This print-out should have 25 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.
Remember to bubble your version number and uteid.

001 4.0 points
When a gas phase reaction takes place...

1. some state functions may increase, others may decrease and some may stay constant. correct

2. all state functions must increase or stay constant.

3. all state functions must stay constant.

4. all state functions must change.

5. all state functions must decrease or stay constant.

Explanation:
State functions are the properties of a system (like $P$, $V$, $T$, ...). During a process some state functions may increase, others may decrease and some may stay constant.

002 4.0 points
Which of the following statements about gas laws is/are true?

I) Boyle’s law says that above the boiling point, the pressure and volume of a gas are directly proportional.

II) Jacques Charles measured an inverse relationship between volume and temperature.

III) The ideal gas law is only accurate at very high concentrations.

1. II, III

2. I, II, III

3. II only

4. I, II

5. None are true correct

6. I only

7. III only

8. I, III

Explanation:
All three statements are false. Boyle’s law describes an inverse proportionality between $P$ and $V$, and says nothing about the boiling point. Charles’ law describes a direct proportionality between $V$ and $T$. Only gases that closely approximate the assumptions of kinetic molecular theory are well described by the ideal gas law - at high concentrations, intermolecular forces become significant.

003 4.0 points
A 22.4 L vessel contains 0.02 mol H$_2$ gas, 0.02 mol N$_2$ gas, and 0.1 mol NH$_3$ gas. The total pressure is 700 torr. What is the partial pressure of the H$_2$ gas?

1. 28 torr

2. 100 torr correct

3. None of these

4. 14 torr

5. 7 torr

Explanation:
State functions are the properties of a system (like $P$, $V$, $T$, ...). During a process some state functions may increase, others may decrease and some may stay constant.

004 4.0 points
What volume will 40.0 L of He at 50.00$^\circ$C and 1201 torr occupy at STP?
1. 26.7 L
2. 53.4 L correct
3. 12.8 L
4. 18.6 L
5. 31.1 L

Explanation:
\[ P_1 = 1201 \text{ torr} \]
\[ P_2 = 760 \text{ torr} \]
\[ V_1 = 40 \text{ L} \]
\[ T_2 = 273.15 \text{ K} \]
\[ T_1 = 50^\circ \text{C} + 273.15 = 323.15 \text{ K} \]

Using the Combined Gas Law,
\[ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \]
and recalling that STP implies standard temperature (273.15 K) and pressure (1 atm or 760 torr), we have
\[ V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} \]
\[ = \frac{(1201 \text{ torr})(40.0 \text{ L})(273.15 \text{ K})}{(323.15 \text{ K})(760 \text{ torr})} \]
\[ = 53.4302 \text{ L} \]

006 4.0 points
A sample of nitrous oxide gas (NO) has a density of 12 g L\(^{-1}\). What pressure does the sample exert at 27 \(^\circ\)C?
1. 9.9 atm correct
2. 1.0 atm
3. 997.9 atm
4. not enough information
5. 61.6 atm

Explanation:
By thoughtful substitutions and rearrangement, the ideal gas law can be used to relate the mass density of a gas to its pressure.
\[ PV = nRT \]
\[ \frac{n}{V} = \frac{P}{RT} \]
with unit of measure mol/L on each side. Multiplying each by molar mass (MM) gives
\[ \frac{n}{V} \cdot \text{MM} = \frac{P}{RT} \cdot \text{MM} = \rho, \]
with units of g/L.
\[ \text{MM} = \frac{\rho RT}{P} \]
\[ = \frac{(8 \text{ g/L})(0.08206 \text{ L atm/mol K})}{1 \text{ atm}} \]
\[ \times (273.15 \text{ K}) \]
\[ = 179.318 \text{ g/mol} \]
\[ P = \frac{m}{V} \frac{RT}{M \cdot W} \]

By substituting the definition of density \((\rho)\), we can arrive at a readily usable equation.

\[ \rho = \frac{m}{V} \]

\[ P = \frac{\rho RT}{M \cdot W} = 12 \frac{0.0821 \times 300}{30} = 9.852 \text{ atm} \]

**What is the final volume if 20 L methane reacts completely with 20 L oxygen**

\[ \text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(\ell) \]

at 100°C and 2 atmospheres?

1. 10 L
2. 30 L
3. 20 L correct
4. Cannot be determined from the information given.
5. 15 L

**Explanation:**

\[ V_1 = 20 \text{ L CH}_4 \quad V_2 = 20 \text{ L O}_2 \]

Avogadro’s Principle tells us that because \(P\) and \(T\) are the same, \(V \propto n\), so we can work with the volume instead of the number of moles. From the equation above, we need 2 times more L of O\(_2\) than that of CH\(_4\), but we only have 20 L, not 40 L of O\(_2\)! This means O\(_2\) is the limiting reactant.

Find out how much CO\(_2\) is made based on the L of O\(_2\):

\[ \text{L CO}_2 = 20 \text{ L O}_2 \times \left( \frac{1 \text{ L CO}_2}{2 \text{ L O}_2} \right) = 10 \text{ L CO}_2 \]

We now find out how much CH\(_4\) was used reacting with all the L of O\(_2\):

\[ \text{L CH}_4 = 20 \text{ L O}_2 \times \left( \frac{1 \text{ L CH}_4}{2 \text{ L O}_2} \right) = 10 \text{ L CH}_4 \]

This means 20 L - 10 L = 10 L CH\(_4\) are unused and still present.

The final mixture is

10 L unreacted CH\(_4\) + 10 L CO\(_2\) = 20 L of gas.

We assume the volume of the water is insignificant.

**Consider the balanced reaction for the combustion of methane below.**

\[ \text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O}(g) \]

If 100 g of methane react completely with 100 g of molecular oxygen in a sturdy, closed 100 L vessel at 227 °C, what is the approximate final pressure in the vessel?

1. 1.92 atm
2. 3.85 atm correct
3. 0.87 atm
4. 1.75 atm

**Explanation:**

Although we have equal masses of methane and oxygen, their different molar masses and different stoichiometric coefficients result in oxygen being the limiting reagent.

\[ 100 \text{ g CH}_4 \times \frac{1 \text{ mol}}{16 \text{ g}} = 6.25 \text{ mol} \]

\[ 100 \text{ g O}_2 \times \frac{1 \text{ mol}}{32 \text{ g}} = 3.125 \text{ mol} \]

In addition to having fewer moles of oxygen, 2 moles of oxygen are required to react with 1 mole of methane; oxygen is definitely the limiting reagent. From this, we can be certain that 0 moles of oxygen will remain once the reaction has gone to completion. In order to answer the question, we will need to determine the total moles of methane remaining and add to that the number of moles of products.

\[ 3.125 \text{ mol O}_2 \times \frac{1 \text{ CH}_4}{2 \text{O}_2} = 1.5625 \text{ mol CH}_4 \]

\[ 6.25 - 1.5625 \text{ mol CH}_4 = 4.6875 \text{ mol CH}_4 \]

\[ 3.125 \text{ mol O}_2 \times \frac{3}{2 \text{O}_2} = 4.6875 \text{ mol products} \]

Thus, once the reaction has gone to completion, there are a total of 9.375 moles of gas on
the container. Under the specified conditions, that produces a pressure of:

$$P = \frac{nRT}{V} = \frac{9.375 \times 0.0821 \times 500}{100} = 3.85 \text{ atm}$$

All of these calculations can also be approximated while still allowing you to reach the correct answer.

$100 \text{ g CH}_4 \times \frac{1 \text{ mol}}{16 \text{ g}} \approx 6 \text{ mol}$

$100 \text{ g O}_2 \times \frac{1 \text{ mol}}{32 \text{ g}} \approx 3 \text{ mol}$

$3 \text{ mol O}_2 \times \frac{1 \text{ CH}_4}{2 \text{ O}_2} = 1.5 \text{ mol CH}_4$

$6 - 1.5 \text{ mol CH}_4 = 4.5 \text{ mol CH}_4$

$3 \text{ mol O}_2 \times \frac{3 \text{ CH}_4}{2 \text{ O}_2} = 4.5 \text{ mol products}$

$$P = \frac{nRT}{V} = \frac{9 \times 0.0821 \times 500}{100}$$

$$P \approx 10 \times 0.08 \times 5 \approx 4 \text{ atm}$$

Even when approximating, it is possible to eliminate all but one answer choice.

009 4.0 points

When two samples of ideal gases have the same $?$, their molecules must have the same $?$.  

1. pressure; average kinetic energy  
2. mass; average kinetic energy  
3. density; mass  
4. density; average kinetic energy  
5. volume; average kinetic energy  
6. volume; mass  
7. pressure; mass  
8. mass; density  
9. temperature; speed  
10. temperature; average kinetic energy correct

Explanation:

From kinetic molecular theory:

$$\bar{U} \propto \sqrt{\frac{T}{MW}}$$

For samples of an ideal gas temperature and average kinetic energy are directly proportional.

010 4.0 points

The graph shows the Maxwell distribution plots for a given gas at three different temperatures.

Which plot corresponds to the highest temperature?  

1. C correct  
2. Can not be determined from this type of plot  
3. B  
4. A

Explanation:  

The higher the temperature, the broader the range of velocity distributions and the higher the average velocity. So curve C matches that criteria.

011 4.0 points

Calculate the ratio of the rate of effusion of He to that of CO$_2$ (at the same temperatures).
1. 1 : 11
2. 1 : 11²
3. $\sqrt{11} : 1$ correct
4. 11 : 1
5. 1 : 1
6. 11² : 1
7. 1 : $\sqrt{11}$

Explanation:

$$\frac{\text{Eff}_{\text{HC}}}{\text{Eff}_{\text{CO}_2}} = \frac{\sqrt{\text{MW}_{\text{CO}_2}}}{\sqrt{\text{MW}_{\text{HC}}}} = \sqrt{\frac{44}{4}} = \sqrt{11}$$

012 4.0 points
Under which of the following conditions is a real gas most likely to deviate from ideal behavior?

1. high volume
2. low density
3. if it is a noble gas
4. Tuesdays and Thursdays
5. zero pressure
6. low pressure
7. new moon
8. low temperature correct

Explanation:

Deviations from ideality occur due to molecular attractions or repulsions. More attractions or repulsions can occur when the molecules are closer together. Low pressure, high volume, and low density all correspond to molecules being far apart. Low temperature often corresponds to molecules being close together. It also corresponds to low kinetic energy which allows molecules to ‘stick together’ easier.

013 4.0 points
Gas X has a larger value than Gas Y for the van der Waals constant “a”. This indicates that

1. the molecules of X have stronger intermolecular attractions for each other than the molecules of Y have for each other. correct
2. the molecules of gas X have a higher velocity than do the molecules of gas Y.
3. the molecules of X are larger than the molecules of Y.
4. the molecules of gas X repel other X molecules.

Explanation:

014 4.0 points
Some of the following terms characterize both the bonding within a molecule (intra- molecular) and that between atoms and molecules (intermolecular). Which of the following is normally considered only when characterizing intermolecular forces?

1. ionic forces
2. covalent bonding
3. van der Waals forces correct
4. polar covalent bonding
5. electrostatic forces

Explanation:

Only van der Waals forces occur between separate molecules; i.e., are intermolecular forces.

015 4.0 points
Dispersion (London) forces result from
1. the balance of attractive and repulsive forces between two polar molecules.

2. attraction between molecules in a liquid and molecules or atoms in a solid surface with which the liquid is in contact.

3. the formation of a loose covalent linkage between a hydrogen atom connected to a very electronegative atom in one molecule and another very electronegative atom in a neighboring molecule.

4. distortion of the electron cloud of an atom or molecule by the presence of nearby atoms or molecules. correct

5. attractive forces between a molecule at the surface of a liquid and those beneath it which are not balanced by corresponding forces from above.

Explanation:

016 4.0 points

hydrogen oxygen

Which figure best describes the hydrogen bonding between two water molecules?

1.  

2.  

3.  correct

4.  

Explanation:

017 4.0 points

Identify the dominant intermolecular force in the following species, respectively: RbCl, C₆H₆ (benzene), HI, Fe₂O₃, CH₂NH.

a) ionic forces
b) hydrogen bonding
c) dipole-dipole

1. a, c, c, d, b

2. a, d, c, a, b correct

3. a, b, c, b, a

4. a, b, d, a, c

5. c, b, d, c, c

6. b, d, c, d, d

7. c, d, a, a, b

Explanation:

Rubidium Chloride and Iron(III) oxide are both ion-ion. Benzene is non-polar and thus has only van der Waal’s forces. Hydroiodic acid is polar and has dipole-dipole interactions. Methylimine has H-bonding.

018 4.0 points

Acetic acid (CH₃COOH) forms a molecular solid. What type of forces hold it in a solid configuration?

I) London forces
II) dipole-dipole forces
III) hydrogen bonding

1. I only

2. I, II, and III correct

3. III only

4. II only

5. II and III only

Explanation:

Note the water molecules line up so the δ⁻ on the oxygen of one water molecule is aligned with a δ⁺ on the hydrogen of the other water molecule.
6. I and II only

**Explanation:**
Acetic acid will exhibit both London forces and dipole-dipole interactions, in addition to hydrogen bonding.

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019 4.0 points

Carbon tetrachloride (CCl\(_4\)) and \(n\)-octane (C\(_8\)H\(_{18}\)) are both non-polar molecules. At standard pressure, they boil at 345 K and 399 K, respectively. Which answer choice below correctly explains their boiling points?

\[
\begin{align*}
\text{Cl} & \\
\mid & \\
\text{Cl} - \text{C} - \text{Cl} & \\
\mid & \\
\text{Cl}
\end{align*}
\]

1. C\(_8\)H\(_{18}\) has a higher boiling point because its electron cloud is larger and allows it to form more instantaneous dipoles. **correct**

2. C\(_8\)H\(_{18}\) has a higher boiling point because its smaller surface area allows it to form stronger instantaneous dipoles.

3. CCl\(_4\) has a lower boiling point because its smaller surface area allows it to form stronger instantaneous dipoles.

4. CCl\(_4\) has a lower boiling point because its greater molecular weight enables it to form stronger instantaneous dipoles.

5. C\(_8\)H\(_{18}\) has a higher boiling point because its greater molecular weight enables it to form stronger instantaneous dipoles.

**Explanation:**
Carbon tetrachloride (CCl\(_4\)) and \(n\)-octane (C\(_8\)H\(_{18}\)) both have only instantaneous dipoles. Despite the fact that (CCl\(_4\)) has a greater molecular weight (153.81 g mol\(^{-1}\)) compared to C\(_8\)H\(_{18}\) (114.23 g mol\(^{-1}\)), the latter boils at a substantially higher temperature. In general, dispersion forces are greater in molecules with greater molecular weight, more total electrons and a larger surface area (i.e., the shape of the molecule). Since \(n\)-octane is a long skinny molecule, more of its electrons are accessible and ready to form instantaneous dipoles.

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020 4.0 points

H\(_2\)S has a lower boiling point than H\(_2\)O or H\(_2\)Se. Which of the following is NOT part of the explanation for this observation?

1. ∆EN for the O—H bond is larger than ∆EN for the S—H bond.

2. The strength of London forces is greater for H\(_2\)Se than for H\(_2\)S.

3. Hydrogen bonding is most significant for compounds containing electronegative atoms in the second row.

4. ∆EN for the Se—H bond is larger than ∆EN for the S—H bond. **correct**

**Explanation:**
All three compounds are polar molecules which possess polar bonds but the ∆EN (electronegativity difference) for O—H is much greater than for S—H or Se—H. H\(_2\)O exhibits H-bonding, so it has the highest boiling point of the three compounds. The relative polarities (∆EN) of the H\(_2\)Se and H\(_2\)S bonds are similar and one would predict slightly smaller for H—Se based on general trends, so dipole-dipole interactions do not explain the trend. However, London interactions become longer as the size of the molecule’s electron cloud increases; since Se is bigger than S, H\(_2\)Se has stronger London forces and thus a higher boiling point than H\(_2\)S.

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021 4.0 points

Surface tension describes

1. the resistance to flow of a liquid.

2. the forces of attraction between the surface of a liquid and the air above it.
3. adhesive forces between molecules.

4. the inward forces that must be overcome in order to expand the surface area of a liquid. correct

5. capillary action.

6. the forces of attraction between surface molecules of a solvent and the solute molecules.

Explanation:
Molecules in the interior of a liquid interact with molecules all around them, whereas molecules at the surface of a liquid can only be affected by those beneath the surface layer. This phenomenon leads to a net inward force of attraction on the surface molecules, contracting the surface and making the liquid behave as though it had a skin. Surface tension is a measure of the inward forces that must be overcome to expand the surface area of a liquid.

022 4.0 points
Which of the following substances would you predict might evaporate the fastest?

1. C₆H₁₄ correct

2. C₈H₁₈

3. C₁₂H₂₄

4. C₁₀H₂₂

Explanation:
All the listed molecules are nonpolar hydrocarbons; therefore the dominant intermolecular force that exists in the condensed phase of all listed molecules is dispersion forces. Therefore, the molecule with the least number of atoms and the lowest molecular weight would have the lowest dispersion forces, and therefore would evaporate the easiest.

023 4.0 points
Which of the following would you expect to have the highest heat of vaporization?

1. C₈H₁₈ correct

2. CH₄

3. C₃H₆

4. C₅H₁₂

5. C₁₂H₂₆ correct

Explanation:

024 4.0 points
Arrange
Al₂O₃  Nb  I₂  C(s) (diamond) in the order metallic solid, covalent network, covalent solid, ionic solid.

1. C(s) (diamond); Nb, Al₂O₃; I₂

2. Nb, I₂; C(s) (diamond); Al₂O₃

3. Al₂O₃; C(s) (diamond); I₂; Nb

4. Nb; C(s) (diamond); I₂; Al₂O₃ correct

Explanation:

025 4.0 points
Put the following compounds in order of increasing melting points.

LiF, HF, F₂, NF₃

1. NF₃, HF, F₂, LiF

2. NF₃, F₂, HF, LiF

3. LiF, NF₃, HF, F₂

4. F₂, HF, NF₃, LiF

5. F₂, NF₃, HF, LiF correct

6. LiF, HF, NF₃, F₂

7. LiF, F₂, HF, NF₃

8. LiF, HF, F₂, NF₃