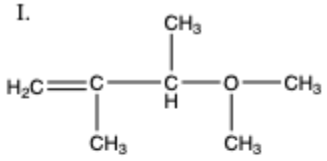
25 multiple-choice questions, 5 options

1. Most of the organic substances have low melting points, because their crystal lattice is:
    a. Ionic
    b. Metallic
    c. Atomic
    d. Molecular
    e. Covalent-network

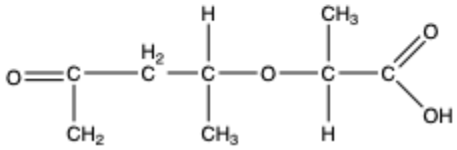
2. Which of the following formulas are drawn incorrectly?

I.

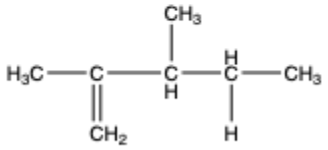


II.

III.



IV.



    a. I
    b. I & III
    c. II & IV
    d. II
    e. IV

3. How many electrons are located in the outer orbital of an atom, whose nucleus has 11 protons?
    a. 11
    b. 1
    c. 23
    d. 2
    e. 8

4. In the middle of the 19th century, Justus von Liebig came up with the process to deposit silver on a surface to create a mirror. Most of the vintage mirrors you can find were made using his technique. The mirror is formed when a thin film of metallic silver deposits on a surface. A reaction between aldehyde and silver nitrate in a basic solution, produces a silver metal:

$$\mathrm{AgNO_{3(aq)} + CH_3CHO_{(aq)} + H_2O_{(l)} \rightarrow Ag_{(s)} + CH_3COOH_{(aq)} + HNO_{3(aq)}}$$

You want to make a 35 by 40 cm mirror, where the thickness of the silver layer would be about 100 nm (1×10^{-5} cm). Using the density of the silver, you calculated that you need 0.147 g of silver. How much silver nitrate would you need to make this mirror?

   a. 0.00136 g
   b. 0.187 g
   c. 0.231 g
   d. 0.147 g
   e. 0.294 g

5. The silver nitrate available to you is laboratory grade, not reagent grade and is only 95.% pure. If you needed 50.0 g of pure silver nitrate, how much would you need to use?
   a. 52.6 g
   b. 47.5 g
   c. 50.0 g
   d. 45.0 g
   e. Not enough information to answer the question

(Questions 6 – 8 refer to the molecule in Figure 1)

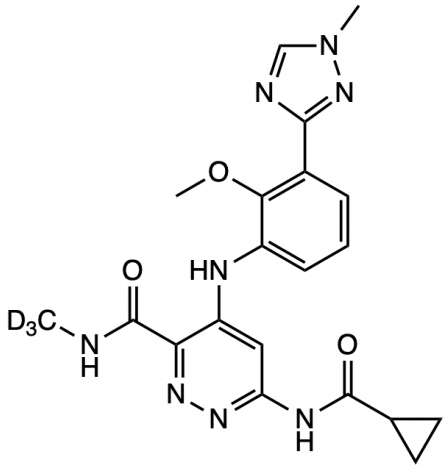


Figure 1. The molecule of the year 2022, deucravacitinib. The first innovation in oral treatment for moderate-to-severe plaque psoriasis in nearly 10 years.

6. How many heteroatoms are present in the heterocyclic rings of the compound deucravacitinib, shown in figure 1?
    a. 2
    b. 3
    c. 5
    d. 6
    e. 11

7. How many carbons in deucravacitinib have tetrahedral geometry?
    a. 0
    b. 3
    c. 4
    d. 5
    e. 6

8. Choose an incorrect statement about deucravacitinib:
    a. There is 1 aromatic ring.
    b. It contains deuterium.
    c. It can have van der Waals interactions with other molecules
    d. It can have hydrogen bonding, but not dipole-dipole interactions
    e. All statements are correct.

9. When describing an ideal gas, what forces occur between particles of such gas?
    a. Van der Waals forces
    b. Repulsive forces
    c. Dipole-dipole interactions
    d. Dispersion forces
    e. None of the above

10. If you have a container with 5.00 L of CO_2 gas at 0°C and 760 mm Hg, what is the molar volume of CO_2? Assume ideal gas behaviour.
    a. 5.00 L/mol
    b. 0.110 L/mol
    c. 22.2 L/mol
    d. 22.4 L/mol
    e. Not enough information provided

11. There has been a spill in one of the laboratories of an unknown strong acid. You are provided with a collected sample and need to determine the identity of this acid. Titration of 25.0 mL of this acid with a 0.150 M solution of sodium hydroxide (NaOH) reveals that the equivalence point is reached when 35.0 mL of the base solution is added.

    You know that this laboratory only has the following acids available: 1.0 M HCl, 0.75 M HBr, 0.21 M HNO_3, and 0.2 M HCOOH.

    Determine the molarity of the unknown acid solution and identify the acid from the list provided (assume the acid is <u>monoprotic</u>):

    a. Hydrochloric acid (HCl)
    b. Hydrobromic acid (HBr)
    c. Nitric acid (HNO_3)
    d. Formic acid (HCOOH)
    e. None of the above

12. Which of the following statements best explains the boiling point trends observed in organic molecules?
    a. As the molecular weight of an organic molecule increases, its boiling point always decreases due to the decrease in surface area.
    b. Polar molecules generally have higher boiling points than nonpolar molecules of similar size because of dipole-dipole interactions.
    c. Boiling points are only dependent on the presence of functional groups and are not affected by the chain length or branching.
    d. Branched alkanes typically have higher boiling points than unbranched isomers because of the increased amount of van der Waals forces.
    e. Boiling point is only determined by the number of electrons, and does not depend on molecular structure.

Questions 13–16 refer to the table below.

Ionization Energy	1^{st} ($kJ \cdot mol^{-1}$)	2^{nd} ($kJ \cdot mol^{-1}$)	3^{rd} ($kJ \cdot mol^{-1}$)
Element X	899.5	1757.1	14,848.7
Element Y	589.8	1145.4	4912.4
Element Z	502.9	965.2	3600

Table 1. Ionization energies of compounds X, Y and Z.

13. Based on the information provided in Table 1, which element is likely to have the lowest electronegativity value? All elements are in the same group of the periodic table.
    a. X
    b. Y
    c. Z
    d. None of the above. Electronegativity is unrelated to the ionization energy
    e. Not enough information to answer the question

14. Based on the information provided in Table 1, which element would you expect to have the smallest atomic radius?
    a. X
    b. Y
    c. Z
    d. None of the above. Atomic radius is unrelated to the first ionization energy
    e. Not enough information to answer the question

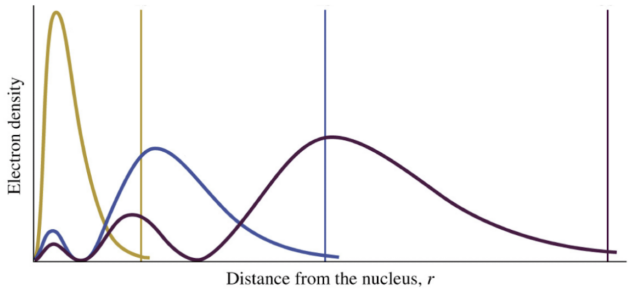
15. Element Z is used in a specific photoelectron spectroscopy experiment. When illuminated, electrons are ejected from its surface. If you were designing this experiment, which wavelength of electromagnetic radiation would you use to ionize Element Z by removing its outermost electron?
    a. 150 nm
    b. 238 nm
    c. 315 nm
    d. 410 nm
    e. 500 nm

16. Based on the information provided in the table, what is the most probable correct order of the elements from top to bottom within a group in the periodic table?
    a. X, Y, Z
    b. Z, Y, X
    c. Y, X, Z
    d. Z, X, Y
    e. Ionization energy is unrelated to an atom’s position in the periodic table.

17. Below are reactions of aluminum salts. Which of them results in a precipitate and gaseous products at the same time?
    a. $KAlO_2 + HCl + H_2O \rightarrow Al(OH)_3 + KCl$
    b. $2AlCl_3 + 3K_2CO_3 + 3H_2O \rightarrow 2Al(OH)_3 + 6KCl + 3CO_2$
    c. $Na[Al(OH)_4] \rightarrow NaAlO_2 + 2H_2O$
    d. None of the above
    e. Multiple answers are correct

18. The reaction that results in a precipitate is an example of a qualitative test for aluminum presence in a mixture. For equation (a) from the previous question (#17), what would be a correct equilibrium constant expression?
    a. $K = \frac{[KAlO_2][HCl][H_2O]}{[KCl][Al(OH)_3]}$
    b. $K = \frac{[KAlO_2][HCl][H_2O]}{[KCl]}$
    c. $K = \frac{[KCl]}{[KAlO_2][HCl][H_2O]}$
    d. $K = \frac{[KCl][Al(OH)_3]}{[KAlO_2][HCl][H_2O]}$
    e. $K = \frac{[KCl]}{[KAlO_2][HCl]}$

19. The graph below depicts the probability of finding an electron against the electron's distance from the nucleus, where each colour corresponds to a different orbital. Which of the following options correctly describes the orbitals depicted?



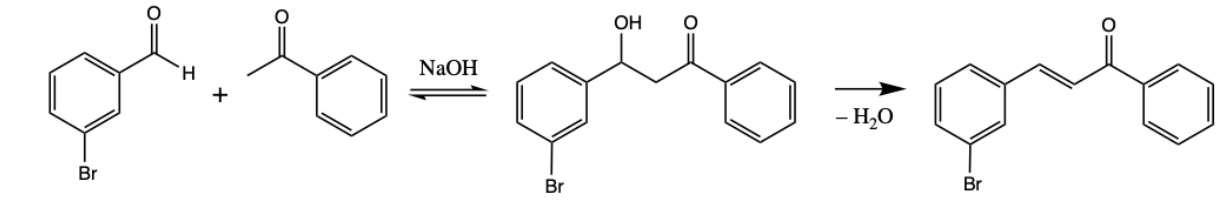
    a. Yellow: 1s; Blue: 2s ; Purple: 3s.
    b. Yellow: 1p; Blue: 2p; Purple: 3p.
    c. Yellow: 3s; Blue: 2s; Purple: 1s.
    d. Yellow: 3p; Blue: 2p; Purple: 1p.
    e. Yellow: 1s; Blue: 2p; Purple: 3d.

Image source: lecture slides from Chemistry: Physical Principles, University of Toronto

Questions 20–23 refer to the reaction scheme of the Claisen-Schmidt condensation below.

The product of the reaction, chalcone, is an important intermediate in the synthesis of other organic compounds, widely used in the pharmaceutical and medicinal chemistry fields. It exhibits anti-inflammatory, antimicrobial, antifungal, anti-HIV properties. For example, some chalcone derivatives are used in the synthesis of compounds that are used as dietary supplements, in cosmetics, and as natural food colouring.

Chalcones can be synthesized by combining an enol or enolate with an aldehyde or ketone, which can then undergo an additional condensation:



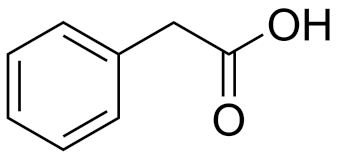
Benzaldehyde derivative (3-bromobezaldehyde) | Acetophenone | β-hydroxylcarbonyl | α,β-unsaturated carbonyl (chalcone) [3-(3-bromophenyl)-1-phenyl-2-propen-1-one]

Scheme 1. Claisen-Schmidt condensation reaction.

20. The experimental procedure for this reaction is very straightforward, so you decide to try it with your chemistry lab instructor. Upon several attempts, you figure out that your reaction yield is 62.0%. Since you want to use the product for more experiments, what is the required mass of acetophenone to generate 20.0 mg of chalcone?
    a. 12.4 mg
    b. 62.0 mg
    c. 13.5 mg
    d. 32.4 mg
    e. 32.3 mg

21. Based on the last step of the reaction in Scheme 1 (β-hydroxycarbonyl to chalcone), how would you expect the melting point and solubility to change?
    a. Melting point slightly increase, solubility slightly increase
    b. Melting point slightly increase, solubility slightly decrease
    c. Melting point slightly decrease, solubility slightly increase
    d. Melting point slightly decrease, solubility slightly decrease
    e. No changes

22. One of the reagents, acetophenone, is not soluble in water. You decide to practice a Baeyer-Villiger oxidation reaction experiment, and convert acetophenone to phenylacetic acid, shown on the right. You dissolve a certain amount of phenylacetic acid in 20 mL of water. After reaching equilibrium, 4.77% of the phenylacetic acid has dissociated. The resulting solution has a pH of 3.0. What is the pKa of the acid?



a. 4.3
b. 5.1
c. 1.3
d. 3.2
e. 4.1

23. What statement is true about pH change in reactions in Scheme 1?
    a. pH would increase in the last step (β-hydroxycarbonyl to chalcone)
    b. pH would decrease in the last step (β-hydroxycarbonyl to chalcone)
    c. pH would increase in the first step
    d. pH would decrease in the first step
    e. pH is the same or change is negligible in all steps

24. Which molecule on Figure 2 is a catalyst?

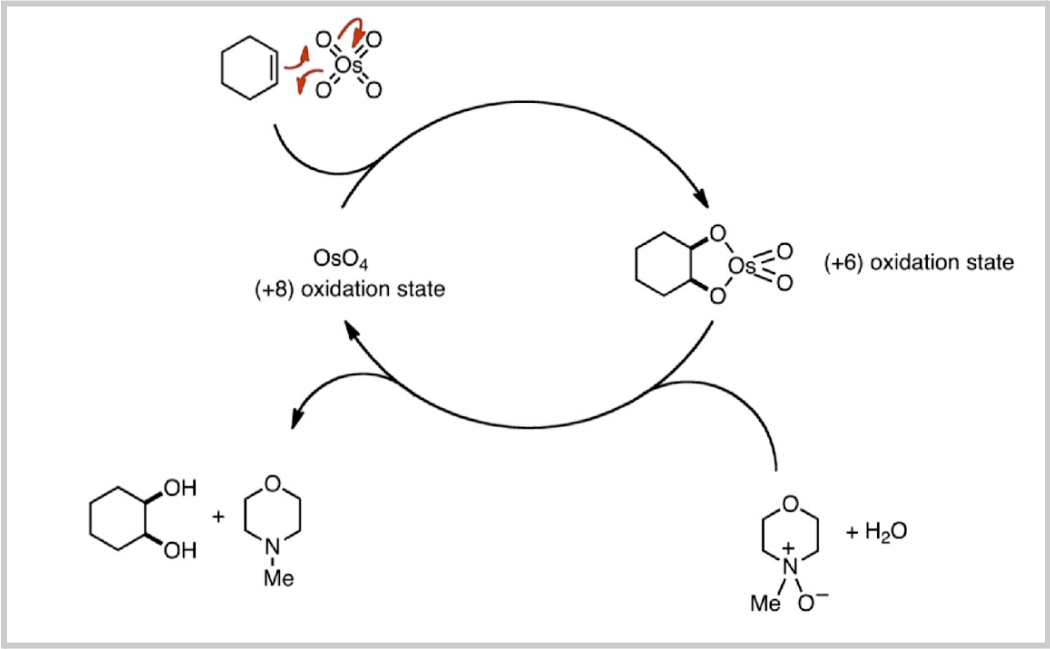
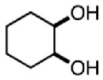
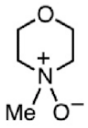


Figure 2. Catalytic cycle.

a. 

b. 

c. 

d. OsO_4
e. None of the above

25. As a part of your lab, you heat up copper (II) sulfate pentahydrate to remove water, and produce 3.20 g of the anhydrous compound. However, you realized that you forgot to record the original mass of the hydrated copper (II) sulfate. Find the mass of the copper (II) sulfate pentahydrate using available information.
    a. 5.00 g
    b. 2.49 g
    c. 0.630 g
    d. 3.20 g
    e. Not enough information to answer the question