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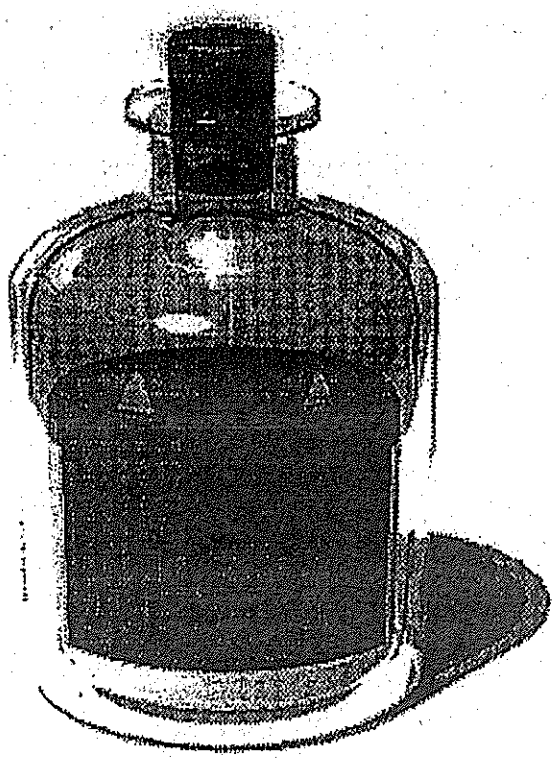
Chemistry

2006 TEE Solutions*



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*These solutions are not a marking key. They are a guide to the possible answers at a depth that might be expected of Year 12 students. It is unlikely that all possible answers to the questions are covered in these solutions.

CHEMISTRY

Tertiary Entrance Examination 2006 Solutions

PART 1: MULTIPLE CHOICE (60 Marks)

1. D	6. A	11. D	16. D	21. B	26. B
2. A	7. D	12. C	17. C	22. A	27. C
3. C	8. B	13. B	18. A	23. A	28. B
4. D	9. A	14. C or D	19. C	24. A	29. C
5. D	10. D	15. C	20. B	25. B	30. A

PART 2: SHORT ANSWER (70 Marks)

1. 1 mark is deducted for each error in the equation. State symbols are not required for full marks. The bulk of the observations must be provided for the full mark.

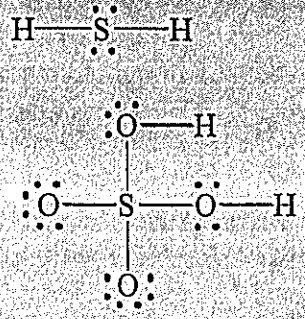
(a) $3Ba^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ba_3(PO_4)_2(s)$ (2 marks)
Two colourless solutions react to form a white precipitate (1 mark)

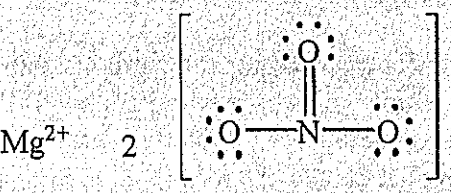
(b) No reaction (2 marks)
No visible reaction (NVR) or No change observed (1 mark)
(Both answers must be provided for full marks)

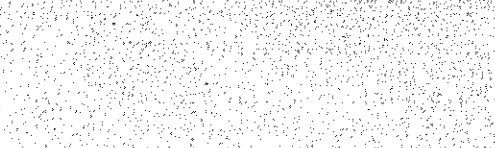
(c) $2Br^-(aq) + Cl_2(g) \rightarrow Br_2(aq \text{ or } l) + 2Cl^-(aq)$ (2 marks)
Greenish gas is bubbled through colourless solution which turns reddish brown (1 mark)

(d) $2MnO_4^-(aq) + 10Cl^-(aq) + 16H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5Cl_2(g \text{ or } aq) + 8H_2O(l)$ (2 marks)
Deep purple colour fades. Pungent odour of chlorine. Effervescence may be seen. Pungent green gas evolved (2 observations adequate for the mark) (2 marks)

2. 2 marks for each correct structural formula. 1 mark is lost overall if brackets are left off, if charge is left off ions and if lone electrons pairs are missing from any structures.







(2 marks each)

3. CO_2, SO_3, NH_3, H_2O, CCl_4 (2 marks)

NH_3, H_2O (2 marks)

CO_2, N_2, Cl_2 (2 marks)

4. In order to change phase sufficient energy must be available to break the intermolecular forces holding molecules together.
Methane is a non-polar molecule and the only form of intermolecular forces present are dispersion forces.
Water is a polar molecule and the intermolecular forces present between the molecules are hydrogen bonds and dispersion forces. These intermolecular forces are significantly stronger than those holding methane molecules together and so more energy is required to break them. As a result water will change phase at a much higher temperature than methane. (3 marks)

5. The hydrogencarbonate ion can act as a base. They consume hydrogen ions and hydroxide ions are produced which raises the pH of the water in the pool.
$H_2O(l) + HCO_3^-(aq) \rightarrow OH^-(aq) + H_2CO_3(aq)$
or
$H_3O^+(aq) + HCO_3^-(aq) \rightarrow H_2O + H_2CO_3(aq)$
or
$H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$ (3 marks)

6. Note: equations are not necessary for full marks if a sufficient explanation is given. One mark for each step.

Hot concentrated sodium hydroxide dissolves the alumina (as it is amphoteric) and partly separates it from other components like iron oxide which remain behind.
$Al_2O_3(s) + 2OH^-(aq) + 3H_2O(l) \rightarrow 2Al(OH)_4^-(aq)$

On cooling, the solubility of the aluminium hydroxide is decreased (or the solution becomes supersaturated)

Pure $Al(OH)_3$ is added to seed growth of aluminium hydroxide crystals
$Al(OH)_4^-(aq) \rightarrow Al(OH)_3(s) + OH^-(aq)$

In the final step water is driven off to give alumina as the product.
$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(g)$

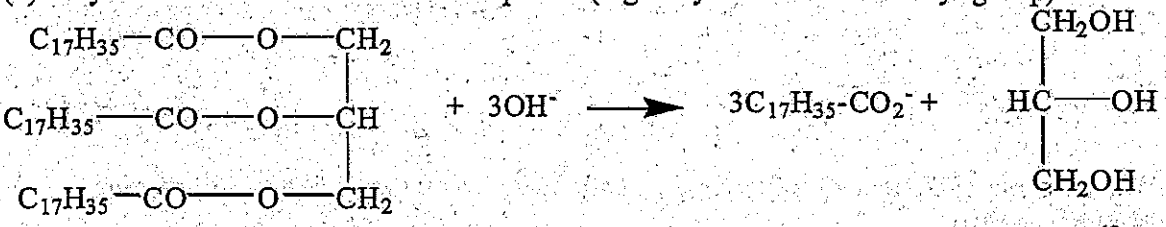
(4 marks)

7. 1 mark is deducted for each error, such as an unbalanced or wrongly balanced equation. 1 mark is deducted if the equation is not ionic.

(a) $2Cs(s) + 2H_2O(l) \rightarrow 2Cs^+(aq) + 2OH^-(aq) + H_2(g)$ (2 marks)

(b) No reaction (2 marks)

8. (a) Any reasonable fat structure is acceptable (e.g. may use 'R' as the alkyl group)



(2 marks)

(b) Soap provides long-chain carboxylate ions such as state. The non-polar carbon chains embed themselves in fatty deposits which break away as droplets (micelles) with the negative ends of the carboxylate ions linking by H-bonding with the water. (A diagram could also be included)
(2 marks)

(c) In the presence of calcium and magnesium ions (the cause of hard water) soaps will precipitate and are unavailable to clean. Detergents do not precipitate with such ions and are therefore are still able to clean in hard water. (2 marks)

9. (a) $K = \dfrac{[HOCl][H^+][Cl^-]}{[Cl_2]}$ (2 marks)

(b)

Change made to the system	Effect on rate of forward reaction	Effect on equilibrium yield of HOC! (aq)
Increase the partial pressure of C! 2(aq)	Increase	Increase
Increase the temperature of the system	Increase	Increase
Acidify the system by the addition of nitric acid	No effect OR increase	Decrease
Add a suitable catalyst	Increase	No effect

(1 mark for each correct entry)

10. Note: A reasonable diagram is required for full marks.

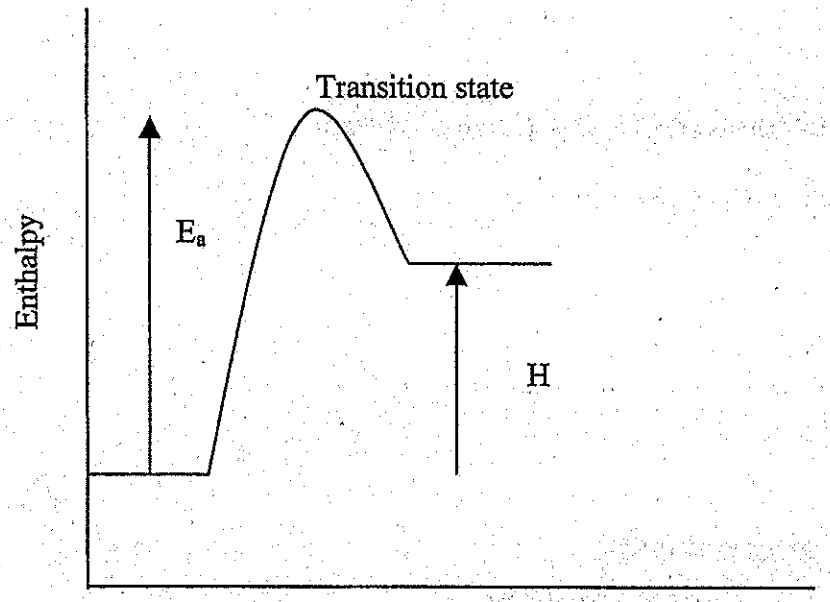
Covalent bonds (from sharing of electrons) between the two iodine atoms in a molecule lead to the existence of the I_2 molecule. Dispersion forces (due to the attraction between temporary dipoles) hold the molecules together to form the solid crystals of $I_2(s)$

(3 marks)

11. (a) $NH_4NO_3(s)$! $NH_4^+(aq) + NO_3^-(aq)$. (1 mark)

(b) The contents of the beaker become cooler. Condensation may appear on the side of the beaker (only one observation is necessary for the mark) (1 mark)

(c)



(1 mark each for shape of graph, activation energy, transition state and H)

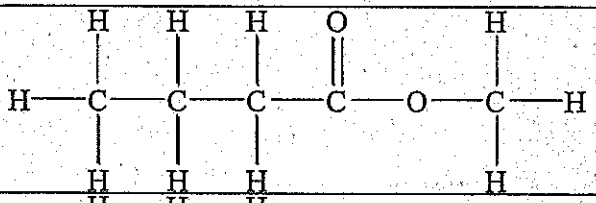
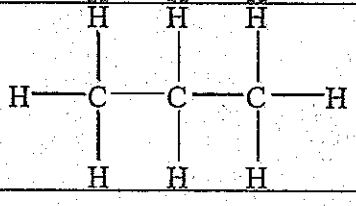
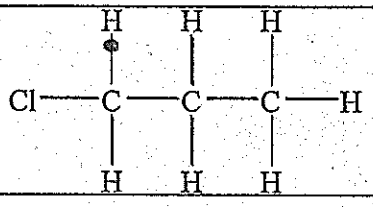
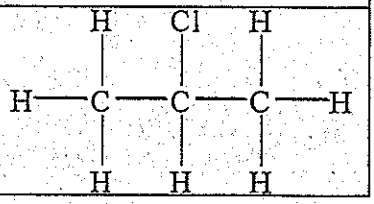
12. The species at the equivalence point are Na^+ and CH_3COO^-. Na^+ does not react with water, but CH_3COO^- acts as a weak base and produces OH^- on reaction with water. The presence of excess OH^- in solution produces a pH of greater than 7. Methyl orange changes colour at 4 – 5, which is not the equivalence point.

$CH_3CHOO^- + H_2O \quad CH_3COOH + OH^-$

(an equation was not required for full marks)

(3 marks)

13.

Reaction	Structural formula
Acidified butanoic acid is added to methanol and heated	
Hydrogen gas is bubbled through but-2-ene	
Acidified potassium dichromate is added to ethanol	or
Chlorine gas is added to excess propane and exposed to UV light	 or 

(1 mark each)

1 mark is deducted if hydrogens are missing.

PART 3: CALCULATIONS (50 Marks)

1 mark is deducted per question for inappropriate number of significant figures.

1. (a) $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

(1 mark)

(b)

$$n(Cu) = \frac{4.56}{63.55}$$

$$= 7.175 \times 10^{-2} \text{ mol}$$

$$n(HNO_3) = 5.55 \times 0.1200$$

$$= 0.666 \text{ mol}$$

1 mole of Cu would require 4 moles of HNO_3

7.175×10^{-2} mol of Cu would require 0.2870 mol HNO_3

The number of moles of HNO_3 required is less than number of moles available, therefore Cu is LR.

(4 marks)

(c) $n(NO_2) = 2 \times n(Cu)$

$= 2 \times 7.175 \times 10\text{-}2$

$= 0.1435 \text{ mol } NO_2$

$$V(NO_2) = \frac{0.1435(8.315)(301.1)}{99.7}$$

$= 3.602 \text{ L}$

(2 marks)

(d) $n(HNO_3)$ remaining = $n(HNO_3)$ initial – $n(HNO_3)$ reacted

$= 0.666 - 0.2870$

$= 0.379 \text{ mol } HNO_3$

(2 marks)

2. (a) $$n(SO_2) = n(S) = \frac{1000000}{32.06}$$

$$= 3.119 \times 10^4 \text{ mol}$$

$$V(SO_2) = 3.119 \times 10^4 \times 22.41 \times \frac{873.1}{273.1}$$

$$= 2.235 \times 10^6 \text{ L } SO_2$$

(3 marks)

(b) $n(SO_3) = 0.95 \times n(SO_2)$

$= 0.95 \times 3.119 \times 10^4$

$= 2.963 \times 10^4 \text{ mol}$

$m(SO_3) = 2.963 \times 10^4 (80.06)$

$= 2.372 \times 10^6 \text{ g of } SO_3$

(2 marks)

(c) (i) If sulfuric acid used is recycled from last step:

$n(H_2S_2O_7) = \rightarrow n(SO_3)$

$= ! \ (2.963 \times 10^4)$
$= 1.482 \times 10^4$ mol
$m(H_2S_2O_7) = 1.482 \times 10^4 (178.136)$
$= 2.639 \times 10^6$ g

(c) (ii) If sulfuric acid in this step is added:
$n(H_2S_2O_7) = n(SO_3) = 2.963 \times 10^4$ mol
$m(H_2S_2O_7) = 2.963 \times 10^4 (178.136)$
$= 5.278 \times 10^6$ g

(2 marks)

(d) (i) $n(H_2SO_4) = 2 \times n(H_2S_2O_7) = n(SO_3)$
$= 2.963 \times 10^4$ mol

$$V(H_2SO_4) = \frac{2.963 \times 10^4}{8.50}$$

$= 3.486 \times 10^3$ L

(d) (ii) $n(H_2SO_4) = 2 \times n(H_2S_2O_7)$
$= 2 \times 2.963 \times 10^4$
$= 5.926 \times 10^4$ mol

$$V(H_2SO_4) = \frac{5.926 \times 10^4}{8.50}$$

$= 6.972 \times 10^3$ L

(2 marks)

3. (a) $Ag^+(aq) + e^- \ ! \ Ag(s)$

$$n(e^-) = n(Ag) = \frac{4.50}{107.9}$$

$= 0.04171$ mol

$Cu^{2+}(aq) + 2e^- \ ! \ Cu(s)$
$n(Cu) = ! \ n(e^-)$
$= 0.02085$ mol
$m(Cu) = 63.55(0.02085)$
$= 1.325$ g

(5 marks)

(b) Oxygen
$2H_2O(l) \ O_2(g) + 4H^+(aq) + 4e^-$

(2 marks)

(c) $n(O_2) = " \ n(e^-)$
$= 0.01043$ mol
At STP $V(O_2) = 0.01043 \times 22.41$
$= 0.2337$ L for one cell
$V(O_2) = 0.4674$ L for two cells (answer for one or two cells equally acceptable)

(2 marks)

(d) $Q = n(e^-) \times F$
$= 0.04171(9.649 \times 10^4)$
$= 4025$ C

$$I = \frac{Q}{t}$$

$$= \frac{4025}{126 \times 60 \text{ s}}$$

$= 0.5324$ A

(2 marks)

4. (a) There are several different methods by which the answer can be determined. The method given here uses percentages. This also could be done with masses.

$$\%C = \frac{12.01}{48.01} x \frac{3.44}{3.45} x100$$
$$= 27.2\%$$

$$\%H = \frac{2 x 1.008}{18.016} x \frac{1.06}{3.45} x100$$
$$= 3.44\%$$

$$\%Ni = \frac{56.89}{88.95} x \frac{1.20}{2.33} x100$$
$$= 33.3\%$$

$$\%O = 100 - (33.3 + 3.44 + 27.2)$$
$$= 36.06\%$$

	C	H	O	Ni
g in 100 g	27.2	3.44	36.06	33.3
n	$\frac{27.2}{12.01}$ = 2.265	$\frac{3.44}{1.008}$ = 3.143	$\frac{36.06}{16.00}$ = 2.254	$\frac{33.3}{58.69}$ = 0.5674
Ratio	$\frac{2.265}{0.5674}$	$\frac{3.143}{0.5674}$	$\frac{2.254}{0.5674}$	$\frac{0.5674}{0.5674}$
	3.992	6.015	3.972	1
Round	4	6	4	1

EF = $C_4H_6O_4Ni$

(8 marks)

$$M = \frac{m}{n}$$

(b) $$= \frac{5.32}{3.00 x 10^{-2}}$$
$$= 177.32 \text{ g mol}^{-1}$$

$EF(C_4H_6O_4Ni) = (4 \times 12.01) + (6 \times 1.008) + (4 \times 16.00) + 58.69$
$= 176.8 \text{ g mol}^{-1}$

MF = EF

(2 marks)

5. (a) $2MnO_4^-(aq) + 5H_2C_2O_4(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$

(2 marks)

(b)

	1	2	3	4
Final volume	29.4	26.45	27.30	24.60

Initial volume	2.6	3.20	4.35	1.50
Titre	**26.8**	**23.25**	**22.95**	**23.10**

Average titre $= \frac{23.25 + 22.95 + 23.10}{3}$ (24.03 is an outlier)

$= 23.10$ mL

$n(H_2C_2O_4)$ reacting with 20.0 aliquot $= 0.0504 \times 0.02310$

$= 1.164 \times 10^{-3}$ mol

Therefore, $n(MnO_4^-)$ remaining in 20.0 mL aliquot $= 2/5 n(H_2C_2O_4)$

$= 2/5 \times 1.164 \times 10^{-3}$

$= 4.657 \times 10^{-4}$ mol

Therefore $n(MnO_4^-)$ in 250.0 mL $= \frac{250}{20} x4.657x10^{14}$

$= 5.821 \times 10^{-3}$ mol

$n(MnO_4^-$ consumed by ethanol$) = n(MnO_4^-$ initial$) - n(MnO_4^-$ remaining$)$

$= (0.255 \times 0.100) - 5.821 \times 10^{-3}$

$= 0.01968$ mol

Therefore $n(CH_3CH_2OH)$ in 8.00 mL aliquot of wine = consumed $n(MnO_4^-) \times \frac{5}{4} = 0.01968 x \frac{5}{4}$

$= 0.02460$ mol

$[CH_3CH_2OH] = \frac{0.02460}{0.00800}$

$= 3.08$ mol L^{-1}

(8 marks)

$[CH_3CH_2OH] = 3.075 \times 46.068$

$= 142$ g L^{-1}

PART 4: EXTENDED RESPONSE (20 marks)

In general for full marks an essay should be a minimum of 1 ! to 2 pages and

- Demonstrate sound understanding of chemistry
- On the topic given
- Written in reasonable English
- With some reasoning shown
- With a beginning, middle and end
- Either no errors, or errors which are trivial.

Conditions for the production of methanol must be discussed with reference to rates and equilibrium. Properties and uses must also be discussed. There is no requirement for these two sections to be equal.

Production

There are a number of steps involved in the production of methanol. The factors that result in a faster rate for each step must be discussed.

Equations

$CH_4(g) + H_2O(g)$! $CO(g) + 3H_2(g)$ step 1

$CO(g) + H_2(g)$! $CH_3OH(g)$ step 2

For both processes

high pressure (increases concentration and therefore number of collisions per unit time),

high temperature (more particles have sufficient energy to react and will be moving faster and so will collide more often)
excess reactants (increase in concentration) and
use of catalyst (alternative reaction pathway with lower activation energy provided so more collisions will be successful) will result in faster reaction rate.
This should be contrasted with the factors that result in a high yield.
For step 1 high yield would be favoured by low pressure (favours side with greater number of gas particles), high temperature (as reaction is endothermic). Yield and rate are favoured by high temperature, however, the pressure conditions are opposing. High pressures are also expensive, the pressure of the reaction would be a compromise.
For step 2, high pressure will favour both yield and rate, while temperature requires a compromise.

Properties and Uses

Physical properties of methanol such as its relatively high melting and boiling point for its molecular size and its miscibility in water needs to be discussed in terms of hydrogen bonding (the inclusion of a diagram would be appropriate here). Methanol's miscibility in water also explains why water can be used to put out methanol fires. The miscibility of methanol in ethanol to form methylated spirits should also be discussed in terms of intermolecular forces.
Methanol's role as antifreeze should be discussed in terms of colligative properties.
Equations should be written for the chemical properties described, e.g.
Combustion: $CH_3OH + O_2$! $CO_2 + H_2O$
Formation of formic acid CH_3OH + (oxidising agent) ! CHOOH
Other reactions of alcohols such as reaction with sodium could also be discussed and equations included.