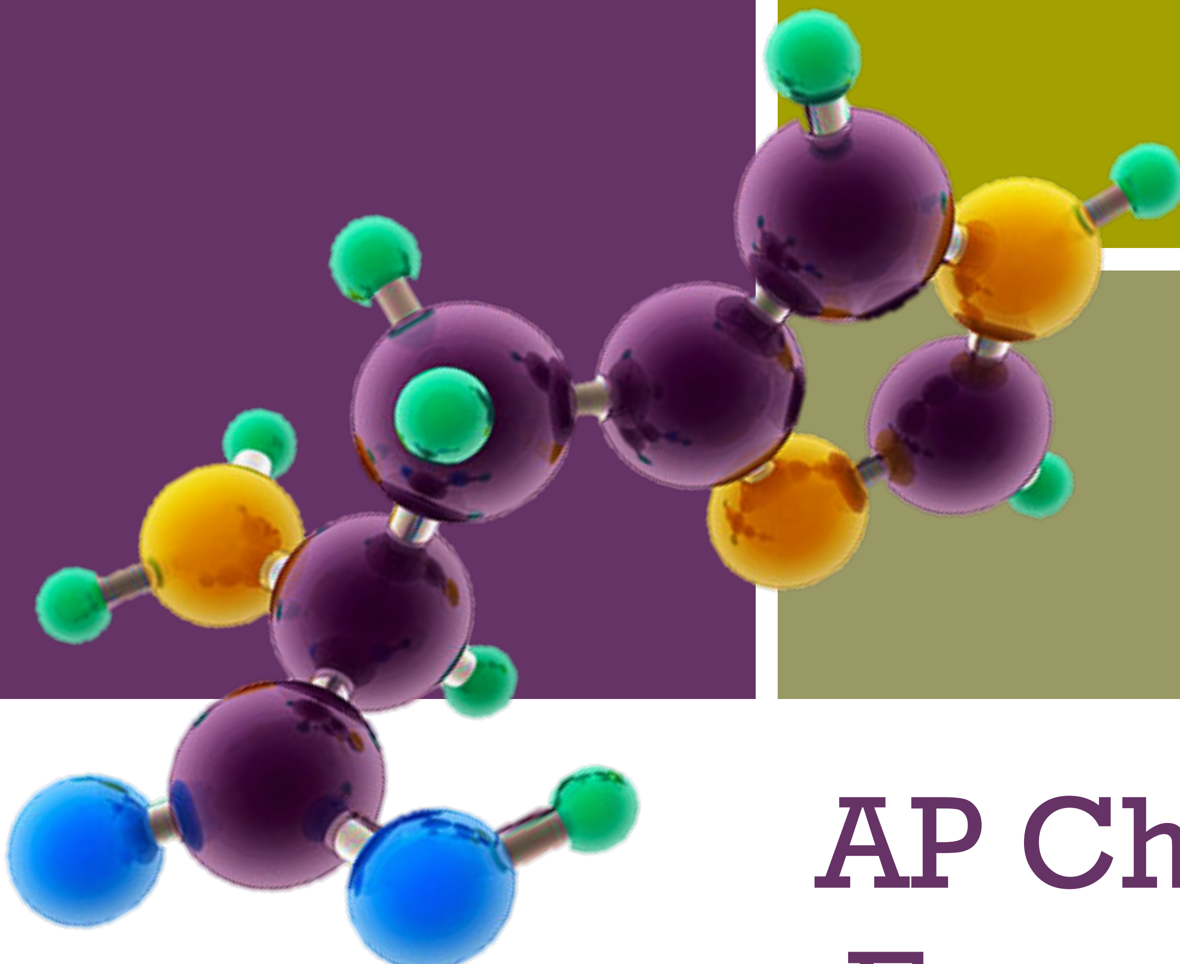
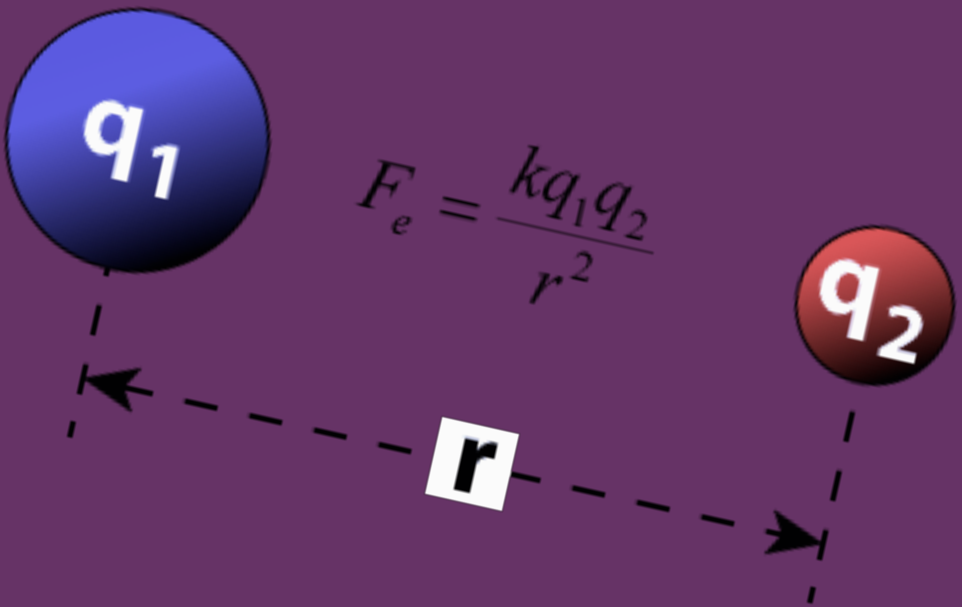


AP Chemistry Exam Review

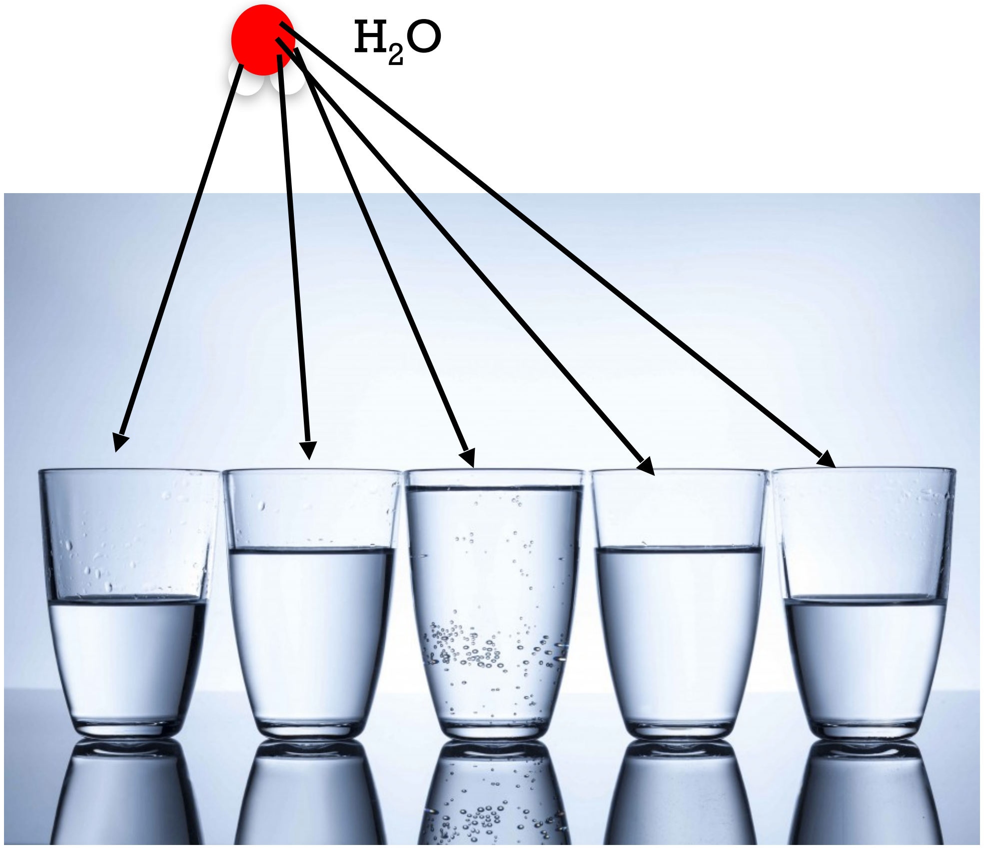


$$F_e = \frac{kq_1q_2}{r^2}$$

Big Idea #1

Properties of Matter

+ Ratio of Masses in a Pure Sample



- All elements and molecules are made up of atoms
- Substances with the same atomic makeup will have same average masses
- The ratio of masses of the same substance is independent of size of the substance
- Molecules with the same atomic makeup (ex: H_2O) will have the same ratio of average atomic masses
  - H_2O_2 ratio would be different than H_2O due to the different chemical makeup

[Video]

LO 1.1: Justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory.

+ Ratio of Masses in a Pure Sample

A 4.50 gram sample of which of the following would have the greatest mass of oxygen?

A. Na_2O (molar mass = 62 g/mol)
B. Li_2O (molar mass = 30 g/mol)
C. MgO (molar mass = 40 g/mol)
D. SrO (molar mass = 108 g/mol

Click reveals answer and explanation.

chemical makeup

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B. Li_2O (molar mass = 30 g/mol)
C. MgO (molar mass = 40 g/mol)
D. SrO (molar mass = 108 g/mol

Answer:
A. 16/62 x 100 = 26%
B. 16/30 x 100 = 53%
C. 16/40 x 100 = 40%
D. 16/104 x 100 = 15%

chemical makeup

LO 1.1: Justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory.

+ Composition of Pure Substances and/or Mixtures

- Percent mass can be used to determine the composition of a substance
  - % mass can also be used to find the empirical formula
- The empirical formula is the simplest formula of a substance
  - It is a ratio between the moles of each element in the substance
  - Quick steps to solve!
    - % to mass, mass to moles, divide by the smallest and multiply 'til whole!)
  - The molecular formula is the actual formula of a substance
    - It is a whole number multiple of the empirical formula

Video

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.

+ Composition of Pure Substances and/

Question:

A compound is determined to contain 14g nitrogen and 32g of oxygen. The empirical formula of the compound is

a. NO
b. N_2O
c. NO_2
d. NO_3
e. N_2O_6

Click reveals answer and explanation.

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.

Composition of Pure Substances and/

Question:

A compound is determined to contain 14g nitrogen and 32g of oxygen. The empirical formula of the compound is

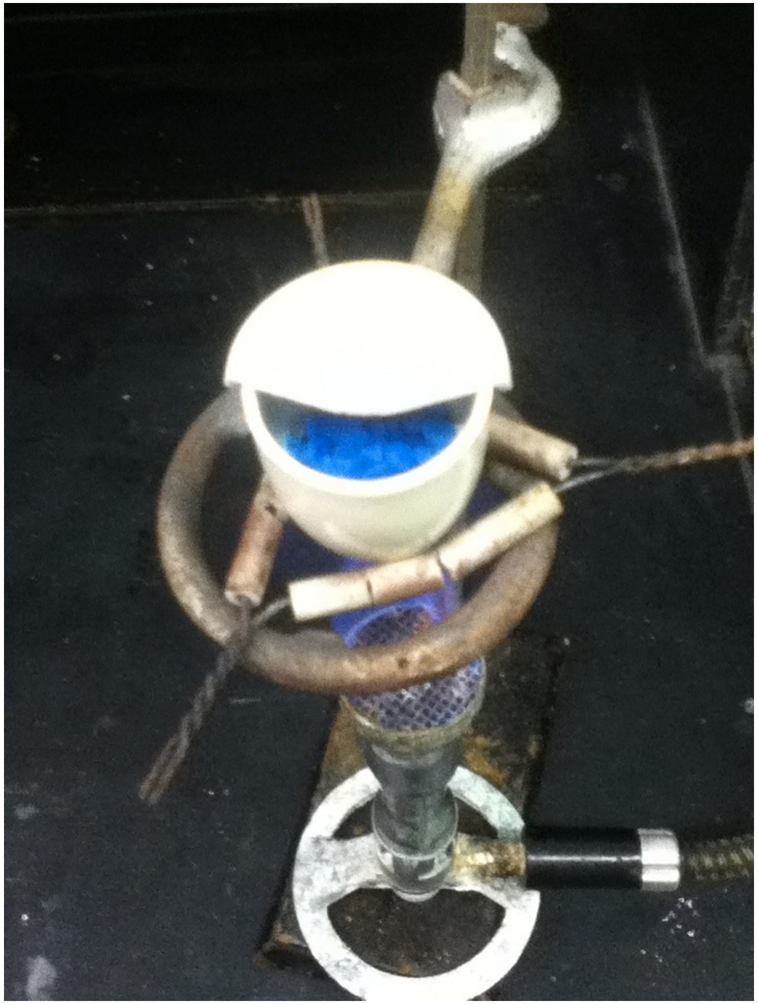
a. NO
b. N_2O
c. NO_2
d. NO_3
e. N_2O_6

Answer:

The correct answer is "c", NO_2. 14g of nitrogen would be 1 mol of nitrogen (14g / 14g mol^{-1}) while 32g of oxygen would be 2 mol of oxygen (32g / 16g mol^{-1}). Therefor the empirical formula should have a ratio of 2 oxygens for every 1 nitrogen, NO_2.

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.

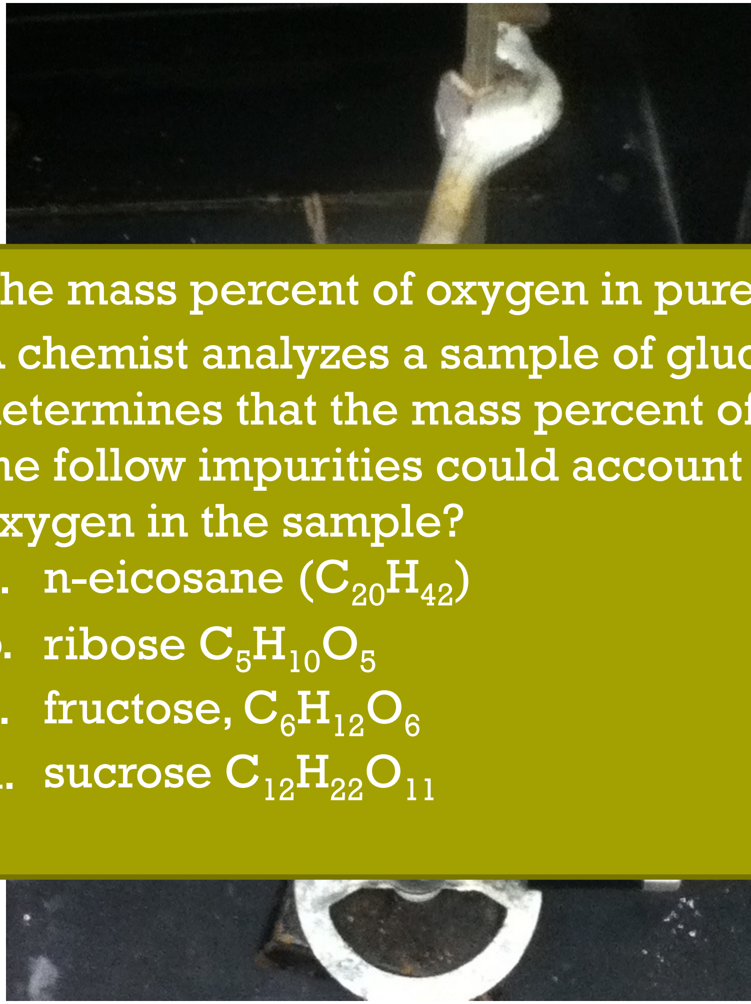
+ Identifying Purity of a Substance



- Impurities in a substance can change the percent composition by mass
- If more of a certain element is added from an impurity, then the percent mass of that element will increase and vice versa
- When heating a hydrate, the substance is heated several times to ensure the water is driven off
  - Then you are simply left with the pure substance and no excess water

LO 1.3: The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.

+ Identifying Purity of a Substance



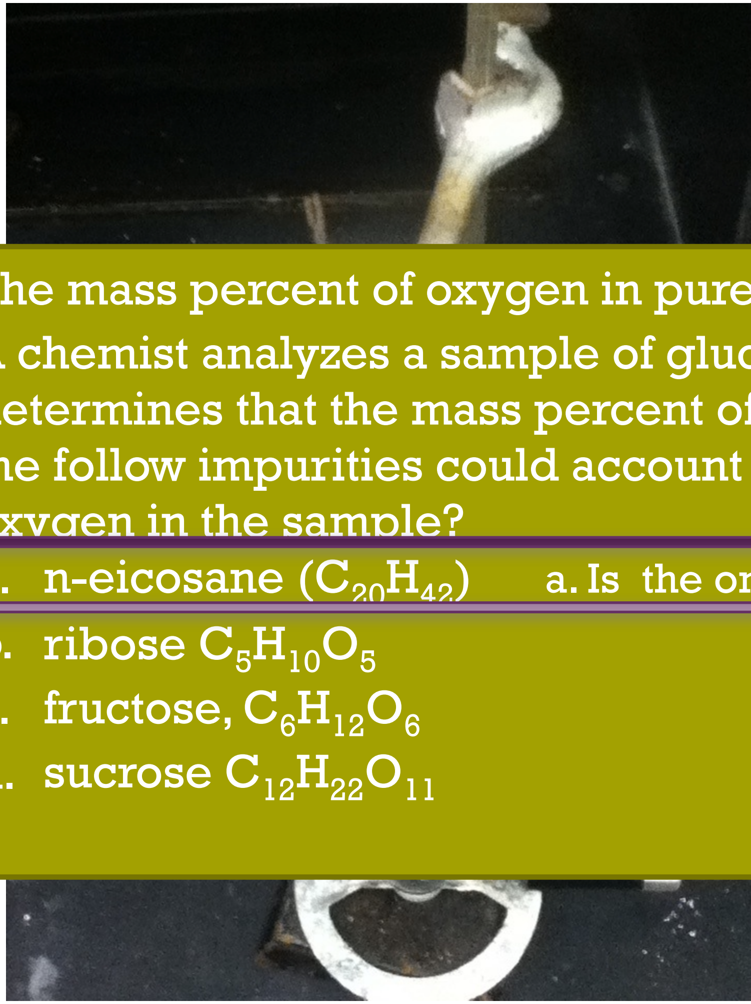
- Impurities in a substance can change the percent composition by mass
- If more of a certain element is

The mass percent of oxygen in pure glucose, $C_6H_{12}O_6$ is 53.3 percent. A chemist analyzes a sample of glucose that contains impurities and determines that the mass percent of oxygen is 49.7 percent. Which of the follow impurities could account for the low mass percent of oxygen in the sample?

a. n-eicosane ($C_{20}H_{42}$)
b. ribose $C_5H_{10}O_5$
c. fructose, $C_6H_{12}O_6$
d. sucrose $C_{12}H_{22}O_{11}$

LO 1.3: The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.

+ Identifying Purity of a Substance



- Impurities in a substance can change the percent composition by mass
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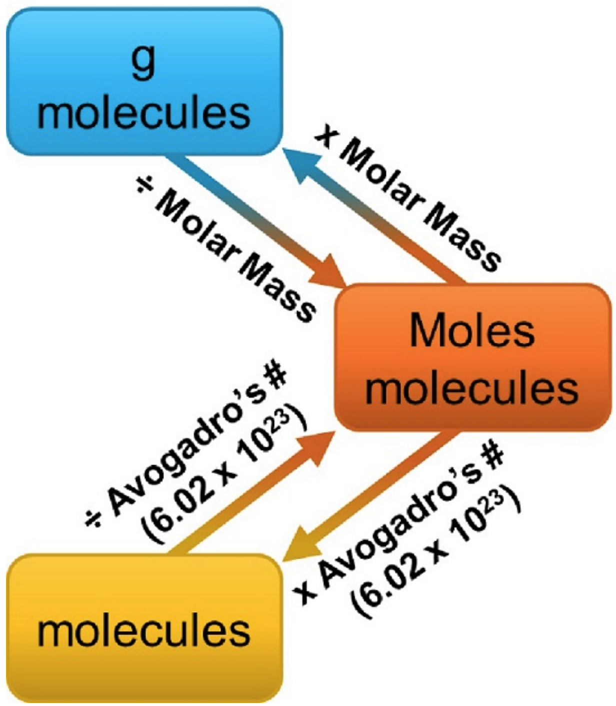
a. n-eicosane ($C_{20}H_{42}$) a. Is the only option with a %O lower than 49.7%
b. ribose $C_5H_{10}O_5$
c. fructose, $C_6H_{12}O_6$
d. sucrose $C_{12}H_{22}O_{11}$

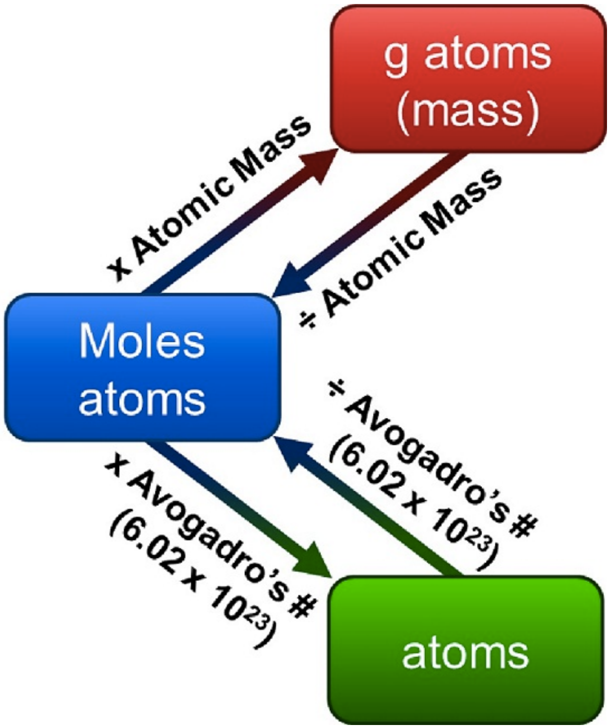
LO 1.3: The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.

+ Mole Calculations

- 1 mole = 6.02 x 10^{23} representative particles
- 1 mole = molar mass of a substance
- 1 mole = 22.4 L of a gas at STP

Video





LO 1.4: The student is able to connect the number of particles, moles, mass and volume of substances to one another, both qualitatively and quantitatively.

+ Mole Calculations

How many moles of carbon are in 88 grams of propane, C_3H_8?

A. 2.0
B. 16.0
C. 6.0
D. 96.0

Click reveals answer and explanation.

LO 1.4: The student is able to connect the number of particles, moles, mass and volume of substances to one another, both qualitatively and quantitatively.

+ Mole Calculations

How many moles of carbon are in 88 grams of propane, C_3H_8?

A. 2.0
B. 16.0
C. 6.0
D. 96.0

Answer: C

Propane has a molar mass of 44, therefore there are 2 moles of propane (88 g/ 44g/mol)

There are 3 moles of carbon in 1 mole of propane, so 2 * 3 = 6 moles of C.

LO 1.4: The student is able to connect the number of particles, moles, mass and volume of substances to one another, both qualitatively and quantitatively.

+ Electronic Structure of the Atom: Electron Configurations

Electron Configurations

	At #	Increasing Energy → 1s	2s	2p	3s	Electron Configuration
H	1	↑				$1s^1$
He	2	↑↓				$1s^2$
Li	3	↑↓	↑			$1s^2 2s^1$
Be	4	↑↓	↑↓			$1s^2 2s^2$
B	5	↑↓	↑↓	↑ | |		$1s^2 2s^2 2p^1$
C	6	↑↓	↑↓	↑ | ↑ |		$1s^2 2s^2 2p^2$
N	7	↑↓	↑↓	↑ | ↑ | ↑		$1s^2 2s^2 2p^3$
O	8	↑↓	↑↓	↑↓ | ↑ | ↑		$1s^2 2s^2 2p^4$
F	9	↑↓	↑↓	↑↓ | ↑↓ | ↑		$1s^2 2s^2 2p^5$
Ne	10	↑↓	↑↓	↑↓ | ↑↓ | ↑↓		$1s^2 2s^2 2p^6$
Na	11	↑↓	↑↓	↑↓ | ↑↓ | ↑↓	↑	$1s^2 2s^2 2p^6 3s^1$ ([Ne]$3s^1$)
Mg	12	↑↓	↑↓	↑↓ | ↑↓ | ↑↓	↑↓	$1s^2 2s^2 2p^6 3s^2$ ([Ne]$3s^2$)

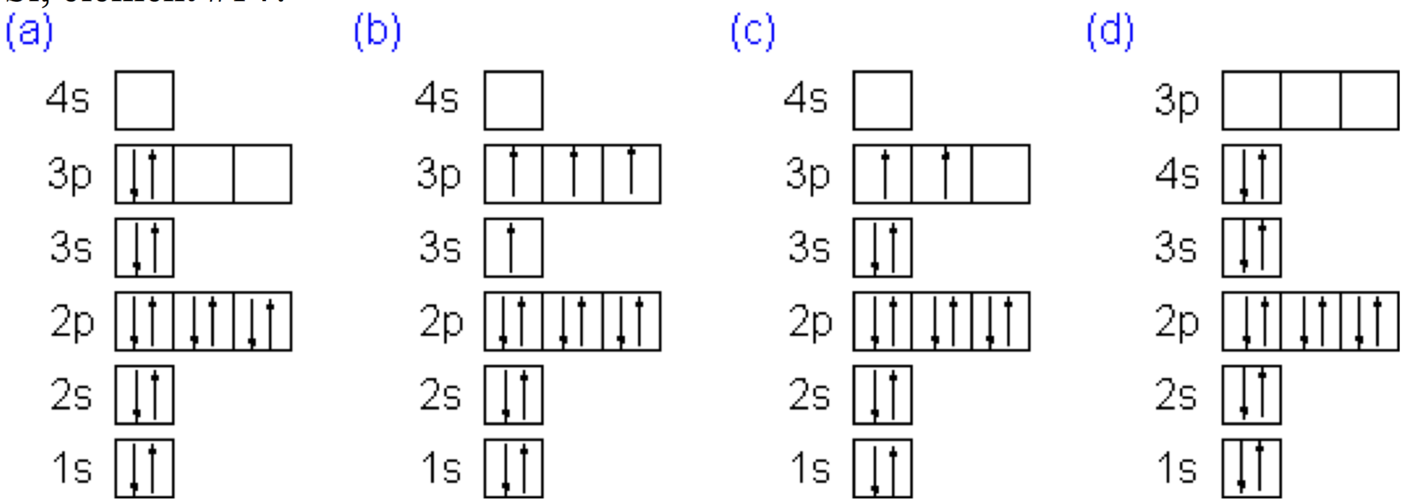
- Electrons in occupy orbitals whose energy level depends on the nuclear charge and average distance to the nucleus
- Electron configurations & orbital diagrams indicate the arrangement of electrons with the lowest energy (most stable):
  - Electrons occupy lowest available energy levels
  - A maximum of two electrons may occupy an energy level
    - Each must have opposite spin (±½)
  - In orbitals of equal energy, electrons maximize parallel unpaired spins

LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.

+ Electronic Structure of the Atom:

H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg

Which of the following electron configurations and orbital diagrams represents Si, element #14?



(a) $1s^2 2s^2 2p^6 3s^2 3p^2$ (b) $1s^2 2s^2 2p^6 3s^1 3p^3$ (c) $1s^2 2s^2 2p^6 3s^2 3p^2$ (d) $1s^2 2s^2 2p^6 3s^2 4s^2$

Click reveals answer and explanation.

LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.

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He
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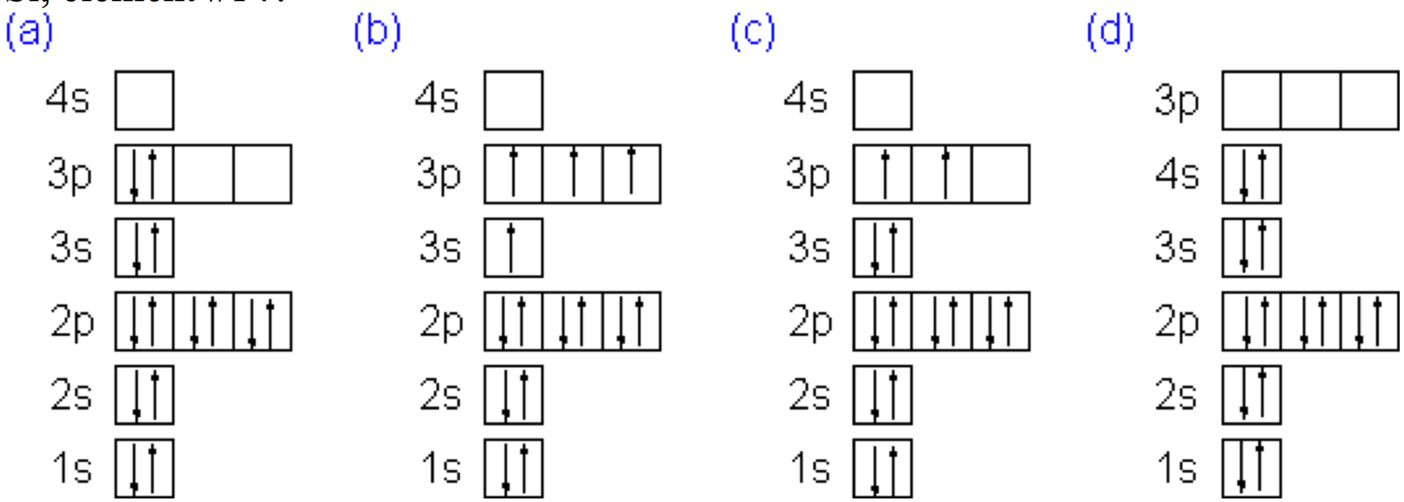
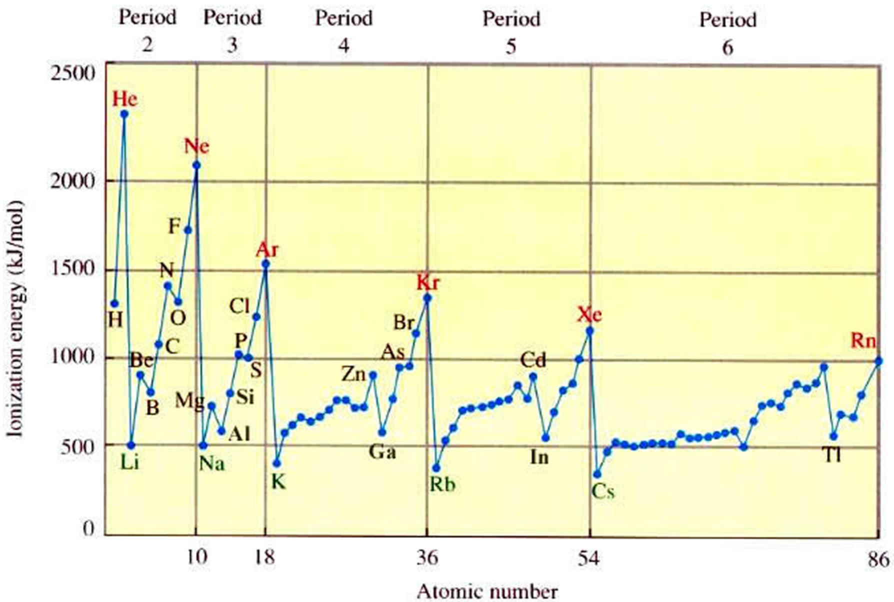


(a) $1s^2 2s^2 2p^6 3s^2 3p^2$ (b) $1s^2 2s^2 2p^6 3s^1 3p^3$ (c) $1s^2 2s^2 2p^6 3s^2 3p^2$ (d) $1s^2 2s^2 2p^6 3s^2 4s^2$

Answer: C. The 11th & 12th electrons occupy the 3s orbital, and the last two electrons occupy the 3p orbitals, and to maximize the unpaired parallel spins, they must individually occupy different 3p orbitals.

LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.

+ Electronic Structure of the Atom: 1st Ionization Energy



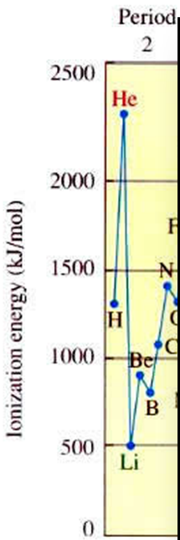
- 1st Ionization Energy Energy (IE) indicates the strength of the coulombic attraction of the outermost, easiest to remove, electron to the nucleus:

$$X(g) + IE \longrightarrow X^{+}(g) + e^{-}$$

- 1st IE generally increases across a period and decreases down a group
  - IE generally increases as #protons increases in same energy level
  - IE decreases as e^{-} in higher energy level: increased shielding, e^{-} farther from nucleus

LO 1.6: The student is able to analyze data relating to electron energies for patterns and relationships.

+ Electronic Structure of the Atom: 1st Ionization Energy



Which of the following groups of elements is arranged correctly in order of increasing first ionization energy?

A. Mg < C < N < F

B. N < Mg < C < F

C. Mg < N < C < F

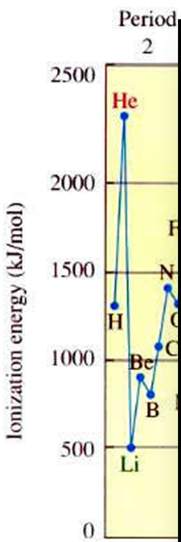
D. F < C < Mg < N

Click reveals answer and explanation.

energy level: increased shielding, e^- farther from nucleus

LO 1.6: The student is able to analyze data relating to electron energies for patterns and relationships.

+ Electronic Structure of the Atom: 1^{st} Ionization Energy



Which of the following groups of elements is arranged correctly in order of increasing first ionization energy?

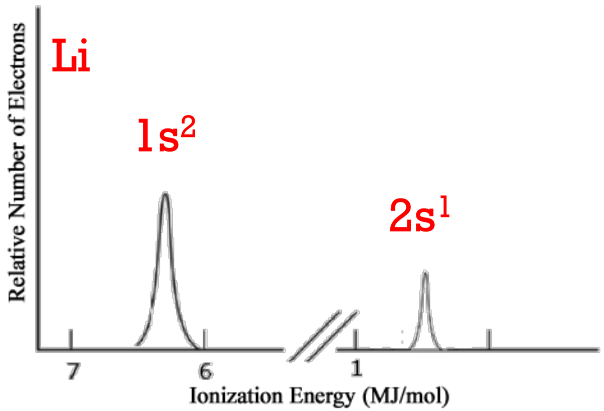
A. Mg < C < N < F
B. N < Mg < C < F
C. Mg < N < C < F
D. F < C < Mg < N

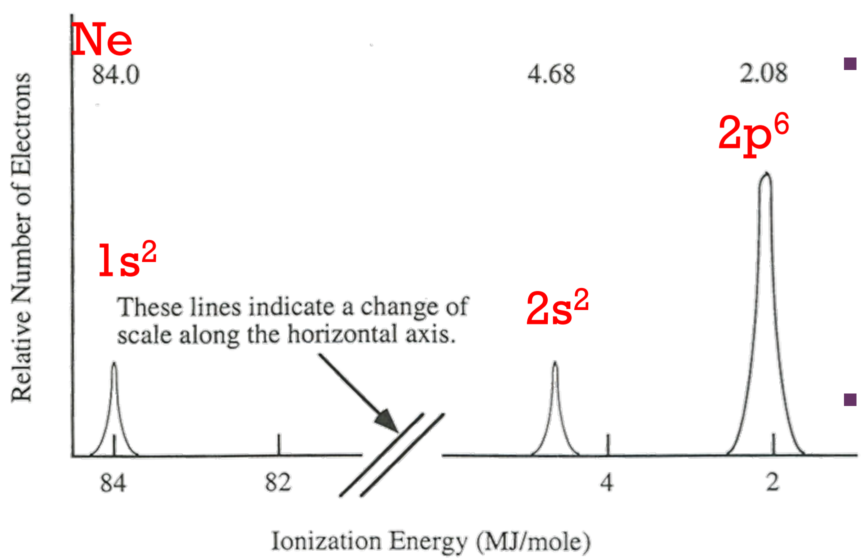
Answer: A. Within the 2^{nd} period, increasing nuclear charge from C – N – F increases the coulombic attraction of the electrons to the nucleus. Mg has a lower IE than its 2^{nd} period counterpart, Be, since its valence electrons are in a higher energy level that is better shielded, so its 1^{st} IE must also be lower than that of C.

energy level: increased shielding, e^- farther from nucleus

LO 1.6: The student is able to analyze data relating to electron energies for patterns and relationships.

+ Electronic Structure of the Atom: Photoelectron Spectroscopy (PES)





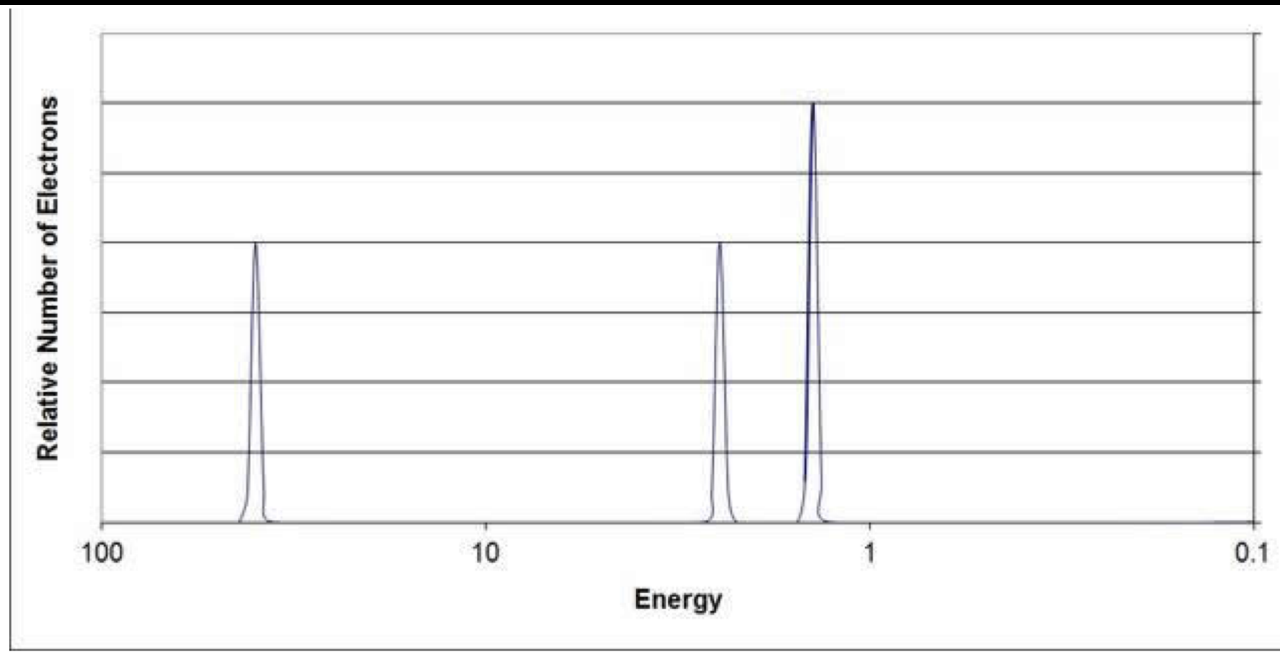
- PES uses high-energy (X-ray) photon to excite *random* e^- from atom
- KE of ejected electron indicates *binding energy* (coulombic attraction) to nucleus:

$$BE = h\varpi_{photon} - KE$$

- Direct measurement of energy and number of each electron
  - Lower energy levels have higher BE
  - Signal size proportional to number of e^- in energy level
- Elements with more protons have stronger coulombic attraction, higher BE at each energy level

LO 1.7: The student is able to describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb's law to construct explanations of how the energies of electrons within shells in atoms vary.

+ Electronic Structure of the Atom: P



Which element could be represented by the complete PES spectrum above?

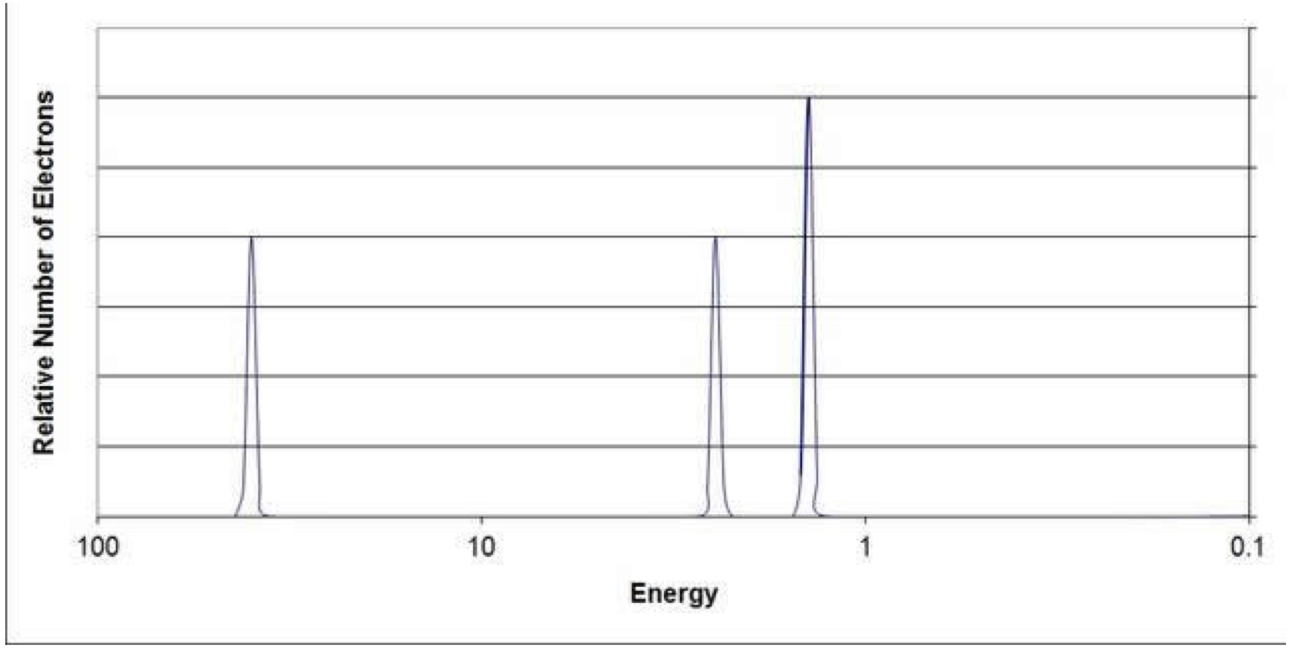
A. Li B. B C. N D. O E. Ne

Click reveals answer and explanation.

LO 1.7: g PES data, ionization energy data, and/or Coulomb's law to construct explanations of how the energies of electrons within shells in atoms vary.

+ Electronic Structure of the Atom: [redacted]

P[redacted]



Which element could be represented by the complete PES spectrum above?

A. Li B. B C. N D. O E. Ne

Answer: C. The first peak at about 60 (units are MJ/mol) represents the two 1s electrons, the second peak is the two 2s electrons, and the third peak represents three 2p electrons.

LO 1.7: [redacted] g PES data, ionization energy data, and/or Coulomb's law to construct explanations of how the energies of electrons within shells in atoms vary.

+ Electronic Structure of the Atom: Higher Ionization Energies

Ionization Energies (kJ/mol)								
	1st	2nd	3rd	4th	5th	6th	7th	8th
H	1312							
He	2372	5250						
Li	520	7297	11810					
Be	899	1757	14845	21000				
B	800	2426	3659	25020	32820			
C	1086	2352	4619	6221	37820	47260		
N	1402	2855	4576	7473	9442	53250	64340	
O	1314	3388	5296	7467	10987	13320	71320	84070
F	1680	3375	6045	8408	11020	15160	17860	92010
Ne	2080	3963	6130	9361	12180	15240	20000	23070
Na	496	4563	6913	9541	13350	16600	20113	25666
Mg	737	1450	7731	10545	13627	17995	21700	25662

Inner Core Electrons

- 2^{nd} & subsequent IE's increase as coulombic attraction of remaining e^-'s to nucleus increases

$$X^+ + IE \longrightarrow X^{2+} + e^-$$

$$X^{2+} + IE \longrightarrow X^{3+} + e^-$$

- Large jump in IE when removing less-shielded core electrons

LO 1.8: The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies.

+ Electronic Structure of the Atom: Higher Ionization Energies

- 2nd & subsequent IE's

H								
He								
Li								
Be								
B								
C								
N								
O								
F								
Ne								
Na								
Mg	737	1450	7731	10545	13627	17995	21700	25662

Ionization Energies for element X (kJ mol^{-1})				
First	Second	Third	Fourth	Five
1086	2352	4619	6221	37820

The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

A. Li B. Be C. B D. C E. P

Click reveals answer and explanation.

LO 1.8: The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies.

+ Electronic Structure of the Atom: Higher Ionization Energies

H								
He								
Li								
Be								
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1086	2352	4619	6221	37820

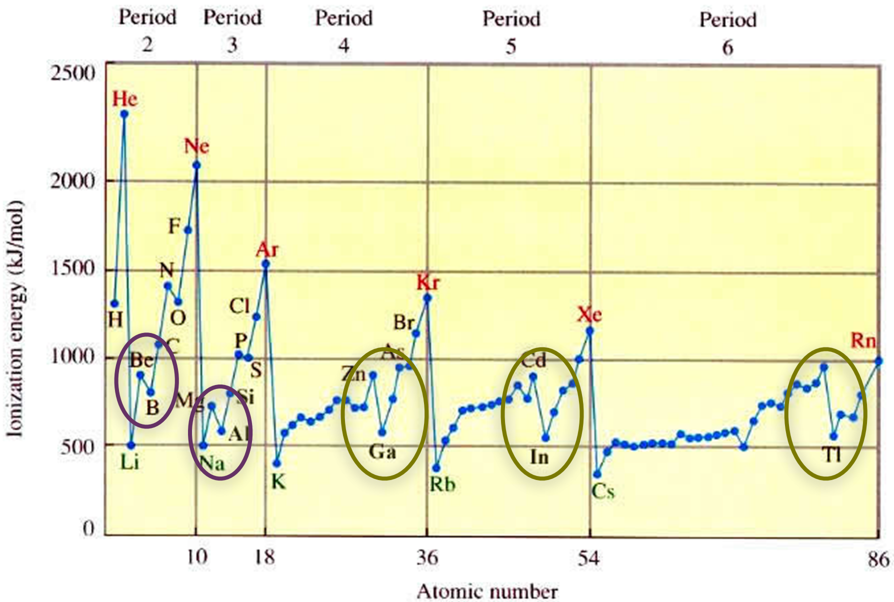
The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

A. Li B. Be C. B D. C E. P

Answer: D. There is a large increase in IE from IE_4 to IE_5, indicating that the element has 4 valence electrons and is in group IVA. Carbon is the only listed element in group IVA.

LO 1.8: The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies.

+ Electronic Structure of the Atom: 1st Ionization Energy Irregularities

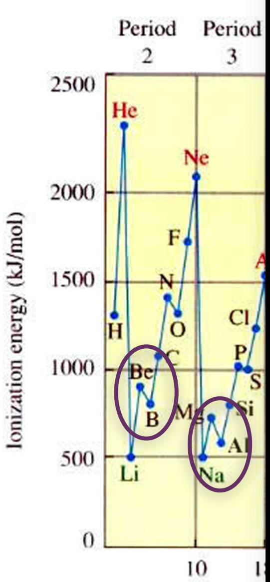


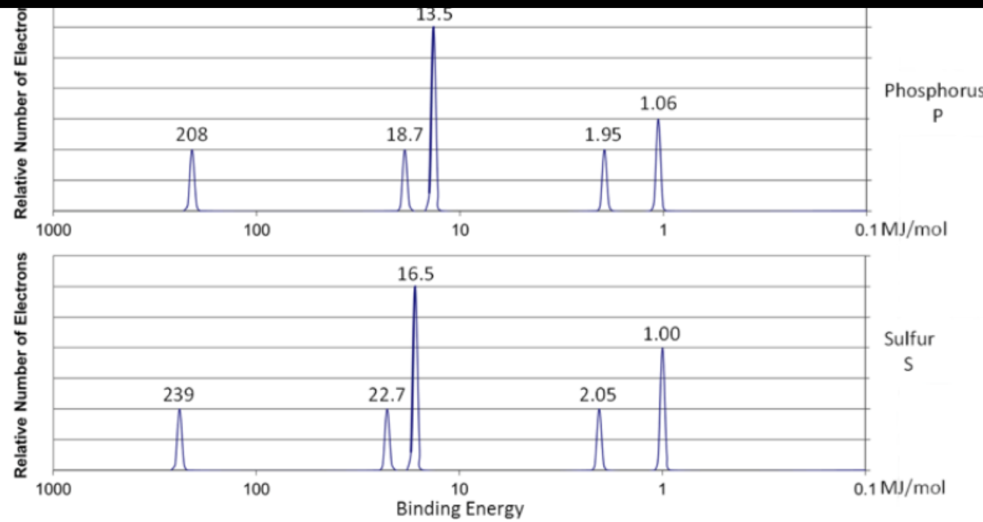
- 1st Ionization Energy Energy (IE) decreases from Be to B and Mg to Al
  - Electron in 2p or 3p shielded by $2s^2$ or $3s^2$ electrons, decreasing coulombic attraction despite additional proton in nucleus.
  - Same effect seen in $3d^{10}$-4p, $4d^{10}$-5p and $5d^{10}$-6p
- 1st Ionization Energy decreases from N to O and P to S
  - np^4 contains first paired p electrons, e^--e^- repulsion decreases coulombic attraction despite additional proton

LO 1.8: The student is able to explain the distribution of electrons using Coulomb's law to analyze measured energies.

+ Elec

1st Io





iven the photoelectron spectra above for phosphorus, P, and sulfur, S, which of the following est explains why the 2p peak for S is further to the left than the 2p peak for P, but the 3p peak or S is further to the right than the 3p peak for P?

. S has a greater effective nuclear charge than P, and the 3p sublevel in S has greater electron repulsions than in P.
. S has a greater effective nuclear charge than P, and the 3p sublevel is more heavily shielded in S than in P.
. S has a greater number of electrons than P, so the third energy level is further from the nucleus in S than in P.
. S has a greater number of electrons than P, so the Coulombic attraction between the electron cloud and the nucleus is greater in S than in P.

Click reveals answer and explanation.

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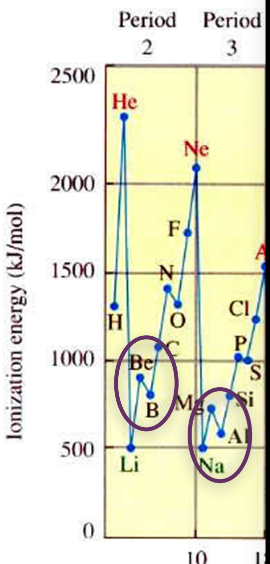
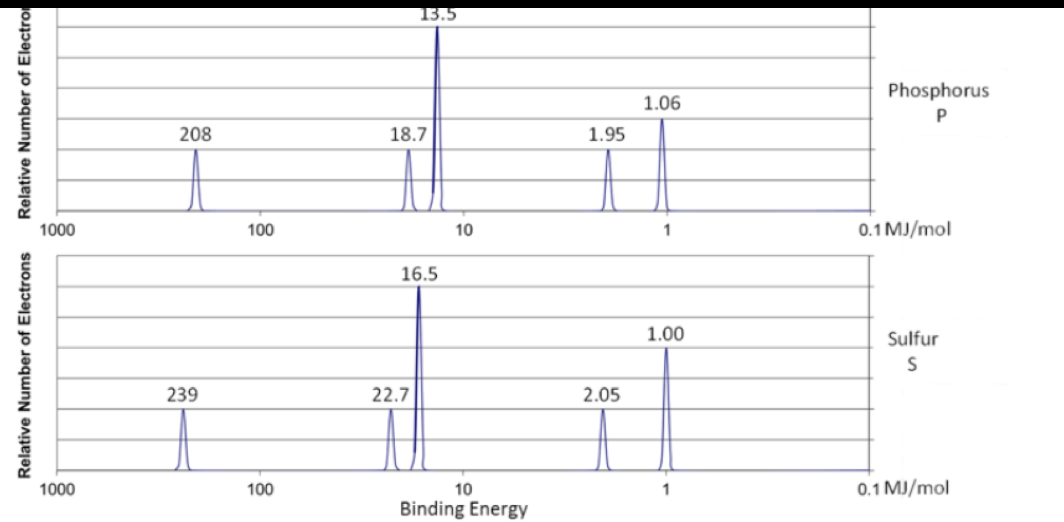
LO 1.8: The stu s law to analyze measured energies.

+Elec

1st Io





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. S has a greater number of electrons than P, so the third energy level is further from the nucleus in S than in P.
. S has a greater number of electrons than P, so the Coulombic attraction between the electron cloud and the nucleus is greater in S than in P.

nswer: A. S has one more proton than P, so a higher effective nuclear charge. However, due to he $3p^4$ configuration of S, it experiences e^--e^- repulsion due to the paired 3p electrons that are ot present in the $3p^3$ configuration of P. This reduces the coulombic attraction of the 3p

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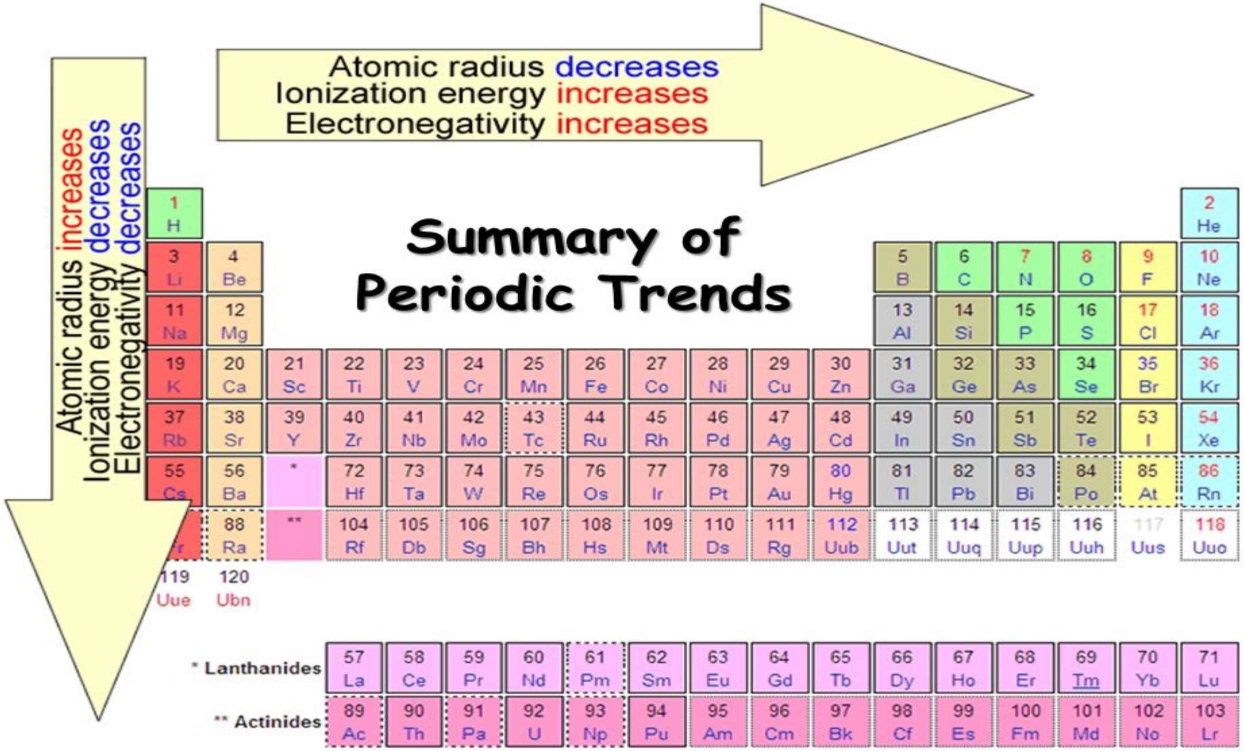
LO 1.8: The stu s law to analyze measured energies.

Predictions with Periodic Trends

Video



Coulomb's Law – Gives the electric force between two point charges.

$$F = k\frac{q_1 q_2}{r^2}$$

Inverse Square Law

k = Coulomb's Constant = 9.0×10^9 Nm^2/C^2

q_1 = charge on mass 1

q_2 = charge on mass 2

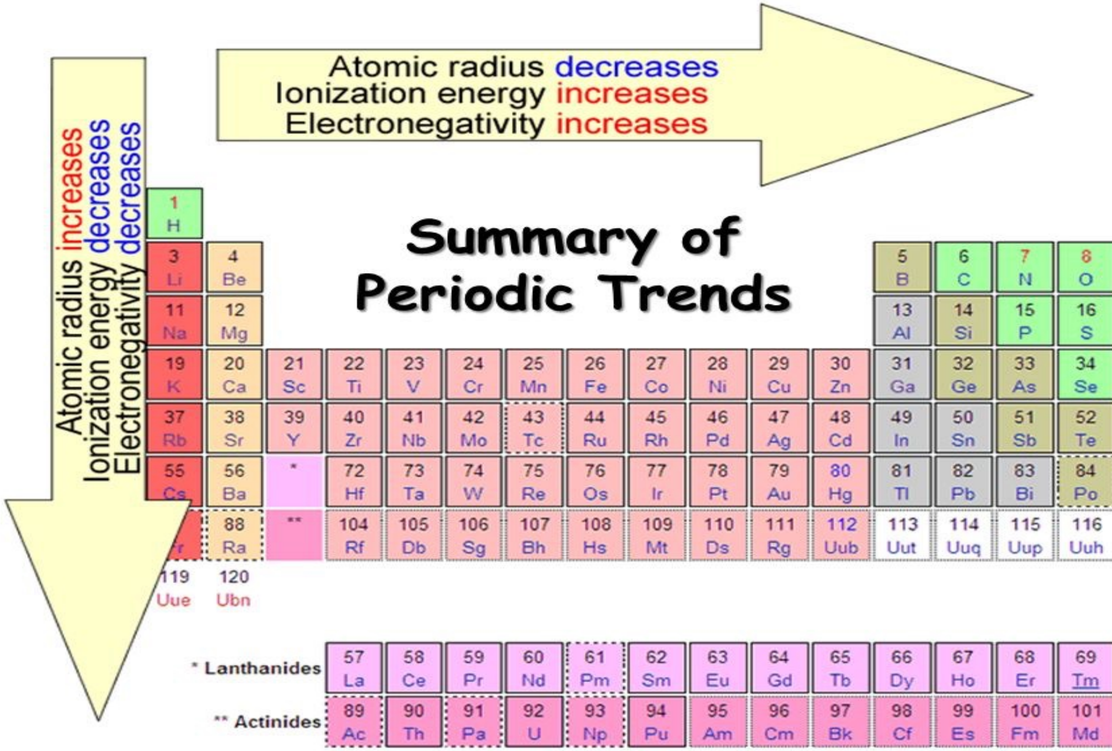
r = the distance between the two charges

The electric force is much stronger than the gravitational force.

- The following explains these trends:
  - Electrons attracted to the protons in the nucleus of an atom
    - So the closer an electron is to a nucleus, the more strongly it is attracted (Coulomb's law)
    - The more protons in a nucleus (effective nuclear force), the more strongly it attracts electrons
  - Electrons are repelled by other electrons in an atom. If valence electrons are shielded from nucleus by other electrons, you will have less attraction of the nucleus (again Coulomb's law- greater the atomic radius, the greater the distance)

L.O. 1.9 The student is able to predict and/or justify trends in atomic properties based on location on periodic table and/or the shell model

Predictions with Periodic Trends



Coulomb's Law – Gives the electric forc
between two point charges.

$$F = k\frac{q_1 q_2}{r^2}$$

Inverse Square Law

k = Coulomb's Constant = $9.0\times10^{9}\ Nm^2/C^2$

q_1 = charge on mass 1

q_2 = charge on mass 2

r = the distance between the two charges

The electric force is much stronger than the gravitational force.

- The following explains these trends:
  - Electrons attracted to the protons in the nucleus of ar
    - So the closer an electron is to a nucleus, the more
    - The more protons in a nucleus (effective nuclear force), the more strongly it attracts electrons
  - Electrons are repelled by other electrons in an atom. If valence electrons are shielded from nucleus by other electrons, you will have less attraction of the nucleus (again Coulomb's law- greater the atomic radius, the greater the distance)

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Predictions with Periodic Trends

Question:

Given the atomic radius and first ionization energy of sodium in the chart below which pair of values would be the most likely values for magnesium?

Elements	First ionization Energy (kJ/mol)	Atomic Radius (pm)
Sodium	495.8	180
Magnesium		

a. 737.7 kJ/mol, 150 pm
b. 737.7 kJ/mol, 200 pm
c. 290.4 kJ/mol, 150 pm
d. 290.4 kJ/mol, 200 pm

Click reveals answer and explanation.

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's law-

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Predictions with Periodic Trends

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b. 737.7 kJ/mol, 200 pm
c. 290.4 kJ/mol, 150 pm
d. 290.4 kJ/mol, 200 pm

Answer:

The correct answer is "a", 737.7 kJ/mol, 150 pm. Magnesium has one more proton in its nucleus than sodium. The additional proton attracts electrons more strongly making the ionization energy higher and the radius smaller.

L.O. 1.9 The student is able to predict and/or justify trends in atomic properties based on location on periodic table and/or the shell model

Chemical Reactivity

- **Using Trends**
- Nonmetals have higher electronegativities than metals --> causes the formation of ionic solids
- Compounds formed between nonmetals are **molecular**
  - Usually gases, liquids, or volatile solids at room temperature
- Elements in the 3rd period and below can accommodate a larger number of bonds
- The first element in a group (upper most element of a group) forms pi bonds more easily (most significant in 2nd row, non-metals)
  - Accounts for stronger bonds in molecules containing these elements
  - Major factor in determining the structures of compounds formed from these elements
- Elements in periods 3-6 tend to form only single bonds
- Reactivity tends to increase as you go down a group for metals and up a group for non-metals.

L.O. 1.10: Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity

+ Chemical Reactivity

- **Using Trends**
- Nonmetals ha … -->
  causes the for
- Compounds f
  - Usually gase
- Elements in th … e a
  larger numbe
- The first elem … roup)
  forms pi bonc … , non-
  metals)
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    elements
  - Major factor … med
    from these el
- Elements in p
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46) Of the elements below, ___________ is the most chemically reactive.

A) sodium

B) barium

C) calcium

D) cesium

E) magnesium

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+ Chemical Reactivity

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Chemical Properties within a Group and across a Period

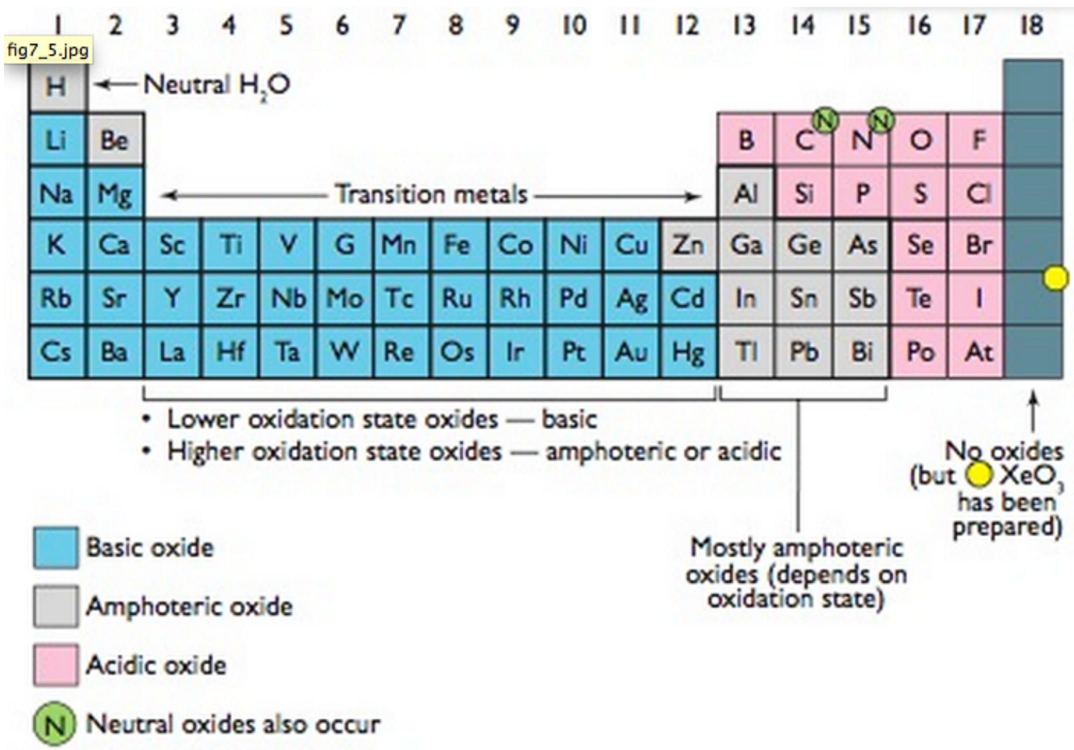


Figure 7.5
The periodic table shows that metallic oxides are mostly basic and that non-metallic oxides are mostly acidic. The elements with amphoteric oxides lie between th attracts two groupings.

- Group 1 metals more reactive than group 2 metals

[Video]

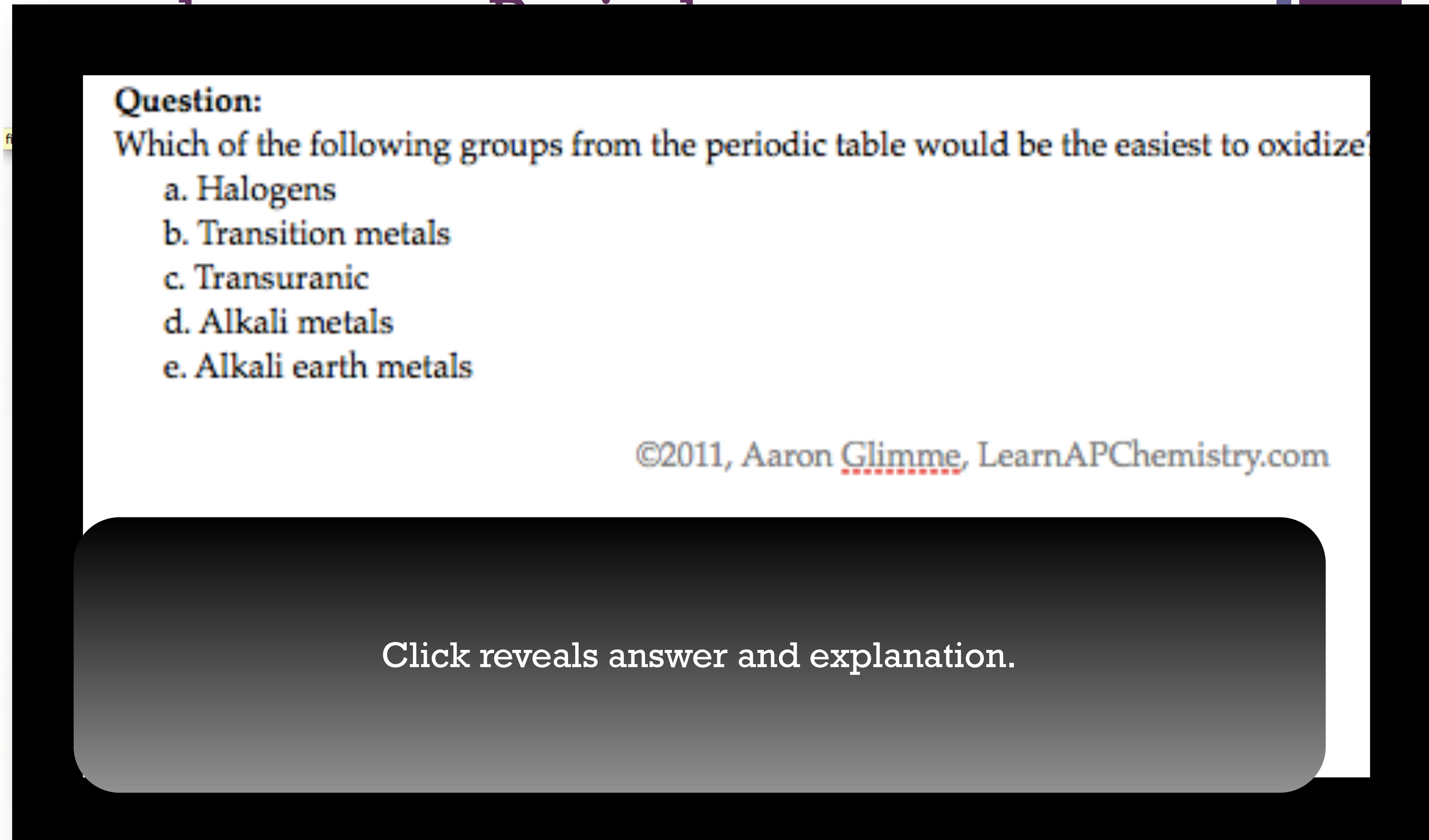
- Reactivity increases as you go down a group
- Metals on left form basic oxides
  - Ex. $Na_2O + H_2O \rightarrow 2\ NaOH$
- Nonmetals on right form form acidic oxides
  - Ex. $SO_3 + H_2O \rightarrow H_2SO_4$
- Elements in the middle, like Al, Ga, etc can behave amphoterically

its

- If SiO_2 can be a ceramic then SnO_2 may be as well since both in the same group

LO 1.11: Analyze data, based on periodicity & properties of binary compounds, to identify patterns & generate hypotheses related to molecular design of compounds

+ Chemical Properties within a Group


Question:
Which of the following groups from the periodic table would be the easiest to oxidize?
a. Halogens
b. Transition metals
c. Transuranic
d. Alkali metals
e. Alkali earth metals

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both in the same group

LO 1.11: Analyze data, based on periodicity & properties of binary compounds, to identify patterns & generate hypotheses related to molecular design of compounds

+ Chemical Properties within a Group

Question:
Which of the following groups from the periodic table would be the easiest to oxidize?

a. Halogens
b. Transition metals
c. Transuranic
d. Alkali metals
e. Alkali earth metals

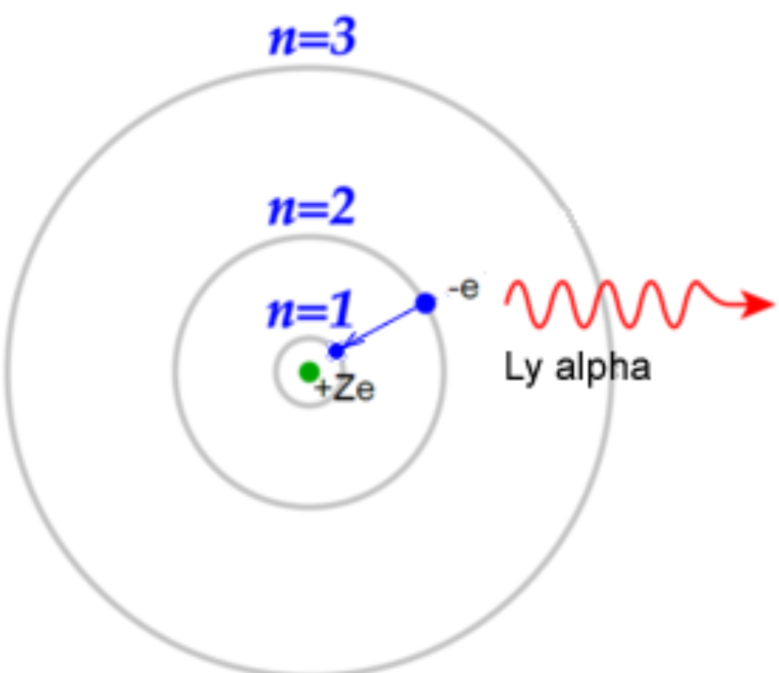
Answer:
The correct answer is *d*. Oxidation involves the loss of electrons, so the group of elements that has the lowest ionization energy would be the easiest to oxidize. The alkali metals have the lowest ionization energy due to the low number of protons compared to the energy level of their lone valence electron.

both in the same group

LO 1.11: Analyze data, based on periodicity & properties of binary compounds, to identify patterns & generate hypotheses related to molecular design of compounds

+ Classic Shell Model of Atom vs Quantum Mechanical Model

Shell Model - Bohr



Developed by Schrodinger and the position of an electron is now represented by a wave equation

- Most ***probable*** place of finding an electron is called an **ORBITAL** (90% probability)
- Each orbital can only hold 2 electrons with opposing spins (S, P, D & F orbitals)

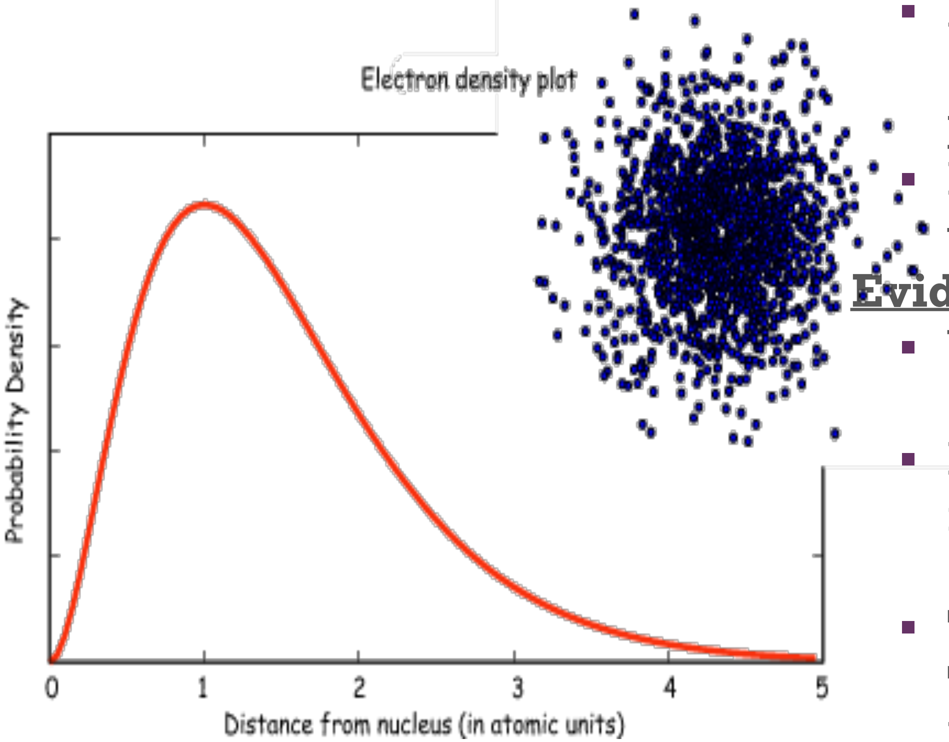
Evidence for this theory:

- Work of DeBroglie and PLanck that electron had wavelike characteristics
- Heisenberg Uncertainty Principle - impossible to predict exact location of electron- contradicted Bohr
- This new evidence caused the Shell Theory to be replaced by the Quantum Mechanical Model of the atom

LO 1.12: Explain why data suggests (or not) the need to refine a model from a classical shell model with the quantum mechanical model

+ Classic Shell Model of Atom vs Quantum Mechanical Model

Quantum Mechanical Model



Developed by Schrodinger and the position of an electron is now represented by a wave equation [Video]

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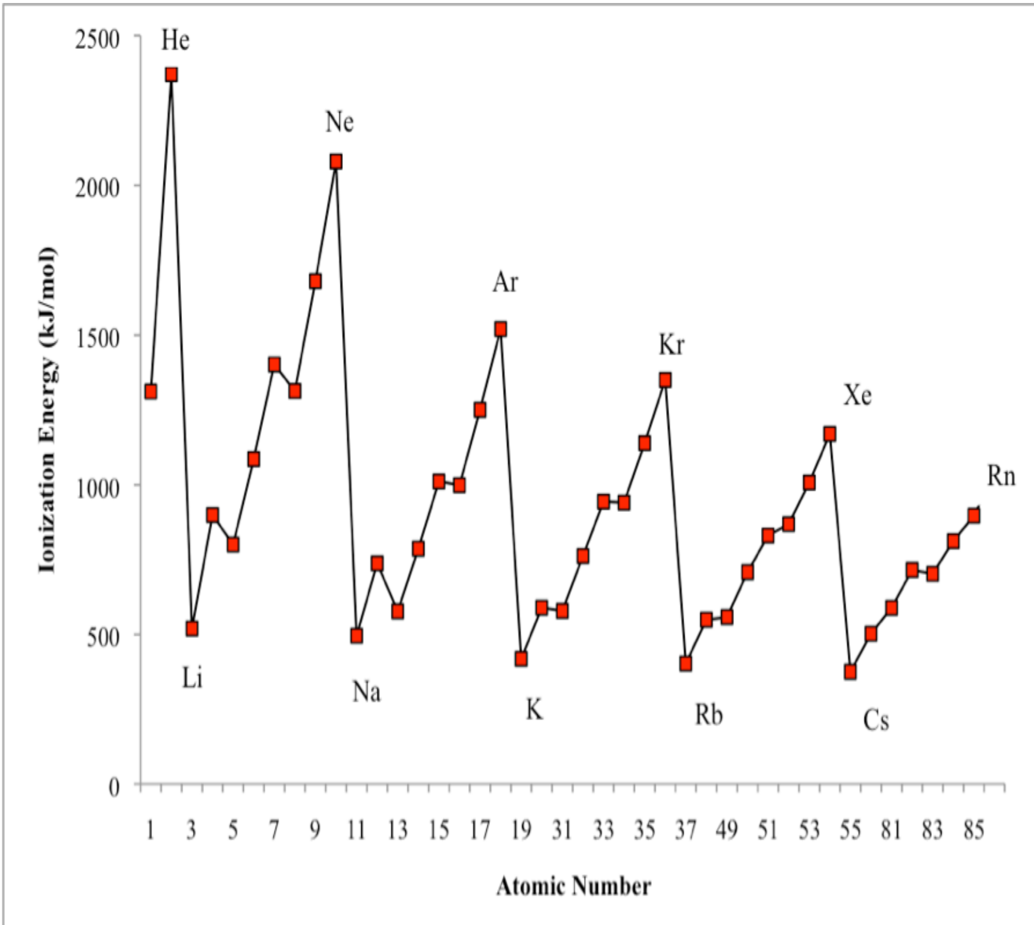
+ Shell Model is consistent with Ionization Energy Data



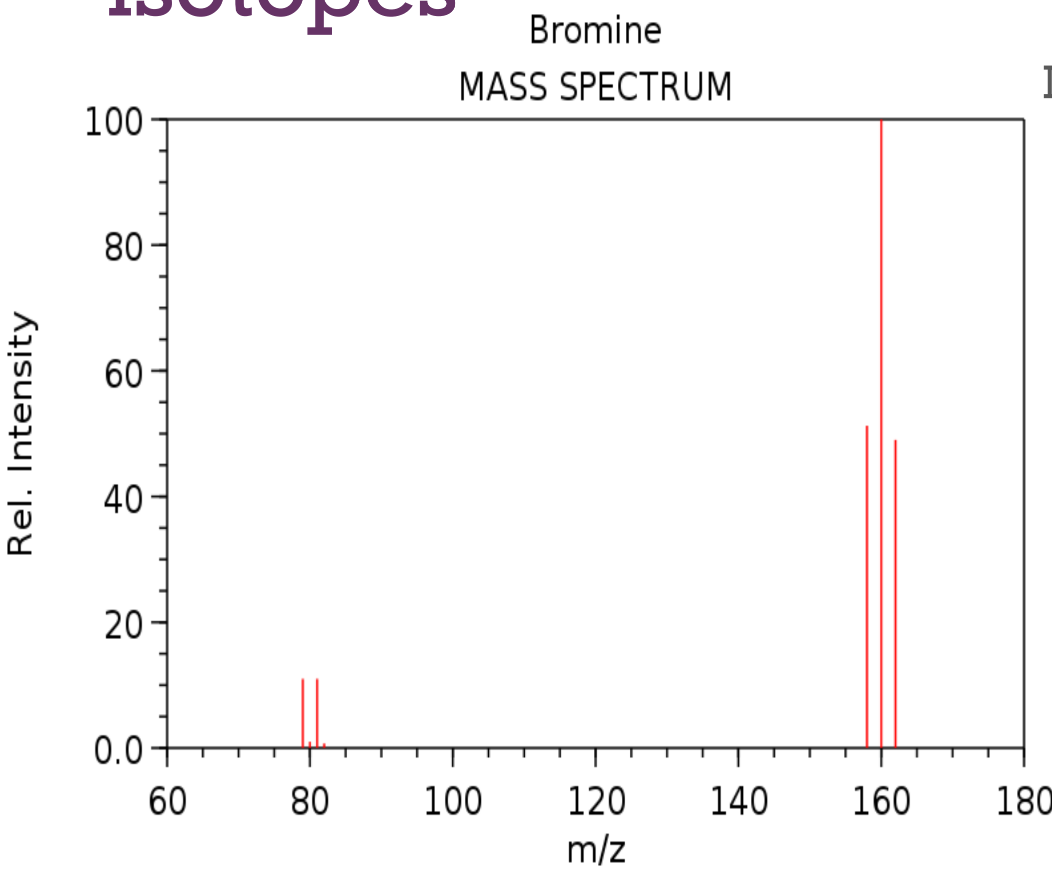
The patterns shown by the IE graph can be explained by Coulomb's law

- As atomic number increases, would expect the ionization energy to constantly increase
- Graph shows that this is NOT observed. WHY NOT?
- The data implies that a shell become full at the end of each period
- Therefore the next electron added must be in a new shell farther away from the nucleus.
- This is supported by the fact that the ionization energy drops despite the addition positive charge in the nucleus

LO: 1.13 Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence

Source

+
Mass Spectrometry - evidence for isotopes



NIST Chemistry WebBook (http://webbook.nist.gov/chemistry)

Video

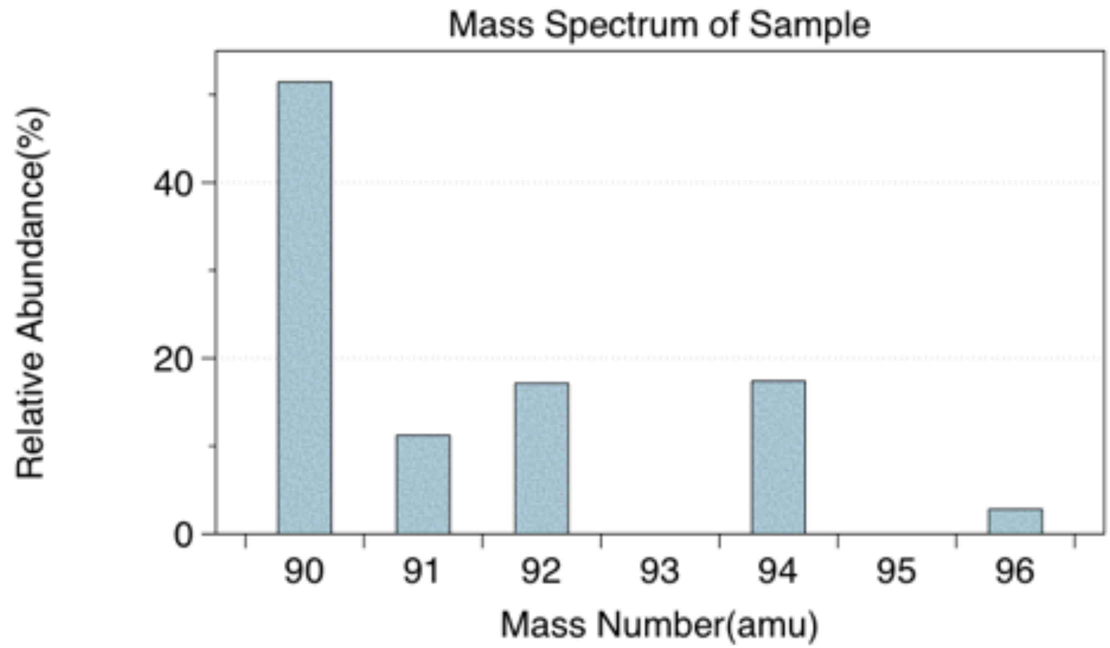
Mass spectrometry showed that elements have isotopes

- This contradicted Dalton's early model of the atom which stated that all atoms of an element are identical
- 3 Br_2 & two Br isotopes shown in diagram
- The average atomic mass of the element can be estimated from mass spectroscopy

$$\text{Average Atomic Mass} = \frac{\sum(\text{mass of isotope} \times \%\,\text{natural abundance})}{100}$$

LO 1.14: The student is able to use the data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element

Question:



Both Zr and Nb have similar average atomic masses. Above is the mass spectrum sample that was believed to have both Zr and Nb. Which of the following stateme would be the best explanation for deciding that the sample contained only Zr?

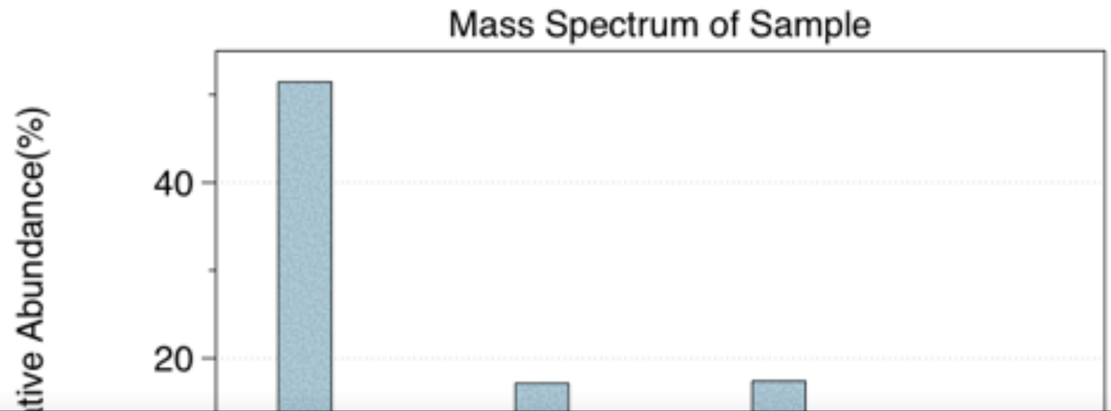
a. Both elements will form ions with many different charges.
b. Zr has 2 unpaired electrons while Nb has 3.
c. Zr has a lower first ionization energy than Nb.
d. Nb has only one stable isotope with a mass of 93 amu.

Rel. Intensity

NIST

LO
ele

Question:



Answer:

The correct answer is "d" Nb has only one stable isotope with a mass of 93 amu. While ll of the statements are true only answer d would indicate that Nb is missing from the ample. If Nb's stable isotope has a mass of 93 amu we would expect some peak at that nass in the mass spectrum. Since there were no atoms measured with that mass, we car

a. Both elements will form ions with many different charges.
b. Zr has 2 unpaired electrons while Nb has 3.
c. Zr has a lower first ionization energy than Nb.
d. Nb has only one stable isotope with a mass of 93 amu.

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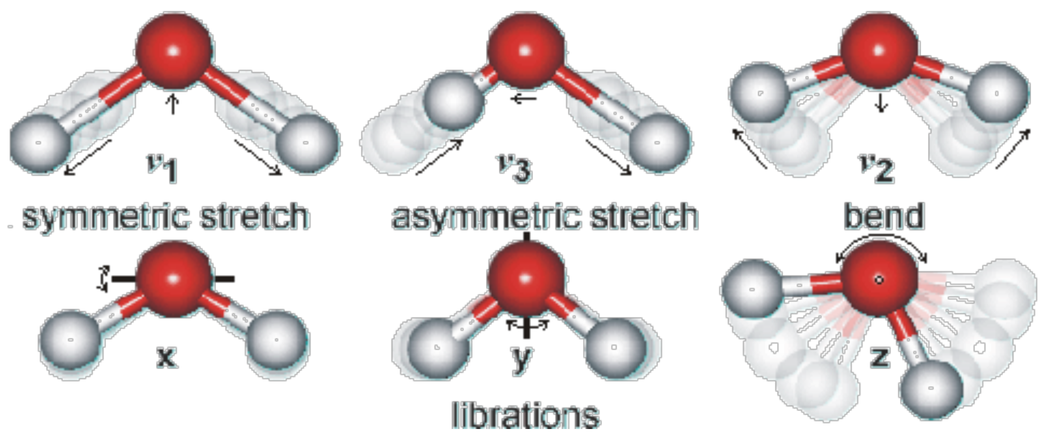
+ Using Spectroscopy to measure properties associated with vibrational or electronic motions of molecules

IR Video
UV Video

IR Radiation - detects different types of bonds by analyzing molecular vibrations

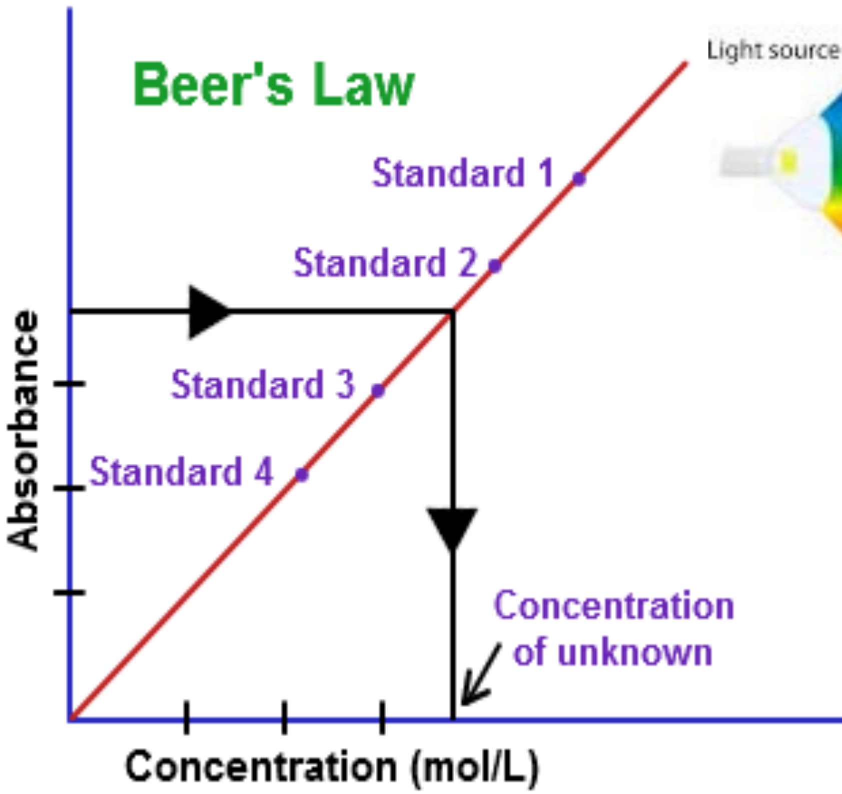


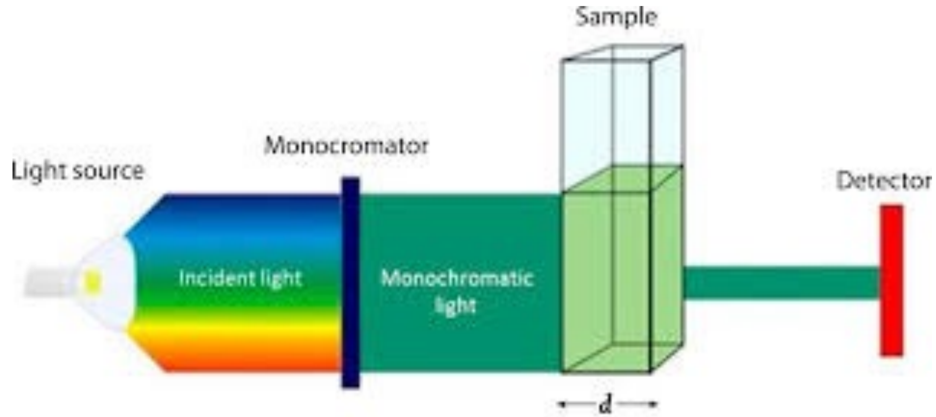
UV or X-Ray Radiation

- Photoelectron Spectroscopy(PES)
- Causes electron transitions
- Transitions provides info on electron configurations

LO: 1.15 Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules

Beer-Lambert Law - used to measure the concentration of ***colored*** solutions





$$A = abc$$

A = absorbance

a = molar absorptivity (constant for material being tested)

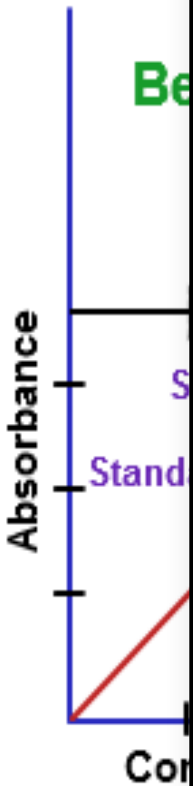
b = path length (cuvette = 1 cm)

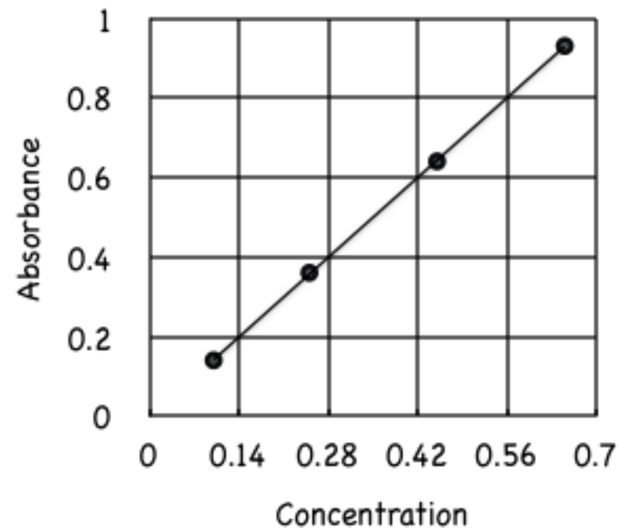
c = concentration

- Taken at fixed wavelength

LO1.16: Design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in solution

+ Bee… the…





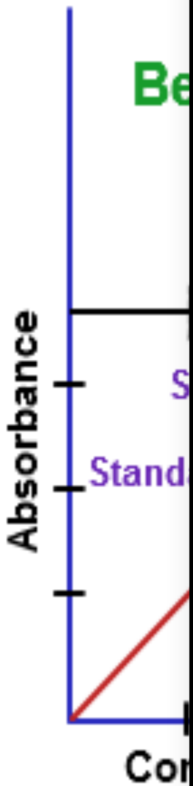
Using the absorbance vs. concentration graph given above. A student is trying to determine the concentration of an unknown substance. If the student measures the absorbance to be 0.4 what would be the concentration of the unknown?

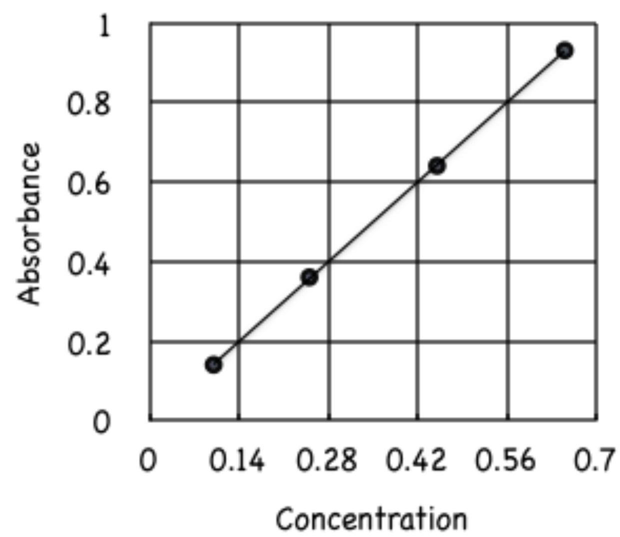
a. 0.04
b. 0.28
c. 0.40
d. 0.42
e. 0.56

Click reveals answer and explanation.

LO1.16: De… …sorption of light to d…

+ Bee
the





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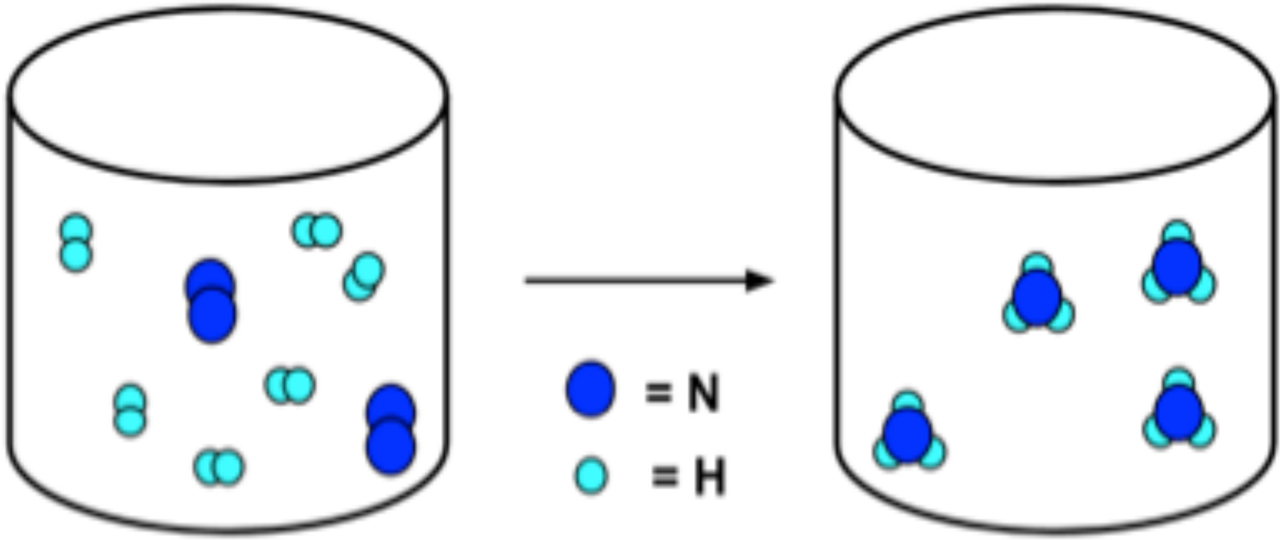
a. 0.04
b. 0.28
c. 0.40
d. 0.42
e. 0.56

Answer:
The correct answer is "b" 0.28. Based on the Beer-Lambert law, for small concentration ranges there is a linear relationship between absorbance and concentration. For an

or

LO1.16: De … absorption of light to d

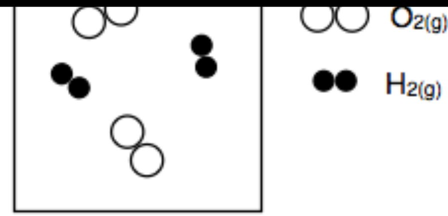
Law of Conservation of Mass



$$N_2 + 3H_2 \rightarrow 2NH_3$$

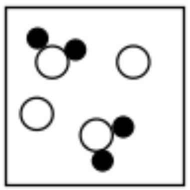
LO1.17: Express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings

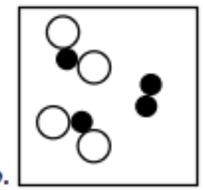
+ Lav

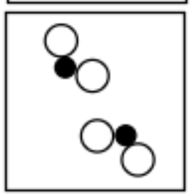


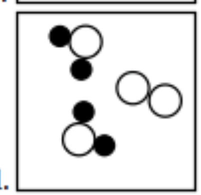
he picture above is a representation of H2(g) and O2(g) in a sealed container. Which of
he following pictures would be the best representation of the products if the reaction
elow were to run to completion?

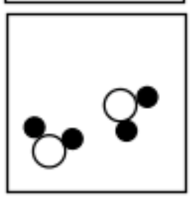
$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)}$$

a. 

b. 

c. 

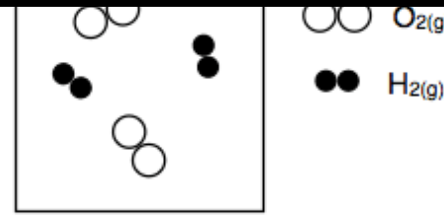
d. 

e. 

Click reveals answer and explanation.

LO1.17: Ex ... atively using
symbolic re

+ Law



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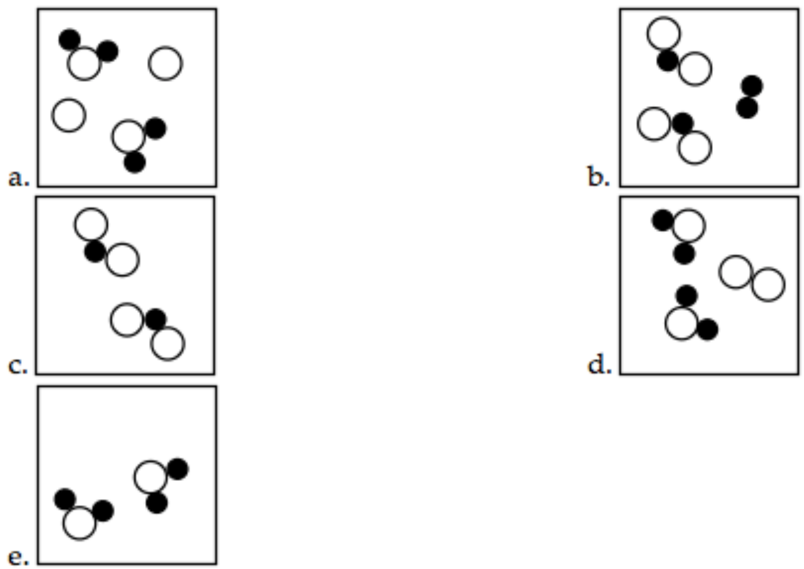


nswer:
he correct answer is "d". In the balanced chemical equation we need 2 hydrogen atoms
or each oxygen atom to form water. We will use up all the hydrogen molecules and

LO1.17: Ex ... atively using
symbolic re

+ Use Mole Ratio in balanced equation to calculate moles of unknown substance

Chemical Reactions

Using Mole Ratios

Using the *balanced* reaction below for the combustion of propane, calculate the number of moles of CO_2 produced if 3.52 g C_3H_8 are burned in excess O_2.

$$\underset{3.52\text{ g}}{C_3H_8\,(g)} + 5O_2\,(g) \rightarrow \underset{?\text{ moles}}{3CO_2\,(g)} + 4H_2O\,(g)$$

$$\text{mass } C_3H_8 \xrightarrow{\text{molar mass}} \text{moles } C_3H_8 \xrightarrow{\text{mole ratio}} \text{moles } CO_2$$

molar mass C_3H_8

C: 12.01 g/mol * 3 = 36.03 g/mol

H: 1.01 g/mol * 8 = 8.08 g/mol

44.11 g/mol

$$3.52\,\cancel{g}\,C_3H_8 \times \frac{1\text{ mole } C_3H_8}{44.11\,\cancel{g}} = 0.0798\text{ mol } C_3H_8$$

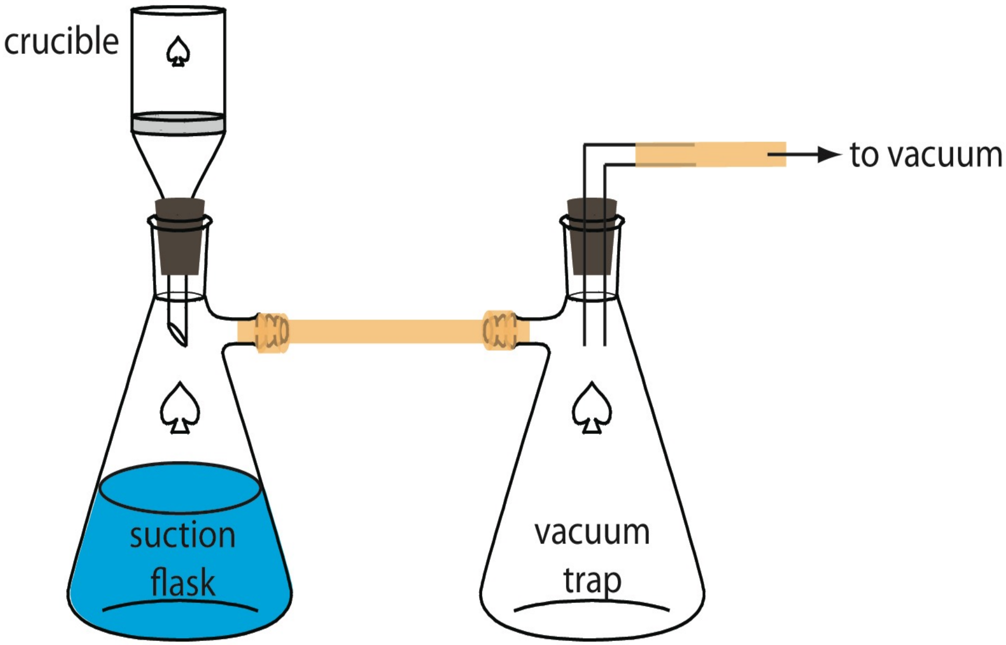
mole ratio: $\dfrac{1\text{ mole } C_3H_8}{3\text{ moles } CO_2}$

$$0.0798\,\cancel{\text{mol } C_3H_8} \times \frac{3\text{ mol } CO_2}{1\,\cancel{\text{mole } C_3H_8}} = 0.239\text{ mol } CO_2$$

LO1.18: Apply the conservation of atoms to the rearrangement of atoms in various processes.

Gravimetric Analysis

Buchner Filtration Apparatus



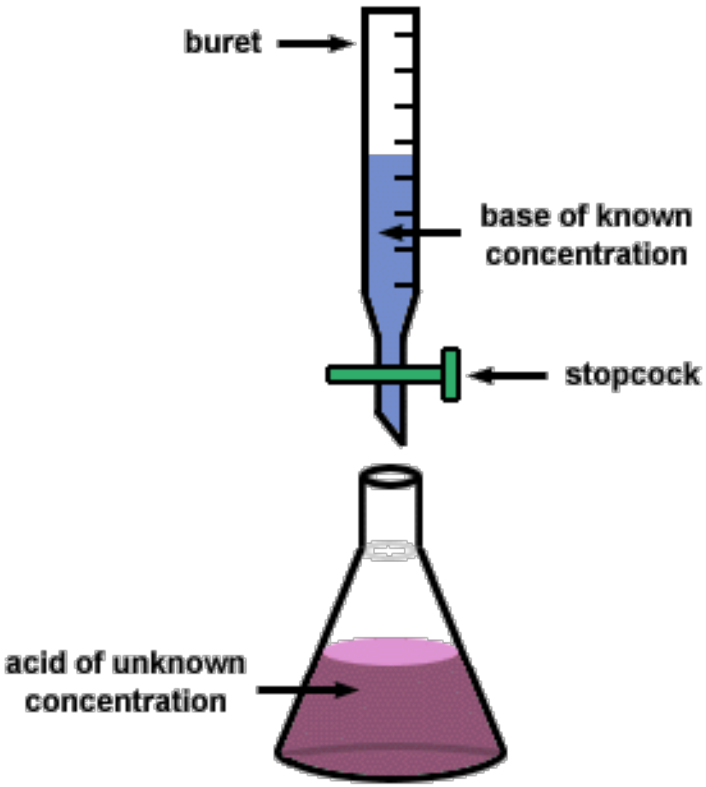
How much lead (Pb^{2+}) in water?

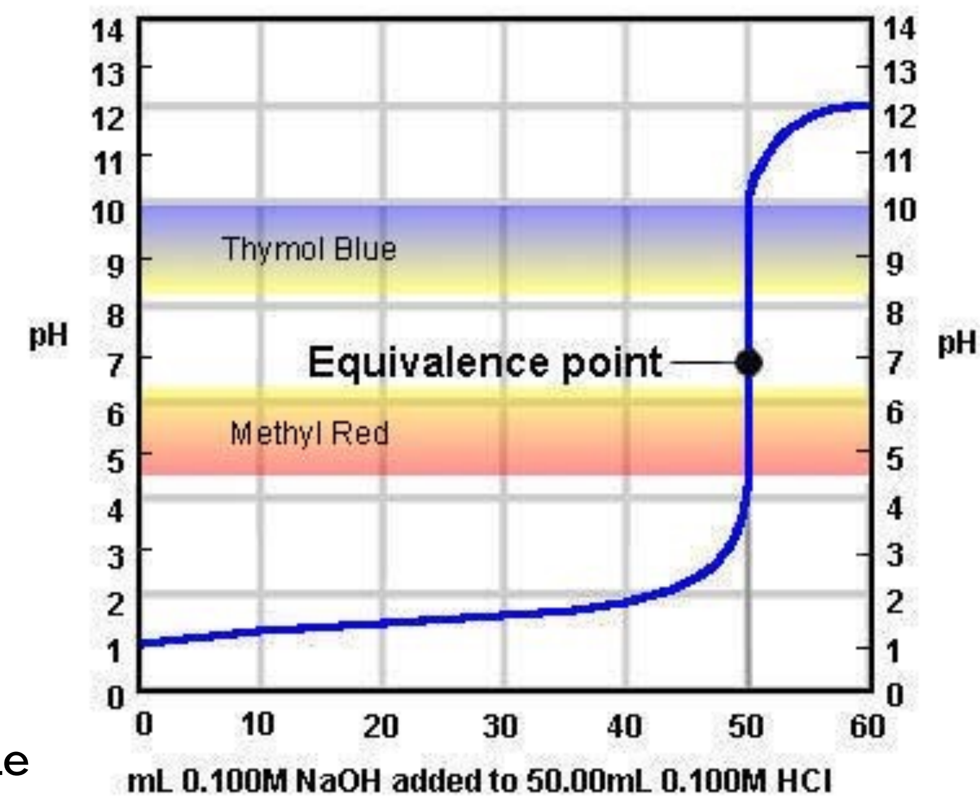
$Pb^{2+}(aq) + 2Cl^{-}(aq) \rightarrow PbCl_2\ (s)$

- By adding excess Cl- to the sample, all of the Pb^{2+} will precipitate as $PbCl_2$
- Solid product is filtered using a Buchner Filter and then dried to remove all water
- Mass of $PbCl_2$ is then determined
- This can be used to calculate the original amount of lead in the water

LO 1.19: Design and/or interpret data from, an experiment that uses gravimetric analysis to determine the the concentration of an analyte in a solution.

+ Using titrations to determine concentration of an analyte





At the equivalence point, the stoichiometric molar ratio is reached

LO1.20: Design and/or interpret data from an experiment that uses titration to determine the concentration of an analyte in a solution.

+ Usi
con

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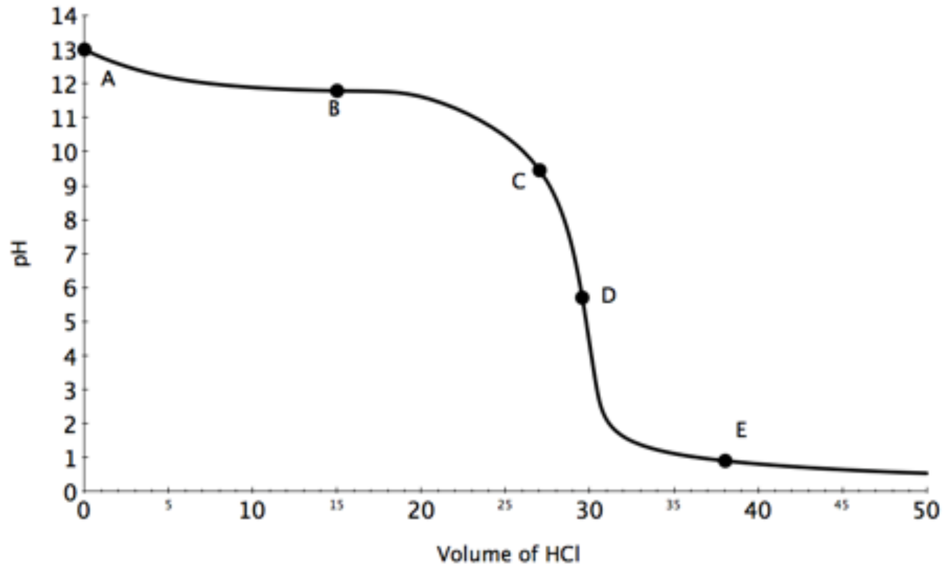
acid of unknown
concentration

At the
stoichiome

LO1.20: Des
determine t

aph which point would represent the pH of the solution at the equivalence point?



a. A
b. B
c. C
d. D
e. E

Click reveals answer and explanation.

+ Usi
con

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stoichiome

LO1.20: Des o
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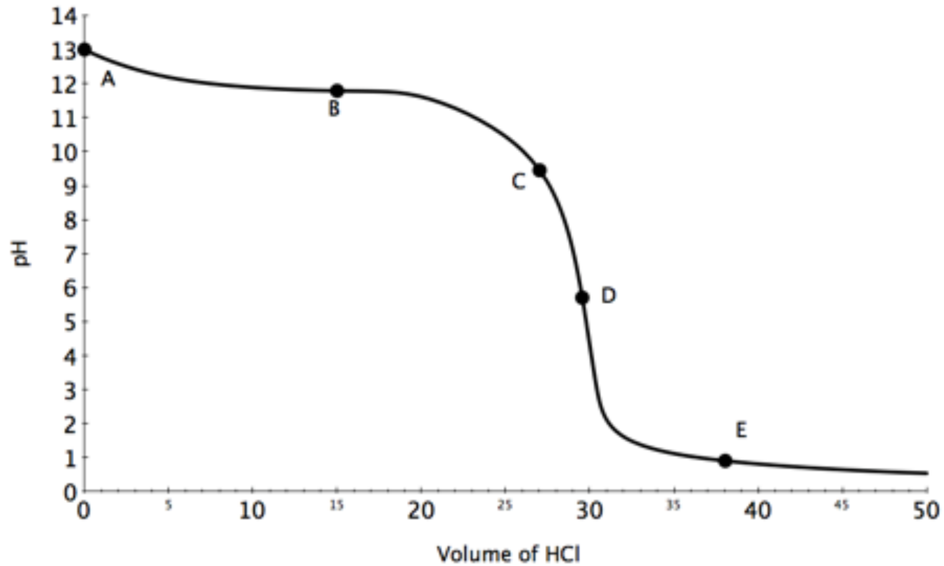
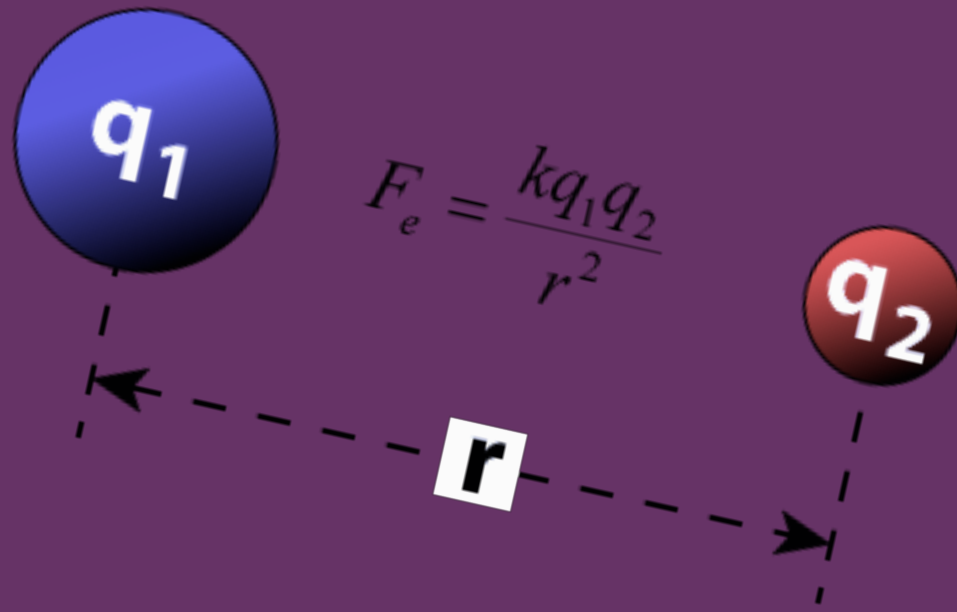


a. A
b. B
c. C
d. D
e. E

nswer:

he correct answer is "d" D. The equivalence point of a titration is when the moles of
id are equal to the moles of base. On a titration curve it is the middle of the vertical
ction. For the titration of a week base the pH at the equivalence point will be less than



+

Big Idea #2

Properties of Matter

Properties Based on Bonding

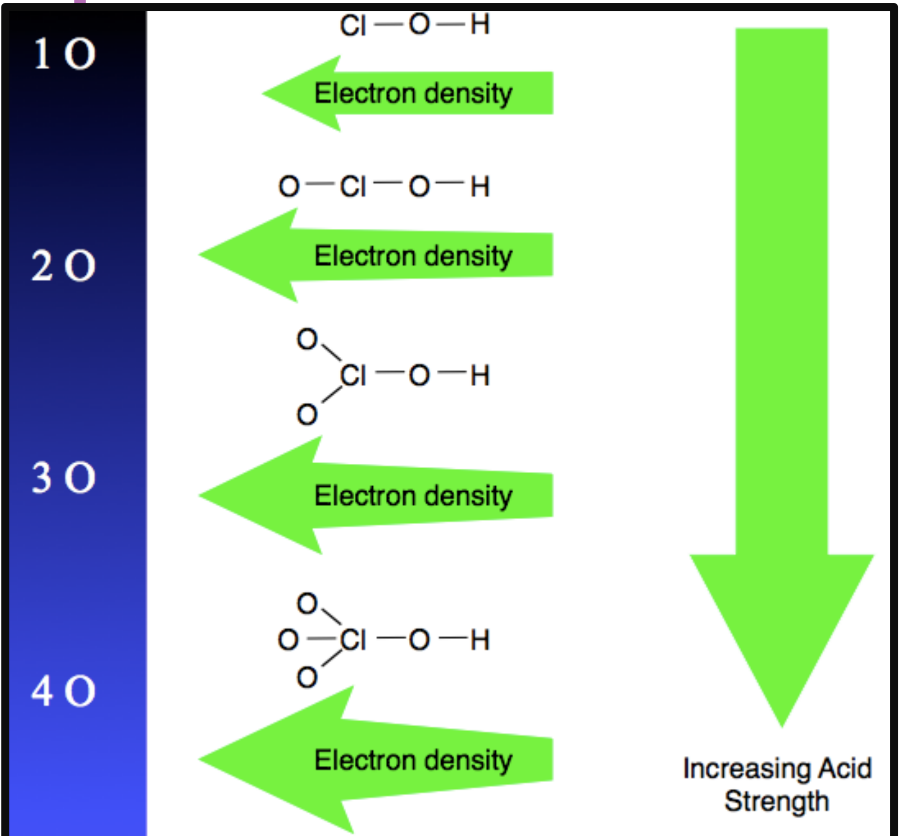
Bonding	e.g.	Melting & Boiling Points	State at 1 atm, 298 K	Does solid conduct electricity	Does liquid conduct electricity	Soluble in H_2O
Ionic	$NaCl$ $MgCl_2$	High	Solid	No	Yes	Yes ☆
Simple Covalent	CO_2 I_2 H_2O	**Low:** Only have to overcome IMF's	Usually liquid or gas but may be solid (I_2)	No	No	Depends how polarised the molecule is
Network Covalent	Diamond Graphite SiO_2	High	Solid	No (except graphite)	/	No
Metallic	Fe Mg Al	High	Solid	Yes	yes	No

- Visit the Virtual Lab to explore properties based on bond type (click on perform)

★Not all ionic compounds are soluble, but those containing ammonium, nitrate, alkali metals, and halogens (except bonded to Ag, Hg and Pb) are typically

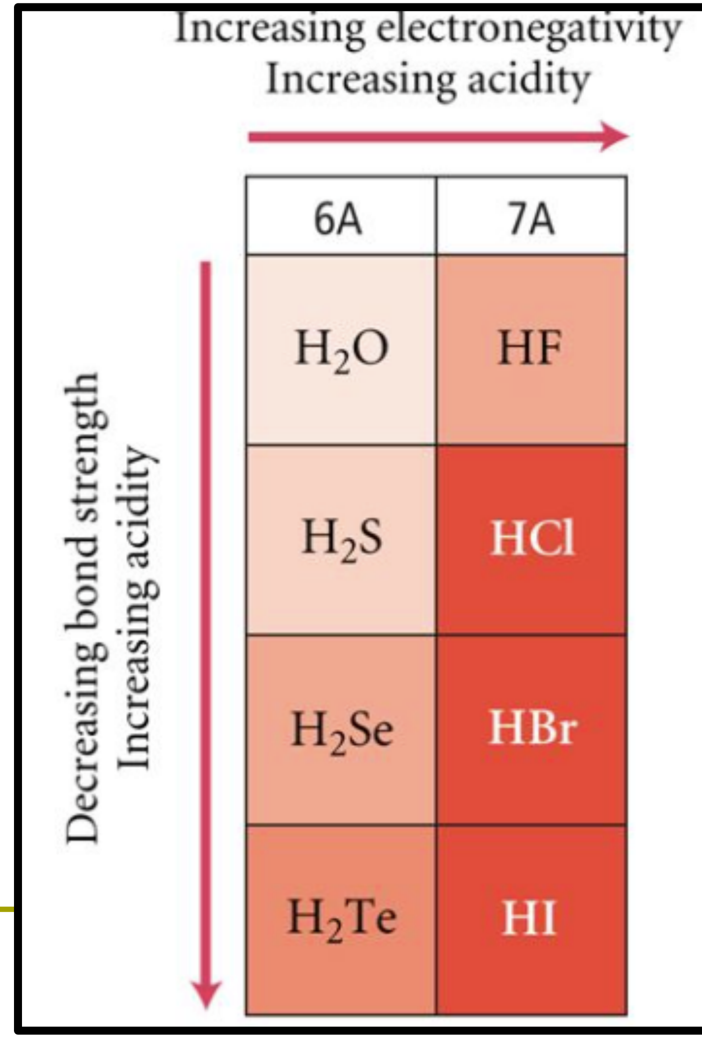
LO 2.1: Students can predict properties of substances based on their chemical formulas, and provide explanations of their properties based on particle views

Oxyacid Strength



The increased number of oxygen atoms pulls negative charge away from the O-H bond, weakening the attraction of the proton for the electron pair and thus strengthening the acid.

Binary Acid Strength



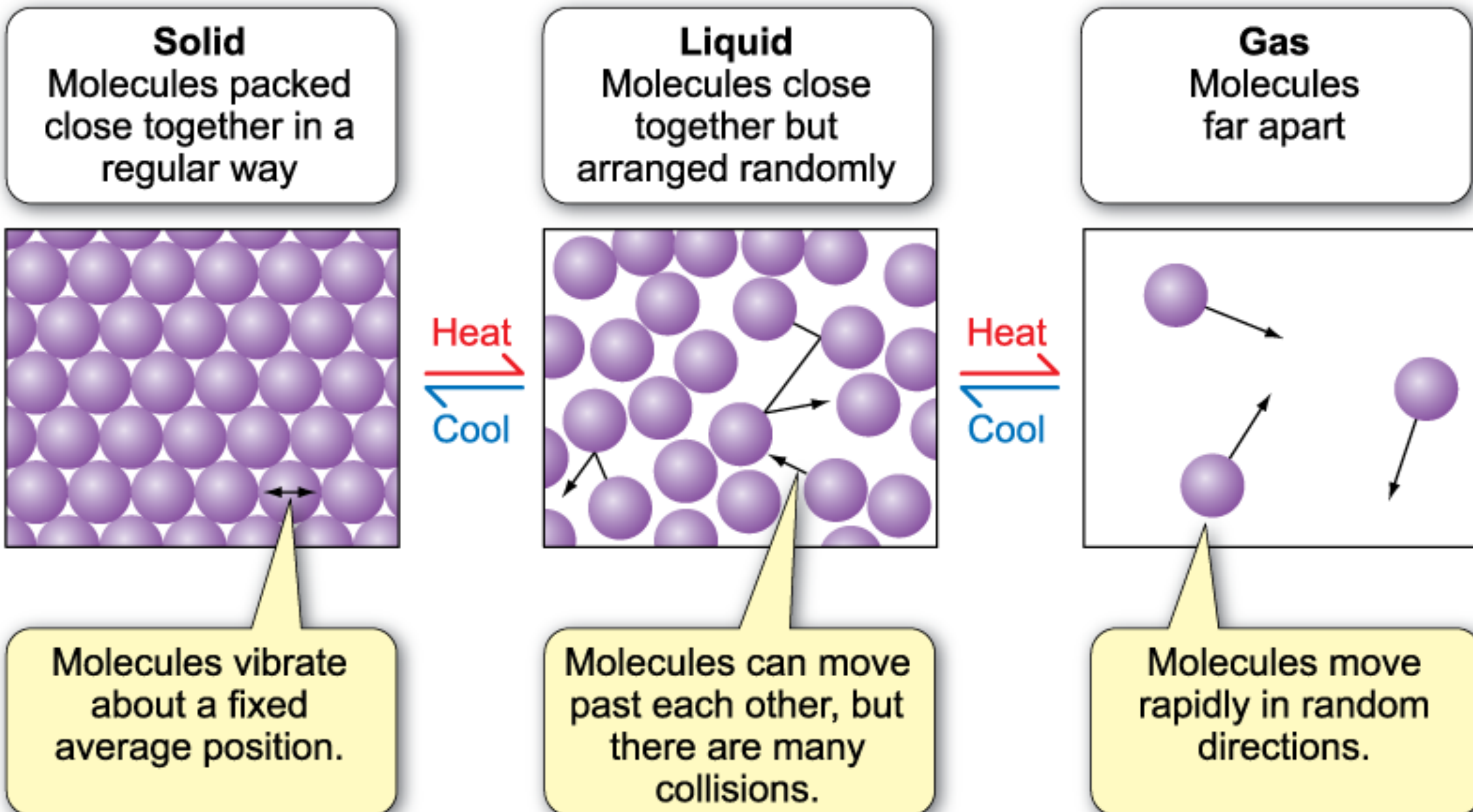
The greater the size of the negative ion, the weaker its attraction for the proton, and so the stronger the acid, and the weaker the conjugate base. HI is the strongest binary acid.

Source

Reading

LO 2.2: student is able to explain the relative strengths of acids and bases based on structure, IMF's, & equilibrium.

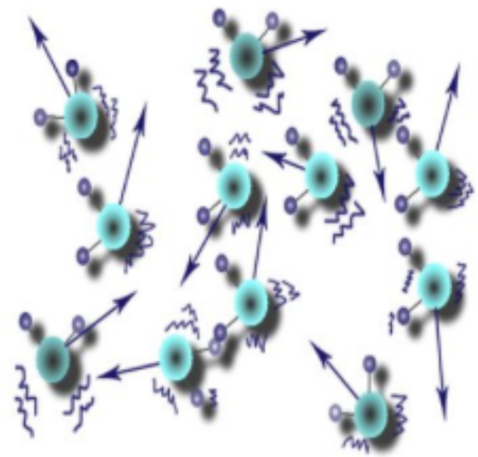
+ Behaviors of Solids, Liquids, and Gases



LO 2.3: The student is able to use particulate models to reason about observed differences between solid and liquid phases and among solid and liquid materials.

Source

Kinetic Molecular Theory (KMT)



1. Lots of tiny particles that are relatively far apart.
2. Elastic collisions- no loss of energy
3. Continuous, rapid, random motion
4. No interaction between molecules

- IF the temperature is not changed, *no matter what else is listed in the problem,* the average kinetic energy of a gas does not change. That is the definition of temperature!
- All gases begin to act non-ideally (aka real) when they are at low temperatures and/or high pressures because these conditions increase particle interactions
- Under the same conditions, the stronger the intermolecular attractions between gas particles, the LESS ideal the behavior of the gas

LO 2.4: The student is able to use KMT and IMF's to make predictions about the macroscopic properties of gases, including both ideal and non-ideal behaviors

Source

+Properties of a Gas - Factors

- Don’t worry about individual gas law names, but do worry about the effect of changing moles, pressure and temperature on a sample of gas

Virtual Lab

(a) *P* vs. *V* (Boyle’s law): At constant temperature and amount of gas, pressure decreases as volume increases (and vice versa).

(b) *V* vs. *T* (Charles’ law): At constant pressure and amount of gas, volume increases as temperature increases (and vice versa).

(c) *V* vs. *n* (Avogadro’s law): At constant pressure and temperature, volume increases as amount of gas increases (and vice versa).

LO 2.5: Refine multiple representations of a sample of matter in the gas phase to accurately represent the effect of changes in macroscopic properties on the sample

+ The Ideal Gas Law

Question:

15.5 grams of an unknown substance are placed in an sealed 5.00 L container. At 150 °C the substance has fully converted to a gas and the pressure in the container is 1.10 atm. Which of the following equations represents the molar mass of the unknown compound?

a. $$\frac{5.00L \cdot 1.10atm}{15.5g \cdot 0.0821 \frac{atm\ L}{mol\ K} \cdot 423K}$$

b. $$\frac{5.00L \cdot 1.10atm}{0.0821 \frac{atm\ L}{mol\ K} \cdot 150K}$$

c. $$\frac{15.5g \cdot 0.0821 \frac{atm\ L}{mol\ K} \cdot 150K}{5.00L \cdot 1.10atm}$$

d. $$\frac{0.0821 \frac{atm\ L}{mol\ K} \cdot 150K}{5.00L \cdot 1.10atm}$$

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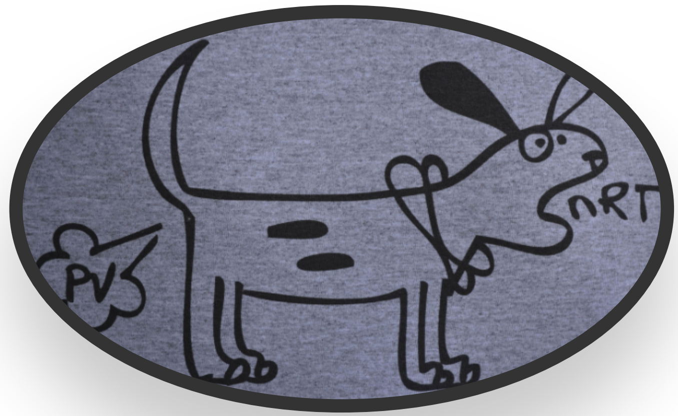

LO 2.6: The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases

Click reveals answer and explanation.

+ The Ideal Gas Law

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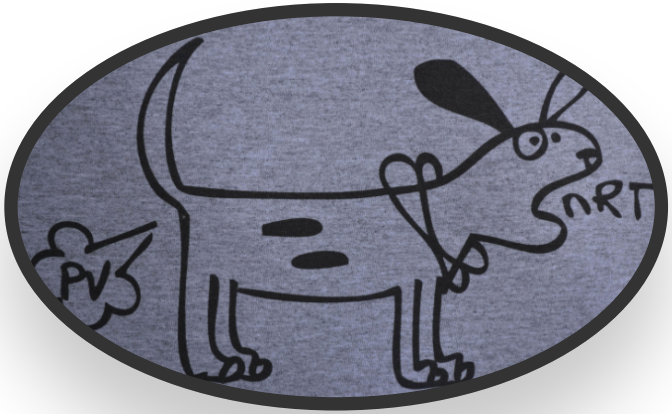
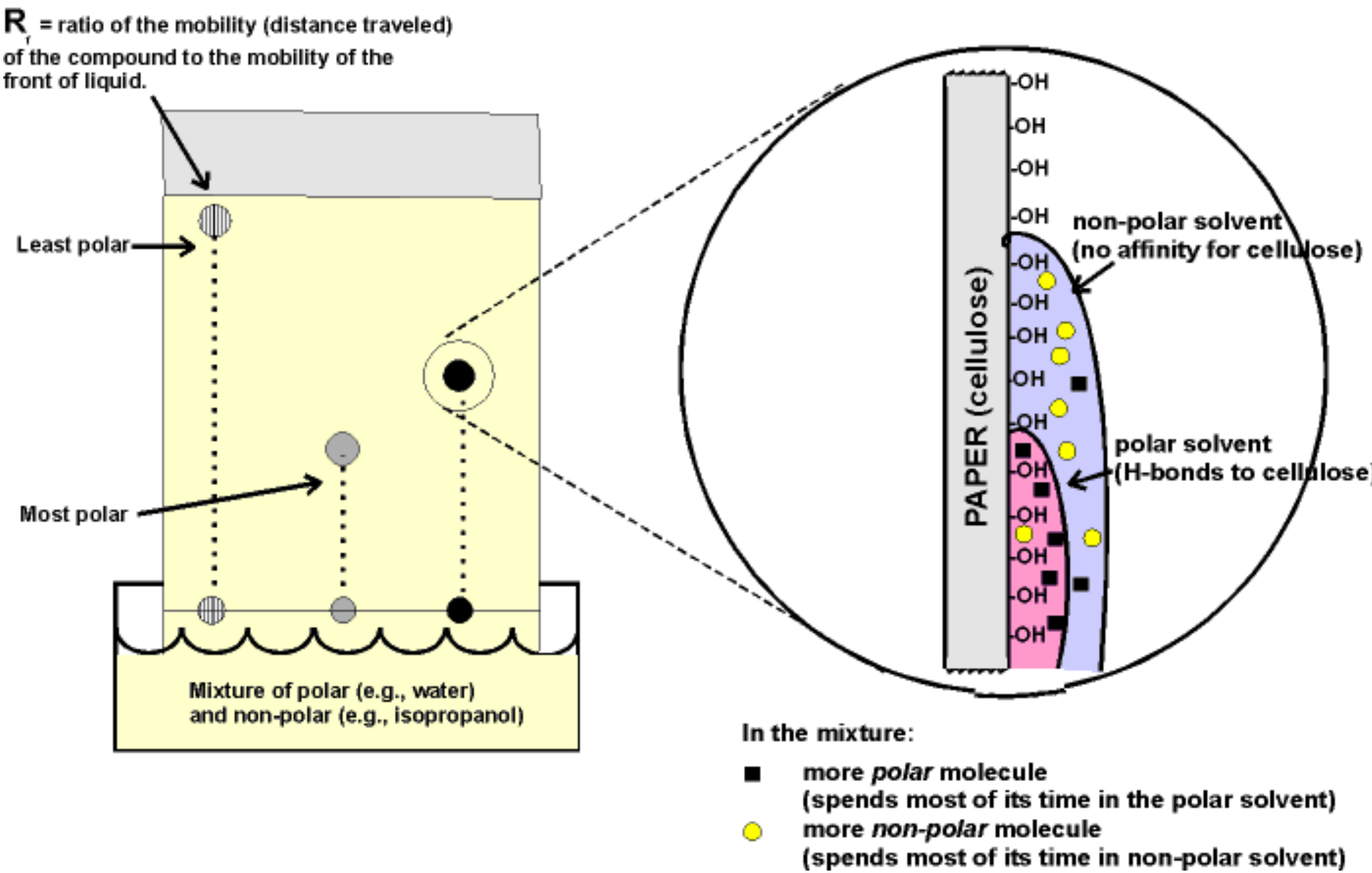


Answer:

The correct answer is "e", $\frac{15.5g \cdot 0.0821 \frac{atm\ L}{mol\ K} \cdot 423K}{5.00L \cdot 1.10atm}$. To calculate the molar mass we need to take the grams of the unknown(15.5g) and divide by how many moles of unknown there are. We can use the ideal gas law to determine the moles of unknown by taking the pressure multiplied by the volume and dividing by R multiplied by the temperature in kelvins, this gets inverted when we divide, giving us the answer above.

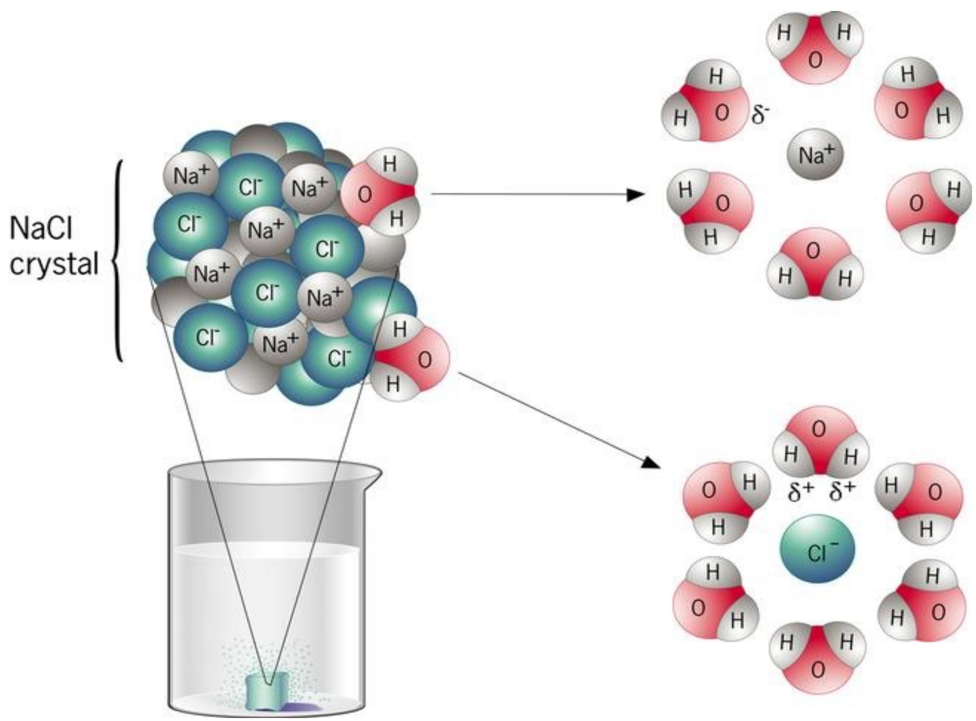
LO 2.6: The student can apply mathematical relationships or estimation to determine macroscopic variables for ideal gases

+ Chromatography



LO 2.7: The student is able to explain how solutes can be separated by chromatography based on intermolecular interactions.

+ Dissolving/Dissociation: Solute and Solvent



- When drawing solute ions:

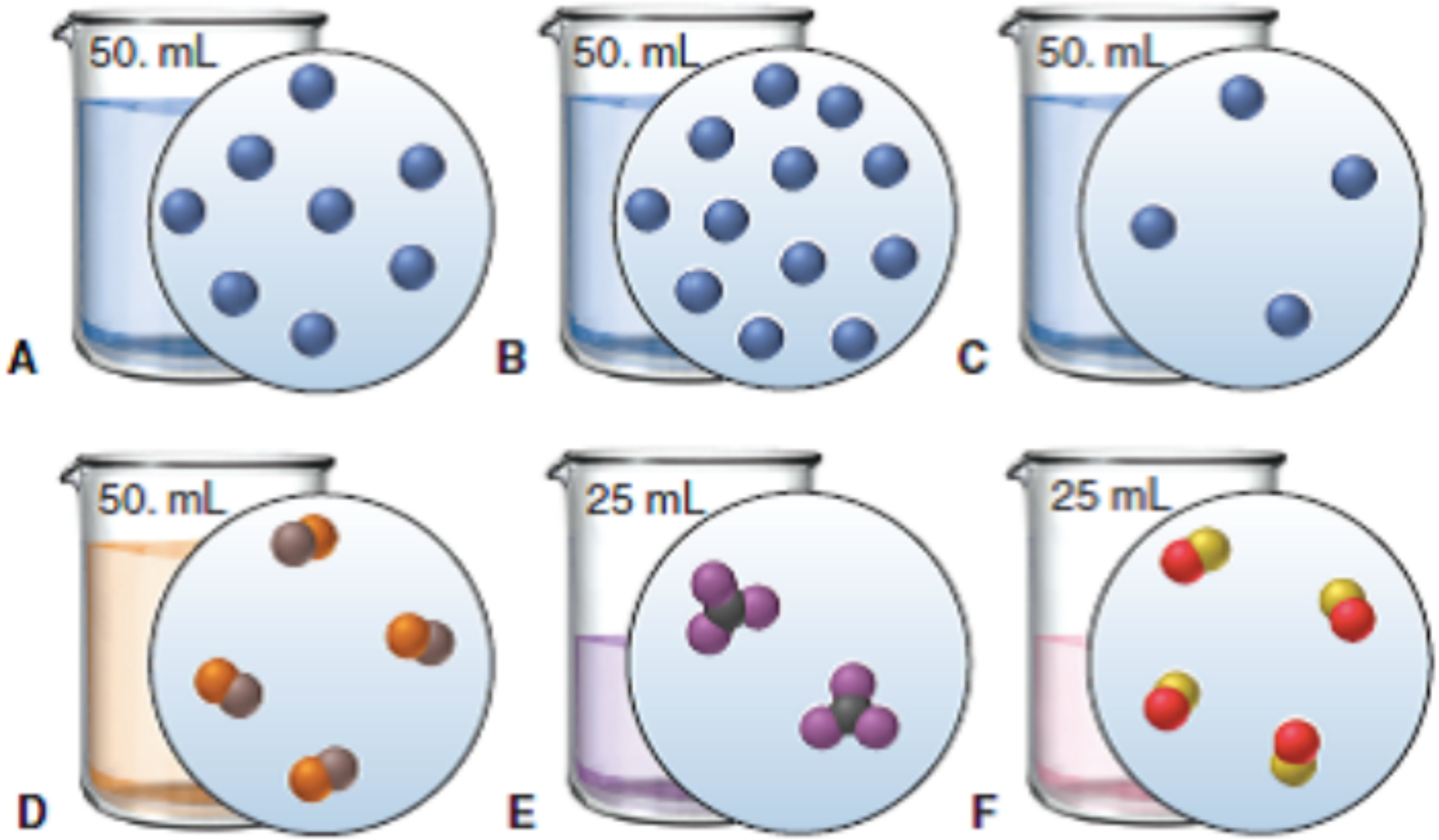
1. pay attention to size (Na^+ is smaller than Cl^-)
2. Draw charges on ion, but not on water
3. draw at least 3 water molecules around each
4. the negative dipole (oxygen side) points toward cation and the postive dipoles (H side) points towards the anion

LO 2.8: The student can draw and/or interpret representations of solutions that show the interactions between the solute and solvent.

Molarity and Particle Views

Source

Video



- QUESTION: Rank the six solutions above in order of increasing molarity. Pay attention to volume, and some have equal concentration

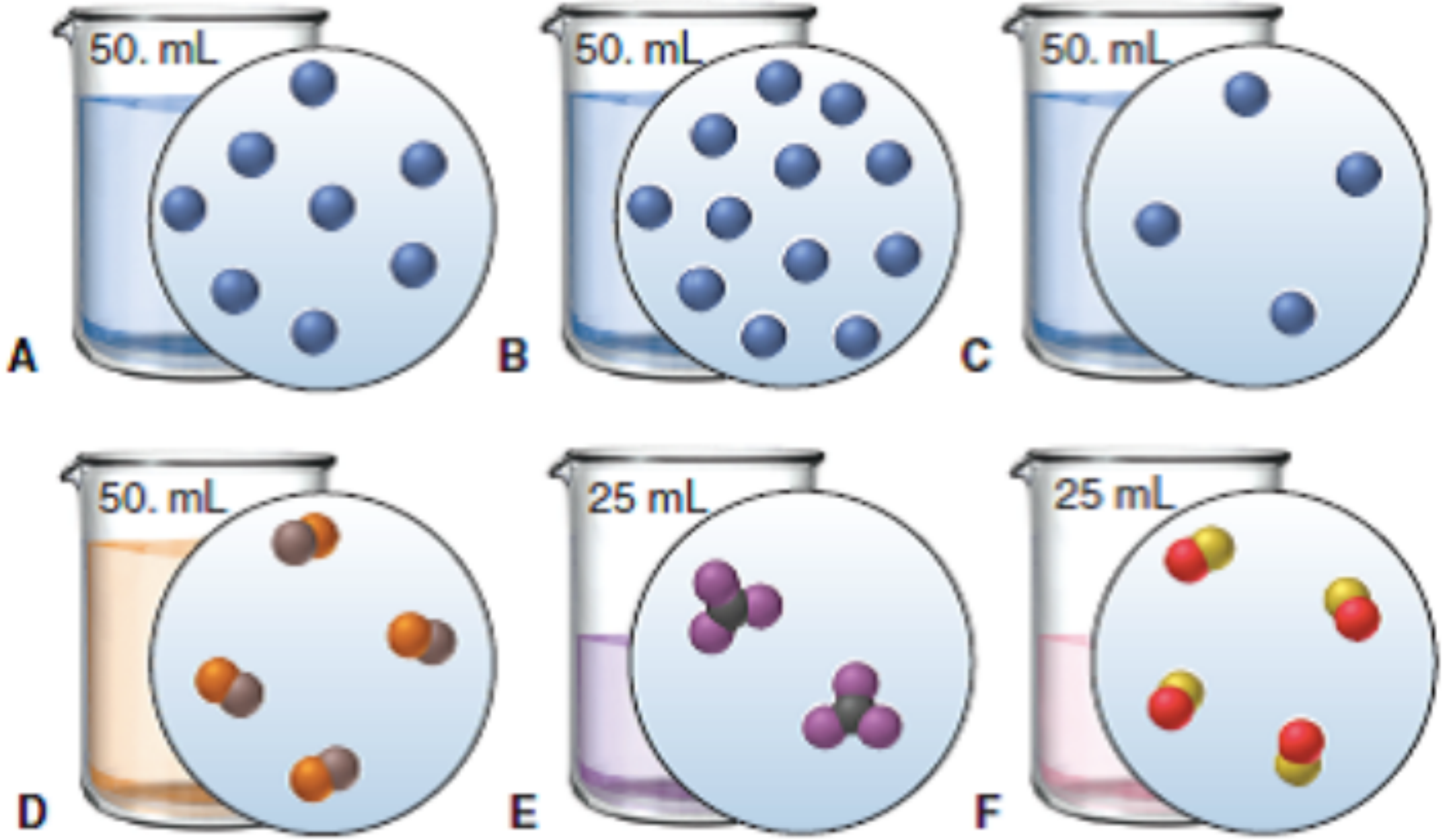
Click reveals answer

LO 2.9: The student is able to create or interpret representations that link the concept of molarity with particle views of solutions

+ Molarity and Particle Views

Source

Video



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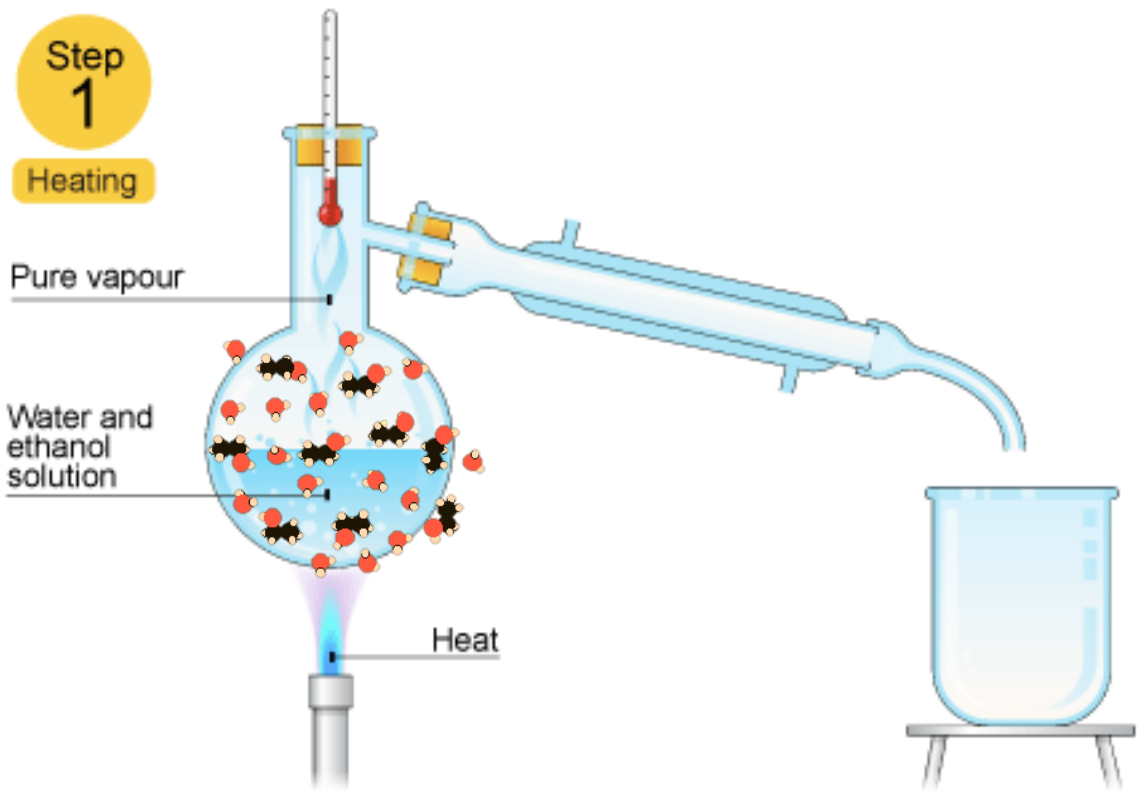
- C,D, and E (tied); A and F (tied); most concentrated is B

LO 2.9: The student is able to create or interpret representations that link the concept of molarity with particle views of solutions

Source

Video

+ Distillation to Separate Solutions



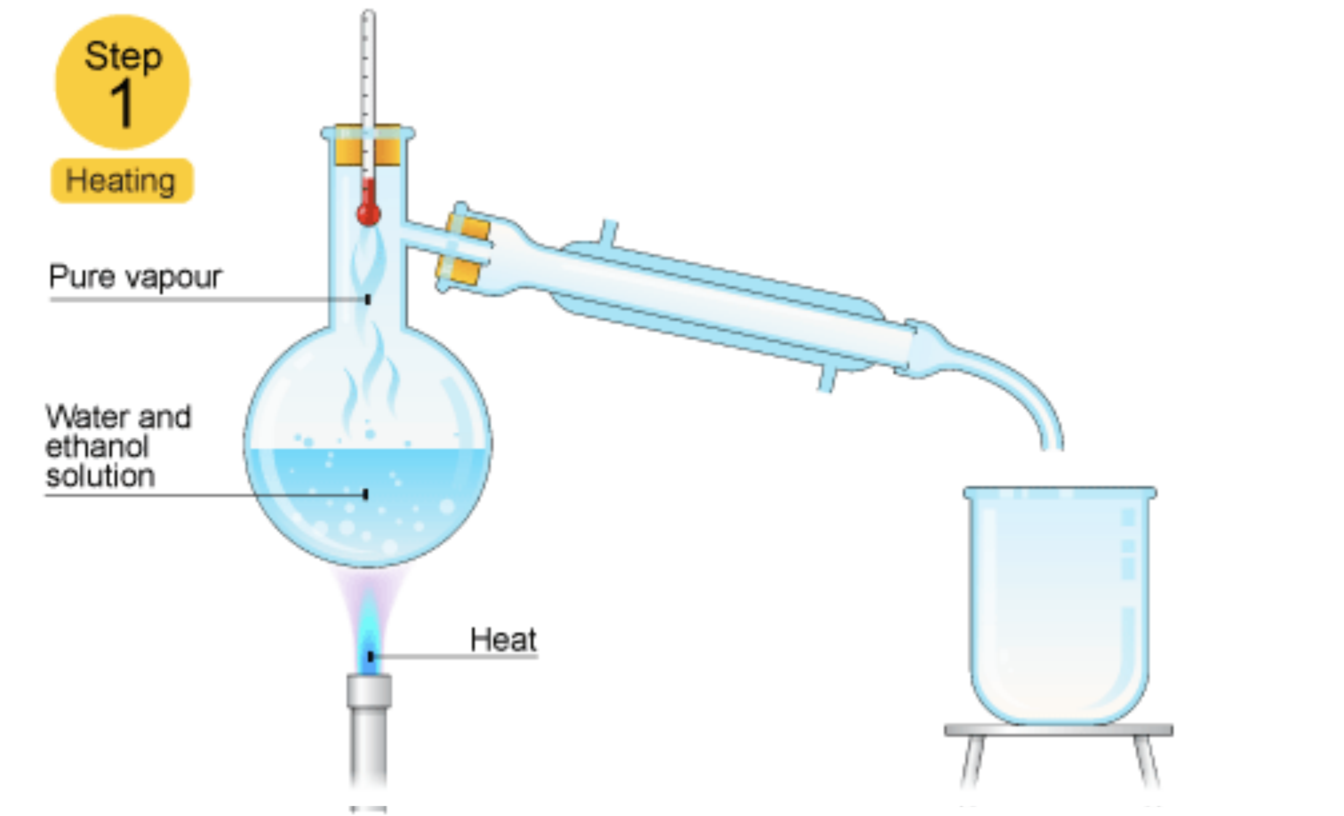
- In the diagram above, ethanol has lower IMF's and a resulting lower boiling point than water, so it can be heated, vaporized and condensed easily.
- Ethanol hydrogen bonds as water does and is polar, but part of the ethanol has only weaker LDF's because it's nonpolar resulting in a lower boiling point

LO 2.10: Design/interpret the results of filtration, paper/column chromatography, or distillation in terms of the relative strength of interactions among the components.

+ Distillation to Separate Solutions

Source

Video



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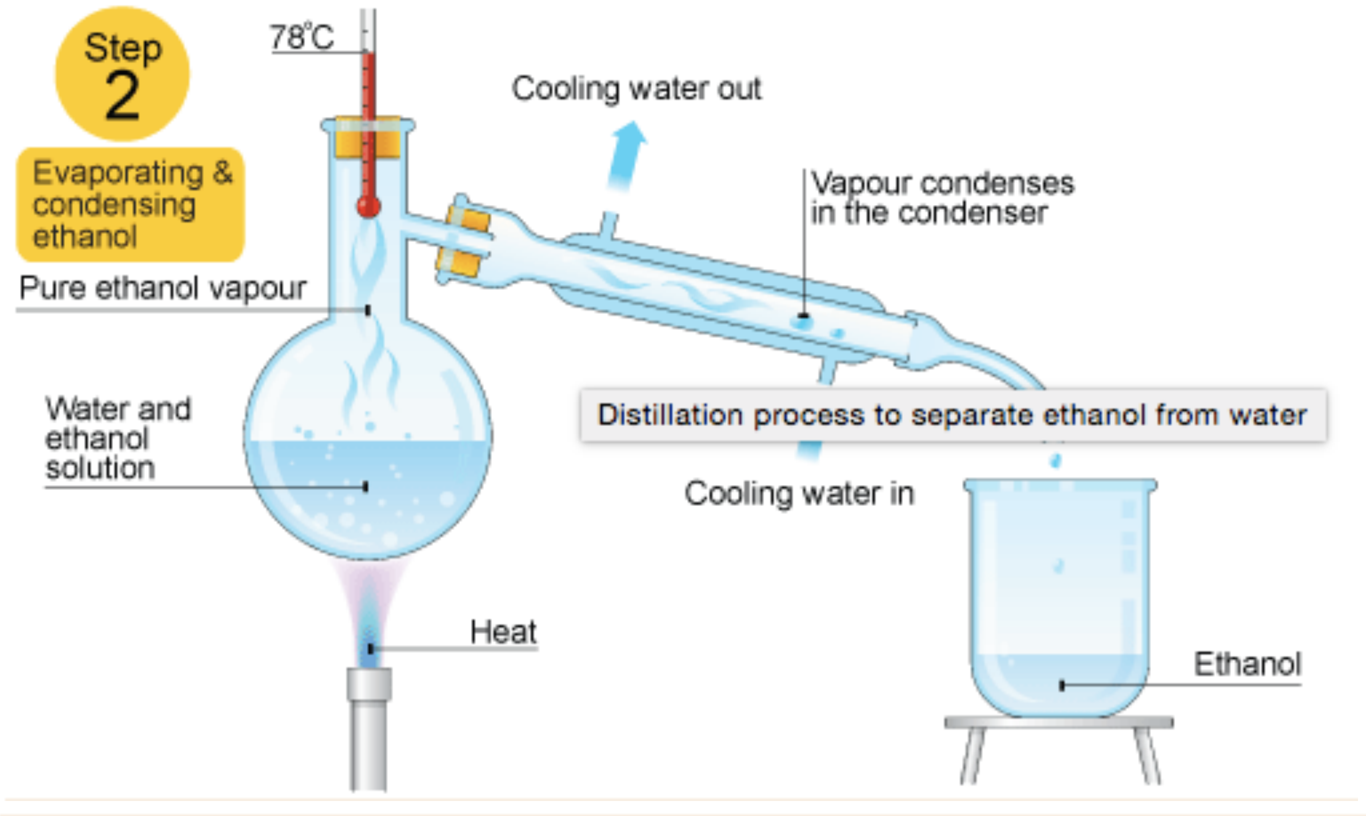

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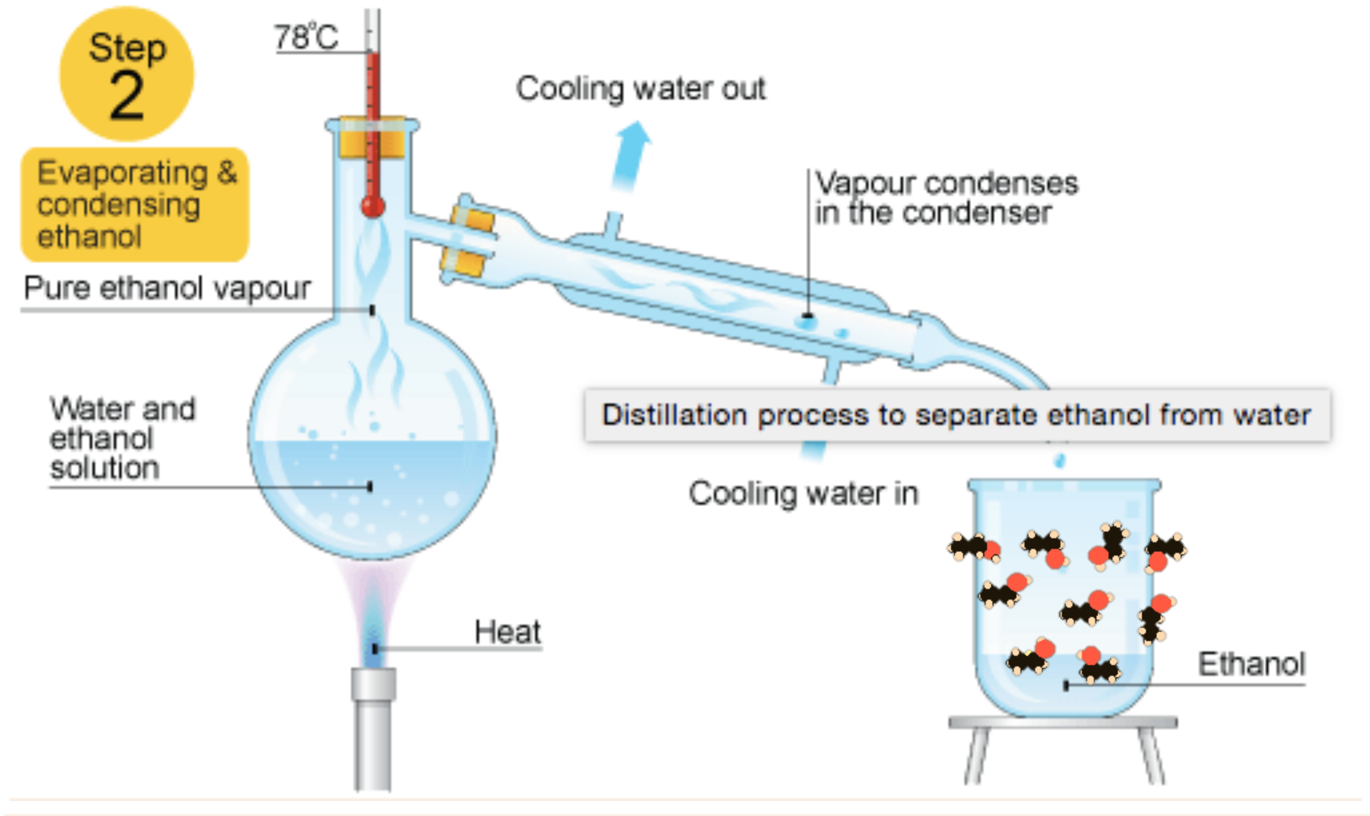

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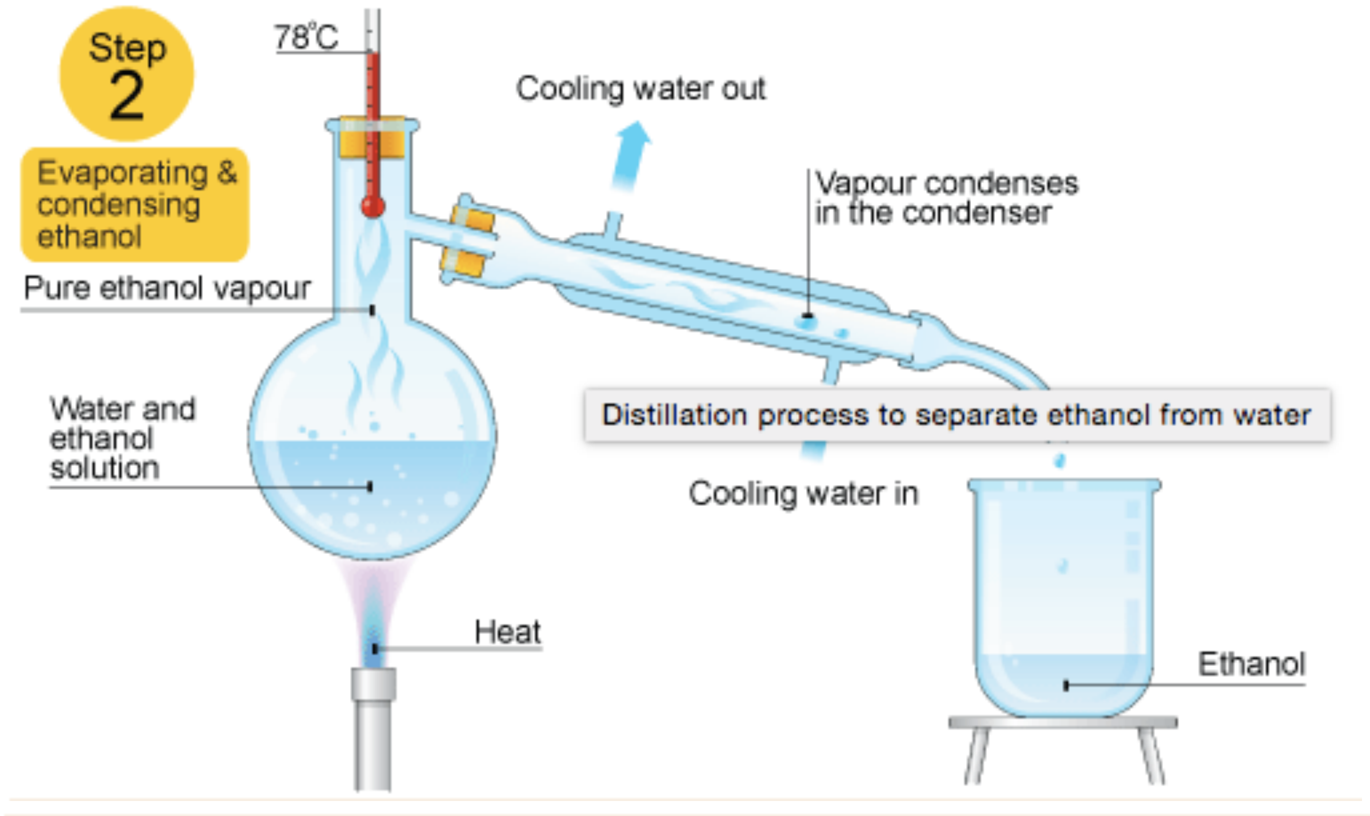

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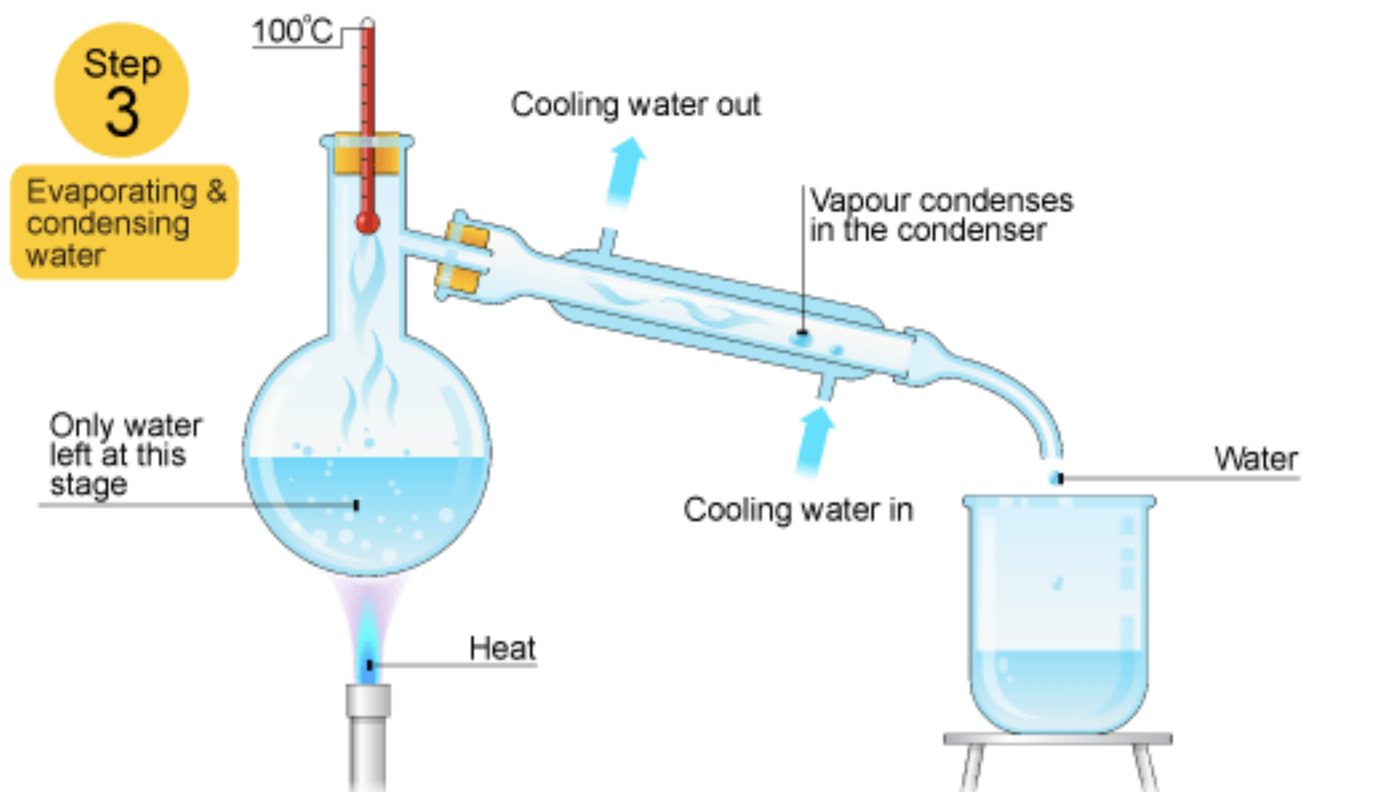

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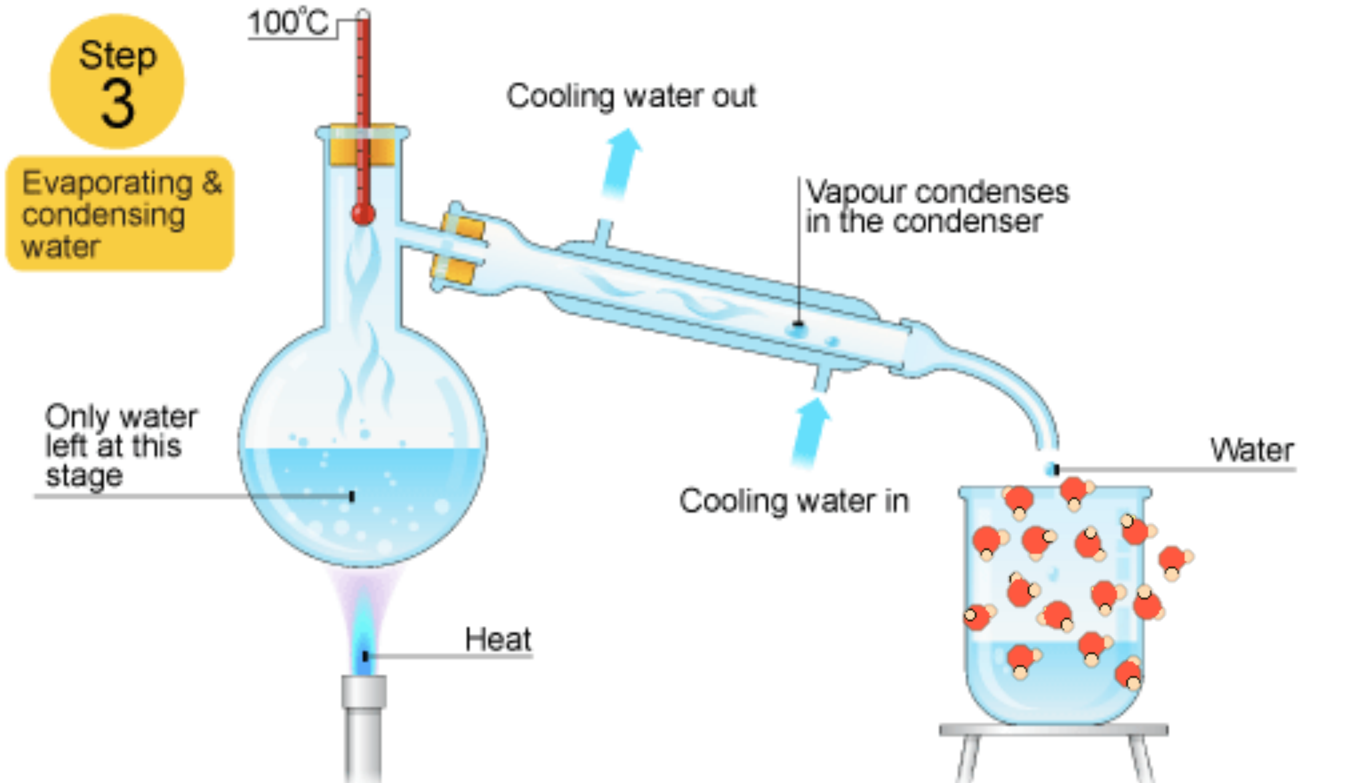

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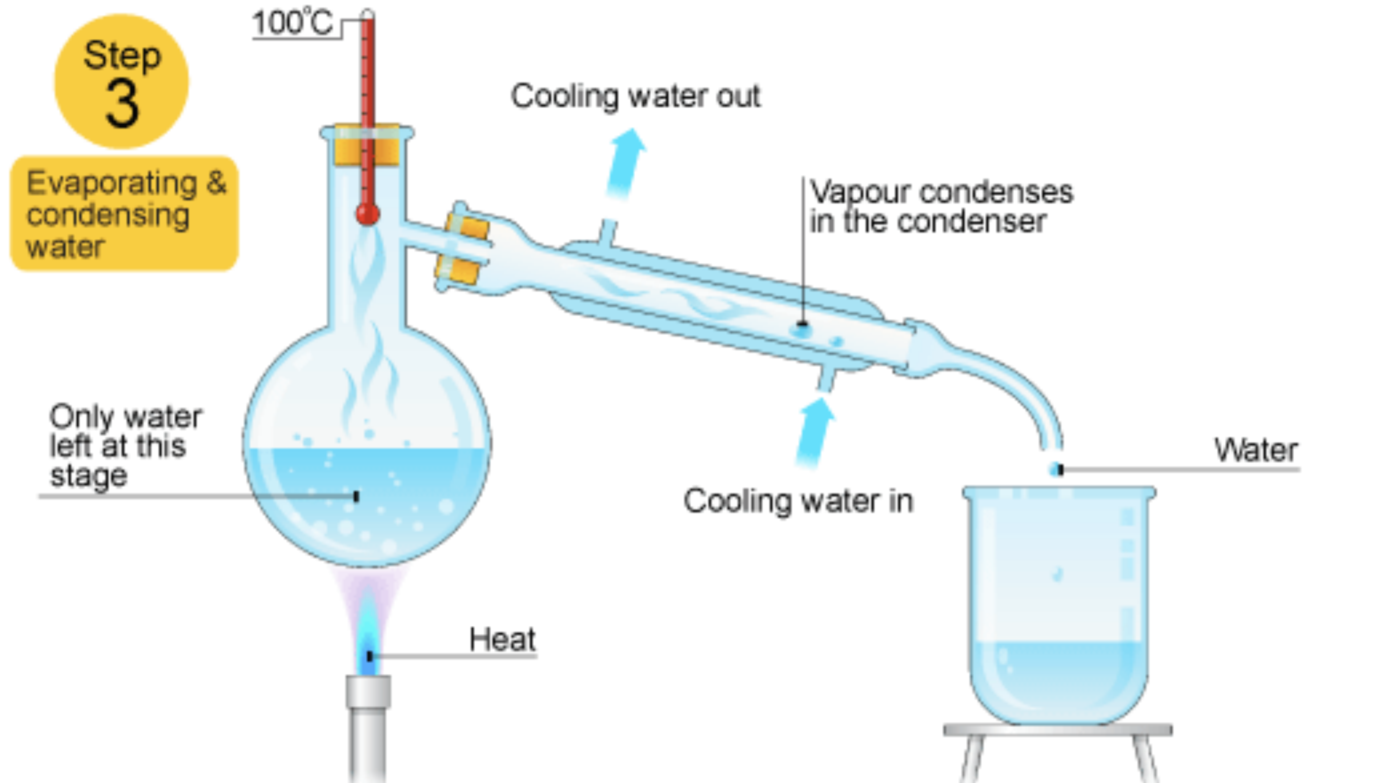

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Source

+ London Dispersion Forces and Noble and Nonpolar Gases

Video

Question:
Which of the following would have the highest boiling point?

a. He
b. Ne
c. Xe
d. Kr

Click reveals answer and explanation.

LO 2.11: The student is able to explain the trends in properties/predict properties of samples consisting of particles with no permanent dipole on the basis of LDF's.

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Answer:
The correct answer is "c". All of the choices are non-polar noble gasses. The only intermolecular forces present are London dispersion forces. The strength of the LDFs are determined by the polarizability of the atoms. The atom with the greatest number of elections will be the most polarizable, having the strongest intermolecular forces and consequently the highest boiling point.

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This answer is VITAL! Remember with increased number of ELECTRONS a particle becomes more polarizable, not with increased mass!

leo

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[Source](#)

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[Video](#)

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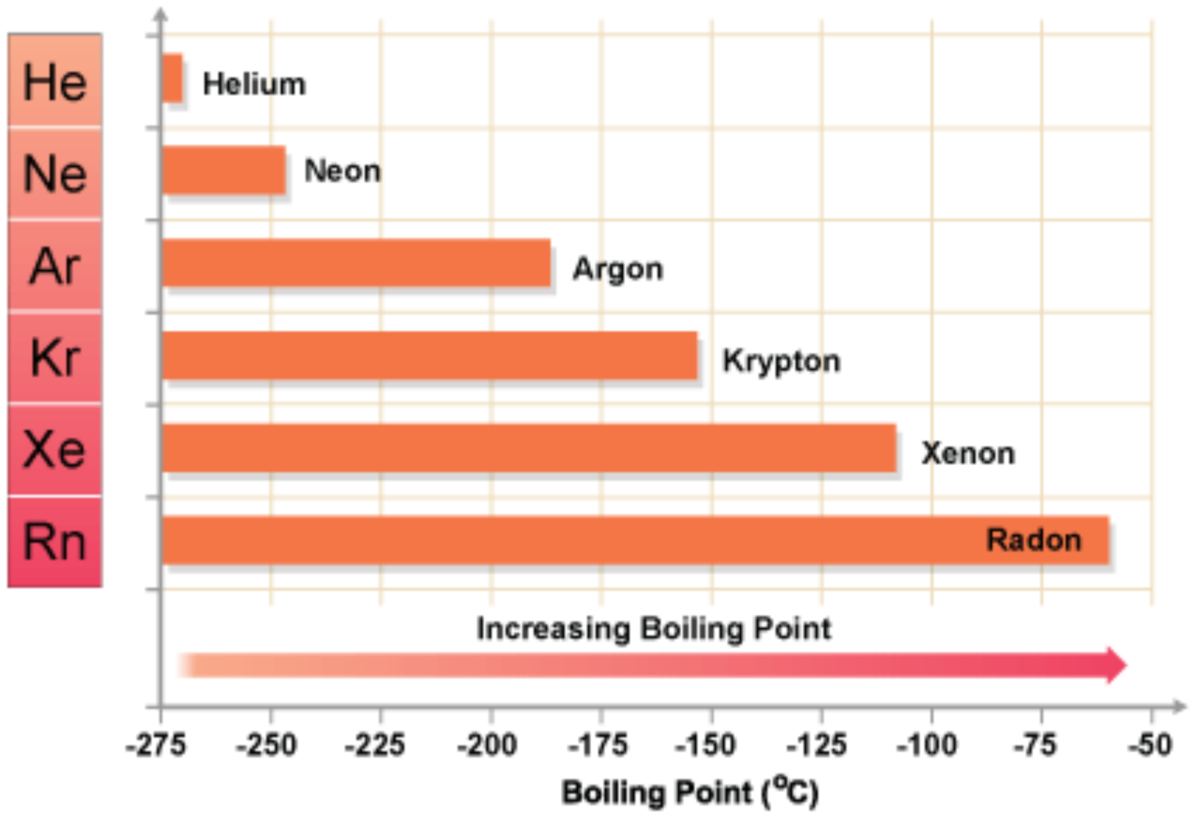

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Source

+ Deviations from Ideal Gas Behavior

Question:
At which values of temperature and pressure will the gas N_2 behave least like an ideal gas?

	Temperature (K)	Pressure (atm)
a.	100	100
b.	100	1.0
c.	700	0.1
d.	700	1.0
e.	700	100

Video

When watching the video, don't concern yourself with Van der Walls – AP Exam focuses on LDF's instead

Click reveals answer and explanation.

LO 2.12: The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions

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Answer:
The correct answer is "a", 100K and 100 atm. The ideal gas law works best at high temperatures and low pressures. When a gas is at low temperatures and high pressures a gas will behave least like an ideal gas.

LO 2.12: The student can qualitatively analyze data regarding real gases to identify deviations from ideal behavior and relate these to molecular interactions

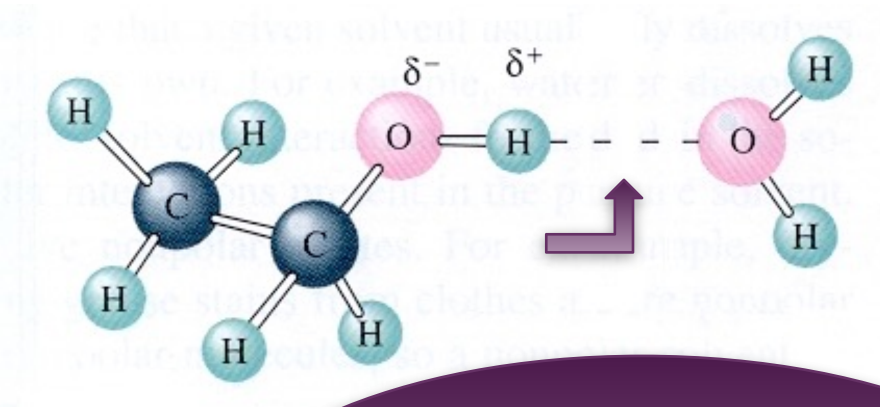
+ Hydrogen Bonding

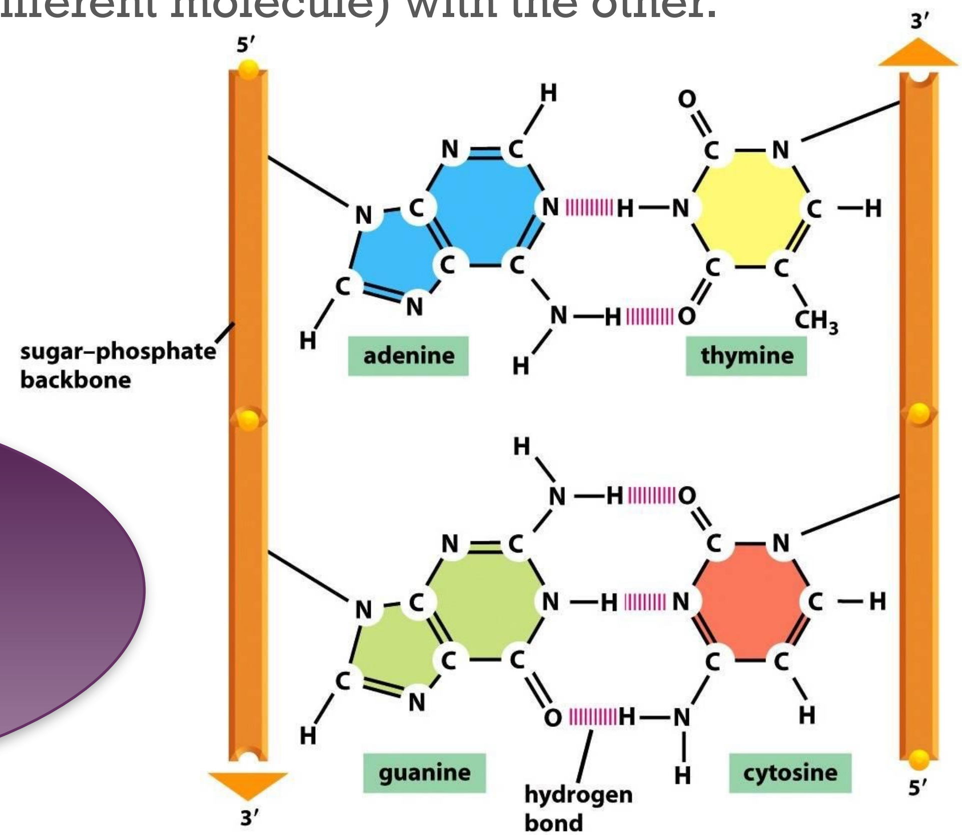
[Source](#)

[Video](#)

- Hydrogen bonding is seen in the following molecules: water, DNA, ammonia, HF, and alcohols. H-bonding is an attraction or force not a true intramolecular bond.

- Hydrogen bonds are like a sandwich with N, O, and/or F as the bread. H will be in a intramolecular (same molecule) bond with one N, O, and/or F and have an intermolecular attraction (different molecule) with the other.





Remember this tip: hydrogen bonds just wanna have <u>FON</u>

LO 2.13: The student is able to describe the relationships between the structural features of polar molecules and the forces of attraction between the particles.

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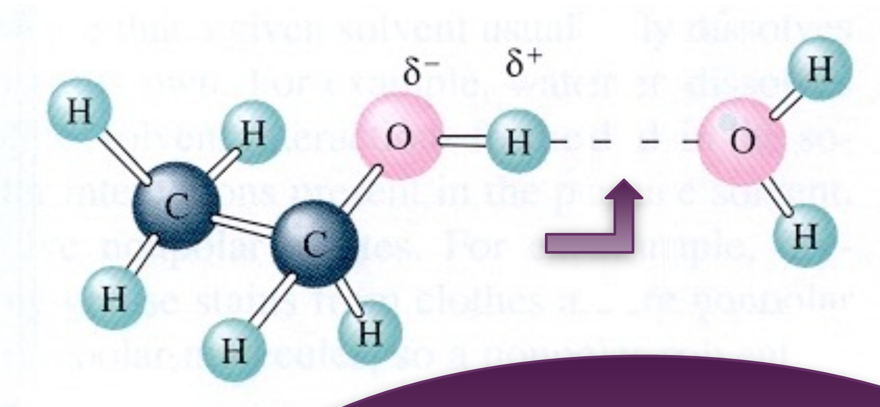

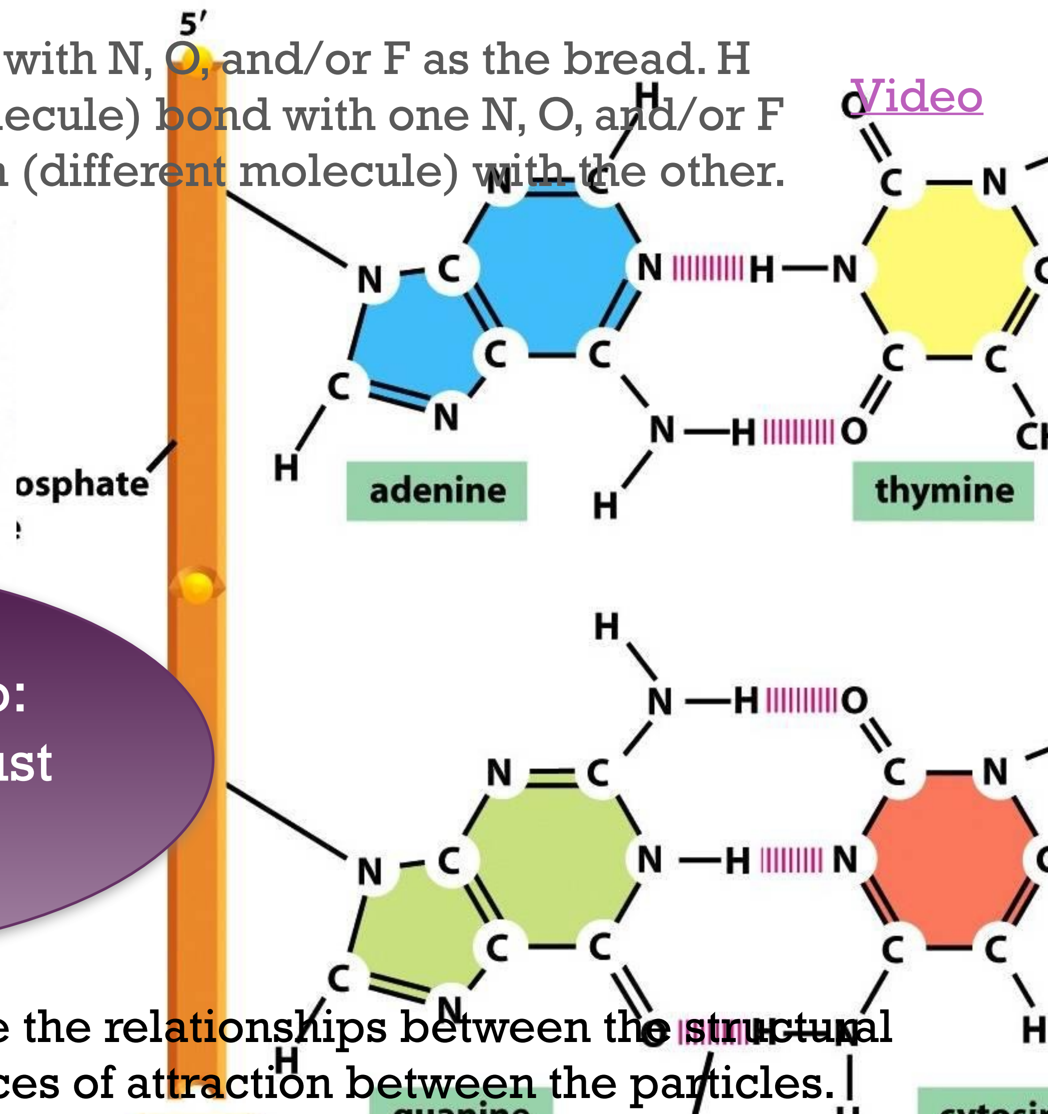

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Source

+ Coulomb's Law and Solubility

- Ionic compounds can dissolve in polar liquids like water because the ions are attracted to either the positive or negative part of the molecule.

- There is a sort of tug-of-war involved with species dissolved in water. The water pulls individual ions away from the solid. The solid is pulling individual ions back out of the water. There exists an equilibrium based on how strongly the water attracts the ions, versus how strong the ionic solid attracts the ions.

- We can predict the degree of solubility in water for different ionic compounds using Coulomb's law. The smaller the ions, the closer together they are, and the harder it is for the water molecules to pull the ions away from each other. The greater the charge of the ions, the harder it is for the water to pull them away as well.

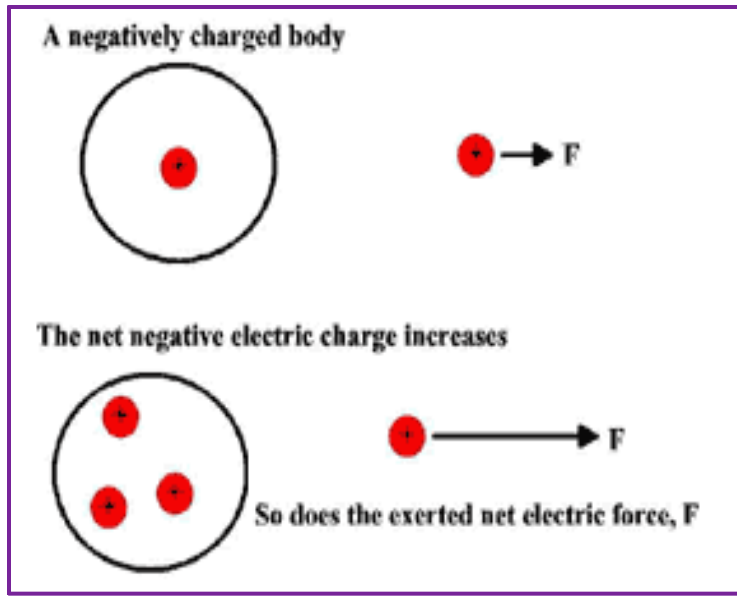
Video

- QUESTION: Predict which of the following pairs should be more soluble in water, based on Coulombic attraction.

- LiF or NaF

- NaF or KF

- BeO or LiF



LO 2.14: Apply Coulomb's law to describe the interactions of ions, & the attractions of ions/solvents to explain the factors that contribute to solubility of ionic compounds.

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Source

Video

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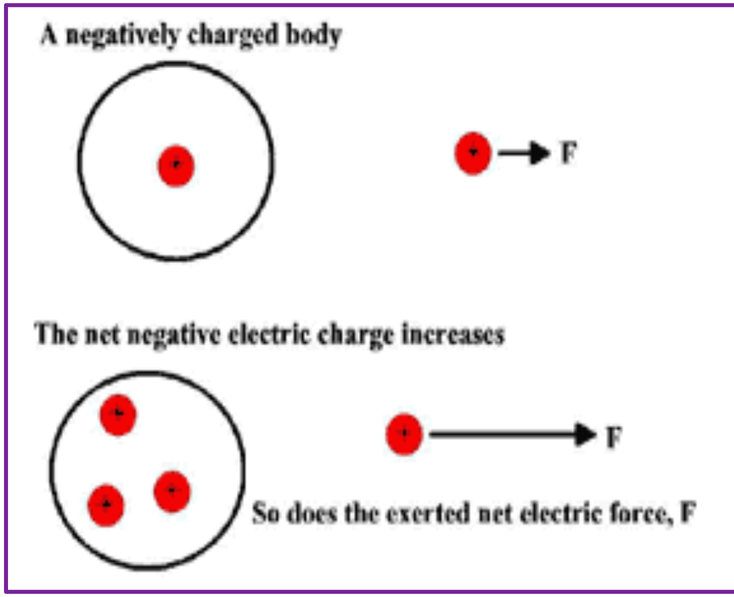

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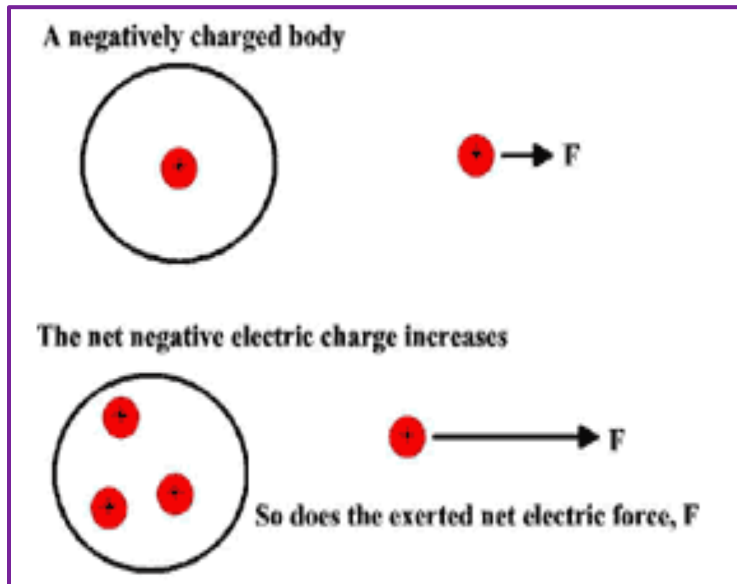

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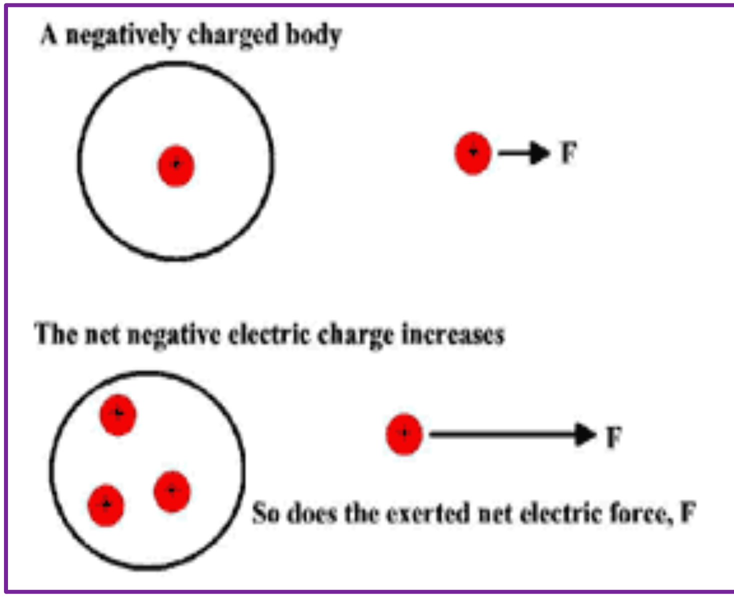

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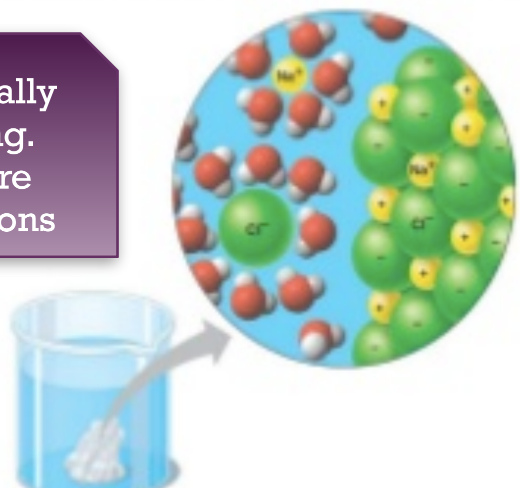
[Source](#)

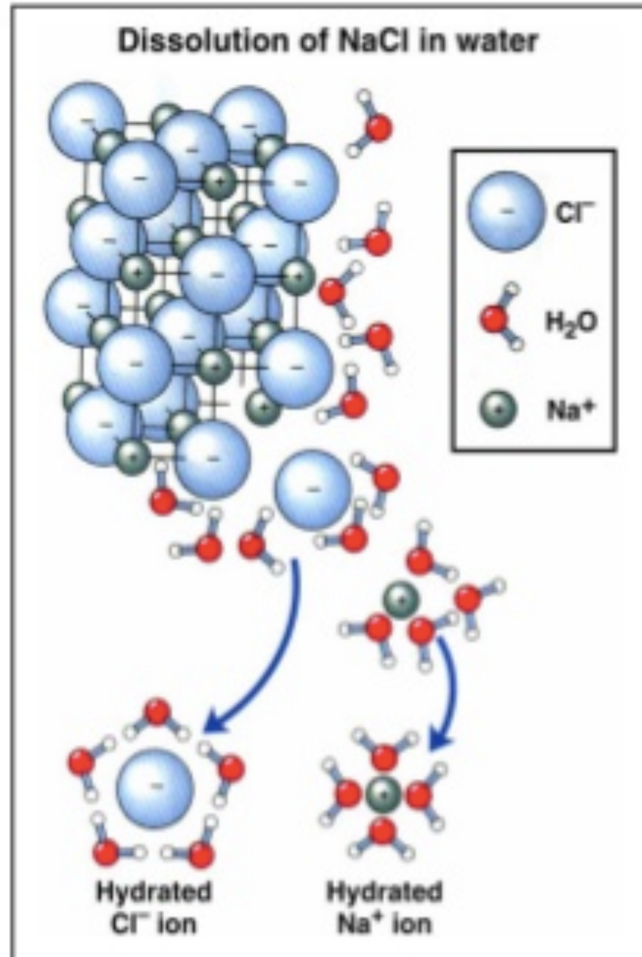
[Video](#)

Entropy in Solutions

Water dissolves salts by forming a shell of interacting water molecules around the ions. This weakens electrostatic interactions between the ions and counteracts their tendency to form a crystal lattice. Dissolution of the salt is accompanied by a large <u>increase in entropy</u> as the individual ions become more mobile. The change in free energy of the system is overall very negative ($\Delta G = \Delta H - T\Delta S$) and hence dissolution of the salt is thermodynamically highly favored.

Generally speaking. There are exceptions





Do NOT say "like dissolves like." You'll, like... get no points.
DO refer to LDF's, hydrogen bonding and dipole-dipole interactions

LO 2.15: Explain observations of the solubility of ionic solids/molecules in water and other solvents on the basis of particle views that include IMF's and entropic effects.

Source

Physical Properties and IMF's

Video

Question:
Which of the following substances would have the highest vapor pressure at 25°C?

a. H_2O
b. Hg
c. CCl_4
d. $C_{10}H_{22}$

Click reveals answer and explanation.

LO 2.16: Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of IMF's.

Source

Physical Properties and IMF's

Video

Question:
Which of the following substances would have the highest vapor pressure at 25°C?

a. H_2O
b. Hg
c. CCl_4
d. $C_{10}H_{22}$

Answer:
The correct answer is "c", CCl_4. The highest vapor pressure will be the substance that have the weakest intermolecular forces. The smallest non-polar molecule will generally have the weakest intermolecular forces and therefor the highest vapor pressure.

LO 2.16: Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of IMF's.

Source

Video

Physical Properties and IMF's

Question:

Which of the follo … 25°C?

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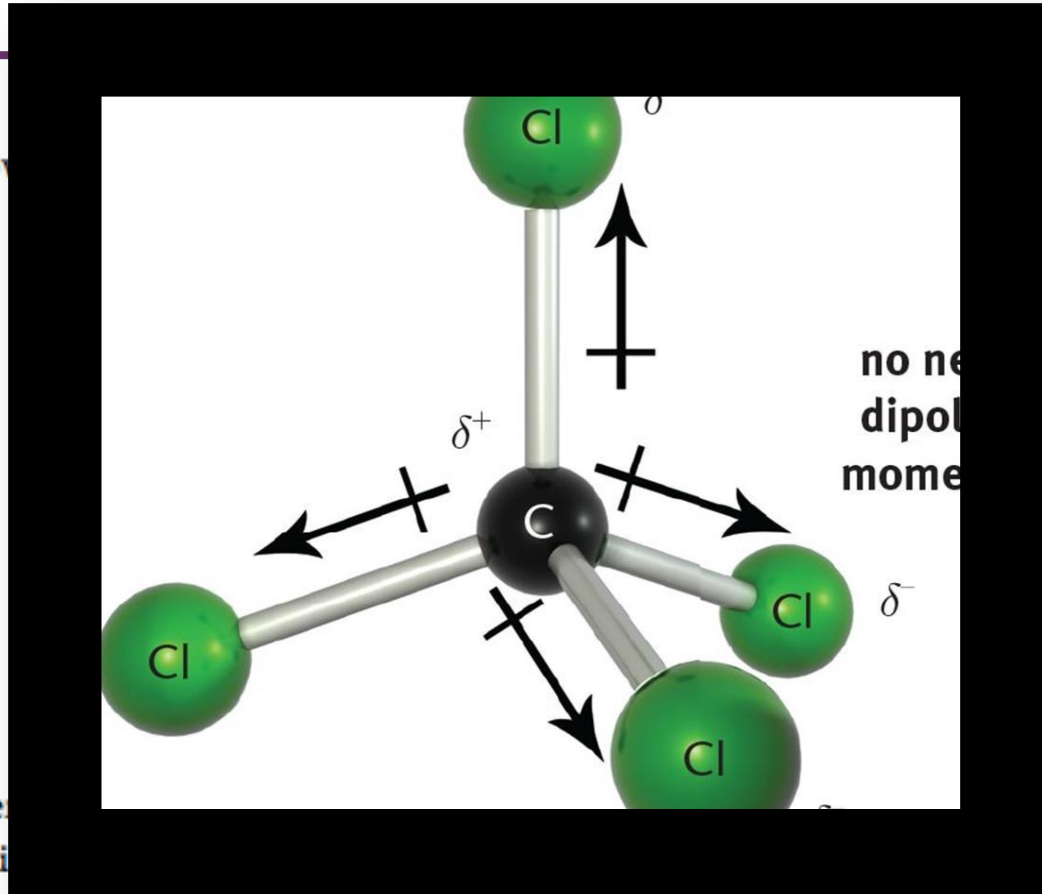

… y.com

Answer:

The correct answe … nce that
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have the weakest intermolecular forces and therefor the highest vapor pressure.

LO 2.16: Explain the properties (phase, vapor pressure, viscosity, etc.) of small and large molecular compounds in terms of the strengths and types of IMF's.

Source

+Bonding and Electronegativity

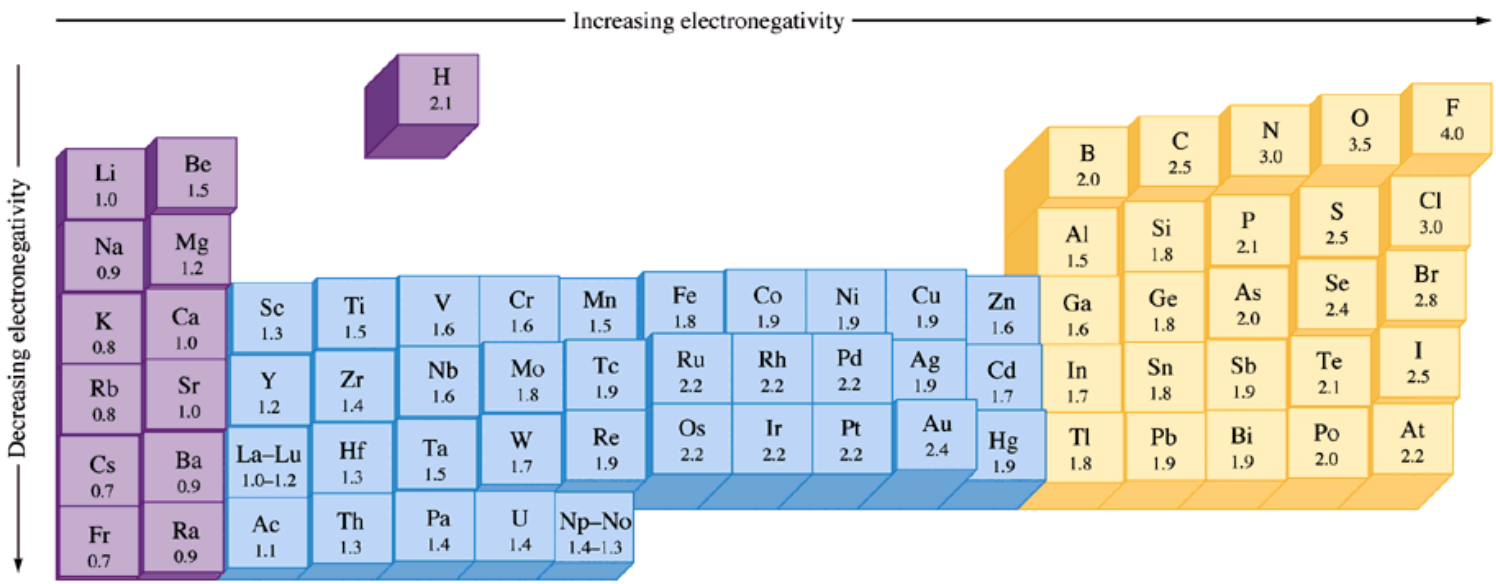
Video

Differences in electronegativities lead to different types of bonding*:

0.0 – 0.4: Bond is generally considered nonpolar

0.5 – 1.7: Bond is generally considered polar

> 1.7: Bond is generally considered ionic



Electronegativities are assigned values and are relative to fluorine. Electronegativity is a function of shielding / effective nuclear charge.
*Values presented are one possibility – other scales exist.

LO 2.17: The student can predict the type of bonding present between two atoms in a binary compound based on position in the periodic table and the electronegativity of the elements.

+ Ranking Bond Polarity

[Source](#)

[Video](#)

Which of the following bonds would be MOST polar?

a. C—O
b. H—O
c. H—F
d. C—N
e. F—O

LO 2.18: The student is able to rank and justify the on the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table.

+ Ranking Bond Polarity

Source

Video

uestion:

Vhich of the following bonds would be MOST polar?

a. C—O
b. H—O
c. H—F
d. C—N
e. F—O

nswer:

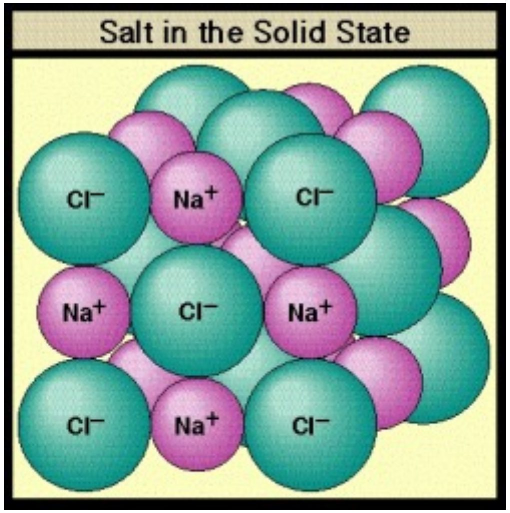
he correct answer is "c", H—F. The polarity of a bond is determined by the difference
n the electronegativity between the two atoms. Atoms that are far apart on the periodi
able will have a greater difference in electronegativity. H and F are the furthest apart i
his list, and will have the biggest difference.

LO 2.18: The student is able to rank and justify the on the ranking of bond polarity on the basis of the locations of the bonded atoms in the periodic table.

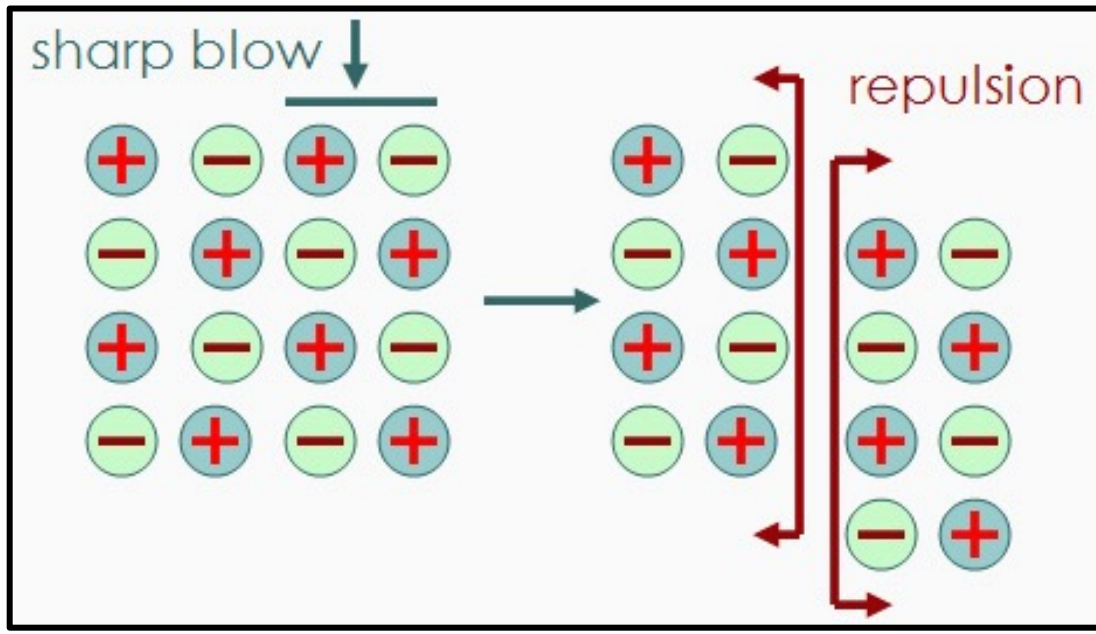
+ Ionic Substances and their Properties

Source

Video



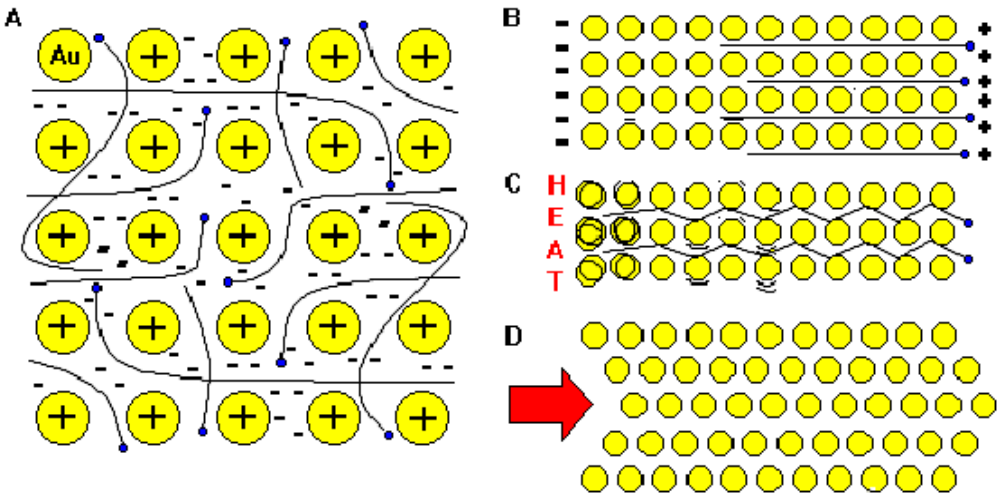
Ionic compounds are brittle. As the crystal structure is struck, the ions become displaced. The displaced ions will repel like charges and fracture.



LO 2.19: The student can create visual representations of ionic substances that connect the microscopic structure to macroscopic properties and/or use representations to connect microscopic structure to macroscopic properties (e.g., boiling point, solubility, hardness, brittleness, low volatility, lack of malleability, ductility, or conductivity).

[Source](#)

Metallic Properties – Sea of Electrons



[Video](#)

"The metallic bond is not the easiest type of bond to understand, so an analogy may help. Imagine filling your bathtub with golf balls. Fill it right up to the top. The golf balls will arrange themselves in an orderly fashion as they fill the space in the tub. Do you see any spaces between the balls? If you turn on the faucet and plug the drain, the water will fill up those spaces. What you now have is something like metallic bonding. The golf balls are the metal kernals, and the water represents the valence electrons shared by all of the atoms."

LO 2.20: The student is able to explain how a bonding model involving delocalized electrons is consistent with macroscopic properties of metals (e.g., conductivity, malleability, ductility, and low volatility) and the shell model of the atom.

+ Lewis Diagrams / VSEPR

Source

Video

Question:
Which of the following molecules has a tetrahedral shape?

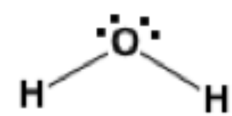
a. NH_3
b. H_2O
c. BH_3
d. CH_4
e. HF

Question:
Which of the following molecules has polar bonds but is a non-polar molecule?

a. O_2
b. NH_3
c. HF
d. H_2O
e. CCl_4

Question:
Which hybridization would best represent the oxygen atom in the following molecule?

a. sp
b. sp^2
c. sp^3
d. dsp^3
e. d^2sp^3



LO 2.21: The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.

Source

+ Lewis Diagrams / VSEPR

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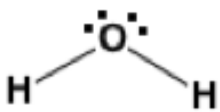

a. sp
b. sp^2
c. sp^3
d. dsp^3
e. d^2sp^3

Answer:
The correct answer is "c", sp^3. The oxygen atom has 4 electron pairs around it, 2 bonds and 2 non-bonding pairs. When there are four pairs the hybridization is sp^3.

Video

LO 2.21: The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.

[Source](#)

+ Lewis Diagrams / VSEPR

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Which of the following molecules has polar bonds but is a non-polar molecule?

a. O_2
b. NH_3
c. HF
d. H_2CO
e. CCl_4

[Video](#)

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Source

+ Lewis Diagrams / VSEPR

Video

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e. HF

hich of the following molecules has polar bonds but is a non-polar molecule?

a. O_2
b. NH_3
c. HF
d. H_2CO
e. CCl_4

nswer:

he correct answer is "e", CCl_4. For a molecule to be non-polar either the bonds in th
olecule need to be non-polar or the polar bonds in the molecule need to be
mmetrically arranged so that they cancel out. The CCl_4 molecule has polar C–Cl

LO 2.21: The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.

Source

Lewis Diagrams / VSEPR

Question:
Which of the following molecules has a tetrahedral shape?

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Video

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Source

+ Lewis Diagrams / VSEPR

Question:
Which of the following molecules has a tetrahedral shape?

a. NH_3
b. H_2O
c. BH_3
d. CH_4
e. HF

Answer:
The correct answer is "d", CH_4. For a molecule to have a tetrahedral shape the central atom needs to have 4 bonds and no un-bonded electron pairs. Only CH_4 has 4 bonds

Video

LO 2.21: The student is able to use Lewis diagrams and VSEPR to predict the geometry of molecules, identify hybridization, and make predictions about polarity.

Great Lab Example

+ Ionic or Covalent? Bonding Tests

As the type of particles and forced of attraction in ionic and covalent compounds differ, their properties also differ!

Properties	Ionic Compounds	Covalent Compounds
Melting/Boiling Points	High	Low except for some giant covalent molecules
Electrical Conductivity	Conduct electricity in molten and in aqueous solution	Does not conduct electricity in any state when pure, may conduct in aqueous solution (i.e., acids)
Solubility in water and organic solvents	Soluble in water Insoluble in organic solvent	Insoluble in water, except for some simple molecule Soluble in organic solvent
Volatility	Not volatile	Highly volatile

Video Source

Substance	Type of Bonding	Phase at room temperature	Melting Point (C)	Electrical Conductivity without water	Electrical conductivity in water	Solubility in water (does it dissolve)
Distilled Water		Liquid	0			n/a
Sodium chloride (NaCl)		Solid				es
Potassium Iodide (KI)		Soli				
Sucrose ($C_{12}H_{22}O_{11}$)						
Olive Oil		Li				no
Ethanol (C_2H_6O)		Liqui				yes
Corn Starch		Solid	Dec at hig temperat		Click to view results	no
Glycerin		Liquid		Click to view results	Click to view results	no
Calcium Chloride ($CaCl_2$)		Solid		Click to view results	Click to view results	yes

Click here to do a virtual lab on bonding type (chart pictured below)

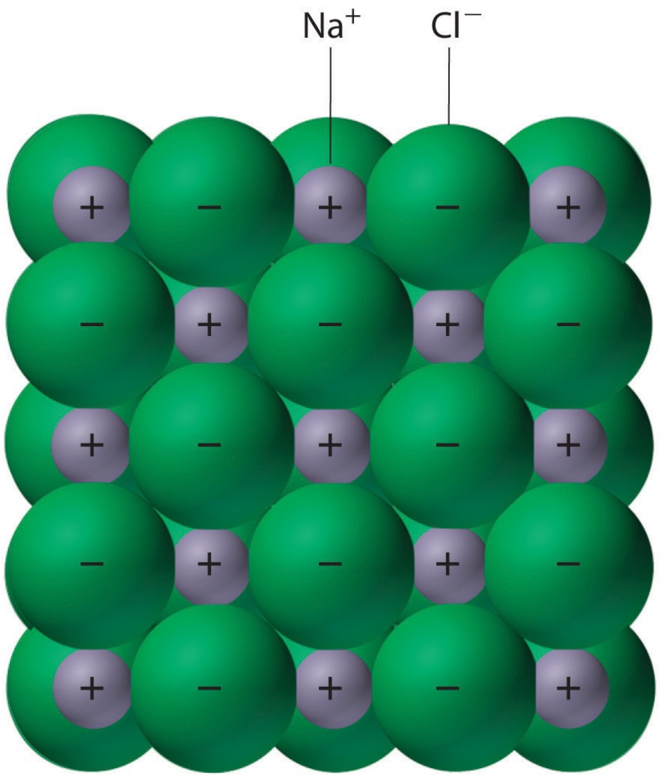
Use properties of compounds to differentiate them from one another. Other tests may be performed to positively identify the compound, but are not necessary to observe types of bonds present.

LO 2.22: The student is able to design or evaluate a plan to collect and/or interpret data needed to deduce the type of bonding in a sample of a solid.

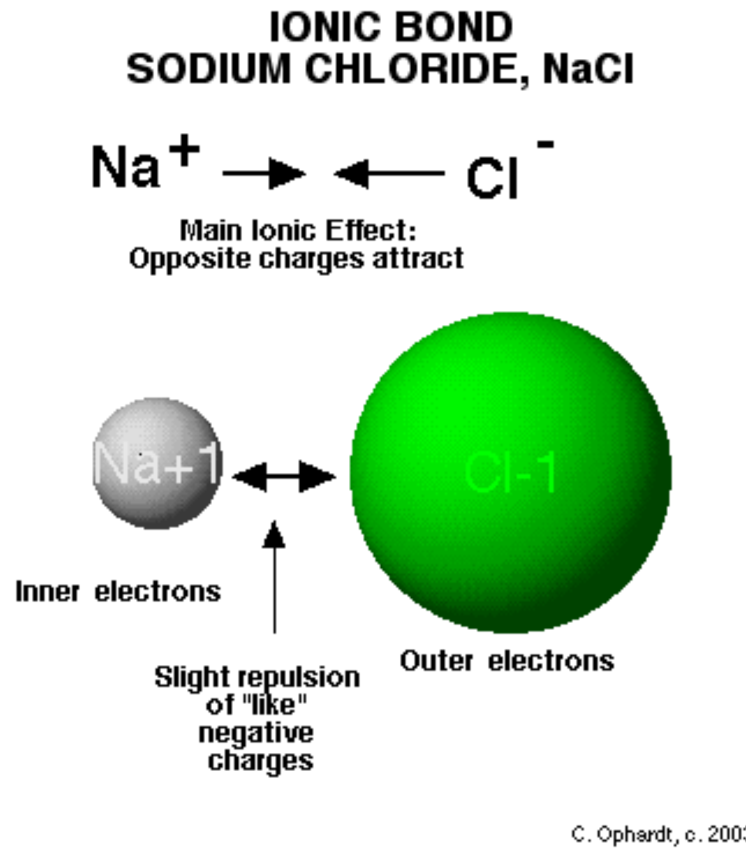
+ Crystal Structure of Ionic Compounds

Source

Video



(a) Ionic solid: strong electrostatic interactions



LO 2.23: The student can create a representation of an ionic solid that shows essential characteristics of the structure and interactions present in the substance.

Source

+ Crystal Structure of Ionic Compounds

Video

Sodium chloride and magnesium oxide have exactly the same structure. Their melting and boiling points are:

	NaCl	MgO
melting point (K)	1074	3125
boiling point (K)	1686	3873

Explain why the values for magnesium oxide are much higher than those for sodium chloride.

LO 2.24: The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level.

Source

+ Crystal Structure of Ionic Compounds

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melting point (K)	1074	3125
boiling point (K)	1686	3873

Explain why the values for magnesium oxide are much higher than those for sodium chloride.

The +2 and -2 ions attract each other more strongly than +1 attracts -1.

The ions Mg^{+2} and O^{-2} are smaller than Na^{+1} and Cl^{-1}, therefore the ions can get closer together, increasing their electrostatic attractions.

LO 2.24: The student is able to explain a representation that connects properties of an ionic solid to its structural attributes and to the interactions present at the atomic level.

Alloys and their Properties

Source

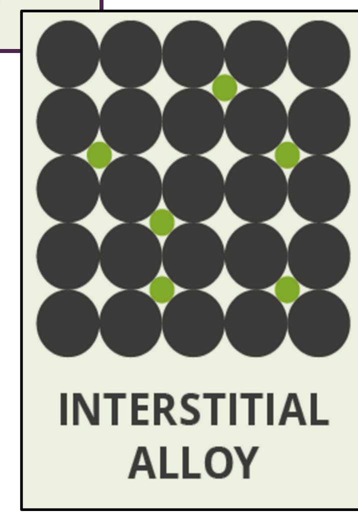
Video

Question:

Metal	Metalic Radius (pm)	Common Oxidation States	Number of Valance Electrons
Silver	144	+1	1
Gold	144	+3	1
Copper	128	+1, +2	1

Pure silver is generally considered too soft to form useful objects and is generally alloyed with other metals such as copper and gold. Two alloys of sliver were created with equal amounts of silver alloyed with either gold or copper. If the silver/copper alloy is harder than the silver/gold alloy, which of the following would best explain the difference based on the table above.

a. Silver and gold have very similar metallic radii making them easy to alloy.
b. Silver has a higher electronegativity than copper making the alloy tougher.
c. Copper has a small radius than silver disturbing the crystal structure and making the alloy harder.
d. Copper and gold do not have any oxidation states in common, making the alloy much softer.



LO 2.25: The student is able to compare the properties of metal alloys with their constituent elements to determine if an alloy has formed, identify the type of alloy formed, and explain the differences in properties using particulate level reasoning.

Alloys and their Properties

[Source]

[Video]

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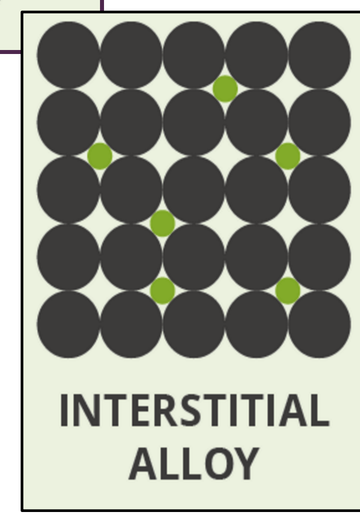
d. Copper and gold do not have any oxidation states in common, making the alloy much softer.

Answer:
The correct answer is "c". When there is a significant difference in the size of the atoms in an alloy the crystal lattice will become distorted, making it more difficult for the crystal structure to shift making the alloy harder. The added copper atoms in the silver lattice pin the lattice in place around the copper atoms preventing movement and making the alloy harder.



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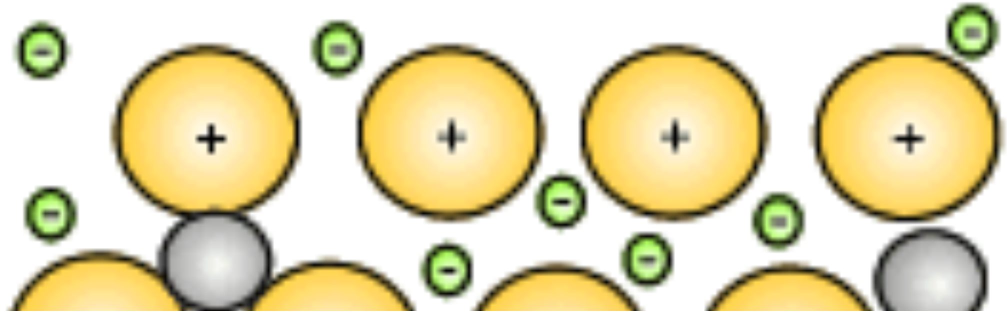
Alloys!

Source

Video



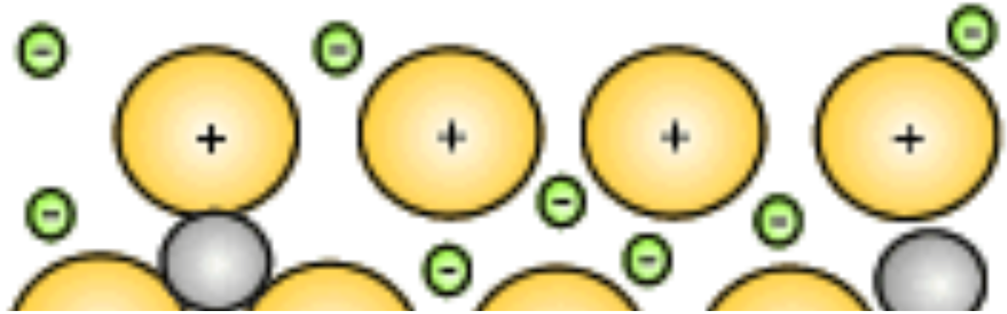
Type of Alloy	Example	Notes:
substitutional	*sterling silver* Ag 93% Cu 7%	- atomic radii are within ~15% to not affect the overall crystal structure[1] - crystal structure of elements *should* be same for least disruption - resulting solid remains malleable, ductile, similar density
interstitial	*steel* Fe >99% C <1%	- interstitial substituted elements commonly non-metals (H, B, C, N, O, Si) - resulting solid is more rigid, less malleable / ductile
intermetallic*[,2]	$MgZn_2$ Na_5Zn_{21} Cu_3Zn	- definite proportions of constituent elements - crystal lattice structure is different from any of constituent metals - resulting solid has properties often different from constituents
heterogeneous	*solder* Pb ~50% Sn ~50%	- multiple phases / crystal structures throughout the solid (ie. phase of lead only → phase of tin and lead* → phase of tin only)[3] - properties can vary broadly

* intermetallic is sometimes used to describe phases in heterogeneous alloys with multiple metals

LO 2.26: Students can use the electron sea model of metallic bonding to predict or make claims about macroscopic properties of metals or alloys.

Source

Alloys!



Video

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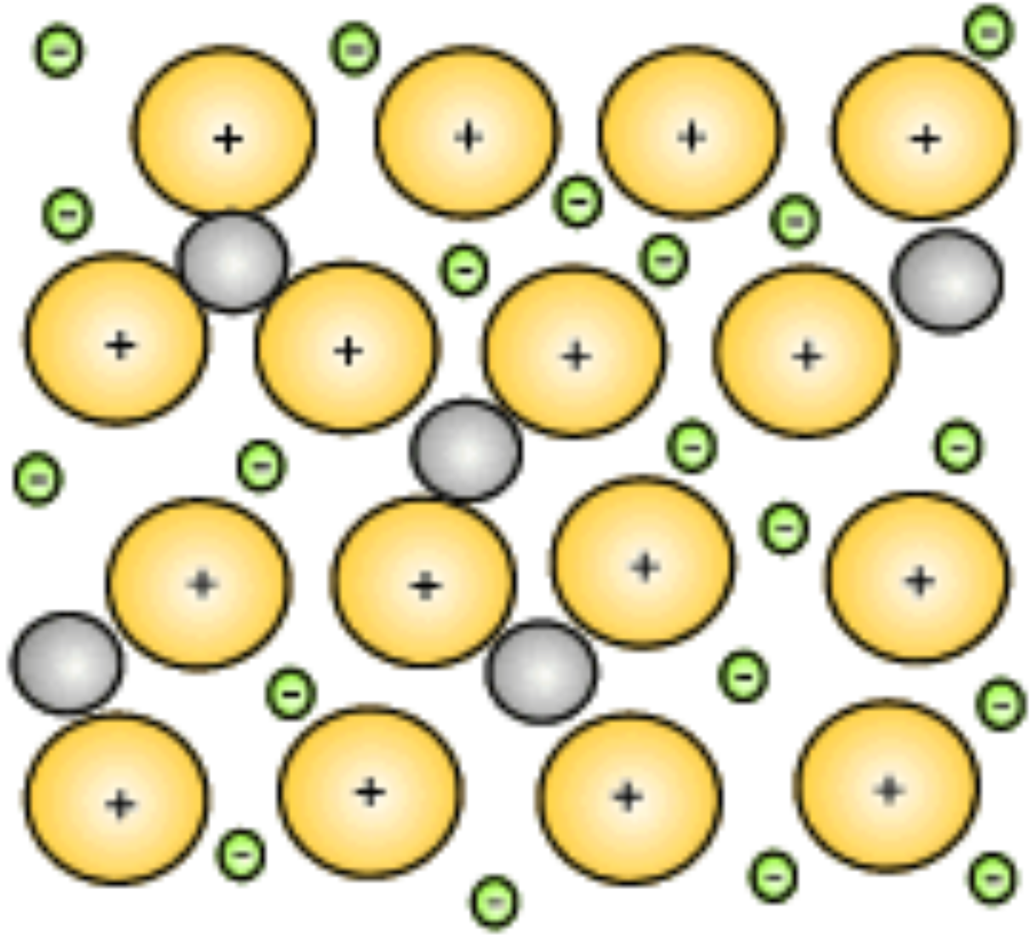
LO 2.26: Students can use the electron sea model of metallic bonding to predict or make claims about macroscopic properties of metals or alloys.

Alloys!

Source

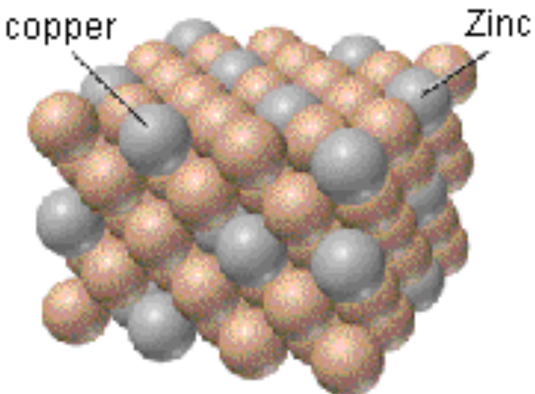
Video



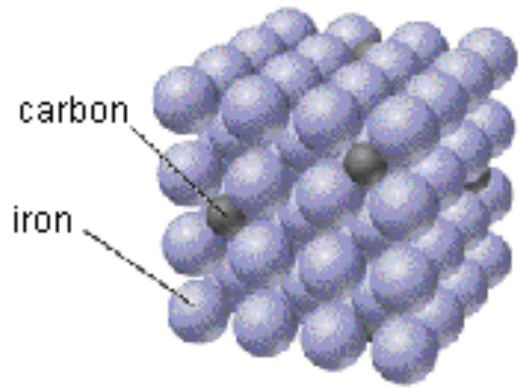
LO 2.26: Students can use the electron sea model of metallic bonding to predict or make claims about macroscopic properties of metals or alloys.

Source

+ Metallic Solids - Characteristics

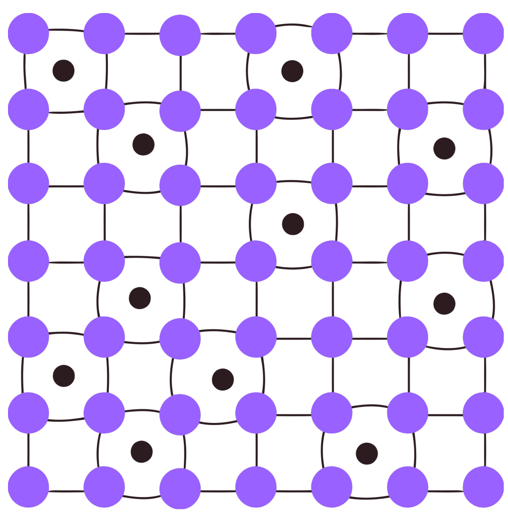


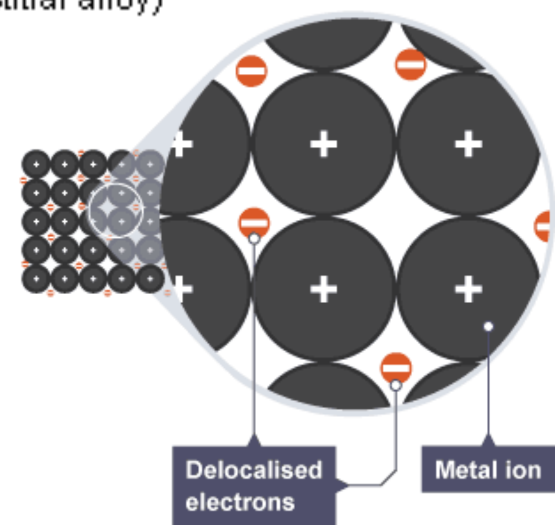
Brass (substitutional alloy)



Carbon steel (interstitial alloy)

Video





LO 2.27: The student can create a representation of a metallic solid that shows essential characteristics of the structure and interactions present in the substance.

Source

+ Properties of Metallic Solids

Video

One type of semiconductor is a germanium crystal adding some impurities can increase he conductivity of the semiconductor. Adding which of the following would create a P-ype semiconductor with increased conductivity?

a. The addition of silicon.
b. The addition of phosphorus.
c. The addition of selenium.
d. The addition of gallium.

LO 2.28: The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level.

Source

+ Properties of Metallic Solids

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nswer:

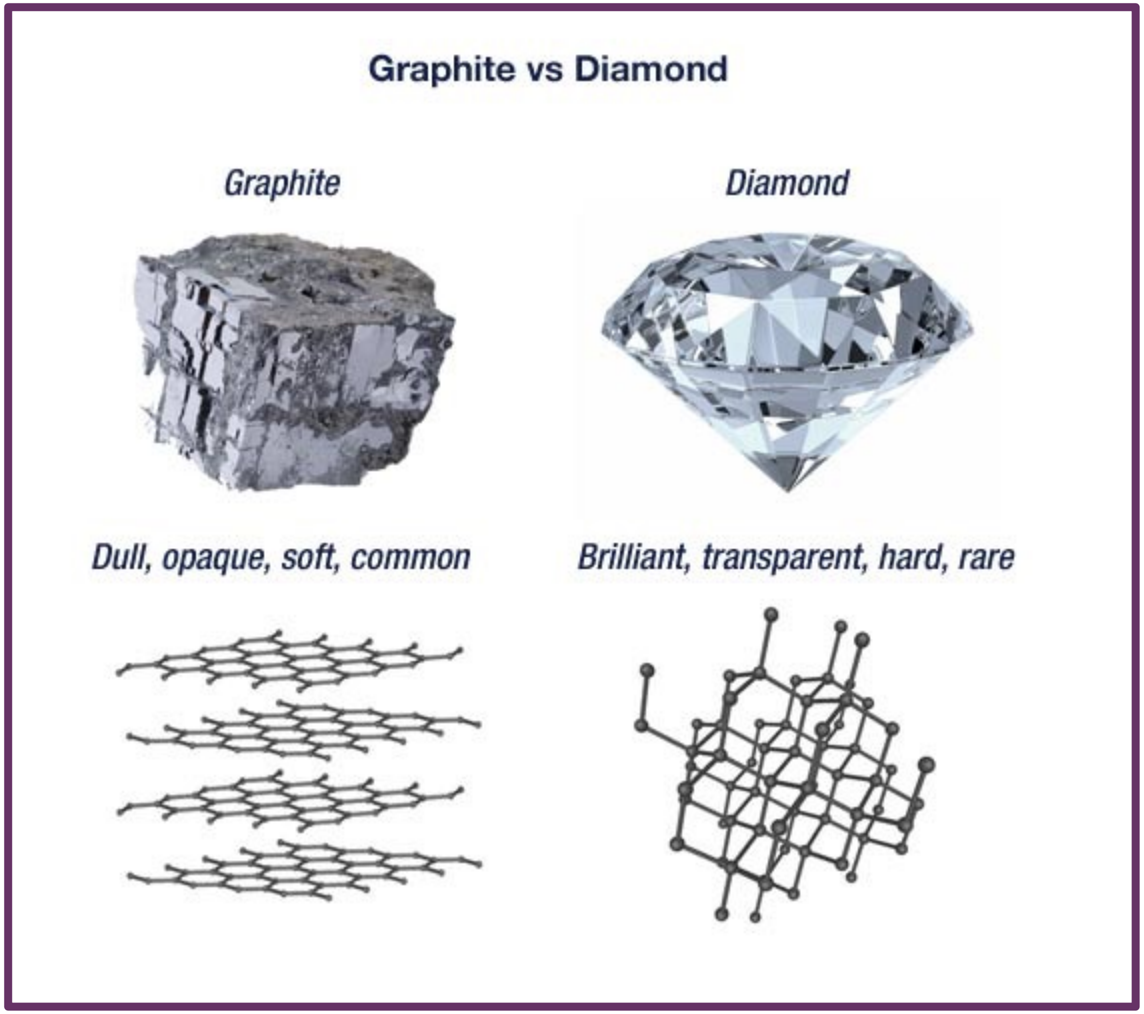
he correct answer is "d". A P-type semiconductor has been doped with the addition of n element with fewer electrons than the element that makes up the crystal matrix. ermanium has four valence electrons, only the gallium has fewer that 4 valance lectrons.

LO 2.28: The student is able to explain a representation that connects properties of a metallic solid to its structural attributes and to the interactions present at the atomic level.

+ Covalent Compounds - Interactions

Source

Video



Graphite are sheets of carbon atoms bonded together and stacked on top of one another. The interactions between sheets is weak, much like the substance itself.

Diamond's carbon atoms are more connected in a three dimensional structure, adding strength to the network.

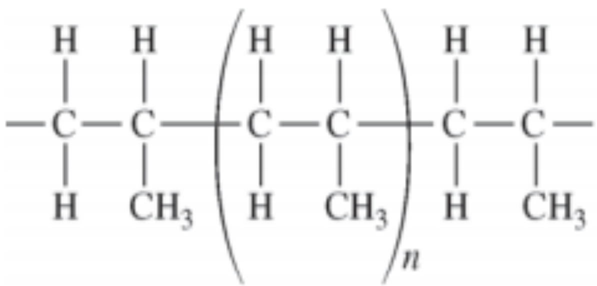
LO 2.29: The student can create a representation of a covalent solid that shows essential characteristics of the structure and interactions present in the substance.

Source

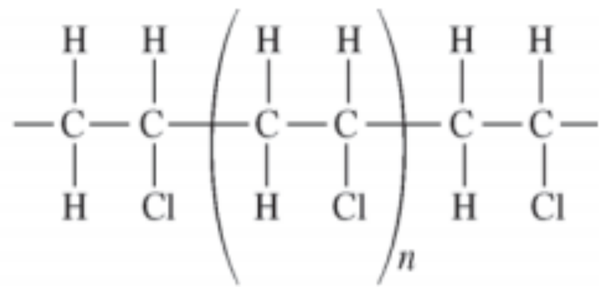
Video

+ Covalent Solids

A student places a mixture of plastic beads consisting of polypropylene (PP) and polyvinyl chloride (PVC) in a 1.0 L beaker containing distilled water. After stirring the contents of the beaker vigorously, the student observes that the beads of one type of plastic sink to the bottom of the beaker and the beads of the other type of plastic float on the water. The chemical structures of PP and PVC are represented by the diagrams below, which show segments of each polymer.



PP



PVC

(a) Given that the spacing between polymer chains in PP and PVC is similar, the beads that sink are made of which polymer? Explain.

LO 2.30: The student is able to explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level.

Source

+ Covalent Solids

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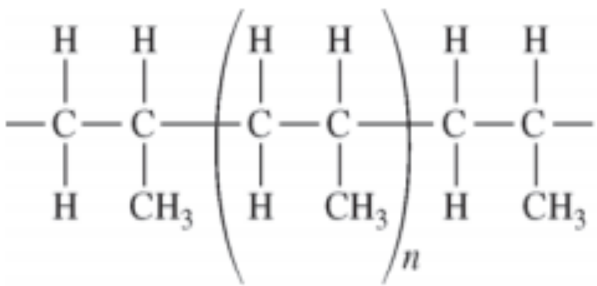
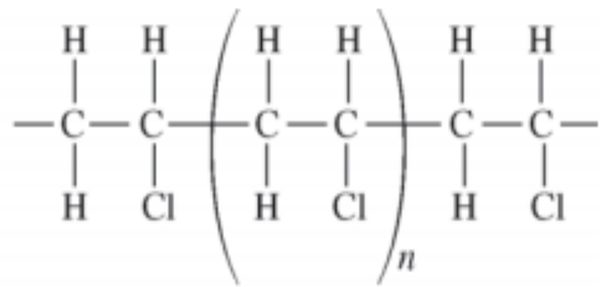


PP



PVC

(a) Given that the spacing between polymer chains in PP and PVC is similar, the beads that sink are made of which polymer? Explain.

The PVC beads sink. The spacing between chains is similar, but a Cl atom has a greater mass than CH_3.

Video

LO 2.30: The student is able to explain a representation that connects properties of a covalent solid to its structural attributes and to the interactions present at the atomic level.

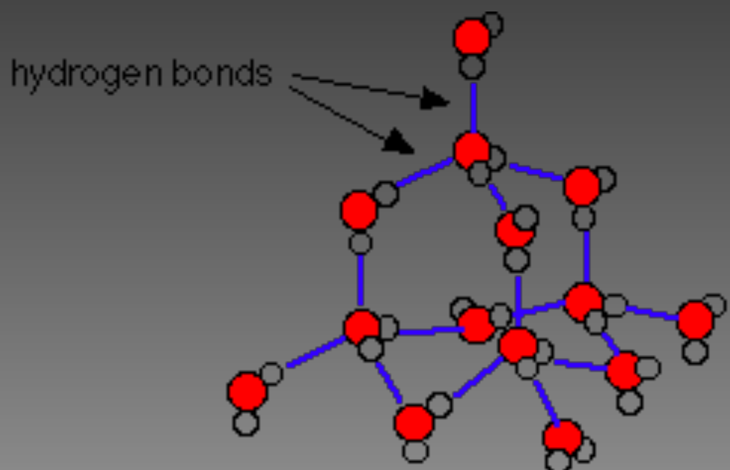
Molecular Compounds - Interactions

Source

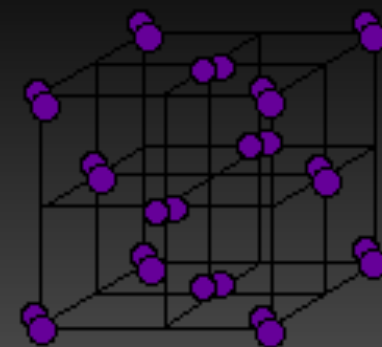
Video

Water (H_2O)

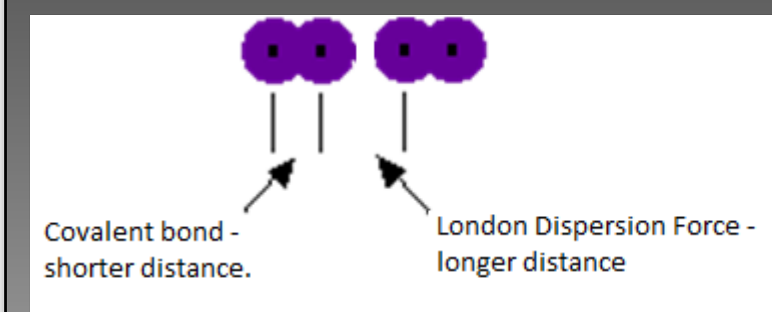
Polar Covalent compounds align according to dipole-dipole interactions.



Iodine (I_2)



Non-Polar Covalent compounds align according to LDF's as a solid.



LO 2.31: The student can create a representation of a molecular solid that shows essential characteristics of the structure and interactions in the substance.

+ Molecular Compound Interactions

[Source](#)

[Video](#)

Which of the following are broken when water boils?

a. Covalent bonds
b. Hydrogen bonds
c. Dipole-dipole interactions
d. London Dispersion Forces

Explain why iodine is a solid with a low melting and boiling point, almost insoluble in water, but soluble in organic solvents such as hexane, and is also a non-conductor of electricity.

LO 2.32: The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level.

+ # Molecular Compound Interactions

Source

Video

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All of these are broken *except* covalent bonds.

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Iodine consists of I_2 molecules, and the only attractions between the molecules are van der Waals dispersion forces. There are enough electrons in the I_2 molecule to make the temporary dipoles creating the dispersion forces strong enough to hold the iodine together as a solid. But they aren't all that strong, and so the solid has a low melting point and boiling point.

It is almost insoluble in water because the only attractions between water molecules and iodine molecules are dispersion forces. But in order to get the iodine molecules in between the water molecules you would have to break hydrogen bonds in the water. This costs too much energy which can't be recovered from the new attractions between water and iodine.

It dissolves in organic solvents such as hexane because, in this case, all you have to do is break the dispersion forces in the iodine and the hexane, and replace them by similar forces between the iodine and hexane.

Iodine doesn't conduct electricity because it doesn't have any mobile delocalised electrons.

LO 2.32: The student is able to explain a representation that connects properties of a molecular solid to its structural attributes and to the interactions present at the atomic level.