

Part A

Answer all questions in this part.

Directions (1–30): For *each* statement or question, write in your answer booklet the *number* of the word or expression that, of those given, best completes the statement or answers the question. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.

- The gold foil experiment led to the conclusion that each atom in the foil was composed mostly of empty space because most alpha particles directed at the foil
 - passed through the foil
 - remained trapped in the foil
 - were deflected by the nuclei in gold atoms
 - were deflected by the electrons in gold atoms
- Which subatomic particles are located in the nucleus of a carbon atom?
 - protons, only
 - neutrons, only
 - protons and neutrons
 - protons and electrons
- Which part of a helium atom is positively charged?
 - electron
 - neutron
 - nucleus
 - orbital
- The mass of a proton is approximately equal to the mass of
 - an alpha particle
 - an electron
 - a neutron
 - a positron
- At STP, solid carbon can exist as diamond and graphite. Compared to the molecular structure and chemical properties of diamond, graphite has
 - a different molecular structure and different properties
 - a different molecular structure and the same properties
 - the same molecular structure and different properties
 - the same molecular structure and the same properties
- Which Group 14 element is classified as a metal?
 - carbon
 - germanium
 - silicon
 - tin
- The light emitted from a flame is produced when electrons in an excited state
 - absorb energy as they move to lower energy states
 - absorb energy as they move to higher energy states
 - release energy as they move to lower energy states
 - release energy as they move to higher energy states
- An atom of which element has the greatest attraction for electrons in a chemical bond?
 - As
 - Ga
 - Ge
 - Se
- Which formula represents a polar molecule?
 - H₂
 - H₂O
 - CO₂
 - CCl₄
- Two categories of compounds are
 - covalent and molecular
 - covalent and metallic
 - ionic and molecular
 - ionic and metallic
- Which type of bond is found between atoms of solid cobalt?
 - nonpolar covalent
 - polar covalent
 - metallic
 - ionic

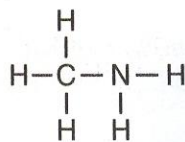
- 12 Which equation represents sublimation?
 (1) $\text{I}_2(\text{s}) \rightarrow \text{I}_2(\text{g})$ (3) $\text{I}_2(\ell) \rightarrow \text{I}_2(\text{g})$
 (2) $\text{I}_2(\text{s}) \rightarrow \text{I}_2(\ell)$ (4) $\text{I}_2(\ell) \rightarrow \text{I}_2(\text{s})$
- 13 Which sample of ethanol has particles with the highest average kinetic energy?
 (1) 10.0 mL of ethanol at 25°C
 (2) 10.0 mL of ethanol at 55°C
 (3) 100.0 mL of ethanol at 35°C
 (4) 100.0 mL of ethanol at 45°C
- 14 The molarity of an aqueous solution of NaCl is defined as the
 (1) grams of NaCl per liter of water
 (2) grams of NaCl per liter of solution
 (3) moles of NaCl per liter of water
 (4) moles of NaCl per liter of solution
- 15 A real gas behaves *least* like an ideal gas under the conditions of
 (1) low temperature and low pressure
 (2) low temperature and high pressure
 (3) high temperature and low pressure
 (4) high temperature and high pressure
- 16 Which sample of matter can be separated into different substances by physical means?
 (1) $\text{LiCl}(\text{aq})$ (3) $\text{NH}_3(\text{g})$
 (2) $\text{LiCl}(\text{s})$ (4) $\text{NH}_3(\ell)$
- 17 At STP, 1.0 liter of helium contains the same total number of atoms as
 (1) 1.0 L of Ne (3) 0.5 L of Rn
 (2) 2.0 L of Kr (4) 1.5 L of Ar
- 18 Which statement describes the particles of an ideal gas?
 (1) The particles move in well-defined, circular paths.
 (2) When the particles collide, energy is lost.
 (3) There are forces of attraction between the particles.
 (4) The volume of the particles is negligible.
- 19 A chemical reaction between iron atoms and oxygen molecules can only occur if
 (1) the particles are heated
 (2) the atmospheric pressure decreases
 (3) there is a catalyst present
 (4) there are effective collisions between the particles
- 20 Given the equation representing a phase change at equilibrium:

$$\text{H}_2\text{O}(\text{s}) \rightleftharpoons \text{H}_2\text{O}(\ell)$$

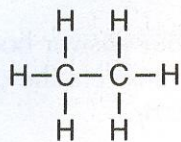
 Which statement describes this equilibrium?
 (1) The $\text{H}_2\text{O}(\text{s})$ melts faster than the $\text{H}_2\text{O}(\ell)$ freezes.
 (2) The $\text{H}_2\text{O}(\ell)$ freezes faster than the $\text{H}_2\text{O}(\text{s})$ melts.
 (3) The mass of $\text{H}_2\text{O}(\text{s})$ must equal the mass of $\text{H}_2\text{O}(\ell)$.
 (4) The mass of $\text{H}_2\text{O}(\ell)$ and the mass of $\text{H}_2\text{O}(\text{s})$ each remain constant.
- 21 A molecule of an organic compound contains at least one atom of
 (1) carbon (3) nitrogen
 (2) chlorine (4) oxygen
- 22 In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the
 (1) activation energy
 (2) entropy of the system
 (3) heat of fusion
 (4) heat of reaction
- 23 A carbon-carbon triple bond is found in a molecule of
 (1) butane (3) butene
 (2) butanone (4) butyne

- 24 Which statement describes one characteristic of an operating electrolytic cell?
- (1) It produces electrical energy.
 - (2) It requires an external energy source.
 - (3) It uses radioactive nuclides.
 - (4) It undergoes a spontaneous redox reaction.
- 25 Which compound when dissolved in water is an Arrhenius acid?
- (1) CH_3OH
 - (2) HCl
 - (3) NaCl
 - (4) NaOH
- 26 An acid can be defined as an
- (1) H^+ acceptor
 - (2) H^+ donor
 - (3) OH^- acceptor
 - (4) OH^- donor
- 27 Which nuclear emission has no charge and no mass?
- (1) alpha particle
 - (2) beta particle
 - (3) gamma ray
 - (4) positron
- 28 During which process can 10.0 milliliters of a 0.05 M $\text{HCl}(\text{aq})$ solution be used to determine the unknown concentration of a given volume of $\text{NaOH}(\text{aq})$ solution?
- (1) evaporation
 - (2) distillation
 - (3) filtration
 - (4) titration
- 29 Which radioisotope is matched with its decay mode?
- (1) H-3 and γ
 - (2) K-42 and β^+
 - (3) N-16 and α
 - (4) P-32 and β^-
- 30 Which reaction is accompanied by the release of the greatest amount of energy?
- (1) combustion of 10. g of propane
 - (2) electrolysis of 10. g of water
 - (3) nuclear fission of 10. g of uranium
 - (4) oxidation of 10. g of iron
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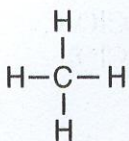
38 Which formula represents a molecule having a nonpolar covalent bond?



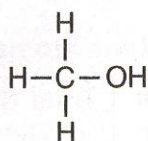
(1)



(3)



(2)

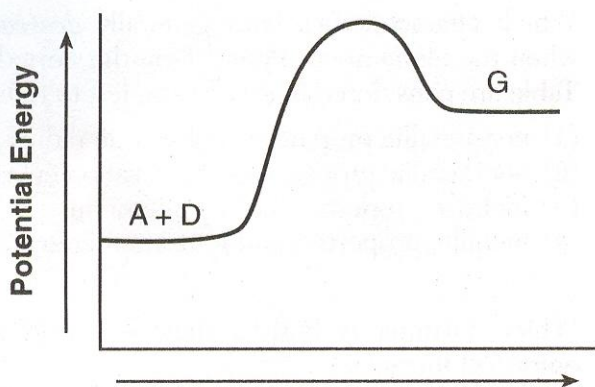


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39 Which compound has the *lowest* vapor pressure at 50°C?

- (1) ethanoic acid (3) propanone
(2) ethanol (4) water

40 Given the potential energy diagram and equation representing the reaction between substances A and D:



Reaction Coordinate



According to Table I, substance G could be

- (1) HI(g) (3) CO₂(g)
(2) H₂O(g) (4) C₂H₆(g)

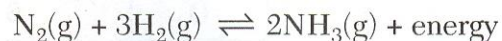
41 A sample of gas confined in a cylinder with a movable piston is kept at constant pressure. The volume of the gas doubles when the temperature of the gas is changed from

- (1) 400. K to 200. K (3) 400.°C to 200.°C
(2) 200. K to 400. K (4) 200.°C to 400.°C

42 According to Table F, which compound is soluble in water?

- (1) barium phosphate (3) silver iodide
(2) calcium sulfate (4) sodium perchlorate

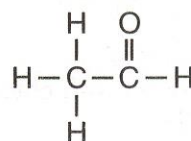
43 Given the equation representing a system at equilibrium:



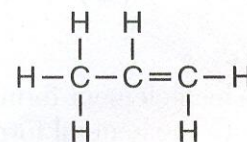
Which changes occur when the temperature of this system is *decreased*?

- (1) The concentration of H₂(g) increases and the concentration of N₂(g) increases.
(2) The concentration of H₂(g) decreases and the concentration of N₂(g) increases.
(3) The concentration of H₂(g) decreases and the concentration of NH₃(g) decreases.
(4) The concentration of H₂(g) decreases and the concentration of NH₃(g) increases.

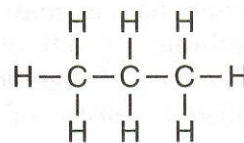
44 Which formula represents an unsaturated hydrocarbon?



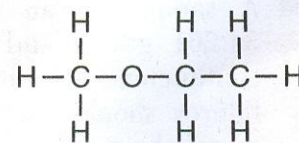
(1)



(3)



(2)



(4)

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

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

46 Which metal is more active than H_2 ?

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

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



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

48 Which laboratory test result can be used to determine if KCl(s) is an electrolyte?

- (1) pH of KCl(aq)
(2) pH of KCl(s)
(3) electrical conductivity of KCl(aq)
(4) electrical conductivity of KCl(s)

49 Which compound is produced when HCl(aq) is neutralized by $\text{Ca(OH)}_2(\text{aq})$?

- (1) CaCl_2 (3) HClO
(2) CaH_2 (4) HClO_2

50 Which nuclides are used to date the remains of a once-living organism?

- (1) C-14 and C-12 (3) I-131 and Xe-131
(2) Co-60 and Co-59 (4) U-238 and Pb-206

Part B-2

Answer all questions in this part.

Directions (51–64): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.

- 51 What is the total number of electron pairs shared between the carbon atom and one of the oxygen atoms in a carbon dioxide molecule? [1]
- 52 Explain, in terms of subatomic particles, why the radius of a chloride ion is larger than the radius of a chlorine atom. [1]
- 53 Explain, in terms of valence electrons, why the bonding in magnesium oxide, MgO, is similar to the bonding in barium chloride, BaCl₂. [1]

Base your answers to questions 54 and 55 on the information below.

An atom in an excited state has an electron configuration of 2-7-2.

- 54 Explain, in terms of subatomic particles, why this excited atom is electrically neutral. [1]
- 55 Write the electron configuration of this atom in the ground state. [1]
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Base your answers to questions 56 through 58 on the information below.

Glycine, NH₂CH₂COOH, is an organic compound found in proteins. Acetamide, CH₃CONH₂, is an organic compound that is an excellent solvent. Both glycine and acetamide consist of the same four elements, but the compounds have different functional groups.

- 56 In the space *in your answer booklet*, calculate the gram-formula mass of glycine. Your response must include *both* a numerical setup and the calculated result. [2]
- 57 Identify *one* functional group in a glycine molecule. [1]
- 58 In the space *in your answer booklet*, draw a structural formula for acetamide. [1]
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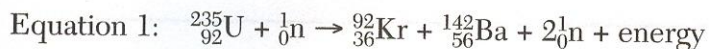
Base your answers to questions 59 through 61 on the information below.

Heat is added to a 200.-gram sample of $\text{H}_2\text{O}(\text{s})$ to melt the sample at 0°C . Then the resulting $\text{H}_2\text{O}(\ell)$ is heated to a final temperature of 65°C .

- 59 Determine the total amount of heat required to completely melt the sample. [1]
- 60 In the space *in your answer booklet*, show a numerical setup for calculating the total amount of heat required to raise the temperature of the $\text{H}_2\text{O}(\ell)$ from 0°C to its final temperature. [1]
- 61 Compare the amount of heat required to vaporize a 200.-gram sample of $\text{H}_2\text{O}(\ell)$ at its boiling point to the amount of heat required to melt a 200.-gram sample of $\text{H}_2\text{O}(\text{s})$ at its melting point. [1]
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Base your answers to questions 62 through 64 on the information below.

When a uranium-235 nucleus absorbs a slow-moving neutron, different nuclear reactions may occur. One of these possible reactions is represented by the complete, balanced equation below.



For this reaction, the sum of the masses of the products is slightly less than the sum of the masses of the reactants. Another possible reaction of U-235 is represented by the incomplete, balanced equation below.



- 62 Identify the type of nuclear reaction represented by equation 1. [1]
- 63 Write a notation for the missing product in equation 2. [1]
- 64 Determine the half-life of krypton-92 if only 6.0 milligrams of an original 96.0-milligram sample remains unchanged after 7.36 seconds. [1]
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Part C

Answer all questions in this part.

Directions (65–83): Record your answers in the spaces provided in your answer booklet. Some questions may require the use of the *Reference Tables for Physical Setting/Chemistry*.

Base your answers to questions 65 through 68 on the information below.

In a laboratory, a student makes a solution by completely dissolving 80.0 grams of $\text{KNO}_3(\text{s})$ in 100.0 grams of hot water. The resulting solution has a temperature of $60.^\circ\text{C}$. The room temperature in the laboratory is 22°C .

- 65 Classify, in terms of saturation, the type of solution made by the student. [1]
- 66 Compare the boiling point of the solution at standard pressure to the boiling point of water at standard pressure. [1]
- 67 Describe the direction of heat flow between the solution made by the student and the air in the laboratory. [1]
- 68 Describe a laboratory procedure that can be used to recover the solid solute from the aqueous solution. [1]
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Base your answers to questions 69 through 71 on the information below.

At room temperature, a reaction occurs when $\text{KIO}_3(\text{aq})$ is mixed with $\text{NaHSO}_3(\text{aq})$ that contains a small amount of starch. The colorless reaction mixture turns dark blue after a period of time that depends on the concentration of the reactants.

In a laboratory, 12 drops of a 0.02 M $\text{NaHSO}_3(\text{aq})$ solution containing starch were placed in each of six test tubes. A different number of drops of 0.02 M $\text{KIO}_3(\text{aq})$ and enough water to maintain a constant volume were added to each test tube and the time for the dark-blue color to appear was measured. The data were recorded in the table below.

Data Table

Test Tube	A	B	C	D	E	F
Number of Drops of 0.02 M $\text{KIO}_3(\text{aq})$	2	4	6	8	10	12
Time for Dark-Blue Color to Appear (s)	210.	88	49	39	33	27

69 On the grid in your answer booklet:

- Mark an appropriate scale on the axis labeled "Time (s)." [1]
- Plot the data from the data table. Circle and connect the points. [1]

70 State how increasing the number of drops of 0.02 M $\text{KIO}_3(\text{aq})$ used in the reaction affects the rate of reaction. [1]

71 Identify *one* factor, other than the concentration of the reactants, that would affect the rate of this reaction. [1]

Base your answers to questions 72 through 75 on the information below.

The Solvay process is a multistep industrial process used to produce washing soda, $\text{Na}_2\text{CO}_3(\text{s})$. In the last step of the Solvay process, $\text{NaHCO}_3(\text{s})$ is heated to 300°C , producing washing soda, water, and carbon dioxide. This reaction is represented by the balanced equation below.



72 Write the IUPAC name for washing soda. [1]

73 Identify the type of chemical reaction represented by the equation. [1]

74 State evidence that indicates the entropy of the products is greater than the entropy of the reactant. [1]

75 Determine the total mass of washing soda produced if 3360. kilograms of NaHCO_3 reacts completely to produce 360. kilograms of H_2O and 880. kilograms of CO_2 . [1]

Base your answers to questions 76 through 79 on the information below.

In liquid water, an equilibrium exists between $\text{H}_2\text{O}(\ell)$ molecules, $\text{H}^+(\text{aq})$ ions, and $\text{OH}^-(\text{aq})$ ions. A person experiencing acid indigestion after drinking tomato juice can ingest milk of magnesia to reduce the acidity of the stomach contents. Tomato juice has a pH value of 4. Milk of magnesia, a mixture of magnesium hydroxide and water, has a pH value of 10.

76 Complete the equation *in your answer booklet* for the equilibrium that exists in liquid water. [1]

77 Compare the hydrogen ion concentration in tomato juice to the hydrogen ion concentration in milk of magnesia. [1]

78 Identify the negative ion found in milk of magnesia. [1]

79 What is the color of thymol blue indicator when placed in a sample of milk of magnesia? [1]

Base your answers to questions 80 through 83 on the information below.

Two sources of copper are cuprite, which has the IUPAC name copper(I) oxide, and malachite, which has the formula $\text{Cu}_2\text{CO}_3(\text{OH})_2$. Copper is used in home wiring and electric motors because it has good electrical conductivity. Other uses of copper not related to its electrical conductivity include coins, plumbing, roofing, and cooking pans. Aluminum is also used for cooking pans.

At room temperature, the electrical conductivity of a copper wire is 1.6 times greater than an aluminum wire with the same length and cross-sectional area. At room temperature, the heat conductivity of copper is 1.8 times greater than the heat conductivity of aluminum. At STP, the density of copper is 3.3 times greater than the density of aluminum.

80 Write the chemical formula of cuprite. [1]

81 Determine the oxidation number of oxygen in the carbonate ion found in malachite. [1]

82 Identify *one* physical property of copper that makes it a good choice for uses that are *not* related to electrical conductivity. [1]

83 Identify *one* physical property of aluminum that could make it a better choice than copper for a cooking pan. [1]
