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

   A) at low temperatures and high pressures
   B) at low temperatures and low pressures
   C) at high temperatures and high pressures
   D) at high temperatures and low pressures

2. Which of these contains only one substance?

   A) distilled water B) sugar water
   C) saltwater D) rainwater

3. When a substance is made up of constantly vibrating particles arranged in a regular geometric pattern, the substance is classified as a

   A) true solid B) supercooled liquid
   C) liquid D) gas

4. When a sample of a gas is heated at constant pressure, the average kinetic energy of its molecules

   A) decreases, and the volume of the gas increases
   B) decreases, and the volume of the gas decreases
   C) increases, and the volume of the gas increases
   D) increases, and the volume of the gas decreases

5. An increase in the average kinetic energy of a sample of copper atoms occurs with an increase in

   A) concentration B) temperature
   C) pressure D) volume

6. How many grams of water will absorb a total of 2520 Joules of energy when the temperature of the water changes from 10.0°C to 30.0°C?

   A) 10.0 g B) 20.0 g C) 30.0 g D) 60.0 g

7. In a laboratory experiment, the melting point of compound *A* was determined to be 82.6ºC. If the accepted value is 80.5ºC, what is the percent error in this determination? (Show proper significant figures)

   A) 2.5 B) 2.54 C) 2.6 D) 2.71

8. A solution contains 12.55 grams of a solid dissolved in 50.0 milliliters of water. What is the number of grams of solid dissolved per milliliter of water, rounded to the correct number of significant figures?

   A) 0.25 g/mL B) 0.251 g/mL
   C) 0.3 g/mL D) 0.2510 g/mL

9. Which kelvin temperature is equivalent to –24ºC?

   A) 226 K B) 249 K C) 273 K D) 297 K

10. Which process is exothermic?

    A) boiling of water
    B) melting of copper
    C) condensation of ethanol vapor
    D) sublimation of iodine

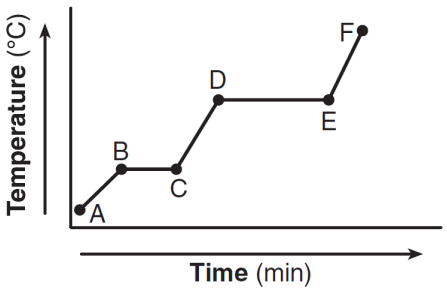
11. Which material is a mixture?

    A) water B) air
    C) methane D) magnesium

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

    A) filtration B) fermentation
    C) distillation D) conductivity

13. The graph below represents the uniform heating of a sample of a substance starting as a solid below its melting point.



    Which statement describes what happens to the energy of the particles of the sample during time interval *DE*?

    A) Average kinetic energy increases, and potential energy remains the same.
    B) Average kinetic energy decreases, and potential energy remains the same.
    C) Average kinetic energy remains the same, and potential energy increases.
    D) Average kinetic energy remains the same, and potential energy decreases

14. Which Kelvin temperature is equal to –73ºC?

    A) 100 K B) 173 K C) 200 K D) 346 K

15. Which temperature is equal to +20 K?

    A) –253ºC B) –293ºC
    C) 253°C D) 293°C

16. Which must be a mixture of substances?

    A) solid B) liquid
    C) gas D) solution

17. The pressure on 20 milliliters of a gas at constant temperature is changed from 4 atmospheres to 2 atmospheres. The new volume of the gas is

A) 5 ml B) 10 ml C) 40 ml D) 80 ml

18. A student measures the mass and volume of a piece of aluminum. The measurements are 25.6 grams and 9.1 cubic centimeters. The. student calculates the density of the aluminum. What is the percent error of the student's calculated density of aluminum?

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

19. Approximately how many Joules of heat are needed to completely change 10.0 grams of ice to water at the melting point temperature?

A) 1.00 J B) 33.4 J
C) 334 J D) 3,340 J

20. When 100 calories of heat energy is added to 10 grams of water at 20ºC, the final temperature of the water will be

A) 10ºC B) 30ºC C) 40ºC D) 100ºC

21. Which species readily sublimes at room temperature?

A) $CO_2(s)$ B) $CO_2(\ell)$
C) $CO_2(g)$ D) $CO_2(aq)$

22. Which process is accompanied by a *decrease* in entropy?

A) boiling of water
B) condensing of water vapor
C) subliming of iodine
D) melting of ice

23. What is the minimum amount of heat required to completely melt 20.0 grams of ice at its melting point?

A) 20.0 J B) 83.6 J
C) 6,680 J D) 45,200 J

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

A) water, only
B) water and sand, only
C) water and salt, only
D) water, sand, and salt

25. Which compound below has the *lowest* boiling point at standard pressure?

A) NaI B) HI C) MgI_2 D) AlI_3

26. Which sample of matter can be separated into different substances by physical means?

A) LiCl(aq) B) LiCl(s)
C) $NH_3(g)$ D) $NH_3(\ell)$

27. Under which conditions of temperature and pressure does carbon dioxide 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

28. Which substance will readily sublime at STP?

A) Fe(s) B) $C_6H_{12}O_6(s)$
C) NaCl(s) D) $CO_2(s)$

29. Which term represents a form of energy?

A) heat B) degree
C) kilocalorie D) temperature

30. Equal volumes of all gases at the same temperature and pressure contain an equal number of

A) molecules B) atoms
C) electrons D) protons

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

A) ionization B) combustion
C) filtration D) sublimation

32. A student observed the following reaction:

$$AlCl_3(aq) + 3\ NaOH(aq) \rightarrow Al(OH)_3(s) + 3\ NaCl(aq)$$

After the products were filtered, which substance remained on the filter paper?

A) NaCl B) NaOH
C) $AlCl_3$ D) $Al(OH)_3$

33. The temperature of a sample of matter is a measure of the

A) average kinetic energy of its particles
B) average potential energy of its particles
C) total kinetic energy of its particles
D) total potential energy of its particles

34. Object A at 40ºC and object *B* at 80ºC are placed in contact with each other. Which statement describes the heat flow between the objects?

A) Heat flows from object *A* to object *B*.
B) Heat flows from object *B* to object *A*.
C) Heat flows in both directions between the objects.
D) No heat flow occurs between the objects.

35. Which physical changes are endothermic?

A) melting and freezing
B) melting and evaporating
C) condensation and sublimation
D) condensation and deposition

36. A real gas differs from an ideal gas because the molecules of real gas have

A) some volume and no attraction for each other
B) some volume and some attraction for each other
C) no volume and no attraction for each other
D) no volume and some attraction for each other

37. Which sample has the *lowest* entropy?

A) 1 mole of $KNO_3(\ell)$
B) 1 mole of $KNO_3(s)$
C) 1 mole of $H_2O(\ell)$
D) 1 mole of $H_2O(g)$

38. Which kelvin temperature is equal to 56°C?

A) -329 K B) -217 K
C) 217 K D) 329 K

39. The boiling point of a liquid is the temperature at which the vapor pressure of the liquid is equal to the pressure on the surface of the liquid. What is the boiling point of propanone if the pressure on its surface is 48 kilopascals?

A) 25°C B) 30.°C C) 35°C D) 40.°C

40. How many calories of heat energy are released when 50 grams of water are cooled from 70ºC to 60ºC?

A) 10 calories B) 50 calories
C) 500 calories D) 1,000 calories

41. A student determines that the gram formula mass of CdO is 133.11 grams. If the accepted value is 128.41 grams, what is the students percent error?

A) 0.366% B) 3.66%
C) 3.80% D) 4.53%

42. At 1 atmosphere of pressure, the steam-water equilibrium occurs at a temperature of

A) 0 K B) 100 K C) 273 K D) 373 K

43. Which substance can be decomposed by chemical means?

A) aluminum B) octane
C) silicon D) xenon

44. The temperature of a sample of water changes from 10.°C to 20.°C when the water absorbs 420 Joules of heat. What is the mass of the sample?

A) 1.0 g B) 10. g
C) 100 g D) 1000 g

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

A) melting point B) conductivity
C) solubility D) boiling point

46. 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?

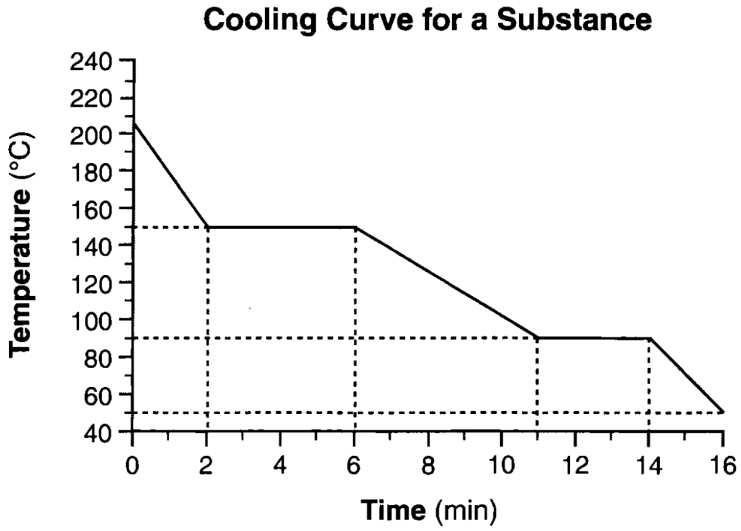
A) *A* and *B* B) *A* and *C*
C) *B* and *C* D) *B* and D

47. A gas has a volume of 1,400 milliliters at a temperature of 20. K and a pressure of 1.0 atm. What will be the new volume when the temperature is changed to 40. K and the pressure is changed to 0.50 atm?

A) 350 mL B) 750 mL
C) 1,400 mL D) 5,600 mL

Base your answers to questions **48** through **50** on the information below.

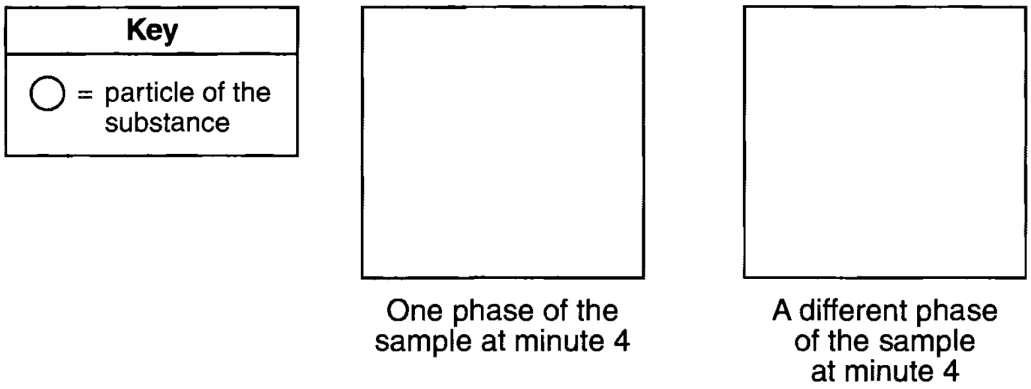
Starting as a gas at 206°C, a sample of a substance is allowed to cool for 16 minutes. This process is represented by the cooling curve below.



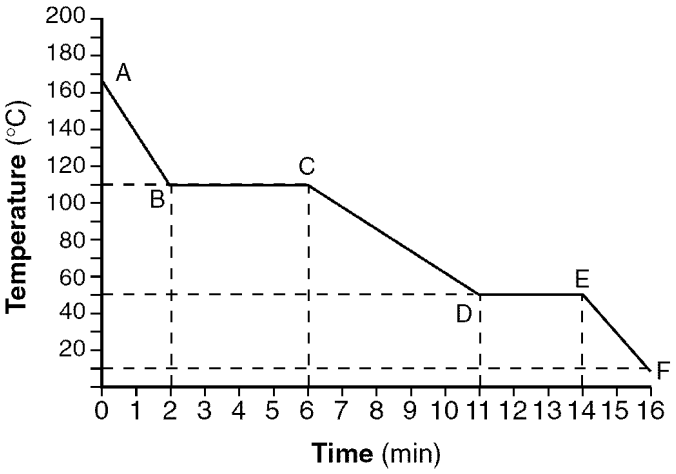
48. What is the melting point of this substance?

49. At what time do the particles of this sample have the *lowest* average kinetic energy?

50. Using the key below, draw *two* particle diagrams to represent the *two* phases of the sample at minute 4. Your response must include *at least six* particles for *each* diagram.



51. Base your answer to the following question on the graph below, which represents the cooling of a substance starting at a temperature above its boiling point.

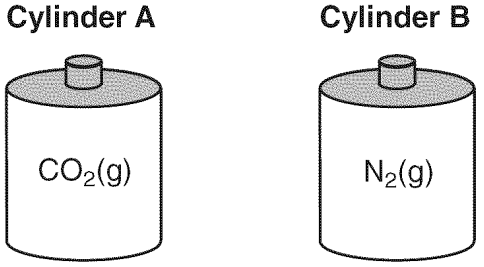


What is the melting point of this substance?

52. 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?

53. Base your answer to the following question on the information and diagrams below.

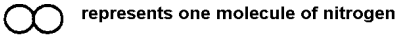
Cylinder A contains 22.0 grams of $CO_2(g)$ and cylinder B contains $N_2(g)$. The volumes, pressures, and temperatures of the two gases are indicated under each cylinder.



Cylinder A	Cylinder B
V = 12.3 L	V = 12.3 L
P = 1.0 atm	P = 1.0 atm
T = 300. K	T = 300. K

The temperature of the $CO_2(g)$ is increased to 450. K and the volume of cylinder A remains constant. Show a correct numerical setup for calculating the new pressure of the $CO_2(g)$ in cylinder A.

54. Base your answer to the following question on Base your answers to the following questions on the diagram of a molecule of nitrogen shown below:



a Draw a particle model that shows at least six molecules of nitrogen gas.
b Draw a particle model that shows at least six molecules of liquid nitrogen.
c Describe, in terms of particle arrangement, the difference between nitrogen gas and liquid nitrogen.
d Good models should reflect the true nature of the concept being represented. What is a limitation of two-dimensional models?

55. Base your answer to the following question on A student used a balance and a graduated cylinder to collect the following data:

Sample mass	10.23 g
Volume of water	20.0 mL
Volume of water and sample	21.5 mL

a Calculate the density of the element. Show your work. Include the appropriate number of significant figures and proper units.

b If the accepted value is 6.93 grams per milliliter, calculate the percent error.

c What error is introduced if the volume of the sample is determined first?