Chemistry Review
Unit 5 – Physical Behavior of Matter

Phases of Matter, Changes of Phase, Substances, Mixtures, Solutions, Effect of Solute on Solution, Energy, Kinetics of Solids, Liquids and Gases

Matter, Phases and Gas Laws

1. Matter is classified as a pure substance or a mixture of substances.
✓ A substance has fixed composition and uniform properties throughout the sample. Element and compounds are substances.

2. A mixture is composed of two or more different substances that may be physically separated.
✓ A mixture may be homogeneous (uniform – a solution), or heterogeneous (uneven).
✓ Substances in a mixture retain their original properties.
✓ Substances in a mixture may be separated by their size, polarity, density, boiling and freezing points, and solubility (among others).
✓ Filtration and distillation are examples of processes used to separate mixtures.

2. An element is a substance composed of atoms with the same atomic number. They cannot be broken down by chemical change.

3. A compound is two or more elements bonded together. It can only be broken down by chemical changes.
✓ Substances that form a compound gain new properties.
✓ The ratio of substances in a compound is constant (e.g. water has a fixed ratio 2:1 ratio of hydrogen to oxygen).

4. A physical change is one that results in the rearrangement of existing particles in a substance (ex: freezing, boiling). A chemical change results in the formation of different substances with different properties.
✓ Chemical and physical changes may be endothermic or exothermic.

5. The three phases of matter are solid, liquid and gas. Each has its own properties.
✓ Solids have a constant volume and shape. Particles are held in a rigid, crystalline structure.
✓ Liquids have a constant volume but a changing shape. Particles are mobile but still held together by strong attraction.
✓ Gasses have no set volume or shape. They will completely fill any closed contained. Particles have largely broken free of the forces holding them together.

6. A heating curve (or cooling curve) traces the changes in temperature of a substance as it changes from solid to liquid to gas (or gas to liquid to solid).
✓ When the substance undergoes a phase change, there is no change in temperature. The line "flattens" until the phase change is complete.
✓ When a phase change is occurring, the potential energy of the substance changes while kinetic energy remains the same.
✓ As temperature increases, kinetic energy increases.

7. Heat of fusion (H_f)is the energy needed to convert one gram of a substance from solid to liquid.

8. Heat of vaporization (H_v) is the energy needed to convert one gram of a substance from liquid to gas.

9. Specific heat (C) is the energy required to raise one gram of a substance 1 degree (Celcius or Kelvin).
✓ The specific heat of liquid water is 1 cal/g*J or 4.2 J/g*K.

10. The combined gas law states the relationship between pressure, temperature and volume in a sample of gas.
✓ Increasing pressure causes a decrease in volume (inverse relationship).
✓ Increasing temperature causes an increase in volume (direct relationship).
✓ Increasing temperature causes an increase in pressure.(direct relationship).

11. An ideal gas model is used to explain the behavior of gasses. A real gas is most like an ideal gas when it is at <u>low temperature and high pressure.</u>

Unit 5 – Physical Behavior of Matter

12. The Kinetic Molecular Theory (KMT) for an ideal gas states that all gas particles:
✓ are in random motion.
✓ have no forces of attraction between them.
✓ have a negligible volume compared to the distances between them.
✓ have collisions that result in the transfer of energy from one particle to another, but there is no net loss of energy from the collision.

13. Equal volumes of gasses at the same temp and pressure have an equal number of particles.

14. Energy can exist in different forms – chemical, electrical, electromagnetic, thermal, mechanical, nuclear.
✓ Stored energy is referred to as <u>potential energy</u>.
✓ Energy of motion is <u>kinetic energy.</u>

15. The Law of Conservation of Energy states that energy can not be lost or destroyed, only changed from one form to another.

16. Heat is a transfer of energy (often but not always thermal energy) from a body of higher temperature to a body of lower temperature.

17. Temperature is a <u>measure</u> of the average kinetic energy of the particles in a sample. <u>Temperature is NOT a form of energy</u> and should not be confused with heat.

18. The concepts of kinetic and potential energy can be used to explain physical processes such as fusion (melting), solidification (freezing), vaporization (boiling, evaporation), condensation, sublimation, and deposition.

19. Processes that are <u>exothermic</u> give off heat energy. This typically causes the surrounding environment to become warmer.

20. Processes that are <u>endothermic</u> absorb energy. This typically causes the surrounding environment to become colder.

21. A solution is a homogeneous mixture of a <u>solute</u> dissolved in a <u>solvent.</u>
✓ Solubility depends on temperature, pressure, and the nature of the solute and solvent.
✓ "Like dissolves like" – polar substances dissolve polar substances, and non-polar substances dissolve non-polar substances. Polar and non-polar do not mix.

22. Ionic substances dissolve in polar solvents. The positive ion is attracted to the negative end of the polar molecule, as the negative ion is attracted to its positive end.

23. Concentration of a solution can be expressed as <u>molarity</u> (M), percent by volume, percent by mass, or parts per million (ppm).

24. Adding a solute to a solvent causes the boiling point of the solvent to <u>increase</u> and the freezing point to <u>decrease</u>.

25. A saturated solution exists in equilibrium – the rate of crystallization equals the rate of dissolving.

38 What is the concentration of $O_2(g)$, in parts per million, in a solution that contains 0.008 gram of $O_2(g)$ dissolved in 1000. grams of $H_2O(\ell)$?

(1) 0.8 ppm   (3) 80 ppm
(2) 8 ppm   (4) 800 ppm

39 The table below shows data for the temperature, pressure, and volume of four gas samples.

Data for Four Gas Samples

Gas Sample	Temperature (K)	Pressure (atm)	Volume (mL)
A	100.	2	400.
B	200.	2	200.
C	100.	2	400.
D	200.	4	200.

Which two gas samples have the same total number of molecules?

(1) A and B   (3) B and C
(2) A and C   (4) B and D

40 At which temperature is the vapor pressure of ethanol equal to the vapor pressure of propanone at 35°C?

(1) 35°C   (3) 82°C
(2) 60.°C   (4) 95°C

7 Which statement describes a chemical property of hydrogen gas?

(1) Hydrogen gas burns in air.
(2) Hydrogen gas is colorless.
(3) Hydrogen gas has a density of 0.000 09 g/cm^3 at STP.
(4) Hydrogen gas has a boiling point of 20. K at standard pressure.

8 Which element has the greatest density at STP?

(1) calcium   (3) chlorine
(2) carbon   (4) copper

9 Which equation shows conservation of atoms?

(1) $H_2 + O_2 \rightarrow H_2O$
(2) $H_2 + O_2 \rightarrow 2H_2O$
(3) $2H_2 + O_2 \rightarrow 2H_2O$
(4) $2H_2 + 2O_2 \rightarrow 2H_2O$

13 Which substance can be broken down by a chemical change?

(1) antimony   (3) hexane
(2) carbon   (4) sulfur

14 Which barium salt is *insoluble* in water?

(1) $BaCO_3$ (3) $Ba(ClO_4)_2$
(2) $BaCl_2$ (4) $Ba(NO_3)_2$

15 Which unit can be used to express solution concentration?

(1) J/mol   (3) mol/L
(2) L/mol   (4) mol/s

16 Under which conditions of temperature and pressure is a gas most soluble in water?

(1) high temperature and low pressure
(2) high temperature and high pressure
(3) low temperature and low pressure
(4) low temperature and high pressure

17 Given the equation representing a system at equilibrium:

$$H_2O(s) \rightleftharpoons H_2O(\ell)$$

At which temperature does this equilibrium exist at 101.3 kilopascals?

(1) 0 K   (3) 32 K
(2) 0°C   (4) 273°C

23 As water is added to a 0.10 M NaCl aqueous solution, the conductivity of the resulting solution

(1) decreases because the concentration of ions decreases
(2) decreases, but the concentration of ions remains the same
(3) increases because the concentration of ions decreases
(4) increases, but the concentration of ions remains the same

August 2007

11 Given the balanced equation representing a reaction:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell) + 55.8 \text{ kJ}$$

In this reaction there is conservation of

(1) mass, only
(2) mass and charge, only
(3) mass and energy, only
(4) mass, charge, and energy

15 Which statement must be true when solution equilibrium occurs?

(1) The solution is at STP.
(2) The solution is supersaturated.
(3) The concentration of the solution remains constant.
(4) The masses of the dissolved solute and the undissolved solute are equal.

16 Which liquid has the highest vapor pressure at 75°C?

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

18 Which sample of matter is a single substance?

(1) air   (3) hydrochloric acid

(2) ammonia gas   (4) salt water

19 At STP, which sample contains the same number of molecules as 11.2 liters of $CO_2(g)$ at STP?

(1) 5.6 L of $NO_2(g)$ (3) 11.2 L of $N_2(g)$

(2) 7.5 L of $H_2(g)$ (4) 22.4 L of $CO(g)$

40 Which kelvin temperature is equal to 56°C?

(1) –329 K   (3) 217 K

(2) –217 K   (4) 329 K

20 A sample of gas is held at constant pressure. Increasing the kelvin temperature of this gas sample causes the average kinetic energy of its molecules to

(1) decrease and the volume of the gas sample to decrease

(2) decrease and the volume of the gas sample to increase

(3) increase and the volume of the gas sample to decrease

(4) increase and the volume of the gas sample to increase

36 At standard pressure, a certain compound has a low boiling point and is insoluble in water. At STP, this compound most likely exists as

(1) ionic crystals

(2) metallic crystals

(3) nonpolar molecules

(4) polar molecules

37 The table below shows mass and volume data for four samples of substances at 298 K and 1 atmosphere.

Masses and Volumes of Four Samples

Sample	Mass (g)	Volume (mL)
A	30.	60.
B	40.	50.
C	45	90.
D	90.	120.

Which two samples could consist of the same substance?

(1) A and B   (3) B and C

(2) A and C   (4) C and D

39 An unsaturated solution is formed when 80. grams of a salt is dissolved in 100. grams of water at 40.°C. This salt could be

(1) KCl   (3) NaCl

(2) KNO_3 (4) $NaNO_3$

Base your answers to questions 57 through 60 on the information below.

The temperature of a sample of a substance is increased from 20.°C to 160.°C as the sample absorbs heat at a constant rate of 15 kilojoules per minute at standard pressure. The graph below represents the relationship between temperature and time as the sample is heated.

Temperature Versus Time
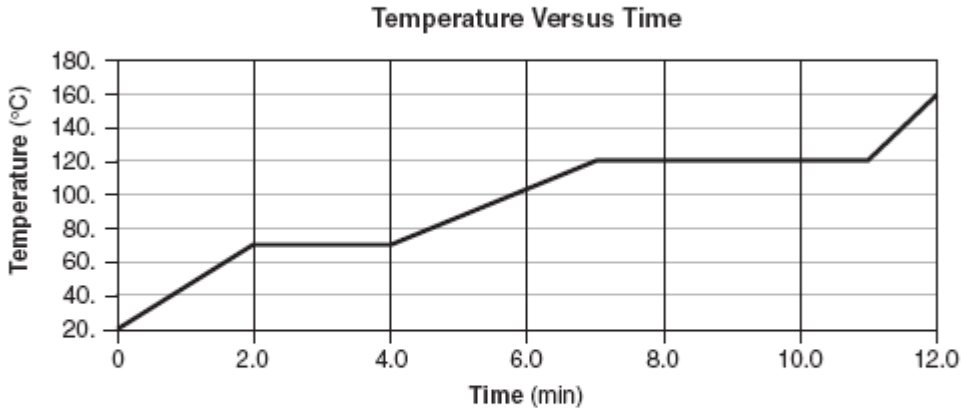
57 What is the boiling point of this sample? [1]

58 *In your answer booklet*, use the key to draw *at least nine* particles in the box, showing the correct particle arrangement of this sample during the first minute of heating. [1]

59 What is the total time this sample is in the liquid phase, only? [1]

60 Determine the total amount of heat required to completely melt this sample at its melting point. [1]

57 _____ °C

58

Key
○ = particle of the substance
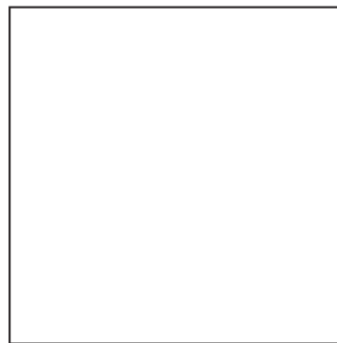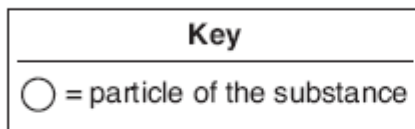
59 _____ min

60 _____ kJ

Unit 5 – Physical Behavior of Matter

June 2007

3 A sample composed only of atoms having the same atomic number is classified as

(1) a compound   (3) an element
(2) a solution   (4) an isomer

12 Which term is defined as a measure of the average kinetic energy of the particles in a sample?

(1) temperature   (3) thermal energy
(2) pressure   (4) chemical energy

13 A 3.0 M HCl(aq) solution contains a total of

(1) 3.0 grams of HCl per liter of water
(2) 3.0 grams of HCl per mole of solution
(3) 3.0 moles of HCl per liter of solution
(4) 3.0 moles of HCl per mole of water

14 A dilute, aqueous potassium nitrate solution is best classified as a

(1) homogeneous compound
(2) homogeneous mixture
(3) heterogeneous compound
(4) heterogeneous mixture

15 Given the equation representing a phase change at equilibrium:

$$C_2H_5OH(\ell) \rightleftharpoons C_2H_5OH(g)$$

Which statement is true?

(1) The forward process proceeds faster than the reverse process.
(2) The reverse process proceeds faster than the forward process.
(3) The forward and reverse processes proceed at the same rate.
(4) The forward and reverse processes both stop.

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

39 Which particle diagram represents a sample of one compound, only?

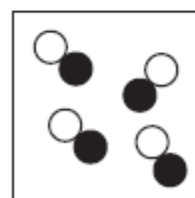| Key |
| --- |
| ◯ = atom of one element |
| ● = atom of a different element |
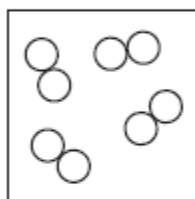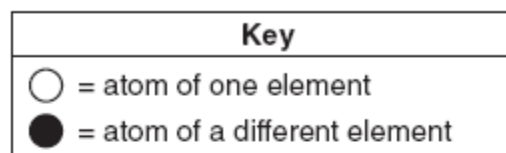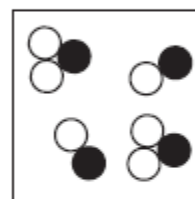
(1)   (3)
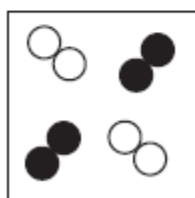
(2)   (4)

40 An atom in the ground state contains a total of 5 electrons, 5 protons, and 5 neutrons. Which Lewis electron-dot diagram represents this atom?

(1)   (2)   (3)   (4)

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

A gas sample is held at constant temperature in a closed system. The volume of the gas is changed, which causes the pressure of the gas to change. Volume and pressure data are shown in the table below.

Volume and Pressure of a Gas Sample

Volume (mL)	Pressure (atm)
1200	0.5
600	1.0
300	2.0
150	4.0
100	6.0

51 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Volume (mL)." [1]

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

Example:

53 Based on your graph, what is the pressure of the gas when the volume of the gas is 200. milliliters? [1]

51–52
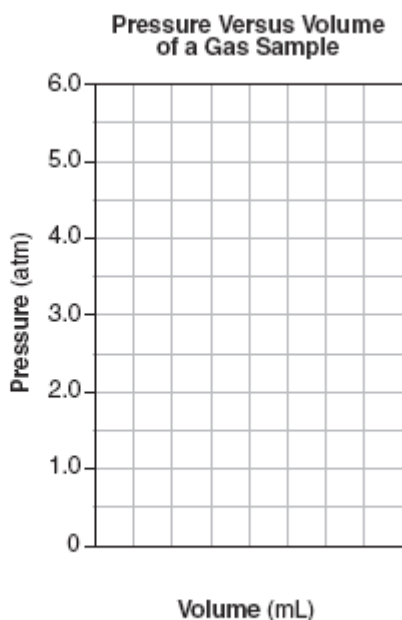
**Pressure Versus Volume
of a Gas Sample**

Pressure (atm)

6.0
5.0
4.0
3.0
2.0
1.0
0

Volume (mL)

53 _____ atm

Base your answers to questions 56 through 58 on the information below.

A 5.00-gram sample of liquid ammonia is originally at 210. K. The diagram of the partial heating curve below represents the vaporization of the sample of ammonia at standard pressure due to the addition of heat. The heat is *not* added at a constant rate.

Partial Heating Curve for Ammonia
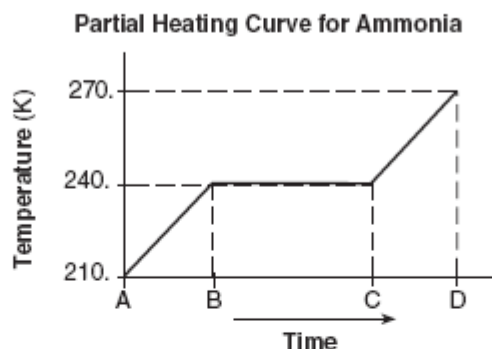
Some physical constants for ammonia are shown in the data table below.

Some Physical Constants for Ammonia

specific heat capacity of $NH_3(\ell)$	4.71 J/g•K
heat of fusion	332 J/g
heat of vaporization	1370 J/g

56 In the space *in your answer booklet*, calculate the total heat absorbed by the 5.00-gram sample of ammonia during time interval *AB*. Your response must include *both* a correct numerical setup and the calculated result. [2]

57 Describe what is happening to *both* the potential energy and the average kinetic energy of the molecules in the ammonia sample during time interval *BC*. Your response must include *both* potential energy and average kinetic energy. [1]

58 Determine the total amount of heat required to vaporize this 5.00-gram sample of ammonia at its boiling point. [1]

56

_____ J

57 _____

_____

58 _____ J

63 A 1.00-mole sample of neon gas occupies a volume of 24.4 liters at 298 K and 101.3 kilopascals. In the *space in your answer booklet*, calculate the density of this sample. Your response must include *both* a correct numerical setup and the calculated result. [2]

63

_____ g/L

Base your answers to questions 64 through 66 on the information below.

Scientists who study aquatic ecosystems are often interested in the concentration of dissolved oxygen in water. Oxygen, O_2, has a very low solubility in water, and therefore its solubility is usually expressed in units of milligrams per 1000. grams of water at 1.0 atmosphere. The graph below shows a solubility curve of oxygen in water.

Solubility of Oxygen in Water Versus Temperature
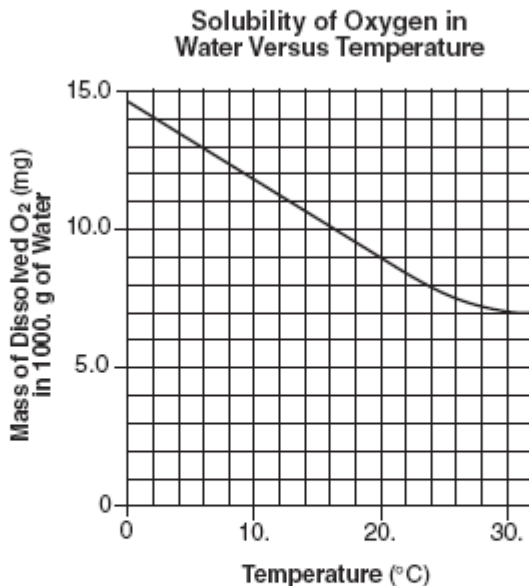
64 A student determines that 8.2 milligrams of oxygen is dissolved in a 1000.-gram sample of water at 15°C and 1.0 atmosphere. In terms of saturation, what type of solution is this sample? [1]

65 Explain, in terms of molecular polarity, why oxygen gas has low solubility in water. Your response must include *both* oxygen and water. [1]

66 An aqueous solution has 0.0070 gram of oxygen dissolved in 1000. grams of water. In the space *in your answer booklet*, calculate the dissolved oxygen concentration of this solution in parts per million. Your response must include *both* a correct numerical setup and the calculated result. [2]

64 _____

65 _____

_____

_____

66

_____ ppm

January 2007

13 Which substance, when dissolved in water, forms a solution that conducts an electric current?

(1) C_2H_5OH (3) $C_{12}H_{22}O_{11}$

(2) $C_6H_{12}O_6$ (4) CH_3COOH

19 Compared to a 2.0 M aqueous solution of NaCl at 1 atmosphere, a 3.0 M aqueous solution of NaCl at 1 atmosphere has a

(1) lower boiling point and a higher freezing point

(2) lower boiling point and a lower freezing point

(3) higher boiling point and a higher freezing point

(4) higher boiling point and a lower freezing point

27 In terms of energy and entropy, systems in nature tend to undergo changes toward

(1) higher energy and higher entropy

(2) higher energy and lower entropy

(3) lower energy and higher entropy

(4) lower energy and lower entropy

39 At which temperature would atoms of a He(g) sample have the greatest average kinetic energy?

(1) 25°C   (3) 273 K

(2) 37°C   (4) 298 K

40 A student prepares four aqueous solutions, each with a different solute. The mass of each dissolved solute is shown in the table below.

**Mass of Dissolved Solute
for Four Aqueous Solutions**

Solution Number	Solute	Mass of Dissolved Solute (per 100. g of H_2O at 20.°C)
1	KI	120. g
2	$NaNO_3$	88 g
3	KCl	25 g
4	$KClO_3$	5 g

Which solution is saturated?

(1) 1 (3) 3
(2) 2 (4) 4

41 At room temperature, a mixture of sand and water can be separated by

(1) ionization (3) filtration
(2) combustion (4) sublimation

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

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 91.8 \text{ kJ}$$
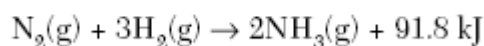
Which statement is true about this reaction?

(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.

43 Which balanced equation represents a phase equilibrium?

(1) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

(2) $2NO_2(g) \rightleftharpoons N_2O_4(g)$

(3) $Cl_2(g) \rightleftharpoons Cl_2(\ell)$

(4) $3O_2(g) \rightleftharpoons 2O_3(g)$

58 A potential energy diagram for a chemical reaction is shown *in your answer booklet*. On this diagram, draw a curve to show how the potential energy diagram will change when a catalyst is added to the reaction. [1]
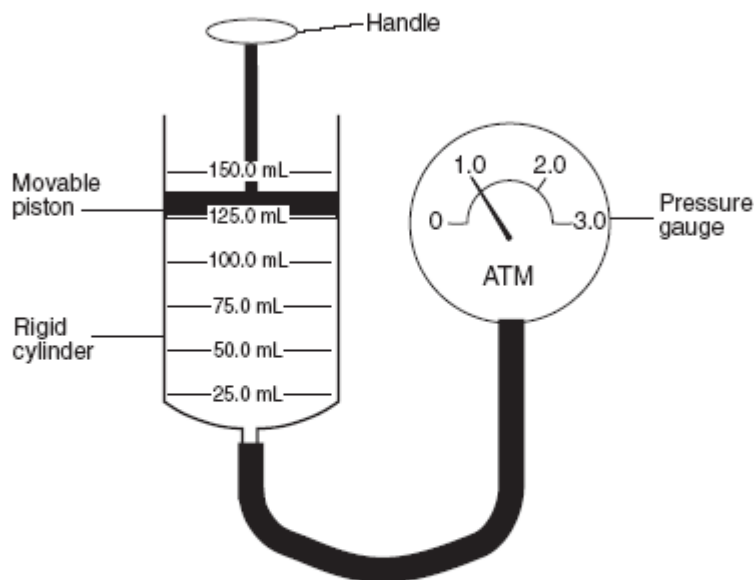
58

Reaction Coordinate
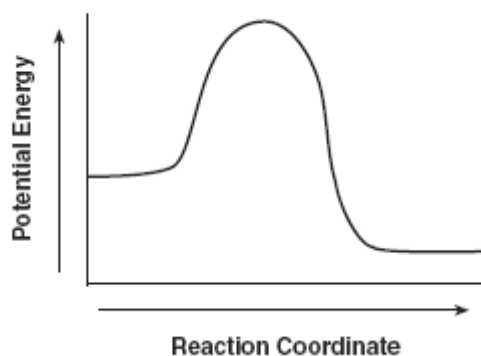
60 An aqueous solution contains 300. parts per million of KOH. Determine the number of grams of KOH present in 1000. grams of this solution. [1]

60 _____ g

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

A rigid cylinder is fitted with a movable piston. The cylinder contains a sample of helium gas, He(g), which has an initial volume of 125.0 milliliters and an initial pressure of 1.0 atmosphere, as shown below. The temperature of the helium gas sample is 20.0°C.

Handle

Movable piston

150.0 mL
125.0 mL
100.0 mL
75.0 mL
50.0 mL
25.0 mL

Rigid cylinder

1.0   2.0
0   3.0
ATM

Pressure gauge

75 Express the initial volume of the helium gas sample, in liters. [1]

76 The piston is pushed further into the cylinder. In the space *in your answer booklet*, show a correct numerical setup for calculating the volume of the helium gas that is anticipated when the reading on the pressure gauge is 1.5 atmospheres. The temperature of the helium gas remains constant. [1]

77 Helium gas is removed from the cylinder and a sample of nitrogen gas, $N_2(g)$, is added to the cylinder. The nitrogen gas has a volume of 125.0 milliliters and a pressure of 1.0 atmosphere at 20.0°C. Compare the number of particles in this nitrogen gas sample to the number of particles in the original helium gas sample. [1]

75 _____ L

76

77 _____

_____

_____

August 2006

3 Which property makes it possible to separate the oxygen and the nitrogen from a sample of liquefied air?

(1) boiling point   (3) hardness
(2) conductivity   (4) electronegativity

4 Which statement explains why ozone gas, O_3, and oxygen gas, O_2, have different properties?

(1) They are formed from different elements.
(2) They have different molecular structures.
(3) They have different oxidation numbers.
(4) They have different electronegativities.

7 Which process is a chemical change?

(1) melting of ice
(2) boiling of water
(3) subliming of ice
(4) decomposing of water

12 Which statement best describes the shape and volume of an aluminum cylinder at STP?

(1) It has a definite shape and a definite volume.
(2) It has a definite shape and no definite volume.
(3) It has no definite shape and a definite volume.
(4) It has no definite shape and no definite volume.

13 Which two substances can *not* be broken down by chemical change?

(1) C and CuO   (3) CO_2 and CuO
(2) C and Cu   (4) CO_2 and Cu

14 Which compound is insoluble in water?

(1) $BaSO_4$ (3) $KClO_3$
(2) $CaCrO_4$ (4) Na_2S

15 A sample of a gas is contained in a closed rigid cylinder. According to kinetic molecular theory, what occurs when the gas inside the cylinder is heated?

(1) The number of gas molecules increases.
(2) The number of collisions between gas molecules per unit time decreases.
(3) The average velocity of the gas molecules increases.
(4) The volume of the gas decreases.

18 The data table below gives the temperature and pressure of four different gas samples, each in a 2-liter container.

Temperature and Pressure of Gas Samples

Gas Sample	Temperature (K)	Pressure (atm)
He	300.	1.20
Ne	300.	1.00
CO_2	200.	1.20
CH_4	300.	1.00

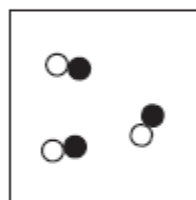Which two gas samples contain the same total number of particles?

(1) CH_4 and CO_2 (3) He and CO_2
(2) CH_4 and Ne   (4) He and Ne

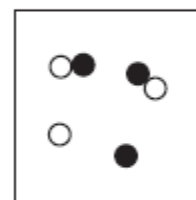39 What amount of heat is required to completely melt a 29.95-gram sample of $H_2O(s)$ at 0°C?

(1) 334 J   (3) 1.00×10^3 J
(2) 2260 J   (4) 1.00×10^4 J

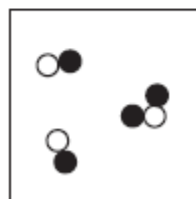40 Which particle diagram represents a mixture of element X and element Z, only?
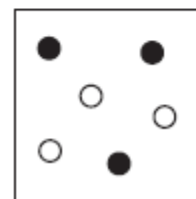
| Key |
|---|
| ● = atom of X |
| ○ = atom of Z |

(1)   (3)

(2)   (4)

41 An unsaturated aqueous solution of NH_3 is at 90.°C in 100. grams of water. According to Reference Table G, how many grams of NH_3 could this unsaturated solution contain?

(1) 5 g   (3) 15 g
(2) 10. g   (4) 20. g

42 How many total moles of KNO_3 must be dissolved in water to make 1.5 liters of a 2.0 M solution?

(1) 0.50 mol   (3) 3.0 mol
(2) 2.0 mol   (4) 1.3 mol

43 Which statement explains why low temperature and high pressure are required to liquefy chlorine gas?

(1) Chlorine molecules have weak covalent bonds.
(2) Chlorine molecules have strong covalent bonds.
(3) Chlorine molecules have weak intermolecular forces of attraction.
(4) Chlorine molecules have strong intermolecular forces of attraction.

46 Given the potential energy diagram for a reaction:

Reaction Coordinate
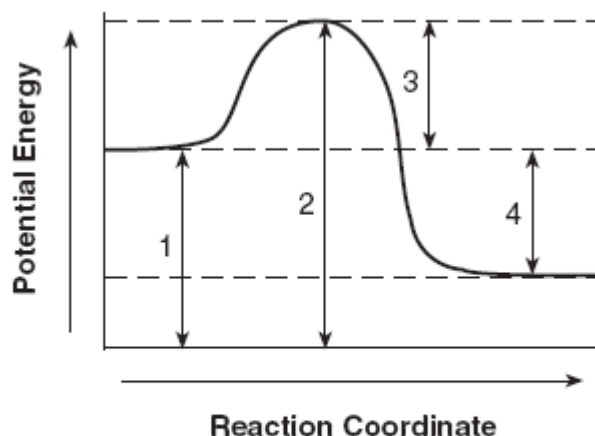
Which interval on this diagram represents the difference between the potential energy of the products and the potential energy of the reactants?

(1) 1   (3) 3
(2) 2   (4) 4

49 Which list of the phases of H_2O is arranged in order of increasing entropy?

(1) ice, steam, and liquid water
(2) ice, liquid water, and steam
(3) steam, liquid water, and ice
(4) steam, ice, and liquid water

Unit 5 – Physical Behavior of Matter

Base your answers to questions 53 through 56 on the diagram below concerning the classification of matter.

Classification of Matter

Matter
→ Mixtures
→ Substances

Mixtures → Homogeneous, X

Substances → Elements, Z
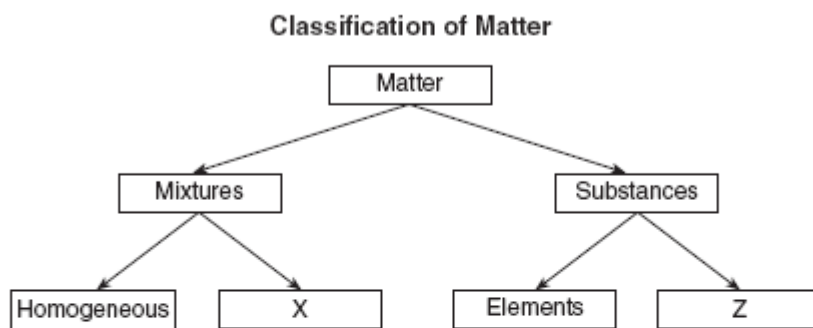
53 What type of mixture is represented by X? [1]

54 What type of substance is represented by Z? [1]

55 Explain, in terms of particle arrangement, why NaCl(aq) is a homogeneous mixture. [1]

56 Given a mixture of sand and water, state *one* process that can be used to separate water from the sand. [1]

53 _____

54 _____

55 _____

_____

_____

56 _____

_____

Base your answers to questions 57 through 60 on the information below.

An investigation was conducted to study the effect of the concentration of a reactant on the total time needed to complete a chemical reaction. Four trials of the same reaction were performed. In each trial the initial concentration of the reactant was different. The time needed for the chemical reaction to be completed was measured. The data for each of the four trials are shown in the table below.

Reactant Concentration and Reaction Time

Trial	Initial Concentration (M)	Reaction Time (s)
1	0.020	11
2	0.015	14
3	0.010	23
4	0.005	58

57 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Reaction Time (s)." An appropriate scale is one that allows a trend to be seen. [1]

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

Example:

59 State the effect of the concentration of the reactant on the rate of the chemical reaction. [1]

60 In a different experiment involving the same reaction, it was found that an increase in temperature increased the rate of the reaction. Explain this result in terms of collision theory. [1]

57 and 58
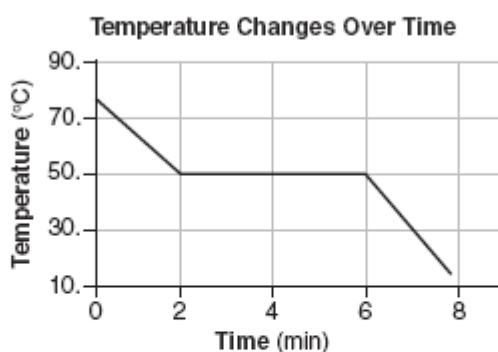
Reaction Time Versus Initial Concentration
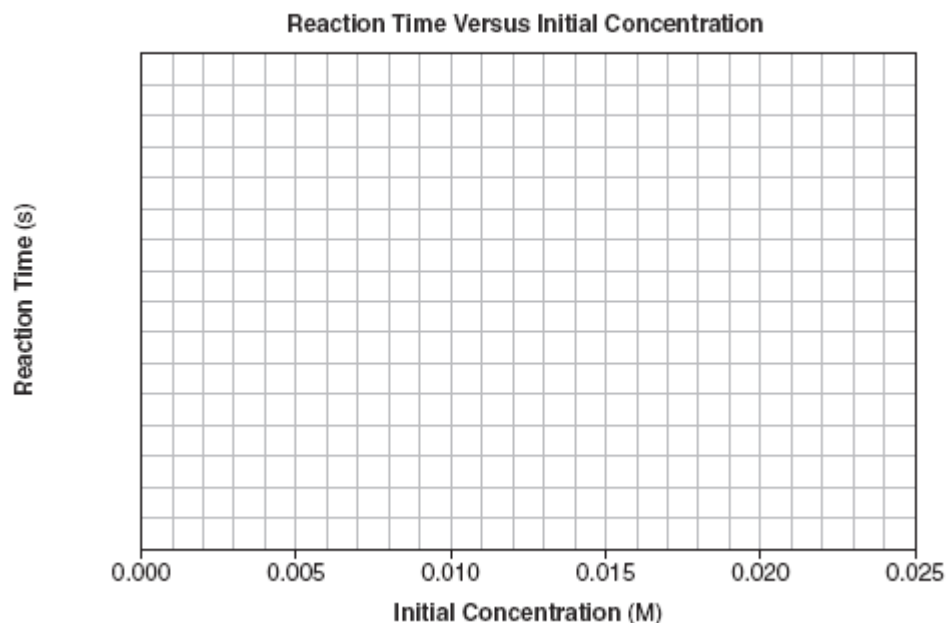
59 _____

_____

60 _____

_____

_____

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

The graph below shows a compound being cooled at a constant rate starting in the liquid phase at 75°C and ending at 15°C.

Temperature Changes Over Time

72 What is the freezing point of the compound, in degrees Celsius? [1]

73 State what is happening to the average kinetic energy of the particles of the sample between minute 2 and minute 6. [1]

74 A different experiment was conducted with another sample of the same compound starting in the solid phase. The sample was heated at a constant rate from 15°C to 75°C. On the graph *in your answer booklet*, draw the resulting heating curve. [1]

75 What kelvin temperature is equal to 15°C? [1]

72 _____ °C

73 _____

_____

74

75 _____ K

June 2006

14 Two substances, A and Z, are to be identified. Substance A can *not* be broken down by a chemical change. Substance Z can be broken down by a chemical change. What can be concluded about these substances?

(1) Both substances are elements.
(2) Both substances are compounds.
(3) Substance A is an element and substance Z is a compound.
(4) Substance A is a compound and substance Z is an element.

15 Which ion, when combined with chloride ions, Cl^-, forms an insoluble substance in water?

(1) Fe^{2+} (3) Pb^{2+}
(2) Mg^{2+} (4) Zn^{2+}

16 Molarity is defined as the

(1) moles of solute per kilogram of solvent
(2) moles of solute per liter of solution
(3) mass of a solution
(4) volume of a solvent

18 Which expression represents the ΔH for a chemical reaction in terms of the potential energy, PE, of its products and reactants?

(1) PE of products + PE of reactants
(2) PE of products – PE of reactants
(3) PE of products $\times$ PE of reactants
(4) PE of products $\div$ PE of reactants

19 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) $N_2(g) + O_2(g) \rightarrow 2NO(g)$
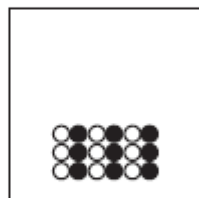
37 Given the key:

Key
O = Atom of oxygen
● = Atom of carbon

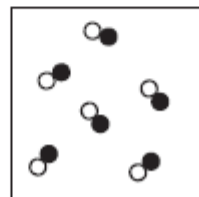Which particle diagram represents a sample containing the compound $CO(g)$?

(1)　　　　　　　　(3)

(2)　　　　　　　　(4)

40 A saturated solution of $NaNO_3$ is prepared at 60.°C using 100. grams of water. As this solution is cooled to 10.°C, $NaNO_3$ precipitates (settles) out of the solution. The resulting solution is saturated. Approximately how many grams of $NaNO_3$ settled out of the original solution?

(1) 46 g　　　　　(3) 85 g
(2) 61 g　　　　　(4) 126 g

41 Which kelvin temperature is equivalent to –24°C?

(1) 226 K　　　　　(3) 273 K
(2) 249 K　　　　　(4) 297 K

42 Which substance has the *lowest* vapor pressure at 75°C?

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

Base your answers to questions 64 through 66 on the information below.

　　　Ethanol, C_2H_5OH, is a volatile and flammable liquid with a distinct odor at room temperature. Ethanol is soluble in water. The boiling point of ethanol is 78.2°C at 1 atmosphere. Ethanol can be used as a fuel to produce heat energy, as shown by the balanced equation below.

$$C_2H_5OH(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell) + 1367 \text{ kJ}$$
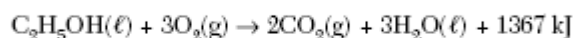
64 At 1 atmosphere, compare the boiling point of pure ethanol to the boiling point of a solution in which a nonvolatile substance is dissolved in ethanol. [1]

65 Determine the total amount of heat produced by the complete combustion of 2.00 moles of ethanol. [1]

66 Identify *one* physical property of ethanol, stated in the passage, that can be explained in terms of chemical bonds and intermolecular forces. [1]

64 _____

_____

65 _____ kJ

66 _____

Base your answers to questions 67 and 68 on the information below.

The graph shows the relationship between the solubility of a sequence of primary alcohols in water and the total number of carbon atoms in a molecule of the corresponding alcohol at the same temperature and pressure. A primary alcohol has the —OH group located on an end carbon of the hydrocarbon chain.

Solubility Versus Total Number of Carbon Atoms
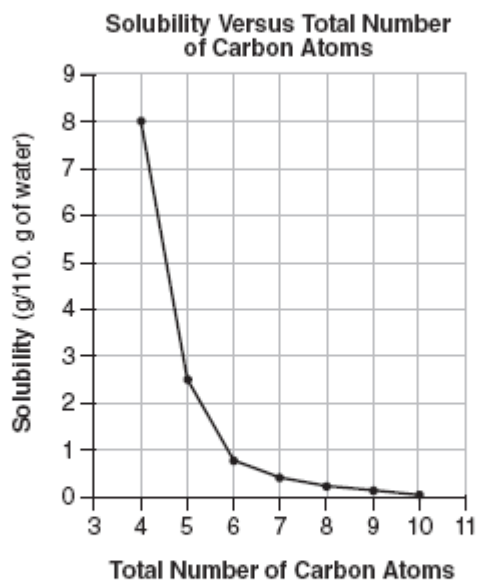
Adapted from *Chemistry*, Collins
Educational Publishing, pp. 227-231

67 Describe the relationship between the solubility of a primary alcohol in water and the total number of carbon atoms in the primary alcohol. [1]

68 Determine the total mass of 1-pentanol that will dissolve in 110. grams of water to produce a saturated solution. [1]

67 _____

_____

68 _____ g

Base your answers to questions 76 and 77 on the information below.

Archimedes (287–212 BC), a Greek inventor and mathematician, made several discoveries important to science today. According to a legend, Hiero, the king of Syracuse, commanded Archimedes to find out if the royal crown was made of gold, only. The king suspected that the crown consisted of a mixture of gold, tin, and copper.

Archimedes measured the mass of the crown and the total amount of water displaced by the crown when it was completely submerged. He repeated the procedure using individual samples, one of gold, one of tin, and one of copper. Archimedes was able to determine that the crown was not made entirely of gold without damaging it.

76 Identify *one* physical property that Archimedes used in his comparison of the metal samples. [1]

77 Determine the volume of a 75-gram sample of gold at STP. [1]

76 _____

77 _____ cm^3

January 2006

5 Which statement describes a chemical property of oxygen?

(1) Oxygen has a melting point of 55 K.
(2) Oxygen can combine with a metal to produce a compound.
(3) Oxygen gas is slightly soluble in water.
(4) Oxygen gas can be compressed.

13 Which substance can *not* be decomposed by ordinary chemical means?

(1) methane   (3) ethanol
(2) mercury   (4) ammonia

14 A mixture of crystals of salt and sugar is added to water and stirred until all solids have dissolved. Which statement best describes the resulting mixture?

(1) The mixture is homogeneous and can be separated by filtration.
(2) The mixture is homogeneous and cannot be separated by filtration.
(3) The mixture is heterogeneous and can be separated by filtration.
(4) The mixture is heterogeneous and cannot be separated by filtration.

15 Under which conditions of temperature and pressure would a sample of $H_2(g)$ behave most like an ideal gas?

(1) 0°C and 100 kPa
(2) 0°C and 300 kPa
(3) 150°C and 100 kPa
(4) 150°C and 300 kPa

16 In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is defined as the

(1) activation energy
(2) ionization energy
(3) heat of reaction
(4) heat of vaporization

18 Given the balanced equation:

$$I_2(s) + energy \rightarrow I_2(g)$$

As a sample of $I_2(s)$ sublimes to $I_2(g)$, the entropy of the sample

(1) increases because the particles are less randomly arranged
(2) increases because the particles are more randomly arranged
(3) decreases because the particles are less randomly arranged
(4) decreases because the particles are more randomly arranged
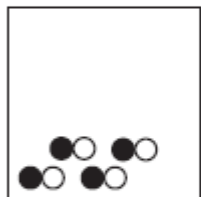
30 Compared to the freezing point of 1.0 M KCl(aq) at standard pressure, the freezing point of 1.0 M $CaCl_2$(aq) at standard pressure is

(1) lower
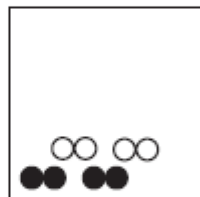(2) higher
(3) the same

32 Given the particle diagram representing four molecules of a substance:
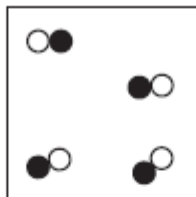
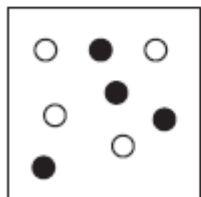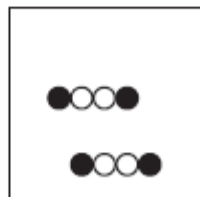Which particle diagram best represents this same substance after a physical change has taken place?

(1)

(3)

(2)

(4)

39 If 0.025 gram of $Pb(NO_3)_2$ is dissolved in 100. grams of H_2O, what is the concentration of the resulting solution, in parts per million?

(1) 2.5×10^{-4} ppm   (3) 250 ppm
(2) 2.5 ppm   (4) 4.0×10^3 ppm

41 A student adds solid KCl to water in a flask. The flask is sealed with a stopper and thoroughly shaken until no more solid KCl dissolves. Some solid KCl is still visible in the flask. The solution in the flask is

(1) saturated and is at equilibrium with the solid KCl
(2) saturated and is not at equilibrium with the solid KCl
(3) unsaturated and is at equilibrium with the solid KCl
(4) unsaturated and is not at equilibrium with the solid KCl

53 In the space *in your answer booklet*, draw a Lewis electron-dot diagram of a selenium atom in the ground state.   [1]

53

58 What is the total amount of heat energy, in joules, absorbed by 25.0 grams of water when the temperature of the water increases from 24.0°C to 36.0°C?   [1]

58 _____ J

Base your answers to questions 61 through 65 on the table below.

Physical Properties of Four Gases

Name of Gas	hydrogen	hydrogen chloride	hydrogen bromide	hydrogen iodide
Molecular Structure	H–H	H–Cl	H–Br	H–I
Boiling Point (K) at 1 Atm	20.	188	207	237
Density (g/L) at STP	0.0899	1.64	?	5.66

61 The volume of 1.00 mole of hydrogen bromide at STP is 22.4 liters. The gram-formula mass of hydrogen bromide is 80.9 grams per mole. What is the density of hydrogen bromide at STP?   [1]

62 The density of hydrogen at STP is 0.0899 gram per liter. Express this density to *two significant figures*.   [1]

63 Explain, in terms of electronegativity difference, why the bond in H–Cl is more polar than the bond in H–I.   [1]

64 Explain, in terms of intermolecular forces, why hydrogen has a *lower* boiling point than hydrogen bromide.   [1]

65 Explain, in terms of molecular polarity, why hydrogen chloride is more soluble than hydrogen in water under the same conditions of temperature and pressure. [1]

61 _____ g/L.

62 _____ g/L.

63 _____

_____

_____

64 _____

_____

_____

65 _____

_____

_____

Base your answers to questions 66 and 67 on the graph below, which represents the cooling of a substance starting at a temperature above its boiling point.
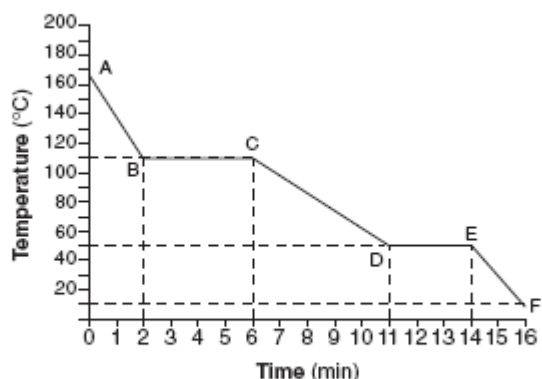
66 What is the melting point of this substance? [1]

67 Which segment of the graph represents the gas phase, only? [1]

66 _____ °C

67 _____

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

A student conducts an experiment to determine how the temperature of water affects the rate at which an antacid tablet dissolves in the water. The student has three antacid tablets of the same size and composition. The student drops one tablet into each of three beakers containing 200. milliliters of water at different temperatures and measures the time it takes for each tablet to completely dissolve. The results are shown in the table below.

Dissolving Data for Three Antacid Tablets

Beaker	Original Temperature of Water (°C)	Time for Tablet to Dissolve (s)
1	20.	40.
2	30.	25
3	40.	10.

68 Describe the effect of water temperature on the rate of dissolving. [1]

69 Explain, in terms of collision theory, how water temperature influences the rate of dissolving. [1]

70 What change, other than temperature, would affect the rate of dissolving? [1]

68 _____

_____

69 _____

_____

_____

70 _____

_____

Base your answers to questions 81 and 82 on the information below.

A lightbulb contains argon gas at a temperature of 295 K and at a pressure of 75 kilo-pascals. The lightbulb is switched on, and after 30 minutes its temperature is 418 K.

81 In the space *in your answer booklet*, show a correct numerical setup for calculating the pressure of the gas inside the lightbulb at 418 K. Assume the volume of the lightbulb remains constant. [1]

82 What Celsius temperature is equal to 418 K? [1]

81

82 _____ °C

August 2005

5 Two different samples decompose when heated. Only one of the samples is soluble in water. Based on this information, these two samples are

(1) both the same element
(2) two different elements
(3) both the same compound
(4) two different compounds

7 Which of these elements has the *lowest* melting point?

(1) Li   (3) K
(2) Na   (4) Rb

10 Which list consists of types of chemical formulas?

(1) atoms, ions, molecules
(2) metals, nonmetals, metalloids
(3) empirical, molecular, structural
(4) synthesis, decomposition, neutralization

12 An aqueous solution of sodium chloride is best classified as a

(1) homogeneous compound
(2) homogeneous mixture
(3) heterogeneous compound
(4) heterogeneous mixture

16 Two samples of gold that have different temperatures are placed in contact with one another. Heat will flow spontaneously from a sample of gold at 60°C to a sample of gold that has a temperature of

(1) 50°C   (3) 70°C
(2) 60°C   (4) 80°C

17 Under which conditions of temperature and pressure would helium behave most like an ideal gas?

(1) 50 K and 20 kPa   (3) 750 K and 20 kPa
(2) 50 K and 600 kPa   (4) 750 K and 600 kPa

18 A sample of oxygen gas is sealed in container X. A sample of hydrogen gas is sealed in container Z. Both samples have the same volume, temperature, and pressure. Which statement is true?

(1) Container X contains more gas molecules than container Z.
(2) Container X contains fewer gas molecules than container Z.
(3) Containers X and Z both contain the same number of gas molecules.
(4) Containers X and Z both contain the same mass of gas.

37 Which process would most effectively separate two liquids with different molecular polarities?

(1) filtration   (3) distillation
(2) fermentation   (4) conductivity

39 A solution contains 35 grams of KNO_3 dissolved in 100 grams of water at 40°C. How much *more* KNO_3 would have to be added to make it a saturated solution?

(1) 29 g   (3) 12 g
(2) 24 g   (4) 4 g

40 Which diagram best represents a gas in a closed container?

(1)   (3)

(2)   (4)

41 What is the total number of moles of NaCl(s) needed to make 3.0 liters of a 2.0 M NaCl solution?

(1) 1.0 mol   (3) 6.0 mol
(2) 0.70 mol   (4) 8.0 mol

43 A student wants to prepare a 1.0-liter solution of a specific molarity. The student determines that the mass of the solute needs to be 30. grams. What is the proper procedure to follow?

(1) Add 30. g of solute to 1.0 L of solvent.
(2) Add 30. g of solute to 970. mL of solvent to make 1.0 L of solution.
(3) Add 1000. g of solvent to 30. g of solute.
(4) Add enough solvent to 30. g of solute to make 1.0 L of solution.

44 What is the total number of joules released when a 5.00-gram sample of water changes from liquid to solid at 0°C?

(1) 334 J   (3) 2260 J
(2) 1670 J   (4) 11 300 J

45 Which set of procedures and observations indicates a chemical change?

(1) Ethanol is added to an empty beaker and the ethanol eventually disappears.
(2) A solid is gently heated in a crucible and the solid slowly turns to liquid.
(3) Large crystals are crushed with a mortar and pestle and become powder.
(4) A cool, shiny metal is added to water in a beaker and rapid bubbling occurs.

46 At STP, a sample of which element has the highest entropy?

(1) Na(s)　　　　　　(3) $Br_2(\ell)$
(2) $Hg(\ell)$　　　　　　(4) $F_2(g)$

62 A sample of oxygen gas in one container has a volume of 20.0 milliliters at 297 K and 101.3 kPa. The entire sample is transferred to another container where the temperature is 283 K and the pressure is 94.6 kPa. In the space *in your answer booklet*, show a correct numerical setup for calculating the new volume of this sample of oxygen gas. [1]

62

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

Element X is a solid metal that reacts with chlorine to form a water-soluble binary compound.

71 State *one* physical property of element X that makes it a good material for making pots and pans. [1]

72 Explain, in terms of particles, why an aqueous solution of the binary compound conducts an electric current. [1]

73 The binary compound consists of element X and chlorine in a 1:2 molar ratio. What is the oxidation number of element X in this compound? [1]

71 _____

72 _____

_____

_____

73 _____

June 2005

6 An example of a physical property of an element is the element's ability to

(1) react with an acid
(2) react with oxygen
(3) form a compound with chlorine
(4) form an aqueous solution

7 Which element is malleable and conducts electricity?

(1) iron   (3) sulfur
(2) iodine   (4) phosphorus

8 At STP, solid carbon can exist as graphite or as diamond. These two forms of carbon have

(1) the same properties and the same crystal structures
(2) the same properties and different crystal structures
(3) different properties and the same crystal structures
(4) different properties and different crystal structures

10 Which substance can be decomposed by a chemical change?

(1) calcium   (3) copper
(2) potassium   (4) ammonia

13 Which terms are used to identify pure substances?

(1) an element and a mixture
(2) an element and a compound
(3) a solution and a mixture
(4) a solution and a compound

14 The solubility of $KClO_3(s)$ in water increases as the

(1) temperature of the solution increases
(2) temperature of the solution decreases
(3) pressure on the solution increases
(4) pressure on the solution decreases

15 Compared to a 0.1 M aqueous solution of NaCl, a 0.8 M aqueous solution of NaCl has a

(1) higher boiling point and a higher freezing point
(2) higher boiling point and a lower freezing point
(3) lower boiling point and a higher freezing point
(4) lower boiling point and a lower freezing point

17 In which process does a solid change directly into a vapor?

(1) condensation (3) deposition
(2) sublimation   (4) solidification

38 According to Reference Table F, which of these compounds is the least soluble in water?

(1) K_2CO_3 (3) $Ca_3(PO_4)_2$
(2) $KC_2H_3O_2$ (4) $Ca(NO_3)_2$

41 According to Reference Table G, which substance forms an unsaturated solution when 80 grams of the substance is dissolved in 100 grams of H_2O at 10°C?

(1) KI   (3) $NaNO_3$
(2) KNO_3 (4) NaCl

42 What is the concentration of a solution, in parts per million, if 0.02 gram of Na_3PO_4 is dissolved in 1000 grams of water?

(1) 20 ppm   (3) 0.2 ppm
(2) 2 ppm   (4) 0.02 ppm

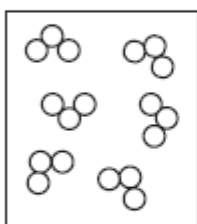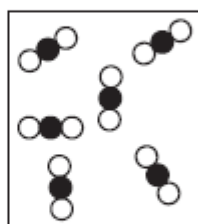43 Given the simple representations for atoms of two elements:

○ = an atom of an element

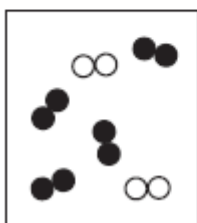● = an atom of a different element

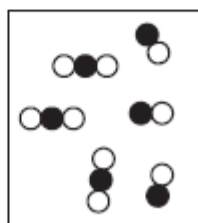Which particle diagram represents molecules of only one compound in the gaseous phase?

(1)

(3)

(2)

(4)

46 At STP, fluorine is a gas and iodine is a solid. This observation can be explained by the fact that fluorine has

(1) weaker intermolecular forces of attraction than iodine
(2) stronger intermolecular forces of attraction than iodine
(3) lower average kinetic energy than iodine
(4) higher average kinetic energy than iodine

Base your answers to questions 66 through 70 on the information below.

A substance is a solid at 15°C. A student heated a sample of the solid substance and recorded the temperature at one-minute intervals in the data table below.

Time (min)	0	1	2	3	4	5	6	7	8	9	10	11	12
Temperature (°C)	15	32	46	53	53	53	53	53	53	53	53	60	65

66 On the grid *in your answer booklet*, mark an appropriate scale on the axis labeled "Temperature (°C)." An appropriate scale is one that allows a trend to be seen. [1]

67 Plot the data from the data table. Circle and connect the points. [1]

Example:

68 Based on the data table, what is the melting point of this substance? [1]

69 What is the evidence that the average kinetic energy of the particles of this substance is increasing during the first three minutes? [1]

70 The heat of fusion for this substance is 122 joules per gram. How many joules of heat are needed to melt 7.50 grams of this substance at its melting point? [1]

66 and 67

Heating Curve

Temperature (°C)

0 1 2 3 4 5 6 7 8 9 10 11 12

Time (min)
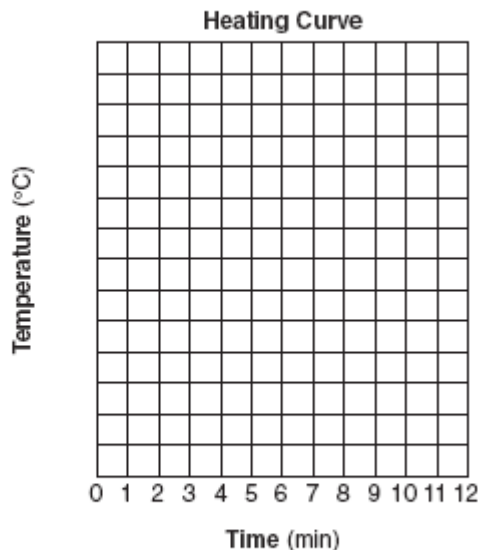
68 _____ °C

69 _____

_____

70 _____ J

Unit 5 – Physical Behavior of Matter

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

Cylinder A contains 22.0 grams of $CO_2(g)$ and cylinder B contains $N_2(g)$. The volumes, pressures, and temperatures of the two gases are indicated under each cylinder.

Cylinder A	Cylinder B
$CO_2(g)$	$N_2(g)$
V = 12.3 L	V = 12.3 L
P = 1.0 atm	P = 1.0 atm
T = 300. K	T = 300. K
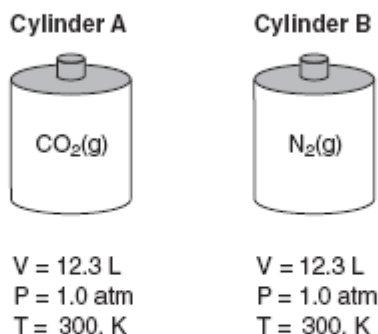
77 What is the total number of moles of $CO_2(g)$ in cylinder A? [1]

78 Explain why the number of molecules of $N_2(g)$ in cylinder B is the same as the number of molecules of $CO_2(g)$ in cylinder A. [1]

79 The temperature of the $CO_2(g)$ is increased to 450. K and the volume of cylinder A remains constant. In the space *in your answer booklet*, show a correct numerical setup for calculating the new pressure of the $CO_2(g)$ in cylinder A. [1]

77 _____ mol

78 _____

_____

_____

79

January 2005

10 Which statement describes a chemical property that can be used to distinguish between compound A and compound B?

(1) A is a blue solid, and B is a white solid.
(2) A has a high melting point, and B has a low melting point.
(3) A dissolves in water, and B does not dissolve in water.
(4) A does not burn in air, and B does burn in air.

12 Which formula represents a nonpolar molecule?

(1) HCl   (3) NH_3
(2) H_2O (4) CF_4

15 A sample is prepared by completely dissolving 10.0 grams of NaCl in 1.0 liter of H_2O. Which classification best describes this sample?

(1) homogeneous compound
(2) homogeneous mixture
(3) heterogeneous compound
(4) heterogeneous mixture

17 Which physical changes are endothermic?

(1) melting and freezing
(2) melting and evaporating
(3) condensation and sublimation
(4) condensation and deposition

18 Which transfer of energy occurs when ice cubes are placed in water that has a temperature of 45°C?

(1) Chemical energy is transferred from the ice to the water.
(2) Chemical energy is transferred from the water to the ice.
(3) Thermal energy is transferred from the ice to the water.
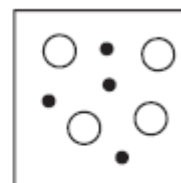(4) Thermal energy is transferred from the water to the ice.

38 According to Reference Table H, what is the boiling point of ethanoic acid at 80 kPa?

(1) 28°C   (3) 111°C
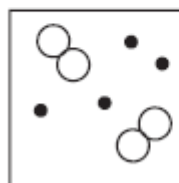(2) 100°C   (4) 125°C

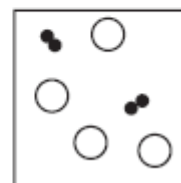39 Which particle diagram represents one pure substance, only?
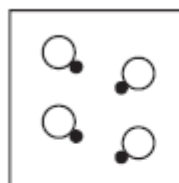

(1)

(3)

(2)

(4)

40 A sample of helium gas has a volume of 900. milliliters and a pressure of 2.50 atm at 298 K. What is the new pressure when the temperature is changed to 336 K and the volume is decreased to 450. milliliters?

(1) 0.177 atm   (3) 5.64 atm
(2) 4.43 atm   (4) 14.1 atm

Base your answers to questions 54 and 55 on the heating curve below, which represents a substance starting as a solid below its melting point and being heated at a constant rate over a period of time.
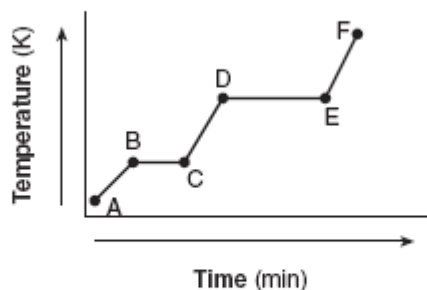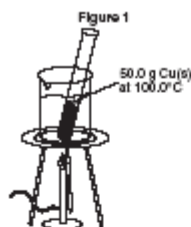

54 What is happening to the average kinetic energy of the particles during segment $\overline{BC}$? [1]

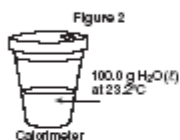55 How does this heating curve illustrate that the heat of vaporization is greater than the heat of fusion? [1]
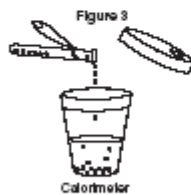
54 _____

55 _____

_____

Base your answers to questions 73 through 76 on the information below:

Figure 1

50.0 g Cu(s) at 100.0°C

In a laboratory investigation, a 50.0-gram sample of copper is at 100.0°C in a boiling water bath.

Figure 2

100.0 g H₂O(ℓ) at 23.2°C

Calorimeter

A Styrofoam cup with a lid is used as a calorimeter. The cup contains 100.0 grams of distilled water at 23.2°C.

Figure 3

Calorimeter

The hot copper is poured into the cup of water, and the cup is quickly covered with the lid.

Figure 4

Calorimeter

A thermometer is inserted through the lid. The copper and water are gently stirred in the cup. The temperature is checked periodically. The highest temperature noted is 26.3°C.

73 In terms of *energy flow*, explain why the temperature of the water in the calorimeter increases. [1]

74 Using the information given, complete the data table provided *in your answer booklet*. [1]

75 In the *space provided in your answer booklet*, show a correct numerical setup for calculating the number of joules of heat gained by the water. [1]

76 In this investigation, the change in heat of the copper is greater than the change in heat of the water. What error could account for this apparent violation of the Law of Conservation of Energy? Do *not* use human error as part of the answer. [1]

73 _____

_____

_____

74 **Data Table**

| Quantity Measured	Data (units are given)
Mass of copper	g
Temperature of hot copper	°C
Mass of H_2O in calorimeter	g
Initial temperature of H_2O in calorimeter	°C
Final temperature of H_2O and copper	°C

75

76 _____

_____

August 2004

6 At 298 K, oxygen (O_2) and ozone (O_3) have different properties because their

(1) atoms have different atomic numbers
(2) atoms have different atomic masses
(3) molecules have different molecular structures
(4) molecules have different average kinetic energies

7 Which substance represents a compound?

(1) C(s)   (3) CO(g)
(2) Co(s)   (4) O_2(g)

11 Which grouping of the three phases of bromine is listed in order from left to right for increasing distance between bromine molecules?

(1) gas, liquid, solid   (3) solid, gas, liquid
(2) liquid, solid, gas   (4) solid, liquid, gas

13 At room temperature, the solubility of which solute in water would be most affected by a change in pressure?

(1) methanol   (3) carbon dioxide
(2) sugar   (4) sodium nitrate

15 The concept of an ideal gas is used to explain

(1) the mass of a gas sample
(2) the behavior of a gas sample
(3) why some gases are monatomic
(4) why some gases are diatomic

16 Molecules in a sample of $NH_3(\ell)$ are held closely together by intermolecular forces

(1) existing between ions
(2) existing between electrons
(3) caused by different numbers of neutrons
(4) caused by unequal charge distribution

17 Which process represents a chemical change?

(1) melting of ice
(2) corrosion of copper
(3) evaporation of water
(4) crystallization of sugar

39 A gas occupies a volume of 444 mL at 273 K and 79.0 kPa. What is the final kelvin temperature when the volume of the gas is changed to 1880 mL and the pressure is changed to 38.7 kPa?

(1) 31.5 K   (3) 566 K
(2) 292 K   (4) 2360 K

40 At STP, which of these substances is most soluble in H_2O?

(1) CCl_4 (3) HCl
(2) CO_2 (4) N_2

42 How much heat energy must be absorbed to completely melt 35.0 grams of H_2O(s) at 0°C?

(1) 9.54 J   (3) 11 700 J
(2) 146 J   (4) 79 100 J

43 The graph below represents the uniform heating of a substance, starting below its melting point, when the substance is solid.

Which line segments represent an increase in average kinetic energy?

(1) $\overline{AB}$ and $\overline{BC}$ (3) $\overline{BC}$ and $\overline{DE}$
(2) $\overline{AB}$ and $\overline{CD}$ (4) $\overline{DE}$ and $\overline{EF}$

47 Which metal reacts spontaneously with a solution containing zinc ions?

(1) magnesium   (3) copper
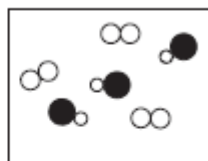(2) nickel   (4) silver

Base your answers to questions 54 through 57 on the particle diagrams below. Samples A, B, and C contain molecules at STP.
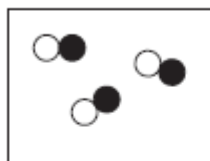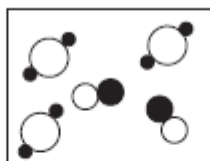
A   B   C

54 Explain why the average kinetic energy of sample B is equal to the average kinetic energy of sample C. [1]

55 Explain, in terms of the *composition*, why sample A represents a pure substance.   [1]

56 Explain why sample C could represent a mixture of fluorine and hydrogen chloride.   [1]

57 Contrast sample A and sample B, in terms of *compounds and mixtures*. Include both sample A and sample B in your answer.   [1]

54 _____

_____

_____

55 _____

_____

_____

56 _____

_____

_____

57 _____

_____

_____

June 2004

12 Conductivity in a metal results from the metal atoms having

(1) high electronegativity
(2) high ionization energy
(3) highly mobile protons in the nucleus
(4) highly mobile electrons in the valence shell

16 Helium is most likely to behave as an ideal gas when it is under

(1) high pressure and high temperature
(2) high pressure and low temperature
(3) low pressure and high temperature
(4) low pressure and low temperature

18 Which sample contains particles in a rigid, fixed, geometric pattern?

(1) $CO_2(aq)$ (3) $H_2O(\ell)$
(2) $HCl(g)$ (4) $KCl(s)$

40 The graph below represents the uniform heating of a substance, starting with the substance as a solid below its melting point.
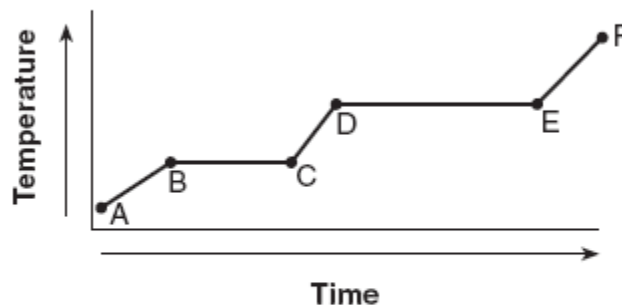
Which line segment represents an increase in potential energy and no change in average kinetic energy?

(1) $\overline{AB}$ (3) $\overline{CD}$
(2) $\overline{BC}$ (4) $\overline{EF}$

41 Using your knowledge of chemistry and the information in Reference Table H, which statement concerning propanone and water at 50°C is true?

(1) Propanone has a higher vapor pressure and stronger intermolecular forces than water.
(2) Propanone has a higher vapor pressure and weaker intermolecular forces than water.
(3) Propanone has a lower vapor pressure and stronger intermolecular forces than water.
(4) Propanone has a lower vapor pressure and weaker intermolecular forces than water.

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

Naphthalene, a nonpolar substance that sublimes at room temperature, can be used to protect wool clothing from being eaten by moths.

68 Explain, in terms of *intermolecular forces*, why naphthalene sublimes.   [1]

69 Explain why naphthalene is *not* expected to dissolve in water.   [1]

70 The empirical formula for naphthalene is C_5H_4 and the molecular mass of naphthalene is 128 grams/mole. What is the molecular formula for naphthalene?   [1]

68 _____

_____

_____

69 _____

_____

_____

70 _____

Base your answers to questions 71 through 74 on the data table below, which shows the solubility of a solid solute.

The Solubility of the Solute at Various Temperatures

Temperature (°C)	Solute per 100 g of $H_2O(g)$
0	18
20	20
40	24
60	29
80	36
100	49

71 On the grid provided *in your answer booklet,* mark an appropriate scale on the axis labeled "Solute per 100 g of $H_2O(g)$." An appropriate scale is one that allows a trend to be seen. [1]

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

Example:

73 Based on the data table, if 15 grams of solute is dissolved in 100 grams of water at 40°C, how many *more* grams of solute can be dissolved in this solution to make it saturated at 40°C? [1]

74 According to Reference Table G, how many grams of $KClO_3$ must be dissolved in 100 grams of H_2O at 10°C to produce a saturated solution? [1]

71 and 72

Solubility Curve

Solute per 100 g of $H_2O(g)$

Temperature (°C)

73 _____ g

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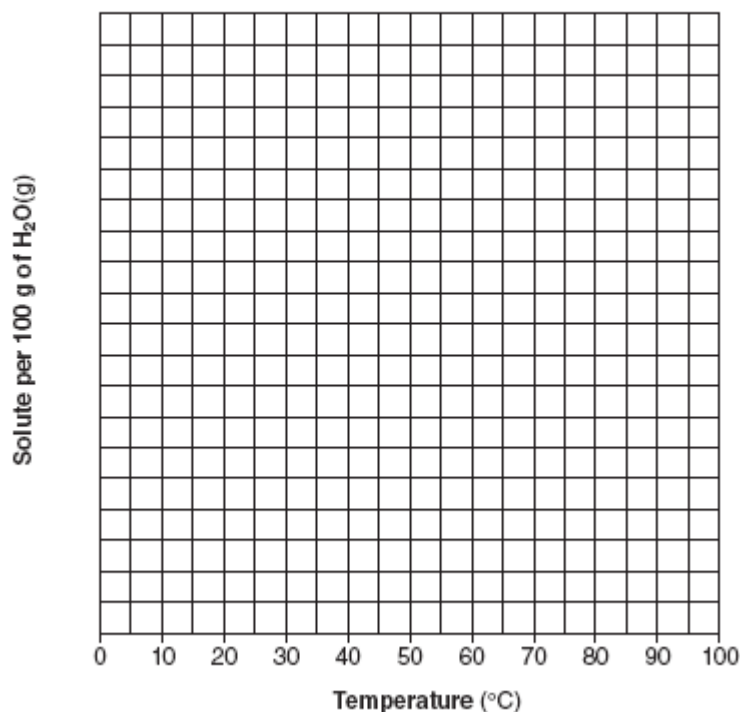
Base your answers to questions 75 through 78 on the information below.

A weather balloon has a volume of 52.5 liters at a temperature of 295 K. The balloon is released and rises to an altitude where the temperature is 252 K.

75 How does this temperature change affect the gas particle motion?   [1]

76 The original pressure at 295 K was 100.8 kPa and the pressure at the higher altitude at 252 K is 45.6 kPa. Assume the balloon does not burst. In the space provided *in your answer booklet*, show a correct numerical setup for calculating the volume of the balloon at the higher altitude.   [1]

77 What Celsius temperature is equal to 252 K?   [1]

78 What pressure, in atmospheres (atm), is equal to 45.6 kPa? [1]

75 _____

_____

76

77 _____ °C

78 _____ atm

January 2004

10 Which molecule is nonpolar?

(1) H_2O (3) CO
(2) NH_3 (4) CO_2

11 Which must be a mixture of substances?

(1) solid   (3) gas
(2) liquid   (4) solution

12 A bottle of rubbing alcohol contains both 2-propanol and water. These liquids can be separated by the process of distillation because the 2-propanol and water

(1) have combined chemically and retain their different boiling points
(2) have combined chemically and have the same boiling point
(3) have combined physically and retain their different boiling points
(4) have combined physically and have the same boiling point

13 Compared to pure water, an aqueous solution of calcium chloride has a

(1) higher boiling point and higher freezing point
(2) higher boiling point and lower freezing point
(3) lower boiling point and higher freezing point
(4) lower boiling point and lower freezing point

14 Under which conditions does a real gas behave most like an ideal gas?

(1) at low temperatures and high pressures
(2) at low temperatures and low pressures
(3) at high temperatures and high pressures
(4) at high temperatures and low pressures

40 The volume of a gas is 4.00 liters at 293 K and constant pressure. For the volume of the gas to become 3.00 liters, the Kelvin temperature must be equal to

(1) $\dfrac{3.00 \times 293}{4.00}$

(2) $\dfrac{4.00 \times 293}{3.00}$

(3) $\dfrac{3.00 \times 4.00}{293}$

(4) $\dfrac{293}{3.00 \times 4.00}$

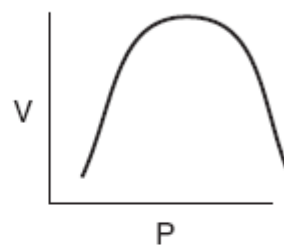41 What is the molarity of a solution containing 20 grams of NaOH in 500 milliliters of solution?
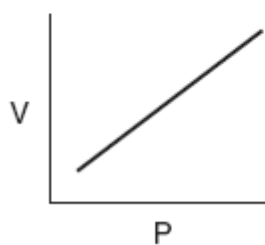
(1) 1 M
(2) 2 M
(3) 0.04 M
(4) 0.5 M

42 Which graph best represents the pressure-volume relationship for an ideal gas at constant temperature?
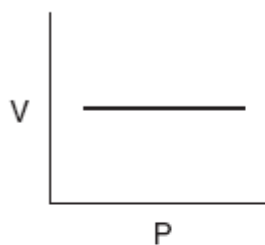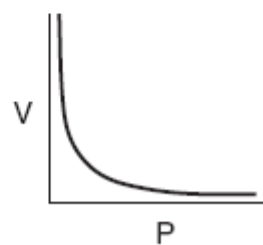
(1)

(3)

(2)

(4)

Base your answers to questions 56 through 58 on the information below.

A student uses 200 grams of water at a temperature of 60°C to prepare a saturated solution of potassium chloride, KCl.

56 Identify the solute in this solution.   [1]

57 According to Reference Table *G*, how many grams of KCl must be used to create this saturated solution?   [1]

58 This solution is cooled to 10°C and the excess KCl precipitates (settles out). The resulting solution is saturated at 10°C. How many grams of KCl precipitated out of the original solution?   [1]

56 _____

57 _____ grams

58 _____ grams

August 2003

14 Which substance can *not* be decomposed by a chemical change?

(1) Ne   (3) HF

(2) N_2O (4) H_2O

15 Which of these substances has the strongest intermolecular forces?

(1) H_2O (3) H_2Se

(2) H_2S (4) H_2Te

16 A real gas behaves more like an ideal gas when the gas molecules are

(1) close and have strong attractive forces between them

(2) close and have weak attractive forces between them

(3) far apart and have strong attractive forces between them

(4) far apart and have weak attractive forces between them

17 Which phase change is an exothermic process?

(1) $CO_2(s) \rightarrow CO_2(g)$ (3) $Cu(s) \rightarrow Cu(\ell)$

(2) $NH_3(g) \rightarrow NH_3(\ell)$ (4) $Hg(\ell) \rightarrow Hg(g)$

18 Which of these contains only one substance?

(1) distilled water   (3) saltwater

(2) sugar water   (4) rainwater

20 At the same temperature and pressure, 1.0 liter of CO(g) and 1.0 liter of $CO_2(g)$ have

(1) equal masses and the same number of molecules

(2) different masses and a different number of molecules

(3) equal volumes and the same number of molecules

(4) different volumes and a different number of molecules

43 Given the diagrams X, Y, and Z below:
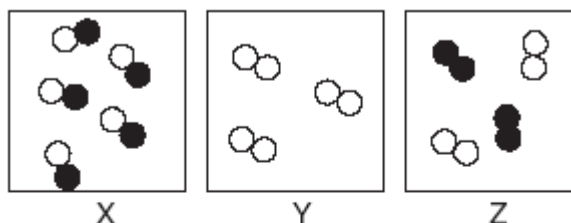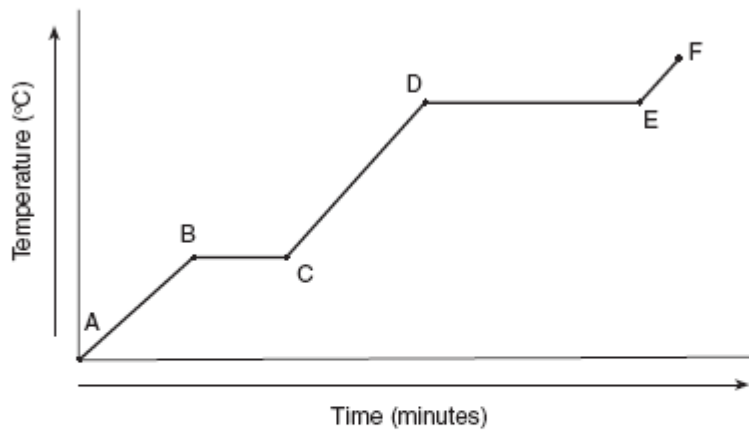

Key
Atom of element A = ○
Atom of element B = ●

Which diagram or diagrams represent a mixture of elements *A* and *B*?

(1) *X*, only   (3) *X* and *Y*

(2) *Z*, only   (4) *X* and *Z*

Base your answers to questions 59 through 62 on the information below.

Given the heating curve where substance X starts as a solid below its melting point and is heated uniformly:

59 Identify the process that takes place during line segment $\overline{DE}$ of the heating curve.   [1]

60 Identify a line segment in which the average kinetic energy is increasing.   [1]

61 Using (•) to represent particles of substance X, draw at least *five* particles as they would appear in the substance at point F. Use the box provided *in your answer booklet*.   [1]

62 Describe, in terms of *particle behavior* or *energy*, what is happening to substance X during line segment $\overline{BC}$.   [1]

59 _____

60 _____

61

62 _____

_____
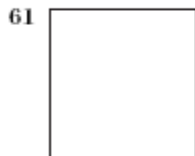
66 A student determines the density of zinc to be 7.56 grams per milliliter. If the accepted density is 7.14 grams per milliliter, what is the student's percent error?

 • Show a correct numerical setup in the space provided *in your answer booklet.* [1]
 • Record your answer. [1]

66

_____% error

June 2003

6 Which is a property of most nonmetallic solids?

 (1) high thermal conductivity
 (2) high electrical conductivity
 (3) brittleness
 (4) malleability

9 Which substance can be decomposed by a chemical change?

 (1) Co   (3) Cr
 (2) CO   (4) Cu

15 Which of these terms refers to matter that could be heterogeneous?

 (1) element   (3) compound
 (2) mixture   (4) solution

16 In which material are the particles arranged in a regular geometric pattern?

 (1) $CO_2(g)$ (3) $H_2O(\ell)$
 (2) $NaCl(aq)$ (4) $C_{12}H_{22}O_{11}(s)$

18 Which type of change must occur to form a compound?

 (1) chemical   (3) nuclear
 (2) physical   (4) phase

33 Which substance contains metallic bonds?

 (1) $Hg(\ell)$ (3) $NaCl(s)$
 (2) $H_2O(\ell)$ (4) $C_6H_{12}O_6(s)$

40 According to Reference Table H, what is the vapor pressure of propanone at 45°C?

 (1) 22 kPa   (3) 70. kPa
 (2) 33 kPa   (4) 98 kPa

41 The freezing point of bromine is

 (1) 539°C   (3) 7°C
 (2) –539°C   (4) –7°C

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

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.

57 State one chemical reason for the different results of students *A* and *B*. [1]

58 Using Reference Table *J*, identify another metal that will react with hydrochloric acid to yield hydrogen gas. [1]

57 _____

_____

58 _____

Base your answers to questions 64 and 65 on the diagram below, which shows a piston confining a gas in a cylinder.

64 Using the set of axes provided *in your answer booklet*, sketch the general relationship between the pressure and the volume of an ideal gas at constant temperature. [1]

65 The gas volume in the cylinder is 6.2 milliliters and its pressure is 1.4 atmospheres. The piston is then pushed in until the gas volume is 3.1 milliliters while the temperature remains constant.

a In the space provided *in your answer booklet*, calculate the pressure, in atmospheres, after the change in volume. Show all work. [1]

b Record your answer. [1]

64

65 *a*

b _____ atm

January 2003

5 Which event must *always* occur for a chemical reaction to take place?

(1) formation of a precipitate
(2) formation of a gas
(3) effective collisions between reacting particles
(4) addition of a catalyst to the reaction system

16 One similarity between all mixtures and compounds is that both

(1) are heterogeneous
(2) are homogeneous
(3) combine in a definite ratio
(4) consist of two or more substances

17 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) $H_2O(g) \rightarrow H_2O(\ell)$

21 When a mixture of water, sand, and salt is filtered, what passes through the filter paper?

(1) water, only
(2) water and sand, only
(3) water and salt, only
(4) water, sand, and salt

24 Which physical property makes it possible to separate the components of crude oil by means of distillation?

(1) melting point
(2) conductivity
(3) solubility
(4) boiling point

40 Solubility data for four different salts in water at 60°C are shown in the table below.

Salt	Solubility in Water at 60°C
A	10 grams / 50 grams H_2O
B	20 grams / 60 grams H_2O
C	30 grams / 120 grams H_2O
D	40 grams/ 80 grams H_2O

Which salt is most soluble at 60°C?

(1) A   (3) C
(2) B   (4) D

44 What is the molarity of a solution of NaOH if 2 liters of the solution contains 4 moles of NaOH?

(1) 0.5 M   (3) 8 M
(2) 2 M   (4) 80 M

45 A gas occupies a volume of 40.0 milliliters at 20°C. If the volume is increased to 80.0 milliliters at constant pressure, the resulting temperature will be equal to

(1) $20°C \times \dfrac{80.0\,mL}{40.0\,mL}$ (3) $293\,K \times \dfrac{80.0\,mL}{40.0\,mL}$

(2) $20°C \times \dfrac{40.0\,mL}{80.0\,mL}$ (4) $293\,K \times \dfrac{40.0\,mL}{80.0\,mL}$

47 The graph below represents the heating curve of a substance that starts as a solid below its freezing point.
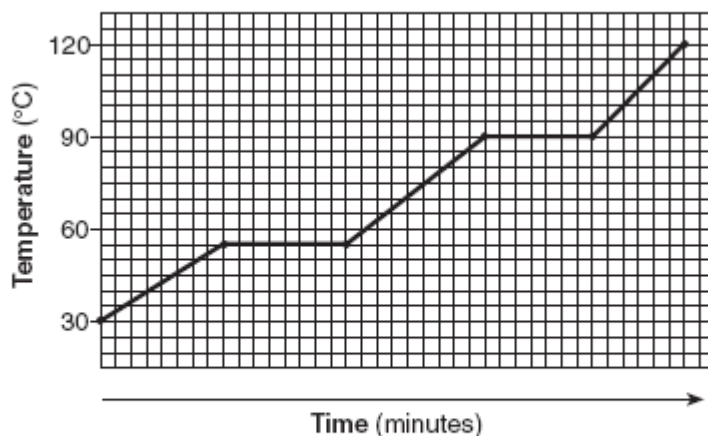
What is the melting point of this substance?

(1) 30°C
(2) 55°C

(3) 90°C
(4) 120°C

51 In the boxes provided *in your answer booklet:*

   a Draw *two* different compounds, one in each box, using the representations for atoms of element X and element Z given below.   [1]

Atom of element X = ○
Atom of element Z = ●

   b Draw a mixture of these two compounds.   [1]

51 *a*

b

52 At equilibrium, nitrogen, hydrogen, and ammonia gases form a mixture in a sealed container. The data table below gives some characteristics of these substances.

Data Table

Gas	Boiling Point	Melting Point	Solubility in Water
Nitrogen	–196°C	–210°C	insoluble
Hydrogen	–252°C	–259°C	insoluble
Ammonia	–33°C	–78°C	soluble

Describe how to separate ammonia from hydrogen and nitrogen.   [1]

52 _____

_____

Base your answers to questions 65 through 67 on the information below.

When cola, a type of soda pop, is manufactured, $CO_2(g)$ is dissolved in it.

65 A capped bottle of cola contains $CO_2(g)$ under high pressure. When the cap is removed, how does pressure affect the solubility of the dissolved $CO_2(g)$? [1]

66 A glass of cold cola is left to stand 5 minutes at room temperature. How does temperature affect the solubility of the $CO_2(g)$? [1]

67 a In the space provided *in your answer booklet*, draw a set of axes and label one of them "Solubility" and the other "Temperature." [1]

   b Draw a line to indicate the solubility of $CO_2(g)$ versus temperature on the axes drawn in part *a*. [1]

65 _____

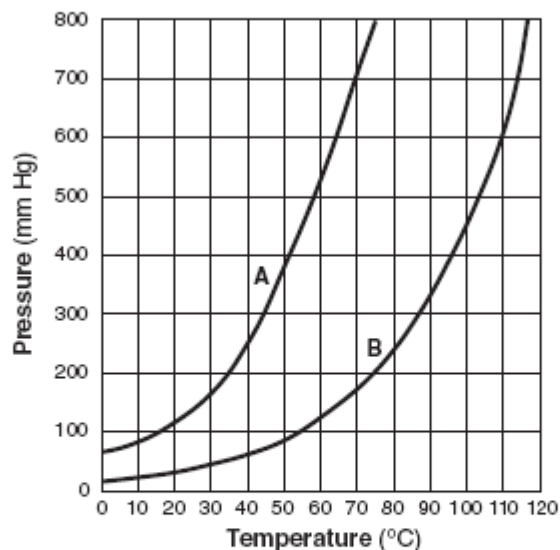_____

66 _____

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67 *a* and *b*

Base your answers to questions 68 through 70 on the graph below, which shows the vapor pressure curves for liquids A and B.

68 What is the vapor pressure of liquid A at 70°C? Your answer must include correct units. [2]

69 At what temperature does liquid B have the same vapor pressure as liquid A at 70°C? Your answer must include correct units.   [2]

70 Which liquid will evaporate more rapidly? Explain your answer in terms of intermolecular forces.   [2]

68 _____

69 _____

70 Liquid: _____

   Explanation: _____

   _____

   _____