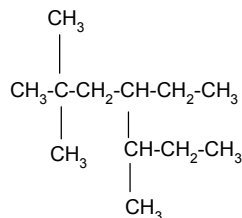


CHEM 12, Exam I
February 7, 2001
Form A

1. What is the correct IUPAC name of the following alkane?



- a. 4-isobutyl-2,2-methylhexane
- b. 2,3-diethyl-5,5-dimethylhexane
- c. 4-ethyl-2,2,5-trimethylheptane
- d. 4-ethyl-2,2-dimethyloctane
- e. 4-ethyl-3,6,6-trimethylheptane

The longest chain has 7 carbons: the parent is, therefore, heptane.

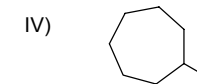
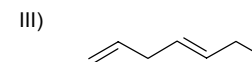
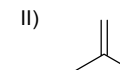
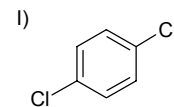
The substituents are: methyl groups on carbons 2, 2, and 5 and ethyl on carbon 4.

(if numbered from the other end, methyl groups would be on carbons 3, 6, 6 and ethyl would be on carbon 4; clearly higher numbers than the first alternative)

Ordered alphabetically:

4-ethyl-2,2,5-trimethylheptane (choice c).

2. Which of the following molecules would you expect to react with Br_2 in an **addition** reaction?



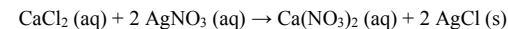
- a. I, II, and III
- b. II and III
- c. I and IV
- d. IV
- e. all of the molecules

Only molecules with double or triple bonds undergo addition reaction.

Aromatic compounds do not undergo addition. (I) is aromatic.

The answer is (II) and (III); i.e. choice b.

3. According to the following balanced chemical reaction, how much of CaCl_2 must be combined with an excess of AgNO_3 to produce 100 g of AgCl ?



- a. 26.4 g
- b. 38.7 g
- c. 50.0 g
- d. 77.6 g
- f. 100 g

Using atomic weights from the periodic table:

Molecular weight of $\text{CaCl}_2 = 40.078 (\text{Ca}) + 2 \times 35.453 (\text{Cl}) = 110.984 \text{ g/mol}$

Molecular weight of $\text{AgCl} = 107.87 (\text{Ag}) + 35.453 (\text{Cl}) = 143.323 \text{ g/mol}$

From the equation: 1 mol of CaCl_2 gives 2 moles of AgCl or:

110.884 g of CaCl_2 gives 2 x 143.323 g of AgCl and
x g of CaCl_2 gives 100 g of AgCl solving for x
 $x = (100 \times 110.884) / (2 \times 143.323) = 38.7 \text{ g}$ (choice b)

4. What is the weight percentage of **nitrogen** in urea [(NH₂)₂CO]?

- a. 46.7%
- b. 31.8%
- c. 23.3%
- d. 48.3%
- e. 63.6%

The molecular weight of urea based on atomic weights from the periodic table:

$$\text{MW (urea)} = 2 \times 14.0 (\text{N}) + 4 \times 1.0 (\text{H}) + 12.0 (\text{C}) + 16.0 (\text{O}) = 60.0$$

There are two atoms of nitrogen in urea. Therefore, the weight percentage of nitrogen is:

$$[(2 \times 14.0)/60.0] \times 100\% = 46.7\% \quad (\text{choice a})$$

5. Which of the following is an isomer of pentane?

- a. 2-methylpropane
- b. 3-ethylpentane
- c. 2,2-dimethylpropane
- d. 2-pentene
- e. 2,2-dimethylbutane

Pentane has a formula of C₅H₁₂. An isomer of pentane must have the same formula. Choice (a) has 4 carbons, choice (b) has 7 carbons, choice (d) has 5 carbons, but only 10 hydrogens (it is not an isomer), choice (e) has 6 carbons.

The correct answer, choice (c) has three carbons in the chain and two as substituents; total of 5 carbons (and, of course, also 12 hydrogens).

6. How many protons, neutrons, and electrons are present in the following ion?



- a. p = 16, n = 15, e = 12
- b. p = 15, n = 16, e = 18
- c. p = 15, n = 16, e = 12
- d. p = 15, n = 16, e = 15
- e. p = 16, n = 15, e = 15

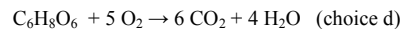
By definition of symbols, this ion has 15 protons, its mass is 31 amu, and therefore, it must have (31 - 15 = 16) neutrons. Since it is an anion with a charge of -3, it must have three extra electrons. In a neutral atom number of electron equals number of protons; so for this ion number of electrons would be (15 + 3) = 18 (choice b).

7. A Chem 12 student completely combusts exactly one mole of ascorbic acid (C₆H₈O₆), commonly known as vitamin C, in a bomb calorimetry experiment. What is the correct coefficient of **water** in the complete combustion reaction of 1 mole of vitamin C?

- a. 8
- b. 6
- c. 5
- d. 4
- e. 2

Since the hydrogen in combustion is provided only by ascorbic acid, having 8 hydrogens, without doing anything you may conclude that that coefficient must be a multiple of 4 (4, 8, 12, ...) since water has two hydrogens per molecule.

Balancing the equation gives you:



8. Which of the following names **does not** follow the official (IUPAC) organic nomenclature rules?

- a. 2-ethylpropane
- b. 3-methylhexane
- c. 3-ethylnonane
- d. 2-methylpropane
- e. 2,3-dimethylpentane

The best systematic way to solve this problem is to draw the structures according to the names, and then name them correctly. If the name comes up different, than the original name, that is the one.

The first one is in fact: 2-methylbutane (correct choice: a).

For students with a little experience: you may deduce that if the length of the side chain (substituent) in the name is longer than any of the two partial chains counting from the point of attachment of that substituent that name will be incorrect.

9. How many structural isomers are there for hexane?

- a. 1
- b. 2
- c. 3
- d. 4
- e. 5

Just systematically draw them:

(I) C(1)-C(2)-C(3)-C(4)-C(5)-C(6) simplest one

Now use 5 carbons in the chain and check how many different places can you put the 6th carbon on it:

C(1)-C(2)-C(3)-C(4)-C(5)

- a) adding it at either end (carbon 1 or 5) gives you (I) again - already counted
- b) adding it to carbon 2 gives you 2-methylpentane (II)
- c) adding it to carbon 3 gives you 3-methylpentane (III)
- d) adding it to carbon 4 gives you again 2-methylpentane - already counted (II)

Now use 4 carbon chain and check how many different ways can you add the remaining two carbons:

C(1)-C(2)-C(3)-C(4)

- a) both carbons (5, 6) are added to C1, or C4 to give (I) - already counted
- b) one carbon added to C1 the other to C4 gives you (I) again - already counted
- c) one carbon added to C1 or C4, the other added anywhere else within the chain is equivalent to possibilities of the 5-carbon chain considered above - already counted
- d) adding both carbons to C2 or C3 gives new isomer, 2,2-dimethylbutane (IV)
- e) adding one carbon to C2 and one to C3 gives new isomer 2,3-dimethylbutane (V)
- f) adding both carbons as an ethyl group to the chain in either position 2, or 3 gives isomers already counted under 5-carbon chain

Considering 3-carbon chain does not add any new possibilities. Total five isomers (I-V) found (choice e).

10. Which of the following **formula – name** combinations are **correct**?

- I. NH₄Br – ammonium bromide
- II. CaO₂ – calcium oxide
- III. KCO₃ – potassium carbonate
- IV. MgSO₄ – magnesium sulfate

- a. all of the above.
- b. I, II, and IV only
- c. I, III, and IV only
- d. II and III only
- e. I and IV only

ammonium bromide - correct NH₄⁺ Br⁻

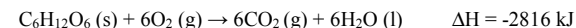
calcium oxide - incorrect Ca²⁺ O₂²⁻, the charges do not add up to neutral (CaO would be correct)

potassium carbonate - incorrect K⁺ CO₃²⁻, the charges do not add up to neutral (K₂CO₃ would be correct)

magnesium sulfate - correct Mg²⁺ SO₄²⁻

This problem requires knowledge of names (inorganic nomenclature) and charges of common ions. Periodic table may be used to decide charges of cations, and some ions as well (bromide, oxide) (correct choice e)

11. Assuming that all energy from glucose (C₆H₁₂O₆) is converted to heat (as shown in the equation below), if a person metabolizes 18 kg of glucose a month, how much heat will her body produce?



- a. 282 kJ
- b. 2816 kJ
- c. 309 kJ
- d. 2.82 x 10⁵ kJ
- e. 3.09 x 10⁵ kJ

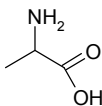
Molecular weight of glucose is MW = 6 x 12 (C) + 12 x 1 (H) + 6 x 16 (O) = 180 g/mol

One mole of glucose gives 2816 kJ of heat

We have 18 kg = 18 000 g of glucose which is equivalent to 18000/180 = 100 moles of glucose

100 moles of glucose would produce (100 x 2816) kJ of heat = 2.82 x 10⁵ kJ (choice d).

12. The molecule below (alanine) is an amino acid. It may polymerize to form a polyalanine. If the polyalanine contains amide functional groups, which of the following statements is true?



- Alanine polymerized through an addition reaction.
- Alanine polymerized through a condensation reaction.
- Alanine polymerized through a pollination reaction.
- Alanine polymerized through a reduction-oxidation reaction.
- Alanine polymerized through an acid-base reaction.

To form amides from carboxylic acids and amines a condensation reaction is involved (choice b)

13. Calcium nitrate (0.015 g) was dissolved in 300 mL of water. What is the molar concentration of NO_3^- ions?

- $4.6 \times 10^{-4} \text{ M}$
- $1.0 \times 10^{-1} \text{ M}$
- $3.0 \times 10^{-4} \text{ M}$
- $1.8 \times 10^{-4} \text{ M}$
- $6.1 \times 10^{-4} \text{ M}$

MW of $\text{Ca}(\text{NO}_3)_2 = 40.078 (\text{Ca}) + 2 \times 14.007 (\text{N}) + 6 \times 15.999 (\text{O}) = 164.1 \text{ g/mol}$

The number of moles of calcium nitrate used is $(0.015 \text{ g}) / (164.1 \text{ g/mol}) = 9.14 \times 10^{-5} \text{ mole}$

The concentration of calcium nitrate in solution $(9.14 \times 10^{-5} \text{ mole}) / (0.300 \text{ mL}) = 3.05 \times 10^{-4} \text{ M}$

Solution of calcium nitrate contains two moles of nitrate per each mole of calcium nitrate dissolved; so the concentration of NO_3^- ions is $2 \times 3.05 \text{ M} = 6.1 \times 10^{-4} \text{ M}$ (choice e)

14. Which of the following reactions illustrates a method for the formation of an ester?

- $\text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_3 + \text{NaOH} \rightarrow \text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{Na} + \text{H}_3\text{C}-\text{OH}$
- $\text{H}_3\text{C}-\text{OH} + \text{H}_3\text{C}-\text{CH}_2-\text{OH} \rightarrow \text{H}_3\text{C}-\text{O}-\text{CH}_2-\text{CH}_3 + \text{H}_2\text{O}$
- $\text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH} + \text{H}_3\text{C}-\text{CH}_2-\text{OH} \rightarrow \text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{O}-\text{CH}_2-\text{CH}_3 + \text{H}_2\text{O}$
- $\text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\text{OH} + \text{H}_3\text{C}-\text{NH}_2 \rightarrow \text{H}_3\text{C}-\text{CH}_2-\overset{\text{O}}{\parallel}{\text{C}}-\underset{\text{H}}{\text{N}}-\text{CH}_3 + \text{H}_2\text{O}$
- none of the above

Only one reaction above involves an ester: choice c

15. If each of the following organic compounds is an alkane, which one is cyclic?

- C_3H_8
- $\text{C}_{22}\text{H}_{46}$
- C_7H_{14}
- $\text{C}_{12}\text{H}_{26}$
- C_8H_{18}

Alkanes have a general formula $\text{C}_n\text{H}_{2n+2}$

Cycloalkanes have a general formula C_nH_{2n}

Only choice c matches the cycloalkane formula.

16. What is the molarity of NaCl in a solution made by mixing 25.0 mL of 0.100 M NaCl with 50.0 mL of 0.100 M NaCl?

- 0.100 M
- 0.0500 M
- 0.0333 M
- 0.0250 M
- 0.0125 M

No calculation necessary: mixing solution of the same concentrations! (choice a)

17. Fructose has weight percentage compositions of 40.0% carbon, 53.3% oxygen, and 6.7% hydrogen. Which of the following is a possible molecular formula for fructose?

- a. $C_5H_5O_8$
- b. CH_4O
- c. $C_{22}H_{33}O_{22}$
- d. $C_6H_{12}O_6$
- e. none of the above

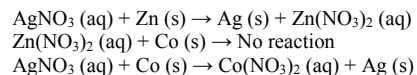
Assume 100 g sample:

C: $(40.0 \text{ g}) / (12 \text{ g/mol}) = 3.33$ mole of carbon
O: $(53.3 \text{ g}) / (16 \text{ g/mol}) = 3.33$ mole of oxygen
H: $(6.7 \text{ g}) / (1 \text{ g/mol}) = 6.7$ mole of hydrogen

The ratio of C: H : O is 3.33 : 6.7 : 3.33 or 1:2:1
The only formula that matches this ratio is $C_6H_{12}O_6$ (choice d).

Note: fructose and glucose (question 11) have the same formula; they are isomers.

18. Consider the following reactions:



Which is the correct order of increasing activity for these metals?

- a. $\text{Ag} < \text{Zn} < \text{Co}$
- b. $\text{Co} < \text{Ag} < \text{Zn}$
- c. $\text{Co} < \text{Zn} < \text{Ag}$
- d. $\text{Ag} < \text{Co} < \text{Zn}$
- e. $\text{Zn} < \text{Ag} < \text{Co}$

These are single displacement reaction (lecture 7)

Zn displaces Ag in solution: Zn is more active than Ag
Co does not displace Zn in solution: Zn is more active than Co
Co displaces Ag in solution: Co is more active than Ag

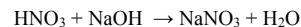
Order of activity: $\text{Ag} < \text{Co} < \text{Zn}$ (choice d)

19. The neutralization reaction between nitric acid and sodium hydroxide produces water and sodium nitrate. Nitric acid (63 g) and sodium hydroxide (60 g) are mixed. Which one of the following is a true statement?

- a. All of the nitric acid will be consumed.
- b. All of the sodium hydroxide will be consumed.
- c. There will be nitric acid left unreacted.
- d. Exactly 27 g of water will form.
- e. The reaction mixture will feel cold

MW of nitric acid (HNO_3) = 63 g/mol
MW of sodium hydroxide (NaOH) = 40 g/mol

The reaction:



One mole of nitric acid reacts with one mole of sodium hydroxide. Since we have exactly one mol of acid (63 g) and excess of hydroxide (one mole is 40 g, we have 60 g) all acid will be consumed, and hydroxide will be left over (one mole of water, 18 g, will also be produced) in this exothermic reaction (it will feel warm). (correct choice a)

20. There are four oxyanions containing chlorine and oxygen (ClO^- , ClO_2^- , ClO_3^- , and ClO_4^-). What is the name of the following acid?



- a. hydrochlorous acid
- b. perchloric acid
- c. hydrochloric acid
- d. hypochlorous acid
- e. chloric acid

From nomenclature rules: if there are multiple oxyanions, the one with most oxygens gets a suffix "per-" and ending "-ic" (choice b)

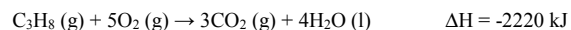
21. When aqueous solutions of LiCl (aq) and AgNO₃ (aq) are mixed, an insoluble salt forms. Which of the following is the **net ionic equation** that describes this reaction?

- a. $\text{LiCl (aq)} + \text{AgNO}_3 \text{ (aq)} \rightarrow \text{AgCl (s)} + \text{LiNO}_3 \text{ (aq)}$
- b. $\text{Cl}^- \text{ (aq)} + \text{Ag}^+ \text{ (aq)} \rightarrow \text{AgCl (s)}$
- c. $\text{Li}^+ \text{ (aq)} + \text{Cl}^- \text{ (aq)} + \text{Ag}^+ \text{ (aq)} + \text{NO}_3^- \text{ (aq)} \rightarrow \text{AgCl (s)} + \text{Li}^+ \text{ (aq)} + \text{NO}_3^- \text{ (aq)}$
- d. $\text{Li}^+ \text{ (aq)} + \text{NO}_3^- \text{ (aq)} \rightarrow \text{LiNO}_3 \text{ (s)}$
- e. $\text{Li}^+ \text{ (aq)} + \text{Cl}^- \text{ (aq)} + \text{Ag}^+ \text{ (aq)} + \text{NO}_3^- \text{ (aq)} \rightarrow \text{Ag}^+ + \text{Cl}^- \text{ (aq)} + \text{LiNO}_3 \text{ (s)}$

The insoluble salt is AgCl (solubility rules). The equation that describes the "essence" of that solid formation is the net ionic equation - choice b.

- (a) includes spectator ions, and does not account for dissociation of salts
- (c) includes spectator ions that do not participate in the reaction
- (d) wrong salt precipitates
- (e) wrong salt precipitates

22. Given the reaction below, which one of the following statements is **false**?

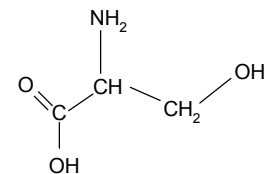


- a. The enthalpy of the reactants is greater than the enthalpy of the products.
- b. The combustion of propane is exothermic.
- c. If 3 moles of CO₂ (g) and 4 moles of H₂O (l) react to form propane gas and oxygen gas, 2220 kJ of heat will be consumed.
- d. The reactants must be provided with 4440 kJ of energy to produce 6 moles of carbon dioxide.
- e. This is an example of a reaction where the energy of chemical bonds is converted to heat.

(d) is a false statement: production of 6 moles of CO₂ will produce 4440 kJ of heat. The reaction is exothermic. Energy would be required if the reaction was endothermic.

- (a) is true since for any exothermic reaction products are more stable than reactants
- (b) is true since heat is evolved by the system (negative sign of ΔH)
- (c) is true; it applies to the reverse (i.e. endothermic) reaction
- (e) is true; bonds are stronger in products than in reactants; "excess" energy is given off as heat

23. Serine, the molecule shown below, contains which of the following functional groups?



- a. amide, alcohol, ester
- b. amide, carboxylic acid, alcohol
- c. amide, ester, carboxylic acid
- d. amine, alcohol, carboxylic acid
- e. amine, ester, alcohol

Serine contains: an alcohol (C-OH), an amine (C-NH₂) and a carboxylic acid (C-COOH) (Correct choice is d)

24. In which of the pairs listed below **both** compounds are strong electrolytes?

- I. CH₃COOH and HClO₄
- II. HF and NH₃
- III. NaCl and Sr(OH)₂
- IV. HCl and C₆H₁₃OH

- a. III only
- b. I and II only
- c. II and IV only
- d. I and III only
- e. II and III only

CH₃COOH is a weak electrolyte (weak acid); HClO₄ is a strong electrolyte (strong acid)

HF (weak acid) and NH₃ (weak base) are both weak electrolytes

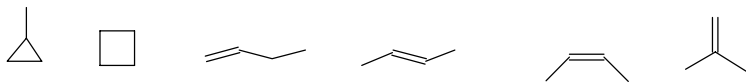
NaCl (salt) and Sr(OH)₂ (strong base) are both strong electrolytes

HCl (strong acid) is an electrolyte and C₆H₁₃OH (organic alcohol) is a non-electrolyte

(correct choice a).

25. Hydrocarbons with formula C_4H_8 can exist as cycloalkanes or alkenes. Considering all possibilities (all ring sizes and branching alternatives) that satisfy the valence rules, how many isomers (structural and geometrical) are there for C_4H_8 ?

- a. 2
- b. 3
- c. 4
- d. 5
- e. 6



Systematically consider all possibilities:

- a) rings: (I) the smallest is 3-membered; one carbon left added to one of the "corners"
(II) next ring size (4) uses all carbons available
- b) linear structures: (III) with double bond at the end
(IV) with double bond in the middle, with trans geometry
(V) with double bond in the middle, with cis geometry
- c) branched structure (VI)

(correct choice e)

26. Which of the following statements regarding **enthalpy** are true?

- I. Enthalpy is an extensive property.
- II. The enthalpy change for a reaction is equal in magnitude but opposite in sign to the enthalpy change for the reverse reaction.
- III. The enthalpy change for a reaction depends on the state of the reactants and products.
- IV. Under constant pressure, the change in enthalpy of a system equals the amount of heat gained or lost by the surroundings.
- V. Enthalpy is a state function.

- a. all of the above.
- b. I, II, III, and IV only
- c. III, IV, and V only
- d. II, III, IV, and V only
- e. I, II, III, and V only

-
- I. true (it depends on amount of matter)
 - II. true (because it is a state function)
 - III. true (because change of state involves change in enthalpy (state transformation like liquid into gas, or solid into liquid etc. require heat exchange))
 - IV. true (from the definition of enthalpy and the law of conservation of energy: enthalpy is the heat exchanged under the constant pressure, and whatever is lost (gained) by the system must be gained (lost) by the surroundings)
 - V. true (in our case because we said so; i.e. by definition)

All are true, (choice a)

END OF EXAM.