1 (a) (i) $2Mg + O_2 \rightarrow 2MgO$ **(1)** or $Mg + \frac{1}{2}O_2 \rightarrow MgO$

(ii) $Si + O_2 \rightarrow SiO_2$ **(1)**

(iii) $S + O_2 \rightarrow SO_2$ **(1)** allow S_2 or S_8; not SO_3 as product

(3 marks)

(b) (i) basic **(1)** not alkaline

(ii)acidic **(1)** **(2 marks)**

(c) (i) $Na_2O + H_2O \rightarrow 2NaOH$ **(1)** allow Na^+OH^- on r.h.s.

(1 mark)

(ii) Ionic **(1)**
O^{2-} ion very polarisable/strong interaction with polar water **(1)**
reacting with water to give OH^- **(1)** **(3 marks)**

(Total 9 marks)

2 (a)
- metal oxides are (more) basic than non-metal oxides/comment on increasing basicity of oxides **(1)**
- CO_2 acidic **(1)**
- PbO amphoteric **(1)** **(3 marks)**

Appropriate equations may be used but these must be wholly correct.

(b) (i) tin +4 **(1)**
lead +2 **(1)** **(2 marks)**

(ii) **Either**
- Bond strength Pb-Cl < Sn-Cl **(1)**
- new bonds formed in the (+4) state of lead not strong enough to compensate **(1)**
- for the promotional energy of the electrons needed to form the (+4) state **(1)**

or
- In tin oxidation state +4 more stable than +2 **(1)**
- In lead oxidation state +2 is more stable than +4 **(1)**

(1/2 for this if no comparison with other oxidation states) **(3 marks)**
- Therefore lead(IV) oxidises chloride ion (to chlorine) **(1)**

(Total 8 marks)

3 (a) The pressure which the gas exerts if it alone occupies the same volume at the same temperature **(1)**
or
partial pressure of a gas in a mixture = mole fraction of gas x total pressure **(1)** **(1 mark)**

(b) (i) $K_p = p(PCl_3)p(Cl_2)/p(PCl_5)$**(1)** no square brackets

Or

$K_p = \frac{P_{PCl3} \times P_{Cl2}}{P_{PCl5}}$ **(1 mark)**

(ii) mark consequentially on (i)

	PCl_5	$\rightleftharpoons$	PCl_3	$+ Cl_2$	
mols at start	1		0	0	
mols at eqm	0.60		0.40	0.40	**(1)**
mol fraction	$\frac{0.60}{1.40}$		$\frac{0.40}{1.40}$	$\frac{0.40}{1.40}$	**(1)**
partial pressures	$\frac{0.60}{1.40}$ x2		$\frac{0.40}{1.40}$ x2	$\frac{0.40}{1.40}$ x2	
	=0.857		=0.571	=0.571	**(1)**

$K_p = (0.571)^2/0.857 = 0.38$ or 0.381 **(1)** atm **(1)** but 2-4 sf acceptable

i.e.
mols at eqm **(1)**
mols fraction **(1)**
partial pressures (i.e. multiply x2) **(1)**
substitute in K_p + answer **(1)**
units **(1)** **(5 marks)**

(c) (i) Endothermic **(1)**
conditional on increase of temperature moves equilibrium in direction that absorbs heat **(1)** **(2 marks)**

(ii) K_p increases **(1)** **(1 mark)**

(d) (i) $K_p = p(CO_2)$ **(1)**
or
$K_p = P_{CO_2}$ **(1 mark)**

(ii) 16 (atm) **(1)** ignore units. Consequential on (d)(i) **(1 mark)**

(Total 12 marks)

4 (a) (i) Pairs up CH_3CH_2COOH and $CH_3CH_2COO^-$ and H_2O/H_3O^+ **(1)**; correct identification of which is acid and which base **(1)** **(2 marks)**

(ii) $K_a = [CH_3CH_2COO^-][H_3O^+]/[CH_3CH_2COOH]$ **(1)**
$[H^+]$ is acceptable. **(1 mark)**

(iii) $[H^+] = (K_a[HA])^{1/2}$ or $\sqrt{Ka[HA]}$ **(1)** $= (1.3 \times 10^{-5} \times 0.10)^{1/2}$
$= 1.14 \times 10^{-3}$ mol dm^{-3} **(1)** pH = 2.9 or 2.94, i.e. to 1 or 2 d.p. **(1)** **(3 marks)**
Consequential on the value of $[H^+]$ provided the pH resulting is between 0 and 7.

(iv) $[H^+][OH^-] = 10^{-14}$ **(1)** $= 1.14 \times 10^{-3}[OH^-]$ **(3 marks)**
Thus $[OH^-] = 10^{-14} / 1.14 \times 10^{-3}$ **(1)**
$= 8.77\ (8.8) \times 10^{-12}$ mol dm^{-3} **(1)** units needed (2 or 3 sf)
Consequential on the answer to (iii) for $[H^+]$.:
Allow 8.71×10^{-12} if solved using pH + pOH and pH = 2.94;
7.9×10^{-12} if solved using pH + pOH and pH = 2.9.

(b) $CH_3CH_2COO^- + H_2O \rightleftharpoons CH_3CH_2COOH + OH^-$ **(1)**
Hydroxide ions make the solution alkaline **(1)** or propanoate ion deprotonates the water

or $CH_3CH_2COONa + H_2O \rightarrow CH_3CH_2COOH + NaOH$ **(1)** **(2 marks)**
Explanation then must comment that acid is weak/not fully ionised

(c) (i) Solution that maintains almost constant pH **(1)** for **small** addition of acid or alkali **(1)** **(2 marks)**

(ii) pH = pK_a + lg [salt]/[acid] **(1)**
= 4.9 + lg (0.05)/(0.025) **(1)** for dividing by 2
= 5.19 or 5.2 **(1)**. **(3 marks)**

If the Henderson equation is wrong but concs are divided by 2 then 1/3 max.

Or

$[H^+] = \frac{Ka[acid]}{[salt]}$ **(1)**

$= \frac{1.30 \times 10^{-5} \times 0.025}{0.050}$ **(1)**

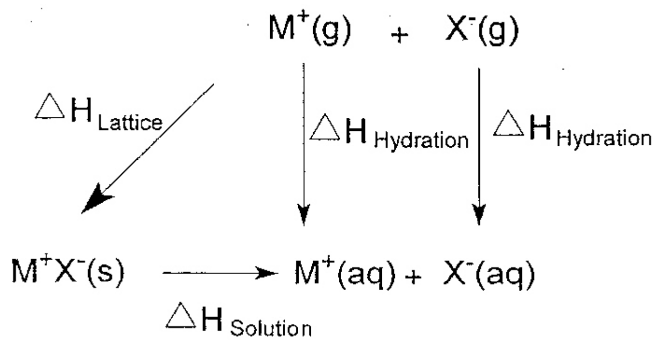
pH = 5.19 or 5.2 **(1)**
If the concns are twice what they should be, i.e. candidate does not spot the volume increase, then max (2). The pH is still 5.2, so care is needed.

(Total 16 marks)

5 (a) (i) Energy/enthalpy released **(1)**
When 1 mol of solid/crystal/lattice **(1)**
is formed from gaseous ions **(1)** not from 1 mol of gaseous ions
Or
Energy released per mole **(1)** for:
$M^+ (g) + X^- (g) \rightarrow MX (s)$ (**1** for species, **1** for phases)
If 'energy change' is written then must show somehow that it is exothermic **(3 marks)**

(ii) Heat or enthalpy change (not energy change) when 1 mole of gaseous ions **(1)** is dissolved
either:
in so much water that further dilution produces no detectable heat change **(1)**
or
to form infinitely dilute solution **(1)** **(2 marks)**

(b) (i)



(1) for each enthalpy change linking correct species including state symbols. Double-headed arrows scores zero **(3 marks)**

(ii) $\Delta H_{sol} = -\Delta H_{latt} + \Delta H_{hyd}$ **(1)** **(1 mark)**

(iii) salt likely to be more soluble if ΔH_{sol} exothermic (less endothermic) **(1)**;
either:
both lattice energy and hydration enthalpies become less exothermic **(1)**
as cations increase in size **(1)**
but lattice energy changes less so enthalpy of solution less exothermic **(1)**
or:
$\Delta H_{lattice}$ is dominated by the large sulphate ion and changes little down the group **(1)**
so solubility depends largely on the hydration enthalpy of the cation **(1)**
which is less exothermic down the group as the cations get larger **(1)**

(4 marks)

(Total 13 marks)

6 (a) (i) A molecule that is non-superimposable on its mirror image **(1)**
or
has no plane of symmetry **(1)** **(1 mark)**
or has a **single** asymmetric carbon atom

(ii) **Rotation** (of the plane of polarisation) of <u>plane-polarised</u> (monochromatic) light **(1 mark)**

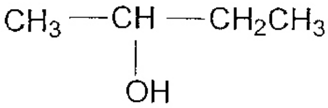
(b) bromine **(1)** allow Br_2, not Br, not bromine water
and sodium hydroxide **(1)**
heat/or warm **(1)** conditional on the correct reagents **(3 marks)**

(c) (i) $CH_3CH_2CH(MgBr)CH_3$ **(1)**
$CH_3CH_2CH(COOH)CH_3$ **(1)**
$CH_3CH_2CH(COCl)CH_3$ **(1)**
If substituents are on the end max. **(2)** **(3 marks)**

(ii) Grignard reagents react with water **(1)** **(1 mark)**

(iii) ammonia **(1)**
room temperature **(1)** **(2 marks)**

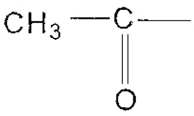
(d) (i)



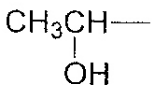
(1 mark)

(ii) contains C=O so reacts with 2,4 dnp **(1)**
but cannot be oxidised so no reaction with Fehlings' solution **(1)** **(2 marks)**

(iii)



If



included then zero

(1) **(1 mark)**

(iv)
CHI_3 **(1)** **(2 marks)**
$CH_3CH_2COO^-$ **(1)** or CH_3CH_2COONa

(Total 17 marks)

END

6245

1 (a)

- $KMnO_4$ (aq) in burette **(1)**
- Pipette known volume (e.g. 25.00 cm^3) of $FeSO_4$(aq) into conical flask **(1)**

[Max 1 out of 2 if $KMnO_4$ in flask]

- Add (dilute) sulphuric acid (to flask) **(1)**
- Add $KMnO_4$ until (faint) pink colour persists **(1)**

[If reagents wrong way round, end point must be pink to colourless]

- Record volume of $KMnO_4$ (aq) added and repeat to concordance/within 0.20cm^3 **(1)**

[Not just "repeat three times"] **(5 marks)**

(b) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ **(1 mark)**

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$ **(1 mark)**

(ii)

$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$ **(1 mark)**

[Mark not awarded if e^- left in final equation]

(iii) Amount MnO_4^- = 0.0200 x 0.0225 = 0.00045 mol **(1)**

Amount Fe^{2+} = 5 x 0.00045 = 0.00225 mol **(1)** (consequential on (b)(ii))

conc. of $FeSO_4$(aq) = 0.00225 / 0.025 = 0.0900 mol dm^{-3} **(1)**
(consequential on (b)(ii))
Must be 2 to 4 sig fig **(3 marks)**

(c) $2Fe^{3+} + Fe \rightarrow 3Fe^{2+}$ **(1)**
(Accept $2Fe^{3+} + 3Fe \rightarrow 3Fe^{2+} + 2Fe$)
Either E (cell) = -0.04 – (-0.44) = + 0.40 V **(1)**
i.e. positive therefore feasible (or answer consequential on E (cell)) **(1)**

Or
Equation **(1)**
Fe^{3+} is the oxidised form of a redox couple with more positive EP **(1)**

Therefore can oxidise iron, the reduced form of other redox couple **(1)** **(3 marks)**

(Total 14 marks)

2 (a) (i)

↑	↑	↑	↑	↑		↑

(1 mark)

(ii)

↑	↑	↑				

(1 mark)

Allow single headed arrows or other suitable notation
[Mark (ii) consequentially on (i)]

(b) (i) Covalent **(1)**
Coordinate or dative **(1)** **(2 marks)**

(ii) Deprotonation or acid-base **(1 mark)**

(iii) $[Cr(H_2O)_3(OH)_3]$ or $Cr(OH)_3$ **(1 mark)**

(iv) Ligand exchange or ligand substitution **(1 mark)**

(v) $[Cr(NH_3)_6]^{3+}$ or $[Cr(OH)_x(H_2O)_y(NH_3)_z]^{charge}$ **(1 mark)**

x + y + z = 6, z at least one, correct charge will be between 0 and +3, x = max 3

(c)
- **d** – orbitals/subshell/energy level split (in energy by ligands)/diagram to illustrate **(1)**
- Electron transitions/jumps from **lower** to **higher** energy level **(1)**
- **Absorbs** light in visible region/reference to white light **(1)** **(3 marks)**

If imply or state that emission is occurring, only the first marking point is available

(Total 11 marks)

3 (a) rate = k[A][B] **(1)** *or any other where m+n = 2*
rate = $k[A]^2$ **(1)**
rate = $k[B]^2$ **(1)** **(3 marks)**

(b) (i) Working to show first order with respect to H_2 **(1)**
Working to show second order with respect to NO **(1)**
Overall rate equation (must be consequential) **(3 marks)**
rate = $k\,[H_2]\,[NO]^2$ **(1)**

(ii) $0.02 = k\,(1.0)^2(1.0)$ or correct use of either of the other two rows of data
k = 0.02 /1.0 = 0.02 **(1)**
$mol^{-2}dm^6s^{-1}$ **(1)** **(2 marks)**
Consequential on (b)(i)

(c)
- Molecules move faster/have more kinetic energy **(1)**
- More molecules / collisions have at least E_{act} **(1)**
- Greater proportion/fraction of collisions are successful OR more of the collisions are successful **(1)** **(3 marks)**

(d) k increases **(1 mark)**

(e)
- Catalyst provides an alternative route **(1)**
- With a lower activation energy *(consequential on first mark)* **(1)**
- Rate increases because more collisions have enough energy to overcome the lower activation energy **(1)**

[Accept argument based on Arrhenius equation for third mark]

(3 marks)

(Total 15 marks)

4 (a) (i) Conc. sulphuric acid **(1)**

Conc. nitric acid **(1)**

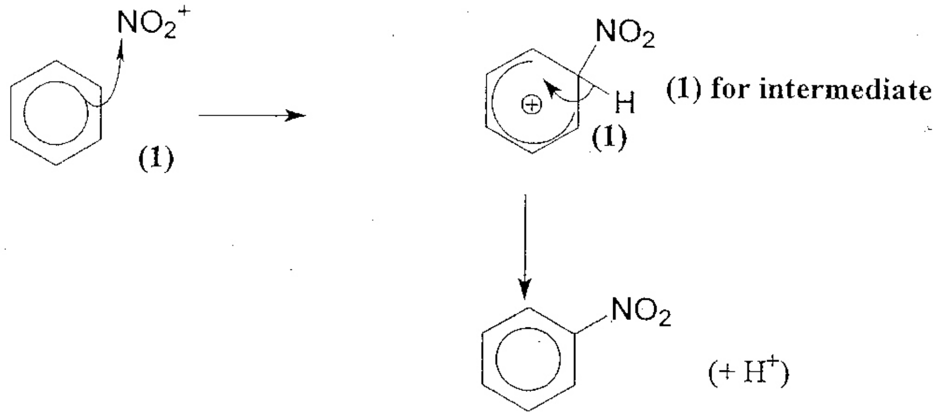
[Conc. must be stated, or implied, for both acids] **(2 marks)**

(ii)

$HNO_3 + H_2SO_4 \rightarrow H_2O + HSO_4^- + NO_2^+$ **(1)** *Can be shown in two stages*

Or

$HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$ **(1)**



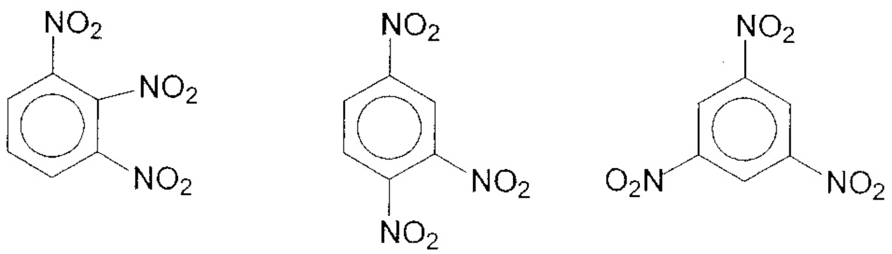
I.e. curved arrow from benzene ring of electrons towards N in NO_2^+ ion **(1)**

Intermediate correctly drawn, including positive charge **(1)**

Curved arrow from C-H bond back into benzene ring **(1)** **(4 marks)**

(iii) Electrophilic substitution **(1 mark)**

(b)



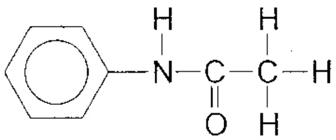
(1) **(1)** **(1)** **(3 marks)**

Vertical/right hand substituents must be shown with C to N bond

[Mark consequentially on structural formula given for "nitrobenzene" in (a)(ii)]

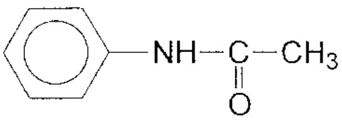
(c) Tin / iron and concentrated hydrochloric acid/conc. HCl **(1)**
Heat (under reflux) **(1)** *Second mark consequential on correct/"near miss" reagents* **(2 marks)**

(d) (i)



(1 mark)

Allow:



(ii)
- Dissolve in minimum volume **(1)**
- Of boiling/hot solvent (or any specified solvent other than water) **(1)**
- Filter through a heated funnel **(1)**
- Cool or leave to crystallise **(1)**
- Filter under suction/filter using Buchner funnel **(1)**
- Wash crystals with cold solvent **(1)** **(6 marks)**

NB If no solvent used, no marks available at all in part (d)(ii)

(Total 19 marks)

5 (a) Heat with Fehling's solution or heat with ammoniacal silver nitrate **(1)**
Ketone: no change **(1)** **(3 marks)**
Aldehyde: red ppt. or silver mirror **(1)**

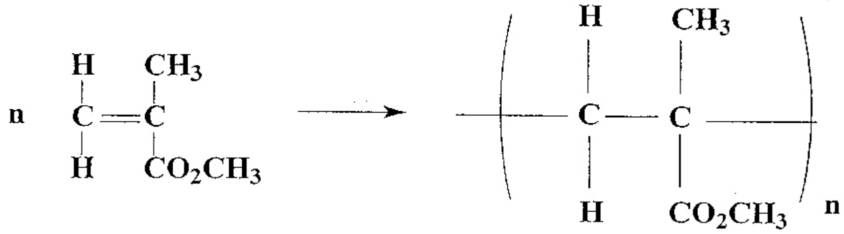
Alternatives

Allow: heat with dilute sulphuric acid and potassium dichromate (VI) OR heat with dilute sulphuric acid and potassium

Ketone: no change **(1)**
Aldehyde: solution turns orange to green OR purple to colourless **(1)**
Allow: iodine + sodium hydroxide solution/potassium iodide + sodium chlorate (I) **(1)**
Ketone: yellow ppt. **(1)**
Aldehyde: no change **(1)**

(b) $K_2Cr_2O_7$ / H_2SO_4 OR $KMnO_4$ / H_2SO_4 **(1)**
Heat (under reflux) *Consequential on correct reagents/OR* identify propanoic acid as the intermediate **(1)**
NaOH/Na_2CO_3 + aqueous/dilute/room temp. (not 'heat') **(1)** **(3 marks)**

(c)



Correct layout of polymer**(1)**

Evidence of correct continuation **(1)**

Correct eqn. **(1)** **(3 marks)**

(d) $CH_3COCH_3^+$ **(1)**
CH_3CO^+ **(1)**
CH_3^+ **(1)** **(3 marks)**
Penalise omission of + charge once only
If m/e not stated, assume ions are listed in m/e order 58, 43 and 15

(e) Propanone has 1 peak **(1)**
Only one type/environment of hydrogen/proton (in a CH_3 group) **(1)**
Propanal has three peaks **(1)**
One in a CH_3, one in a CH_2 and one as part of a CHO group OR other suitable justification **(1)** **(4 marks)**
NB Answers in terms of e.g. I.R./M.S. scores zero

(Total 16 marks)

6246/02
Section A

1 (a) **Equation:**

$NH_3 + HCl \rightarrow NH_4Cl$ or $NH_4^+ Cl^-$ **(1)** state symbols *not* required — 1

Calculation:

Amount HCl = 0.11 mol dm^{-3} x 0.0371 dm^3 = 0.004081 mol **(1)**
Amount of NH_3 in 25.0 cm^3 = 0.004081 mol
Amount in 250 cm^3 = 0.04081 mol **(1)**
Amount of NH_3 in 10 cm^3 of **X** = 0.04081 mol **(1)**
$[NH_3]$ in **X** = 0.04081 mol / 0.0100 dm^3 = 4.08 (4.081) mol dm^{-3}
or $[NH_3]$ in **X** = 0.4081 mol / 0.100 dm^3 = 4.08 (4.081) mol dm^{-3} **(1)** — 4

Mark consequentially for processes:

1. volume of acid to moles of acid
2. multiplying by ten to get moles in 250 cm^3
3. calculate amount of NH_3 in 10 (or 100) cm^3 of **X**
4. calculating concentration by dividing moles in 10 or 100 cm^3 of **X** by 0.01 (for 10 cm^3) or 0.1 (for 100 cm^3)

(b) **Graph:**

Axes labelled **(1)**
pH at start between 9 and 12 **(1)**
graph vertical at 37.1 cm^3 of acid **(1)**
pH at end point between 6 and 4 with a vertical range of 3 to 5 pH units **(1)**
pH at 50 cm^3 of acid between 1 and 3 **(1)** — 5

Indicator: (consequential on graph)
methyl orange / methyl red / bromophenol blue / bromocresol green **(1)**
(not phenol phthalein / thymol blue / bromothymol blue / phenol red)
pK_{ind} ±1 lies completely within the pH of the vertical range
or it changes colour / working range **within** the pH of the vertical part of the curve **(1)** — 2

(c) Add **excess** of solution **X** to copper sulphate solution / zinc sulphate solution (or add a **little** of the test solution to some X) **(1)**
(blue ppt) giving deep blue solution with excess **X** or white **ppt** giving colourless **solution** with zinc sulphate (or equivalent with cobalt(II) chloride) **(1)**

or add excess of solution **X** to a suspension / solid silver chloride **(1)** which forms a colourless solution **(1)**
or add any named aldehyde to a mixture of **X** and silver nitrate solution **(1)** and observe silver mirror **(1)** — 2

Total 14 marks

Section B

2 (a) (i)

P 24.6 / 31 } (1) 0.794 / 0.794 = 1 } EF is PF_5 (1)
F 75.4 / 19 } 3.97 / 0.794 = 5 }

M_r of EF = 126 **(1)**

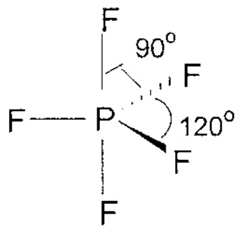
Therefore MF = EF = PF_5 **(1)** **4**

There must be some use of the data of 126 g mol^{-1}

OR

Mass of phosphorus in 1 mole = 126 x 24.6/100 = 31 **(1)**
Mass of fluorine in 1 mole = 126 x 75.4/100 = 95 **(1)**
Moles of phosphorus in 1 mole compound = 31/31 = 1
Mole of fluorine in 1 mole compound = 95/19 = 5 **(1)**
MF = PF_5 **(1)**

(ii)



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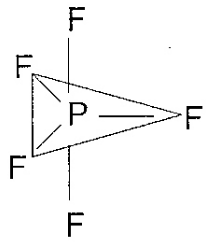
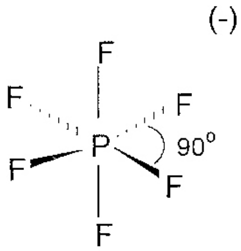


(1)

note: there must be an attempt at a 3-D drawing (i.e. one wedge and one dotted line)

Angles **drawn** on diagram of 90^0 **(1)** and 120^0 **(1)** **3**

(iii)



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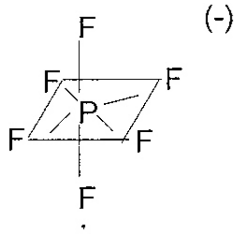


(1)

note: again it must be 3-D (again wedges and dotted lines)

Name stated as octahedral **(1)**

Angle marked / stated as 90^0 **(1)** **3**

(b) HF has **inter**molecular **hydrogen** bonding (but others do not) **(1)**

Because F atom is very small / other halogen atoms / chlorine etc. radii are too large **(1)**

Hydrogen bonding is **stronger** than IMF/vdW/dipole-dipole/induced dipole-dipole/dispersion forces and so more **energy** required (to boil) **(1)** **3**

Do not give any marks if the candidate answers in terms of strength of covalent bonds.

Do not give all 3 marks unless the candidate has expressed their ideas clearly.

(c) $K_a = \frac{[H^+][F^-]}{[HF]}$ **(1)** allow H^+ or H_3O^+

$[H^+] = 10^{-2.04}$ **(1)** = 0.009120 mol dm^{-3}

$[H^+] = [F^-]$ or $K_a = [H^+]^2 / [HF]$

$= \frac{(0.009120)^2}{(0.150 - 0.009120)}$ or $= \frac{(0.009120)^2}{0.150}$ **(1)**

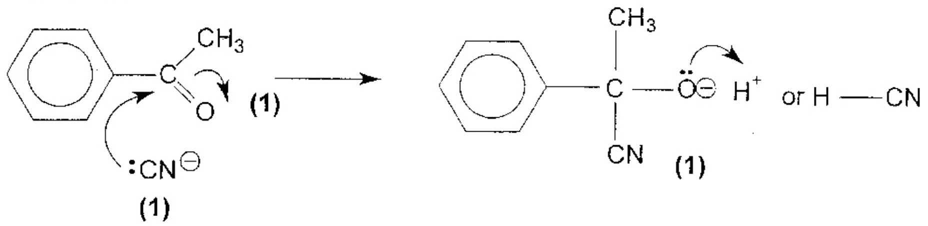
= 5.90×10^{-4} **(1)** mol dm^{-3} **(1)** or = 5.55 (or 5.54) $\times 10^{-4}$ **5**

the unit mark can be given in the expression for K_a

Total 18 marks

3 (a) (i) **Reagent**: ethanoyl chloride / CH_3COCl **(1)**
Conditions
step 1 **anhydrous** aluminium chloride/$AlCl_3$ (as catalyst) **or** anhydrous $FeCl_3$**(1)**
step 3 no $AlCl_3$ / catalyst **or** step 1 needs heating, step 3 does not **(1)** **3**

(ii) **Reagents**: potassium cyanide + named acid / potassium cyanide buffered between pH 6 to 8 / hydrogen cyanide + named base / hydrogen cyanide buffered between pH 6 to 8 / HCN + KCN **(1)** **1**
Names or full formulae acceptable
Mechanism:



Marks awarded for:
Curly arrow from C (**not** the minus) of ^{-}CN ion towards C of C=O **(1)**
Curly arrow from C=O bond to O atom **(1)**
Intermediate with its charge and a curly arrow from O (not the minus) to H^+ or to H of HCN **(1)** **3**

Type: nucleophilic addition **(1)** **1**

(iii) **Calculation:**
Amount of benzene = 10.0 g / 78 g mol^{-1} = 0.1282 mol **(1)**
Maximum amount of product = 0.1282 mol **(1)**
Maximum mass of product = 189 g mol^{-1} **(1)** x 0.1282 mol = 24.2(3) g
Yield = (3.00 / 24.23) x 100 = 12.4 % **(1)** **4**
Or by mole ratio
Moles benzene = 10.0/78 = 0.1282 **(1)**
Moles product = 3.00/189 = 0.01587 **(1)**
They react in 1:1 ratio **(1)**
Yield = 0.01587 x 100/0.1282 = 12.4% **(1)**
If the erratum had not been read out, the M_r of the product would be 177 g mol^{-1}, giving a yield of 13.2%
Explanation: Yield low because so many / 3 steps / side reactions at **each** step **(1)** **1**

(b) (i) Urea has δ+ H and / or δ- O and / or δ- N atoms **(1)**
so it can form hydrogen bonds with water **(1)**
to δ- O and / or δ+ H in water/diagram showing charges and dotted lines**(1)** **3**
Do not give all 3 marks unless the candidate has expressed their ideas clearly

(ii) Any **two** of:
Lowers pH **(1)**
Low % nitrogen **(1)**
(high osmotic pressure) can cause scorching of foliage **(1)**
leached out / very soluble **(1)** **2**

Total 18 marks

4 (a)

$K_c = \frac{[CO_2]\ [H_2]^4}{[CH_4]\ [H_2O]^2}$ **(1)**

Starting amounts:

CH_4 = 10 g / 16 g mol^{-1} = 0.625 mol
H_2O = 54 g / 18 g mol^{-1} = 3.0 mol } **(1)**

Equilibrium amounts:

CH_4 = 0.625 – ¼ x 2.0 = 0.125 mol **(1)**
H_2O = 3.0 – ½ x 2.0 = 2.0 mol **(1)**
CO_2 = 0.0 + ¼ x 2.0 = 0.500 mol **(1)**
H_2 = 2.0 mol (given)

Equilibrium concentrations:

above values ÷ 4 dm^3 **(1)** (mark consequentially)
$[CH_4]$ = 0.03125 mol dm^{-3}
$[H_2O]$ = 0.500 mol dm^{-3}
$[CO_2]$ = 0.125 mol dm^{-3}
$[H_2]$ = 0.50 mol dm^{-3}

$K_c = \frac{[CO_2]_{eq}\ [H_2]_{eq}^4}{[CH_4]_{eq}\ [H_2O]_{eq}^2} = \frac{0.125 \times 0.50^4}{0.03125 \times 0.500^2}$

= 1.0 (or 1 or 1.00) **(1)** mol^2 dm^{-6}**(1)** **8**

(b)

ΔH = (-394) – [(-76) + (2 x –242)] **(2)** *1 mark for x 2, 1 mark for signs and values*
= + 166 **(1)** kJ mol^{-1} **3**
-166 scores zero

(c)

A **catalyst** (of nickel) is used because the reaction, even at 750^{0}C, is too slow / to speed up the reaction **(1)**

Then any **six** of the following eight points:
a **temperature** of 750^{0}C is used:

- as the reaction is endothermic **(1)**
- a high temperature increases the value of the equilibrium constant **(1)**
- and so **increases** the equilibrium yield **(1)**
- a high temperature also favours a fast rate **(1)**
- but a temperature > 750 would be too expensive / cause engineering problems **(1)**

Temperature could score up to 5 but max 6 for T and P combined.
If their calculation in (b) gives an exothermic answer, mark consequentially [exothermic (1),decreases K_p (1), decreases yield (1) but faster rate(1), so 750 is compromise of fast rate and lower yield (1)]

A **pressure** of 30 atm is used

- even though the reaction goes from 3 to 5 gas moles / more gas moles of right of equation **(1)**
- causing a **decrease** in equilibrium yield **(1)**
- but a moderately high pressure is needed to push the gases through the plant **(1)** **7**

Ignore any reference to rate
Pressure could score up to 3 but max 6 for T and P combined.
Do not give all 7 marks unless the candidate has expressed their ideas clearly

Total 18 marks