1. The average kinetic energy of water molecules increases when
   1) $H_2O(s)$ changes to $H_2O(\ell)$ at 0ºC
   2) $H_2O(\ell)$ changes to $H_2O(s)$ at 0ºC
   3) $H_2O(\ell)$ at 10ºC changes to $H_2O(\ell)$ at 20ºC
   4) $H_2O(\ell)$ at 20ºC changes to $H_2O(\ell)$ at 10ºC

2. An increase in the average kinetic energy of a sample of copper atoms occurs with an increase in
   1) concentration 2) temperature 3) pressure 4) volume

3. Solid *X* is placed in contact with solid *Y*. Heat will flow spontaneously from *X* to *Y* when
   1) *X* is 20ºC and *Y* is 20ºC
   2) *X* is 10ºC and *Y* is 5ºC
   3) *X* is –25ºC and *Y* is –10ºC
   4) *X* is 25ºC and *Y* is 30ºC

4. 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 2) 60°C 3) 70°C 4) 80°C

5. Which temperature is equal to +20 K?
   1) –253ºC 2) –293ºC 3) 253°C 4) 293°C

6. Which kind of energy is stored within a chemical substance?
   1) free energy 2) activation energy 3) kinetic energy 4) potential energy

7. At 1 atmosphere and 298 K, 1 mole of $H_2O(\ell)$ molecules and 1 mole of $C_2H_5OH(\ell)$ molecules both have the same
   1) vapor pressure
   2) average kinetic energy
   3) mass
   4) density

8. The temperature 30. K expressed in degrees Celsius is
   1) 243ºC 2) –243ºC 3) 303ºC 4) –303ºC

9. The potential energy possessed by a molecule is dependent upon
   1) its composition, only
   2) its structure, only
   3) both its composition and its structure
   4) neither its composition nor its structure

10. As a substance undergoes a change from the solid to the liquid phase, *at constant temperature*, the average kinetic energy of its molecules
    1) decreases 2) increases 3) remains the same

11. As the temperature of a sample of $H_2O(\ell)$ decreases, the average kinetic energy of its molecules will
    1) decrease 2) increase 3) remain the same

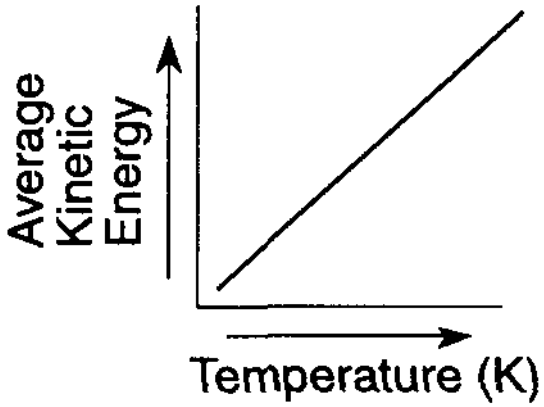
12. Which phase change is exothermic?
    1) solid to liquid 2) solid to gas 3) liquid to solid 4) liquid to gas

13. 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 2) liquid, solid, gas 3) solid, gas, liquid 4) solid, liquid, gas

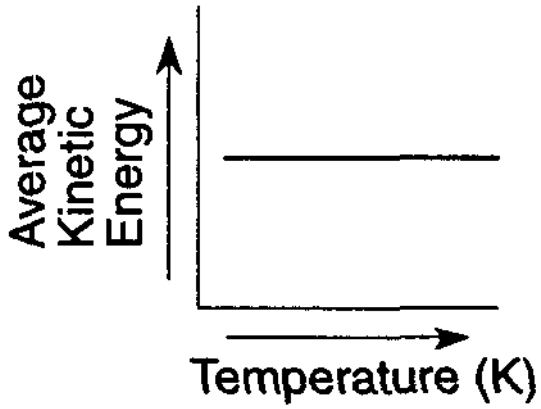
14. The volume of a 1.00-mole sample of an ideal gas will decrease when the
    1) pressure decreases and the temperature decreases
    2) pressure decreases and the temperature increases
    3) pressure increases and the temperature decreases
    4) pressure increases and the temperature increases

15. Which graph best shows the relationship between Kelvin temperature and average kinetic energy?

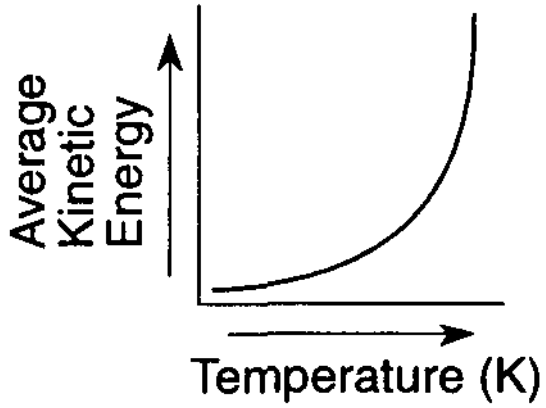
1)



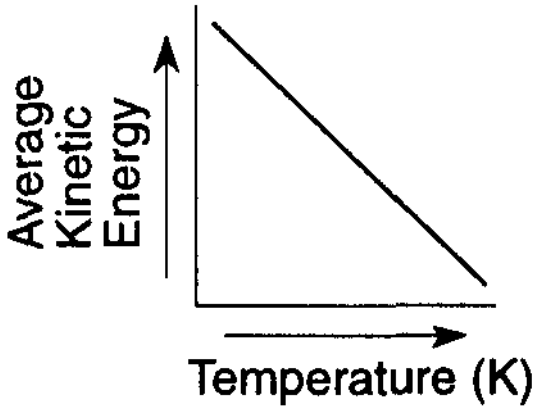

3)



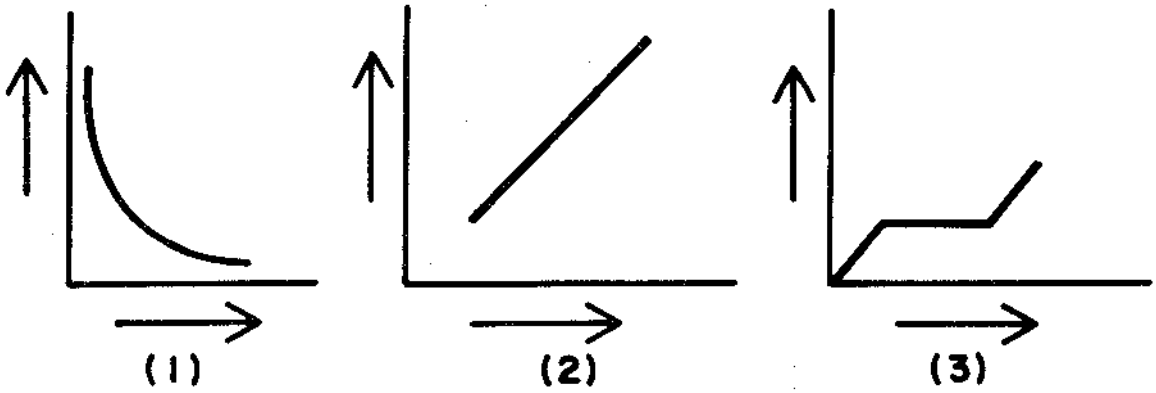

2)




4)




16. Base your answer to the following question on the graphs shown below.




Which graph best represents how the volume of a given mass of a gas varies with the pressure exerted on it at constant temperature?

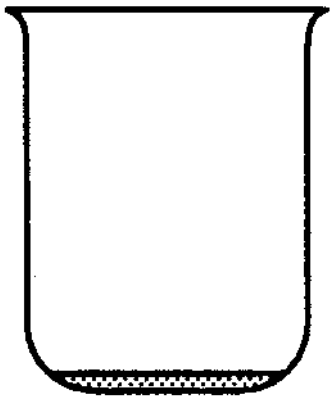
1) 1 2) 2 3) 3

17. One kilocalorie is the same as

1) 0.001 calorie 2) 0.01 calorie 3) 100 calories 4) 1,000 calories

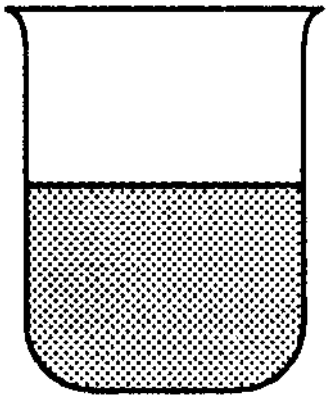
18. In which beaker would the particles have the highest average kinetic energy?

1)



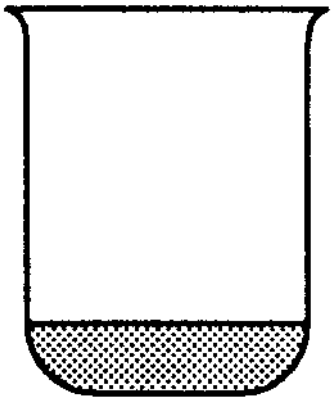
10 milliliters
0.1 M HCl at 20°C

3)



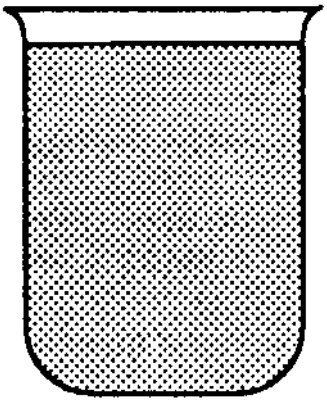
200 milliliters
0.1 M HCl at 30°C

2)



50 milliliters
0.1 M HCl at 10°C

4)



400 milliliters
0.1 M HCl at 15°C

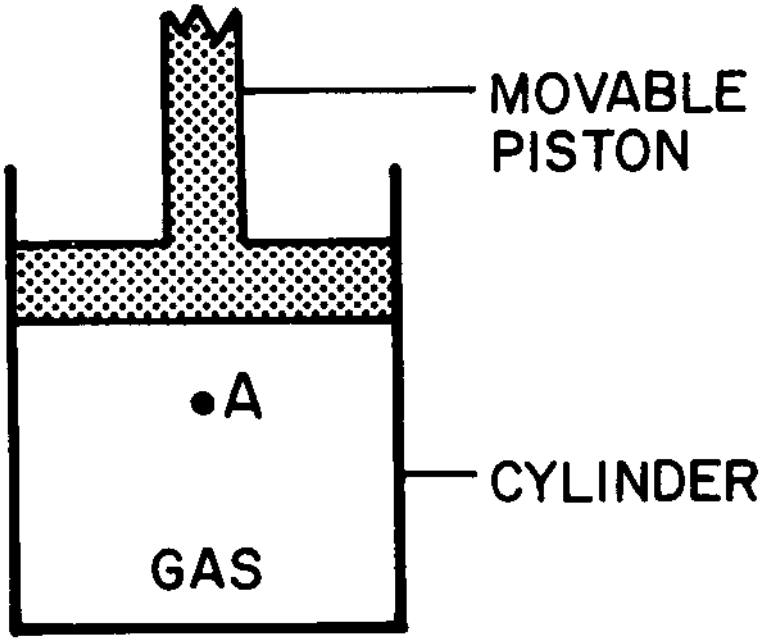
19. At a temperature of 273 K, a 400.-milliliter gas sample has a pressure of 760. millimeters of mercury. If the pressure is changed to 380. millimeters of mercury, at which temperature will this gas sample have a volume of 551 milliliters?
    1) 100 K 2) 188 K 3) 273 K 4) 546 K

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

21. As the temperature of a gas increases at constant pressure, the volume of the gas
    1) decreases 2) increases 3) remains the same

22. Standard temperature and a pressure of 0.5 atmosphere are equal to
    1) 0°C and 51.6 kPa 2) 32°C and 51.6 kPa 3) 0°C and 101.3 kPa 4) 32°C and 101.3 kPa

23. The diagram below represents a gas confined in a cylinder fitted with a movable piston.




As the piston moves toward point *A* at constant temperature, which relationship involving pressure (*P*) and volume (*V*) is correct?

1) $P + V = k$ 2) $P - V = k$ 3) $P \div V = k$ 4) $P \times V = k$

24. 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

25. Which changes in pressure and temperature occur as a given mass of gas at 50.6 kPa and 546 K is changed to STP?
1) The pressure is doubled and the temperature is halved.
2) The pressure is halved and the temperature is doubled.
3) Both the pressure and the temperature are doubled.
4) Both the pressure and the temperature are halved.

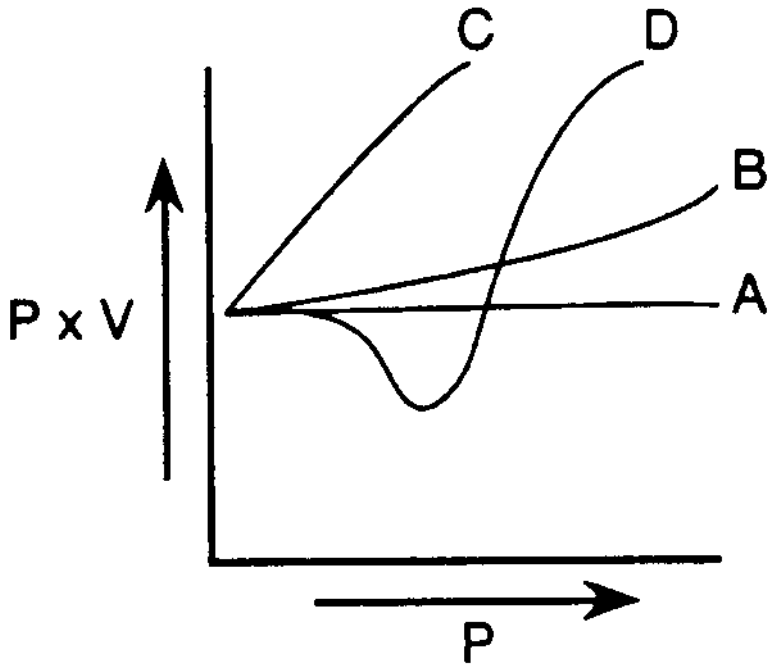
26. A flask contains a mixture of $N_2(g)$ and $O_2(g)$ at STP. If the partial pressure exerted by the $N_2(g)$ is 40.0 kPa, the partial pressure of the $O_2(g)$ is
1) 21.3 kPa 2) 37.3 kPa 3) 61.3 kPa 4) 720 kPa

27. Gas samples *A*, *B,* and *C* are contained in a system at STP. The partial pressure of sample *A* is 38.0 kPa and the partial pressure of sample *B* is 19.0 kPa. What is the partial pressure of sample *C*?
1) 19.0 kPa 2) 38.0 kPa 3) 44.3 kPa 4) 63.3 kPa

28. As the pressure of a gas at 150 kPA is changed to 100 kPa at constant temperature, the volume of the gas
1) decreases 2) increases 3) remains the same

29. As a solid substance absorbs heat at its melting point, the melting point will
1) decrease 2) increase 3) remain the same

30. In the graph below, the product of the pressure ($P$) and the volume ($V$) is plotted against the pressure ($P$) for gases $A$, $B$, $C$, and $D$.




Which gas behaves like an ideal gas?
1) $A$ 2) $B$ 3) $C$ 4) $D$

31. The van der Waals forces of attraction between molecules always become stronger as molecular size
1) increases, and the distance between the molecules increases
2) increases, and the distance between the molecules decreases
3) decreases, and the distance between the molecules increases
4) decreases, and the distance between the molecules decreases

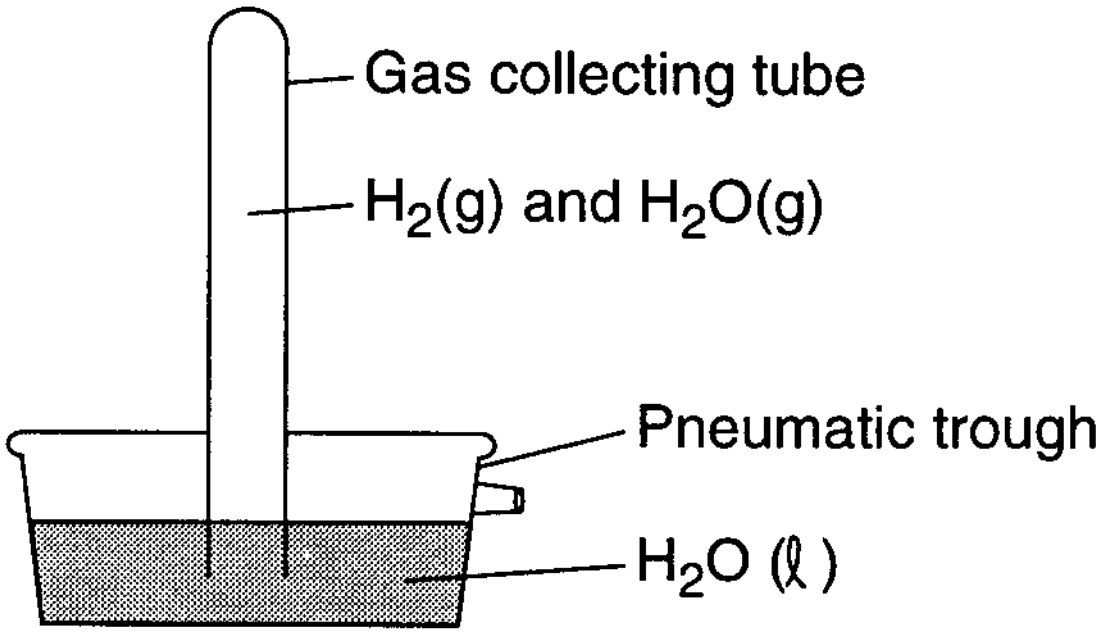
32. What is the total number of calories of heat that must be absorbed to change the temperature of 100 grams of $H_2O$ from 25ºC to 30ºC?
1) 100 2) 500 3) 2,500 4) 3,000

33. Which substance has the *lowest* vapor pressure at 75°C?
1) water 2) ethanoic acid 3) propanone 4) ethanol

34. How many calories of heat energy are absorbed in raising the temperature of 10. grams of water from 5.0°C to 20.°C?
1) $2.5 \times 10^2$ 2) $2.0 \times 10^2$ 3) $1.5 \times 10^2$ 4) $5.0 \times 10^1$

35. The kind of attractions that result in the dissolving of sodium chloride in water are
1) ion-ion 2) molecule-ion 3) atom-atom 4) molecule-atom

36. The diagram below shows the collection of $H_2$ gas over water at 25°C. The total pressure in the tube is 760.0 torr.




What is the pressure exerted by the hydrogen gas alone?
1) 23.8 torr 2) 736.2 torr 3) 760.0 torr 4) 793.8 torr

37. What is the normal boiling point of ethanoic acid?
1) 52°C 2) 55°C 3) 101.3°C 4) 150°C

38. What is the total number of kiloJoules required to boil 100. grams of water at 100°C and 1 atmosphere? [Refer to Reference Table *B*.]
1) 22.6 kJ 2) 33.4 kJ 3) 226 kJ 4) 334 kJ

39. When the vapor pressure of a liquid is equal to the atmospheric pressure, the liquid will
1) freeze 2) boil 3) melt 4) condense

40. The temperature of 100. grams of water changes from 16.0ºC to 20.0ºC. What is the total number of Joules of heat energy absorbed by the water?
1) 105 2) 168 3) 420. 4) 1680

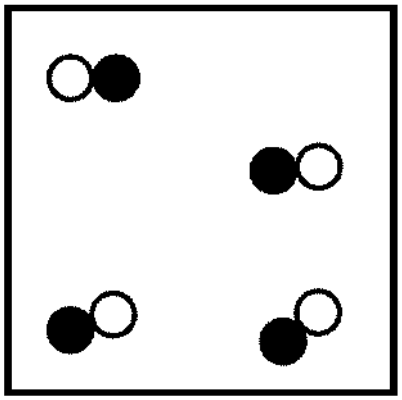
41. A gas is most likely to change to the liquid phase when the pressure on the gas
1) decreases and its temperature increases
2) decreases and its temperature decreases
3) increases and its temperature increases
4) increases and its temperature decreases

42. Based on Reference Table *H*, which sample has the highest vapor pressure?
1) water at 20ºC 2) water at 80ºC 3) ethanol at 50ºC 4) ethanol at 65ºC

43. An example of a heterogeneous mixture is
1) soil 2) sugar 3) carbon monoxide 4) carbon dioxide

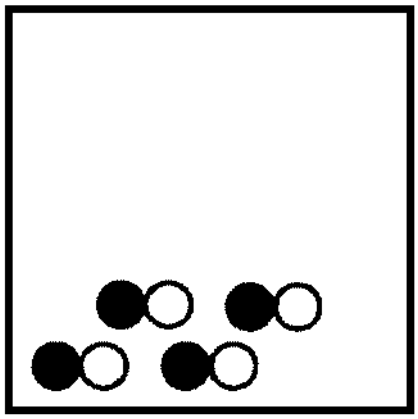
44. Which must be a mixture of substances?
1) solid 2) liquid 3) gas 4) solution

45. Given the particle diagram representing four molecules of a substance:

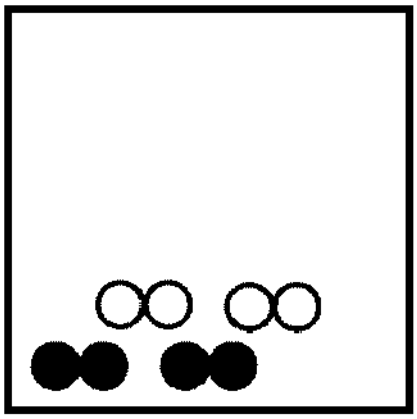


Which particle diagram best represents this same substance after a physical change has taken place?

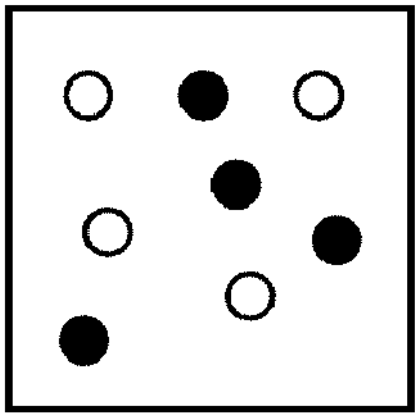
1)



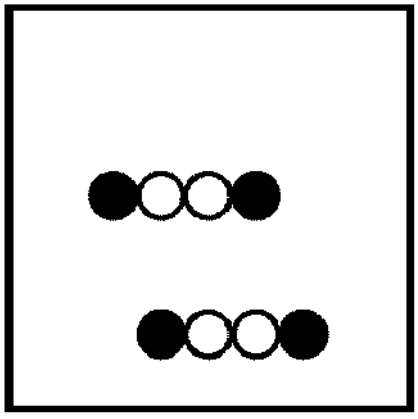
3)



2)



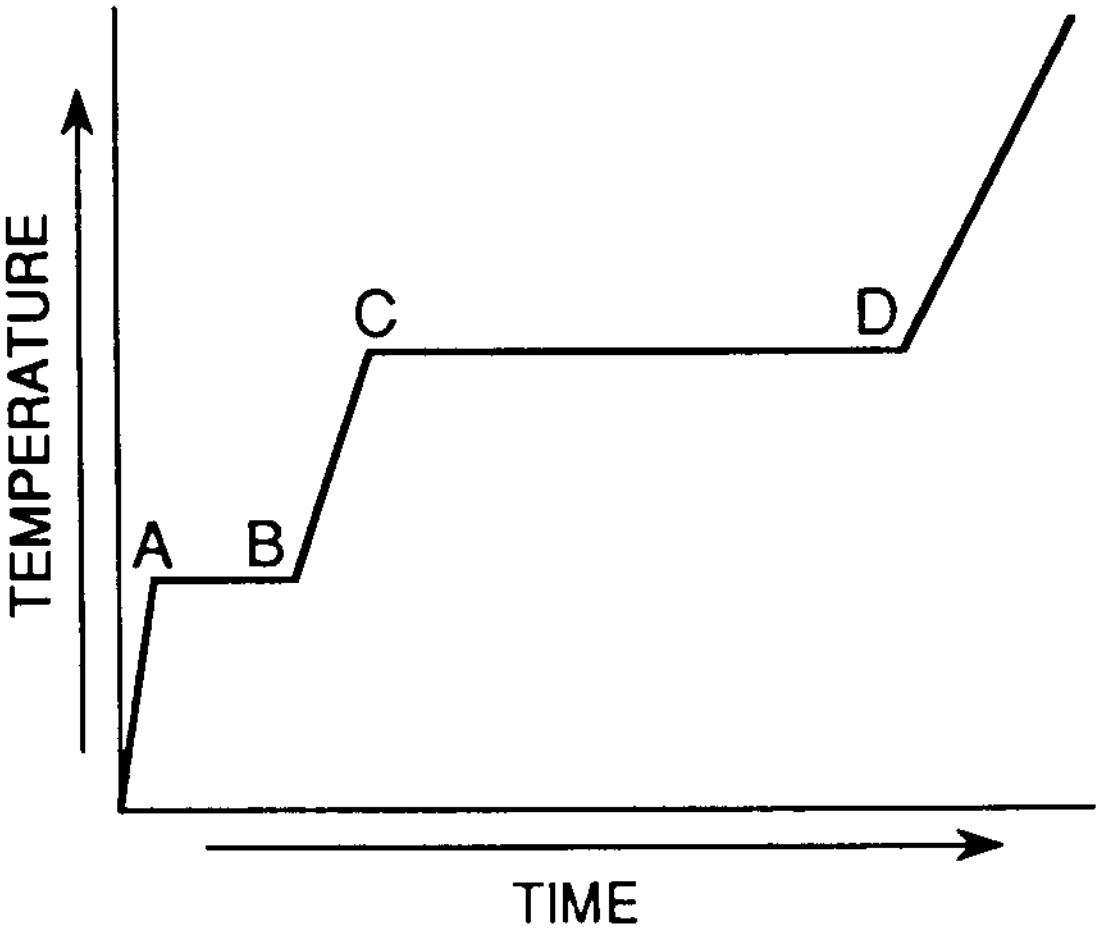
4)



46. Which of these terms refers to matter that could be heterogeneous?
    1) element
    2) mixture
    3) compound
    4) solution

47. A dry mixture of $KNO_3$ and sand could be separated by
    1) adding water to the mixture and filtering
    2) adding water to the mixture and evaporating
    3) heating the mixture to a high temperature
    4) cooling the mixture to a low temperature

48. In the heating curve shown below, heat is applied to a solid substance at a constant rate.




What accounts for the fact that segment *CD* is longer than segment *AB*?

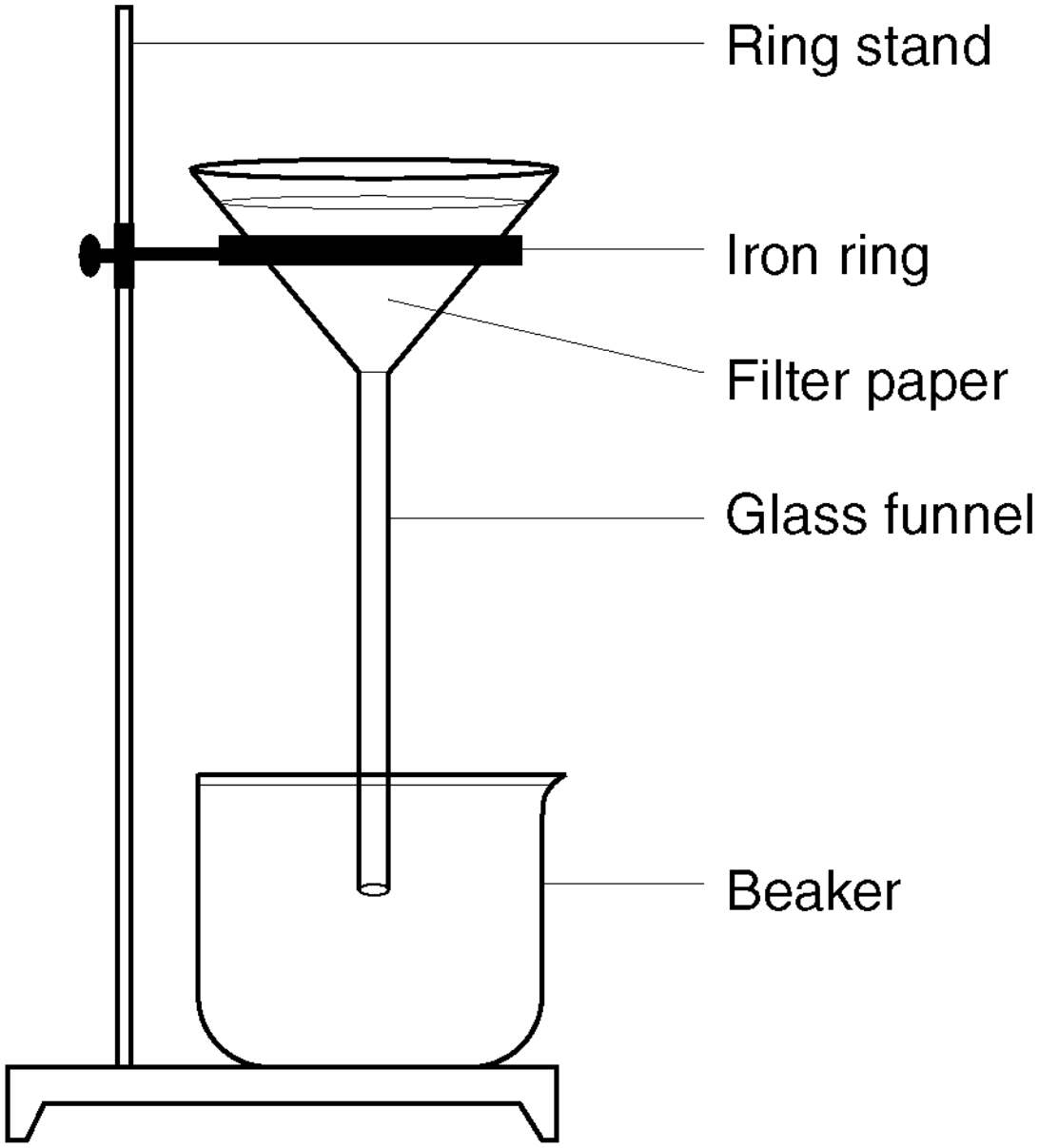
1) Boiling occurs at a higher temperature than melting.
2) The heat of vaporization is greater than the heat of fusion.
3) Average kinetic energy increases at a greater rate during boiling than during melting.
4) Potential energy is being released during boiling.

49. Base your answer to the following question on the information below.

A student is instructed to make 0.250 liter of a 0.200 M aqueous solution of $Ca(NO_3)_2$.

In order to prepare the described solution in the laboratory, two quantities must be measured accurately. One of these quantities is the volume of the solution. What other quantity must be measured to prepare this solution?

50. Which mixture can be separated by using the equipment shown below?




1) $NaCl(aq)$ and $SiO_2(s)$
2) $NaCl(aq)$ and $C_6H_{12}O_6(aq)$
3) $CO_2(aq)$ and $NaCl(aq)$
4) $CO_2(aq)$ and $C_6H_{12}O_6(aq)$

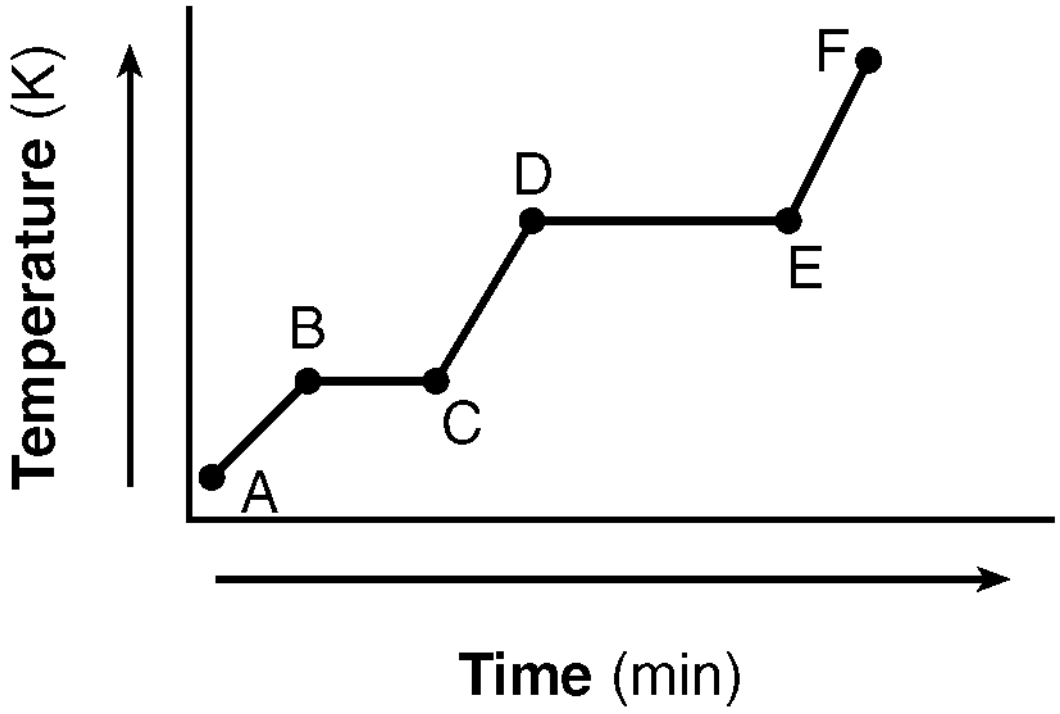
51. At equilibrium, nitrogen, hydrogen, and ammonia gases form a mixture in a sealed container. The data table below gives some characteristics of these substances.

**Data Table**

| Gas | Boiling Point | Melting Point | Solubility in Wa |
|---|---|---|---|
| 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.

52. Base your answer to the following question 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.




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

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

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

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

Base your answers to questions **54** and **55** 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.

54. Explain, in terms of *intermolecular forces*, why naphthalene sublimes.

55. Explain why naphthalene is *not* expected to dissolve in water.

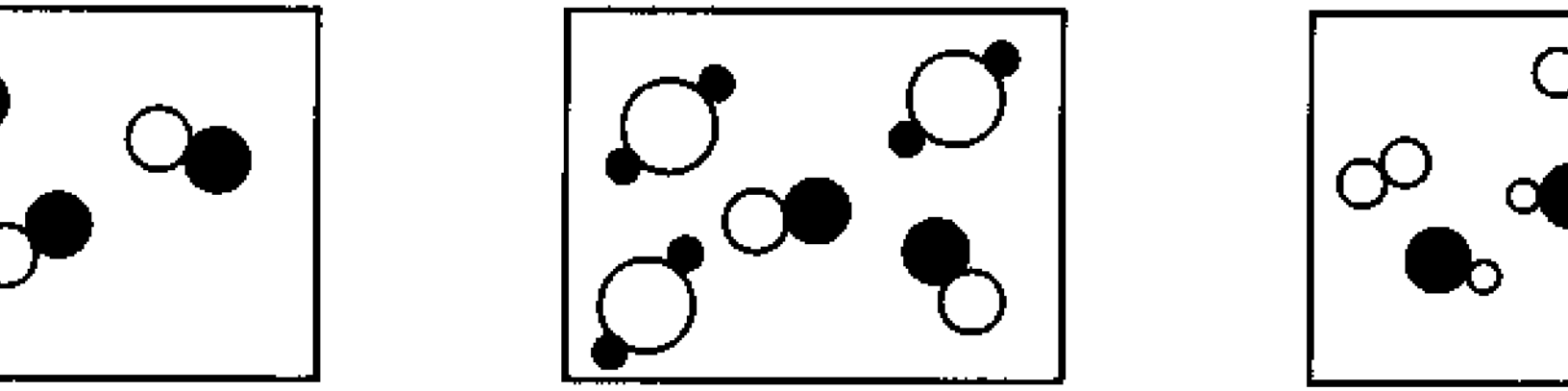
---

56. Base your answer to the following question 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.

What pressure, in atmospheres (atm), is equal to 45.6 kPa?

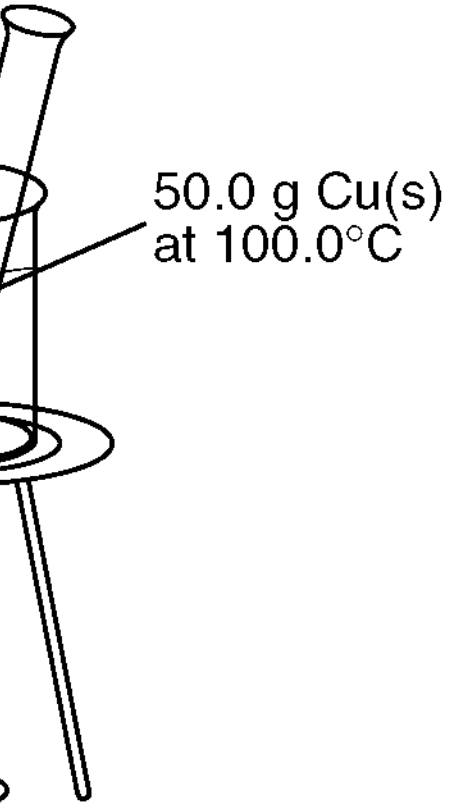
57. Base your answer to the following question on the pictures below:




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

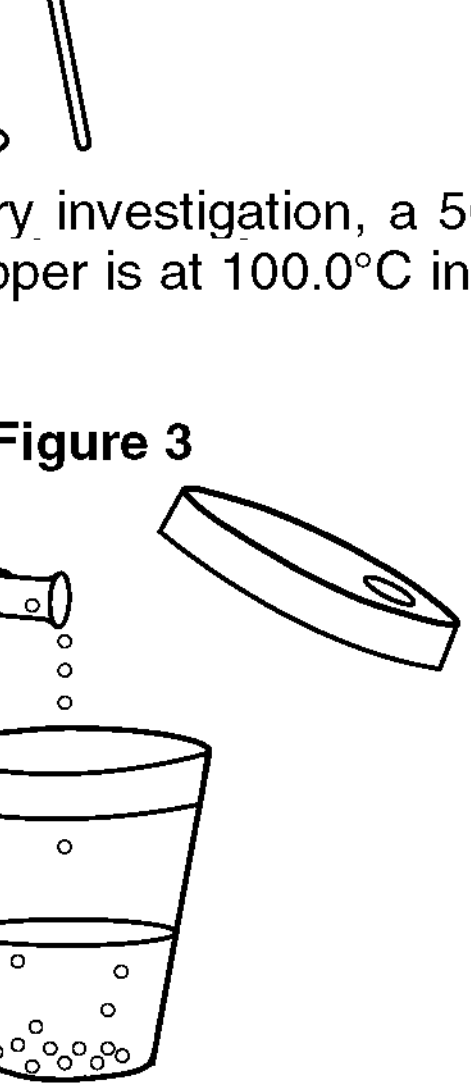
58. Base your answer to the following question on the information below.

**Figure 1**



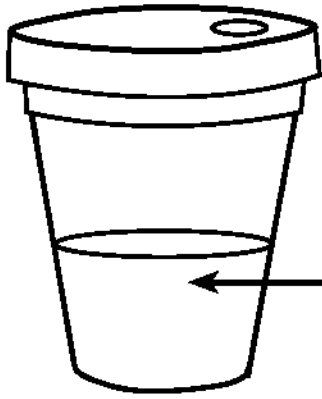

ry investigation, a 50.0-gram
pper is at 100.0°C in a boiling

**Figure 3**



lorimeter
r is poured into the cup of water,
s quickly covered with the lid.

**Fig**



Calorimeter

A Styrofoam cup with a lid is used a
The cup contains 100.0 grams o
23.2°C.

**Fig**

Calo

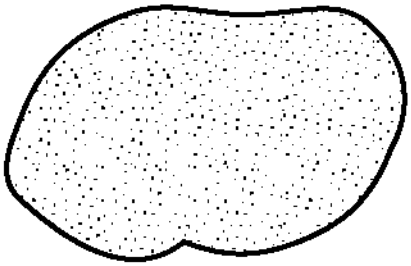
A thermometer is inserted through
and water are gently stirred in the
checked periodically. The highes

Using the information given, complete the data table above.

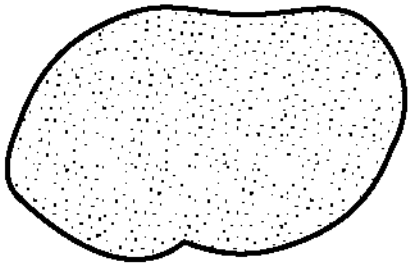
59. On a field trip, Student *X* and Student *Y* collected two rock samples. Analysis revealed that both rocks contained lead and sulfur. One rock contained a certain percentage of lead and sulfur by mass, and the other rock contained a different percentage of lead and sulfur by mass. Student *X* stated that the rocks contained two different mixtures of lead and sulfur. Student *Y* stated that the rocks contained two different compounds of lead and sulfur. Their teacher stated that both students could be correct.

    Draw particle diagrams in *each* of the rock diagrams *below* to show how Student *X*'s and Student *Y*'s explanations could both be correct. Use the symbols in the key provided *below* to sketch lead and sulfur atoms.

Student *X*'s explanation:



Rock A



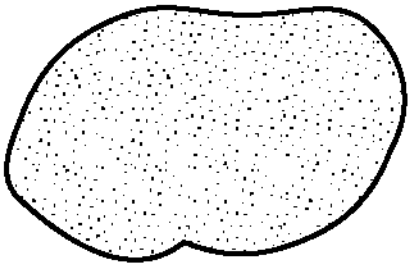
Rock B

Key

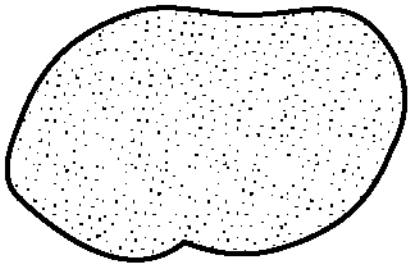
Lead =

Sulfur =

Student *Y*'s explanation:



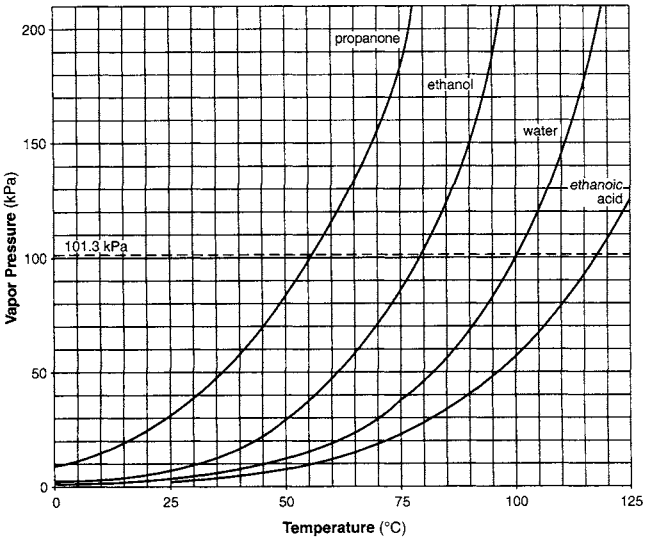
Rock A



Rock B

# Reference Tables

**Table H**
**Vapor Pressure of Four Liquids**



# Reference Tables

| Name | Value | Unit |
|---|---|---|
| Standard Pressure | 101.3 kPa<br>1 atm | kilopascal<br>atmosphere |
| Standard Temperature | 273 K<br>0°C | kelvin<br>degree Celsius |

# Reference Tables

| | |
|---|---|
| Heat of Fusion | 333.6 J/g |
| Heat of Vaporization | 2259 J/g |
| Specific Heat Capacity of $H_2O$ ($\ell$) | 4.2 J/g•K |

**Answer Key**

1. 3
2. 2
3. 2
4. 1
5. 1
6. 4
7. 2
8. 2
9. 3
10. 3
11. 1
12. 3
13. 4
14. 3
15. 1
16. 1
17. 4
18. 3
19. 2
20. 3
21. 2
22. 1
23. 4
24. 3
25. 1
26. 3
27. 3
28. 2
29. 3
30. 1
31. 2
32. 2
33. 2
34. 3
35. 2
36. 2
37. 4
38. 3
39. 2
40. 4
41. 4
42. 4
43. 1
44. 4
45. 1
46. 2
47. 1
48. 2
49. Examples: – mass of $Ca(NO_3)_2$ – mass of solute – mass

50. 1

51. Examples:
– Lower the temperature to condense ammonia.
– Place all three gases in water. Ammonia will dissolve (is soluble).
– distillation

52. It does not change.

53. The aqueous solution has mobile ions. Charged particles can move in water.

54. Acceptable responses: Naphthalene has weak intermolecular forces; They are weak.

55. Acceptable responses: Naphthalene is nonpolar and water is polar; Nonpolar won't dissolve in polar; Like dissolves like.

56. .45 or 0.45

57. Particles in sample *A* show molecules of a compound whereas particles in sample *B* show two compounds as a mixture *or A* – compound, *B* – mixture *or A* – 1 compound, *B* – 2 compounds

58.

**Data Table**

| **Quantity Measured** | **Data** (units are given) |
|---|---|
| Mass of copper | **50.0** or **50** g |
| Temperature of hot copper | **100.0** or **100**°C |
| Mass of $H_2O$ in calorimeter | **100.0** or **100** g |
| Initial temperature of $H_2O$ in calorimeter | **23.2**°C |
| Final temperature of $H_2O$ and copper | **26.3**°C |

59.