Quiz Question for Callister Ch. 2

All problem sets and solutions have been written/adapted by J. Emery. Authors include J. Emery, J. Rondinelli, J. Snyder, and various teaching assistance.

Directories are searched using Ch-Compile.py, which searches the home director for files starting with C-Ch2 adds them to the problem list. As new problems are added, this script should be run to provide the most up-to-date version of the problems.

The problems below are updated as of: Friday 30th June, 2017, at 14:09

Questions are organized into groups.

Q01-01| **File Information:** **Flagged:See comments.**

#FileTag:C-Ch2-Q01-01.tex	#SourceTag:Original
#AuthorTag:GJSnyder	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondCharacter	
#TypeTag:MultipleChoice	
#CallisterProblems:C|2.25,C|2.26	

The bonding in lithium nitride (Li_3N) is predominantly:

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

The primary bond type in Li_3N is ionic. N is not a metal, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of 1.7 yields a bond with predominantly ionic character.

Or, the full calculation from the Pauling approximation for percent ionic character(%IC): $\%IC = 100 \times (1 - \exp(-\frac{1}{4}(X_N - X_{Li})^2))$, where X indicates the electronegativity on the Pauling scale. $X_N - X_{Li} = 2$ so $\%IC = 100 \times (1 - \exp(-1)) = 100 \times 1 - \frac{1}{e} \cong 70\%$. So, mostly ionic.

Grading Rubric:

1. Give 25% pts for covalent.

Outcomes:

The most common error is covalent.

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
-	-	-	-%/-%/-%

Comments/Extensions:

This is one of the only

A point of confusion may be the Li to N ratio. JDE typically limits these calculation to 1-1 stoichiometry as to avoid this confusion.

This approximation can be used for simple bonds, but in more complex compounds we must consider all bonds formed. Regardless, this analysis works with 10% of measured values even for more complex compounds [cite].

If C|2.26 is assigned and the point is made that Al_6Mn can be well-approximated by assuming a 1-1 stoiciometry, then this problem is acceptable.

Q01-02| File Information:

#FileTag:C-Ch2-MC-Q01-02.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: Midterm1	#TermTag: F16
#AssignmentTag: QuizD2	#TermTag: S17
#TopicTag:BondCharacter	#TopicTag:Electronegativity
#TypeTag:MultipleChoice	

The bonding in SiC ($X_{\mathrm{Si}} = 1.9$ and $X_{\mathrm{C}} = 2.6$) is:

A. Predominantly covalent

B. Only ionic

C. Only covalent

D. Only metallic

E. Predominately ionic

F. Predominately metallic

Solution:

SiC is made up of two non-metals, and so we can eliminate metallic bonding as being the predominant character. Now, if there is any difference in electronegativity, we will have some ionic character in bond. The difference ΔX is small (less than 1.7), so this material is mostly covalent. The students should know this is the cutoff: 1.7 was covered explicitly in class by solving $\%\mathrm{IC} = 50\%(1 - \exp[-\frac{1}{4}(X_{\mathrm{A}} - X_{\mathrm{B}})^2]) \times 100\%$ and is mentioned in the solutions for assigned problems..

Grading Rubric:

- ◇ 50% pts for only covalent.
- ◇ 50% pts if they show the equation and describe what's going on, even if they forgot the 1.7 "rule". They do have calculators on quizzes, although they don't need it here.

Outcomes: Most common error is "only covalent".

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
F16	Emery	Midterm1	95%/2%/0%
S17	Emery	QuizD2	90%/10%/0%

Comments/Extensions:

Students want to plug the numbers into a calculator but didn't recognize that you need large differences in electronegativity (like O, F, or Cl and a alkaline metal) to get predominantly ionic bonding. They understand how to calculate the value, but they're missing the concept.

Q01-03| File Information:

#FileTag:C-Ch2-MC-Q01-03.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondType	
#TypeTag:MultipleChoice	

The bonding in yttrium nitride (YN) is predominantly:

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

The primary bond type in YN is ionic. N is not a metal, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of 1.7 yields a bond with predominantly ionic character. Or, the full calculation from the Pauling approximation for percent ionic character(%IC): $\%\text{IC} = 100(1-\exp -\frac{1}{4}(X_\text{N} - X_\text{Y})^2)$, where X indicates the electronegativity on the Pauling scale, gives $\%\text{IC}_\text{YN} = 56.3\%$. Slightly more ionic than covalent.

Grading Rubric:

- ◇ Give 25% pts for covalent.
- ◇ Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
W16	Emery	Midterm1	Needs input

Comments/Extensions:

This requires knowledge of the 1.7 % ionicity cutoff.

Q01-04| **File Information:**

#FileTag:C-Ch2-MC-Q01-04.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:Bondtype	#TopicTag:MaterialsClass
#TypeTag:MultipleChoice	

Niobium carbide (NbC) is a material that is commonly used in cutting tools and to strengthen steels. The bonding in NbC is predominantly of which type?

A. Covalent

B. Ionic

C. Metallic

D. van der Waals

Solution:

Here we recognize that we have either a covalent or ionic bond, so we do the electronegativity test. We use Pauling's rule: $\%\text{IC} = 100\% \times (1 - \exp[-\frac{(\Delta X)^2}{4}])$ and plug in $\Delta X = 1$:

$$\begin{aligned}\%\text{IC} &= 100\% \times (1 - \exp[-\frac{(\Delta X)^2}{4}]) \\ &= 100\% \times (1 - \exp[-\frac{1}{4}]) \\ &= 100\% \times (1 - \frac{1}{e^{\frac{1}{4}}})\end{aligned}$$

So, I made a mistake here (I had meant for ΔX to be 2). But, if you remember your Taylor series, $e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \frac{x^3}{3!}....$ So, $e^{\frac{1}{4}} = 1 + \frac{\frac{1}{4}}{1!} + \frac{\frac{1}{4}^2}{2!} + \frac{\frac{1}{4}^3}{3!}$, but this series is dominated by the first and second terms, so $e^{\frac{1}{4}} = 1.25$.

$$\begin{aligned}&= 100\% \times (1 - \frac{4}{5}) \\ \boxed{\%\text{IC} = 20\%}\end{aligned}$$

That's mostly covalent. You can also use the $\Delta X = 1.7$ rule.

Grading Rubric:

- ◇ Give 25% pts for ionic.
- ◇ Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
W16	Emery	QuizD2	Needs input

Comments/Extensions:

I gave full points for metallic because the students some students thought this could be an alloy — they aren't yet familiar with the notation differentiating alloys (Nb-C) and compounds (NbC).

Don't use this unless you a.) are using calculators on the quiz or b.) provide them with the form of the Taylor expansion.

Q01-05| **File Information:** **Flagged: See comments.**

#FileTag:C-Ch2-MC-Q01-04.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondTye	
#TypeTag:MutipleChoice	

The bonding in AlN_3 is predominantly (note: $X_{Al} = 1.61 \text{and} X_N = 3.04$):

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

The primary bond type in AlN_3 is covalent. N is not a metal, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of less than 1.7 yields a bond with predominantly covalent character. Or, the full calculation from the Pauling approximation for percent ionic character(%IC): $\%\text{IC} = 100(1 - e^{-\frac{1}{4}(X_N - X_Y)^2})$, where X indicates the electronegativity on the Pauling scale, gives $\%\text{IC}_{AlN_3} = 40.0\%$- slightly more covalent than ionic.

Grading Rubric:

- ◇ Give 25% pts for ionic.
- ◇ Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
-	-	-	-

Comments/Extensions:

Students may get confused by the stoichiometry.

This requires knowledge of the 1.7 % ionicity cutoff.

Q01-06| **File Information:**

#FileTag:C-Ch2-MC-Q01-06.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondType	
#TypeTag:MultipleChoice	

The bonding in a Ni-Ti alloy is predominantly (note: $X_{\text{Ni}} = 1.91 \text{and} X_{\text{Ti}} = 1.54$):

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

Ni-Ti is an alloy and therefore has metallic bonding. There is a difference in electronegativity, and so it will have some ionic (and likely some covalent) character.

Grading Rubric:

- Give 25% pts for ionic.
- Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

This one is a bit tricky because they may think that they should use the percent ionicity calculator — but that's fine.

Using the word "alloy" is a bit explicit and gives the answer away, but the students don't know the nomenclature that well after the first week of class, so it isn't a realy problem.

This requires knowledge of the 1.7 % ionicity cutoff.

Q01-07| File Information:

#FileTag:C-Ch2-MC-Q01-07.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondCharacter	
#TypeTag:MultipleChoice	

The bonding in GaN is predominantly what character? Note: $X_{\text{Ga}} = 1.81$ and $X_{\text{N}} = 3.04$:

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

The primary bond type in GaN is covalent. These two atomic species are not metallic, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of 1.7 yields a bond with predominantly ionic character. Or, the full calculation from the Pauling approximation for percent ionic character(%IC): $\%\text{IC} = 100(1 - exp{-\frac{1}{4}(X_N - X_{Ga})^2})$, where X indicates the electronegativity on the Pauling scale, gives $\%\text{IC}_{\text{GaN}} = 31.5\%$.

Grading Rubric:

- Give 25% pts for ionic.
- Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

This requires knowledge of the 1.7 % ionicity cutoff.

Q01-08| File Information:

#FileTag:C2-MC-Q01-08.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondType	
#TypeTag:MultipleChoice	

The bonding in Si_3N_4 is predominantly what character? Note: $X_{\text{Si}} = 1.90$ and $X_{\text{N}} = 3.04$:

A. Covalent

B. Ionic

C. Metallic

D. Van der Waals

Solution:

The primary bond type in GaN is covalent. These two atomic species are not metallic, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of less than 1.7 yields a bond with predominantly covalent character. Or, the full calculation from the Pauling approximation for percent ionic character(%IC): %IC $= 100(1-\exp\left(-\frac{1}{4}(X_N - X_{Si})\right)^2)$, where X indicates the electronegativity on the Pauling scale, gives $\%\text{IC}_{\text{Si}_3\text{N}_4} = 27.7\%$.

Grading Rubric:

- ◇ Give 25% pts for ionic.
- ◇ Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
-	-	-	-%/-%/-%

Comments/Extensions:

Students may wonder how to address the stoichiometry in this problem.

This requires knowledge of the 1.7 % ionicity cutoff.

Q01-09| **File Information:**

#FileTag:C-Ch2-MC-Q01-09.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondType	
#TypeTag:MultipleChoice	

Niobium carbide (NbC) is a material that is commonly used in cutting tools and is also used to strengthen steels. The bonding in a NbC ($X_{\text{Nb}} = 1.60$ and $X_{\text{C}} = 2.60$) is predominantly of type:

A. Covalent

B. Ionic

C. Metallic

D. van der Waals

Solution:

The primary bond type in NbC is covalent. Carbon is not metallic, so we can exclude metallic bonding as a predominant type. As a rule of thumb, a ΔX of less than 1.7 yields a bond with predominantly covalent character.

The full calculation from the Pauling approximation could be done but is unnecessary. Percent ionic character(%IC): $\%\text{IC} = 100\% \times (1 - \exp(-\frac{1}{4}(X_{\text{C}} - X_{\text{Nb}})^2))$, where X indicates the electronegativity on the Pauling scale.

Here, we get $\%\text{IC} = 100\% \times (1 - \exp(-\frac{1}{4}))$. A Taylor expansion (you certainly don't need to know this) gives us $\exp(-\frac{1}{4}) \approx 1 - \frac{1}{4} = 0.75$, so $\%\text{IC} = 25\%$ and we're mostly covalent.

Grading Rubric:

- Give 25% pts for ionic.
- Give up to 50% pts for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

This is a great one if they don't have a calculator and they know $e^x \approx 1 + x$

Q01-10| File Information:

#FileTag:C-Ch2-Q01-10.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondType	
#TypeTag:MultipleAnswer	

For this question, select one or more answers. What are the primary type(s) of bonding that you would expect for solid elemental boron (B)?

A. Ionic bonding

B. Metallic bonding

C. Covalent bonding

D. van der Waals bonding

Solution:

Boron possesses a mixture of both covalent and metallic bonding because it only has three valence electrons. It cannot fulfill the octet rule by itself and some of the electrons are delocalized.

Grading Rubric:

1. 25% pt for each correct answer.
2. 50% pt for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
-	-	-	-%/-%/-%

Comments/Extensions:

This is a very hard question, and probably requires more knowledge than we have at this point. Not an easy problem or one at the level of MAT_SCI 201 students.

Q01-11| File Information:

#FileTag:C-ch2-MC-Q01-11.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: Midterm1	#TermTag: S17
#TopicTag:BondCharacter	#TopicTag:Electronegativity
#TypeTag:MultipleChoice	

Five materials are listed below. Which do you expect to have the largest covalent bond character?

A. Elemental silicon (Si)

B. LiF

C. Molybdenum (BCC structure)

D. InP

E. Helium gas

Solution:

Silicon will have the highest covalent bond character — there is no difference between electronegativities of Si and Si and so it will share its electrons in order to achieve a stable bond configuration. LiF is an ionic solid (large ΔX), Mo is a metal. InP will have a large degree of covalent bonding, but there is still some electronegativity difference $\Delta X \approx 0.4$. Helium gas only makes secondary, induced dipole bonds.

Grading Rubric:

- 25% pts for InP

Outcomes:

S17: InP was common error — students don't know that "elemental" doesn't mean atomic.

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
S17	Emery	Midterm1	25%/55%/20%

Comments/Extensions:

Q01-12 File Information:

#FileTag:C-Ch2-MC-Q01-12.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: Midterm1	#TermTag: S17
#TopicTag:BondCharacter	#TopicTag:Electronegativity
#TypeTag:MultipleChoice	

For this question, select one or more answers. Graphite (or "pencil lead") is made of layers of hexagonally arranged carbon atoms (black spheres), as shown in Fig. 1.

From the options below, select the predominant type(s) of bonding in graphite.

A. Metallic

B. Covalent

C. Ionic

D. van der Waals

E. Hydrogen

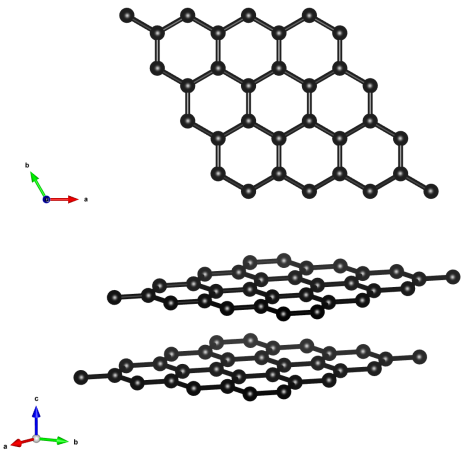


FIGURE 1: Graphite, from two views.

Solution:

Graphite has covalent bonds (sp^2 hybridization) between the carbon atoms and van der Waals bonds between the sheets. This can be interpreted directly from the drawing.

Grading Rubric:

- ◇ -25% pts for each wrong/missed answer
- ◇ Minimum of 0%.

Outcomes:

S17: Many selected only one.

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
S17	Emery	Midterm1	75%/25%/0%

Comments/Extensions:

Q02-01 File Information:

#FileTag:C-Ch2-MC-Q02-01.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondCharacter	
#TypeTag:MultipleChoice	

A highly electropositive metal and a highly electronegative non-metal are likely to form:

A. A covalent bond

B. An ionic bond

C. A metallic bond

D. A hydrogen bond

E. An induced dipole - induced dipole bond

Solution:

Ionic bonds are formed when there is a large difference in the electronegativity between two elements- especially between metals and non-metals. Note: a difference in electronegativity between two atoms of $\Delta X = 1.7$ defines the bonding as predominantly ionic.

Grading Rubric:

- 25% points for covalent.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
S17	Emery	Midterm1	75%/25%/0%

Comments/Extensions:

Q02-02 File Information:

#FileTag:C-Ch2-MC-Q02-02.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:QuizD2	#TermTag:S17
#TopicTag:BondType	
#TypeTag:MultipleChoice	#TypeTag:LearningCatalytics

Which of the following best describes the hydrogen bond?

A. A bond formed due to sharing of electrons between two atoms.

B. A bond formed due to weak electrostatic interaction between permanent electric dipoles.

C. A bond formed due to strong electrostatic interaction between two ionized atoms.

D. A bond formed due to very weak electrostatic interactions that arise from transient induced dipoles of atoms' electron clouds.

E. A bond formed due to the donation of electrons to the "electron sea".

Solution:

Hydrogen bonds are formed due to the (relatively) strong interaction of two permanent electric dipoles.

Grading Rubric:

- ◇ Full points only for the correct answer.
- ◇ Perhaps some partial credit for a good drawing and the wrong answer.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
S17	Emery	Midterm1	80%/20%/0%

Comments/Extensions:

Q03-01| **File Information:** **Flagged: See comments.**

#FileTag:C-Ch3-MC-Q03-01.tex	#SourceTag:Original
#AuthorTag:JMRondinelli	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:PeriodicTable	#ElectronicStructure
#TypeTag:MultipleChoice	

The valence of germanium (Ge) is:

A. 2

B. 1

C. 4

D. 14

E. 3

Solution:

The valence of an element is the number of atoms in the outermost shell (not subshell!). Ge has a filled $3d^{10}$ band and 2 electrons in each its $4s^2$ and $4p^2$, for a valence of 4.

Grading Rubric:

- Full pts only for correct answer.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Full/Partial/No Credit
F15	Emery	Midterm1	95%/0%/0%

Comments/Extensions:

The material covered in this question has been moved to a chemistry review session and not covered in the course. These are not used on test.

The valence of aluminum (Al) is:

A. 1

B. 2

C. 3

D. 5

E. 13

File Information:

#FileTag:C3-MC-Q3-2.tex	#SourceTag:Original
#AuthorTag:JRRondinelli	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:ElectronicStructure	
#TypeTag:MutipleChoice	

Solution:

Valence is the number of electrons in the outermost electron shell. The electronic configuration for aluminum is $1s^2 2s^2 2p^6 3s^2 3p^1$. The $n = 1$ and $n = 2$ shells are full, and there are 3 electrons in the $n = 3$ shell, therefore the valence is 3.

Grading Rubric:

- Full pts only for correct answer.
- Pts up to 50% of value for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16			95%

Comments/Extensions:

The valence of sulfur (S) is:

A. 1

B. 4

C. 3

D. 6

E. 15

File Information:

#FileTag:C2-MC-Q3-3.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:ElectronicStructure	
#TypeTag:MutipleChoice	

Solution:

Valence is the number of electrons in the outermost electron shell. The electronic configuration for aluminum is $1s^2 2s^2 2p^6 3s^2 3p^4$. The $n = 1$ and $n = 2$ shells are full, and there are 6 electrons in the $n = 3$ shell, therefore the valence is 6.

Grading Rubric:

- Full pts only for correct answer.
- 25% for 4.
- Pts up to 50% of value for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16			95%

Comments/Extensions:

The next 2 questions refer to the interatomic distance-energy curves in Figure 7 (below) for different two-element materials with the same structure.

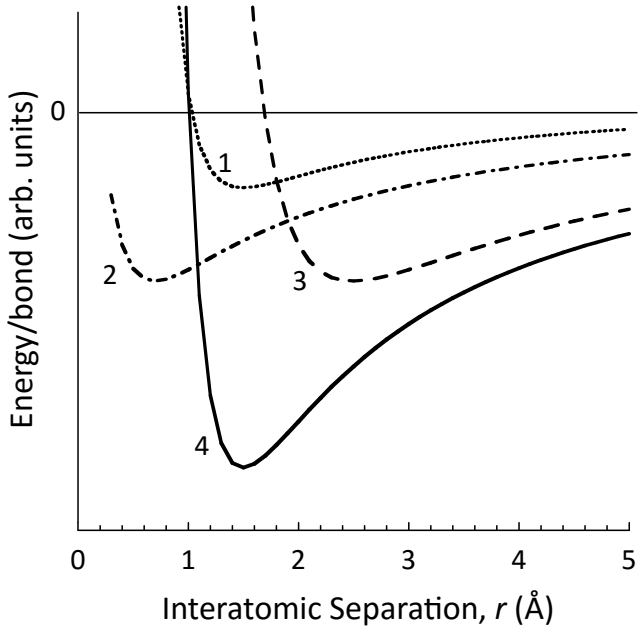


FIGURE 2: Interatomic bond distance versus bond energy for two atoms.

The material with the shortest equilibrium bond distance (r_0) in Figure 7 has r_0 of approximately:

A. 0.2 Å

B. 0.7 Å

C. 1.0 Å

D. 1.5 Å

E. 1.7 Å

F. 2.5 Å

G. >3.0 Å

File Information:

#FileTag:C2-MC-Q4-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Quiz1	#TermTag:2015F
#TopicTag:InteratomicBonding	
#TypeTag:MutipleChoice	

Solution:

The equilibrium bond distance is defined at the position at which energy is at a minimum.

Ca^{2+} and Na^{+} ions are about the same size, and O^{2-} and F^{-} are about the same size. Identify the two curves in Figure 7 which qualitatively represent CaO and NaF, then identify which of those two curves is like to be CaO.

A. 1 and 2; 1 is CaO

B. 1 and 4; 4 is CaO

C. 2 and 3; 2 is CaO

D. 2 and 3; 3 is CaO

Solution:

The interatomic spacing for ions can be approximated by the sum of the ionic radii (see Callister Example Problem 2.2). If the Ca and Na ions are about the same size and the O and F ions are about the same size, the interatomic spacing will be about the same. The magnitude of the energy well is dependent on the product of the charge of the ions: $|E_0| \propto |z_1||z_2|$ (note Callister Eq. 2.19, 2.10, and Fig. 2.10). The CaO have ionic species of C^{2+} and O^{2-}, while NaF has Na^{+} and F^{-}, respectively. The energy well for CaO should therefore be deeper.

Grading Rubric:

The students should recognize what is the smallest bond distance. No points for selecting the smallest bond energy. Give up to 50% pts for work on the graph that shows they have an inkling of what's going on.

Outcomes:

Students typically do well on this problem. Students that get it incorrect misread the problem as being the smallest *energy*.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W15	Emery	Quiz #1	50%

The next 2 questions refer to the interatomic distance-energy curves in Figure 3 (below) for different two-element materials with the same structure.

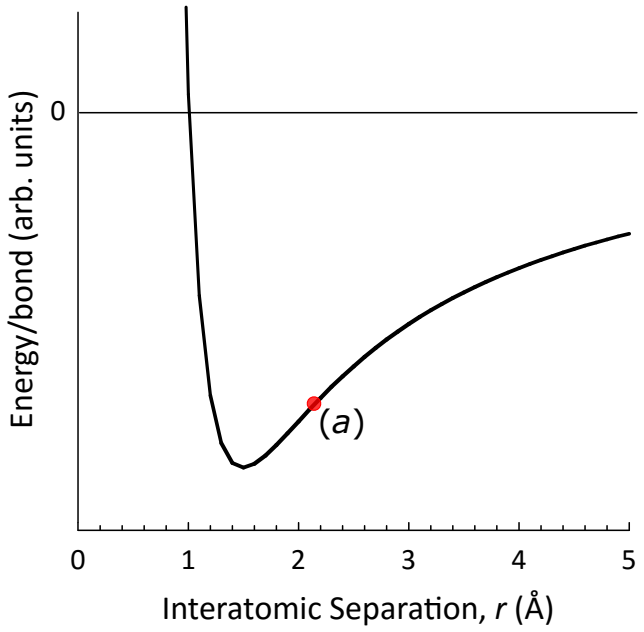


FIGURE 3: Interatomic bond distance versus bond energy for two atoms.

The material with the shortest equilibrium bond distance (r_0) in Figure 3 has r_0 of approximately:

A. 0.2 Å

B. 0.7 Å

C. 1.0 Å

D. 1.5 Å

E. 1.7 Å

F. 2.5 Å

G. >3.0 Å

File Information:

#FileTag:C2-MC-Q4-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Midterm1	#TermTag:2016W
#TopicTag:InteratomicBonding	
#TypeTag:MutipleChoice	

Solution:

The equilibrium bond distance is defined at the position at which *energy* is at a minimum. In the figure, this shortest equilibrium bond distance is at $r_0 = 0.7$ Å.

Grading Rubric:

The students should recognize what is the smallest bond distance. No points for selecting the smallest bond energy. Give up to 50% pts for work on the graph that shows they have an inkling of what's going on.

Outcomes:

Students typically do well on this problem. Students that get it incorrect misread the problem as being the smallest *energy*.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16	Emery	Midterm #1	85%

Comments/Extensions:

Directly related to Callister problems 2.16 (C02p16) and 2.18 (C02p18).

Ca^{2+} and Na^{+} ions are about the same size, and O^{2-} and F^{-} are about the same size. Identify the two curves in Figure 3 which qualitatively represent MgO and NaF, then identify which of those two curves is likely to be MgO.

A. 1 and 2; 1 is MgO

B. 2 and 3; 2 is MgO

C. 1 and 4; 4 is MgO

D. 2 and 3; 3 is MgO

File Information:

#FileTag:C2-MC-Q4-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Quiz1	#TermTag:2015F
#AssignmentTag:Midterm1	#TermTag:2016W
#TopicTag:InteratomicBonding	
#TypeTag:MutipleChoice	

Solution:

The interatomic spacing for ions can be approximated by the sum of the ionic radii (see Callister Example Problem 2.2). If the Ca and Na ions are about the same size and the O and F ions are about the same size, the interatomic spacing will be about the same. The magnitude of the energy well is dependent on the product of the charge of the ions: $|E_0| \propto |z_1||z_2|$ (note Callister Eq. 2.19, 2.10, and Fig. 2.10). The MgO have ionic species

of Mg^{2+} and O^{2-}, while NaF has Na^{+} and F^{-}, respectively. The energy well for MgO should therefore be deeper.

Grading Rubric:

This is a challenging question. Give 50% pts for getting the correct curves (they must be the same) and 50% pts for knowing that the C^{2+} and O^{2-} bond will be stronger.

Outcomes:

Students need to identify two things, here. One, that ions with approximately the same sum of radii have approximately the same bond length. they often understand this. However, many students don't understand that the depth of the energy well is $|E_0| \propto |z_1||z_2|$. They often guess on the second part.

A lot of students get this wrong. Mostly they chose curves 2 and 3; 2 is MgO. A lot of students tried to use electronegativity arguments rather than just considering the charges of the given ions.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16	Emery	Midterm #1	50%

Comments/Extensions:

This question and the next refer to the interatomic distance-energy curves in Figure 7 (below) for different two-element materials with the same structure.

The material with the *smallest* equilibrium *bond energy* (E_0) in Figure 7 has an equilibrium bond distance r_0 of approximately:

A. 0.7 Å

B. 1.0 Å

C. 1.5 Å

D. 1.7 Å

E. 2.5 Å

F. >3.0 Å

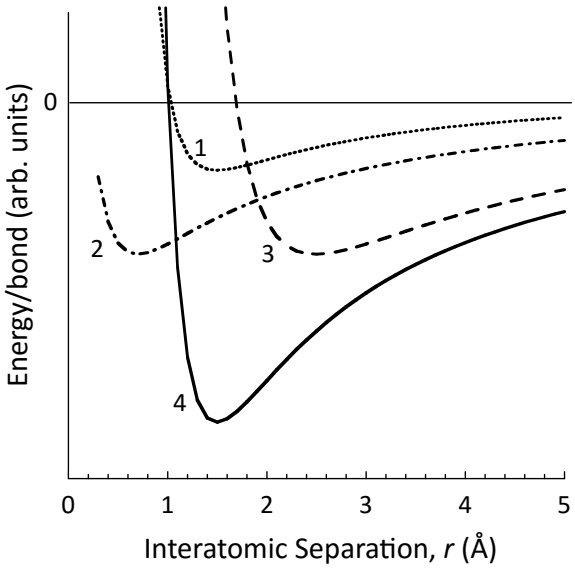


FIGURE 4: Interatomic bond distance versus bond energy for two atoms.

File Information:

#FileTag:C2-MC-Q4-3.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Quiz1	#TermTag:2015F
#AssignmentTag:Midterm1	#TermTag:2016F
#TopicTag:InteratomicBonding	
#TypeTag:MutipleChoice	#TypeTag:LearningCatalytics

Solution:

The equilibrium bond distance defined as $r = r_0$ when the bond energy is minimized. The smallest equilibrium bond energy is the shallowest trough: Curve 1. The equilibrium distance here is approximately 1.5 Å.

Grading Rubric:

Full pts only for Curve 1, the shallowest trough. Students do good work on this problem but often the the question wrong due to some misinterpretation. Give up to 50% pts for good work, even if the answer is incorrect.

Outcomes:

Students that get it incorrect misread the problem as being the smallest *energy*.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16	Emery	W16QuizD3	50%
201-F16	Emery	F16Midterm1	80% Full, 5% Partial

Ca^{2+} and Na^{+} ions are about the same size, and O^{2-} and F^{-} ions are about the same size. Identify the two curves in Figure 7 which qualitatively represent CaO and NaF, then identify which of those two curves is likely to be CaO.

A. 1 and 2; 1 is CaO

B. 1 and 2; 2 is CaO

C. 1 and 4; 4 is CaO

D. 2 and 3; 2 is CaO

E. 2 and 3; 3 is CaO

F. 1 and 4; 1 is CaO

File Information:

#FileTag:C2-MC-Q4-3.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Quiz1	#TermTag:2015F
#AssignmentTag:Midterm1	#TermTag:2016F
#TopicTag:InteratomicBonding	
#TypeTag:MutipleChoice	#TypeTag:LearningCatalytics

Solution:

This is a challenging, multi-faceted problem.

The interatomic spacing for ions can be approximated by the sum of the ionic radii (see Callister Example Problem 2.2). If the Ca^{2+} and Na^{+} ions are about the same size and the O^{2-} and F^{-} ions are about the same size, the interatomic spacing will be about the same. These are Curves 1 and 4.

The magnitude of the energy well is dependent on the product of the charge of the ions: $|E_0| \propto |z_1||z_2|$ (note Callister Eq. 2.19, 2.10, and Fig. 2.10). The CaO have ionic species of Ca^{2+} and O^{2-}, while NaF has Na^{+} and F^{-}, respectively. The energy well for CaO should therefore be deeper, and is better represented by Curve 4.

Grading Rubric:

50% pts for recognizing that the minima are at the same r position (selecting 1/4 as the curves). 50% pts for getting curve 4 as CaO.

Student will draw on the graph. Give up to 50% pts for good work, even if the answer is incorrect.

Outcomes:

Students typically do well on this problem. Students that get it incorrect misread the problem as being the smallest *energy*.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W15	Emery	QuizD3	50%
201-F16	Emery	Midterm1	70% Full 10% Partial

Refer to the net interionic energy curve for an Na^+-Cl^+ pair, Fig. 6below. Describe the force on the system at point a.

A. The sign of the force is negative, and the force is repulsive.

B. The sign of the force is positive, and the force is repulsive.

C. The sign of the force is negative, and the force is attractive.

D. The sign of the force is positive, and the force is attractive.

E. The force is zero, and therefore the force is neither attractive or repulsive.

File Information:

#FileTag:C2-MC-Q5-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: QuizD2	#TermTag: F16
#TopicTag:InteratomicForce	InteratomicEnergy
#TypeTag:MultipleChoice	

Solution:

The

Grading Rubric:

- Full pts for correct answer.
- Pay attention to work. Good work deserves up to 50% partial credit.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16	Emery	Midterm #1	%

Comments/Extensions:

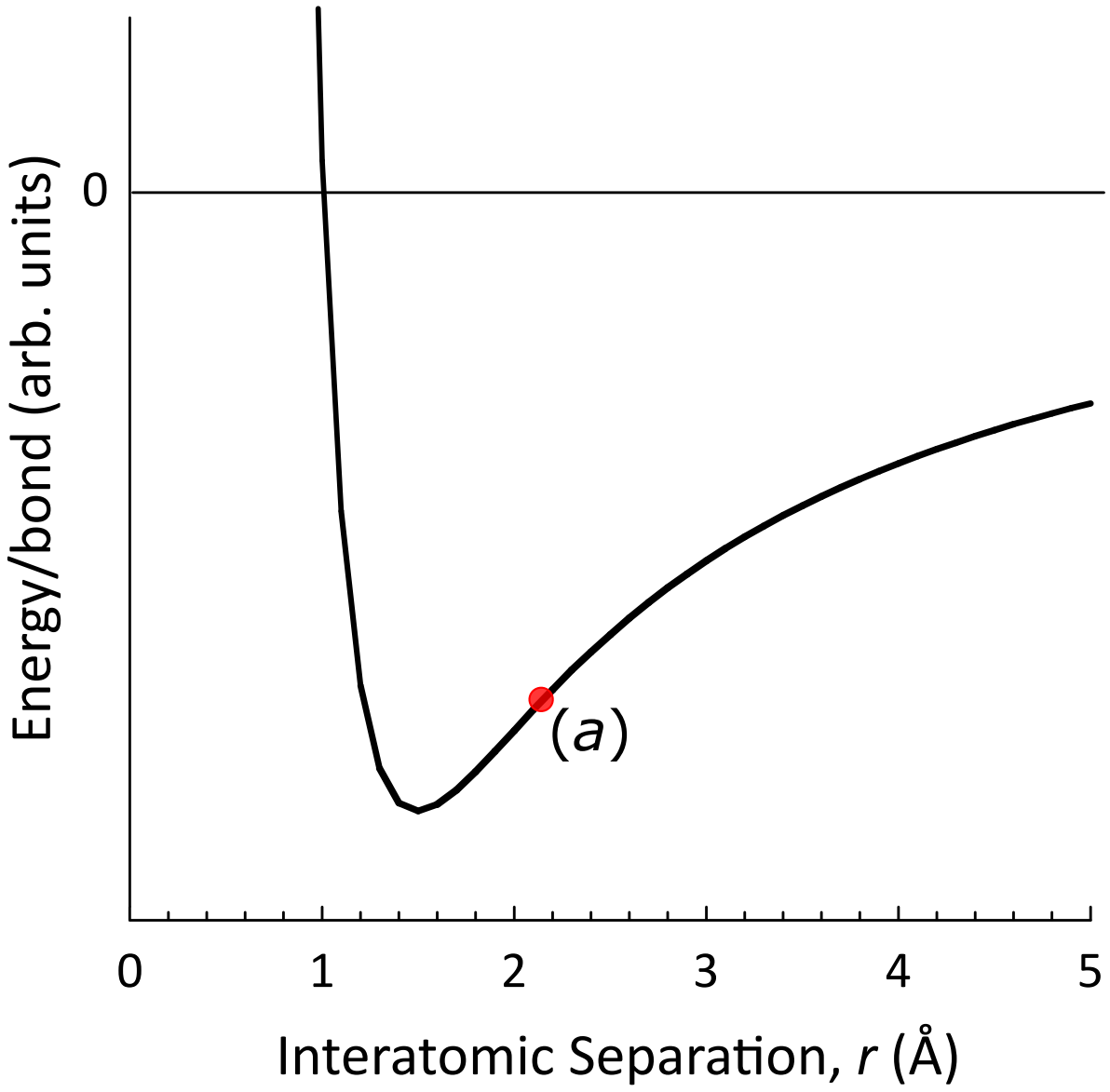


FIGURE 5: The interionic energy curve for an Na^+-Cl^+ pair

For this question, select one or more answers. The type(s) of bonding that prefer(s) particular coordination numbers and bond angles (i.e., directional bonding) is(are):

A. Metallic

B. Ionic

C. Covalent

D. Induced-dipole — induced-dipole

E. Hydrogen bonds

File Information:

#FileTag:C2-MC-Q6-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Quiz1	#TermTag:F16
#AssignmentTag:LearningCatalytics	#TermTag:W17
#AssignmentTag:ConceptCheck	#TermTag:S17
#AssignmentTag:Midterm1	#TermTag:S17
#TopicTag:BondDirectionality	#TopicTag:BondType
#TypeTag:MutipleChoice	MultipleAnswer

Solution:

Directional bonds are those that possess specific orientations in space.

- **Ionic bonds** are derived from electrostatic attraction — which is non-directional. Imagine two charged oppositely charged ions at some distance r from each other. It doesn't matter *where* in space they are with respect to each other — the strength of the interaction doesn't change.
- **Metallic bonds** are similar and can be described modeled by positive ionic cores sitting within the electron sea. They are non-directional.
- The way that **covalent bonds** share valence electrons makes the bonds directional. That is, there exists overlap between specific orbitals (p-orbitals, for example) that are directional in nature. If you rotate one atom that is covalently bonded to another, the overlap will change and the bond strength with change.
- **Induced-dipole** — induced-dipole form due to mutual polarization of the electron cloud and are not considered directional.
- **Hydrogen bonds** are directional because there exists a permanent electronic dipole that has a specific orientation in space.

Grading Rubric:

- -25% pt for each wrong/missed answer.
- Minimum of 0 pts.

S17: Got either hydrogen or covalent, not both. This was an example on the slides.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F16	Emery	QuizD2	50%
201-W17	Emery	LearningCatalytics	%
201-W17	Emery	ConceptCheck	%
201-S17	Emery	Midterm1	45% Full, 40% Partial

Comments/Extensions:

Which of the following interactions is likely to show the *weakest* secondary bonding?:

A. Two Ar atoms with fluctuating induced dipoles

B. Two Xe atoms with fluctuating induced dipoles

C. An HCl molecule inducing a dipole in an Ar atom

D. Two HCl molecules with permanent dipoles

File Information:

#FileTag:C-Ch2-MC-Q6-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Midterm1	#TermTag:W17
#TopicTag:BondType	
#TypeTag:MultipleChoice	

Solution:

Permanent dipoles show the strongest secondary bonding, which in this case is two HCl molecules. Permanent dipole-induced dipole interactions are slightly weaker, e.g. an HCl molecule inducing a dipole in Ar. But fluctuating induced dipoles are the weakest, as seen in the noble gases Xe and Ar.

Note that the polarizablity and possible fluctuating induced dipoles will be greater for Xe-Xe because the electron states are larger and more easily polarizable and are therefore a bit stronger than Ar-Ar.

Grading Rubric:

- W17: 100% pts for both Xe-Xe and Ar-Ar.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W17	Emery	Midterm1	x% Full, x% Partial

Comments/Extensions:

We don't really spend much time talking about these bonds later in the course — may not be terribly relevant.

For this question, select one or more answers. Which of the following types of bonding are *non-directional*?:

A. Metallic

B. Ionic

C. Covalent

D. Induced-dipole — induced-dipole

E. Hydrogen bonds

File Information:

#FileTag:C2-MC-Q6-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondDirectionality	#TopicTag:BondType
#TypeTag:MutipleChoice	MultipleAnswer

Solution:

The main concept to understand here is that directional bonds occur at fixed angles with respect to each other due to the *sharing* of electrons and arise due to directional electron orbital overlap. Non-directional bonds are equally probable at all angles.

The way that covalent bonds share valence electrons makes the bonds directional. Ionic bonds are derived from electrostatic attraction - which is non-directional (place two oppositely charge ions anywhere in space with respect to each other - it doesn't not change their attraction.). Metallic bonds are modeled by positive ionic cores sitting within the electron sea and are also non-directional. Induced-dipoe — induced-dipole form due to mutual polarization of the electron cloud and are not considered directions. Only hydrogen bonds are directional because there exists a permanent electronic dipole .

Grading Rubric:

- -25% pt for each wrong answer. Minimum of 0 pts.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			50%

About 50% of students got this completely right. Students struggle a bit with the conceptual understanding of what is going on, here.

A drawing of each in different configurations would be very helpful.

Comments/Extensions:

Good potential for Learning Catalytics.

Which of the following interactions is likely to show the *weakest* secondary bonding?:

A. Two Ar atoms with fluctuating induced dipoles

B. Two Xe atoms with fluctuating induced dipoles

C. An HCl molecule inducing a dipole in an Ar atom

D. Two HCl molecules with permanent dipoles

File Information:

#FileTag:C2-MC-Q6-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondDirectionality	BondType
#TypeTag:MutipleChoice	MultipleAnswer

Solution:

Permanent dipoles show the strongest secondary bonding, which in this cas is two HCl molecules. Permanent dipole-induced dipole interactions are slightly weaker, e.g. an HCl molecule inducing a dipole in Ar. But fluctuating induced dipoles are the weakest, as seen in the noble gases Xe and Ar. Note that the polarizability and possible fluctuating induced dipoles will be greater for Xe because the higher atomic number allows for greater fluctuations in the electron distribution. Therefore, Ar atoms show the weakest secondary bonding among these choices.

Grading Rubric:

- Give some partial credit for any good work. Up to 50% for good work.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			50%

Comments/Extensions:

We don't really spend much time talking about these bonds later in the course - may not be terribly relevant.

Sulfur (S) and Selenium (Se) are in the same group of the Periodic Table (Group 16). This implies that they have:

A. The same valence.

B. Similar properties.

C. Neither the same valence or similar properties.

D. Both the same valence and similar properties.

File Information:

#FileTag:C2-MC-Q3-3.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:ElectronicStructure	
#TypeTag:MultipleChoice	

Solution:

In general, atoms in the same group of the periodic table often have the same valence and similar properties.

Grading Rubric:

- 50% pts for getting one of the two.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W16			%

Comments/Extensions:

At large interatomic separations (say, 10 nm), the net force between a Na^+ ion and a Cl^- ion is:

A. Attractive and becomes more attractive as they are moved further apart.

B. Repulsive and becomes more repulsive as they are moved further apart.

C. Attractive and becomes less attractive as they are moved further apart.

D. Repulsive and becomes less repulsive as they move further apart.

File Information:

#FileTag:C-Ch2-MC-Q9-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:Midterm1	#TermTag:W17
#TopicTag:InteratomicBonding	#TopicTag:InterionicBonding
#TypeTag:MultipleChoice	

Solution:

At large distances, the attrative force will dominate to pull the ions together — there's very little Pauli exclusion going on at 10 nm, so it is all attractive force. As you pull the ions further apart the atractio gets weak, though.

Grading Rubric:

- 50% pts if they got the answer half correct: e.g., got attractive, but thought they were more repulsive as they are pulled apart.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F15			%
201-W16	Emery	QuizD2	80%

Comments/Extensions:

A sodium ion (Na^+) and a chlorine ion (Cl^-) experience a *force* of attraction which is:

A. Directly proportional to the distance of separation.

B. Inversely proportional to the distance of separation.

C. Directly proportional to the square of the distance of separation.

D. Inversely proportional to the square of the distance of separation.

File Information:

#FileTag:C-Ch2-MC-Q9-3.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:QuizD2	#TermTag:S17
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

The force of attraction for two ions is Coulombic. The attractive force as a function of distance is defined as $F_A = \frac{A}{r^2}$, where r is the distance between the two ions and A is a constant that depends on the valences of the ions. Therefore, the force is *inversely* proportional to the square of the ions' distance of separation.

Grading Rubric:

- 25% pts if they got the answer half correct: e.g., got inversely proportional, but missed the square term.)

Outcomes: Common errors are flipped signs, or struggling graphically to take a derivative.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F15			%
201-W16			%
201-S17	Emery	QuizD2	95% Full 5% Partial

Comments/Extensions:

SrO and CaO are two ionically bonded materials that possess similar properties. While the attractive energy terms (E_A) for both cation-anion pairs are identical, the repulsive terms differ and are provided below:

Cation-anion Pair	E_R
Ca-O	$\frac{3\times10^{-6}\,\text{eV-nm}^8}{r^8}$
Sr-O	$\frac{3\times10^{-6}\,\text{eV-nm}^9}{r^9}$

From this information, which of the statements regarding melting temperatures (T_M) and equilibrium interionic distances (r_0) is expected to be true?

A. T_M of CaO is greater than that of SrO, and r_0 for CaO is greater than that of SrO.

B. T_M of SrO is greater than that of CaO, and r_0 for CaO is greater than that of SrO.

C. T_M of CaO is greater than that of SrO, and r_0 for SrO is greater than that of CaO.

D. T_M of SrO is greater than that of CaO, and r_0 for SrO is greater than that of CaO.

E. CaO and Sro will have the same values for T_M and r_0.

File Information:

#FileTag:C2-MC-Q9-4.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:QuizD2	#TermTag:W17
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

The larger denominator in the repulsive term in the Sr-O pair effectively shifts the net energy curve up in energy and to larger r near r_0. Therefore, the melting temperature for the CaO is greater than that of SrO and the r_0 distance is greater for the SrO.

Grading Rubric:

- 50% pts if they got the answer half correct: e.g., got inversely proportional, but missed the square term.)

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W17	Emery	QuizD2	85%

Comments/Extensions:

Directly related to C|2.19.

W17: Students that missed this (which were few) probably didn't understand what increasing the n in the denominator does.

The net potential energy between two adjacent ions of opposite sign is described as the sum of the attractive Coulombic interaction and a repulsive Pauli interaction. If the ions instead have the *same* sign, the net energy would be:

A. Attractive at all interionic separation distances.

B. Repulsive at all interionic separation distances.

C. Attractive at short separation distances and repulsive at long separation distances.

D. Repulsive at short separation distances and attractive at long separation distances.

File Information:

#FileTag:C2-MC-Q9-5.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

The same charge of ion would lead to an repulsive force at all positions in space.

Grading Rubric:

- ◇ No pts for other solutions here, unless they make a good argument.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W17	Emery	QuizD2	75%

Comments/Extensions:

Directly related to C|2.17.

W17: Some students got confused with the term "charge" which I used in a previous version of this problem — possibly interpreting it as "charge magnitude". Changed.

Do something with force?

You and a friend have a very useful magical power: you can change ions' charges and radii by will and measure interatomic forces!

You are competing with your friend to measure the largest force of attraction between two ions. You begin by measuring the attractive force between a divalent cation and a divalent anion (charges of 2+ and 2-, respectively), each of which have ionic radii of 1 nm.

Of the actions below, which would result in the largest measured *attractive* force?

A. Changing the cation charge to 4+.

B. Tripling the cation radius and halving the anion radius.

C. Doubling the cation radius and increasing the anion charge to 3-.

D. Halving the anion radius and increasing the anion charge to 3-.

E. Converting the cation into an anion.

F. No change, the original configuration will give the greatest force.

File Information:

#FileTag:C-Ch2-MC-Q9-6.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:QuizD2	#TermTag:W17
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

We need to play around with the Coulombic force to find this value:

$$F_A = \frac{1}{4\pi\epsilon_0 r^2}(|Z_1|e)(|Z_2|e)$$

.

We're looking for relative changes, so we can simply calculate any changes as

$$\begin{aligned}\frac{F_{A,f}}{F_{A,i}} &= \frac{|Z_{1,f}||Z_{2,f}|(r_{\text{cation},i}+r_{\text{anion},i})^2}{(|Z_{1,i}||Z_{2,i}|(r_{\text{cation},f}+r_{\text{anion},f})^2} \\ &= \frac{4\,\text{nm}^2}{4}\frac{|Z_{1,f}||Z_{2,f}|}{(r_{\text{cation},f}+r_{\text{anion},f})^2} \\ \frac{F_{A,f}}{F_{A,i}} &= 1\,\text{nm}^2\frac{|Z_{1,f}||Z_{2,f}|}{(r_{\text{cation},f}+r_{\text{anion},f})^2}\end{aligned}$$

We can see quickly that if we increase ionic charges (but make sure they are opposite!) the force increases. So, we want to maximize $|Z_{1,f}||Z_{2,f}|$ and minimize $(r_{\text{cation},f}+r_{\text{anion},f})$.

Changing the cation to an anion would cause a repulsive force and is not the answer we're looking for. That's out.

Changing the cation charge to 4+ gives us a factor of two, which isn't bad. This also means the original situation is not the best solution.

Next, we notice that tripling the radius of the cation and halving the radius of the anion gives us a larger radius overall (3.5 nm vs 2 nm) and will therefore a lesser force. Out.

The last two options are easy to compare because they are opposite: they both increase the ionic charge, but one decreases the radius (which will increase the force of attraction) while the other one increases the radius (which will drop the force of attraction). Let's check the better solution to see if it beats 2×:

$$\begin{aligned}\frac{F_{A,f}}{F_{A,i}} &= 1\,\text{nm}^2 \frac{6}{(\frac{3}{2}\,\text{nm})^2} \\ &= \frac{8\,\cancel{\text{nm}^2}}{3\,\cancel{\text{nm}^2}} \\ \frac{F_{A,f}}{F_{A,i}} &= 2\frac{2}{3}\end{aligned}$$

That's the one! Halve the anion radius but increase the anion charge to 3+.

Grading Rubric:

- ◇ If they get the wrong answer, give up to 50% pts for good work.
- ◇ If they only write down the starting equation correctly and can't take it further correctly, give 25% pts.
- ◇ 25% pts without work but getting a solution that increases the force.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-W17	Emery	QuizD2	95%

Comments/Extensions:

A longer problem, but most students get this correct because they can plug the numbers in to an equation. The ones that got it wrong probably got energy instead of force.

Two Na^+ and Cl^- ions are very close to each other (say, $\frac{1}{2}$ the equilibrium bond distance or $\frac{1}{2}r_0$). Which of the following best describes the net force between the ions?:

A. Attractive, and becomes *more attractive* as they are moved closer.

B. Repulsive, and becomes *more repulsive* as they are moved closer.

C. Attractive, and becomes *less attractive* as they are moved closer.

D. Repulsive, and becomes *less repulsive* as they move closer.

File Information:

#FileTag:C2-MC-Q9-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

At short distances — at interatomic separations smaller than the equilibrium distance — the repulsive force between two ions dominates due to Pauli repulsion (and nuclear Coulomb repulsion). The net force will then be repulsive. It becomes *even more* repulsive if you try to push them even closer together.

Grading Rubric:

- 50% pts if they got the answer half correct: e.g., got repulsive, but thought they were more attractive as they are brought together.)

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F15	Emery	Quiz1	%
201-W16	Emery	QuizD2	%

Comments/Extensions:

At large interatomic separations (say, 10 nm), the net force between a Na^+ ion and a Cl^- ion is:

A. Attractive and becomes more attractive as they are moved further apart.

B. Repulsive and becomes more repulsive as they are moved further apart.

C. Attractive and becomes less attractive as they are moved further apart.

D. Repulsive and becomes less repulsive as they move further apart.

E. The net force between the ions is zero.

File Information:

#FileTag:C2-MC-Q9-2.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:F15
#AssignmentTag:	#TermTag:W16
#AssignmentTag:Miderm1	#TermTag:S17
#TopicTag:InteratomicBonding	
#TypeTag:MultipleChoice	

Solution:

At large distances the Pauli repulsion term is negligible and the Coloumb attraction term will dominate. There will be attraction

Grading Rubric:

- 50% pts if they got the answer half correct: e.g., got attractive, but thought they were more repulsive as they are brought together.)

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F15	Emery		%
201-W16	Emery		%
201-S17	Emery	Midterm1	85% Full, 15% Partial

Comments/Extensions:

Which of the following compounds to you expect to possess the largest percent ionicity? You are provided with a periodic table with relevant information on the last page of the quiz. Atomic numbers are provided in parentheses, below.

A. GaS ($Z_{\text{Ga}} = 31$, $Z_{\text{S}} = 16$)

B. BSb ($Z_{\text{B}} = 5$, $Z_{\text{Sb}} = 51$)

C. NiO ($Z_{\text{Ni}} = 28$, $Z_{\text{O}} = 8$)

D. AgCl ($Z_{\text{Ag}} = 47$, $Z_{\text{Cl}} = 17$)

E. NiAs ($Z_{\text{Ni}} = 28$, $Z_{\text{As}} = 33$)

File Information:

#FileTag:C2-MC-Q10-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: QuiD2	#TermTag: F16
#TopicTag:BondCharacter	Electronegativity
#TypeTag:MultipleChoice	

Solution:

We only need the largest percent ionicity, we don't need to actually know the percent ionicity. Because a binary compound has a larger percent ionicity if the difference in electronegativity (ΔX) between the two compounds is larger, the compound with the largest ΔX will have the largest percent ionicity.

- $\text{GaAs}_{\Delta X} = 0.37$
- $\text{BSb}_{\Delta X} = 0.01$
- $\text{NiO}_{\Delta X} = 1.53$
- $\text{AgCl}_{\Delta X} = 1.23$
- $\text{AlP}_{\Delta X} = 0.58$

Remember, you can typically whittle down this type of problem and do the analysis for only 1-2 compounds. We know that Cl and O are highly electronegative, so those are our most likely solutions. Then, we find that NiO is the correct answer (electronegativity for O is second only to F).

Grading Rubric:

- Full points only for NiO. Give partial credit for work (up to 50% pts) if they show electronegativity calculations.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

Which of the following compounds to you expect to possess the largest percent ionicity? You are provided with a periodic table with relevant information on the last page of the quiz. Atomic numbers are provided in parentheses, below.

A. GaS ($Z_{\text{Ga}} = 31$, $Z_{\text{S}} = 16$)

B. BSb ($Z_{\text{B}} = 5$, $Z_{\text{Sb}} = 51$)

C. NiO ($Z_{\text{Ni}} = 28$, $Z_{\text{O}} = 8$)

D. AgCl ($Z_{\text{Ag}} = 47$, $Z_{\text{Cl}} = 17$)

E. NiAs ($Z_{\text{Ni}} = 28$, $Z_{\text{As}} = 33$)

File Information:

#FileTag:C2-MC-Q10-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: QuiD2	#TermTag: F16
#TopicTag:BondCharacter	Electronegativity
#TypeTag:MultipleChoice	

Solution:

We only need the largest percent ionicity, we don't need to actually know the percent ionicity. Because a binary compound has a larger percent ionicity if the difference in electronegativity (ΔX) between the two compounds is larger, the compound with the largest ΔX will have the largest percent ionicity.

- $\text{GaAs}_{\Delta X} = 0.37$
- $\text{BSb}_{\Delta X} = 0.01$
- $\text{NiO}_{\Delta X} = 1.53$
- $\text{AgCl}_{\Delta X} = 1.23$
- $\text{AlP}_{\Delta X} = 0.58$

Grading Rubric:

- Full points only for NiO. Give partial credit for work (up to 50% pts) if they show electronegativity calculations.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

Refer to the net interionic energy curve for an Na^+-Cl^+ pair, Fig. 6, below. Describe the net force in the system at point (a).

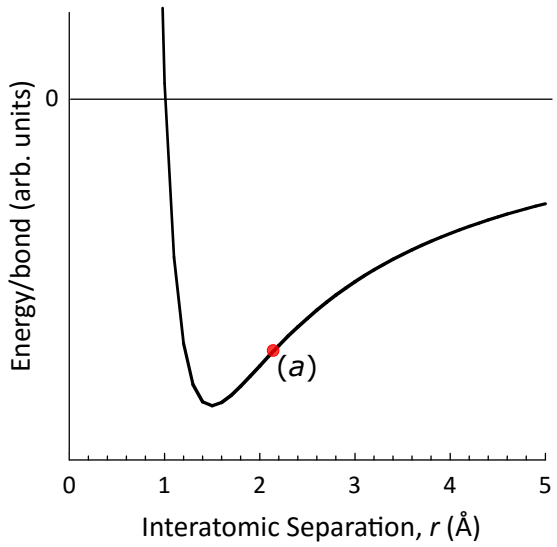


FIGURE 6: The interionic energy curve for an Na^+-Cl^+ pair

A. The sign of the force is negative, and the force is repulsive.

B. The sign of the force is positive, and the force is repulsive.

C. The sign of the force is negative, and the force is attractive.

D. The sign of the force is positive, and the force is attractive.

E. The force is zero, and therefore the force is neither attractive or repulsive.

File Information:

#FileTag:C2-MC-Q11-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag: QuizD2	#TermTag: F16
#TopicTag:InteratomicForce	InteratomicEnergy
#TypeTag:MutipleChoice	

Solution:

The net force is defined as $F_N \frac{dE_N}{dr}$, and the slope of the curve at a is positive, so the force is positive. The atoms would move closer to each other to reach equilibrium, so the net force is attractive in the syste,

Grading Rubric:

- ◇ Full pts for correct answer.
- ◇ Pay attention to work. Good work deserves up to 50% partial credit.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-F16	Emery	QuizD2	%

Comments/Extensions:

Two atoms are ionically bonded to form a diatomic molecule. During formation of the bond, *two* electrons are transferred. After bonding, the electron configurations for *both* atoms are [Ar] $3d^{10}$ $4s^2$ $4p^6$. From the choices below, select the *two* atoms in the diatomic model below. *Select only* two *answers.*

A. S	**F. Sc**	K. Sr
B. Cl	G. Se	**L. Y**
C. Ar	H. Br	M. Te
D. K	I. Kr	
E. Ca	J. Rb	

File Information:

#FileTag:C2-MC-Q2-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:BondCharacter	
#TypeTag:MultipleChoice	

Solution:

We only need the largest percent ionicity, we don't need to actually know the percent ionicity. Because a binary compound has a larger percent ionicity if the difference in electronegativity (ΔX) between the two compounds is larger, the compound with the largest ΔX will have the largest percent ionicty.

- $GaAs_{\Delta X} = 0.37$
- $BSb_{\Delta X} = 0.01$
- $NiO_{\Delta X} = 1.53$
- $AgCl_{\Delta X} = 0.73$
- $AlP_{\Delta X} = 0.58$

Grading Rubric:

- Full points only for NiO. Give partial credit for work (up to 50% pts) if they show electronegativity calculations.

Outcomes:

Class-Term Used	Term Instructor	Assessment	Percent Correct
			%

Comments/Extensions:

Good potential for Learning Catalytics.

The next 3 questions refer to the bond-energy curves in Figure 7 (below) for different two-element materials with the same structure.

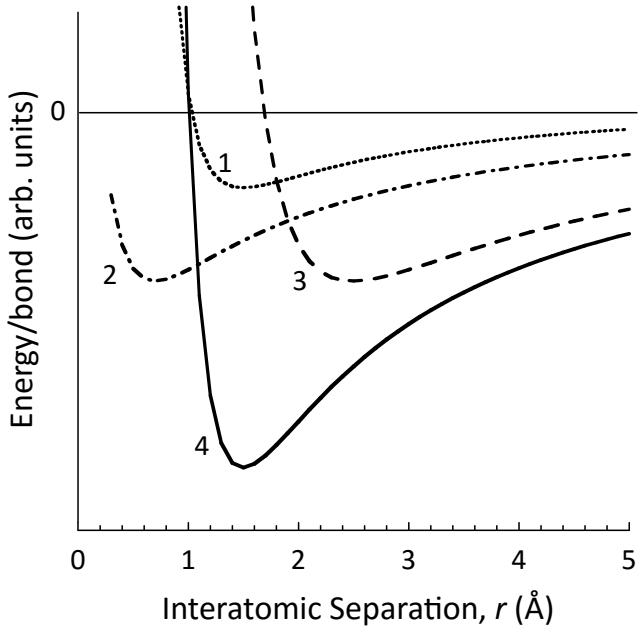


FIGURE 7: Interatomic bond distance versus bond energy for two a two-element material.

Part I

T

he material with the *smallest* equilibrium bond energy magnitude ($|E_0|$) in Figure 7 is represented by:

A. Curve 1

B. Curve 2

C. Curve 3

D. Curve 4

(1)

Solution: The equilibrium bond energy magnitude is the depth of the well at the equilibrium bond distance. Curve 1.

Grading:
Only pts for Curve 1.

F15 Outcome:
A very high percentage of students got this right. If they didn't, they usually misread the problem and selected Curve 4.

Part II

W

hich of the materials in Figure 7 has the *smallest* elastic modulus?

A. Curve 1

B. Curve 2

C. Curve 3

D. Curve 4

(1)

Solution: A small elastic modulus is indicative of weak bonding in a material. The smallest $|E_0|$ belongs to Curve 1 (I think), and it will have the smallest elastic modulus.

In the future, I think I have to be careful, here. $Y = (\frac{d^2E}{dr})_{r_0}$, so it should be the curvature of the function. Pr. Snyder *did* actually show this (L2S32), but the curvatures are difficult to discern by eye. In any case, is best to ask for the *largest* elastic modulus in the future.

Grading:
Points for anything but Curve 4, which has the largest curvature.

F15 Outcome:
Very good, considering I took 3/4 answers. 1-2 out of 80 students missed it.

Part III

T

he material represented by Curve 4 is heated but not melted or sent through a phase transition. The average interatomic separation for the atoms in this material:

A. Decreases to be closer to that of Curve 2

B. Stays the same.

C. Increases to be closer to that of Curve 3

(1)

Solution:

Heating the material supplies vibrational energy to the system. Because the energy trough is asymmetric, the mean interatomic spacing of the atoms will increase.

Grading:
Only took points for increasing to be closer to that of curve Curve 3.

F15 Outcome:
Only 1-2 out of 80 students missed it.

File Information:

#FileTag:C-Ch2-Sketch-Q1-1.tex	#SourceTag:Original
#AuthorTag:JDEmery	#UseTag:QuizExam
#AssignmentTag:	#TermTag:
#TopicTag:InteratomicBonding	
#TypeTag:Sketch	

Below is a figure [Fig. 8(a)] showing *net* interatomic energy curve for two ions.

1. On Fig. 8(a), sketch and label curves corresponding for both the attractive and repulsive energy terms. Be accurate in your representation, but the actual values on the curves need not be precise.
2. In Fig. 8(b) sketch the corresponding *net* interatomic *force* curve. Be accurate in your representation, but the actual values on the curve need not be precise.

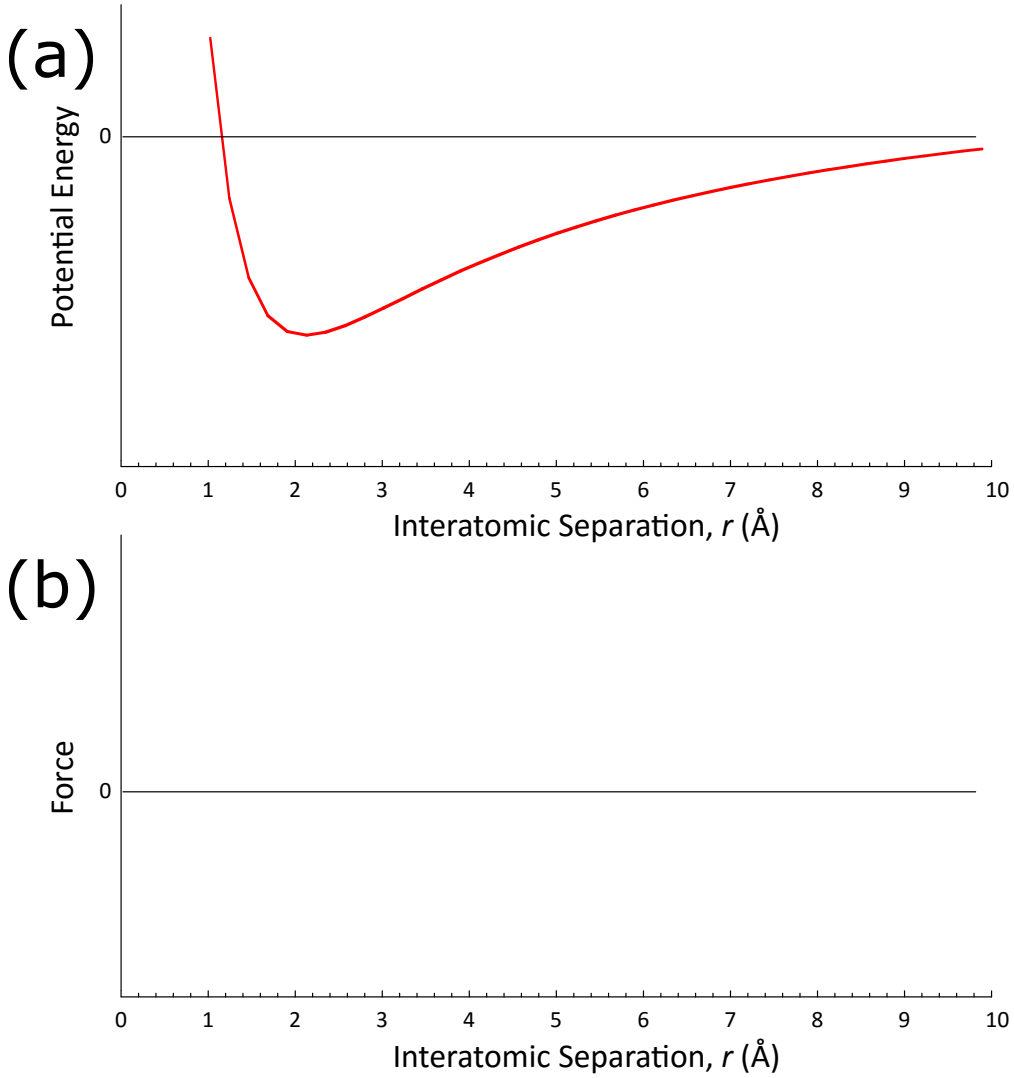
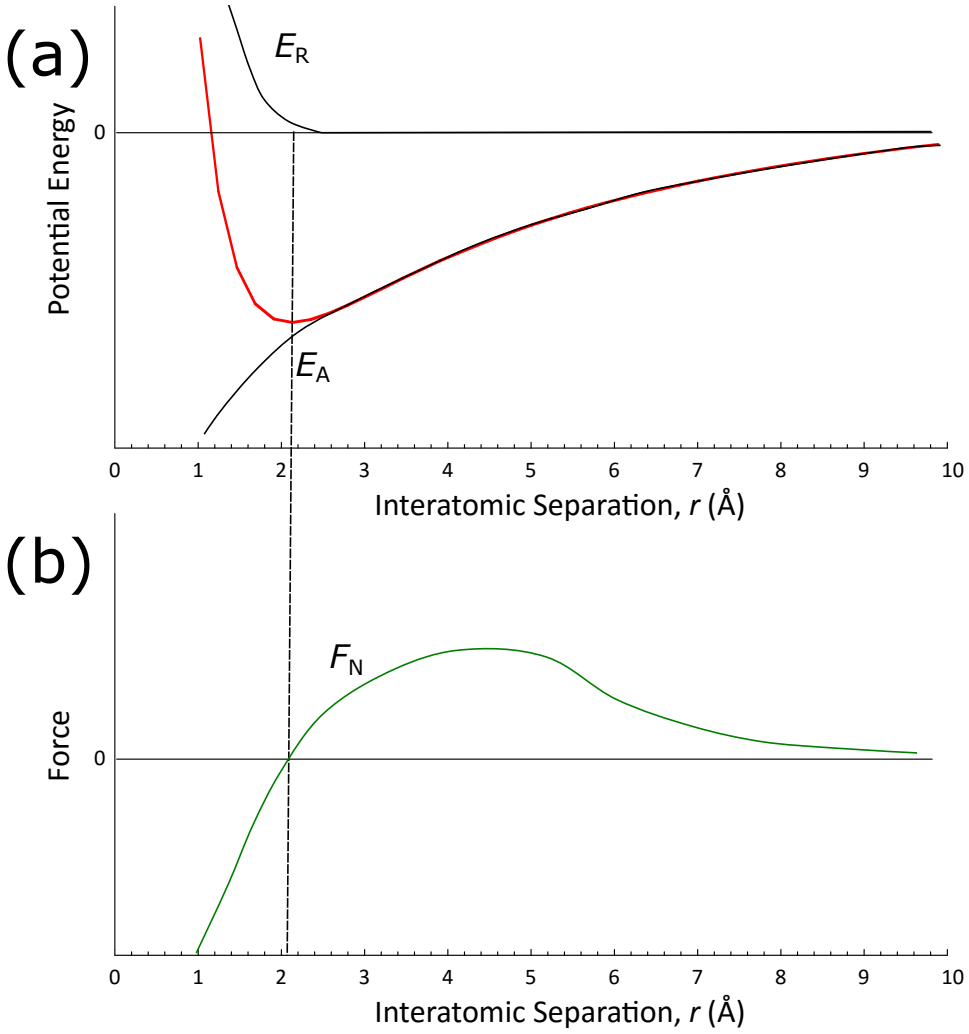


FIGURE 8: Interatomic energy curve (a), in red, and a space for the interatomic force (b) curve.

Solution:

The solution is shown below.



Grading Rubric:

- 25% pts for correct repulsive term with label.
- 25% pts for correct attractive term with label.
- The two terms should have the correct relative magnitudes in the correct ranges. Take 25% pts off if this is not the case.
- 25% pts for having the force curve be *approximately* the derivative of the energy curve.
- 25% for crossing 0 at the interatomic energy minimum, is negative to the left and positive to the right.
- Minimum of zero points (e.g. if they left it blank.)

Outcomes: Common errors are flipped signs, or struggling graphically to take a derivative.

Class-Term Used	Term Instructor	Assessment	Percent Correct
201-S17	Emery	QuizD2	Full 50%, Partial 50%

Comments/Extensions:

Directly related to C|2.17, C|2.18, C|2.19.