatest amount of energy per 2 moles of product?

   (1) $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
   (2) $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
   (3) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
   (4) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ 5 _____

6. In a potential energy diagram, the difference between the potential energy of the products and the potential energy of the reactants is equal to the

   (1) heat of reaction
   (2) entropy of the reaction
   (3) activation energy of the forward reaction
   (4) activation energy of the reverse reaction

   6 _____

7. Which balanced equation represents an endothermic reaction?

   (1) $C(s) + O_2(g) \rightarrow CO_2(g)$
   (2) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$
   (3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
   (4) $N_2(g) + O_2(g) \rightarrow 2NO(g)$ 7 _____

8. Which statement correctly describes an endothermic chemical reaction?

   (1) The products have higher potential energy than the reactants, and the ΔH is negative.
   (2) The products have higher potential energy than the reactants, and the ΔH is positive.
   (3) The products have lower potential energy than the reactants, and the ΔH is negative.
   (4) The products have lower potential energy than the reactants, and the ΔH is positive. 8 _____

9. According to Table I, which salt releases energy as it dissolves?

(1) KNO_3 (3) NH_4NO_3
(2) LiBr (4) NaCl 9 _____

10. Given the balanced equation:

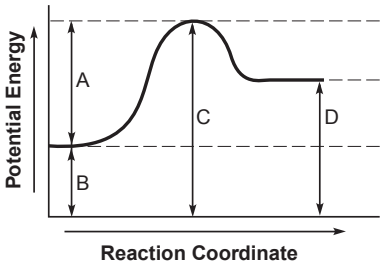
$$KNO_3(s) + 34.89\ kJ \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$$

Which statement best describes this process?

(1) It is endothermic and entropy increases.
(2) It is endothermic and entropy decreases.
(3) It is exothermic and entropy increases.
(4) It is exothermic and entropy decreases.

10 ____

11. Given the potential energy diagram of a chemical reaction:

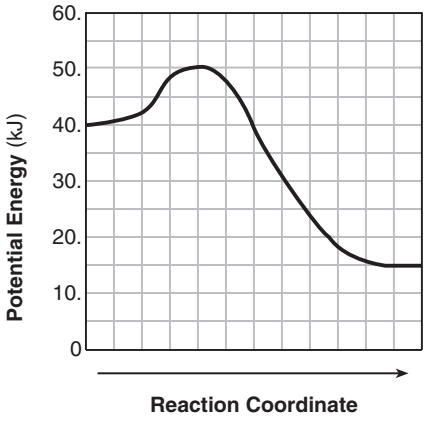


Which arrow represents the potential energy of the reactants?

(1) *A* (3) *C*
(2) *B* (4) *D* 11 ____

12. Given the potential energy diagram for a chemical reaction. Which statement correctly describes the energy changesthat occur in the forward reaction?

(1) The activation energy is 10. kJ and the reaction is endothermic.
(2) The activation energy is 10. kJ and the reaction is exothermic.
(3) The activation energy is 50. kJ and the reaction is endothermic.
(4) The activation energy is 50. kJ and the reaction is exothermic.



12_____

13. Given the balanced equation representing a reaction:

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g) + \text{energy}$$

Which statement describes the energy changes in this reaction?

(1) Energy is absorbed as bonds are formed, only.
(2) Energy is released as bonds are broken, only.
(3) Energy is absorbed as bonds are broken, and energy is released as bonds are formed.
(4) Energy is absorbed as bonds are formed, and energy is released as bonds are broken. 13_____

Base your answer to question 14 using the information below and your knowledge of chemistry.

Given the balanced equation for dissolving $NH_4Cl(s)$ in water:

$$NH_4Cl(s) \xrightarrow{H_2O} NH_4^+(aq) + Cl^-(aq)$$

14. A student is holding a test tube containing 5.0 milliliters of water. A sample of $NH_4Cl(s)$ is placed in the test tube and stirred. Describe the heat flow between the test tube and the student's hand.

_____

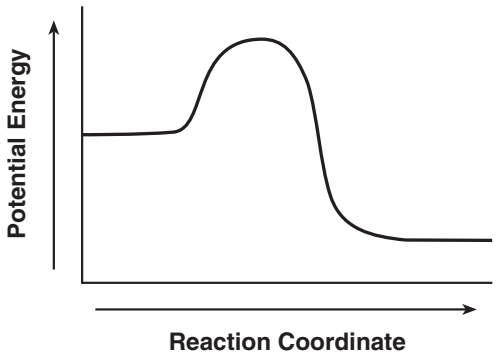
_____

Base your answers to question 15 on the information below.

The catalytic converter in an automobile changes harmful gases produced during fuel combustion to less harmful exhaust gases. In the catalytic converter, nitrogen dioxide reacts with carbon monoxide to produce nitrogen and carbon dioxide. This reaction is represented by the balanced equation below.

Reaction 1: $2NO_2(g) + 4CO(g) \rightarrow N_2(g) + 4CO_2(g) + 1198.4\ kJ$

15. The accompanying potential energy diagram represents reaction 1 without a catalyst. On the same diagram, draw a dashed line to indicate how potential energy changes when the reaction is catalyzed in the converter.



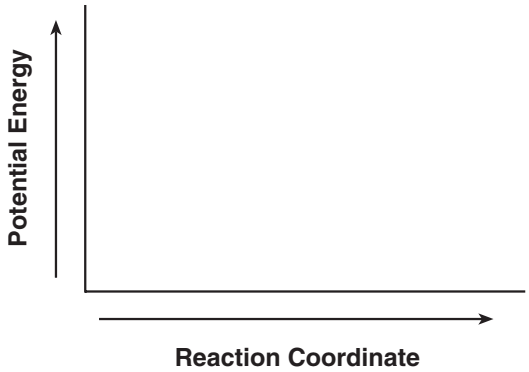
Given the balanced equation representing a reaction:

$$N_2(g) + O_2(g) + 182.6\ kJ \rightarrow 2NO(g)$$

16. *a*) On the accompanying labeled axes, draw a potential energy diagram for this reaction.

b) What is the ΔH for this reaction?

_____ kJ



17. Which phase change is endothermic?

(1) gas → solid (3) liquid → solid
(2) gas → liquid (4) liquid → gas 17 ____

18. Of the following reactions, which one releases the most heat?

(1) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$
(2) $2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(\ell)$
(3) $N_2(g) + O_2(g) \rightarrow 2NO(g)$
(4) $2C(s) + H_2(g) \rightarrow C_2H_2(g)$ 18 ____

19. Given the balanced equation representing a reaction:

$CH_4(g) + 2O_2(g) \rightarrow 2H_2O(\ell) + CO_2(g) + \text{heat}$

Which statement is true about energy in this reaction?

(1) The reaction is exothermic because it releases heat.
(2) The reaction is exothermic because it absorbs heat.
(3) The reaction is endothermic because it releases heat.
(4) The reaction is endothermic because it absorbs heat. 19 ____

20. Given the balanced equation representing a reaction at 101.3 kPa and 298 K:

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 91.8\ kJ$

Which statement is true about this reaction?

(1) It is exothermic and ΔH equals –91.8 kJ.
(2) It is exothermic and ΔH equals +91.8 kJ.
(3) It is endothermic and ΔH equals –91.8 kJ.
(4) It is endothermic and ΔH equals +91.8 kJ.

20 ____

21. When lithium bromide crystals are dissolved in water, the temperature of the water increases. What does this temperature change indicate about the dissolving of lithium bromide in water?

(1) It is an endothermic reaction because it absorbs heat.
(2) It is an endothermic reaction because it releases heat.
(3) It is an exothermic reaction because it absorbs heat.
(4) It is an exothermic reaction because it releases heat. 21 ____

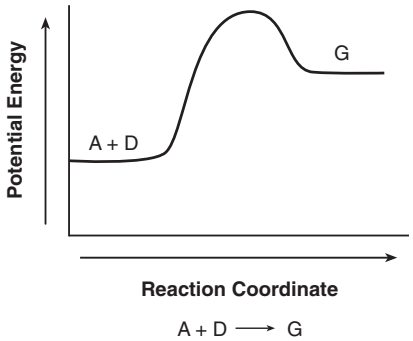
22. Given the reaction:

$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell) + 571.6\ kJ$

What is the approximate ΔH for the formation of 1 mole of $H_2O(\ell)$?

(1) –285.8 kJ (3) –571.6 kJ
(2) +285.8 kJ (4) +571.6 kJ 22 ____

23. Given the potential energy diagram and equation representing the reaction between substances *A* and *D*:



A + D ⟶ G

According to Table I, substance G could be
(1) HI(g) (3) $CO_2(g)$
(2) $H_2O(g)$ (4) $C_2H_6(g)$ 23 ____

24. For a given reaction, adding a catalyst increases the rate of the reaction by
(1) providing an alternate reaction pathway that has a higher activation energy
(2) providing an alternate reaction pathway that has a lower activation energy
(3) using the same reaction pathway and increasing the activation energy
(4) using the same reaction pathway and decreasing the activation energy 24____

25. Which phase change results in the release of energy?

(1) $H_2O(s) \rightarrow H_2O(\ell)$
(2) $H_2O(s) \rightarrow H_2O(g)$
(3) $H_2O(\ell) \rightarrow H_2O(g)$
(4) $H_2O(g) \rightarrow H_2O(\ell)$ 25 ____

26. Given the balanced equation representing a phase change:

$C_6H_4Cl_2(s) + \text{energy} \rightarrow C_6H_4Cl_2(g)$

Which statement describes this change?
(1) It is endothermic, and entropy decreases.
(2) It is endothermic, and entropy increases.
(3) It is exothermic, and entropy decreases.
(4) It is exothermic, and entropy increases.
26 ____

27. Which balanced equation represents a chemical change?

(1) $H_2O(\ell) + \text{energy} \rightarrow H_2O(g)$
(2) $2H_2O(\ell) + \text{energy} \rightarrow 2H_2(g) + O_2(g)$
(3) $H_2O(\ell) \rightarrow H_2O(s) + \text{energy}$
(4) $H_2O(g) \rightarrow H_2O(\ell) + \text{energy}$ 27 ____

Base your answers to question 28 using the information below and your knowledge of chemistry.

Propane is a fuel that is sold in rigid, pressurized cylinders. Most of the propane in a cylinder is liquid, with gas in the space above the liquid level. When propane is released from the cylinder, the propane leaves the cylinder as a gas. Propane gas is used as a fuel by mixing it with oxygen in the air and igniting the mixture, as represented by the balanced equation below.

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell) + 2219.2\ kJ$$

28. *a*) Determine the total amount of energy released when 2.50 moles of propane is completely reacted with oxygen. _____ kJ

b) Is the above reaction exothermic or endothermic? _____

Base your answers to question 29 on the information below and your knowledge of chemistry.

A hot pack contains chemicals that can be activated to produce heat. A cold pack contains chemicals that feel cold when activated.

29. *a*) Based on energy flow, state the type of chemical change that occurs in a hot pack.

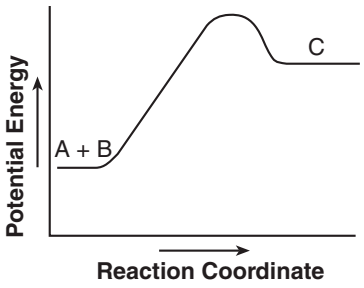
_____

b) A cold pack is placed on an injured leg. Indicate the direction of the flow of energy between the leg and the cold pack.

_____

Base your answer to question 30 using your knowledge of chemistry and the information and accompanying diagram, which represent the changes in potential energy that occur during the given reaction.

Given the reaction: $A + B \rightarrow C$

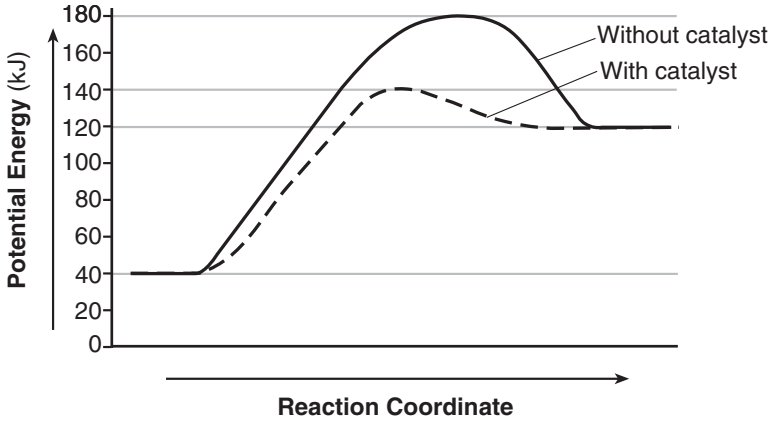


30. Does the diagram illustrate an exothermic or an endothermic reaction? State one reason, in terms of energy, to support your answer.

_____

_____

Base your answers to question 31 on the potential energy diagram.



31. *a*) What is the heat of reaction for the forward reaction?

_____ kJ

b) What is the activation energy for the forward reaction with the catalyst?

_____ kJ

c) Explain, in terms of the function of a catalyst, why the curves on the potential energy diagram for the catalyzed and uncatalyzed reactions are different.

_____

_____

32. Explain what will happen to the thermometer reading when 22 grams of NaOH(s) is dissolved in the water.

_____

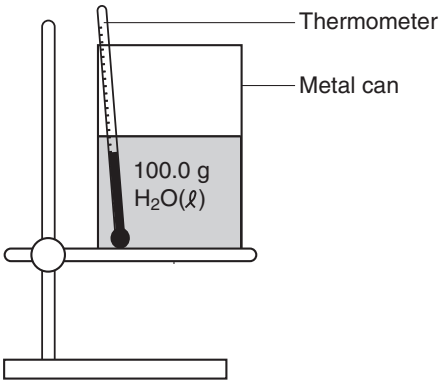


Table I – Heats of Reaction

Answers

Set 1

1. 1 All exothermic reactions release heat and have a negative (minus) ΔH. This information is given at the bottom of Table I.

2. 2 Melting and evaporation are phase changes that absorb heat making them endothermic phase changes. Condensation and freezing are phase changes that release heat making them exothermic phase changes. Condensation is when a gas changes to a liquid.

3. 2 An exothermic reaction releases energy. Open to Table I. It shows that $C(s) + O_2(g) \rightarrow CO_2(g)$ releases 393.5 kJ of heat, indicated by a negative ΔH. At the bottom of this chart it states "Minus sign indicates an exothermic reaction".

4. 1 In Table I, locate the equation involving the reactant NaOH. The ΔH for this reaction is –44.51 kJ, making this an exothermic reaction. This reaction releases heat as chemical energy, which converted to heat energy.

5. 2 When a reaction releases energy it is an exothermic reaction, having a negative ΔH. The reaction shown in choice 2 releases 3351 kJ of energy per 2 moles of product. This is the greatest amount of energy of the given choices.

6. 1 The reactants involved in a chemical reaction will be at a specific potential energy, measured in kilojoules (kJ). After the reaction, the products will be at a different potential energy level. The net difference between these two energy levels, as shown by two plateaus on a potential energy graph, is the referred to as the heat of reaction.

7. 4 In Table I, locate this equation. Its ΔH is + 182.6 kJ. All endothermic reactions have a positive ΔH.

8. 2 When the products have a higher potential energy than the reactants, the chemical reaction must have absorbed energy, which makes it an endothermic reaction. A graph would show the reactants at a lower potential energy than the products.

9. 2 As shown on Table I, when LiBr(s) is dissolved, an exothermic reaction takes place releasing 48.83 kJ of energy. All other choices are endothermic reactions, which would absorb heat.

10. 1 The equation shows that 34.89 kJ of energy being absorbed by the reactants, making it endothermic reaction. Entropy is a measure of the disorder of a system. The greater the disorder, the greater the entropy. The equation shows that the solid KNO_3 is being dissolved to form an aqueous solution. Whenever a solid is dissolved, entropy increases.

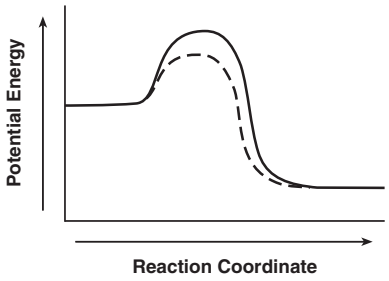
11. 2 The potential energy of the reactants is shown by the initial plateau, which is letter B. The potential energy of the products is shown by the second plateau, letter D.

12. 2 The graph shows that it took 10 kJ (40 kJ to 50 kJ) of activation energy for this reaction to occur. The graph also shows that the potential energy of the products is lower then that of the reactants. This is true for all exothermic reactions.

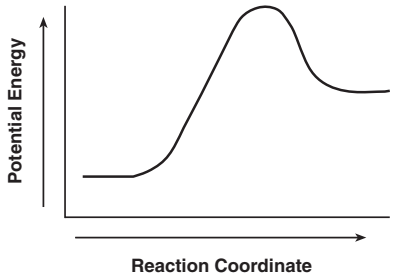
13. 3 The equation shows the reaction between two diatomic molecules (H_2 and Cl_2) to produce a single product (HCl). The bonds between the Cl atoms in Cl_2 and the H atoms in H_2 must first be broken, which requires the absorption of energy. The separate H atoms and Cl atoms then bond to each other to form the product, HCl. Bond formation releases energy.

14. Answer: Heat flows from the student's hand to the test tube.
or The test tube absorbs heat from the hand.

Explanation: As shown in Table I, this reaction is endothermic absorbing 14.78 kJ. The reaction will absorb heat from the water and from the student's hand. As heat is removed (being absorbed) from the student's hand, the test tube will feel colder.

15. 

Explanation: Refer to page 41 and the given explanation for the catalyst diagram.

16. *a*) 

Explanation: The given equation is an endothermic reaction since the heat is included on the reactant side of the chemical equation. On a graph, the potential energy of the products must be greater than the potential energy of the reactants for endothermic reactions.

b) Answer: + 182.6 kJ

Explanations: This is an endothermic reaction. Endothermic reactions will always have a positive heat of reaction (ΔH).

Table J — Activity Series

Overview:

You have probably noticed that if iron is not painted or coated, it starts to rust in days, especially if moisture is present. But silver, and especially gold, seem to be unaffected by substances in the environment and keep their brilliant luster. The reason for this is that different metals exhibit different chemical activity. In other words, some metals are very reactive, while other metals are less reactive. By studying the chemical activities of elements (metals and nonmetals), chemists have been able to arrange them based upon chemical reactivity.

The Table:

This table shows the relative chemical activity of metals and nonmetals, both arranged in order of decreasing chemical activity. Although H_2 is not a metal, it is listed on the metallic side because the table is based on the hydrogen standard.

In a chemical reaction, a more active metal (higher up on Table J) will replace a less active metal when placed in an aqueous solution containing the ion of the less active metal. For example, lithium (Li), being the most active metal, will replace any metallic ion found below it from a solution of its salt. Rubidium (Rb) will replace any metal found below it from a solution of its salt, but because it is under Li, indicating that it is less active than Li, it will not replace Li from a solution of its salt.

Most Active	Metals	Nonmetals	Most Active
	Li	F_2	
	Rb	Cl_2	
	K	Br_2	
	Cs	I_2	
	Ba		
	Sr		
	Ca		
	Na		
	Mg		
	Al		
	Ti		
	Mn		
	Zn		
	Cr		
	Fe		
	Co		
	Ni		
	Sn		
	Pb		
	H_2		
	Cu		
	Ag		
Least Active	Au		Least Active

**Activity Series is based on the hydrogen standard. H_2 is *not* a metal.

Metals found above H_2 are more active than hydrogen. Therefore, it will replace the H^+ in an aqueous acidic solution, producing hydrogen gas and a solution of a salt containing that metal. Those metals below H_2 will not react with acids in this fashion.

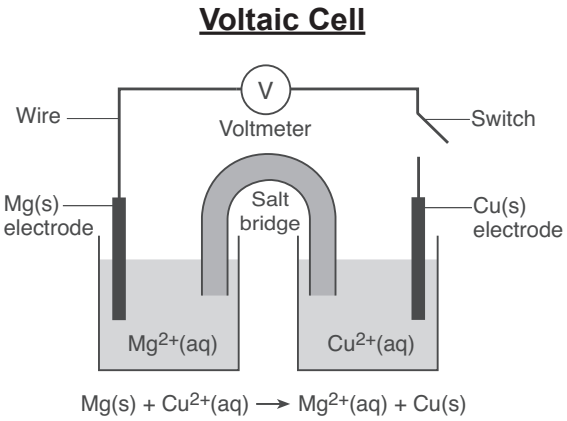
For example: $Mg + 2HCl \rightarrow MgCl_2 + H_2\uparrow$ reacted, because Mg is more active (being above H_2) than H_2, as shown on Table J.

$Ag + HCl \rightarrow$ no reaction, because Ag is less active (being lower than H_2) than H_2, as shown on Table J.

In a similar fashion, in a chemical reaction, a nonmetal will replace a less active nonmetal when interacting with a solution containing the ion of the less active nonmetal. For example, fluorine (F_2) will replace Cl^-, Br^- and I^- in solutions containing those ions, but chlorine (Cl_2) cannot replace F^- from a solution containing the F^- ion; however, chlorine will replace Br^- and I^- in solutions containing these ions.

Voltaic Cell:

An electrochemical or voltaic cell uses a spontaneous redox reaction to produce an electric current. It consists of two different metals, called electrodes, immersed in a solution of that metals salt, called an electrolyte. The electrodes are connected by a wire conductor. The electrolytes are connected by a salt bridge. The more active metal, higher up on Table J, undergoes oxidation and is called the anode (the negative electrode). The electrons flow through the wire to the less active metal, lower down on Table J, where they reduce that metals ions in the electrolyte. This electrode is called the cathode (the positive electrode).



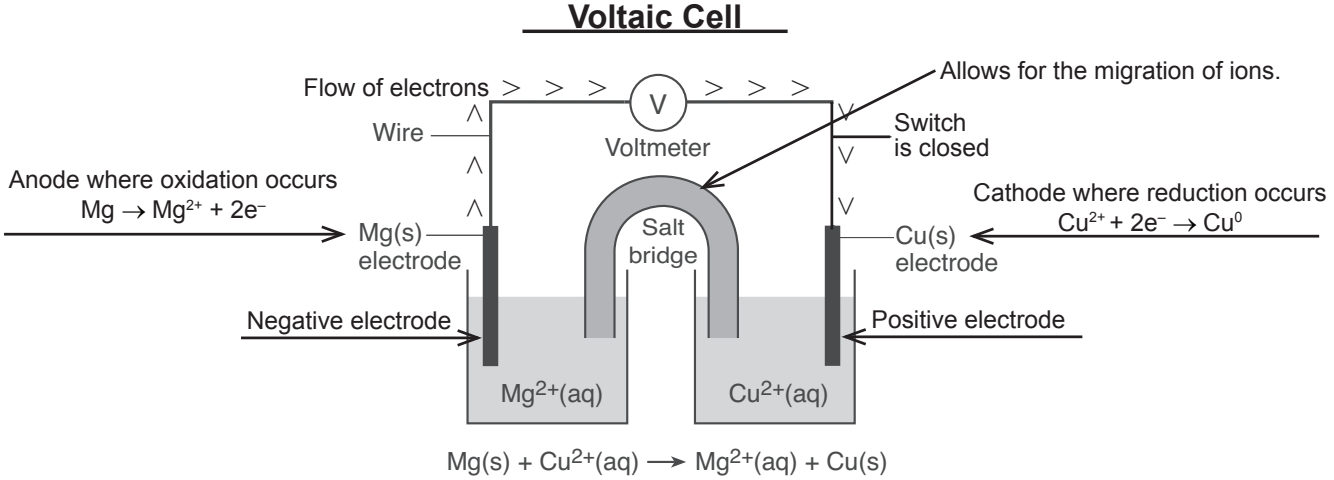
Example:

A voltaic cell with magnesium and copper electrodes is shown in the above diagram. The copper electrode has a mass of 15.0 grams. Below the diagram is the balanced ionic equation for the reaction in the cell.

When the switch is closed, the salt bridge allows ions to flow between the half-cells and the reaction in the cell begins. The more active metal, Mg being higher up on Table J, will undergo oxidation (acting as a reducing agent) and the less active metal, Cu will undergo reduction (acting as an oxidizing agent). The electrons flow from the Mg electrode (losing electrons during oxidation) to the copper electrode where they will be used in the reduction of the Cu^{2+} ions found in the electrolyte. As Cu^{2+} ions become reduced to Cu^{o} (a neutral copper atom), the atoms become part of the copper electrode, increasing its mass.

In an electrolytic cell, an electric current is used to cause a nonspontaneous redox reaction to occur. It needs a power source, such as a battery, to begin and sustain the reaction. In this reaction, electrical energy is converted to chemical energy. In the voltaic cell, chemical energy is converted to electrical energy.

Review:



Additional Information:

- In the single replacement reaction $A + BC \rightarrow B + AC$ where A is a metal, the reaction will occur spontaneously if A is above B on Table J. If A is below B, the reaction will not occur.
- The most active metals are those that readily lose an electron, thus are easily oxidized. They tend to be the strongest reducing agents. Typically, they are Group 1 and Group 2 elements.
- In the single replacement reaction $A + BC \rightarrow C + BA$ where A is a nonmetal, the reaction will occur spontaneously if A is above C on Table J. If A is below C, the reaction will not occur.
- The most active nonmetals are those that more readily gain an electron, thus most easily reduced. They tend to be the strongest oxidizing agents. Typically, they are Group 17 elements.
- Fluorine is the most active of all the elements.
- Gold (Au) a very inactive metal, which is why it keeps its brilliant luster. Being inactive, it is used in electrical connections that are exposed to hostile conditions, such as those found in space vehicles.

Set 1 — Activity Series

1. According to Reference Table J, which of these metals will react most readily with 1.0 M HCl to produce $H_2(g)$?

   (1) Ca (3) Mg
   (2) K (4) Zn 1 _____

2. Which metal is more active than H_2?

   (1) Ag (3) Cu
   (2) Au (4) Pb 2 _____

3. According to Reference Table J, which metal will react with Zn^{2+} but will not react with Mg^{2+}?

   (1) Al(s) (3) Ni(s)
   (2) Cu(s) (4) Ba(s) 3 _____

4. Which metal reacts spontaneously with a solution containing zinc ions?

   (1) strontium (3) copper
   (2) nickel (4) silver 4 _____

5. Which of the following metals is most active?

   (1) Ag (3) Sn
   (2) Zn (4) Li 5 _____

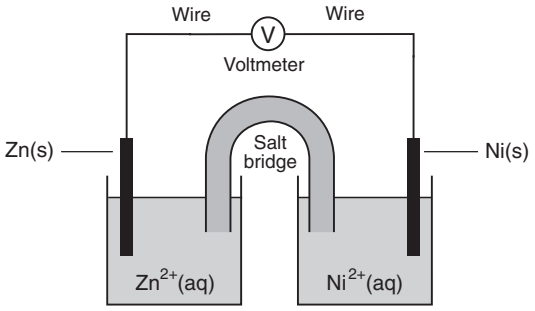
6. Which metal is more active than Ni and less active than Zn?

   (1) Cu (3) Cr
   (2) Mg (4) Pb 6 _____

7. Which half-reaction equation represents the reduction of an iron(II) ion?

   (1) $Fe^{2+} \rightarrow Fe^{3+} + e^-$
   (2) $Fe^{2+} + 2e^- \rightarrow Fe$
   (3) $Fe^{3+} + e^- \rightarrow Fe^{2+}$
   (4) $Fe \rightarrow Fe^{2+} + 2e^-$ 7 _____

8. The diagram below represents an operating electrochemical cell and the balanced ionic equation for the reaction occurring in the cell.



$Zn(s) + Ni^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Ni(s)$

Which statement identifies the part of the cell that conducts electrons and describes the direction of electron flow as the cell operates?

(1) Electrons flow through the salt bridge from the Ni(s) to the Zn(s).
(2) Electrons flow through the salt bridge from the Zn(s) to the Ni(s).
(3) Electrons flow through the wire from the Ni(s) to the Zn(s).
(4) Electrons flow through the wire from the Zn(s) to the Ni(s). 8 _____

9. Which statement is true for any electrochemical cell?

(1) Oxidation occurs at the anode, only.
(2) Reduction occurs at the anode, only.
(3) Oxidation occurs at both the anode and the cathode.
(4) Reduction occurs at both the anode and the cathode. 9 _____

10. Which energy conversion occurs during the operation of an electrolytic cell?

(1) chemical energy to electrical energy
(2) electrical energy to chemical energy
(3) nuclear energy to electrical energy
(4) electrical energy to nuclear energy 10 ____

11. Which process occurs at the anode in an electrochemical cell?

(1) the loss of protons
(2) the loss of electrons
(3) the gain of protons
(4) the gain of electrons 11 ____

12. Given the balanced ionic equation representing the reaction in an operating voltaic cell:

$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

The flow of electrons through the external circuit in this cell is from the

(1) Cu anode to the Zn cathode
(2) Cu cathode to the Zn anode
(3) Zn anode to the Cu cathode
(4) Zn cathode to the Cu anode 12 ____

13. A student collects the materials and equipment below to construct a voltaic cell.

- two 250-mL beakers
- wire and a switch
- one strip of magnesium
- one strip of copper
- 125 mL of 0.20 M $Mg(NO_3)_2(aq)$
- 125 mL of 0.20 M $Cu(NO_3)_2(aq)$

Which additional item is required for the construction of the voltaic cell?

(1) an anode
(2) a battery
(3) a cathode
(4) a salt bridge 13 ____

14. Identify one metal from Reference Table J that is more easily oxidized than Mg(s). _____

Base your answer to question 15 using the information below and your knowledge of chemistry.

Two chemistry students each combine a different metal with hydrochloric acid. Student *A* uses zinc, and hydrogen gas is readily produced. Student *B* uses copper, and no hydrogen gas is produced.

15. State one chemical reason for the different results of students *A* and *B*.

_____

_____

16. When a nickel-cadmium battery produces electricity, the following reaction takes place:

$$Cd(s) + NiO_2(s) + 2H_2O(\ell) \rightarrow Cd(OH)_2(s) + Ni(OH)_2(s).$$

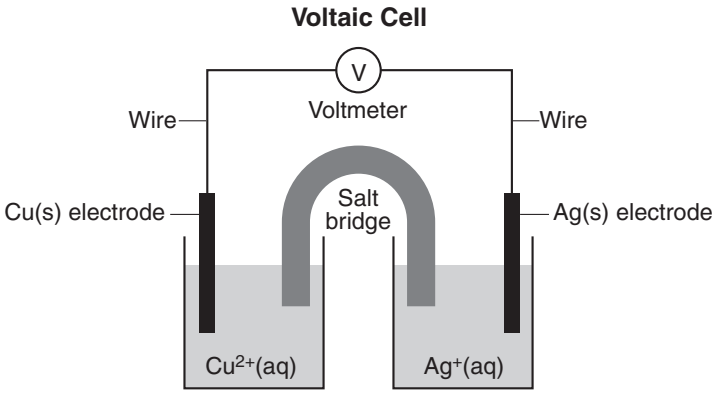
Explain why Cd would be above Ni if placed on Table J.

_____

_____

Base your answers to question 17 on the information below.

The diagram and balanced ionic equation represent a voltaic cell with copper and silver electrodes and the reaction that occurs when the cell is operating.



$$Cu(s) + 2Ag^{+}(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$$

17. *a*) Describe the direction of electron flow in the external circuit in this operating cell.

_____

b) State the purpose of the salt bridge in this voltaic cell.

_____

c) Write a balanced half-reaction equation for the oxidation that occurs in this cell.

_____

18. Based on Reference Table J, which metal will react spontaneously with Al^{3+}?

(1) Co(s) (3) Cu(s)
(2) Cr(s) (4) Ca(s) 18 ____

19. Given the balanced equation representing a reaction occurring in an electrolytic cell:

$2NaCl(\ell) \rightarrow 2Na(\ell) + Cl_2(g)$

Where is $Na(\ell)$ produced in the cell?
(1) at the anode, where oxidation occurs
(2) at the anode, where reduction occurs
(3) at the cathode, where oxidation occurs
(4) at the cathode, where reduction occurs
19 ____

20. Under standard conditions, which metal will react with 0.1 M HCl to liberate hydrogen gas?

(1) Ag (3) Cu
(2) Au (4) Mg 20 ____

21. Which reaction occurs spontaneously?

(1) $Cl_2(g) + 2NaBr(aq) \rightarrow Br_2(\ell) + 2NaCl(aq)$
(2) $Cl_2(g) + 2NaF(aq) \rightarrow F_2(g) + 2NaCl(aq)$
(3) $I_2(s) + 2NaBr(aq) \rightarrow Br_2(\ell) + 2NaI(aq)$
(4) $I_2(s) + 2NaF(aq) \rightarrow F_2(g) + 2NaI(aq)$
21 ____

22. Which of the following metals has the least tendency to undergo oxidation?

(1) Ag (3) Zn
(2) Pb (4) Li 22 ____

23. Which of the following nonmetals is most active?

(1) F_2 (3) Br_2
(2) Cl_2 (4) I_2 23 ____

24. Which half-reaction correctly represents reduction?

(1) $Mn^{4+} \rightarrow Mn^{3+} + e^-$
(2) $Mn^{4+} \rightarrow Mn^{7+} + 3e^-$
(3) $Mn^{4+} + e^- \rightarrow Mn^{3+}$
(4) $Mn^{4+} + 3e^- \rightarrow Mn^{7+}$ 24 ____

25. Which energy change occurs in an operating voltaic cell?

(1) chemical to electrical
(2) electrical to chemical
(3) chemical to nuclear
(4) nuclear to chemical 25 ____

26. Given the balanced equation representing the reaction occurring in a voltaic cell:

$Zn(s) + Pb^{2+}(aq) \rightarrow Zn^{2+}(aq) + Pb(s)$

In the completed external circuit, the electrons flow from

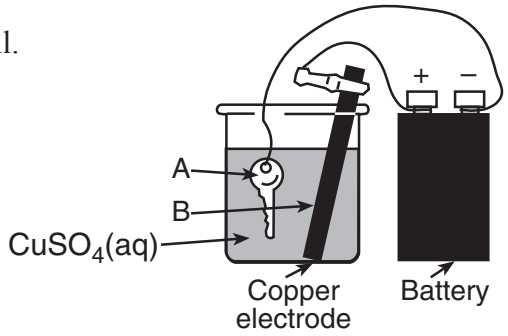
(1) Pb(s) to Zn(s)
(2) $Pb^{2+}(aq)$ to $Zn^{2+}(aq)$
(3) Zn(s) to Pb(s)
(4) $Zn^{2+}(aq)$ to $Pb^{2+}(aq)$ 26 ____

27. The accompanying diagram shows a key being plated with copper in an electrolytic cell. Given the reduction reaction for this cell:

$$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$$

This reduction occurs at

(1) *A*, which is the anode
(2) *A*, which is the cathode
(3) *B*, which is the anode
(4) *B*, which is the cathode



27_____

Base your answer to question 28 using the information below and your knowledge of chemistry.

The outer structure of the Statue of Liberty is made of copper metal. The framework is made of iron. Over time, a thin green layer (patina) forms on the copper surface.

28. Where the iron framework came in contact with the copper surface, a reaction occurred in which iron was oxidized. Using information from Reference Table J, explain why the iron was oxidized.

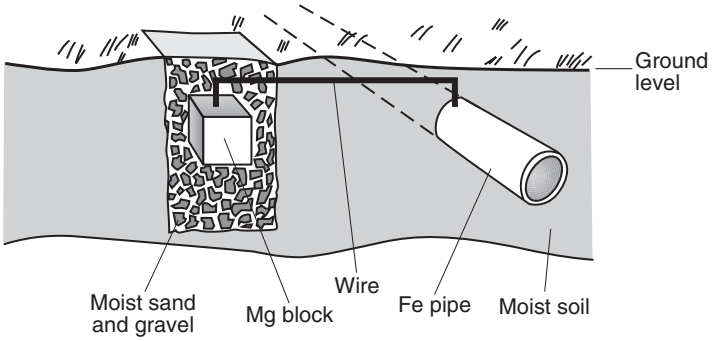
_____

_____

Base your answers to question 29 on the information below.

Underground iron pipes in contact with moist soil are likely to corrode. This corrosion can be prevented by applying the principles of electrochemistry. Connecting an iron pipe to a magnesium block with a wire creates an electrochemical cell. The magnesium block acts as the anode and the iron pipe acts as the cathode. A diagram of this system is shown to the right.

Cross-Sectional View of Underground Pipe Protection System



29. *a*) State the direction of the flow of electrons between the electrodes in this cell.

_____

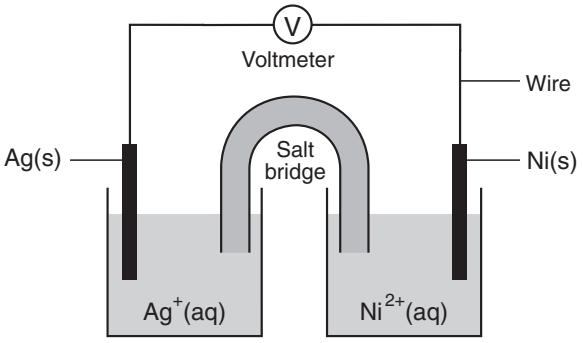
b) Explain, in terms of reactivity, why magnesium is preferred over zinc to protect underground iron pipes. Your response must include both magnesium and zinc.

_____

_____

Base your answers to question 30 on the information below.

The accompanying diagram represents an operating voltaic cell at 298 K and 1.0 atmosphere in a laboratory investigation. The reaction occurring in the cell is represented by the balanced ionic equation below the diagram.



$$2Ag^+(aq) + Ni(s) \longrightarrow 2Ag(s) + Ni^{2+}(aq)$$

30. *a*) Identify the anode in this cell.

_____

b) Determine the total number of moles of $Ni^{2+}(aq)$ ions produced when 4.0 moles of $Ag^+(aq)$ ions completely react in this cell. _____

c) Write a balanced half-reaction equation for the reduction that occurs in this cell.

_____

31. Based on Table J, identify one metal that does not react spontaneously with HCl(aq). _____

32. Because tap water is slightly acidic, water pipes made of iron corrode over time, as shown by the balanced ionic equation below:

$$2Fe + 6H^+ \rightarrow 2Fe^{3+} + 3H_2$$

Explain, in terms of chemical reactivity, why copper pipes are less likely to corrode than iron pipes.

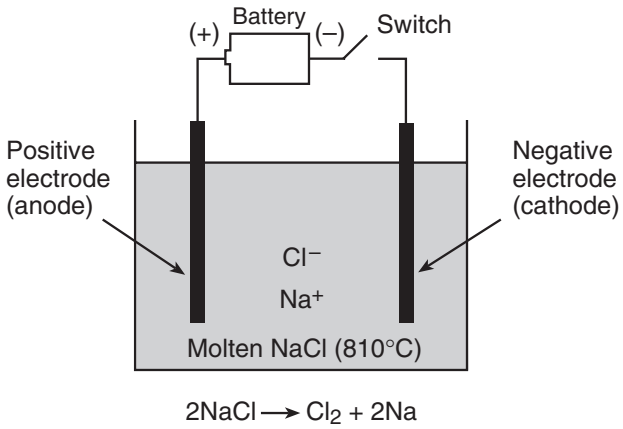
_____

33. Explain, in terms of electrical energy, how the operation of a voltaic cell differs from the operation of an electrolytic cell used in the Hall process. Include both the voltaic cell and the electrolytic cell in your answer.

_____

34. Identify *one* metal from Reference Table J that is more easily oxidized than Ba(s). _____

Base your answers to question 35 on the diagram and balanced equation, which represent the electrolysis of molten NaCl.



$2NaCl \longrightarrow Cl_2 + 2Na$

35. *a*) When the switch is closed, which electrode will attract the sodium ions?

_____

b) What is the purpose of the battery in this electrolytic cell?

_____

c) Write the balanced half-reaction for the reduction that occurs in this electrolytic cell.

_____

Base your answers to question 36 on the information below.

In a laboratory investigation, a student constructs a voltaic cell with iron and copper electrodes. Another student constructs a voltaic cell with zinc and iron electrodes. Testing the cells during operation enables the students to write the balanced ionic equations below.

Cell with iron and copper electrodes: $Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$

Cell with zinc and iron electrodes: $Fe^{2+}(aq) + Zn(s) \rightarrow Fe(s) + Zn^{2+}(aq)$

36. *a*) State evidence from the balanced equation for the cell with iron and copper electrodes that indicates the reaction in the cell is an oxidation-reduction reaction.

_____

b) Identify the particles transferred between Fe^{2+} and Zn during the reaction in the cell with zinc and iron electrodes.

_____

c) Write a balanced half-reaction equation for the reduction that takes place in the cell with zinc and iron electrodes.

_____

d) State the relative activity of the three metals used in these two voltaic cells.

_____

Table J – Activity Series

Answers – Set 1

1. 2 The more active a metal is, the more readily it will react with a 1.0 M solution of HCl. In Table J, K (potassium) is the highest up on the metal activity list and is therefore more active than the other metals given as choices.

2. 4 Metals found above H_2 on Table J are more active than hydrogen. This would be lead (Pb).

3. 1 Any metal that is more active (higher up on Table J) will react with any metallic ion that is less active. Al is higher than Zn on the metal activity list, thus it will react with Zn^{2+}. However, Al is lower on the metal activity list than Mg, therefore it would not react with Mg^{2+}.

4. 1 A spontaneous reaction will occur with zinc ions with any metal that is higher than Zn on Table J. Strontium would have a spontaneous reaction with zinc ions.

5. 4 The most active metal of the given choices would be the one that is higher up on Table J. This would be lithium (Li).

6. 3 Using Table J, the higher up a metal is on this table, the more active it is. Notice that Cr is between Zn and Ni. This makes Cr more active than Ni, but less active than Zn.

7. 2 In a reduction reaction, electrons are gained and the oxidation state is lowered or reduced. In choice 2, Fe^{2+} gains 2 electrons, becoming Fe^{o}.

8. 4 Electrons flow from the electrode where oxidation or a loss of electrons occurs to the electrode where reduction or a gain of electrons occurs. The equation shows that Zn(s) is oxidized and the Ni^{2+} is reduced. The electrons therefore flow from the Zn(s) to the Ni(s), allowing the Ni^{2+} to be reduced. Ions, not electrons, flow through the salt bridge.

9. 1 In any chemical cell (voltaic or electrolytic cell), oxidation (loss of electrons) always occurs at the anode.

10. 2 See last paragraph on page 51.

11. 2 The anode is the electrode where oxidation occurs. Here, a metal gives up or loses electrons.

12. 3 Electrons flow from the anode, where oxidation occurs, to the cathode, where reduction occurs. In the equation, Zn is undergoing oxidation by losing two electrons, thus Zn is the anode. The Cu^{2+} is gaining these electrons, therefore the Cu(s) is the cathode.

13. 4 A salt bridge is an essential part of a voltaic cell. It allows the flow of ions between each half-cell, completing the circuit, allowing the cell to function.

14. Answer: Li *or* Ba *or* Rb *or* Sr *or* K *or* Ca *or* Cs *or* Na

Explanation: Any metal that is higher up on Table J than Mg would be more active, thus more easily oxidized than Mg.

15. Answer: Cu is less active than hydrogen gas (weaker reducing agent).
or Zn is more reactive (stronger reducing agent than H_2 gas).
or Cu is below H_2 on the activity series and Zn is above H_2.

Explanation: Any metal that is above hydrogen on Table J will react with hydrochloric acid releasing hydrogen gas. Any metal below hydrogen will not react with hydrochloric acid and will not produce hydrogen gas. Therefore, student *A*, using Zn, produced hydrogen gas and student *B*, using copper, did not have a reaction with hydrochloric acid.

16. Answer: Cd is more active than Ni. *or* Cd oxidizes in the presence of Ni^{4+}.

Explanation: The higher up a metal is on Table J, the more active it is and the greater its tendency to undergo oxidation. In this reaction, Cd is shown to be more active than Ni since it undergoes oxidation, replacing Ni.

17. *a*) Answer: From the copper electrode to the silver electrode.

Explanation: Electrons flow from the anode, where oxidation occurs, to the cathode, where reduction occurs. The equation shows that copper loses electrons and therefore must be the anode.

b) Answer: Migration of ions *or* allows ions to flow between half-cells *or* maintains electrical neutrality *or* prevents polarization

Explanation: The salt bridge allows migration of ions between the half-cells, completing the circuit, allowing the cell to function.

c) Answer: $Cu^0 \rightarrow Cu^{2+} + 2e^-$

Explanation: In oxidation there is a loss of electrons. The copper metal loses two electrons, becoming a copper ion.

Table O Symbols Used in Nuclear Chemistry

Name	Notation	Symbol
alpha particle	$^{4}_{2}\mathrm{He}$ or $^{4}_{2}\alpha$	α
beta particle	$^{0}_{-1}\mathrm{e}$ or $^{0}_{-1}\beta$	β^-
gamma radiation	$^{0}_{0}\gamma$	γ
neutron	$^{1}_{0}\mathrm{n}$	n
proton	$^{1}_{1}\mathrm{H}$ or $^{1}_{1}\mathrm{p}$	p
positron	$^{0}_{+1}\mathrm{e}$ or $^{0}_{+1}\beta$	β^+

Overview:

Radioactive elements emit particles and/or energy from their nuclei. These nuclear particles or energy have different effects on the nuclei of these elements. This radioactive decay process can be represented by nuclear equations, showing the identity of the reactants, products and the radiation released. In these equations, both charge and mass must be conserved. To balance a nuclear equation, the sum of the atomic or charge numbers on each side must be equal, and the sum of the mass numbers on each side must be equal.

The Table:

This table gives the Name, Notation (used in writing nuclear equations) and Symbol of the common types of radiation.

Going down this chart in order:

- The alpha particle (α) is a helium nucleus and is therefore positively charged.
- The beta particle (β^-) is an ordinary electron and is therefore negatively charged.
- Gamma radiation (γ), is the emission of pure energy from the nucleus – it carries no charge or mass.
- The neutron (n) is a neutral particle of unit mass found in the nucleus of atoms.
- The proton (p) is a hydrogen nucleus, a positive particle of unit mass found in the nucleus of atoms.
- The positron (β^+) is a positive electron.

As shown in the Notation section, the mass number is the number at the upper left and the atomic number is the number at the lower left. When a particle is emitted, conservation of these numbers must take place with the reactants and products. If the emission of the particle affects the atomic number, the identity of the element changes. The specifics of these changes are given on the next page.

Additional Information:

Going down the chart in order:

- During alpha decay or emission, the atomic number decreases by 2 and the mass number decreases by 4. Example: ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\text{He}$

- During negative beta decay or emission, the atomic number increases by 1 and the mass number remains the same. Example: ${}^{235}_{92}\text{U} \rightarrow + {}^{235}_{93}\text{Np} + {}^{0}_{-1}\text{e}$

- During gamma emission, both the atomic number and mass number remain the same. Example: ${}^{239}_{92}\text{U} \rightarrow + {}^{239}_{92}\text{U} + {}^{0}_{0}\gamma$

- During neutron emission, the atomic number remains the same and the mass number decreases by 1. Example: ${}^{226}_{88}\text{Ra} \rightarrow {}^{225}_{88}\text{U} + {}^{1}_{0}\text{n}$

- During proton emission, both the atomic number and mass number decrease by 1. Example: ${}^{53}_{27}\text{Co} \rightarrow {}^{52}_{26}\text{Fe} + {}^{1}_{1}\text{H}$

- During positron emission, also known as positive beta emission, the atomic number decreases by 1 and the mass number remains the same. Example: ${}^{58}_{29}\text{Cu} \rightarrow {}^{58}_{28}\text{Ni} + {}^{0}_{+1}\text{e}$

- In natural transmutation, the identity of a nucleus or element changes due to a change in the number of protons (atomic number) in the nucleus. Example: ${}^{239}_{94}\text{Pu} \rightarrow {}^{235}_{92}\text{U} + {}^{4}_{2}\text{He}$

- Artificial transmutation occurs when a stable (nonradioactive) nucleus is bombarded with particles, causing it to become radioactive. Example: ${}^{9}_{4}\text{Be} + {}^{4}_{2}\text{He} \rightarrow {}^{12}_{6}\text{C} + {}^{1}_{0}\text{n}$

- Nuclear fusion is the combining of lightweight nuclei to produce a heavier nucleus. This usually involves hydrogen nuclei combining to produce a helium nucleus. This is the source of solar energy. Example: ${}^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + \text{energy}$

- Nuclear fission is the splitting of a heavier nucleus into lighter weight nuclei. U-235 and Pu-239 are the most common elements to under go fission. This is the source of the energy produced in nuclear reactors. Example: ${}^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{144}_{54}\text{Xe} + {}^{90}_{38}\text{Sr} + 2{}^{1}_{0}\text{n} + \text{energy}$

- Nuclear reactions release large amounts of energy due to the conversion of some mass into energy according to Einstein's equation, $E = mc^2$.

- Alpha radiation, being the largest particle, has the weakest penetrating power.

- Gamma radiation, being massless and neutral, has the greatest penetrating power.

Set 1 — Symbols Used in Nuclear Chemistry

1. Which particle has the *least* mass?

   (1) $^{4}_{2}\mathrm{He}$ (3) $^{1}_{0}\mathrm{n}$

   (2) $^{1}_{1}\mathrm{H}$ (4) $^{0}_{-1}\mathrm{e}$ 1 _____

2. In the reaction $^{239}_{93}\mathrm{Np} \rightarrow {}^{239}_{94}\mathrm{Pu} + X$, what does X represent?

   (1) a neutron
   (2) a proton
   (3) an alpha particle
   (4) a beta particle 2 _____

3. Positrons are spontaneously emitted from the nuclei of

   (1) potassium-37
   (2) radium-226
   (3) nitrogen-16
   (4) thorium-232 3 _____

4. Given the nuclear equation:

   $$^{19}_{10}\mathrm{Ne} \rightarrow X + {}^{19}_{9}\mathrm{F}$$

   Which particle is represented by X?

   (1) alpha (3) neutron

   (2) beta (4) positron 4 _____

5. Which list of radioisotopes contains an alpha emitter, a beta emitter, and a positron emitter?

   (1) C-14, N-16, P-32
   (2) Cs-137, Fr-220, Tc-99
   (3) Kr-85, Ne-19, Rn-222
   (4) Pu-239, Th-232, U-238 5 _____

6. Which product of nuclear decay has mass but no charge?

   (1) alpha particles
   (2) neutrons
   (3) gamma rays
   (4) beta positrons 6 _____

7. Which type of radioactive emission has a positive charge and weak penetrating power?

   (1) alpha particle (3) gamma ray

   (2) beta particle (4) neutron 7 _____

8. Which of these types of radiation has the greatest penetrating power?

   (1) alpha (3) gamma

   (2) beta (4) positron 8 _____

9. Which reaction is an example of natural transmutation?

   (1) $^{239}_{94}\mathrm{Pu} \rightarrow {}^{235}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$

   (2) $^{27}_{13}\mathrm{Al} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{30}_{15}\mathrm{P} + {}^{1}_{0}\mathrm{n}$

   (3) $^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{239}_{94}\mathrm{Pu} + 2\,{}^{0}_{-1}\mathrm{e}$

   (4) $^{239}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{147}_{56}\mathrm{Ba} + {}^{90}_{38}\mathrm{Sr} + 3\,{}^{1}_{0}\mathrm{n}$

   9 _____

10. Given the balanced equation representing a nuclear reaction:

    $$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3X + \text{energy}$$

    Which particle is represented by X?

    (1) $^{0}_{-1}\mathrm{e}$ (3) $^{4}_{2}\mathrm{He}$

    (2) $^{1}_{1}\mathrm{H}$ (4) $^{1}_{0}\mathrm{n}$ 10 ____

11. The change that is undergone by an atom of an element made radioactive by bombardment with high-energy protons is called

(1) natural transmutation
(2) artificial transmutation
(3) natural decay
(4) radioactive decay 11 ____

12. One benefit of nuclear fission reactions is

(1) nuclear reactor meltdowns
(2) storage of waste materials
(3) biological exposure
(4) production of energy 12 ____

13. In a nuclear fusion reaction, the mass of the products is

(1) less than the mass of the reactants because some of the mass has been converted to energy
(2) less than the mass of the reactants because some of the energy has been converted to mass
(3) more than the mass of the reactants because some of the mass has been converted to energy
(4) more than the mass of the reactants because some of the energy has been converted to mass 13 ____

---

14. Given the nuclear equation: $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{142}_{56}\mathrm{Ba} + {}^{91}_{36}\mathrm{Kr} + 3\,{}^{1}_{0}\mathrm{n} + \text{energy}$

a) State the type of nuclear reaction represented by the equation. _____

b) The sum of the masses of the products is slightly less than the sum of the masses of the reactants. Explain this loss of mass.

_____

_____

c) This process releases greater energy than an ordinary chemical reaction does. Name another type of nuclear reaction that releases greater energy than an ordinary chemical reaction.

_____

15. Using Reference Table N, complete the equation below for the nuclear decay of $^{226}_{88}\mathrm{Ra}$. Include both atomic number and mass number for each particle.

$^{226}_{88}\mathrm{Ra} \rightarrow$ _____ + _____

Set 2 — Symbols Used in Nuclear Chemistry

16. A beta particle may be spontaneously emitted from

(1) a ground-state electron
(2) a stable nucleus
(3) an excited electron
(4) an unstable nucleus 16 ____

17. Given the nuclear equation:

$$^{14}_{7}\mathrm{N} + X \rightarrow {}^{16}_{8}\mathrm{O} + {}^{2}_{1}\mathrm{H}$$

What is particle *X*?

(1) an alpha particle
(2) a beta particle
(3) a deuteron
(4) a triton 17 ____

18. In the reaction $^{9}_{4}\mathrm{Be} + X \rightarrow {}^{6}_{3}\mathrm{Li} + {}^{4}_{2}\mathrm{He}$, the *X* represents

(1) $^{0}_{+1}\mathrm{e}$ (3) $^{0}_{-1}\mathrm{e}$
(2) $^{1}_{1}\mathrm{H}$ (4) $^{1}_{0}\mathrm{n}$ 18 ____

19. Given the nuclear reaction:

$$^{32}_{16}\mathrm{S} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{1}_{1}\mathrm{H} + X$$

What does *X* represent in this reaction?

(1) $^{31}_{15}\mathrm{P}$ (3) $^{31}_{16}\mathrm{S}$
(2) $^{32}_{15}\mathrm{P}$ (4) $^{32}_{16}\mathrm{S}$ 19 ____

20. Given the nuclear equation:

$$^{253}_{99}\mathrm{Es} + X \rightarrow {}^{1}_{0}\mathrm{n} + {}^{256}_{101}\mathrm{Md}$$

Which particle is represented by X?

(1) $^{4}_{2}\mathrm{He}$ (3) $^{1}_{0}\mathrm{n}$
(2) $^{0}_{-1}\mathrm{e}$ (4) $^{0}_{+1}\mathrm{e}$ 20 ____

21. Given the equation: $^{239}_{93}\mathrm{Np} \rightarrow {}^{239}_{94}\mathrm{Pu} + X$

When the equation is balanced correctly, which particle is represented by *X*?

(1) $^{0}_{-1}\mathrm{e}$ (3) $^{2}_{1}\mathrm{H}$
(2) $^{1}_{1}\mathrm{H}$ (4) $^{1}_{0}\mathrm{n}$ 21 ____

22. Which of these particles has the greatest mass?

(1) alpha (3) neutron
(2) beta (4) positron 22 ____

23. Types of nuclear reactions include fission, fusion, and

(1) single replacement
(2) neutralization
(3) oxidation-reduction
(4) transmutation 23 ____

24. Nuclear fusion differs from nuclear fission because nuclear fusion reactions

(1) form heavier isotopes from lighter isotopes
(2) form lighter isotopes from heavier isotopes
(3) convert mass to energy
(4) convert energy to mass 24 ____

25. Energy is released during the fission of Pu-239 atoms as a result of the

(1) formation of covalent bonds
(2) formation of ionic bonds
(3) conversion of matter to energy
(4) conversion of energy to matter 25 ____

26. Which equation is an example of artificial transmutation?

(1) ${}^{9}_{4}\mathrm{Be} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{1}_{0}\mathrm{n}$
(2) $\mathrm{U} + 3\ \mathrm{F}_2 \rightarrow \mathrm{UF}_6$
(3) $\mathrm{Mg(OH)}_2 + 2\ \mathrm{HCl} \rightarrow 2\ \mathrm{H}_2\mathrm{O} + \mathrm{MgCl}_2$
(4) $\mathrm{Ca} + 2\ \mathrm{H}_2\mathrm{O} \rightarrow \mathrm{Ca(OH)}_2 + \mathrm{H}_2$

26 ____

27. Which equation represents a fusion reaction?

(1) ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He}$
(2) ${}^{14}_{6}\mathrm{C} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{14}_{7}\mathrm{N}$
(3) ${}^{238}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{241}_{94}\mathrm{Pu} + {}^{1}_{0}\mathrm{n}$
(4) ${}^{1}_{0}\mathrm{n} + {}^{27}_{13}\mathrm{Al} \rightarrow {}^{24}_{11}\mathrm{Na} + {}^{4}_{2}\mathrm{He}$

27 ____

---

28. Which list of nuclear emissions is arranged in order from the least penetrating power to the greatest penetrating power?

(1) alpha particle, beta particle, gamma ray
(2) alpha particle, gamma ray, beta particle
(3) gamma ray, beta particle, alpha particle
(4) beta particle, alpha particle, gamma ray

28____

29. Complete the equation below for the radioactive decay of ${}^{137}_{55}\mathrm{Cs}$. Include both atomic number and mass number for each particle.

${}^{137}_{55}\mathrm{Cs} \rightarrow$ _____ + _____

30. Complete the nuclear equation below for the decay of K-42. Your response must include the atomic number, the mass number, and the symbol of the missing particle.

${}^{42}_{19}\mathrm{K} \rightarrow {}^{0}_{-1}\mathrm{e} +$ _____

31. Identify particle *X* in the equation ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + X + \text{energy}$. Your response must include the symbol, the atomic number, and mass number of the particle.

_____

32. Complete the nuclear equation below for the decay of C-14. Your response must include the atomic number, the mass number, and the symbol of the missing particle.

${}^{14}_{6}\mathrm{C} \rightarrow {}^{0}_{-1}\mathrm{e} +$ _____

33. Nuclear equation: ${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{92}_{38}\mathrm{Sr} +$ _____ $+ 2\,{}^{1}_{0}\mathrm{n} + \text{energy}$

Write an isotopic notation for the missing product in the nuclear equation.

_____

34. Which nuclear emission has no mass and no charge? _____

Table O – Symbols Used in Nuclear Chemistry

Answers

Set 1

1. 4 Choice 4 is a negative beta particle which is an ordinary electron. The mass of an electron is negligible compared to a proton or a neutron.

2. 4 In a nuclear reaction, the sum of the atomic numbers on each side must be equal and the sum of the mass numbers on each side must be equal. Particle *X* therefore must have a charge number of –1 and a mass number of 0. From Table O, this must be a beta particle. Np, element 93, is a man-made radioactive element that decays to Pu, element 94, by releasing a beta particle.

3. 1 Table O shows that a positron, also known as a positive beta particle, has the symbol β^+. Open to Table N and locate K-37. Under Decay Mode, it shows that this element undergoes positron emission. During positron emission, the atomic number decreases by 1 and the mass number remains the same.

4. 4 To balance the nuclear equation, particle *X* must have a +1 charge and zero mass. Using the notation column in Table O, a positron has a +1 charge and 0 mass. During positron emission, the atomic number decreases by 1 and the mass number remains the same.

5. 3 Table O gives the particles and their notations referred to in this question. Using Table N, find the radioisotopes given in choice 3. The Decay Mode shows that choice 3 contains an alpha emitter, a beta emitter and a positron emitter.

6. 2 Looking at Table O, the neutron has the symbol ${}^{1}_{0}\mathrm{n}$, indicating it has an atomic mass of 1 and carries no charge.

7. 1 The first particle shown in Table O is the alpha particle. This particle is a helium nucleus, consisting of 2 protons and 2 neutrons. This makes this particle positive in charge. The alpha particle is the largest particle that is emitted in radioactive decay. Being the largest particle, it would have the weakest penetrating power, giving up more energy with each particle it collides with.

8. 3 In the notation column of Table O, it shows that gamma radiation has no charge or mass. A massless, neutral entity can easily pass through matter without interacting with it. This makes the gamma radiation the most penetrating of the given choices.

9. 1 In natural radioactivity, also called natural transmutation, a radioactive element will undergo a spontaneous decay process involving the nucleus. An example of this decay is radioactive Pu-239 changing to U-235 by alpha emission. Choices 2 and 3 show artificial transmutation (see explanation for answer no. 11). Choice 4 shows the fission of a Pu-239 nucleus.

10. 4 In a nuclear reaction, the sum of the atomic numbers and the sum of the mass numbers on each side must be equal. Particle 3X must have a charge number of 0 and a mass number of 1 (making a total mass number of 3(1) = 3). From Table O this particle is a neutron.

11. 2 In artificial transmutation, the nucleus of a non-radioactive element is bombarded with high energy particles, such as alpha particles, protons or neutrons. The end product of artificial transmutation is the formation of new radioactive elements.

12. 4 When nuclear fission occurs, a very large amount of energy is released. Under controlled conditions, this energy can safely be harnessed, changed to electrical energy and distributed to benefit mankind.

13. 1 In any nuclear reaction, the mass of the products is less than the mass of the reactants. This difference in mass is converted into a large amount of energy according to Einstein's equation, $E = mc^2$.

14. *a*) Answer: nuclear fission

Explanation: A neutron is captured by the nucleus of a uranium atom. This causes uranium to undergo nuclear fission, producing two lighter elements, while giving off subatomic particles and energy.

b) Answer: Mass has been converted into energy.

Explanation: In any nuclear reaction, the mass of the products is less than the mass of the reactants. This difference in mass is converted into a large amount of energy according to Einstein's equation, $E = mc^2$.

c) Answer: Nuclear fusion *or* natural transmutation *or* radioactive decay *or* nuclear decay

Explanation: In a nuclear fusion reaction, lighter nuclei combine or unite to form a heavier nucleus. As in any nuclear reaction, the mass of the products is less than the mass of the reactants. This difference in mass has been converted into energy.

15. Answer: ${}^{226}_{88}\text{Ra} \rightarrow {}^{4}_{2}\text{He} + {}^{222}_{86}\text{Rn}$ *or* ${}^{226}_{88}\text{Ra} \rightarrow {}^{222}_{86}\text{Rn} + {}^{4}_{2}\alpha$

Explanation: Locate Ra-226 in Table N. It shows that this element undergoes alpha emission. Table O shows the notation of an alpha particle. The above equations show that the total atomic numbers and mass numbers are conserved.