# CM1401* (Practice Questions)

NUS Chemical Sciences Society Editorial Team

Disclaimer: This set of practice questions is designed to complement your personal practice and revision only. It is NOT meant to simulate any part of the actual test/exam.

## Physical Chemistry

1. The absolute potential of a redox reaction can be given as:

$$E_{abs} = E + E_{abs}(H^+/H)$$

where $E_{abs}(H^+/H)$ is the absolute potential of the $H^+/H$ couple and E is the redox potential against the standard hydrogen electrode. The following data are provided:

At 298K,
$\Delta G_{aq}^{o}(H^+) = -1104.5$ kJ mol$^{-1}$
$\Delta G_{f}^{o}(H) = +203.246$ kJ mol$^{-1}$
$\Delta S^{o}(IE, H) = +16.968$ J mol$^{-1}$ K$^{-1}$
$E^{o}(Fe^{2+}/Fe^{3+}) = +0.770$ V

(a) Use the Bohr model to calculate the ionisation energy of H, $\Delta H(IE, H)$, in kJ mol$^{-1}$.

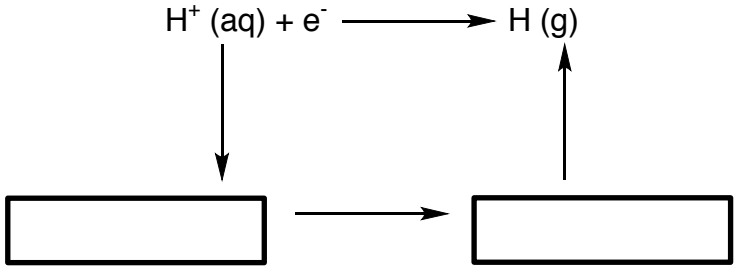
(b) Hence, find $\Delta G(IE, H)$.

(c) By considering the following Hess' Cycle or otherwise, determine ΔG for the reaction:

$$H^+(aq) + e^- \rightarrow H(g)$$

Hence determine the potential for this reaction, $E_{abs}(H^+/H)$.

Hess' Cycle




(d) Use all the information above to calculate the **absolute** potential of a $Fe^{3+}/Fe^{2+}$ cell where $[Fe^{2+}]$ = 2 M, $[Fe^{3+}]$ = 0.5 M. If you are unable to produce a value from part (c), use $E_{abs}(H^+/H)$ = 4.22 V. (Hint: the given cell is NOT at standard conditions!)

(15 marks)

2. $CH_3COCH_3$ reacts with $I_2$ under acidic condition to form $CH_3COCH_2I$. The reaction can be studied by monitoring the concentration of $I_2$ using UV-vis spectroscopy. $I_2$ absorbs radiation at 540 nm.

(a) If the absorption at 540 nm is due to electronic transition between the HOMO and LUMO in $I_2$, what is the energy gap between the two orbitals?

A student, Laurel, was tasked to analyse reaction mixtures **A** to **C**. She failed to label the printout of her results. The results were reported in arbitrary units.

**Table 1 – Solutions that Laurel prepared.**

| Solutions | Volumes (mL) | | | |
|---|---|---|---|---|
| | 1 M HCl | 4 M $CH_3COCH_3$ | 40 μM $I_2$ | DI $H_2O$ |
| **A** | 1 | 1 | 1 | 2 |
| **B** | 1 | 1 | 2 | 1 |
| **C** | 2 | 1 | 1 | 1 |

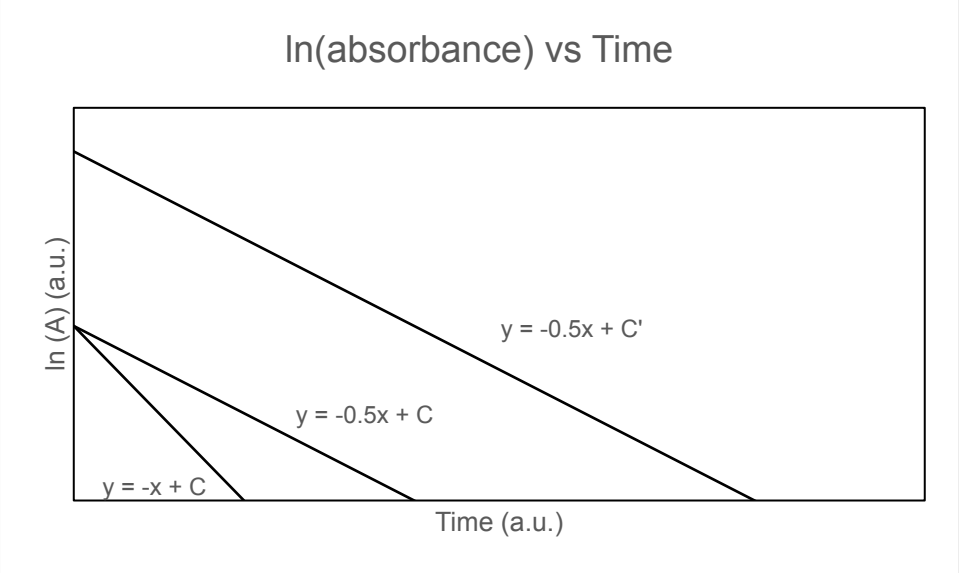


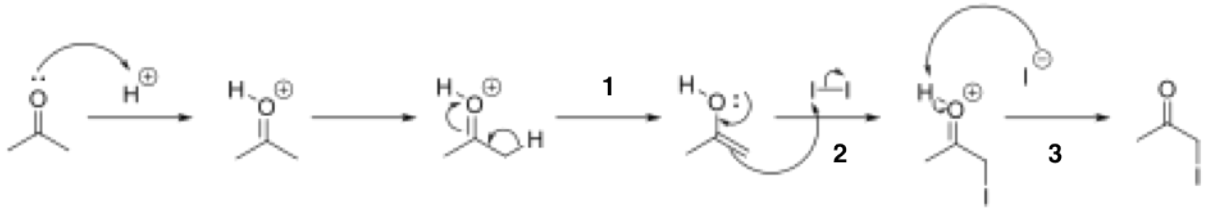

**Figure 1 – Laurel's results printout.**

Each graph corresponds to changes in ln(Absorbance) for a particular solution over time. Label each graph with the solution it represents (**A**, **B** or **C**)

(c) Write down the relationship between C and C' in the equations of the graphs.

(d) What is the order of reaction with respect to $I_2$?

(e) The mechanism for the reaction is shown. Based on your answer to (d), identify which step (**1**, **2** or **3**) is the slow step.




(15 marks)

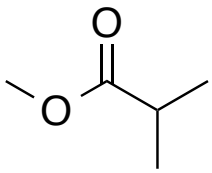
3(a) Calculate the pH of a 0.26 M solution of HF ($pK_a$ = 3.14).

(b) Clement is a life science student investigating a pH-dependent drug delivery system. He requires a buffer solution of pH 5.2 to test out his experimental procedure. Unfortunately, Clement has 100 mL of 0.100 M hydrochloric acid, solid sodium ethanoate and a lack of Chemistry knowledge. Given $pK_a$ of ethanoic acid = 4.75, explain to Clement what mass of sodium ethanoate ($M_r$ = 82.0) should be dissolved in his hydrochloric acid solution to form the required buffer.

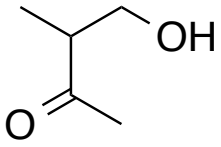
(10 marks)

**Organic Chemistry**

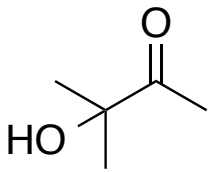
1. The details of three $^{1}H$ NMR spectra (1—3) were obtained from compounds **A**, **B** and **C**, not necessarily in that order. Determine which spectrum belongs to which molecule and briefly explain your reasoning.




**A**




**B**




**C**

**Spectrum 1**

| Chemical Shift (ppm) | Integral | Multiplicity |
|---|---|---|
| 3.669 | 3 H | singlet |
| 2.557 | 1 H | septet |
| 1.170 | 6 H | doublet |

**Spectrum 2**

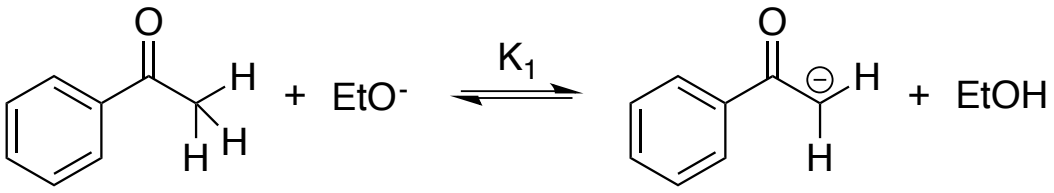
| Chemical Shift (ppm) | Integral | Multiplicity |
|---|---|---|
| 3.8 | 1 H | singlet |
| 2.249 | 3 H | singlet |
| 1.394 | 6 H | singlet |

**Spectrum 3**

| Chemical Shift (ppm) | Integral | Multiplicity |
|---|---|---|
| 3.715 | 2 H | multiplet |
| 2.7 | 1 H | singlet |
| 2.69 | 1 H | sextet |
| 2.206 | 3 H | singlet |
| 1.134 | 3 H | doublet |

(9 marks)

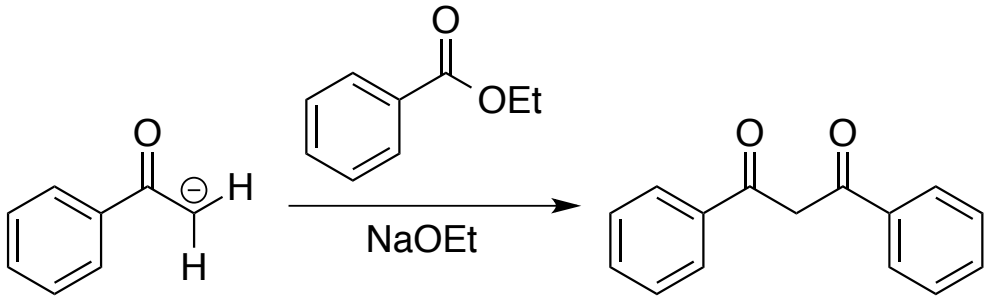
2(i) The carbon atoms adjacent to the C=O bond in carbonyl compounds are known as the alpha-carbon atoms. Hydrogens bonded to this carbon are acidic and can be removed by a strong base such as ethoxide to give a stable carbanion.




$pK_a = 26$

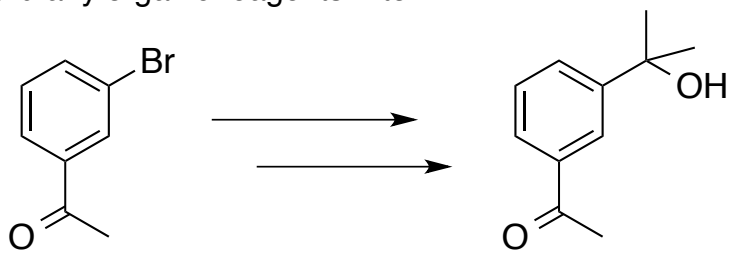
The $pK_a$ of ethanol is 15.7. Calculate the value of $K_1$.

(ii) Carbanions such as the one above can act as nucleophiles. Draw the stepwise mechanism for the following reaction:

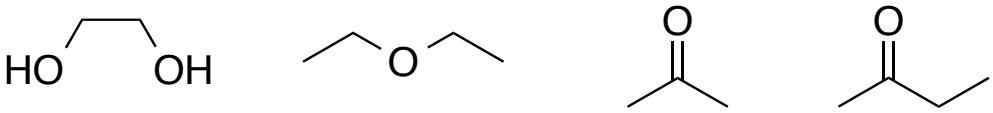



(9 marks)

3. Propose a reasonable synthesis for compound **E** from compound **D**. You may use any inorganic reagent and any organic reagents **F** to **I**.



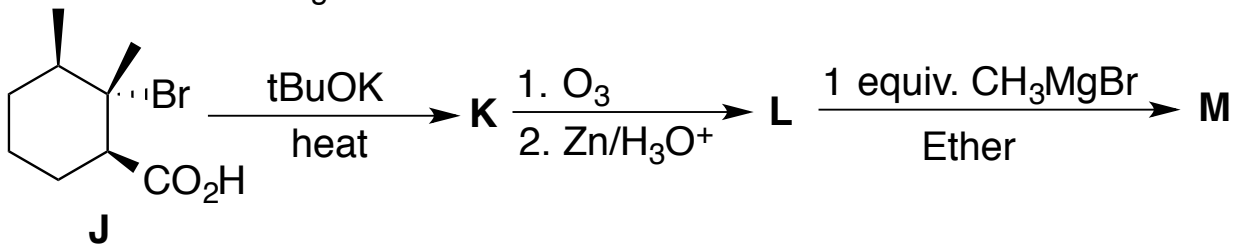

**D** **E**




**F** **G** **H** **I**

(8 marks)

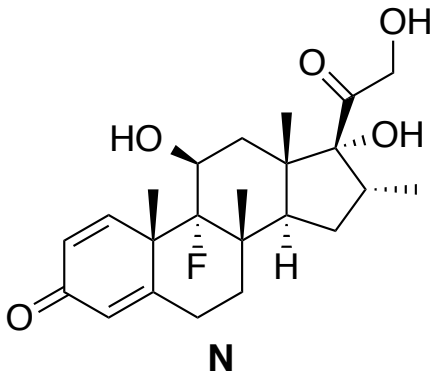
4. Consider the following reaction scheme:




(i) Give the IUPAC name for compound **J**.
(ii) Predict the products **K, L** and **M**.

(12 marks)

5. For compound **N**, mark all the chiral centres with an asterisk (*) and assign absolute configurations (R or S) to each chiral centre.




**N**

(12 marks)