Atomic Structure / Periodic Table

Base your answers to questions 79 through 83 on the information below.

Arsenic is often obtained by heating the ore arsenopyrite, FeAsS. The decomposition of FeAsS is represented by the balanced equation below.

$$FeAsS(s) \xrightarrow{heat} FeS(s) + As(g)$$

In the solid phase, arsenic occurs in two forms. One form, yellow arsenic, has a density of 1.97 g/cm^3 at STP. The other form, gray arsenic, has a density of 5.78 g/cm^3 at STP. When arsenic is heated rapidly in air, arsenic(III) oxide is formed.

Although arsenic is toxic, it is needed by the human body in very small amounts. The body of a healthy human adult contains approximately 5 milligrams of arsenic.

79 Convert the mass of arsenic found in the body of a healthy human adult to grams. [1]

.005 grams

80 When heated, a 125.0-kilogram sample of arsenopyrite yields 67.5 kilograms of FeS. Determine the total mass of arsenic produced in this reaction. [1]

81 Write the formula for the compound produced when arsenic is heated rapidly in air. [1]

$As^{+3}\ O^{-2}$ As_2O_3

82 Explain, in terms of the arrangement of atoms, why the two forms of arsenic have different densities at STP. [1]

b/c the atoms are closer together

83 Calculate the percent composition by mass of arsenic in arsenopyrite. Your response must include *both* a correct numerical setup and the calculated result. [2]

Base your answers to questions 66 and 67 on the information below.

In 1897, J. J. Thomson demonstrated in an experiment that cathode rays were deflected by an electric field. This suggested that cathode rays were composed of negatively charged particles found in all atoms. Thomson concluded that the atom was a positively charged sphere of almost uniform density in which negatively charged particles were embedded. The total negative charge in the atom was balanced by the positive charge, making the atom electrically neutral.

In the early 1900s, Ernest Rutherford bombarded a very thin sheet of gold foil with alpha particles. After interpreting the results of the gold foil experiment, Rutherford proposed a more sophisticated model of the atom.

66 State *one* conclusion from Rutherford's experiment that contradicts one conclusion made by Thomson. [1]

67 State *one* aspect of the modern model of the atom that agrees with a conclusion made by Thomson. [1]

Base your answers to questions 64 and 65 on the information below.

The nucleus of one boron atom has five protons and four neutrons.

64 Determine the total number of electrons in the boron atom. [1]

65 Determine the total charge of the boron nucleus. [1]

Base your answers to questions 63 through 65 on the information below.

Naturally Occurring Isotopes of Sulfur

Isotope	Atomic Mass (atomic mass units, u)	Natural Abundance (%)
^{32}S	31.97	94.93
^{33}S	32.97	0.76
^{34}S	33.97	4.29
^{36}S	35.97	0.02

63 State, in terms of the number of subatomic particles, *one* similarity and *one* difference between the atoms of these isotopes of sulfur. [1]

64 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for an atom of sulfur-33. [1]

65 In the space *in your answer booklet*, show a correct numerical setup for calculating the atomic mass of sulfur. [1]

Base your answers to questions 76 through 78 on the information below.

Carbon has three naturally occurring isotopes, C-12, C-13, and C-14. Diamond and graphite are familiar forms of solid carbon. Diamond is one of the hardest substances known, while graphite is a very soft substance. Diamond has a rigid network of bonded atoms. Graphite has atoms bonded in thin layers that are held together by weak forces.

Recent experiments have produced new forms of solid carbon called fullerenes. One fullerene, C_{60}, is a spherical, cagelike molecule of carbon.

76 Determine *both* the total number of protons and the total number of neutrons in an atom of the naturally occurring carbon isotope with the largest mass number. [1]

77 Identify the type of bonding in a fullerene molecule. [1]

78 State, in terms of the arrangement of atoms, the difference in hardness between diamond and graphite. [1]

Base your answers to questions 66 through 68 on the information below.

At STP, iodine, I_2, is a crystal, and fluorine, F_2, is a gas. Iodine is soluble in ethanol, forming a tincture of iodine. A typical tincture of iodine is 2% iodine by mass.

66 Compare the strength of the intermolecular forces in a sample of I_2 at STP to the strength of the intermolecular forces in a sample of F_2 at STP. [1]

67 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for a molecule of I_2. [1]

68 Determine the total mass of I_2 in 25 grams of this typical tincture of iodine. [1]

51 Explain, in terms of protons and neutrons, why U-235 and U-238 are different isotopes of uranium. [1]

Base your answers to questions 59 and 60 on the information below.

In the gold foil experiment, a thin sheet of gold was bombarded with alpha particles. Almost all the alpha particles passed straight through the foil. Only a few alpha particles were deflected from their original paths.

59 State *one* conclusion about atomic structure based on the observation that almost all alpha particles passed straight through the foil. [1]

60 Explain, in terms of charged particles, why some of the alpha particles were deflected. [1]

Base your answers to questions 54 through 56 on the elements in Group 2 on the Periodic Table.

54 State the general trend in first ionization energy for the elements in Group 2 as these elements are considered in order from top to bottom in the group. [1]

55 State, in terms of the number of electron shells, why the radius of a strontium atom in the ground state is larger than the radius of a magnesium atom in the ground state. [1]

56 Explain, in terms of atomic structure, why the elements in Group 2 have similar chemical properties. [1]

51 *In your answer booklet*, write an electron configuration for a silicon atom in an excited state. [1]

Base your answers to questions 55 through 59 on the information below.

The ionic radii of some Group 2 elements are given in the table below.

Ionic Radii of Some Group 2 Elements

Symbol	Atomic Number	Ionic Radius (pm)
Be	4	44
Mg	12	66
Ca	20	99
Ba	56	134

55 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Ionic Radius (pm)." [1]

56 On the same grid, plot the data from the data table. Circle and connect the points. [1]

57 Estimate the ionic radius of strontium. [1]

58 State the trend in ionic radius as the elements in Group 2 are considered in order of increasing atomic number. [1]

as the atomic # increases also the ionic radius increases

59 Explain, in terms of electrons, why the ionic radius of a Group 2 element is smaller than its atomic radius. [1]

ion has less ~~less~~ e⁻ than atom

Base your answers to questions 61 through 63 on the information below.

The atomic and ionic radii for sodium and chlorine are shown in the table below.

Atomic and Ionic Radii

Particle	Radius (pm)
Na atom	190.
Na^+ ion	102
Cl atom	97
Cl^- ion	181

61 Write the ground state electron configuration for the ion that has a radius of 181 picometers. [1]

62 Convert the radius of an Na^+ ion to meters. [1]

63 Explain, in terms of atomic structure, why the radius of an Na atom is larger than the radius of an Na^+ ion. [1]

Base your answers to questions 66 through 68 on the information below.

In the early 1800s, John Dalton proposed an atomic theory that was based on experimental observations made by several scientists. Three concepts of Dalton's atomic theory are stated below.

Statement *A*: Atoms are indivisible and cannot be destroyed or broken down into smaller parts.

Statement *B*: Atoms of one element cannot be changed into atoms of another element.

Statement *C*: All atoms of one element have the same mass.

66 Explain, in terms of particles, why statement *A* is no longer accepted. [1]

67 The decay of N-16 is represented by the balanced equation below.

$$^{16}_{7}N \rightarrow {}^{0}_{-1}e + {}^{16}_{8}O$$

State evidence that indicates statement *B* is *not* always true. [1]

68 Explain, in terms of particles in the atoms of an element, why statement *C* is *false*. [1]

53 Copper has two naturally occurring isotopes. Information about the two isotopes is shown in the table below.

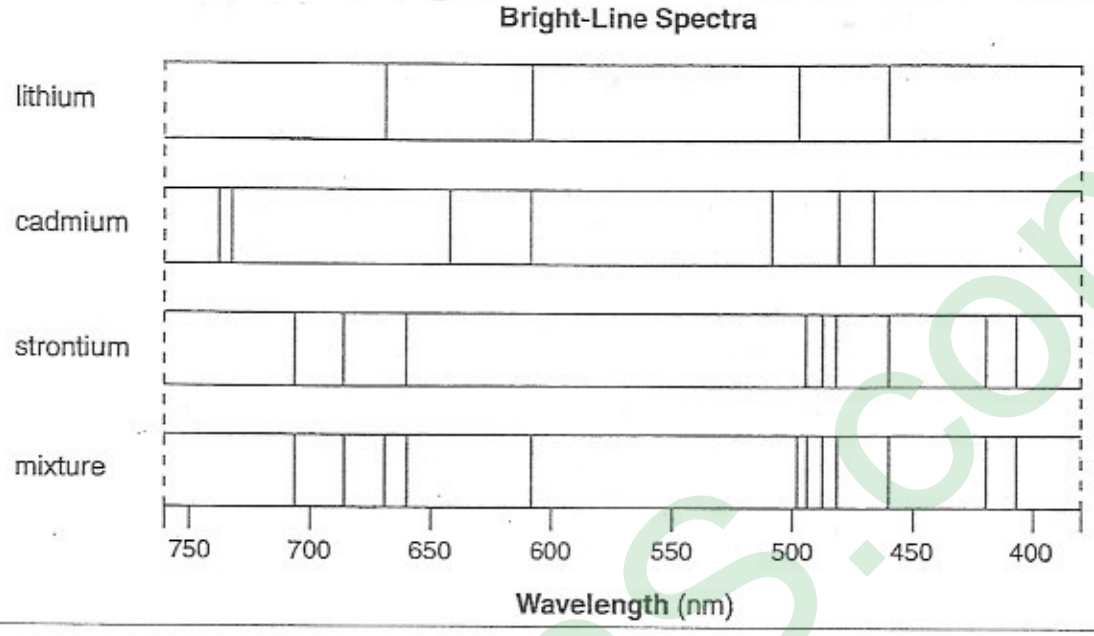
Naturally Occurring Isotopes of Copper

Isotope	Atomic Mass (atomic mass units, u)	Percent Natural Abundance (%)
Cu-63	62.93	69.17
Cu-65	64.93	30.83

In the space *in your answer booklet*, show a numerical setup for calculating the atomic mass of copper. [1]

Base your answers to questions 52 through 54 on the information below.

The bright-line spectra for three elements and a mixture of elements are shown below.



52 Explain, in terms of *both* electrons and energy, how the bright-line spectrum of an element is produced. [1] electrons go from excited state to ground releasing light energy

53 Identify *all* the elements in the mixture. [1] lithium strontium

54 State the total number of valence electrons in a cadmium atom in the ground state. [1]

2

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] Same # of p and e

55 Write the electron configuration of this atom in the ground state. [1]

51 Explain, in terms of electronegativity difference, why the bond in a molecule of HF is more polar than the bond in a molecule of HI. [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, $BaCl_2$. [1]

Base your answers to questions 51 through 54 on the information below.

The atomic radius and the ionic radius for some Group 1 and some Group 17 elements are given in the tables below.

Atomic and Ionic Radii of Some Elements

Group 1

Particle	Radius (pm)
Li atom	130.
Li^+ ion	78
Na atom	160.
Na^+ ion	98
K atom	200.
K^+ ion	133
Rb atom	215
Rb^+ ion	148

Group 17

Particle	Radius (pm)
F atom	60.
F^- ion	133
Cl atom	100.
Cl^- ion	181
Br atom	117
Br^- ion	?
I atom	136
I^- ion	220.

Estimate the radius of a Br ion. [1]

200

Explain, in terms of electron shells, why the radius of a K^+ ion is greater than the radius of an Na^+ ion. [1]

K^+ has 1 more electron shell than Na^+

Write *both* the name and the charge of the particle that is gained by an F atom when the atom becomes an F ion. [1]

State the relationship between atomic number and first ionization energy as the elements in Group 1 are considered in order of increasing atomic number. [1]

As atomic # increases IE decreases

Nuclear Chemistry

Base your answers to questions 68 through 70 on the information below.

Cobalt-60 is commonly used as a source of radiation for the prevention of food spoilage. Bombarding cobalt-59 nuclei with neutrons produces the nuclide cobalt-60. A food irradiation facility replaces the cobalt-60, a source of gamma rays, when the radioactivity level falls to $\frac{1}{8}$ of its initial level. The nuclide cesium-137 is also a source of radiation for the prevention of food spoilage.

68 Identify *one* emission spontaneously released by a cobalt-60 nucleus. [1]

69 Determine the total number of years that elapse before an original cobalt-60 source in an irradiation facility must be replaced. [1]

70 Complete the nuclear equation *in your answer booklet* for the decay of cesium-137. Your response must include the symbol, atomic number, and mass number of the missing particle. [1]

Base your answers to questions 79 through 81 on the information below.

Hydrocarbons and fissionable nuclei are among the sources used for the production of energy in the United States. A chemical reaction produces much less energy than a nuclear reaction per mole of reactant.

The balanced chemical equation below represents the reaction of one molecule of a hydrocarbon with two molecules of oxygen.

Chemical equation: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + 1.48 \times 10^{-18}\ J$

The nuclear equation below represents one of the many possible reactions for one fissionable nucleus. In this equation, X represents a missing product.

Nuclear equation: ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{89}_{36}Kr + X + 3{}^{1}_{0}n + 3.36 \times 10^{-11}\ J$

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

80 On the labeled axes *in your answer booklet*, draw a potential energy diagram for the reaction of the hydrocarbon with oxygen. [1]

81 Write an isotopic notation for the missing product represented by X in the nuclear equation. [1]

52 Determine the total time that must elapse until only ¼ of an original sample of the radioisotope Rn-222 remains unchanged. [1]

Base your answers to questions 79 through 81 on the information below.

The radioisotope uranium-238 occurs naturally in Earth's crust. The disintegration of this radioisotope is the first in a series of spontaneous decays.

The sixth decay in this series produces the radioisotope radon-222. The decay of radon-222 produces the radioisotope polonium-218 that has a half life of 3.04 minutes. Eventually, the stable isotope lead-206 is produced by the alpha decay of an unstable nuclide.

79 Explain, in terms of electron configuration, why atoms of the radioisotope produced by the sixth decay in the U-238 disintegration series do not readily react to form compounds. [1]

80 Complete the nuclear equation *in your answer booklet* for the decay of the unstable nuclide that produces Pb-206, by writing a notation for the missing nuclide. [1]

81 Determine the original mass of a sample of Po-218, if 0.50 milligram of the sample remains unchanged after 12.16 minutes. [1]

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.

Equation 1: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{142}_{56}Ba + 2^{1}_{0}n + \text{energy}$

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.

Equation 2: $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{38}Sr + \_\_\_\_\_ + 2^{1}_{0}n + \text{energy}$

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]

Base your answers to questions 82 through 85 on the information below.

Nuclear radiation is harmful to living cells, particularly to fast-growing cells, such as cancer cells and blood cells. An external beam of the radiation emitted from a radioisotope can be directed on a small area of a person to destroy cancer cells within the body.

Cobalt-60 is an artificially produced radioisotope that emits gamma rays and beta particles. One hospital keeps a 100.0-gram sample of cobalt-60 in an appropriate, secure storage container for future cancer treatment.

82 State *one* risk to human tissue associated with the use of radioisotopes to treat cancer. [1]

83 Compare the penetrating power of the two emissions from the Co-60. [1]

84 Complete the nuclear equation *in your answer booklet* for the beta decay of the Co-60 by writing an isotopic notation for the missing product. [1]

85 Determine the total time that will have elapsed when 12.5 grams of the original Co-60 sample at the hospital remains unchanged. [1]

Base your answers to questions 83 through 85 on the information below.

Polonium-210 occurs naturally, but is scarce. Polonium-210 is primarily used in devices designed to eliminate static electricity in machinery. It is also used in brushes to remove dust from camera lenses.

Polonium-210 can be created in the laboratory by bombarding bismuth-209 with neutrons to create bismuth-210. The bismuth-210 undergoes beta decay to produce polonium-210. Polonium-210 has a half-life of 138 days and undergoes alpha decay.

83 State *one* beneficial use of Po-210. [1]

84 Complete the nuclear equation *in your answer booklet* for the decay of Po-210, by writing a notation for the missing product. [1]

85 Determine the total mass of an original 28.0-milligram sample of Po-210 that remains unchanged after 414 days. [1]

BONDING

Base your answers to questions 66 through 69 on the information below.

During a fireworks display, salts are heated to very high temperatures. Ions in the salts absorb energy and become excited. Spectacular colors are produced as energy is emitted from the ions in the form of light.

The color of the emitted light is characteristic of the metal ion in each salt. For example, the lithium ion in lithium carbonate, Li_2CO_3, produces a deep-red color. The strontium ion in strontium carbonate, $SrCO_3$, produces a bright-red color. Similarly, calcium chloride is used for orange light, sodium chloride for yellow light, and barium chloride for green light.

66 Write the formula for the salt used to produce green light in a fireworks display. [1]

67 Identify the *two* types of chemical bonds found in the salt used to produce a deep-red color. [1]

68 Determine the oxidation state of carbon in the salt used to produce a bright-red color. [1]

69 Explain, in terms of subatomic particles and energy states, how the colors in a fireworks display are produced. [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 $Cu_2CO_3(OH)_2$. 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]

Base your answers to questions 66 through 68 on the information below.

Ozone, $O_3(g)$, is produced from oxygen, $O_2(g)$, by electrical discharge during thunderstorms. The unbalanced equation below represents the reaction that forms ozone.

$$O_2(g) \xrightarrow{\text{electricity}} O_3(g)$$

66 Balance the equation *in your answer booklet* for the production of ozone, using the smallest whole-number coefficients. [1]

67 Identify the type of bonding between the atoms in an oxygen molecule. [1]

Base your answers to questions 71 through 73 on the information below.

In 1864, the Solvay process was developed to make soda ash. One step in the process is represented by the balanced equation below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

71 Write the chemical formula for *one* compound in the equation that contains *both* ionic bonds and covalent bonds. [1]

72 Explain, in terms of electronegativity difference, why the bond between hydrogen and oxygen in a water molecule is more polar than the bond between hydrogen and nitrogen in an ammonia molecule. [1]

73 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for the reactant containing nitrogen in the equation. [1]

Base your answers to questions 61 through 63 on the information below.

Some Properties of Three Compounds at Standard Pressure

Compound	Boiling Point (°C)	Solubility in 100. Grams of H_2O at 20.°C (g)
ammonia	–33.2	56
methane	–161.5	0.002
hydrogen chloride	–84.9	72

61 Convert the boiling point of hydrogen chloride at standard pressure to kelvins. [1]

62 Explain, in terms of molecular polarity, why hydrogen chloride is more soluble than methane in water at 20.°C and standard pressure. [1]

63 Explain, in terms of intermolecular forces, why ammonia has a higher boiling point than the other compounds in the table. [1]

Base your answers to questions 56 and 57 on the information below.

Physical Properties of CF_4 and NH_3 at Standard Pressure

Compound	Melting Point (°C)	Boiling Point (°C)	Solubility in Water at 20.0°C
CF_4	–183.6	–127.8	insoluble
NH_3	–77.7	–33.3	soluble

56 State evidence that indicates NH_3 has stronger intermolecular forces than CF_4. [1]

57 In the space *in your answer booklet*, draw a Lewis electron-dot diagram for CF_4. [1]

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]

Matter + Energy (+ Kinetics)

Base your answers to questions 74 through 76 on the information below.

During a bread-making process, glucose is converted to ethanol and carbon dioxide, causing the bread dough to rise. Zymase, an enzyme produced by yeast, is a catalyst needed for this reaction.

74 Balance the equation *in your answer booklet* for the reaction that causes bread dough to rise, using the smallest whole-number coefficients. [1]

75 In the space *in your answer booklet*, draw a structural formula for the alcohol formed in this reaction. [1]

76 State the effect of zymase on the activation energy for this reaction. [1]

Base your answers to questions 58 and 59 on the information below.

At a pressure of 101.3 kilopascals and a temperature of 373 K, heat is removed from a sample of water vapor, causing the sample to change from the gaseous phase to the liquid phase. This phase change is represented by the equation below.

$$H_2O(g) \rightarrow H_2O(\ell) + \text{heat}$$

58 Explain, in terms of particle arrangement, why entropy *decreases* during this phase change. [1]

59 Determine the total amount of heat released by 5.00 grams of water vapor during this phase change. [1] 5×2260

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

An experiment is performed to determine how concentration affects the rate of reaction. In each of four trials, equal volumes of solution *A* and solution *B* are mixed while temperature and pressure are held constant. The concentration of solution *B* is held constant, but the concentration of solution *A* is varied. The concentration of solution *A* and the time for the reaction to go to completion for each trial are recorded in the data table below.

Data Table

Trial	Concentration of Solution A (M)	Reaction Time (s)
1	0.0200	4.5
2	0.0150	7.0
3	0.0100	12.0
4	0.0050	20.0

72 Describe the relationship between the concentration of solution *A* and the time for the reaction to go to completion. [1]

73 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Reaction Time (s)." [1]

74 On the same grid, plot the data from the data table. Circle and connect the points. [1]

75 Identify *one* factor, other than the concentration of the solutions, that can affect the rate

Base your answers to questions 57 and 58 on the information below.

Heat is added to a sample of liquid water, starting at 80.°C, until the entire sample is a gas at 120.°C. This process, occurring at standard pressure, is represented by the balanced equation below.

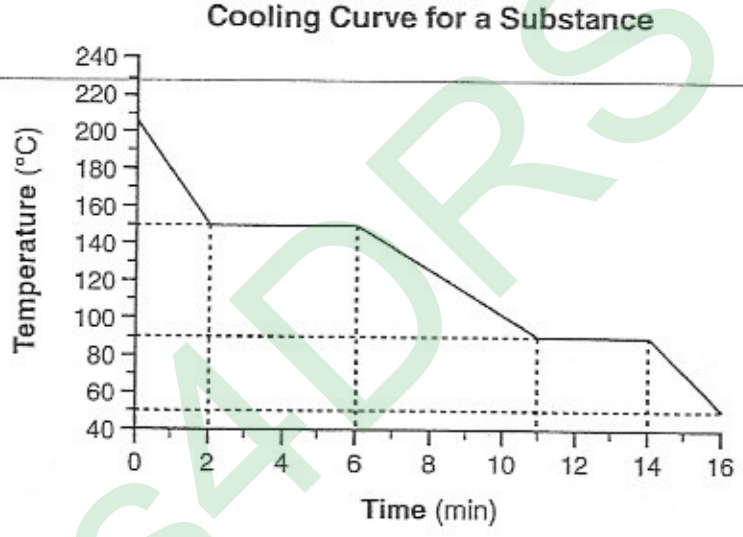
$$H_2O(\ell) + \text{heat} \rightarrow H_2O(g)$$

57 In the box *in your answer booklet*, using the key, draw a particle diagram to represent *at least five* molecules of the product of this physical change at 120.°C. [2]

58 On the diagram *in your answer booklet*, complete the heating curve for this physical change. [1]

Base your answers to questions 55 through 57 on the information below.

Starting as a gas at 206°C, a sample of a substance is allowed to cool for 16 minutes. This process is represented by the cooling curve below.



55 What is the melting point of this substance? [1]

90°C

56 At what time do the particles of this sample have the *lowest* average kinetic energy? [1]

16 min

57 Using the key *in your answer booklet*, draw *two* particle diagrams to represent the *two* phases of the sample at minute 4. Your response must include *at least six* particles for *each* diagram. [1]

Base your answers to questions 74 through 76 on the information below.

A student prepared two mixtures, each in a labeled beaker. Enough water at 20.°C was used to make 100 milliliters of each mixture.

Information about Two Mixtures at 20.°C

	Mixture 1	Mixture 2
Composition	NaCl in H_2O	Fe filings in H_2O
Student Observations	• colorless liquid • no visible solid on bottom of beaker	• colorless liquid • black solid on bottom of beaker
Other Data	• mass of NaCl(s) dissolved = 2.9 g	• mass of Fe(s) = 15.9 g • density of Fe(s) = 7.87 g/cm^3

74 Classify *each* mixture using the term "homogeneous" or the term "heterogeneous." [1]

75 Determine the volume of the Fe filings used to produce mixture 2. [1]

76 Describe a procedure to physically remove the water from mixture 1. [1]

Base your answers to questions 69 through 71 on the information below.

At room temperature, a reaction occurs when $KIO_3(aq)$ is mixed with $NaHSO_3(aq)$ 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 $NaHSO_3(aq)$ solution containing starch were placed in each of six test tubes. A different number of drops of 0.02 M $KIO_3(aq)$ 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 KIO_3(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 $KIO_3(aq)$ 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]

Mathematics + Solutions

Base your answers to questions 71 through 73 on the information below.

A soft-drink bottling plant makes a colorless, slightly acidic carbonated beverage called soda water. During production of the beverage, $CO_2(g)$ is dissolved in water at a pressure greater than 1 atmosphere. The bottle containing the solution is capped to maintain that pressure above the solution. As soon as the bottle is opened, fizzing occurs due to $CO_2(g)$ being released from the solution.

71 Explain why $CO_2(g)$ is released when a bottle of soda water is opened. [1]

72 Write the chemical name of the acid in soda water. [1]

73 State the relationship between the solubility of $CO_2(g)$ in water and the temperature of the aqueous solution. [1]

Base your answers to questions 51 through 53 on the information below.

A sample of helium gas is in a closed system with a movable piston. The volume of the gas sample is changed when both the temperature and the pressure of the sample are increased. The table below shows the initial temperature, pressure, and volume of the gas sample, as well as the final temperature and pressure of the sample.

Helium Gas in a Closed System

Condition	Temperature (K)	Pressure (atm)	Volume (mL)
initial	200.	2.0	500.
final	300.	7.0	?

51 In the space *in your answer booklet*, show a correct numerical setup for calculating the final volume of the helium gas sample. [1]

52 Convert the final temperature of the helium gas sample to degrees Celsius. [1]

53 Compare the total number of gas particles in the sample under the initial conditions to the total number of gas particles in the sample under the final conditions. [1]

Base your answers to questions 53 through 55 on the information below.

A phase change for carbon dioxide that occurs spontaneously at 20.°C and 1.0 atmosphere is represented by the balanced equation below.

$$CO_2(s) + \text{energy} \rightarrow CO_2(g)$$

53 Write the name of this phase change. [1]

54 Describe what happens to the potential energy of the CO_2 molecules as this phase change occurs. [1]

55 *In your answer booklet*, use the key to draw *at least five* molecules in the box to represent CO_2 after this phase change is completed. [1]

15

Base your answers to questions 56 and 57 on the information below.

The dissolving of solid lithium bromide in water is represented by the balanced equation below.

$$LiBr(s) \xrightarrow{H_2O} Li^+(aq) + Br^-(aq)$$

56 Calculate the total mass of LiBr(s) required to make 500.0 grams of an aqueous solution of LiBr that has a concentration of 388 parts per million. Your response must include *both* a correct numerical setup and the calculated result. [2]

57 Based on Table *F*, identify *one* ion that reacts with Br^- ions in an aqueous solution to form an insoluble compound. [1]

Base your answers to questions 69 through 71 on the information below.

A tablet of one antacid contains citric acid, $H_3C_6H_5O_7$, and sodium hydrogen carbonate, $NaHCO_3$. When the tablet dissolves in water, bubbles of CO_2 are produced. This reaction is represented by the incomplete equation below.

$$H_3C_6H_5O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3CO_2(g) + 3 \_\_\_\_\_ (\ell)$$

69 Complete the equation *in your answer booklet* by writing the formula of the missing product. [1]

70 State evidence that a chemical reaction occurred when the tablet was placed in the water. [1]

71 Determine the total number of moles of sodium hydrogen carbonate that will completely react with 0.010 mole of citric acid. [1]

51 Based on Table *G*, determine the total mass of NH_3 that must be dissolved in 200. grams of water to produce a saturated solution at 20.°C. [1]

Base your answers to questions 70 and 71 on the information below.

A scientist makes a solution that contains 44.0 grams of hydrogen chloride gas, HCl(g), in 200. grams of water, $H_2O(\ell)$, at 20.°C. This process is represented by the balanced equation below.

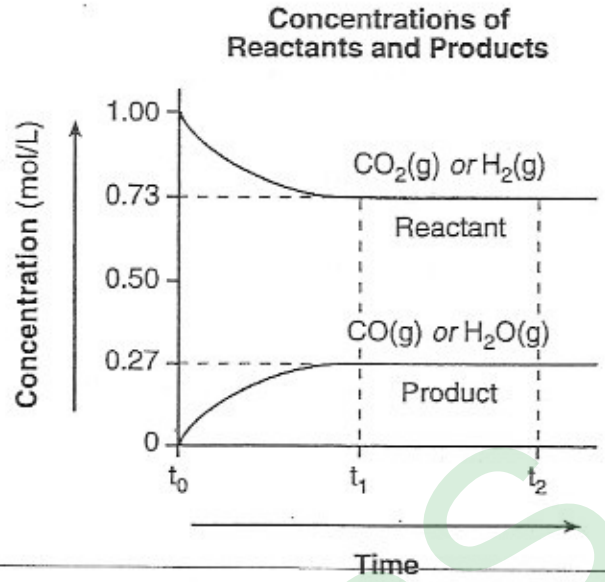
$$HCl(g) \xrightarrow{H_2O} H^+(aq) + Cl\ (aq)$$

70 Based on Reference Table *G*, identify, in terms of saturation, the type of solution made by the scientist. [1]

71 Explain, in terms of the distribution of particles, why the solution is a homogeneous mixture. [1]

Base your answers to questions 62 and 63 on the information below.

At 550°C, 1.00 mole of $CO_2(g)$ and 1.00 mole of $H_2(g)$ are placed in a 1.00-liter reaction vessel. The substances react to form $CO(g)$ and $H_2O(g)$. Changes in the concentrations of the reactants and the concentrations of the products are shown in the graph below.



62 Determine the change in the concentration of $CO_2(g)$ between time t_0 and time t_1. [1]

63 What can be concluded from the graph about the concentrations of the reactants and the concentrations of the products between time t_1 and time t_2? [1]

Base your answers to questions 75 through 78 on the information below.

Vitamin C, also known as ascorbic acid, is water soluble and cannot be produced by the human body. Each day, a person's diet should include a source of vitamin C, such as orange juice. Ascorbic acid has a molecular formula of $C_6H_8O_6$ and a gram-formula mass of 176 grams per mole.

75 What is the color of the indicator thymol blue after it is added to an aqueous solution of vitamin C? [1]

76 Determine the number of moles of vitamin C in an orange that contains 0.071 gram of vitamin C. [1]

77 In the space *in your answer booklet*, show a numerical setup for calculating the percent composition by mass of oxygen in ascorbic acid. [1]

78 Write the empirical formula for ascorbic acid. [1]

Base your answers to questions 72 through 74 on the information below.

Cold packs are used to treat minor injuries. Some cold packs contain $NH_4NO_3(s)$ and a small packet of water at room temperature before activation. To activate this type of cold pack, the small packet must be broken to mix the water and $NH_4NO_3(s)$. The temperature of this mixture decreases to approximately 2°C and remains at this temperature for 10 to 15 minutes.

72 State the direction of heat flow that occurs when the activated cold pack is applied to the body. [1]

73 Identify *both* types of bonds in the $NH_4NO_3(s)$. [1]

74 Identify the type of mixture formed when the $NH_4NO_3(s)$ is completely dissolved in the water. [1]

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 $KNO_3(s)$ in 100.0 grams of hot water. The resulting solution has a temperature of 60.°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]

Base your answers to questions 52 and 53 on the information below.

Densities of Group 14 Elements

Element	Density at STP (g/cm^3)
C	3.51
Si	2.33
Ge	5.32
Sn	7.31
Pb	11.35

52 Identify *one* element from this table for *each* type of element: metal, metalloid, and nonmetal. [1]

53 Calculate the volume of a tin block that has a mass of 95.04 grams at STP. Your response must include *both* a numerical setup and the calculated result. [2]

Base your answers to questions 70 through 72 on the information below.

Hydrogen peroxide, H_2O_2, is a water-soluble compound. The concentration of an aqueous hydrogen peroxide solution that is 3% by mass H_2O_2 is used as an antiseptic. When the solution is poured on a small cut in the skin, H_2O_2 reacts according to the balanced equation below.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

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

71 Calculate the total mass of H_2O_2 in 20.0 grams of an aqueous H_2O_2 solution that is used as an antiseptic. Your response must include *both* a numerical setup and the calculated result. [2]

72 Determine the gram-formula mass of H_2O_2. [1]

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

In an experiment, 2.54 grams of copper completely reacts with sulfur, producing 3.18 grams of copper(I) sulfide.

54 Determine the total mass of sulfur consumed. [1]

55 Write the chemical formula of the compound produced. [1]

Base your answers to questions 58 and 59 on the information below.

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

58 Determine the molarity of the solution. [1]

59 Identify the *two* ions present in the solute. [1]

Kinetics + Equilibrium

Base your answers to questions 77 through 79 on the information below.

A student performed a laboratory activity to observe the reaction between aluminum foil and an aqueous copper(II) chloride solution. The reaction is represented by the balanced equation below.

$$2Al(s) + 3CuCl_2(aq) \rightarrow 3Cu(s) + 2AlCl_3(aq) + \text{energy}$$

The procedures and corresponding observations for the activities are given below.

Procedure	Observation
In a beaker, completely dissolve 5.00 g of $CuCl_2$ in 80.0 mL of H_2O.	• The solution is blue green.
Cut 1.5 g of Al(s) foil into small pieces. Add all the foil to the mixture in the beaker. Stir the contents for 1 minute.	• The surface of Al(s) foil appears partially black. • The beaker feels warm to the touch.
Observe the beaker and contents after 10 minutes.	• The liquid in the beaker appears colorless. • A reddish-brown solid is seen at the bottom of the beaker. • Some pieces of Al(s) with a partially black coating remain in the beaker.

77 State *one* observation that indicates Cu^{2+} ions became Cu atoms. [1]

78 Describe *one* change in the procedure that would cause the reaction to occur at a faster rate. [1]

79 State *one* safety procedure the student should perform after completing the laboratory activity. [1]

Base your answers to questions 73 and 74 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. In addition, some carbon monoxide reacts with oxygen, producing carbon dioxide in the converter. These reactions are represented by the balanced equations below.

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

Reaction 2: $2CO(g) + O_2(g) \rightarrow 2CO_2(g) + 566.0\ kJ$

73 The potential energy diagram *in your answer booklet* 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. [1]

74 Determine the oxidation number of carbon in *each* carbon compound in reaction 2. Your response must include *both* the sign and value of *each* oxidation number. [1]

Base your answers to questions 59 through 61 on the information below.

Heat is added to a 200.-gram sample of $H_2O(s)$ to melt the sample at 0°C. Then the resulting $H_2O(\ell)$ 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 $H_2O(\ell)$ from 0°C to its final temperature. [1]

61 Compare the amount of heat required to vaporize a 200.-gram sample of $H_2O(\ell)$ at its boiling point to the amount of heat required to melt a 200.-gram sample of $H_2O(s)$ at its melting point. [1]

Base your answers to questions 79 through 81 on the information below.

Several steps are involved in the industrial production of sulfuric acid. One step involves the oxidation of sulfur dioxide gas to form sulfur trioxide gas. A catalyst is used to increase the rate of production of sulfur trioxide gas. In a rigid cylinder with a movable piston, this reaction reaches equilibrium, as represented by the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + 392\ kJ$$

79 Explain, in terms of collision theory, why increasing the pressure of the gases in the cylinder increases the rate of the forward reaction. [1]

80 Determine the amount of heat released by the production of 1.0 mole of $SO_3(g)$. [1]

81 State, in terms of the concentration of $SO_3(g)$, what occurs when more $O_2(g)$ is added to the reaction at equilibrium. [1]

Base your answers to questions 72 through 74 on the information below.

Iron has been used for thousands of years. In the air, iron corrodes. One reaction for the corrosion of iron is represented by the balanced equation below.

Equation 1: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

In the presence of water, iron corrodes more quickly. This corrosion is represented by the unbalanced equation below.

Equation 2: $Fe(s) + O_2(g) + H_2O(\ell) \rightarrow Fe(OH)_2(s)$

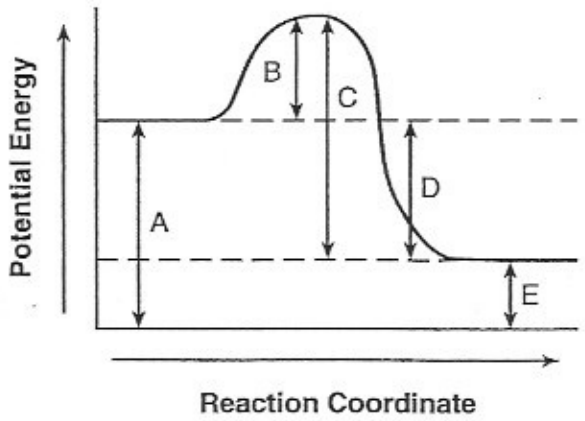
72 Identify *one* substance in the passage that can *not* be broken down by a chemical change. [1]

73 Using equation 1, describe *one* chemical property of iron. [1]

74 Balance the equation *in your answer booklet*, using the smallest whole-number coefficients. [1]

Base your answers to questions 60 and 61 on the information below.

The chemical reaction between methane and oxygen is represented by the potential energy diagram and balanced equation below.



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

60 Which potential energy interval in the diagram represents the activation energy of the forward reaction? [1]

61 Explain, in terms of collision theory, why a lower concentration of oxygen gas *decreases* 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, $Na_2CO_3(s)$. In the last step of the Solvay process, $NaHCO_3(s)$ is heated to 300°C, producing washing soda, water, and carbon dioxide. This reaction is represented by the balanced equation below.

$$2NaHCO_3(s) + \text{heat} \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

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]

ACIDS + BASES

Base your answers to questions 77 and 78 on the information below.

In performing a titration, a student adds three drops of phenolphthalein to a flask containing 25.00 milliliters of HCl(aq). Using a buret, the student slowly adds 0.150 M NaOH(aq) to the flask until one drop causes the indicator to turn light pink. The student determines that a total volume of 20.20 milliliters of NaOH(aq) was used in this titration.

77 The concentration of the NaOH(aq) used in the titration is expressed to what number of significant figures? [1]

78 Calculate the molarity of the HCl(aq) used in this titration. Your response must include *both* a correct numerical setup and the calculated result. [2]

52 Explain, in terms of activity, why HCl(aq) reacts with Zn(s), but HCl(aq) does *not* react with Cu(s). [1]

Base your answers to questions 69 through 71 on the information below.

In a laboratory investigation, magnesium reacts with hydrochloric acid to produce hydrogen gas and magnesium chloride. This reaction is represented by the unbalanced equation below.

$$Mg(s) + HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$$

69 State, in terms of the relative activity of elements, why this reaction is spontaneous. [1]

70 Balance the equation *in your answer booklet*, using the smallest whole-number coefficients. [1]

71 Write a balanced half-reaction equation for the oxidation that occurs. [1]

Base your answers to questions 81 through 83 on the information below.

A student, wearing chemical safety goggles and a lab apron, is to perform a laboratory test to determine the pH value of two different solutions. The student is given one bottle containing a solution with a pH of 2.0 and another bottle containing a solution with a pH of 5.0. The student is also given six dropping bottles, each containing a different indicator listed in Reference Table *M*.

81 State *one* safety precaution, *not* mentioned in the passage, that the student should take while performing tests on the samples from the bottles. [1]

82 Identify an indicator in Reference Table *M* that would differentiate the two solutions. [1]

83 Compare the hydronium ion concentration of the solution having a pH of 2.0 to the hydronium ion concentration of the other solution given to the student. [1]

Base your answers to questions 64 and 65 on the information below.

A 20.0-milliliter sample of HCl(aq) is completely neutralized by 32.0 milliliters of 0.50 M KOH(aq).

64 Calculate the molarity of the HCl(aq). Your response must include *both* a numerical setup and the calculated result. [2]

65 According to the data, to what number of significant figures should the calculated molarity of the HCl(aq) be expressed? [1]

Base your answers to questions 75 through 78 on the information below.

In one trial of an investigation, 50.0 milliliters of HCl(aq) of an unknown concentration is titrated with 0.10 M NaOH(aq). During the titration, the total volume of NaOH(aq) added and the corresponding pH value of the reaction mixture are measured and recorded in the table below.

Titration Data

Total Volume of NaOH(aq) Added (mL)	pH Value of Reaction Mixture
10.0	1.6
20.0	2.2
24.0	2.9
24.9	3.9
25.1	10.1
26.0	11.1
30.0	11.8

75 On the grid *in your answer booklet*, plot the data from the table. Circle and connect the points. [1]

76 Determine the total volume of NaOH(aq) added when the reaction mixture has a pH value of 7.0. [1]

77 Write a balanced equation that represents this neutralization reaction. [1]

78 In another trial, 40.0 milliliters of HCl(aq) is completely neutralized by 20.0 milliliters of this 0.10 M NaOH(aq). Calculate the molarity of the titrated acid in this trial. Your response must include *both* a numerical setup and the calculated result. [2]

Base your answers to questions 80 through 82 on the information below.

Some carbonated beverages are made by forcing carbon dioxide gas into a beverage solution. When a bottle of one kind of carbonated beverage is first opened, the beverage has a pH value of 3.

80 State, in terms of the pH scale, why this beverage is classified as acidic. [1]

81 Using Table *M*, identify *one* indicator that is yellow in a solution that has the same pH value as this beverage. [1]

82 After the beverage bottle is left open for several hours, the hydronium ion concentration in the beverage solution decreases to $\frac{1}{1000}$ of the original concentration. Determine the new pH of the beverage solution. [1]

Base your answers to questions 63 through 65 on the information below.

In a titration, a few drops of an indicator are added to a flask containing 35.0 milliliters of $HNO_3(aq)$ of unknown concentration. After 30.0 milliliters of 0.15 M NaOH(aq) solution is slowly added to the flask, the indicator changes color, showing the acid is neutralized.

63 The volume of the NaOH(aq) solution is expressed to what number of significant figures? [1]

64 Complete the equation *in your answer booklet* for this neutralization reaction by writing the formula of *each* product. [1]

65 In the space *in your answer booklet*, show a numerical setup for calculating the concentration of the $HNO_3(aq)$ solution. [1]

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

In liquid water, an equilibrium exists between $H_2O(\ell)$ molecules, $H^+(aq)$ ions, and $OH^-(aq)$ 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]

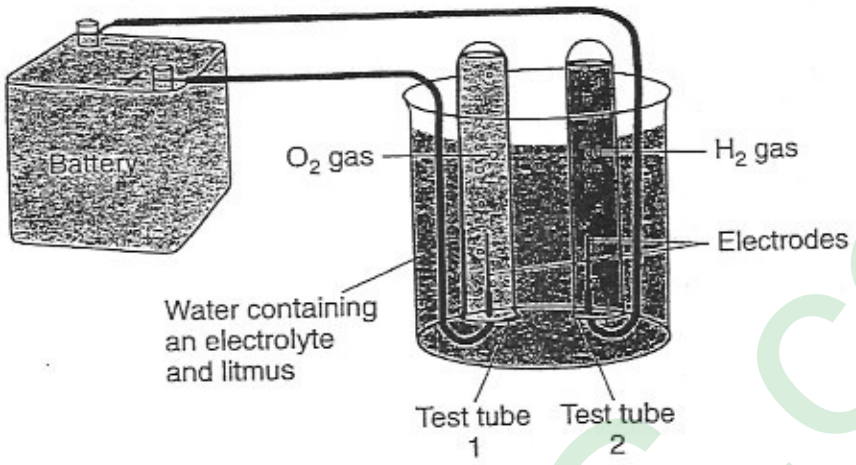
78 Identify the negative ion found in milk of magnesia. [1]

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

REDOX + Electrochemistry

Base your answers to questions 82 through 84 on the information below.

The diagram below shows a system in which water is being decomposed into oxygen gas and hydrogen gas. Litmus is used as an indicator in the water. The litmus turns red in test tube 1 and blue in test tube 2.



The oxidation and reduction occurring in the test tubes are represented by the balanced equations below.

Test tube 1: $2H_2O(\ell) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Test tube 2: $4H_2O(\ell) + 4e^- \rightarrow 2H_2(g) + 4OH^-(aq)$

82 Identify the information in the diagram that indicates this system is an electrolytic cell. [1]

83 Determine the change in oxidation number of oxygen during the reaction in test tube 1. [1]

84 Explain, in terms of the products formed in test tube 2, why litmus turns blue in test tube 2. [1]

Base your answers to questions 75 through 77 on the information below.

Litharge, PbO, is an ore that can be roasted (heated) in the presence of carbon monoxide, CO, to produce elemental lead. The reaction that takes place during this roasting process is represented by the balanced equation below.

$$PbO(s) + CO(g) \rightarrow Pb(\ell) + CO_2(g)$$

75 Write the balanced equation for the reduction half-reaction that occurs during this roasting process. [1]

76 Determine the oxidation number of carbon in carbon monoxide. [1]

77 Calculate the percent composition by mass of oxygen in litharge (gram-formula mass = 223.2 grams per mole). Your response must include *both* a numerical setup and the calculated result. [2]

25