Name: _____ Student number: _____

**Chemistry 1AA3** **Final Exam** **April 20, 2007**

**McMaster University** **VERSION 1**

Instructors: H. Jenkins, B. McCarry, H. Stöver

Duration: 3 hours

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This test contains 30 numbered pages printed on both sides. There are **34** multiple-choice questions appearing on pages numbered 3 to 15. Page 26 includes some useful data. There is a periodic table on page 30. Pages 27 - 29 may be used for rough work. You may tear off the last pages to view the periodic table and to do your rough work.

**You must enter your name and student number on the question sheets, as well as on the answer sheet**. Your invigilator will be checking your student card for identification.

**You are responsible** for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1 to 24 are each worth 2 marks; questions 25 – 34 are each worth 3 marks. The total marks available are 78. There is **no** additional penalty for incorrect answers.

**BE SURE TO ENTER THE CORRECT VERSION NUMBER OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.**

**ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.**
Instructions for entering multiple-choice answers are given on page 2.

**SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION** from the answers **(A)** through **(E). No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc*.) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem, please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of periodic tables or any aids, other than those provided, is not allowed.

Name: _____ Student number: _____

**You are writing VERSION 1 of this test. Make sure you have correctly entered your version number ("1") in the correct column on your scan sheet (see p. 2 for details).**

**Questions 1 through 24 are worth two (2) marks each.**

1. Indicate the **correct** statements below:

   The activation energy for a chemical reaction is:

   i. the minimum amount of kinetic energy required for each molecule in a collision to produce a reaction.
   ii. the minimum total kinetic energy required for the molecules in a collision to produce a reaction.
   iii. a factor used in determining the rate of a reaction.
   iv. large in value for fast reactions.
   v. large in value for endothermic processes.

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

2. The rate of decay of a sample of a particular radioactive nuclide is 6740 disintegrations/hr and the half-life of this nuclide is 5.2 years. Given that radionuclides decay by first-order processes, calculate the **number of atoms in the sample**.

**(A)** $4.43 \times 10^{8}$ atoms
**(B)** $1.96 \times 10^{17}$ atoms
**(C)** $5.07 \times 10^{4}$ atoms
**(D)** $2.67 \times 10^{24}$ atoms
**(E)** $8.86 \times 10^{8}$ atoms

3. Determine the **correct rate law** for the hypothetical reaction shown below, using the initial reaction rates listed in the table:

A + B + C → D + E

| Exp. # | [A] | [B] | [C] | Initial Rate |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 0.103 |
| 2 | 1 | 2 | 1 | 0.051 |
| 3 | 2 | 1 | 1 | 0.207 |
| 4 | 1 | 2 | 2 | 0.203 |

**(A)** Rate = k $[A][C]^2$

**(B)** Rate = k $[A][B]^2[C]$

**(C)** Rate = k $[A][B][C]^2$

**(D)** Rate = k $[A][B]^{-1}[C]^2$

**(E)** Rate = k $[A][C]^4$

4. For the following equilibrium reaction,

$$2\ MgCl_2\ (s) + O_2\ (g) \rightleftharpoons 2\ MgO\ (s) + 2\ Cl_2\ (g)$$

$K_c = 0.0500$ at 500 K and $\Delta H = 39.6$ kJ/mol

For the reaction shown below:

$$MgO\ (s) + Cl_2\ (g) \rightleftharpoons MgCl_2\ (s) + 1/2\ O_2\ (g)$$

**Calculate $K_c$** for the reaction at 500 K and **indicate** whether this value for $K_c$ will increase or decrease if the reaction is carried out at a temperature lower than 500 K.

**(A)** 4.47; increase

**(B)** 4.47; decrease

**(C)** 0.224; increase

**(D)** 0.224; decrease

**(E)** -0.100; increase

5. A solid monoprotic acid (0.375 g, MW= 245 g/mol) was dissolved in 25.0 mL water to give a solution with pH = 3.28. What is the **ionization constan**t of the acid?

**(A)** $5.25 \times 10^{-4}$

**(B)** $4.54 \times 10^{-6}$

**(C)** $7.42 \times 10^{-5}$

**(D)** $4.50 \times 10^{-3}$

**(E)** $2.30 \times 10^{-2}$

6. A saturated aqueous solution of calcium hydroxide is 0.13% calcium hydroxide by mass and has a density of 1.02 g/mL. What is the **pH** of this solution?

**(A)** 11.95

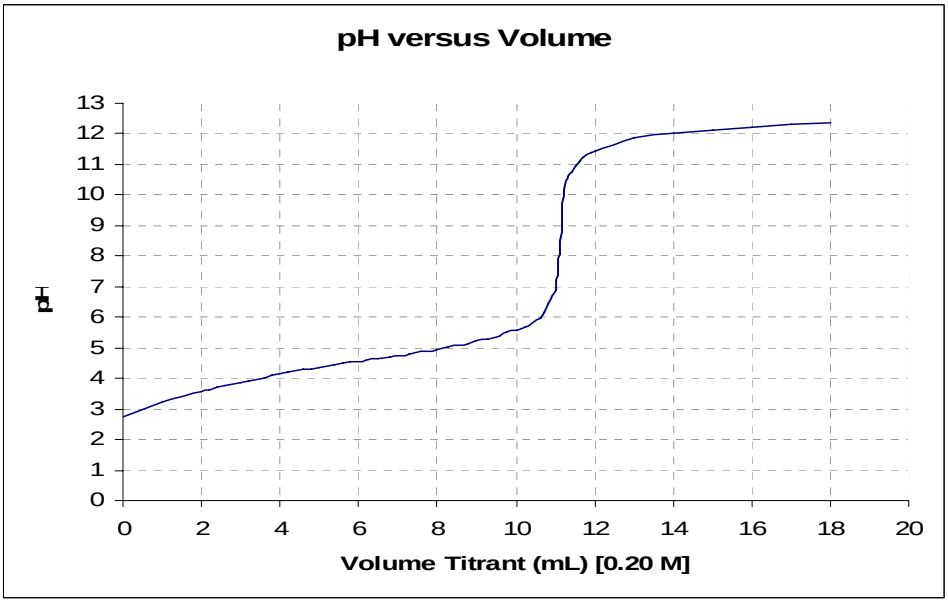
**(B)** 12.25

**(C)** 12.55

**(D)** 12.75

**(E)** 13.00

7. Indicate the **correct** statements regarding the following plot of pH versus volume of titrant added for a monoprotic acid-base titration. (titrant: solution being used to titrate; titrand: solution being titrated).




i. The graph describes the titration of a strong acid with a strong base (titrant).

ii. The graph describes the titration of a weak acid with a strong base (titrant).

iii. The graph describes the titration of a weak base with a strong acid (titrant)

iv. The initial concentration of a 15 mL sample of titrand is ~ 0.20 M

v. The initial concentration of a 15 mL sample of titrand is ~ 0.15 M

**(A)** ii and iv

**(B)** i and iv

**(C)** iii and v

**(D)** ii and v

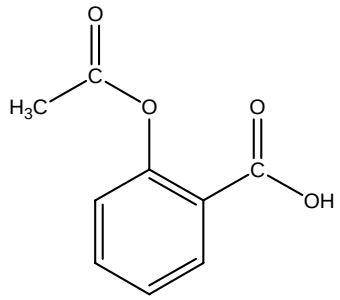
**(E)** iii and iv

8. Identify which of the following combination(s) of an acid and a base will form a **buffer solution** (all solutions are aqueous and 1.0 M):

   i. 10 mL HCl and 5 mL NaOH
   ii. 10 mL acetic acid and 20 mL NaOH
   iii. 10 mL $NH_4Cl$ and 10 mL $NH_3$
   iv. 10 mL acetic acid and 5 mL NaOH
   v. 10 mL HCl and 20 mL $NH_3$

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

9. A tablet of Aspirin contains 500 mg ASA (acetylsalicylic acid, shown below, $K_a$ = 3.24 x $10^{-4}$). What is the **pH** of an aqueous 500. mL solution with two Aspirin tablets dissolved in it?




**(A)** 2.76
**(B)** 2.72
**(C)** 1.72
**(D)** 2.68
**(E)** 2.50

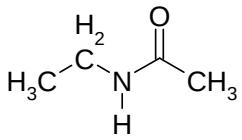
10. Indicate the **correct** statement(s) regarding the reaction shown below:

$CH_3COOH + NaOH \rightarrow CH_3COO^-Na^+ + H_2O$

i. In both acetic acid and in the acetate anion, the carbonyl C is $sp^2$ hybridized.
ii. Addition of excess NaOH will make an effective buffer solution.
iii. This reaction can be reversed by the addition of $HNO_3$ (aq).
iv. Rotation about the C-C bond is severely restricted.
v. Both of the C—O bonds in the acetate anion are the same length.

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

11. Indicate the **incorrect** statement(s) about the molecule below:




i. The molecule above is an amine.
ii. The molecule can be prepared by heating ethylammonium acetate.
iii. The reaction of the molecule with $LiAlH_4$ would yield a secondary amine.
iv. The molecule above is shown as one of two principal resonance contributors.

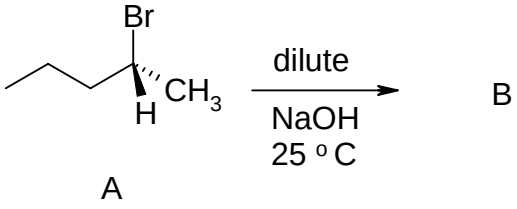
**(A)** i
**(B)** ii
**(C)** iii
**(D)** iv
**(E)** i, iv

12. The reaction of cyclopentanone with sodium borohydride was followed by the addition of dilute HCl, from which an organic reaction product A was isolated. Indicate the correct statements about this product:

i. Product A is cyclopentanol.
ii. Product A is cyclopentene.
iii. Sodium borohydride behaves as a source of $H_2$ (g).
iv. Product A has one less degree of unsaturation than cyclopentanone.
v. Sodium borohydride is an oxidizing agent.

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

13. Indicate the **correct** IUPAC name for the product, **B**, of the reaction of **A** with dilute NaOH at 25°C:




**(A)** (R)-2-pentanol
**(B)** 2-pentanol
**(C)** (S)-2-pentanol
**(D)** *Z*-2-pentene
**(E)** *E*-2-pentene

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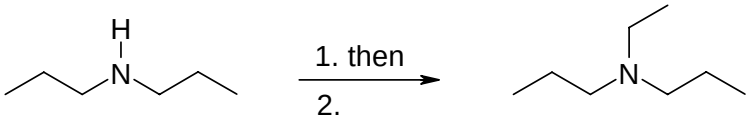
14. Indicate which of the following reaction sequences (reaction 1 followed by reaction 2) **can accomplish** the conversion shown below:




**(A)** 1. $CH_3CH_2Br$ 2. dilute $H_3O^+$

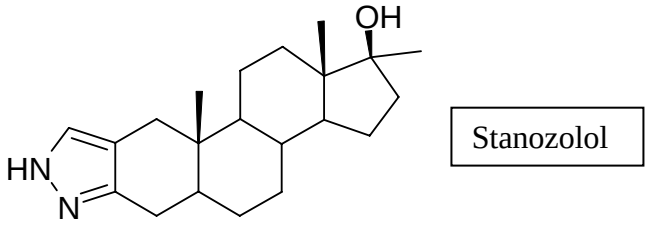
**(B)** 1. $CH_3CH_2Br$ 2. dilute NaOH

**(C)** 1. $CH_3CH_2OH$, heat 2. dilute NaOH

**(D)** 1. $CH_3CH_2OCH_2CH_3$ 2. dilute $H_3O^+$

**(E)** 1. $CH_3COOH$, heat 2. $LiAlH_4$ in ether then dilute $H_3O^+$

15. Stanozolol is a banned anabolic steroid that has at times been used by amateur and professional athletes. Famous abusers include the Canadian sprinter Ben Johnson and the baseball player Barry Bonds. Indicate the **correct** statements regarding this compound:




Stanozolol

The stanozolol structure contains:

i. six degrees on unsaturation

ii. a tertiary alcohol function

iii. four $sp^2$-hybridized carbon atoms

iv. a heterocyclic ring

**(A)** i, ii

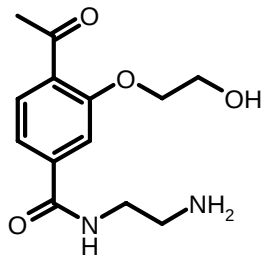
**(B)** i, iii

**(C)** ii, iii

**(D)** ii, iv

**(E)** iii, iv

16. Identify the functional groups present in the following molecule.




**(A)** alcohol, amide, amine, ether, ketone

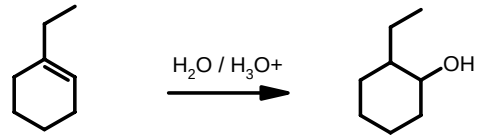
**(B)** alcohol, aldehyde, amide, amine, ether

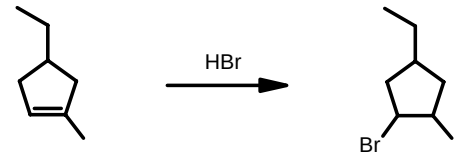
**(C)** alcohol, amide, amine, ester, ketone

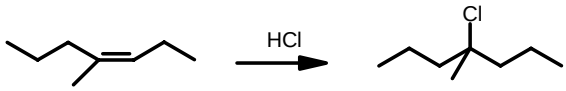
**(D)** alcohol, amine, ether, ketone, nitrile

**(E)** aldehyde, amide, amine, ester, ketone

17. Indicate which of the schemes below give(s) addition product(s) formed according to Markovnikov's rule:

i. 


ii. 


iii. 


**(A)** i

**(B)** i, ii

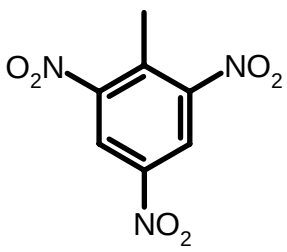
**(C)** ii

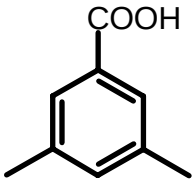
**(D)** ii, iii

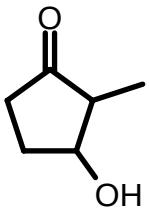
**(E)** iii

Name: _____ Student number: _____

18. Indicate the correct names for the following compounds.




**(A)** 3,5-dimethyl benzoic acid; 2,4,6-trinitrotoluene; 3-hydroxy-2-methyl-cyclopentanone

**(B)** 3-hydroxy-2-methyl-cyclopentanone; 3,5-dimethyl benzoic acid; 1,3,5-trinitrotoluene

**(C)** 2,4-dimethyl benzoic acid; 2,4,6-trinitrotoluene; 3-hydroxy-2-methyl-cyclopentanone

**(D)** 3,5-dimethyl-benzoic acid; 2,4,6-trinitrotoluene; 2-hydroxy-1-methyl-cyclopentanone

**(E)** *meta*-xylene-benzoic acid; 3-hydroxy-2-methyl-cyclopentanone; 2,4,6-trinitrotoluene

19. Indicate the correct number of structural isomers of $C_4H_8O_3$ that contain both a carboxylic acid and an alcohol.

**(A)** 3

**(B)** 4

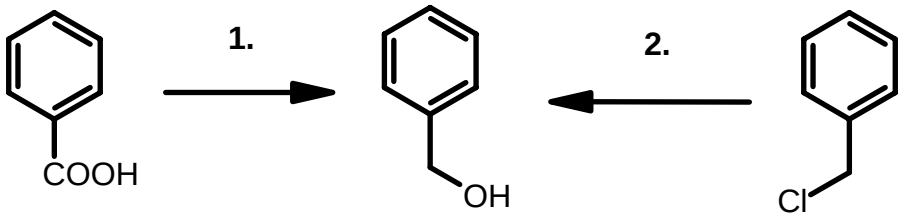
**(C)** 5

**(D)** 6

**(E)** 7

Name: _____ Student number: _____

20. Indicate the **correct** types of reaction for the two reactions in the scheme below:




| | Reaction 1. | Reaction 2. |
|---|---|---|
| **(A)** | elimination | reduction |
| **(B)** | nucleophilic substitution | aromatic substitution |
| **(C)** | aromatic substitution | nucleophilic substitution |
| **(D)** | addition | elimination |
| **(E)** | reduction | nucleophilic substitution |

21. Indicate any **incorrect** statement below:

i. $S_N1$ reactions produce equal amounts of (R) and (S) products from reactions with chiral alkyl halides.

ii. Tertiary alkyl halides react preferentially by the $S_N1$ mechanism.

iii. A tertiary alcohol cannot be oxidized to a ketone.

iv. A ketone can be reacted with methyl lithium (and subsequently treated with dilute acid) to form a tertiary alcohol.

**(A)** All statements are correct

**(B)** ii

**(C)** i

**(D)** iv

**(E)** iii

22. Indicate the **correct** statements concerning polymers, below:

i. Nylon 6.6 is a polyamide that can be prepared by a step-growth (condensation) polymerization of a diamine and a diacid.
ii. A radical initiator, typically a peroxide, is commonly added to facilitate the formation of polyamides.
iii. Polyamides like Nylon 6.6 produce alkaline solutions when dissolved in water.
iv. Polyethylene is a waxy material that is nonpolar compared with polyamides.

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

23. Legend has it that following contact with a werewolf, elemental silver will return the subject to human form. You suspect the course instructors have been bitten and consequently turned into werewolves. Suggest the mixture you would prepare that would be best suited to returning the instructors to their human form.

**(A)** $Ag(NH_3)_2^+$ / $H_2O$
**(B)** $Ag(NH_3)_2^+$ / $CH_3COOH$ / $H_2O$
**(C)** $Ag(NH_3)_2^+$ / $C_6H_5CHO$ / $H_2O$
**(D)** $Ag(NH_3)_2^+$ / $CH_3COCH_3$ / $H_2O$
**(E)** $Ag(NH_3)_2^+$ / $C_6H_5NO_2$ / $H_2O$

24. In attempting to recrystallize 4-ethoxyacetanilide (phenacetin) from water in experiment # 9, you realize that, after cooling in an ice bath for a few minutes, no product has crystallized. Indicate the reasonable approaches to obtain crystals of your product:

i. Add more crude phenacetin to the re-heated solution, filter and cool again.
ii Reduce the volume of the solution and proceed to cool again.
iii. Add some cold water to the solution and keep in the ice bath.
iv. Place the solution in a freezer (-15ºC).
v. Gently scratch the bottom of your vessel with a glass rod.

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

Name: _____ Student number: _____

**Questions 25 through 34 are worth three (3) marks each.**

25. For the reaction:

$2\ N_2O_5\ (g) \rightarrow 4\ NO_2\ (g) + O_2\ (g)$

the rate law is

$$\frac{\Delta[O_2]}{\Delta t} = k[N_2O_5]$$

At 300K, the half-life is $2.50 \times 10^4$ seconds and the activation energy is 103.3 kJ/mol. What is the rate constant at 350K?

**(A)** $4.58\ s^{-1}$

**(B)** $2.77 \times 10^{-5}\ s^{-1}$

**(C)** $6.38 \times 10^{-4}\ s^{-1}$

**(D)** $7.47 \times 10^{-8}\ s^{-1}$

**(E)** $1.03 \times 10^{-2}\ s^{-1}$

26. The water-gas shift reaction is used in the steam reforming of hydrocarbons and is a key reaction in automobile catalytic converters. The equilibrium constant $K_p$ for the reaction

$$CO\,(g) + H_2O\,(g) \rightleftharpoons CO_2\,(g) + H_2\,(g)$$

is 0.013 at 830°C. In one experiment 0.200 mol CO and 0.186 mol $H_2O$ were initially present in a 10.0L flask. What is the **equilibrium pressure of $CO_2$ (g)** at 830°C?

**(A)** 0.18 atm

**(B)** 1.7 atm

**(C)** 1.8 atm

**(D)** 0.22 atm

**(E)** $2.0 \times 10^{-3}$ atm

27. For the decomposition of ammonium carbamate at 400 K, $K_c = 2.11 \times 10^3$:

$$NH_4(NH_2CO_2)\ (s) \rightleftharpoons 2\ NH_3\ (g) + CO_2\ (g)$$

At this temperature, a solid sample of ammonium carbamate was placed in an evacuated flask and allowed to equilibrate; at equilibrium there was still some solid $NH_4(NH_2CO_2)$ present. **What is the total pressure in the container at equilibrium?**

**(A)** 0.246 atm

**(B)** 265 atm

**(C)** 0.738 atm

**(D)** 796 atm

**(E)** 25.9 atm

28. How many **moles of HCl (g)** must be added to a 1.0 L solution containing 0.10 mole acetic acid ($K_a = 1.8 \times 10^{-5}$) and 0.30 mole sodium acetate in order to shift the pH of the solution by 1.0 pH units?

**(A)** 0.10

**(B)** 0.087

**(C)** 0.0090

**(D)** 0.21

**(E)** zero

29. In a lab experiment you carefully diluted 3.36 mL HF (density = 0.818 g/mL; $K_a$ = 6.31 x $10^{-4}$) to 100. mL with water. When preparing a 25.0 mL aqueous sodium hydroxide solution, your laboratory partner forgot to record how many grams of NaOH was added. To determine this, you added 10.0 mL of the NaOH solution to 10.0 mL of the HF solution. The pH of this resulting solution was 3.54. How many **grams of NaOH** did your partner add to make their original 25.0 mL solution?

**(A)** 0.376 g

**(B)** 0.943 g

**(C)** 3.00 g

**(D)** 0.485 g

**(E)** 1.25 g

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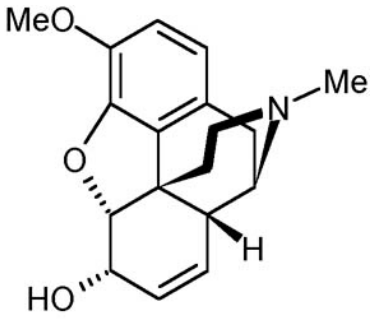
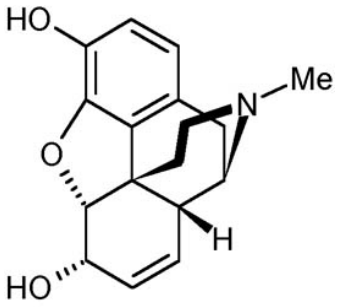
30. Codeine is an opiate found in some over-the-counter painkillers (Coryphen and Tylenol 3, for example). In the body, the enzyme cytochrome $P_{450}$ 2D6 converts codeine into morphine at a conversion rate of approximately 10% per hour. Among Caucasians, approximately 7% of the population do not have this enzyme and hence cannot convert codeine to morphine; adverse side-effects are observed in these individuals. Codeine and morphine (shown below) **both** contain:




codeine




morphine

**(A)** 10 $sp^3$ carbons, 5 chiral carbons, 8 $sp^2$ carbons

**(B)** a tertiary amine, 8 $sp^2$ carbons, 3 $sp^3$ oxygens

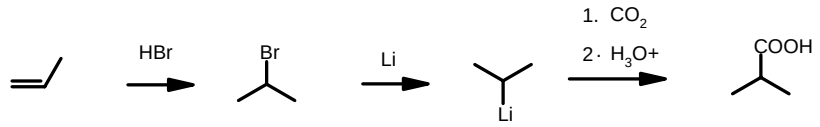
**(C)** 5 chiral carbons, a tertiary amine, 9 $sp^2$ carbons

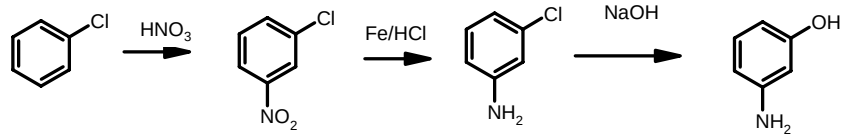
**(D)** 3 *sp* oxygens, 10 $sp^3$ carbons, 1 $sp^3$ nitrogen

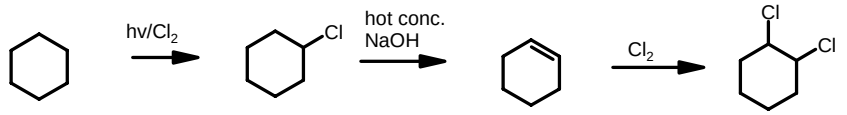
**(E)** 10 $sp^2$ carbons, 1 tertiary amine, 6 chiral carbons

Name: _____ Student number: _____

31. Indicate which of the reaction sequence(s) below is/are **CORRECT**. That is, which reaction sequences will convert the starting compound into the final product?

i. 


ii. 


iii. 


**(A)** i

**(B)** iii

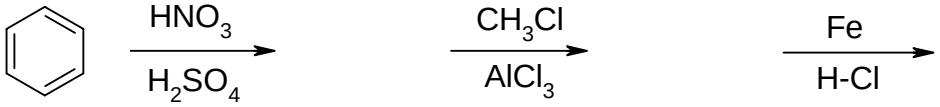
**(C)** ii

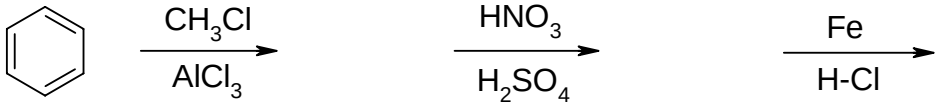
**(D)** ii, iii

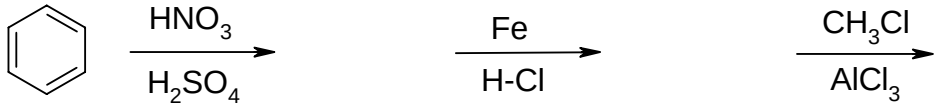
**(E)** i, iii

Name: _____ Student number: _____

32. Identify the reaction sequence(s) below that will lead to the preferential formation of *meta*-aminotoluene (*meta*-methylaniline).

i. 


ii. 


iii. 


**(A)** i

**(B)** ii

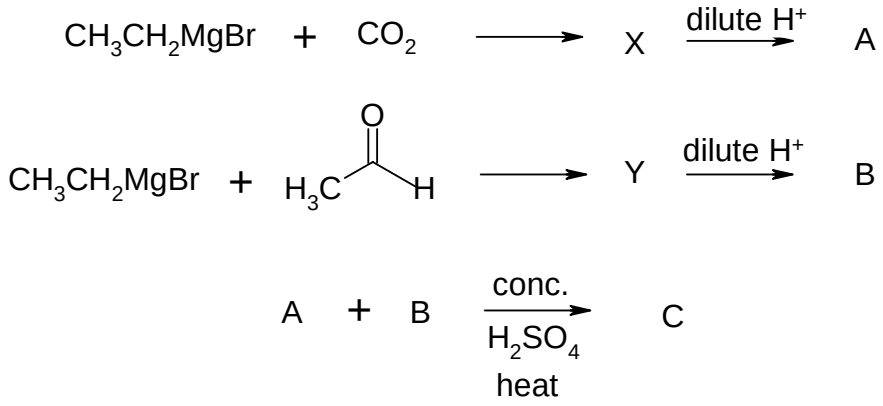
**(C)** iii

**(D)** i, ii

**(E)** ii, iii

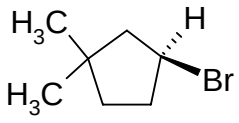
Name: _____ Student number: _____

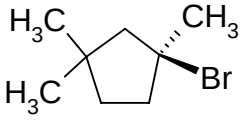
33. Ethylmagnesium bromide was used in two separate reactions to prepare products **A** and **B**, respectively. Products **A** and **B** were isolated, then combined and heated together in the presence of concentrated $H_2SO_4$ to give the organic product(s) **C**. Identify the products **A**, **B** and **C** below.




| | **Product A** | **Product B** | **Product(s) C** |
|---|---|---|---|
| **(A)** | propanal | 2-ethyl-2-butanol | propanal and 3-methyl-2-butene |
| **(B)** | propanoic acid | 2-butanol | (2-butyl) propanoate |
| **(C)** | 1-propanol | 2-butanol | propyl (2-butyl) ether |
| **(D)** | propanoic acid | 2-ethyl-2-butanol | propanoic acid and 3-methyl-2-butene |
| **(E)** | 1-propanol | 2-ethyl-2-butanol | propene and 3-methyl-2-butene |

34. Indicate the **correct** statement(s) about Reactions 1 and 2 below:

Reaction 1  + LiCN (excess) $\xrightarrow[25\ deg\ C]{acetone}$

Reaction 2  + LiCN (excess) $\xrightarrow[25\ deg\ C]{CH_3OH}$

i. The product of Reaction 1 has (R) absolute stereochemistry.

ii. The product of Reaction 2 has (R) absolute stereochemistry.

iii. Reaction 2 proceeds via a carbocation intermediate.

iv. If an equimolar amount of 1-bromopentane were added to Reaction 1, the bromocyclopentane shown and 1-bromopentane would react at the same rate in the presence of a large excess of LiCN.

**(A)** i, iii

**(B)** i, ii, iii

**(C)** iii

**(D)** ii, iv

**(E)** all statements correct

Name: _____ Student number: _____

**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 $0°C = 273.15\ K$

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

**END OF EXAM**