1. Which two particle diagrams represent mixtures of diatomic elements?

A) A and B  
B) A and C  
C) B and C  
D) B and D

2. At STP, which physical property of aluminum always remains the same from sample to sample?

A) mass  
B) density  
C) length  
D) volume

3. Which sample of CO$_2$ has a definite shape and a definite volume?

A) CO$_2$(aq)  
B) CO$_2$(g)  
C) CO$_2$(l)  
D) CO$_2$(s)

4. Which statement describes a chemical property of bromine?

A) Bromine is soluble in water.  
B) Bromine has a reddish-brown color.  
C) Bromine combines with aluminum to produce AlBr$_3$.  
D) Bromine changes from a liquid to a gas at 332 K and 1 atm.

5. Which substance can *not* be broken down by a chemical change?

A) C$_2$H$_6$  
B) C$_3$H$_8$  
C) Si  
D) H$_2$O

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

A) It has a definite shape and a definite volume.  
B) It has a definite shape and no definite volume.  
C) It has no definite shape and a definite volume.  
D) It has no definite shape and no definite volume.

7. Which equation represents a physical change?

A) H$_2$O(s) + 6.01 kJ → H$_2$O(l)  
B) 2H$_2$(g) + O$_2$(g) → 2H$_2$O(g) + 483.6 kJ  
C) H$_2$(g) + I$_2$(g) + 53.0 kJ → 2HI(g)  
D) N$_2$(g) + 2O$_2$(g) + 66.4 kJ → 2NO$_2$(g)

8. The energy absorbed when ammonium chloride dissolves in water can be measured in

A) degrees  
B) kiloJoules  
C) parts per million  
D) liters per mole

9. What occurs when a 35-gram aluminum cube at 100°C is placed in 90. grams of water at 25°C in an insulated cup?

A) Heat is transferred from the aluminum to the water, and the temperature of the water decreases.  
B) Heat is transferred from the aluminum to the water, and the temperature of the water increases.  
C) Heat is transferred from the water to the aluminum, and the temperature of the water decreases.  
D) Heat is transferred from the water to the aluminum, and the temperature of the water increases.

10. Which kind of energy is stored within a chemical substance?

A) free energy  
B) activation energy  
C) kinetic energy  
D) potential energy

11. The particles in which sample of LiCl(s) have the same average kinetic energy as the particles in a 2.0-mole sample of H$_2$O(l) at 25°C?

A) 1.0 mol at 75°C  
B) 2.0 mol at 50°C  
C) 3.0 mol at 25°C  
D) 4.0 mol at 0°C

12. A sample of helium gas is in a sealed, rigid container. What occurs as the temperature of the sample is increased?

A) The mass of the sample decreases.  
B) The number of moles of gas increases.  
C) The volume of each atom decreases.  
D) The frequency of collisions between atoms increases.
13. Which sample of ethanol has particles with the highest average kinetic energy?
A) 10.0 mL of ethanol at 25°C  
B) 10.0 mL of ethanol at 55°C  
C) 100.0 mL of ethanol at 35°C  
D) 100.0 mL of ethanol at 45°C

14. Which is a measure of the average kinetic energy of the particles of a substance?
A) pressure  
B) mass  
C) density  
D) temperature

15. The temperature 30. K expressed in degrees Celsius is
A) 243°C  
B) −243°C  
C) 303°C  
D) −303°C

16. Which change of phase is exothermic?
A) NaCl(s) → NaCl(ℓ)  
B) CO₂(s) → CO₂(g)  
C) H₂O(ℓ) → H₂O(s)  
D) H₂O(s) → H₂O(g)

17. Which change results in a release of energy?
A) the melting of H₂O(s)  
B) the boiling of H₂O(ℓ)  
C) the evaporation of H₂O(ℓ)  
D) the condensation of H₂O(g)

18. A sample of chlorine gas is at 300. K and 1.00 atmosphere. At which temperature and pressure would the sample behave more like an ideal gas?
A) 0 K and 1.00 atm  
B) 150. K and 0.50 atm  
C) 273 K and 1.00 atm  
D) 600. K and 0.50 atm

19. Two basic properties of the gas phase are
A) a definite shape and a definite volume  
B) a definite shape but no definite volume  
C) no definite shape but a definite volume  
D) no definite shape and no definite volume

20. Under which conditions of temperature and pressure does a real gas behave most like an ideal gas?
A) low temperature and low pressure  
B) low temperature and high pressure  
C) high temperature and low pressure  
D) high temperature and high pressure

21. According to the kinetic molecular theory for an ideal gas, all gas particles
A) are in random, constant, straight-line motion  
B) are separated by very small distances relative to their sizes  
C) have strong intermolecular forces  
D) have collisions that decrease the total energy of the system

22. Under which conditions of temperature and pressure would gaseous molecules most likely be closest together?
A) high pressure and low temperature  
B) high pressure and high temperature  
C) low pressure and high temperature  
D) low pressure and low temperature

23. Under which conditions of temperature and pressure does carbon dioxide gas behave most like an ideal gas?
A) 1 L of CO(g) and 0.5 L of N₂(g)  
B) 2 L of CO(g) and 0.5 L of NH₃(g)  
C) 1 L of H₂(g) and 2 L of Cl₂(g)  
D) 2 L of H₂(g) and 2 L of Cl₂(g)

24. Which two samples of gas at STP contain the same total number of molecules?
A) 1 L of CO(g) and 0.5 L of N₂(g)  
B) 2 L of CO(g) and 0.5 L of NH₃(g)  
C) 1 L of H₂(g) and 2 L of Cl₂(g)  
D) 2 L of H₂(g) and 2 L of Cl₂(g)

25. A 220.0-mL sample of helium gas is in a cylinder with a movable piston at 105 kPa and 275 K. The piston is pushed in until the sample has a volume of 95.0 mL. The new temperature of the gas is 310 K. What is the new pressure of the sample?
A) 51.1 kPa  
B) 216 kPa  
C) 243 kPa  
D) 274 kPa
26. The pressure on a 200-milliliter sample of CO$_2$(g) at constant temperature is increased from 60 kPa to 120 kPa. What is the new volume of the gas?

A) 100 mL  B) 300 mL  C) 400 mL  D) 600 mL

27. Given four particle models:

[Key]

- Circle: an atom of element T
- Dot: an atom of element X
- Circle with dot: an atom of element Z

Which two models can be classified as elements?

A) I and II  B) I and IV  C) II and III  D) II and IV

28. Which set of values represents standard pressure and standard temperature?

A) 1 atm and 101.3 K  B) 1 kPa and 273 K  C) 101.3 kPa and 0°C  D) 101.3 atm and 273°C

29. Base your answer to the following question on the graph below, which represents uniform cooling of a sample of a pure substance, starting as a gas.

Solid and liquid phases can exist in equilibrium between points?

A) E and F  B) B and C  C) C and D  D) D and E

30. The temperature of 100 grams of water changes from 16.0°C to 20.0°C. What is the total number of Joules of heat energy absorbed by the water?

A) 105  B) 168  C) 420  D) 1680

31. How much heat energy must be absorbed to completely melt 35.0 grams of H$_2$O(s) at 0°C?

A) 9.54 J  B) 146 J  C) 11 700 J  D) 79 100 J

32. What is the total number of Joules lost when 10 grams of water at 80°C is cooled to 60°C?

A) 42  B) 84  C) 420  D) 840
33. Which particle diagram represents a sample of matter that can not be broken down by chemical means?

A)  

B)  

C)  

D)  

34. What is the total number of kiloJoules of heat needed to change 150 grams of ice to water at 0°C?

A) 50.1 B) 2.22 C) 184 D) 484

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

A) 28°C  B) 100°C  C) 111°C  D) 125°C

36. How much energy is required to vaporize 10.00 grams of water at its boiling point?

A) 2.26 kJ  B) 3.34 kJ  C) 4.2 kJ  D) 22.6 kJ

37. Which equation represents sublimation?

A) I₂(s) → I₂(g)  B) I₂(s) → I₂(ℓ)
C) I₂(ℓ) → I₂(g)  D) I₂(ℓ) → I₂(s)

38. Powdered sulfur is yellow, and powdered iron is gray. When powdered sulfur and powdered iron are mixed at 20°C, the powdered iron

A) becomes yellow
B) becomes a liquid
C) remains ionic
D) remains magnetic

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

A) homogeneous compound
B) homogeneous mixture
C) heterogeneous compound
D) heterogeneous mixture

40. 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?

A) The mixture is homogeneous and can be separated by filtration.
B) The mixture is homogeneous and cannot be separated by filtration.
C) The mixture is heterogeneous and can be separated by filtration.
D) The mixture is heterogeneous and cannot be separated by filtration.

41. One similarity between all mixtures and compounds is that both

A) are heterogeneous
B) are homogeneous
C) combine in a definite ratio
D) consist of two or more substances
42. When sample $X$ is passed through a filter paper a white residue, $Y$, remains on the paper and a clear liquid, $Z$, passes through. When liquid $Z$ is vaporized, another white residue remains. Sample $X$ is best classified as

A) an element  
B) a compound  
C) a heterogeneous mixture  
D) a homogeneous mixture 

43. Any substance composed of two or more elements that are chemically combined in a fixed proportion is

A) an isomer  
B) an isotope  
C) a solution  
D) a compound 

44. Petroleum can be separated by distillation because the hydrocarbons in petroleum are

A) elements with identical boiling points  
B) elements with different boiling points  
C) compounds with identical boiling points  
D) compounds with different boiling points 

45. Recovering the salt from a mixture of salt and water could best be accomplished by

A) evaporation  
B) filtration  
C) paper chromatography  
D) density determination

Base your answers to questions 46 through 48 on the information below.

A student investigated heat transfer using a bottle of water. The student placed the bottle in a room at 20.5°C. The student measured the temperature of the water in the bottle at 7 a.m. and again at 3 p.m. The data from the investigation are shown in the table below.

<table>
<thead>
<tr>
<th>Water Bottle Investigation Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7 a.m.</strong></td>
</tr>
<tr>
<td>Mass of Water (g)</td>
</tr>
<tr>
<td>800.</td>
</tr>
</tbody>
</table>

46. State the direction of heat transfer between the surroundings and the water in the bottle from 7 a.m. to 3 p.m.
47. Show a numerical setup for calculating the change in the thermal energy of the water in the bottle from 7 a.m. to 3 p.m.

48. Compare the average kinetic energy of the water molecules in the bottle at 7 a.m. to the average kinetic energy of the water molecules in the bottle at 3 p.m.

Base your answers to questions 49 through 51 on the information below.

Nitrogen gas and oxygen gas make up about 99% of Earth's atmosphere. Other atmospheric gases include argon, carbon dioxide, methane, ozone, hydrogen, etc. The amount of carbon dioxide in the atmosphere can vary. Data for the concentration of CO2(g) from 1960 to 2000 are shown in the table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>316.9</td>
</tr>
<tr>
<td>1980</td>
<td>338.7</td>
</tr>
<tr>
<td>2000</td>
<td>369.4</td>
</tr>
</tbody>
</table>

49. Explain, in terms of types of matter, why methane can be broken down by chemical means, but argon cannot be broken down by chemical means. Your response must include both methane and argon.

50. Explain why the atmosphere is classified as a mixture.

51. Identify one diatomic element found in the atmosphere.

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

<table>
<thead>
<tr>
<th>Substance</th>
<th>Molar Mass (g/mol)</th>
<th>Boiling Point at 1 atm (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>16</td>
<td>112</td>
</tr>
<tr>
<td>ethane</td>
<td>30.</td>
<td>185</td>
</tr>
<tr>
<td>propane</td>
<td>44</td>
<td>231</td>
</tr>
<tr>
<td>butane</td>
<td>58</td>
<td>273</td>
</tr>
</tbody>
</table>

52. State, in terms of intermolecular forces, why the boiling point of propane at 1 atmosphere is lower than the boiling point of butane at 1 atmosphere.

53. Based on the data in the table, state the relationship between the boiling point at 1 atmosphere and molar mass for these four substances.
Base your answers to questions 54 through 56 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.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Temperature (K)</th>
<th>Pressure (atm)</th>
<th>Volume (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>200.</td>
<td>2.0</td>
<td>500.</td>
</tr>
<tr>
<td>final</td>
<td>300.</td>
<td>7.0</td>
<td>?</td>
</tr>
</tbody>
</table>

54. 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.

55. Convert the final temperature of the helium gas sample to degrees Celsius.

56. In the space below show a correct numerical setup for calculating the final volume of the helium gas sample.
57. Identify the process that takes place during line segment $DE$ of the heating curve.

58. Identify a line segment in which the average kinetic energy is increasing.

59. 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 above.

60. Describe, in terms of particle behavior or energy, what is happening to substance $X$ during line segment $DE$.

61. Determine the amount of energy required for 150.0 grams of water to undergo the process at segment $DE$. 
1. B  36. D  49. –Methane is a compound consisting of two elements, so it can be broken down by chemical means, but argon is an element, which cannot be broken down.

3. D  37. A  42. C

4. C  38. D  43. D

5. C  39. B  44. D

6. A  40. B  45. A

7. A  41. D

8. B  46. –Heat was transferred from the surroundings to the water in the bottle.

9. B  47. q = (800. g)(4.18 J/g °C)(20.5°C – 12.5°C)

10. D  48. –The average kinetic energy of the water molecules at 7 a.m. is less than the average kinetic energy of the water molecules at 3 p.m.

11. C  49. –Methane is a compound consisting of two elements, so it can be broken down by chemical means, but argon is an element, which cannot be broken down.

12. D  50. –The gases in a mixture can be separated by physical means.


14. D  52. The boiling point of propane at 1 atm is lower than the boiling point of butane at 1 atm because propane has weaker intermolecular forces than butane; butane has stronger intermolecular forces.

15. B

16. C

17. D

18. D

19. D

20. C

21. A

22. A

23. C

24. D

25. D

26. A

27. C

28. C

29. D

30. D

31. C

32. D

33. D

34. A

35. C

53. As molar mass increases, boiling point at 1 atm increases; the smaller the molar mass, the lower the boiling point.

54. –The total number of gas particles is the same under the initial and final conditions.

55. 27°C

56. \[ \frac{(2.0 \text{ atm})(500 \text{ mL})}{200 \text{ K}} = \frac{7.0 \text{ atm} \cdot \text{L}}{300 \text{ K}} \]


58. Examples: $\overline{AB}$ or $\overline{CD}$ or $\overline{EF}$
60. Examples: –The potential energy of the particles increases. –PE increases.
–KE remains the same. –particles more disordered
–Particles are spreading farther apart.
–Intermolecular forces of attraction decrease.

61. \( q = mH_v \)
\[
q = (150.0 g)(2260 \text{ J/g}) = 339,000 \text{ J}
\]