Here are questions from the 2006 final exam for Chem 1aa3.

Some questions which were not relevant have been removed.

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Questions 1 through 30 are worth two (2) marks each.

1. Use the data below to **calculate the equilibrium constant, K_C,** for the following reaction:

$$CH_3COOH(aq) + NO_2^-(aq) \rightleftharpoons CH_3COO^-(aq) + HNO_2(aq) \qquad K_C = ?$$

Data: $K_a\ (CH_3COOH) = 1.8 \times 10^{-5}$ $K_b\ (NO_2^-) = 2.2 \times 10^{-11}$

(A) 2.5×10^{15}

(B) 8.2×10^{5}

(C) 4.0×10^{-2}

(D) 1.2×10^{-6}

(E) 8.2×10^{-9}

2. How many **grams of NaCN** would you need to dissolve in enough water to make exactly 250. mL of solution with a pH of 10.00? ($K_b\ CN^- = 2.0 \times 10^{-5}$).

(A) 5.00×10^{-6} g

(B) 2.45×10^{-5} g

(C) 1.50×10^{-4} g

(D) 3.90×10^{-3} g

(E) 7.35×10^{-3} g

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3. The K_a of methanoic acid (HCOOH) is 1.7×10^{-4} at 25°C. Choose the statements that are **TRUE** regarding this acid.

   (i) The acid will become stronger at 40°C.

   (ii) A 0.10 M solution of methanoic acid will have a higher percent ionization than a 0.75 M solution.

   (iii) A 0.75 M solution of methanoic acid will contain a lower concentration of $H_3O^+(aq)$ than a 0.10 M solution.

   (iv) Its conjugate base, $HCOO^-$, is a stronger base than the ethanoate ion (K_b of ethanoate ion = 5.6×10^{-10}).

(A) i, ii
(B) i, iii
(C) i, iv
(D) ii, iii
(E) iii, iv

4. Novocaine, which is used by dentists as a 'local' anaesthetic, is a weak base. What is the **ratio of the concentration of Novocaine to that of its conjugate acid** in a patient's blood plasma (pH = 7.40)?
   (K_b Novocaine = 8.91×10^{-6})

(A) 4.47×10^{-3}
(B) 0.0282
(C) 1.86
(D) 35.5
(E) 224

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5. Choose, where possible, the **stronger Lewis acid** from each pair:

   Fe^{2+}, Fe^{3+} and BF_3, BCl_3

   The **stronger Lewis acids** are:

(A) Fe^{2+}, BF_3

(B) Fe^{3+}, BF_3

(C) Fe^{2+}, BCl_3

(D) Fe^{3+}, BCl_3

(E) Each pair of acids is equally strong.

6. Chlorophenol blue is an acid-base indicator with a pK_a of 5.6. The acidic form is yellow and the basic form is red. A few drops of this indicator are added to the titration of caffeine (pK_b = 3.4) with HCl. Find the **TRUE** statement(s) about this titration experiment.

   (i) The chlorophenol blue indicator is an appropriate choice for locating the equivalence point of this titration.

   (ii) The indicator starts to change from red to orange at about pH = 6.6 and completes the change from orange to yellow at about pH = 4.6.

   (iii) The indicator will change from red to yellow during the buffer region of the titration curve.

(A) i

(B) i, ii

(C) i, ii, iii

(D) ii, iii

(E) iii

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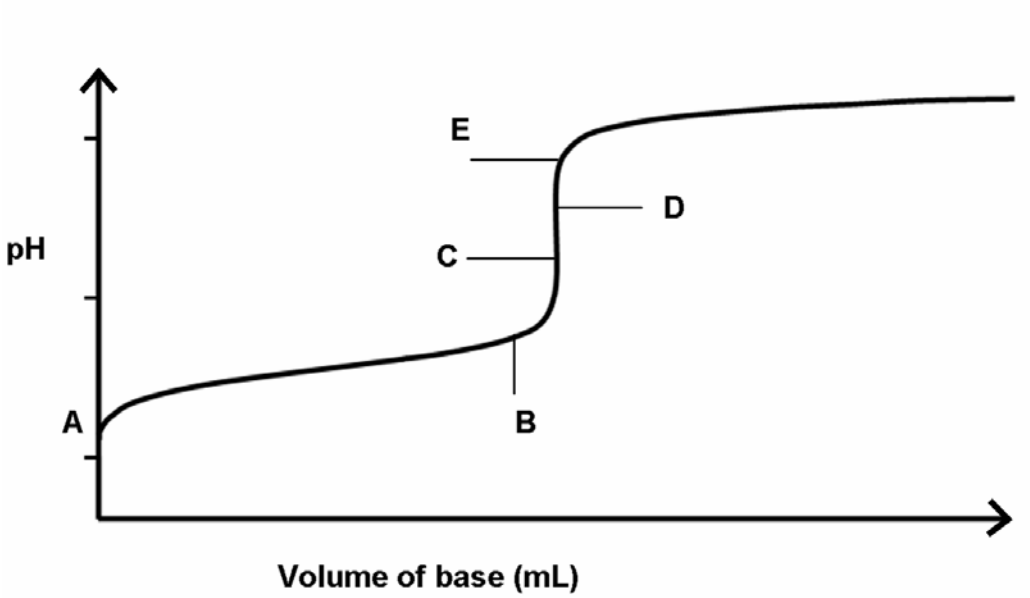
7. A student gradually adds a base to an acid, and monitors the change in pH as base is added. For the following graph of pH change, which statement is **TRUE**?



(i) The pH at point B is most likely more than 7.

(ii) An indicator that changed colour at point C would not be suitable for monitoring this acid-base reaction.

(iii) The solution at point D contains a mixture of weak base and its conjugate acid, whose concentrations are within a 1:10 – 10:1 ratio.

(iv) The major determinant of pH at point E is the concentration of weak base present in solution.

(A) i

(B) ii

(C) iii

(D) iv

(E) none is true.

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Question 8 removed

9. The thermal decomposition of N_2O_5 obeys first-order kinetics. At 45°C, a plot of ln $[N_2O_5]$ *versus* t gives a slope of $-0.037\ h^{-1}$. If you start with 0.188 g of N_2O_5 in a reaction vessel, **how much time (in hours)** does it take until only 0.0363 g of N_2O_5 remains?

(A) 44 h

(B) 36 h

(C) 14 h

(D) 2.7 h

(E) 0.023 h

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10. At 25°C the reaction between H_3O^+ and HCO_3^- proceeds rapidly with a half-life of 5.0 seconds. In the presence of the enzyme carbonic anhydrase the half-life is only 700 nanoseconds. Calculate the **difference in activation energies (in kJ mol^{-1})** between the enzymatic and non-enzymatic reactions [a nanosecond = 10^{-9} second].

$$H_3O^+ + HCO_3^- \rightarrow CO_2 + 2\ H_2O$$

(A) 3.3

(B) 16

(C) 17

(D) 39

(E) 50

11. Select the **TRUE** statements regarding the following reaction:

$$5\ Br^-(aq) + BrO_3^-(aq) + 6H^+(aq) \rightarrow 3\ Br_2(l) + 3\ H_2O(l)$$

(i) If Br^- disappears at a rate of 0.066 M s^{-1}, then Br_2 appears at a rate of 0.040 M s^{-1}.

(ii) If Br_2 appears at a rate of 0.074 M s^{-1}, then H^+ disappears at a rate of 0.037 M s^{-1}.

(iii) The reaction rate can be expressed as: Rate = + 1/3 $\Delta[Br_2] / \Delta t$.

(iv) From the information given, the rate law for the overall reaction can be written as:

$$\text{Rate} = k\ [Br^-][BrO_3^-][H^+]^6.$$

(A) i, iii

(B) i, iv

(C) ii, iii

(D) ii, iv

(E) iii, iv

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12. For the reaction X + Y $\rightarrow$ Z, the following data were obtained:

Expt.#	[X]	[Y]	$-\Delta[X] / \Delta t$, $M^{-1} s^{-1}$
1	0.200	0.300	0.127
2	0.400	0.600	1.02
3	0.200	0.600	0.254
4	0.400	0.300	0.509

Find the **rate of reaction when [X] = 0.30 M and [Y] = 0.40 M**.

(A) 0.15 $M^{-1} s^{-1}$

(B) 0.38 $M^{-1} s^{-1}$

(C) 0.51 $M^{-1} s^{-1}$

(D) 1.3 $M^{-1} s^{-1}$

(E) 11 $M^{-1} s^{-1}$

13. At the same concentrations, the reaction $CO(g) + Cl_2(g) \rightarrow COCl_2(g)$ is 1.50×10^3 times faster at 250ºC than at 150ºC. **Calculate Ea**, assuming the frequency factor is constant.

(A) 135 kJ mol^{-1}

(B) 22.8 kJ mol^{-1}

(C) 1.33 kJ mol^{-1}

(D) 1330 kJ mol^{-1}

(E) 67.5 kJ mol^{-1}

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14. The rate constant for the first-order decomposition of dimethyl ether

$$(CH_3)_2O(g) \rightarrow CH_4(g) + H_2(g) + CO(g)$$

is 3.20×10^{-4} s^{-1} at 450°C. The reaction is carried out in a constant-volume flask, starting with 0.350 atm of dimethyl ether. What is the **pressure in the flask (in atm)** after 8.00 minutes? (Assume ideal gas behaviour).

(A) 0.450 atm

(B) 0.352 atm

(C) 0.300 atm

(D) 0.245 atm

(E) 0.125 atm

15. Identify the **CORRECT** statements below:

(i) For a reaction carried out in presence of a heterogeneous catalyst, the reaction rate depends on the surface area of the catalyst.

(ii) Addition of a catalyst will not change the mechanism of a reaction.

(iii) Catalysts lower both the activation energy and the reaction enthalpy of a reaction.

(iv) Catalysts can often be isolated at the end of the reaction, and recycled.

(v) Addition of a catalyst will lower the activation energies of forward and reverse reactions by the same amount.

(A) i, iv, v

(B) iv, v

(C) ii, iv, v

(D) i, iii, v

(E) i, iii, iv

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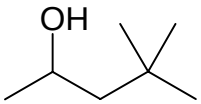
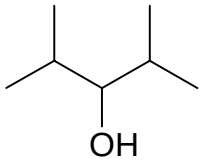
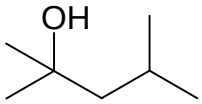
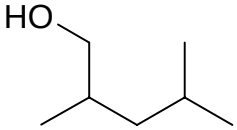
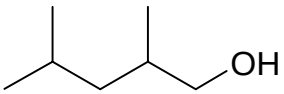
16. **Select the correct structure of the organic product** that results when 2,4-dimethylpent-2-ene is warmed with dilute H_2SO_4.

(A) 

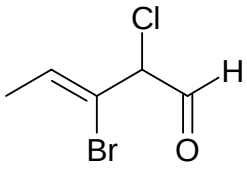
(B) 

(C) 

(D) 

(E) 

17. Use IUPAC rules to **name the following molecule**:



(A) *E*-3-bromo-2-chloropent-3-enal

(B) *Z*-3-bromo-2-chloropent-3-enal

(C) *E*-4-bromo-3-chlorohex-3-enal

(D) *Z*-4-bromo-3-chlorohex-3-enal

(E) *E*-4-bromo-3-chloropent-4-enone

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18. Select the **TRUE** statements about bonding:

(i) Pi (π) bonds are formed from end-to-end overlap of p orbitals.

(ii) Sigma (σ) bonds have higher bond energies than pi (π) bonds.

(iii) The C=O bond in propanone is shorter than the C-O bond in propanol.

(iv) The C=O bond in propanone is stronger than the C-O bond in propanol.

(v) The C≡C bond in ethyne is formed from 2 σ and 1 π bonds.

(A) i, iv, v

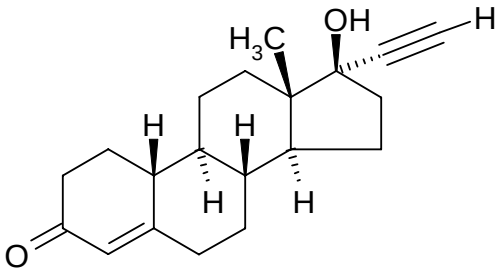
(B) i, iii, v

(C) ii, iii

(D) ii, iv

(E) ii, iii, iv

19. Norethindrone (shown below) is a synthetic progestin used as a contraceptive. Which of the following statements about this molecule are **TRUE**?



(i) Norethindrone contains a tertiary alcohol group.

(ii) There are exactly 3 sp^2 hybridized atoms in norethindrone.

(iii) Norethindrone contains at least one quaternary carbon atom.

(iv) Norethindrone has eight degrees of unsaturation.

(A) i, ii

(B) i, iii

(C) i, iii, iv

(D) ii, iv

(E) ii, iii, iv

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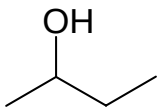
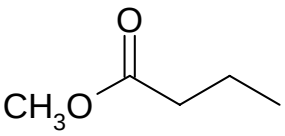
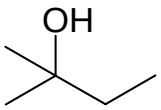
20. A student working in the lab was given an unknown compound and asked to identify it. The student performed chemical tests and made the following observations:

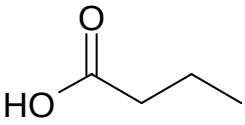
- The unknown reacted with sodium metal to produce a gas.
- When $KMnO_4(aq)$ was added to the unknown, the purple colour of $KMnO_4$ gradually disappeared.
- The unknown produced no visible reaction with a solution of $NaHCO_3(aq)$.
- The unknown produced no visible reaction with a solution of $Ag(NH_3)_2^+(aq)$.

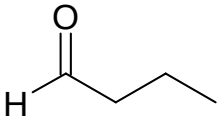
Based on the student's observations, **which one of the following structures** could be the unknown compound?

(A) 

(B) 

(C) 

(D) 

(E) 

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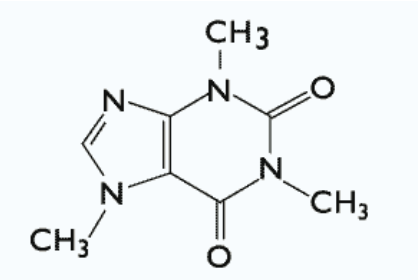
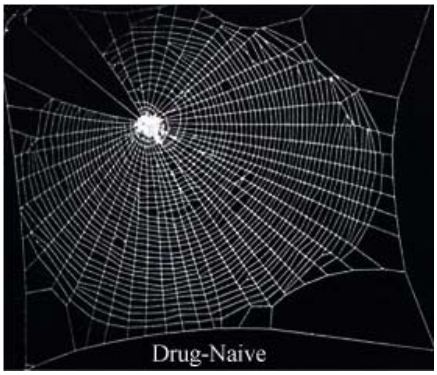
21. Caffeine, shown below, affects how spiders construct their webs (see Figures below). Indicate the correct **number of sp^2 and sp^3 hybridized carbon atoms, and of π (pi) bonds** in caffeine.





(Source: Wikipedia)

	sp^2 carbons	**sp^3 carbons**	**π (pi) bonds**
(A)	5	6	4
(B)	6	3	4
(C)	5	3	4
(D)	8	6	8
(E)	6	12	8

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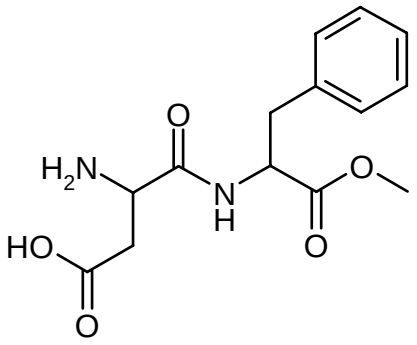
22. Aspartame, an artificial sweetener, is a synthetic dipeptide. Its formal structure is shown below. Indicate the **CORRECT functional groups** found in its structure.



(A) amide, primary amine, carboxylic acid, ether, ketone

(B) primary amine, amide, carboxylic acid, ester

(C) secondary amine, carboxylic acid, ester, ketone

(D) amide, carboxylic acid, ester, ether

(E) primary amine, amide, carboxylic acid, ether

23. Indicate the **FALSE statement** about organic chemistry lab procedures.

(A) Bunsen burners are not used in organic chemistry labs because organic substances are very often flammable.

(B) Recrystallizations are usually carried out by dissolving the substance in a minimum volume of a suitable solvent near the boiling point of the solvent.

(C) Hot solutions should not be filtered by suction filtration.

(D) Higher rates of heating usually lead to more accurate melting point determinations.

(E) Fluted filter paper results in faster filtrations, because of the larger surface area of the filter paper.

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24. In an organic chemistry experiment $KMnO_4(aq)$ and $H_2SO_4(aq)$ were mixed with different alcohols. Indicate the **TRUE statements** about this process.

(i) The colour change of $KMnO_4$ proves that a redox reaction took place.
(ii) Tertiary alcohols are not oxidized by $KMnO_4$.
(iii) Dilute sulfuric acid acts as an oxidizing agent in these reactions.
(iv) Ethanol is a good oxidizing agent.
(v) Secondary alcohols can be oxidized to carboxylic acids.

(A) i, ii, v
(B) i, iii
(C) ii, iii, iv
(D) ii, iii, v
(E) i, ii

25. Choose the **FALSE** statement about propyllithium ($CH_3CH_2CH_2Li$). Propyllithium

(i) is soluble in diethyl ether.
(ii) reacts as though it is polarized $CH_3CH_2CH_2^{\delta-}Li^{\delta+}$.
(iii) can be prepared by reacting Li metal with 1-bromopropane.
(iv) reacts with water to produce 1-propanol.

(A) i
(B) ii
(C) iii
(D) iv
(E) All statements are true.

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26. Select the **TRUE** statements regarding some properties of organic compounds:

(i) The boiling points of CH_3-O-CH_3 (molecular mass = 46 g mol^{-1}) and $CH_3CH_2CH_3$ (molecular mass = 44 g mol^{-1}) are almost identical.

(ii) At 25ºC the vapour pressure of CH_3-O-CH_3 is greater than that of its isomer, CH_3CH_2-OH.

(iii) The acidity of CH_3-O-CH_3 is greater than that of its isomer, CH_3CH_2-OH.

(iv) The dipole moments of $CH_3CH_2CH_3$ and CH_3-O-CH_3 are almost identical.

(v) The dipole moment of CH_3-O-CH_3 is much smaller than the dipole moment of CH_3CH_2-OH.

(A) i, iv

(B) ii, v

(C) i, iii, iv

(D) i, ii, v

(E) ii, iii, v

question 27 removed

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28. Which of the following statements about the reaction that occurs when 2-propanol is heated with concentrated H_2SO_4 is / are **FALSE**?

    (i) The reaction mechanism involves a carbocation intermediate.

    (ii) The reaction product is 2-propene.

    (iii) The overall reaction is a reversible reaction.

(A) i
(B) ii
(C) iii
(D) i, ii
(E) none is false

question 29 removed

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Questions 30 through 40 are worth three (3) marks each.

30. Equal volumes of 0.200 M NH_3 and 0.200 M $CoCl_2$ were combined to establish the unbalanced reaction shown below. If the pH of the resulting solution was 10.60, **calculate the equilibrium constant** for the formation of this cobalt-ammonia complex. Assume that the cobalt-ammonia complex does not participate in aqueous acid-base reactions. $K_b(NH_3) = 1.8 \times 10^{-5}$

$$NH_3 + Co(H_2O)_6^{2+} \rightleftharpoons Co(NH_3)_5(H_2O)^{2+} + H_2O$$

(A) 2.5×10^{1}

(B) 8.0×10^{3}

(C) 4.2×10^{10}

(D) 2.0×10^{11}

(E) 3.4×10^{9}

31. During a titration a student added 200. mL of NaOH(aq) solution to 400. mL of 2.00 M HNO_2(aq). The measured pH of the mixture was 1.50 units greater than that of the original acid solution. **Calculate the molarity (M) of the NaOH(aq)** solution. (K_a $HNO_2 = 4.50 \times 10^{-4}$).

(A) 3.99 M

(B) 1.28 M

(C) 0.798 M

(D) 0.257 M

(E) 0.0518 M

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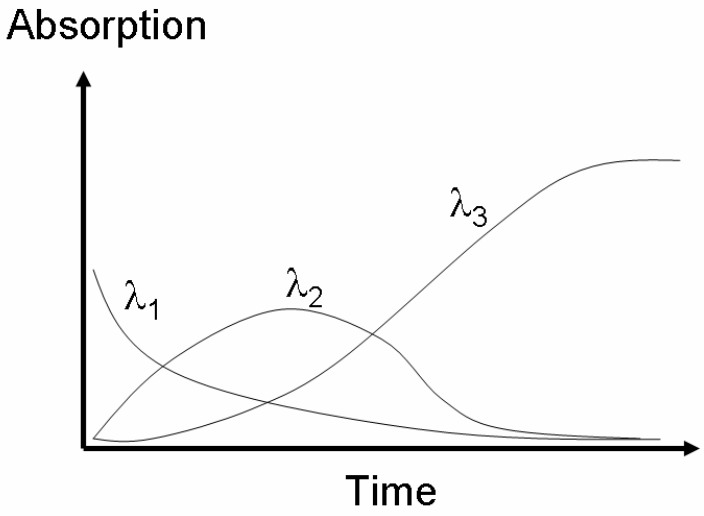
32. The progress of the conversion of starting material **A** to product **C** was followed by monitoring the change of absorption of light at three different wavelengths (λ_1, λ_2, λ_3). Indicate which of the following mechanisms are **in agreement** with these experimental data.



(i) A → B
B → C

(ii) A → B + C

(iii) A → B
A → C

(iv) A → B
2B → 2C

(v) A → C

(A) i, iv
(B) i, ii
(C) iii, v
(D) ii, iv
(E) iii, v

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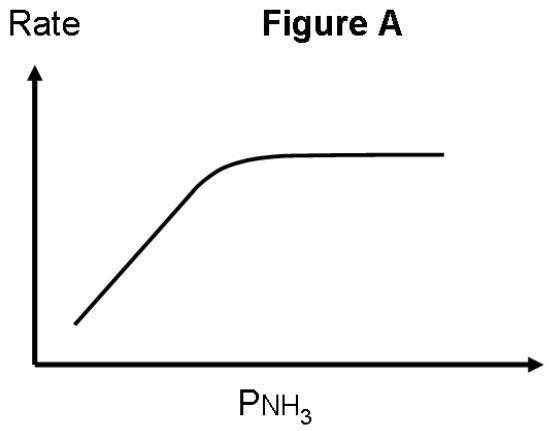
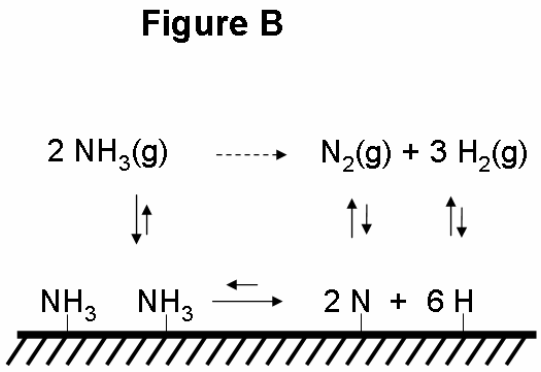
33. The graph in Figure A below shows how the rate of the tungsten-catalyzed decomposition of ammonia to nitrogen and hydrogen depends on the partial pressure of ammonia. This process is illustrated in Figure B. Indicate the **CORRECT statement(s)** below:





(i) The observed rate is second order with regard to ammonia.

(ii) The initial linear increase of rate with partial pressure of ammonia reflects equilibrium binding of ammonia to the catalyst surface.

(iii) At higher partial pressures of ammonia the rate levels off because of saturation of the catalyst surface.

(A) i

(B) i, ii

(C) ii, iii

(D) ii

(E) iii

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34. There exist a large number of isomers of C_5H_8. Indicate the **CORRECT number of structural isomers** of C_5H_8 that contain a **four-membered ring**:

(A) 3

(B) 4

(C) 5

(D) 6

(E) 2

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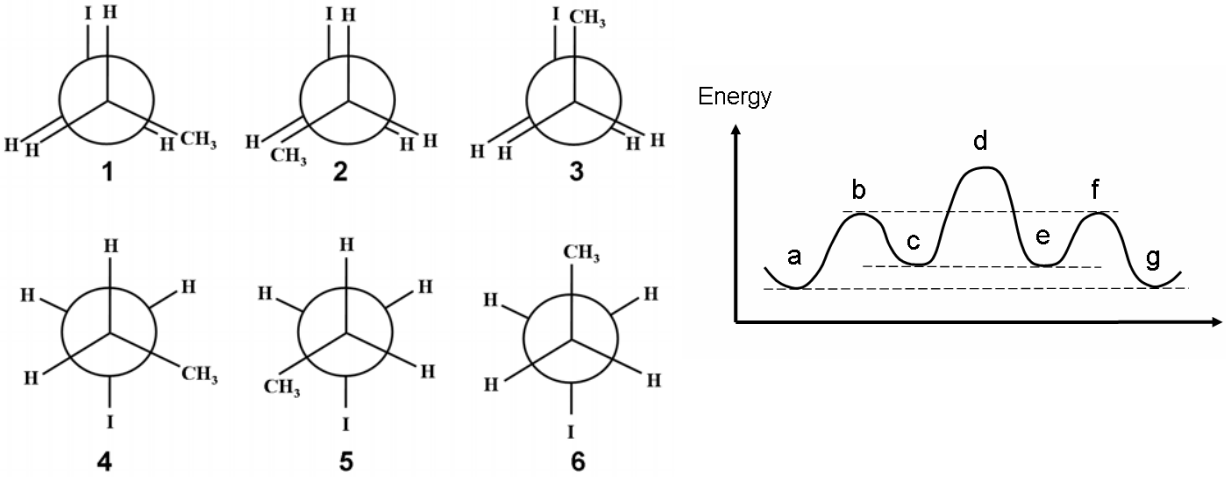
35. The scheme below shows the Newman projections for six conformations of 1-iodo-propane, as well as a rotational energy diagram.



Indicate **which positions on the rotational energy diagram match the Newman projections**:

Newman Projection:	**1**	**2**	**3**	**4**	**5**	**6**
(A)	c/e	c/e	d	a/g	a/g	b/f
(B)	a/g	a/g	c/e	b/f	b/f	d
(C)	b	f	a/g	c	e	d
(D)	c/e	c/e	d	b/f	b/f	a/g
(E)	b/f	b/f	d	c/e	c/e	a/g

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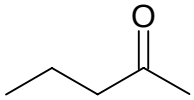
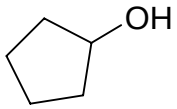
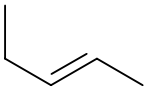
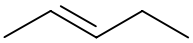
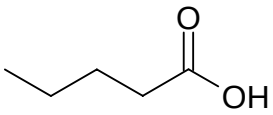
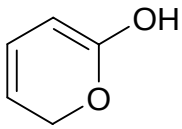
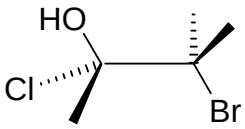
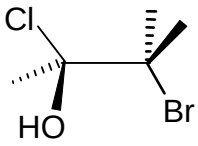
36. Indicate the **CORRECT** statements identifying the relationship between the following pairs of molecules:

(i)  and  are structural isomers

(ii)  and  are geometrical isomers

(iii)  and  are structural isomers

(iv)  and  are different conformations of the same molecule

The **CORRECT** statements are:

(A) i, iv

(B) i, ii

(C) ii, iv

(D) ii, iii

(E) i, iii

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37. Indicate the **TRUE statements** below:

(i) The reaction of nucleophiles with primary alkyl halides proceeds predominantly by the S_N2 mechanism.

(ii) Substitutions on tertiary alkyl halides are best carried out in polar solvents, as these solvents promote the reaction by solvating the forming ions.

(iii) Addition of silver nitrate to a solution of an alkyl halide changes the mechanism of nucleophilic substitution reactions from S_N1 to S_N2.

(iv) Secondary alkyl halides react preferentially by the S_N1 mechanism at low temperatures.

(v) Alkyl lithium compounds react efficiently with many carbonyl compounds.

(A) i, ii

(B) i, ii, v

(C) ii, v

(D) iii, iv

(E) i, iii, iv

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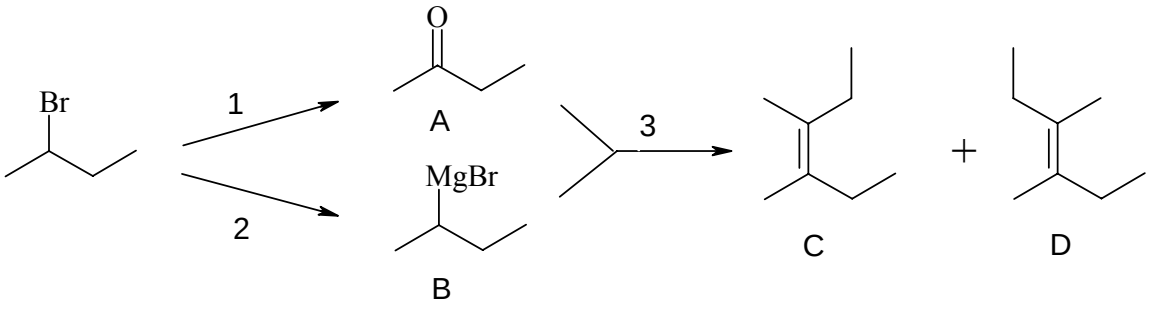
The following list of chemical reagents and reaction conditions is to be used to answer the following 3 questions.

Reagents and Reaction Conditions: all reactions conducted at 25°C except where noted

a. Br_2, CH_2Cl_2	**b**. Cl_2, CH_2Cl_2	**c**. Br_2, CH_2Cl_2, hν
d. NaOH (dilute)	**e**. NaOH (conc.), heat	**f**. Na
g. HCl (dilute)	**h**. HCl (conc.)	**i**. H_2SO_4 (conc.), heat
j. PCC, CH_2Cl_2	**k**. acidic $K_2Cr_2O_7$ (aq)	**l**. CH_3MgBr, ether
m. CH_3Br	**n**. CH_3CH_2OH	**o**. NH_2NH_2, CH_3CH_2OH, heat
p. Mg, ether	**q**. 2-propanone	**r**. H_2, Pt

38. From the list above **select the reagents and conditions** needed to effect the following sequence of chemical transformations. The two reaction products A and B are reacted with each other in step 3 to afford C and D.



	Reagents 1	Reagent 2	Reagent 3
(A)	**e**, then **k**	**p**	combine products then **g**
(B)	**d**, then **k**	**p**	combine products then **i**
(C)	**d**, then **j**	**p**	combine products then **g**
(D)	**e,** then **j**	**l**	combine products then **i**
(E)	**d**, then **k**	**l**	combine products then **g**

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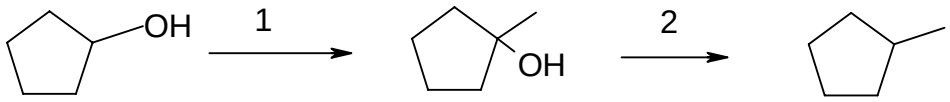
39. From the list above **select the reagents and conditions** needed to effect the following sequence of chemical transformations:



	Reagents 1	**Reagents 2**
(A)	**j** then **p** then **l**	**e** then **g**
(B)	**e** then **l** then **g**	**k** then **d**
(C)	**k** then **l** then **g**	**i** then **r**
(D)	**l** then **g**	**i** then **r**
(E)	**m** then **d**	**c** then **e**

40. The conversion of 2-propanol into 2,3-dimethyl-2-butanol can be accomplished by **ONE** of the following sequences of reactions:

(A) **c** then **q** then **e**

(B) **k** then **l** then **g**

(C) **h** then **q** then **g**

(D) **h** then **p** then **q** then **g**

(E) **i** then **c** then **q** then **g**

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Data page

Some general data are provided on this page. Other data appear with the questions.

$R = 8.314\ J\ K^{-1}\ mol^{-1} = 0.08206\ L\ atm\ K^{-1}\ mol^{-1}$ $N_A = 6.022 \times 10^{23}\ mol^{-1}$

1 atm = 760 mm Hg = 101.325 kPa $0°C = 273.15\ K$

$K_w = 1.0 \times 10^{-14}$

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