RLP-CHEMA · RLP Chemistry A — Atoms, Bonding, Reactions, Gases and Solutions

Unit 2: Bonding, Structure and the Properties of Materials

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 2.1 — Missouri Limestone: One Rock, Three Kinds of Bonding

FLUENCY

1. Electronegativities: Ca 1.00, O 3.44. Find the difference and classify the Ca–O bond.

2. Electronegativities: C 2.55, O 3.44. Find the difference and classify the C–O bond.

3. Electronegativities: Mg 1.31, Cl 3.16. Find the difference and classify the Mg–Cl bond.

4. Electronegativities: C 2.55, H 2.20. Classify the C–H bond.

5. Count the valence electrons to place in the Lewis structure of (a) CO_2, (b) NH_3, (c) OH^-.

6. Write the formulas of the compounds formed by (a) Ca^{2+} and Cl^{-}, (b) Al^{3+} and O^{2-}, (c) Na^{+} and CO_3^{2-}.

7. Using the atomic weights in this lesson's reading, find the molar mass of calcium carbonate, $CaCO_3$.

APPLICATION

8. A kiln burns 250 kg of pure limestone ($CaCO_3$) to CaO and CO_2. Use molar masses 100.086, 56.077 and 44.009 g/mol to find the mass of lime and the mass of CO_2 produced.

9. USGS estimates 1.5 billion tons of crushed stone were produced in the United States in 2025, 17% of it for cement manufacturing and 6% for lime manufacturing. How many million tons went to each use?

10. Describe the Lewis structure of CO_2 in words and compute the formal charge on carbon and on each oxygen.

11. Predict which has the higher melting point, MgO or NaCl, and give two reasons from the properties of the ions.

CHALLENGE

12. A Missouri limestone sample is 94.0% $CaCO_3$ by mass (an illustrative value; the rest is clay and quartz that do not decompose). How many kilograms of lime come from 1,000 kg of this stone, assuming all the carbonate breaks down?

13. In carbonate, all three C–O bonds have the same length, but the Lewis structure shows one double and two single bonds. Explain how resonance resolves this and give the average bond order.

REVIEW

14. Write the full electron configuration of calcium (Z = 20) and state the charge of the ion it forms and why.

15. NIST lists chlorine-35 (34.969 u, 75.76%) and chlorine-37 (36.966 u, 24.24%). Calculate the average atomic mass of chlorine.

Lesson 2.2 — Shape, Polarity and Forces: A Kitchen Investigation

FLUENCY

1. Give the number of electron domains and the molecular shape of (a) CH_4, (b) NH_3, (c) H_2O, (d) CO_2, (e) BF_3.

2. Which of CH_4, NH_3, H_2O and CO_2 are polar molecules? Use the NIST dipole moments in the reading as a check.

3. Using the atomic weights in the reading, calculate the molar mass of SO_2.

4. Name the strongest intermolecular force in each: (a) liquid CH_4, (b) liquid HCl, (c) liquid H_2O.

5. Count the valence electrons in SO_2 and state how many electron domains surround sulfur.

6. Which molecule can hydrogen-bond with others of its own kind: CH_3OH, CH_4, CH_3Cl or CO_2? Explain.

7. LED brightness: salt solution 2, sugar solution 0. Which dissolved solid produced mobile ions, and which produced neutral molecules?

APPLICATION

8. NIST lists vapor pressures at 25 °C of 3.17 kPa for water and 16.98 kPa for methanol. By what factor is methanol's vapor pressure greater, and what does that say about the forces between its molecules?

9. Hexane has a vapor pressure of 20.16 kPa and octane 1.87 kPa at 25 °C. Both are nonpolar. Compute the ratio and explain which force accounts for the difference.

10. Three testers counted drops of tap water on a coin: 25, 24 and 26; and drops of soapy water: 11, 12 and 10. Find each mean and the ratio of the means.

11. The surface tension of water at 25 °C is 71.97 mN/m and of methanol 22.15 mN/m. Compute the ratio and say which liquid would hold more drops on a coin, with a reason.

CHALLENGE

12. Draw (in words) the Lewis structure of SO_2 with one S=O double bond, one S–O single bond and a lone pair on sulfur, and compute the formal charge of every atom. Do the charges sum correctly?

13. The recorded runs show 5 drops of water drying in a mean of 95 minutes and 5 drops of vanilla extract (a mixture containing ethanol) in a mean of 31 minutes. Using the vapor pressures 7.87 kPa (ethanol) and 3.17 kPa (water), compare the time ratio with the vapor-pressure ratio and say what the match or mismatch tells you.

REVIEW

14. Electronegativities: N 3.04, H 2.20. Find the difference, classify the N–H bond and say which atom carries the partial negative charge.

15. Count the valence electrons in the nitrate ion, NO_3^-, and in H_2O_2.

Lesson 2.3 — Why Ethanol Boils Higher Than Its Twin: Arguing from NIST Data

FLUENCY

1. The NIST boiling points are 351.5 K for ethanol and 248.2 K for dimethyl ether. Find the difference in kelvins.

2. Calculate the molar mass of ethanol, C_2H_6O, and of dimethyl ether, CH_3OCH_3.

3. Convert the boiling points of ethanol (351.5 K) and water (373.17 K) to °C and find the gap.

4. Find the slope of boiling point against molar mass between propane (44.097 g/mol, 231.1 K) and butane (58.124 g/mol, 273 K).

5. Which of these can form hydrogen bonds with molecules of its own kind: CH_3CH_2OH, CH_3OCH_3, CH_3COCH_3, CH_3COOH?

6. NIST gives an average enthalpy of vaporization of 42.3 kJ/mol for ethanol. How much energy does it take to vaporize 1.00 kg?

7. Missouri's ethanol plants can produce 287 million gallons a year (Missouri DNR). Convert to millions of liters (1 gal = 3.785 L).

APPLICATION

8. Using the line through butane and hexane (slope 2.46 K per g/mol), predict the boiling point of heptane (100.205 g/mol) and compare it with NIST's 371.5 K.

9. Interpolating between propane and butane gives a London-only baseline of about 237 K for a molecule of mass 46.069 g/mol. By how many kelvins do ethanol (351.5 K) and dimethyl ether (248.2 K) exceed the baseline? What does each excess say about its forces?

10. Boiling points (K): H_2O 373.17, H_2S 212.87; HF 292.7, HCl 188; NH_3 240, PH_3 186. Compute how far above its heavier neighbor each period-2 hydride boils and rank the three.

11. A plant heats a fermented mixture. Using NIST boiling points of ethanol (351.5 K) and water (373.17 K), explain why ethanol-rich vapor leaves first and give the temperature gap. (Ignore the fact that the two form a mixture that cannot be fully separated by one distillation.)

CHALLENGE

12. A student claims, “Ethanol boils higher than hexane because ethanol has a greater molar mass.” Use NIST data (ethanol 46.069 g/mol, 351.5 K; hexane 86.178 g/mol, 341.9 K) to rebut the claim and state the correct reasoning.

13. Acetic acid (60.052 g/mol, 391.2 K) boils 20.9 K above 1-propanol (60.096 g/mol, 370.3 K), though both hydrogen-bond and have almost the same mass. Propose a particle-level explanation and one way to test it.

REVIEW

14. Count the valence electrons in ethanol, C_2H_6O, and describe the shape around its oxygen atom.

15. Methanol's NIST dipole moment is 1.672 D and methane's is 0 D, and their molar masses are 32.042 and 16.043 g/mol. Name the strongest intermolecular force in each and say which should have the higher boiling point.

Lesson 2.4 — Structure Sets the Job: Metals, Ceramics, Network Solids and Polymers

FLUENCY

1. Classify each as metallic, ionic, network covalent or molecular/polymer: (a) copper wire, (b) table salt, (c) quartz, (d) polyethylene bag, (e) aluminum foil, (f) calcium oxide.

2. Calculate the molar mass of SiO_2 and the percent of silicon by mass.

3. Calculate the molar mass of the CH_2 repeating unit and of a polyethylene chain with 5,000 units.

4. Convert the NIST melting points of lead (600.64 K), aluminum (933.45 K) and copper (1357.95 K) to °C.

5. Which of lead, calcium oxide, quartz and polyethylene conducts electricity as a solid? Explain with particles.

6. How many moles of lead atoms are in 100 g of lead (atomic weight 207.2 g/mol)?

7. A hammer breaks a crystal of an ionic solid cleanly along a flat plane. Explain in one sentence why the crystal breaks instead of bending.

APPLICATION

8. A lead sheet is 0.50 m × 0.50 m × 2.0 mm thick. Using a density of 11.34 g/cm^3, find its volume in cm^3 and its mass in kg.

9. USGS lists the 2025 average North American lead price at 106 cents per pound. Convert to dollars per metric ton (1 metric ton = 2,204.62 lb) and find the raw-metal value of the 5.67 kg sheet.

10. A solid is very hard, melts at 2,613 °C, does not conduct as a solid but does when molten, and shatters under a hammer. Identify the class of solid, name the type of bonding, and explain each property in one phrase.

11. Rank these by melting point from lowest to highest and give the reason for the order: hexane (178 K), lead (600.64 K), sodium chloride (1073.9 K), quartz (about 1,983 K).

CHALLENGE

12. Diamond and graphite are both pure carbon. Diamond is extremely hard and does not conduct electricity; graphite is soft and conducts. Explain both differences from how each structure bonds the carbon atoms.

13. A manufacturer wants a plastic that does not soften in hot sunlight. Using the idea of cross-links, explain what structural change to a thermoplastic would help and what trade-off it creates.

REVIEW

14. Electronegativities: Si 1.90, O 3.44. Find the difference and classify the Si–O bond. Why can a bond classified this way still form a hard, high-melting solid?

15. NIST boiling points: methane 111 K, hydrogen sulfide 212.87 K, water 373.17 K. Rank them and name the strongest intermolecular force in each.

Unit 2 checkpoint

1. Electronegativities: Li 0.98, F 3.98. The bond in LiF is
   A. nonpolar covalent
   B. polar covalent
   C. ionic
   D. metallic
2. How many valence electrons are placed in the Lewis structure of NH₃?
   A. 3
   B. 5
   C. 8
   D. 10
3. Water has four electron domains around oxygen, two of them lone pairs. Its shape is
   A. linear
   B. bent
   C. trigonal planar
   D. tetrahedral
4. True or false: CO₂ is a nonpolar molecule even though each C=O bond is polar.
5. At 25 °C, water has a surface tension of 71.97 mN/m and methanol 22.15 mN/m. The best explanation is that
   A. methanol is heavier than water
   B. water has stronger hydrogen bonding between its molecules
   C. methanol is an ionic compound
   D. water has weaker forces and therefore a stronger skin
6. Ethanol and dimethyl ether both have a molar mass of _____ g/mol, but their NIST boiling points differ by _____ K.
7. Which of these molecules can form hydrogen bonds with other molecules of its own kind?
   A. CH₃OCH₃
   B. CH₃CH₂OH
   C. CH₄
   D. CO₂
8. True or false: Heavier molecules always have higher boiling points than lighter ones.
9. A solid is very hard, melts above 2,500 °C, does not conduct as a solid, and shatters under a hammer. It is most likely
   A. a metal
   B. an ionic ceramic such as CaO or MgO
   C. a polymer
   D. a molecular solid such as hexane
10. The molar mass of SiO₂ is _____ g/mol and it is _____ % silicon by mass.
11. True or false: Metals bend instead of shattering because layers of positive ions can slide while the sea of mobile electrons keeps them bonded.

12. A weighted decision matrix uses weights of 35%, 30%, 25% and 10% and scores of 5, 3, 3 and 5 for a candidate. Its weighted total is

    A. 3.65
    B. 3.80
    C. 3.90
    D. 4.10

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