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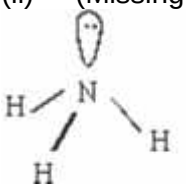
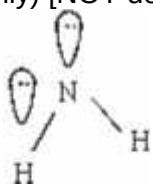
1. (a) (i) $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$
(or multiples)

1

(ii) (Missing 'H' penalise once only) [NOT dot-and-cross diagrams]





1

[NOT 90° / 180° angles] (need 2 lp & 'bent' shape)

1

(iii) 107°

1

(iv) More lone pairs on NH_2^-, than on NH_3

1

Lone pairs repel more than bonding pairs
Must be comparison
(Mark separately)
[NOT repulsion between atoms or between bonds]

1

(b) (i) Simplest ratio of atoms of each element in a compound / substance / species / entity / molecule

1

(ii)

	Mg	N	O
$\frac{16.2}{(24)}$	$\frac{16.2}{24.3}$	$\frac{18.9}{14}$	$\frac{64.9}{16}$
(0.675)	0.667	1.37	4.06
	1	2	6

MgN_2O_6

1

(Mark M1 first. If any wrong A_r used = CE = 0)
(Accept $Mg(NO_3)_2$ for M3 if above working shown)

1

[9]

2. (a) 242
Units not essential

1

(b) Bond is shorter or bonding pair closer to nucleus
Allow Cl is a smaller atom
Allow fewer electron shells
do not allow smaller molecules

1

So attraction (between nucleus and) (to) bond pair is stronger
Allow shared pair (or bonding electrons) held more tightly

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Mention of Cl^- loses M2

1

(c) Net attraction between the chlorine nucleus and the extra electron

Allow Cl^- ion more stable than Cl

1

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(d) (i) step 1 $Ag(s) \rightarrow Ag(g)$ only change

1

step 2 $Ag(s) \rightarrow Ag^{+}(g) + e^{-}$ only change

1

step 3 $\frac{1}{2}Cl_2(g) \rightarrow Cl(g)$ only change

This step can be first, second or third

1

(ii) 127 + 289 + 732 + 121 – 364

1

= 905 kJ mol^{-1}

–905 scores 1 mark only

1

(e) (i) Ions can be regarded as point charges (or perfect spheres)

Allow no polarisation

***OR** only bonding is ionic*

***OR** no covalent character*

1

(ii) Greater

Electronegativity argument or mention of intermolecular,

CE =0

1

Chloride ions are smaller than bromide

Mark independently but see above

1

They are attracted more strongly to the silver ions

Mark independently

1

(iii) AgCl has covalent character

Ignore reference to molecules

1

Forces in the lattice are stronger than pure ionic attractions

Allow stronger bonding OR additional/extra bonding

1

[15]

3. (a) Particles are in maximum state of order

(or perfect order or completely ordered or perfect crystal or minimum disorder or no disorder)

(entropy is zero at 0 k by definition)

1

(b) (Ice) melts

(or freezes or changes from solid to liquid or from liquid to solid)

1

(c) Increase in disorder

1

Bigger (at T_2)

1

Second mark only given if first mark has been awarded

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(d) (i) Moles of water = 1.53/18 (= 0.085)

1

Heat change per mole = 3.49/0.085 = 41.1 (kJ mol^{-1})
(allow 41 to 41.1, two sig. figs.)
(penalise –41 (negative value), also penalise wrong units but allow kJ only)

1

(ii) $\Delta G = \Delta H - T\Delta S$

1

(iii) $\Delta H = T\Delta S$ or $\Delta S = \Delta H/T$
(penalise if contradiction)

1

ΔS = 41.1/373 = 0.110 kJ K^{-1} (mol^{-1}) (or 110 (J K^{-1} (mol^{-1}))
(allow 2 sig. figs.)
(if use value given of 45, answer is 0.12 (or 120 to 121)
(if ΔH is negative in (d) (i), allow negative answer)
(if ΔH is negative in (d) (i), allow positive answer)
(if ΔH is positive in (d) (i), penalise negative answer)

1

Correct units as above (mol^{-1} not essential)

1

[10]

4. M1 equilibrium moles of CO = 62.8 - 26.2 = 36.6

1

M2 equilibrium moles of H_2 = 146 – 2(26.2) = 93.6

1

M3 total no moles = 36.6 + 93.3 + 26.2 = 156.4

1

M4 partial pressure = mole fraction x total pressure

1

$$K_p = \frac{PCH_3OH}{PCO \times P^2H_2}$$

M5

1

$$= \frac{\left(\frac{26.2}{156.4} \times 9.50\right)}{\left(\frac{36.6}{156.4} \times 9.50\right) \times \left(\frac{93.6}{156.4} \times 9.50\right)^2}$$

M6

$$\frac{(0.168 \times 9.5)}{(0.234 \times 9.50) \times (0.598 \times 9.5)^2}$$

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$$\frac{(1.59)}{(2.22)\times(5.69)^2}$$

1

M7 0.022(1) $2.2(l)\times10^{-8}$ $2.2(l)\times10^{-14}$

1

M8 MPa^{-2} kPa^{-2} Pa^{-2}

1

If no subtraction lose M1, M2 and M3)
(If ×2 missed in M2, lose both M2 and M3)
(If M1 gained but moles of H_2 = 73.2 (i.e. double CO), M2 and M3 lost)
(If M1 gained but mol H_2 = 2(146 – 26.2), M2 and M3 lost)
(If M1 and M2 correct but M3 lost for CE, penalise M6 also)
(M4 can be gained from the numbers in the expression for M6 even if these numbers are wrong)
(If K_p contains [ ] lose M5 but then mark on)
(If chemically wrong expression for K_p, lose M5, M6 and M7 (allow M8 conseq on their K_p))
(If divided by 9.5, or not used 9.5 at all, lose M6 and M7 (and M4))
(If tried to convert to kPa and is factor(s) of 10 out, penalise in M6 and allow M8 for kPa^{-2})

[8]

5. (a) $pH = -\log[H^+]$

1

$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or $[H^+]=[A^-]$

1

$[H^+] = 1.74 \times 10^{-5} \times 0.15$ (or 1.62×10^{-3})

1

pH = 2.79 (penalise 1 dp or more than 2dp once in the qu)

1

(b) (i) Solution which resists change in pH /maintains pH

1

despite the addition of (small amounts of) acid/base (or dilution)

1

(ii) $CH_3COO + H^+ \quad CH_3COOH$

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must show an equation full or ionic in which ethanoate ions are converted to ethanoic acid

1

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MEGA LECTURE

$$[H^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]}$$

(c) (i) if rearrangement incorrect, no further marks

1

$$= 1.74 \times 10^{-5} \times \frac{0.15}{0.10}$$

1

$(= 2.61 \times 10^{-5})$

pH = 4.58

1

(ii) Ml moles H^+ added = $10 \times 10^{-3} \times 1.0 = 0.01$

1

M2 moles ethanoic acid after addition = 0.15 + 0.01 = 0.16

1

M3 moles ethanoate ions after addition = 0.10 -0.01 = 0.09

1

$$[H^+] = \frac{K_a[CH_3COOH]}{[CH_3COO^-]} = 1.74 \times 10^{-5} \times \frac{0.16/V}{0.09/V}$$

M4

1

$(= 3.09 \times 10^{-5})$

M5 pH = 4.51

The essential part of this calculation is addition/subtraction of 0.01 moles to gain marks M2 and M3. If both of these are missing,
only mark M1 is available. Thereafter treat each mark independently,
except if the expression in M4 is wrong, in which case both M4 and M5 are lost.

1

[15]

alternative scheme for part (c)(i)

$$\text{pH } pK_a - \log \frac{[CH_3COOH]}{[CH_3COO^-]}$$

1

$pK_a = 4.76$

1

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$$pH = (4.76 - \log\frac{0.15}{0.10}) = 4.58$$

1

alternative for penultimate mark of part (c)(ii)

$$pH = 4.76 - \log\frac{0.16}{0.09}$$

1

6. Penalise pH given to 1 dp first time it would have scored only

(a) (i) $K_w = [H^+]\,[OH^-]$ **(1)**

(ii) $pH = -\log [H^+]$ **(1)**

or in words or below unless contradiction

(iii) *Calculation*: $[H^+] = \sqrt{5.48 \times 10^{-14}}$ **(1)**

$= 2.34 \times 10^{-7}$

$\therefore$ pH = 6.63 or 6.64 **(1)**

Explanation: pure water $\therefore$ $[H^+] = [OH^-]$ **(1)**

5

(b) (i) $[OH^-] = 0.150$ $\therefore$ $[H^+] = 10^{-14}/0.15 = 6.66 \times 10^{-14}$

or pOH = 0.82

$\therefore$ pH = 13.18 **(1)**

or pH= 13.17

(ii) moles OH^- = $(35 \times 10^{-3}) \times 0.150 = 5.25 \times 10^{-3}$ **(1)**[a]

moles H^+ = $(40 \times 10^{-3}) \times 0.120 = 4.8(0) \times 10^{-3}$ **(1)**[b]

$\therefore$ excess moles of OH^- = 4.5×10^{-4} **(1)**[c]

$\therefore$ $[OH^-] = (4.5(0) \times 10^{-4}) \times 1000/75$[d] **(1)**[e]

$= 6.0(0) \times 10^{-3}$

$[H^+] = \frac{10^{-14}}{6.00 \times 10^{-3}} = 1.66 \times 10^{-12}$ or pOH = 2.22

$\therefore$ pH = 11.78 **(1)**[f]

or 11.77

8

(c) (i) $K_a = \frac{[H^+][X^-]}{[HX]}$ **(1)**

(ii) $[H^+] = 1.80 \times 10^{-2} \times 0.150 = 2.70 \times 10^{-3}$ (1)

$K_a = \frac{[H^+]^2}{[HX]}(1) = \frac{(2.70 \times 10^{-3})^2}{0.150} = 4.86 \times 10^{-5}$ **(1)** mol dm^{-3} **(1)**

or $\frac{(2.70 \times 10^{-3})^2}{0.1473} = 4.95 \times 10^{-5}$

5

Notes

(a) If K_w includes H_2O allow 6.63 if seen otherwise no marks likely

(b) (ii) If no vol, max 4 for a, b, c, f answer = 10.65

If wrong volume max 5 for a, b, c, e, f

If no substraction max 3 for a, b, d

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MEGA LECTURE

If missing 1000 max 5 for a, b, c, d, f answer = 8.78
If uses excess as acid, max 4 for a, b, d, f answer = 2.22
If uses excess as acid and no volume, max 2 for a,
b answer = 3.35

(c) If wrong K_a in (i) max 2 in part (ii) for $[H^+]$ **(1)** and conseq units **(1)**
but mark on fully from minor errors
eg no [ ] or charges missing

[18]

7. (a) C **1**

A **1**

D **1**

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MEGA LECTURE

(b) (i) Bromocresol green

Allow wrong spellings

1

(ii) Purple to yellow

Must have both colours:
Purple start – yellow finish

1

[5]

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