FUNDAMENTALS OF CHEMISTRY 1B (CHEM1002)

November 2001 - Part A

Q1. As_2O_3
potassium permanganate
KCH_3CO_2
hexaaquairon(II) ion
$Na_2[CuCl_4]$
sodium dicyanoargentate(I)
$[Cr(H_2O)_3Cl_3]$
ammonium chloride
$[Fe(CN)_6]^{3-}$
triaquachlorocopper(II) ion

Q2. (a) (i) selenium (Se)

(ii) chlorine (Cl)

(b) (i) $1s^2\ 2s^2\ 2p^6$ (note that it's an ion)

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

(c) Paramagnetism arises from unpaired electrons.

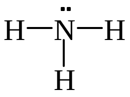
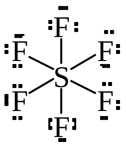
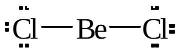
3*d*	↑↓	↑↓	↑↓	↑	↑

Ni^{2+} has two unpaired electrons in the 3d orbitals

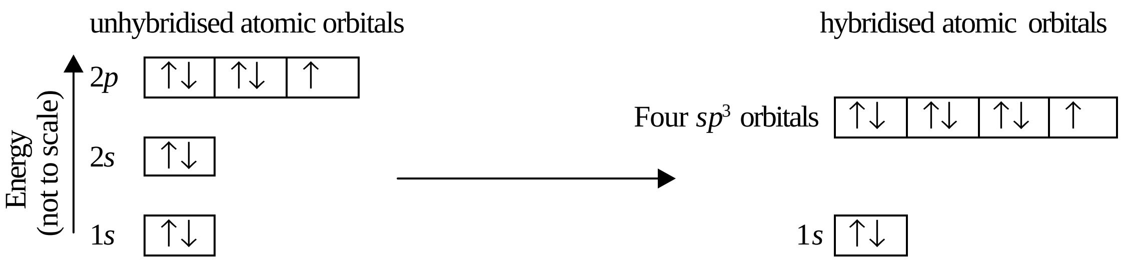
(d) $Cl(g) + e^- \rightarrow Cl^-(g)$ (NB must be gas phase)

Q3. Across a field, as more electrons occupy the same principal energy level, they are accompanied by additional protons in the nuclei. All outer electrons experience greater attraction to the nucleus (effective nuclear charge is increasing), and the radius decreases. After the noble gas in each row, the next atom (Group I) must use the next higher energy level for its last electron which is screened from the nucleus, so the radius increases sharply at that point. Repetition of this process means that the atomic radius increases down any group.

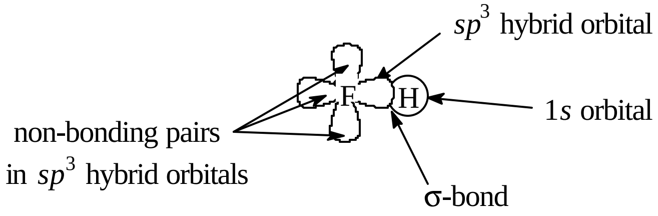
Q4.

	tetrahedral	trigonal pyramidal
	octahedral	octahedral
	linear	linear

Q5.



The $2s$, $2p_x$, $2p_y$ and $2p_z$ orbitals of the fluorine atom undergo a mixing process called hybridisation to produce four equivalent sp^3 hybrid orbitals. Three of these orbitals already contain 2 electrons (the non-bonding pairs on the fluorine). The remaining sp^3 orbital that contains 1 electron can overlap with the $1s$ orbital of a H atom to form a σ-bond.

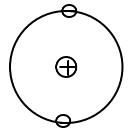


Q6. $$2NH_3 + Ag^+ \rightleftharpoons [Ag(NH_3)_2]^+$$

The equilibrium for this reaction lies far to the right, removing most of the Ag^+ from the solution and converting it to the complex ion, diamminesilver(I) ion.

Q7. For elements of Period 2, the only orbitals that are energetically available are the $2s$ and three $2p$ orbitals, which can accommodate only 8 electrons (2 in each orbital). For elements in Period 3 and above, d orbitals are energetically available to accommodate more electrons. This allows the valence level to expand beyond the limit of 8 electrons.
SF_6 and PF_5 contain 12 and 10 electrons in their valence levels, respectively.

Q8.



H^- has two electrons around a single proton nucleus. There are no electrons inside the $1s$ orbital to screen the electrons, so they both experience a high effective nuclear charge.

Q9. Buffers contain a weak acid (HA) and its conjugate base (A^-), both in significant amounts. Buffers resist change in pH by the following reactions.

$HA + OH^- \rightarrow H_2O + A^-$ (removes added OH^-)

$A^- + H_3O^+ \rightarrow H_2O + HA$ (removes added H^+)

The pH of the buffer is determined by the pK_a of the weak acid and the ratio of [HA]:[A^-]. The capacity of the buffer is determined by the amounts (concentrations) of HA and A^-. The most effective buffer has $[HA] = [A^-]$ as this can remove H^+ or OH^- equally well.

Q10. (a) (i) pH = 2.43

(ii) pH = 11.12

(b) $[CH_3CO_2^-] = 1.1$ M

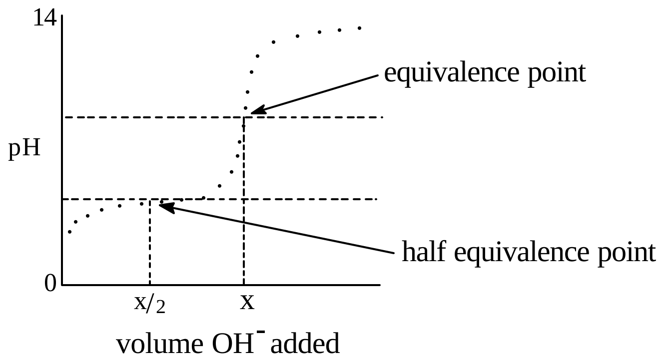
Q11. The reaction is $CH_3COOH + NaOH \rightarrow H_2O + NaCH_3CO_2$

The $CH_3CO_2^-$ ion is a weak base reacting partially with water to give $[OH^-] > 10^{-7}$.

$$CH_3CO_2^- + H_2O \rightleftharpoons OH^- + CH_3COOH$$

Na^+ ions do not change the pH.

Q12



At the half equivalence point, the amount of HA consumed equals the amount of A^- produced, and therefore $[HA] = [A^-]$.

For a weak acid, HA, $K_a = \dfrac{[H^+] \times [A^-]}{[HA]}$

When $[HA] = [A^-]$, $K_a = [H^+]$ and pH = pK_a.

Q13. From a knowledge of the titration type:

Strong acid v. strong base has equivalence point at pH = 7.

Strong acid v. weak base has equivalence point at pH < 7.

Weak acid v. strong base has equivalence point at pH > 7.

Choose an indicator that has a $pK_a \approx$ pH at equivalence point.

Q14. ammonium ion < lactic acid < nitrous acid < hydrogen chloride

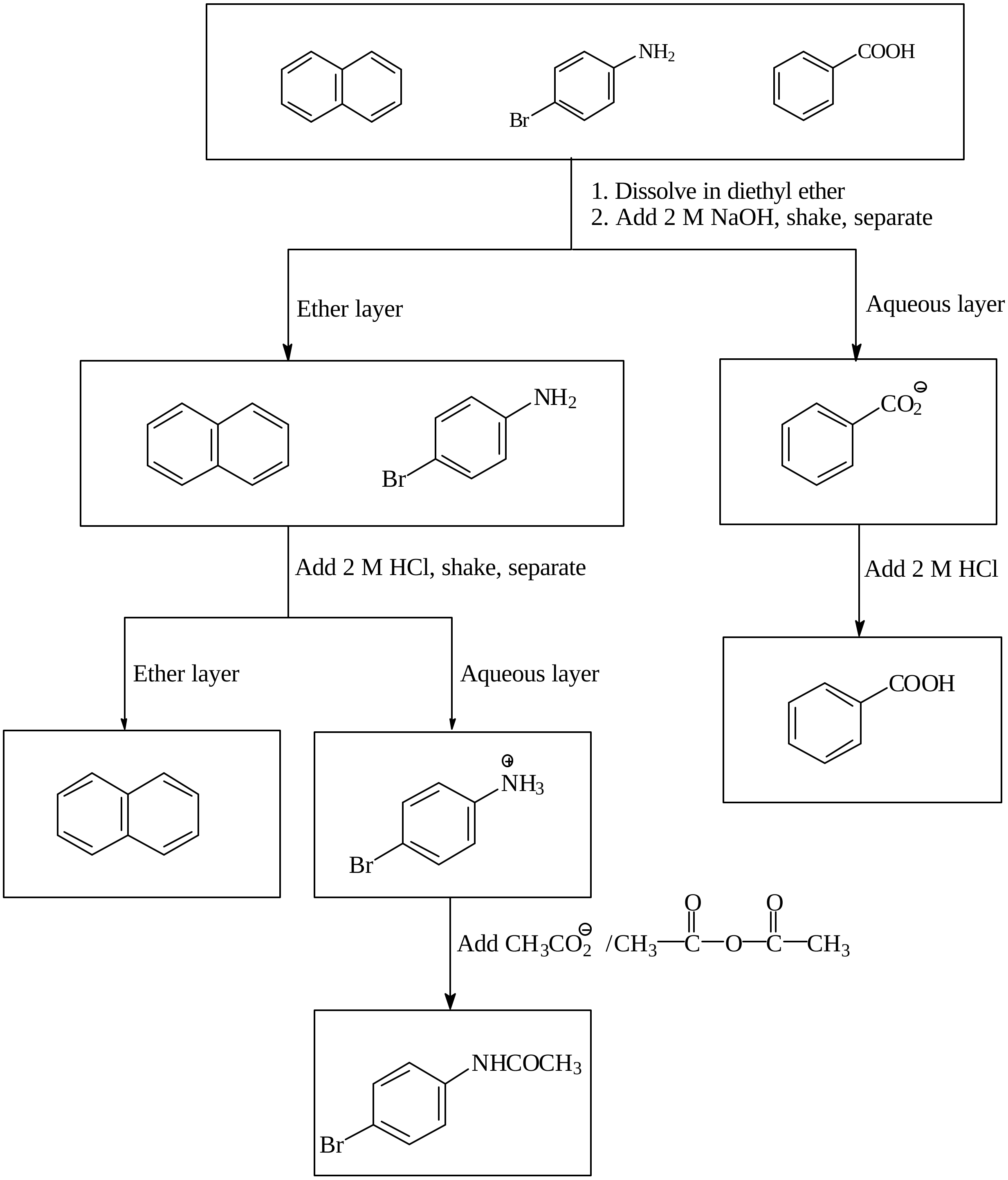
$NH_4^+ < CH_3CH(OH)COOH < HNO_2 < HCl$

Q15. The hydrolysis of the hydrated Fe^{3+} ion increases $[H_3O^+]$ to $> 10^{-7}$ M.

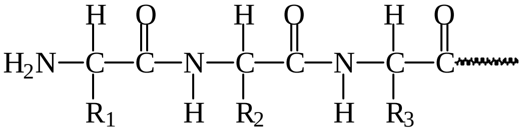
$$[Fe(H_2O)_6]^{3+} + H_2O \rightleftharpoons H_3O^+ + [Fe(H_2O)_5OH]^{2+}$$

November 2001 - Part B

01-N-2



01-N-3 Many answers are possible. Biopolymers include proteins, DNA, starch, cellulose, rubber, etc. Proteins consist of polymeric chains of amino acids linked by the amide functional group (–CONH–).



$$H_2N-\underset{R_1}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-\underset{H}{N}-\underset{R_2}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}-\underset{H}{N}-\underset{R_3}{\overset{H}{C}}-\overset{O}{\overset{\|}{C}}\sim\sim$$

Different proteins have different lengths and different R groups and different biological functions (eg as enzymes or for structure).

A: HBr in CCl_4 solvent

B: hot dilute NaOH in water

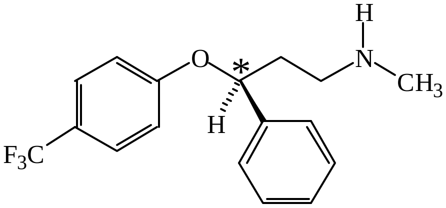
C: Cl_2 in CCl_4 solvent

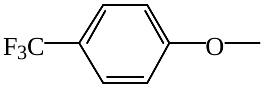
D: $N(CH_3)_3$

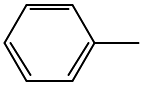
E: $Cr_2O_7^{2-}$ / H^+

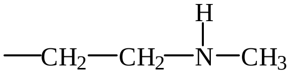
1,2-dichlorobutane

01-N-4









$$-CH_2-CH_2-\overset{H}{N}-CH_3$$

H—

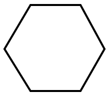
(*S*)-

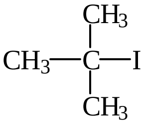
a = (secondary) amine

b = aromatic ring

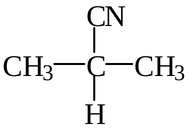
01-N-5

CH_3COOH + CH_3CH_2OH





$$CH_3-\underset{CH_3}{\overset{CH_3}{C}}-I$$



$$CH_3-\underset{H}{\overset{CN}{C}}-CH_3$$