Topics in the June 2006 Exam Paper for CHEM1102

Click on the links for resources on each topic.

2006-J-2:

- Physical States and Phase Diagrams
- Intermolecular Forces and Phase Behaviour

2006-J-3:

- Physical States and Phase Diagrams
- Kinetics
- Kinetics - Influences

2006-J-4:

- Solubility Equilibrium

2006-J-5:

- Coordination Chemistry
- Strong Acids and Bases
- Weak Acids and Bases

2006-J-6:

- Calculations Involving pK_a

2006-J-7:

- Alkenes
- Alcohols
- Organic Halogen Compounds
- Carboxylic Acids and Derivatives

2006-J-8:

- Synthetic Strategies

2006-J-9:

- Organic Halogen Compounds
- Synthetic Strategies

2006-J-10:

- Stereochemistry
- Carboxylic Acids and Derivatives

Marks 4

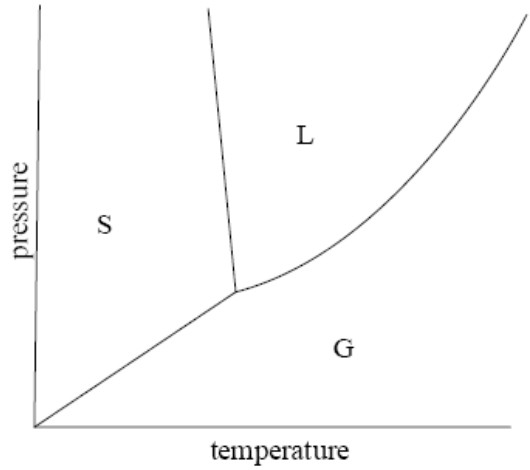
- A lecture demonstration showed that a wire with a weight attached can cut through a block of ice (solid water) without the block falling apart. Explain that phenomenon.

Liquid water is more dense than solid water (ice). When pressure is applied to the ice by the wire, it melts and gravity pulls the wire downwards through the liquid water.

Once the pressure is removed the water refreezes above the wire. The speeds of the two processes are such that the wire slowly cuts through the block without the block falling apart.

Sketch the phase diagram of water and explain how the above phenomenon manifests itself in the phase diagram.

The phase diagram with S = solid, L = liquid and G = gas is shown below:



The negative slope of the S/L equilibrium line means that, increasing the pressure with S ⇆ L moves the system into the liquid region.

- Carbon has a number of allotropes, the two major ones being graphite and diamond. What are allotropes?

Marks 3

Allotropes are different structural forms of the same element.

Give a different example for allotropes.

Examples include red and white phosphorus and O_2 and O_3.

The phase diagram of carbon shows that diamond is not the stable allotrope under normal conditions. Why then does diamond exist under normal conditions?

There is a very high activation energy for the conversion from diamond to graphite as they are structurally dissimilar. This energy is not available under normal conditions.

- Briefly describe two factors that determine whether a collision between two molecules will lead to a chemical reaction.

1

For a collision to lead to a chemical reaction:

- **the molecules must collide with sufficient energy to overcome the activation energy for the reaction, and**
- **the molecules need to be orientated in the correct way for the reaction to occur.**

Marks 4

- Magnesium hydroxide, $Mg(OH)_2$, is used as treatment for excess acidity in the stomach. Its solubility product constant, K_{sp}, is 7.1×10^{-12} M^3. Calculate the pH of a solution that is in equilibrium with $Mg(OH)_2(s)$.

The dissolution equilibrium is: $Mg(OH)_2(s) \leftrightarrows Mg^{2+}(aq) + OH^-(aq)$

Hence, $K_{sp} = [Mg^{2+}(aq)][OH^-(aq)]^2$

If $[Mg^{2+}(aq)] = x$ then $[OH^-(aq)] = 2x$ and $K_{sp} = (x)(2x)^2 = 4x^3$

As $K_{sp} = 7.1 \times 10^{-12}$, $x = 1.2 \times 10^{-4}$ M and so $[OH^-(aq)] = 2.4 \times 10^{-4}$ M

As pH + pOH = 14.0 and $pOH = -\log[OH^-(aq)] = -\log(2.4 \times 10^{-4}) = 3.6$:

pH = 14.0 – 3.6 = 10.4

Answer: **pH = 10.4**

Determine whether 3.0 g of $Mg(OH)_2$ will dissolve in 1.0 L of a solution buffered to a pH of 8.00.

If pH = 8.00 then pOH = 14.00 – 8.00 = 6.00. As $pOH = -\log[OH^-(aq)]$:

$[OH^-(aq)] = 1.00 \times 10^{-6}$.

As $K_{sp} = [Mg^{2+}(aq)][OH^-(aq)]^2 = 7.1 \times 10^{-12}$, the $[Mg^{2+}(aq)]$ is:

$$[Mg^{2+}(aq)] = \frac{K_{sp}}{[OH^-(aq)]^2} = \frac{7.1\times10^{-12}}{(1.00\times10^{-6})^2} = 7.1\,M$$

As 1 mol of $Mg(OH)_2(s)$ dissolves to give 1 mol of $[Mg^{2+}(aq)]$, this is also the number of moles of $Mg(OH)_2(s)$ which dissolves.

The molar mass of $Mg(OH)_2$ is (24.31 (Mg)) + 2×(16.00 (O) + 1.008 (H)) = 58.326

The mass of $Mg(OH)_2$ which can dissolve is therefore 7.1 × 58.326 = 410 g.

YES / NO

Marks

- Consider the compound with formula $[CoCl_2(NH_3)_4]Br{\cdot}2H_2O$. **3**

Write the formula of the complex ion. **$[CoCl_2(NH_3)_4]^+$**

Write the symbols of the ligand donor atoms. **Cl, N**

What is the *d* electron configuration of the metal ion in this complex? **Co^{3+}: $3d^6$**

- Describe the difference between a strong and a weak acid. **4**

A strong acid dissociates completely in water: HA(aq) → H^+(aq)\+ A^-(aq)

A weak acid dissociates only partially: HA(aq) ⇆ H^+(aq) + A^-(aq) (favours the left hand side – undissociated acid)

Describe in qualitative terms how the percentage ionisation of a weak acid changes when an aqueous solution thereof is diluted.

The percentage ionization increases as a weak acid is diluted.

Which chemical principle can be used to explain the change in percentage ionisation of a weak acid on dilution and how?

The equilibrium of interest is HA(aq) + H_2O(l) ⇆ H_3O^+(aq) + A^-(aq). From Le Chatelier's principle, as more water is added, the equilibrium is pushed to the right: the amount of acid present does not change but more molecules dissociate.

Marks 4

- Buffer systems are frequently used in chemistry. What is a buffer system and how does it function? Use equations where appropriate.

Buffer systems resist changes in pH: a buffer will maintain a relatively constant pH when acid or base is added.

They consist of mixtures of a weak acid (HA) and its conjugate base (A^-) in high concentration.

If acid is added, the system can respond by removing it using A^-:

$$H^+(aq) + A^-(aq) \rightarrow HA(aq)$$

If base is added, the system can respond by removing it using HA:

$$OH^-(aq) + HA(aq) \rightarrow H_2O(l) + A^-(aq)$$

What ratio of concentrations of acetic acid to sodium acetate would you require to prepare a buffer with pH = 4.00? The K_a of acetic acid is 1.8×10^{-5} M.

The pH of a buffer system made from a mixture of the weak acid (HA) and its conjugate base (A^-) is described by the equation:

$$\mathbf{pH = pK_a + \log\frac{[A^-(aq)]}{[HA(aq)]}}$$

For acetic acid, $K_a = 1.8 \times 10^{-5}$ or $pK_a = -\log(K_a) = 4.74$. To obtain pH = 4.00:

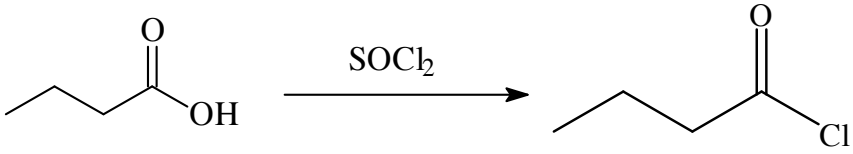
$$\mathbf{4.00 = 4.74 + \log\frac{[A^-(aq)]}{[HA(aq)]}} \text{ and so } \mathbf{\frac{[A^-(aq)]}{[HA(aq)]} = 10^{-0.74} = 0.18}$$

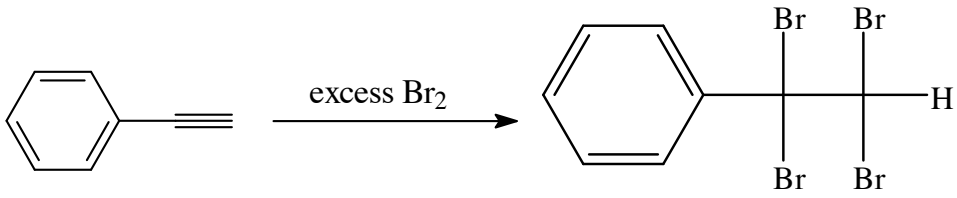
$$\text{Alternatively, } \mathbf{\frac{[HA(aq)]}{[A^-(aq)]} = \frac{1}{0.18} = 5.56}$$

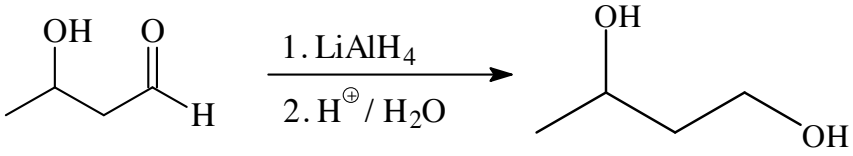
Answer: **5.56: 1**

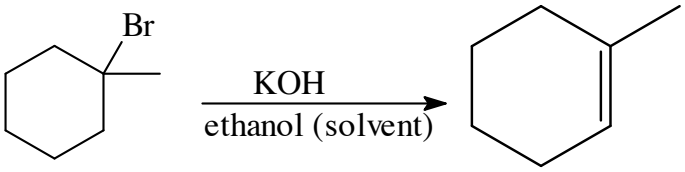
• Draw the structure of the major organic product formed in the following reactions.

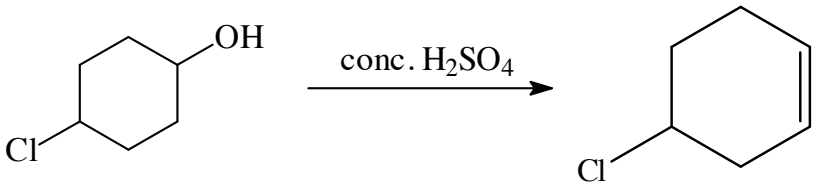
Marks 5





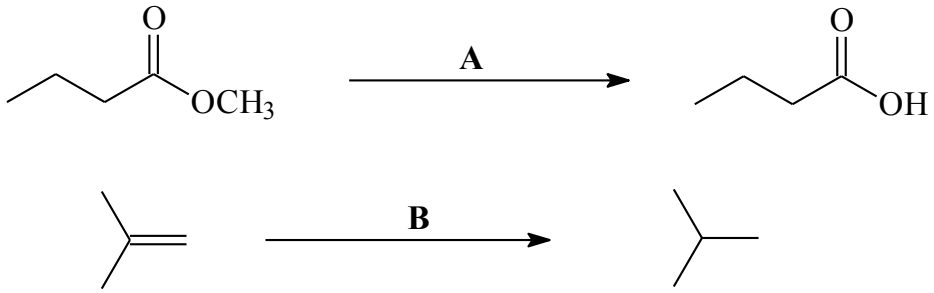






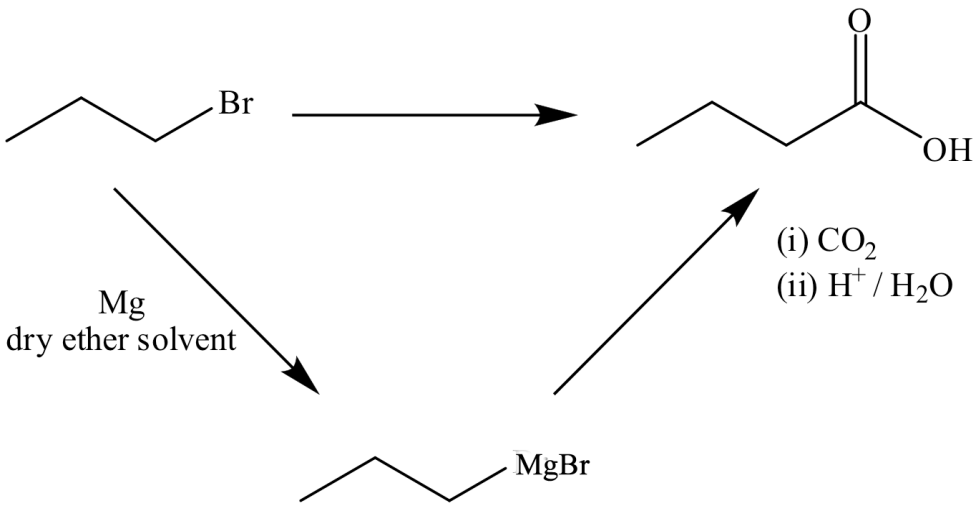
Marks

- Suggest reagents you could use to achieve the following transformations: **2**



A: **H^+ / H_2O / heat**	**B**: **H_2 / Pd catalyst**

- Clearly show the reagents you would use to carry out the following chemical conversion. Draw constitutional formulas for any intermediate compounds. Note that more than one step is required. **3**



- Add curly arrows to complete the following mechanism.

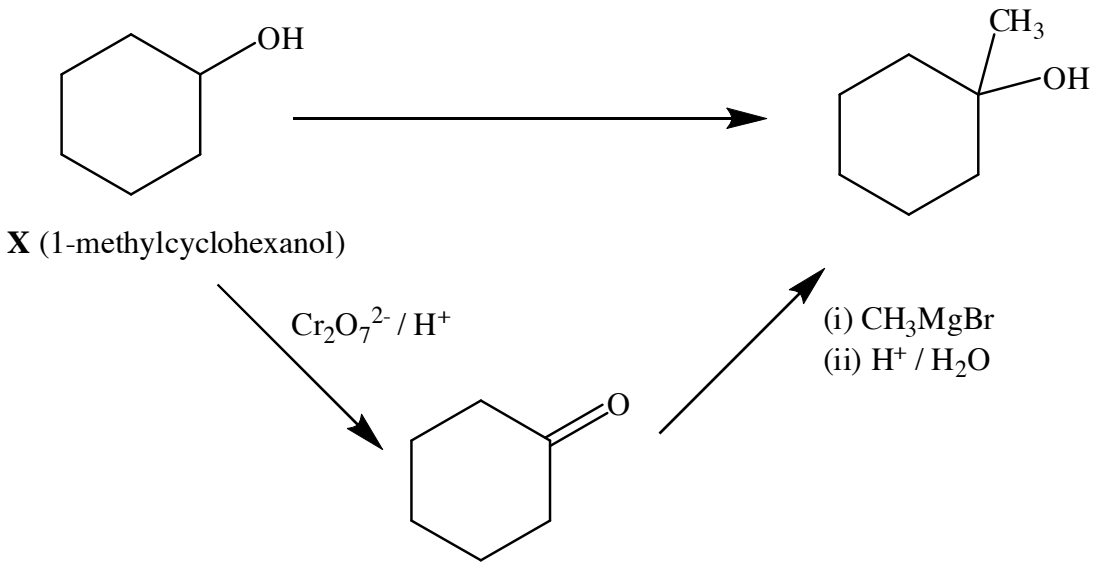
Marks 5

Classify this reaction as S_N1 or S_N2 and explain what the three parts of this descriptor signify.

The reaction is S_N2: a substitution ('S') (CN^- for Br^-) involving nucleophilic ('N') attack of CN^- on the substrate. The rate determining step is bimolecular as two ('2') molecules (CN^- and CH_3CH_2Br) are involved.

4

- Devise a synthesis of the product **Y**, starting from compound **X**. Note that more than one step may be required and you should indicate all necessary steps and the constitutional formulas of any intermediate compounds.

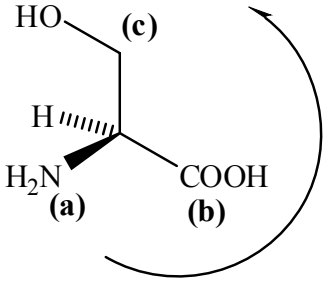


What is the systematic name for compound **Y**?

1-methylcyclohexanol

Marks 6

- The amino acid serine is shown below:

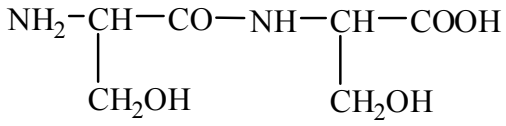


List the substituents attached to the stereogenic centre in order of decreasing priority.

highest priority			lowest priority
NH_2	**COOH**	**CH_2OH**	**H**

Assign the absolute configuration of the stereoisomer shown above. **S**

Draw the dipeptide formed by the condensation of two serine residues.



Explain briefly what is meant by the *primary structure* of a protein.

The primary sequence is the sequence in which the amino acids occur. For example, ala-ser-tyr:

- Draw the repeating unit of the polymer formed in the following reaction. **2**