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Chemistry

2000 TEE Solutions*

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Science Teachers' Association of
Western Australia (Inc).
PO Box 1099
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The Curriculum Council
27 Walters Drive
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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.

 STAWA appreciates the support of the Curriculum Council, which provided the marker's guides used a basis for these solutions.

TEE Chemistry 2000 Solutions

Part 1

1. c	6. b	11. b	16. b	21. a	26. d
2. d	7. d	12. b	17. c	22. a	27. d
3. c	8. d	13. a	18. d	23. a	28. c
4. a	9. b	14. d	19. b	24. b	29. b
5. a	10. (deleted)	15. d	20. b	25. d	30. d

For Parts 2 and 3, the answers have been prepared according to the following guidelines:

- We have tried to prepare a set of model answers. As such we have not attempted to cover all possibilities and thus clutter the document with qualifications. The aim has been to produce one set of answers that a good student could aspire to.
- In most cases, only one answer has been given even when other answers are correct.
- In the calculations, a method of working has been used which emphasises reasoning. The answers given here are modelled on approaches adopted by students where their schools have been conspicuously successful in public examinations.

Part 2

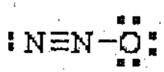
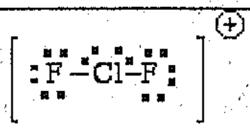
1. (a) $NaOH\ (s) + H^+\ (aq) \rightarrow Na^+\ (aq) + H_2O\ (l)$
White solid dissolves to give a colourless solution.

(b) No reaction
No visible reaction.

(c) $CH_3CH_2COOH\ (aq) + OH^-\ (aq) \rightarrow CH_3CH_2COO^-\ (aq) + H_2O\ (l)$
Loss of vinegary smell.

(d) $2\ CrO_4^{2-}\ (aq) + 2\ H^+\ (aq) \rightarrow Cr_2O_7^{2-}\ (aq) + H_2O\ (l)$
Yellow solution turns to orange.

2.

Species	Structural formula	Shape
Dinitrogen monoxide, NNO		linear
Difluorochlorine(I) cation, ClF_2^+		bent

3.

Hydrogen Bonding	Dipole-dipole interactions	Dispersion forces
NH_3, H_2O, CH_3COOH	H_2S, CH_3CHO	Cl_2

4. NH_4Cl (ammonium chloride)
SO_2 (sulfur dioxide)
CH_3CH_2COOH (propanoic acid)
$CH_3CHCHCH_3$ (2-butene)
Cyclobutene (any cyclic compound containing double bond)
Propan-2-ol etc. (any secondary alcohol)
Hg, Br_2 (mercury, bromine)

Note: there are many different possible answers for question 4.

5. (a) Can be obtained pure and can be obtained dry (not hydroscopic). Stable, doesn't decompose, has high molecular weight.

(b) In general, most substances do not have the above properties. The primary standard provides a solution of *known* concentration and hence a starting point for analysing solutions.

6. What is done: Colourless odourless liquid added to green solid.

Observation: Green solid dissolves, evolution of colourless odourless gas leaving green solution.

$NiCO_3\,(s) + 2\,H^+\,(aq) \rightarrow Ni^{2+}\,(aq) + CO_2\,(g) + H_2O\,(l)$

(iron(II) carbonate and chromium(III) carbonate could also be accepted).

What is done: Excess of a solution with pH of about 9 is added to a blue solution.

Observation: First a light blue precipitate forms.

$Cu^{2+}\,(aq) + 2\,NH_3\,(aq) + 2\,H_2O\,(l) \rightarrow Cu(OH)_2\,(s) + 2\,NH_4^+\,(aq)$

Observation: Light blue precipitate then dissolves and a deep blue solution forms.

$Cu(OH)_2\,(s) + 4NH_3\,(aq) \rightarrow Cu(NH_3)_4^{2+}\,(aq) + 2\,OH^-\,(aq)$

OR

$Cu(OH)_2\,(s) + 2NH_3\,(aq) + 2\,NH_4^+\,(aq) \rightarrow Cu(NH_3)_4^{2+}\,(aq) + H_2O\,(l)$

7 For $K_w = 4.8\times10^{-13}$ at 95°, $[H^+] = [OH^-] = 6.9\times10^{-7}$ mol $L^{-1} > 1\times10^{-7}$ mol L^{-1} (equilibrium constant changes with temperature).

Water at 95° is neutral, since $[H^+] = [OH^-]$.

8.

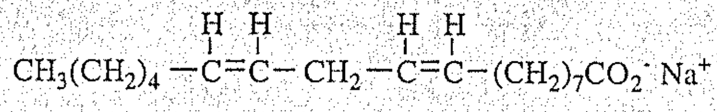
	What happens to total pressure?	What happens to the partial pressure of CO?	What happens to the equilibrium position?
System is heated above 300°C	increase	increase	move to the right
More $CH_4(g)$ is injected into the box (at 300°C)	increase	increase	move to the right
Ne(g) in injected into the box (at 300°C)	increase	no change	no change
The volume of the box is halved	increase	increase	move to the left

9. $K = \dfrac{[Fe(H_2O)_6^{3+}][NCS^-]}{[Fe(H_2O)_5NCS^{2+}]}$

$K = \dfrac{[Cl_2][NO]^2}{[NOCl]^2}$

10. (a) Br
(b) H_2Te
(c) Rb, Ra
(d) H_2TeO_4
(e) Rh
(f) Rb_2SO_4
(g) RaO, Rb_2O etc.

11. (a)



and CH_3OH

(b)

— $OCH_2CH_2CH_2CH_2$ —— $OOCCH_2CH_2CH_2COO$——

(c) condensation polymerisation

12. (a) An increase in molecular weight (or surface area or number of electrons) results in an increase in the dispersion intermolecular forces.

(b) The relatively high boiling point of NH_3 is a result of the stronger hydrogen bonding intermolecular forces which exist between the NH_3 molecules.

Part 3

1. (a) $CaCO_3\,(s) + 2\,H^+ \rightarrow Ca^{2+} + CO_2 + H_2O$

(b)

MWt of $CaCO_3$	$= (40.08 + 3\times16.00 + 12.01)$
	$= 100.09$
m($CaCO_3$ reacted)	$= 0.6342 - 0.392$
	$= 0.2422$ g
n($CaCO_3$)	$= \dfrac{0.2422}{100.09}$
	$= 0.0024198$ mol
n(HCl) = n(H^+)	$= 2\times$ n($CaCO_3$)
	$= 0.0048396$ mol
c(HCl)	$= \dfrac{0.0048396}{0.02500}$
	$= 0.194$ mol L^{-1} (0.1936 mol L^{-1})

2. (a)

$C_xH_yO_z$	$\rightarrow$	CO_2	+	H_2O
1.0640 g		1.462 g		0.894 g

m(C)	$= 1.462 \times \dfrac{12.01}{44.01}$
	$= 0.3990$ g
m(H)	$= 0.894 \times \dfrac{2\times1.008}{18.016}$
	$=0.1000$ g
m(Si)	$= 0.832 \times \dfrac{28.09}{60.09}$
	$= 0.3889$ g
$\therefore$ m(O)	$= 1.0640 - (0.3990 + 0.1000 + 0.3889)$
	$= 0.1761$ g

	C	H	Si	O
mass (g)	0.3990	0.1000	0.3889	0.1761
÷ At Wt	12.01	1.008	28.09	16.00
= (mol)	0.03322	0.09925	0.01385	0.01101
÷ smallest no (0.01101)	3.017	9.015	1.258	1
×4	12.07	36.06	5.03	4
Round	12	36	5	4

ie Empirical Formula = $C_{12}H_{36}Si_5O_4$

(b) m('A') $= 0.0138$ g

n('A') $= \dfrac{PV}{RT} = \dfrac{2.0 \times 0.067}{8.315 \times (150 + 273)}$

$= 3.810 \times 10^{-5}$ mol

MWt ('A') $= \dfrac{0.0138}{3.810 \times 10^{-5}}$

$= 362$ g

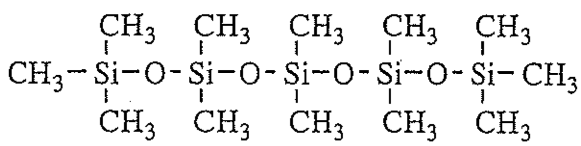
(c) MWt of $C_{12}H_{36}Si_5O_4$ $= (12 \times 12.01) + (36 \times 1.008) + (5 \times 28.09) + (4 \times 16)$

$= 384.86$

≈ 362

$\therefore$ Molecular formula = empirical formula = $C_{12}H_{36}Si_5O_4$

(d)



or similar.

3. (a) $2NiO(OH) + 2\,H_2O + Cd \rightarrow 2\,Ni(OH)_2 + Cd(OH)_2$

(b) $E^\circ = 0.64 - (-0.76)$

$= 1.40\ V$

(c) $n(Cd) = \dfrac{1.420}{112.4}$

$= 0.012633\ mol$

$n(NiO(OH)) = 2 \times n(Cd)$

$m(NiO(OH)) = 2 \times 0.012633 \times (58.69 + 2 \times 16 + 1.008)$

$= 2.32\ g$

(d) $n(e^-) = 2 \times n(Cd)$

For 95% consumption:

$q = n(e^-) \times 9.649 \times 10^4$

$= 0.95 \times 2 \times 0.012633 \times 9.649 \times 10^4$

$= 2.32 \times 10^3\ C$

(e) $q = I \times t$

$t = \dfrac{2.32 \times 10^3}{0.150}$

$= 1.544 \times 10^4\ s$ (4.29 hours)

(f) Cd is a toxic metal

4. (a) $2\,Cr_2O_7^{2-} + 16\,H^+ + 3\,CH_3CH_2OH \rightarrow 4\,Cr^{3+} + 11\,H_2O + 3\,CH_3COOH$

(b) $n(Cr_2O_7^{2-})$ added $= 0.1005 \times \dfrac{25.00}{1000}$

$= 2.513 \times 10^{-3}\ mol$

(c) $n(Fe^{2+})$ used $= 0.3005 \times \dfrac{23.55}{1000}$

$= 7.0768 \times 10^{-3}\ mol$

$n(Cr_2O_7^{2-})$ excess $= n(Fe^{2+}) \times \dfrac{1}{6}$

$= 1.179 \times 10^{-3}\ mol$

(d) $n(Cr_2O_7^{2-})$ combined $= n(Cr_2O_7^{2-})$ added - $n(Cr_2O_7^{2-})$ excess

$= 2.5125 \times 10^{-3} - 1.179 \times 10^{-3}$ mol

$= 1.3330 \times 10^{-3}$ mol

(e) $n(CH_3CH_2OH)$ $= n(Cr_2O_7^{2-})$ combined $\times \frac{3}{2}$

$= 1.9996 \times 10^{-3}$ mol

$m(CH_3CH_2OH)$ $= 1.9996 \times 10^{-3} \times (2 \times 12.01 + 6 \times 1.008 + 16)$

$= 0.092116$ g in 1.00 mL

$= 9.21$ g in 100 mL $(0.0921 \times \frac{100}{1})$

5. (a) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

(b) $n(SO_4^{2-})$ $= n(BaSO_4)$

$$= \frac{0.218}{(137.3 + 32.06 + 4 \times 16.00)}$$

$= 9.342 \times 10^{-4}$ mol

$n(K_2SO_4)$ $= n(SO_4^{2-})$

$m(K_2SO_4)$ $= 9.342 \times 10^{-4} \times (2 \times 39.10 + 32.06 + 4 \times 16.00)$

$= 0.1628$ g in 25.00 mL

$= 1.63$ g in 250.00 mL $(0.1628 \times \frac{250.00}{25.00})$

(c) $Pb^{2+} + SO_4^{2-} \rightarrow PbSO_4$

$Pb^{2+} + 2\,I^- \rightarrow PbI_2$

(d) $n(PbSO_4)$ $= n(SO_4^{2-})$ in 25.00 mL

$= 9.342 \times 10^{-4}$ mol

$m(PbSO_4)$ $= 9.342 \times 10^{-4} \times (207.2 + 32.06 + 4 \times 16.00)$

$= 0.2833$ g

$m(PbI_2)$ $= m(total) - m(PbSO_4)$

$= 0.607 - 0.2833$

$= 0.3237$ g

$n(KI) = n(I^-)$ $= 2 \times n(PbI_2)$

$$= 2 \times \frac{0.3237}{(207.2 + 2 \times 126.9)}$$

$= 1.404 \times 10^{-3}$ mol

$$m(KI) = 1.404 \times 10^{-3} \times 166.0$$
$$= 0.233 \text{ g in the 25.00 mL sample}$$
$$= 2.33 \text{ g in 250.00 mL } (0.233 \times \frac{250.00}{25.00})$$

Part 4

This section is designed to give you the opportunity to demonstrate what you know rather than what you do not know. Hence there is no one model answer. Several students could write quite different essays and yet could all score full marks.

Clear setting out and logical order are important, as is clear and concise English expression. Ideally you should include a brief introduction and conclusion.

In general, for full marks you need to write 2 pages of:
- good chemistry
- on the topic given
- written in reasonable English
- with reasoning, relating evidence and theory - reasoning and argument are important
- with a beginning, middle, and an end

Q1

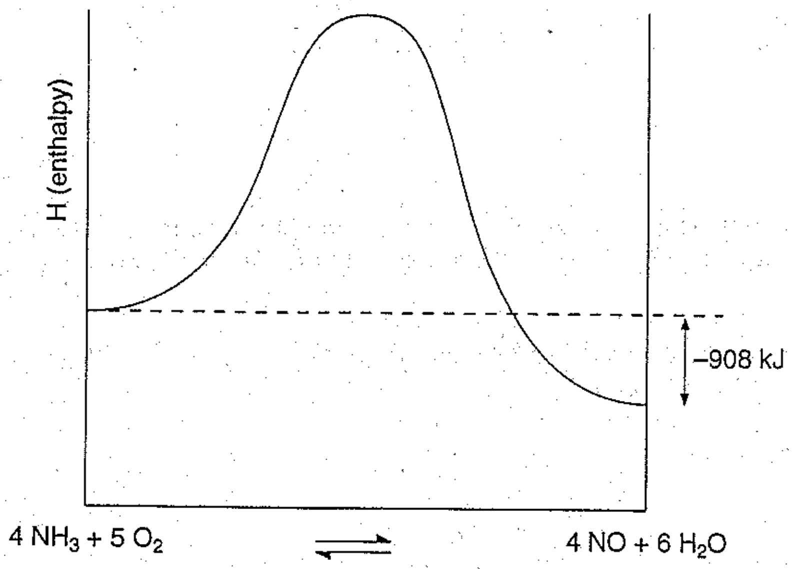
The following points could be made:

In general:
- Discuss the characteristics of equilibrium and Le Chatelier's Principle
  Explain the effect of different factors on the equilibrium position
  e.g. changes in temperature, concentration pressure, mass or catalysts
- Describe the factors which affect reaction rate (temperature, catalyst, pressure).
- Define the reaction profile

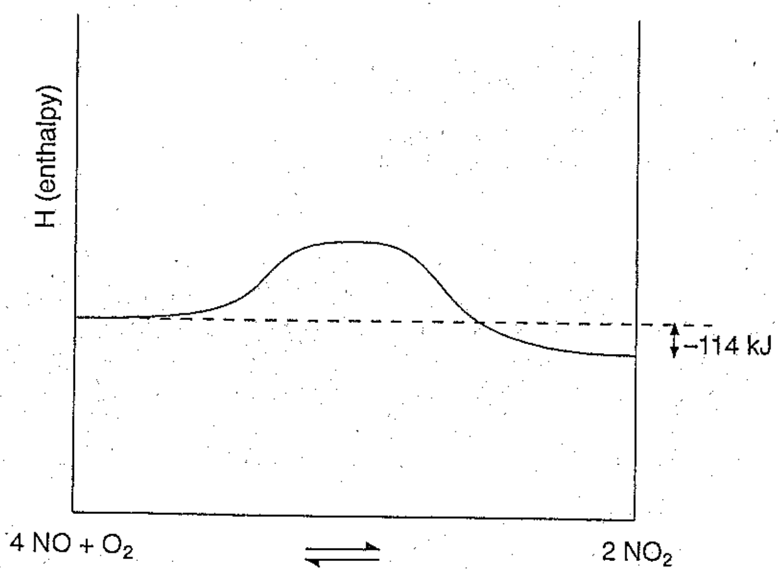
Then for each stage of the process:
- Draw a suitable reaction profile (see below). In particular, note the activation energy (E_A) and the heat of reaction (ΔH). Relate these to the reaction conditions at each stage of the process.
- State that for exothermic reactions, high temperatures will lower the equilibrium yield. However, for reactions with a relatively high activation energy, high temperatures are required to achieve a satisfactory rate of reaction.
- Recognise that, for endothermic reactions, high temperatures will increase both yield and reaction rate.
- Comment on the effect of pressure and catalysts for each stage.
- The more reacting molecules, the less straightforward the reaction profile (this is a minor point).
- Comment on the effect of temperature on the solubility of NO_2 and NO (relevant to stages 3 and 4).

Possible reaction profiles for Q1:

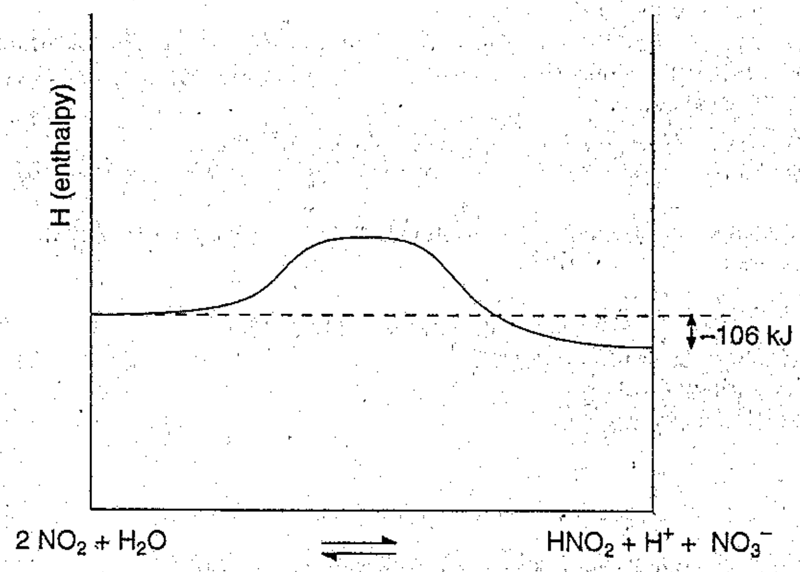
Stage 1



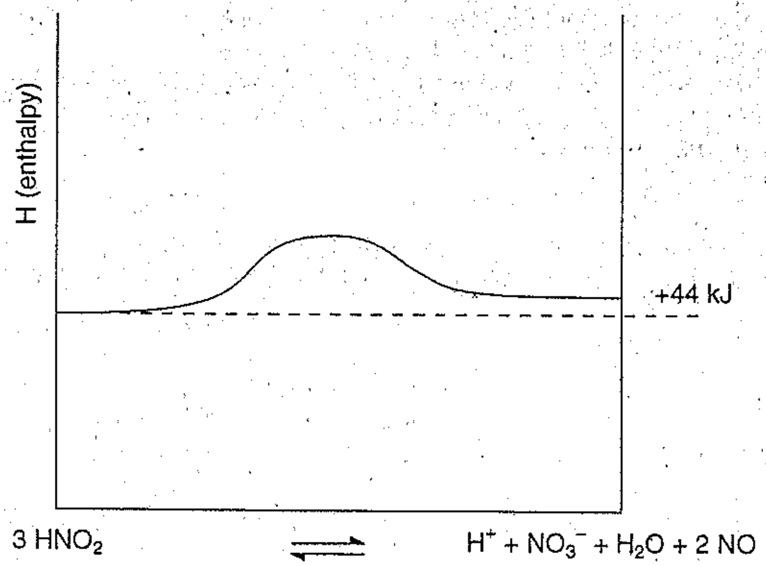
Stage 2



Stage 3



Stage 4



Q2

The following points could be made:

- Defining corrosion in metals as a redox reaction (the unwanted oxidation of metals). Recognise that there must be a species which is reduced - the oxidant.
- Explain, using reduction potentials, the tendency of most metals to corrode in air (the spontaneity of the reactions). Can also discuss corrosion of metals with acids, or metal displacement reactions.
- Describe the relative stability of metals in air
  eg. Aluminium forms a protective oxide layer, hence oxidation in air is slow
- Discussion of the role of water in the corrosion process, with particular reference to rust (the corrosion of iron).
  eg. the ions present in salt water and acidic water provide an environment for rapid corrosion.
- Discuss ways in which corrosion may be minimised:
  eg. Protective coatings
  Preventing access by H_2O or O_2 (or whichever species is the oxidant)
  Sacrificial anodes and other cathodic protection
  Coating with impervious metal oxide layer

  More than one metal must have been discussed.

Q3

The following points could be made:

- Discussion of intermolecular forces, in particular dipole-dipole and dispersion.
- Explain the relative solubilities of solutes in solvents where there are different intermolecular forces.
- Note that soap and detergent molecules contain a charged region (polar) and an uncharged region consisting of a long carbon chain (non-polar).
- Describe how this allows the soaps and detergents to act as cleaning agents
  eg. charged end forms strong ion-ion and ion-dipole interactions (can dissolve in water)
  dispersion forces between long chain end and other non-polar substances
  this allows the emulsification of fat and grease (non-polar substances)
- Discuss the precipitation of the soap ions in "hard" water and the deactivation of the soap ions in acidic solution. State that detergents do not form precipitates in hard water (include an equation)
- Discuss how soaps and detergents clean (use a diagram)
- Discuss the chemical composition of hard water.

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