1992

CHEMISTRY

UNIT 4

TRIAL EXAM

CHEMISTRY ASSOCIATES
P.O. BOX 2227
KEW, VIC., 3101
AUSTRALIA
TEL:(03) 9817 5374 FAX: (03) 9817 4334

email: chemas@vicnet.net.au

Internet: http://www.vicnet.net.au/~chemas/education.htm

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ã **CHEMISTRY ASSOCIATES 1997**

STUDENT NUMBER Letter

Figures									
Words									

CHEMISTRY ASSOCIATES 1992

CHEMISTRY
COMMON ASSESSMENT TASK 3 TRIAL: ANALYSIS AND EVALUATION

(not to be used before Monday October 5, 1992)
Time allowed for task: 1 hour 30 minutes.

QUESTION AND ANSWER BOOKLET

Structure of booklet

NUMBER OF QUESTIONS	NUMBER OF QUESTIONS TO BE ANSWERED	PERCENTAGE OF EXAMINATION
9	9	100

Dirctions to students

Materials
Question and answer booklet of 17 pages, including data on page 2.
An approved calculator may be used.

The task
Answer questions 1, 2, 3, 4, 5, 6, 7, 8 and 9 in the spaces provided following each question.
There is provision for rough working throughout the booklet.
All written responses should be in English.

At the end of the task
Please ensure that you write your student number in the space provided on this booklet.

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DATA

TABLE 1: RELATIVE ATOMIC MASS (^{12}C = 12.00)

Element	Symbol	Atomic No.	Relative Atomic Mass
Aluminium	Al	13	27.0
Calcium	Ca	20	40.1
Carbon	C	6	12.0
Copper	Cu	29	63.5
Hydrogen	H	1	1.0
Magnesium	Mg	12	24.3
Nitrogen	N	7	14.0
Oxygen	O	8	16.0
Silver	Ag	47	107.9
Zinc	Zn	30	65.4

TABLE 2: PHYSICAL CONSTANTS

Avogadro Constant (N_A)	6.023×10^{23} mol^{-1}
Faraday (F)	96 500 C mol^{-1}

TABLE 3: THE ELECTROCHEMICAL SERIES (alphabetical)

Oxidant				Reductant	E^o/V
$Ag^+(aq)$	+	e^-	=	$Ag(s)$	+0.80
$Al^{3+}(aq)$	+	$3e^-$	=	$Al(s)$	-1.67
$Cu^{2+}(aq)$	+	$2e^-$	=	$Cu(s)$	+0.34
$2H^+(aq)$	+	$2e^-$	=	$H_2(g)$ (defined)	0.00
$2H_2O(l)$	+	$2e^-$	=	$H_2(g) + 2OH^-(aq)$	-0.83
$K^+(aq)$	+	e^-	=	$K(s)$	-2.93
$Zn^{2+}(aq)$	+	$2e^-$	=	$Zn(s)$	-0.76

CHEMISTRY CAT 3 TRIAL
ANALYSIS AND EVALUATION

SPECIFIC INSTRUCTIONS

The marks allotted to each question and suggested times are indicated at the end of the question.

Questions should be answered in the spaces provided in this booklet.

To obtain full credit for your responses you should

(1) give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full credit.

(2) show all working in your answers to numerical questions. No credit can be given for an incorrect answer unless it is accompanied by details of the working.

(3) make sure chemical equations are balanced and that the formulas for individual substances include an indication of state, eg $H_2(g)$; NaCl(s).

QUESTION 1

(a) Ozone, O_3, is one of the most important gases in the atmosphere. It decomposes to form O_2 according to the equation: $2O_3 = 3O_2$; $\Delta H = -285$ kJ mol^{-1}. What is the amount of heat released when 10^{-3} mol of ozone decomposes?

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(b) When an electric current is passed through pure oxygen gas in the presence of aluminium metal, an extremely bright flash is produced and a considerable amount of heat. Aluminium burns in pure oxygen according to the equation:

$$4Al(s) + 3O_2(g) = 2Al_2O_3(s) ; \Delta H = -3340 \text{ kJ mol}^{-1}$$

How much heat produced by burning 0.027 g of aluminium in pure oxygen.
(The energy associated with the light is very small and may be disregraded in this calculation)

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5 + 5 = 10 marks

(suggested time: 10 minutes)

QUESTION 2 (10 minutes, 10 marks)
For small devices such as watches and calculators, it is necessary to have very small sources of electric current that operate at the correct voltage.One such galvanic cell makes use of silver oxide and zinc according to the equation:

$$Zn(s) + Ag_2O(s) + H_2O(l) = 2Ag(s) + Zn^{2+}(aq) + 2OH^-(aq)$$

The e.m.f. of the cell is 1.5V.

(a) Write the partial ionic equations for the reactions occurring at the cathode and anode.

(b) Name the oxidant and the reductant in the cell.

(c) One of these galvanic cells delivers a continuous current of 0.10 mA for 90 days. Calculate the mass of Ag_2O consumed during this time.

4 + 2 + 4 = 10 marks

(suggested time: 10 minutes)

QUESTION 3

(a) Give a concise explanation for the following experimental observation:

"Copper metal can be obtained by electrolysing an aqueous solution containing Cu^{2+}*(aq) ions, causing copper metal to be deposited on the negative electrode or cathode. However, potassium metal cannot be prepared in the same way from an aqueous solution containing* K^{+}*(aq)."*

(b) A metal disc of total surface area 10 cm^2 is to be covered with 0.5 g of copper. The coating is to be applied by electrolysis with the disc forming the cathode or negative electrode of an electrolysis cell. The disc is suspended by a conducting wire into a large volume of an aqueous solution containing the ions Cu^{2+}(aq) and SO_4^{2-}(aq). The Cu^{2+}(aq) ion is discharged at the CATHODE or NEGATIVE electrode according to

$$Cu^{2+}(aq) + 2e^- = Cu(s)$$

Calculate the time needed to deposit this coating, if a steady current of 0.500 A is passed through the cell.

5 + 5 = 10 marks

(suggested time: 10 minutes)

QUESTION 4

A student is studying the energy content of low alcohol beer using a bomb calorimeter.

The ethanol in beer undergoes oxidation in the body according to the equation:

$$C_2H_5OH(aq) + 3O_2(g) = 2CO_2(g) + 3H_2O(g) ; \quad \Delta H = -1370 \text{ kJ mol}^{-1}.$$

If the student completely oxidised 750 g of beer, with an alcohol content of 2.1% by mass, how much energy would be released assuming that the ethanol is the only source of energy in the beer?

10 marks

(suggested time: 10 minutes)

WORKING SPACE

QUESTION 5
The primary structure of a protein is a long chain of amino acids joined by peptide links.

(a) Explain what is meant by the term 'peptide link'.

The structure of part of a protein composed of two different amino acids is

$$\mathrm{-NH.CH_2.CONH.\underset{\underset{CH_3}{|}}{CH}.CONH.\underset{\underset{CH_3}{|}}{CH}.CONH.CH_2.CONH.\underset{\underset{CH_3}{|}}{CH}.CONH.CH_2CO-}$$

(b) How could this protein be converted into its constituent amino acids?

(c) Give the structural formulas of the two different amino acids from which the protein shown above is made.

4 + 2 + 4 = 10 marks

(suggested time: 10 minutes)

QUESTION 6

(a) Give a concise explanation for the following observation.

"A nucleus of helium-4 contains 2 protons and 2 neutrons, while a nucleus of hydrogen-2 contains 1 proton and 1 neutron. However, a helium-4 nucleus has a lower mass than two hydrogen-2 nuclei."

(b) It has been proposed that the element helium is the first element produced from hydrogen in the process known as nucleosynthesis. Briefly describe this process and include in your answer the conditions necessary for heavier elements such as oxygen to be produced.

3 + 7 = 10 marks

(suggested time: 10 minutes)

QUESTION 7

When calcium atoms are excited by heating in a flame, red light is emitted. Examination of the light shows it to consist only of a small number of wavelengths. Write a brief explanation of why light of only a few particular wavelengths is emitted by excited calcium atoms.

10 marks

(suggested time: 10 minutes)

WORKING SPACE

QUESTION 8

In the Periodic Table below, write the correct names and symbols for the elements labelled **A , D , E , G and J.**

	I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	**D**	12 Mg											13 Al	**G**	15 P	16 S	**J**	18 Ar
4	**A**	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	**E**	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	104 Rt	105 Hn													

A ____________________ ____________________

D ____________________ ____________________

E ____________________ ____________________

G ____________________ ____________________

J ____________________ ____________________

5 x 1 = 5 marks

(suggested time: 5 minutes)

WORKING SPACE

QUESTION 9

The Periodic Table is one of the great summaries of knowledge in the whole of science. Explain briefly:

(a) What was the experimental evidence that led early chemists, such as Mendeleev, to draw up a periodic table?

(b) What is meant by the terms 'shell' and 'subshell' in relation to the electronic structure of an atom?

QUESTION 9 (continued)

(c) How has a knowledge of the electronic structure of atoms led to the modern view of the periodic table?

5 + 5 + 5 = 15 marks

(suggested time: 15 minutes)

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KEW, VIC., 3101
AUSTRALIA
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CHEMISTRY CAT 3 TRIAL
ANALYSIS AND EVALUATION
SUGGESTED SOLUTIONS

Question 1

(a) When 2 mol of ozone decomposes according to the equation, 285 kJ is produced. Note that 285 kJ mol^{-1} means 285 kJ per mol of equation **AS WRITTEN**.
When 10^{-3} mol of ozone decomposes, the amount of energy produced is

$$\frac{285 \times 10^{-3}}{2} = 0.1425 \text{ kJ} = 0.143 \text{ kJ} \quad \textbf{ANS}$$

(b) The number of mol of aluminium = $\frac{m}{M} = \frac{0.027}{27.0}$ = 0.001 mol. From the balanced equation, 4 mol of aluminium burning in pure oxygen produces 3340 kJ. Note that 3340 kJ mol^{-1} means 3340 kJ per mol of equation **AS WRITTEN**. When 0.001 mol of aluminium burns, the amount of energy produced is

$$3340 \times \frac{0.001}{4} = 0.835 \text{ kJ} \quad \textbf{ANS}$$

Question 2

(a)

Cathode: $Ag_2O(s) + H_2O(l) + 2e^- = 2Ag(s) + 2OH^-(aq)$

Anode: $Zn(s) = Zn^{2+}(aq) + 2e^-$

(b) Oxidant is $Ag_2O(s)$ and reductant is Zn(s)

(c) $n(Ag_2O) = \frac{1}{2} \times n(e^-) = \frac{1}{2} \times \frac{0.10 \times 10^{-3} \times 90 \times 24 \times 3600}{96500}$

$= 4.03 \times 10^{-3}$

$m(Ag_2O) = n(Ag_2O) \times 231.8 = 4.03 \times 10^{-3} \times 231.8 = 0.934$ g **ANS**

Question 3 (a)

$Cu^{2+}(aq)$	+	$2e^-$	=	Cu			+0.34
$2H_2O(l)$	+	$2e^-$	=	$H_2(g)$	+	$2OH^-(aq)$	-0.83V
$K^+(aq)$	+	e^-	=	K(s)			-2.93V

From the E^0 values above, it can be seen that $Cu^{2+}(aq)$ is a stronger oxidant than $H_2O(l)$. Hence, Cu(s) is produced at the cathode in preference to $H_2(g)$. On the other hand, $H_2O(l)$ is a stronger oxidant than $K^+(aq)$. Hence, $H_2(g)$ is produced at the cathode in preference to K(s). Since $H_2O(l)$ is always present, K(s) will never be produced from aqueous solution.

SUGGESTED SOLUTIONS

Question 3 (continued)

(b) The number of mol of Cu = $\frac{0.5}{63.5}$.

Hence, from the balanced equation, the number of mol of electrons = $\frac{0.5}{63.5}$ x 2.

The quantity of electricity equals the number of mol of electrons x 96 500 C mol^{-1}

= $\frac{0.5 \text{ x } 2}{63.5}$ x 96 500 C.

The quantity of electricity also equals the current x time = 0.500 x t.

Therefore, t = $\frac{0.5 \text{ x } 2}{63.5}$ x $\frac{96\ 500}{0.500}$ = 3039 s = 0.84 hours **ANS**

Question 4

Mass of ethanol = $\frac{2.1}{100}$ x 750

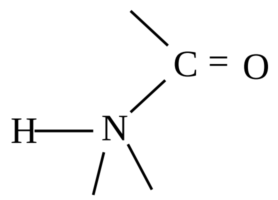
Molecular mass of ethanol = (2 x 12) + 5 + 16 + 1 = 46 g mol^{-1}.

Hence, the number of mol of ethanol = $\frac{2.1}{100}$ x $\frac{750}{46}$.

Therefore, the energy produced = $\frac{2.1}{100}$ x $\frac{750}{46}$ x 1370 = 469 kJ **ANS**

Question 5

(a) A peptide link is the combination of atoms CONH. These atoms are linked by single bonds (-) and double bonds (=) as shown below

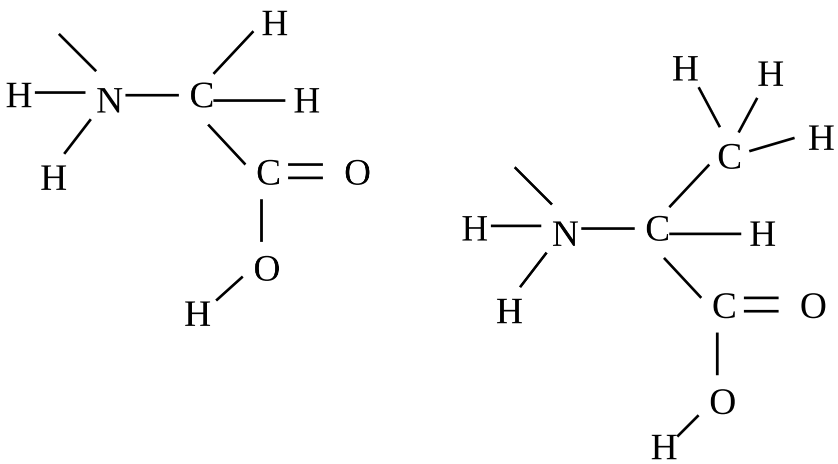


(b) The protein can be converted into its constituent amino acids by an acid catalysed hydrolysis reaction (reaction with water). This addition of water reverses the condensation reaction which occurred to produce the protein from the original amino acids. Such a reaction occurs in the stomach.

SUGGESTED SOLUTIONS

Question 5 (continued)

(c) The two amino acids are NH_2CH_2COOH and $NH_2CH(CH_3)COOH$. The structures are shown below.



Question 6

(a) In the nuclear fusion reaction: $2\ {}^{2}H_{1} \rightarrow {}^{4}He_{2}$, energy is released which is equivalent to the mass difference between the reactants and product according to the equation $E = \Delta mc^2$ where E = energy, Δm = difference in mass and c = speed of light.

(b) Hydrogen atoms in space are attracted to each other by gravity. As gravitational potential energy decreases, the kinetic energy of the atoms rises and the temperature of the hydrogen cloud increases. Soon the electrons are stripped from the atoms leaving positively charged hydrogen nuclei (protons). These protons tend to repel each other electrostatically but eventually the temperature caused by gravitational collapse becomes sufficiently high to cause fusion of nuclei to occur according to the equation

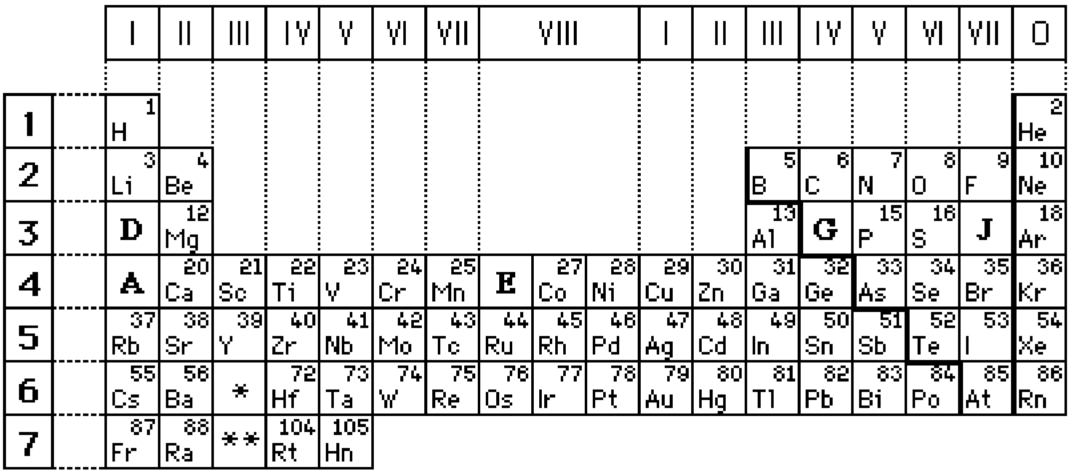
$4\ {}^{1}H_{1} \rightarrow {}^{4}He_{2} + 2({}^{0}e_{1})$ + energy. Nucleosynthesis has begun! The energy released in the formation of helium nuclei causes this reaction to be self-sustaining. Further gravitational collapse causes still higher temperatures and additional fusion reactions can occur to give elements such as oxygen. The extent to which the heavier elements such as oxygen are produced depends on the original mass of the hydrogen cloud. If the mass of the original cloud is sufficiently high, fusion reactions will occur up to the formation of the iron nucleus which has the maximum binding energy per nucleon.

SUGGESTED SOLUTIONS

Question 7

The examination of the emission spectra of atoms provides good evidence for the existence of electron shells or energy levels in these atoms.
When calcium atoms are excited by heating in a flame , some electrons are promoted to higher energy levels. When these electrons drop back into lower energy levels, energy is emitted in the form of electromagnetic radiation. This energy is emitted only in discrete packets called quanta and is equal to the difference in energy between the energy levels in the atom. For example, in the case of a calcium atom with the ground electronic configuration $1s^22s^22p^63s^23p^64s^2$, the 4s electrons may be promoted to, say, the 3d or 4p levels. Therefore, possible energies to be emitted would be (among others): ΔE_1 = E(3d level) - E(4s level); ΔE_2 = E(4p level) - E(4s level).
Each of these discrete energy packets corresponds with one particular wavelength (or frequency) of light since $E_2 - E_1 = \Delta E = hf$. If electrons did not occupy definite energy levels in atoms, a continuous emission spectrum and not a discrete spectrum would be expected.

Question 8



A	potassium	K
D	sodium	Na
E	iron	Fe
G	silicon	Si
J	chlorine	Cl

SUGGESTED SOLUTIONS

Question 9

(a) In the early nineteenth century, the number of known chemical elements was increasing rapidly and there was an urgent need to classify the elements in a systematic manner. The obvious way to do this was on the basis of the atomic weights (relative atomic masses) of the elements. **Dobereiner** discovered triads of chemically similar elements in which the atomic weight of the middle element was approximately equal to the mean of the atomic weights of the other two. For example, two triads are: Ca, Sr, Ba and Cl, Br, I. **Newlands** took this classification one step further when he arranged the known elements in order of increasing atomic weight and found that when these were arranged in horizontal rows, the vertical groups contained elements that were chemically similar. In 1871, **Mendeleev** expanded on these early attempts at classification by arranging the elements in horizontal rows of unequal length in which he deliberately left gaps for elements which, he predicted, would be discovered. His predictions proved to be remarkably successful. At the same time, properties such as atomic volume and boiling temperatures were shown by **Meyer**, independently of Mendeleev, to vary periodically with the atomic weight of the elements. For most of the elements. it was true that the chemical properties were a periodic function of their atomic weights. However, in a few cases, e.g. the elements Te and I, Mendeleev had the elements in the wrong order, and it was only after the work of **Rutherford** (discovery of the nucleus) and **Moseley** (discovery of a method for determining atomic numbers), that it was realised that the chemical properties of the elements were a periodic function of their atomic numbers and not atomic weights.

(b) A fundamental explanation of the similar properties of certain elements was found in the electronic structure of these elements. The number of electrons in an atom is equal to the number of protons, and these electrons are arranged in shells (energy levels) around the atom. Each shell is made up of one or more subshells (divisions of the main energy level). The shells are numbered 1, 2, 3, 4 . . . and the subshells are labelled
s, p, d, f . . . The subshells are filled with electrons in a specific order, namely *s* before *p* before *d* before *f,* and each subshell can only hold a certain number of electrons: *s* - 2; *p* - 6; *d* - 10; *f* - 14. Elements have similar chemical properties when they have the same outer shell electronic configuration. For example Li $2s^1$, Na $3s^1$, K $4s^1$

(c) The modern view of the Periodic Table is that the chemical properties of the elements are a periodic function of the outer shell electronic configuration of the atoms of the elements. It is important to remember that just as modifications were needed to Mendeleev's Periodic Table in order to bring it into line with experimental evidence, so too the modern Periodic Table will have to change as new experimental data comes to light.

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