SOME USEFUL INFORMATION

1atm = 101 000Pa = 760mmHg; the molar volume of any gas at s.t.p. is 22·4dm^3; R = 8·31Jmol^{-1}K^{-1} = 0·0821Latmmol^{-1}K^{-1}. Avogadro's number = 6·02 × 10^{23}

PERIODIC TABLE OF THE ELEMENTS

showing relative atomic masses

I	II											III	IV	V	VI	VII	0
1 H 1·0																	2 He 4·0
3 Li 6·9	4 Be 9·0											5 B 10·8	6 C 12·0	7 N 14·0	8 O 16·0	9 F 19·0	10 Ne 20·2
11 Na 23·0	12 Mg 24·3											13 Al 27·0	14 Si 28·1	15 P 31·0	16 S 32·1	17 Cl 35·5	18 Ar 39·9
19 K 39·1	20 Ca 40·1	21 Sc 45·0	22 Ti 47·9	23 V 50·9	24 Cr 52·0	25 Mn 54·9	26 Fe 55·8	27 Co 58·9	28 Ni 58·7	29 Cu 63·5	30 Zn 65·4	31 Ga 69·7	32 Ge 72·6	33 As 74·9	34 Se 79·0	35 Br 79·9	36 Kr 83·8
37 Rb 85·5	38 Sr 87·6	39 Y 88·9	40 Zr 91·2	41 Nb 92·9	42 Mo 95·9	43 Tc 98·9	44 Ru 101·1	45 Rh 102·9	46 Pd 106·4	47 Ag 107·9	48 Cd 112·4	49 In 114·8	50 Sn 118·7	51 Sb 121·8	52 Te 127·6	53 I 126·9	54 Xe 131·3
55 Cs 132·9	56 Ba 137·3	57 La 138·9	72 Hf 178·5	73 Ta 180·9	74 W 183·85	75 Re 186·2	76 Os 190·2	77 Ir 192·2	78 Pt 195·1	79 Au 197·0	80 Hg 200·6	81 Tl 204·4	82 Pb 207·2	83 Bi 209·0	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac															

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
90	91	92	93	94	95	06	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

SECTION I: Multiple Choice Questions

Select the SINGLE best alternative in each of the following cases and mark the appropriate letter on the separate answer sheet according to the instructions on it.

Questions 1 to 3 refer to the following shapes.

A V-shaped
B Square planar
C Tetrahedral
D Triangular planar
E Linear

Use the VSEPR theory to predict the most probable shapes of these molecules and ions:

1. H_2O
2. CO_3^{2-}
3. SiH_4^-

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Questions 4 to 6 refer to the following features of the periodic table.

A alkali metal
B d-block element
C f-block element
D p-block element
E noble gas

For each of the following electronic configurations decide which of the above applies.

4) $[Kr]5s^24d^{10}5p_x^{\ 1}5p_y^{\ 1}$
5) $1s^22s^22p_x^{\ 2}2p_y^{\ 2}2p_z^{\ 2}3s^23p_x^{\ 2}3p_y^{\ 2}3p_z^{\ 2}4s^23d^5$
6) $1s^22s^22p_x^{\ 2}2p_y^{\ 2}2p_z^{\ 2}3s^1$
7) $1s^22s^22p_x^{\ 2}2p_y^{\ 2}2p_z^{\ 2}$
8) $[Kr]5s^24d^{10}5p^66s^24f^2$

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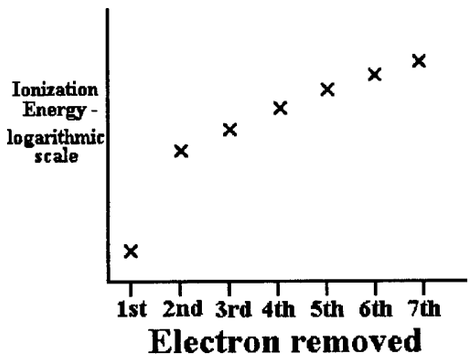
9) Which one of the following facts is explained by *hydrogen bonding*?
   A A great deal of heat is given out when hydrogen and oxygen combine.
   B The methane molecule (CH_4) is stable.
   C Hydrogen fluoride boils at a higher temperature than hydrogen chloride.
   D Methane (CH_4) boils at a lower temperature than silane (SiH_4).
   E Propane (C_3H_8) boils at a higher temperature than ethane (C_2H_6).

10) The beryllium chloride molecule ($BeCl_2$) has no dipole moment because
A beryllium and chlorine have the same electronegativities.
B the molecule is symmetrical.
C the molecule is V-shaped.
D beryllium has a very low electronegativity.
E beryllium and chlorine differ too much in their electronegativities.

11) Which of the following halogens is expected to have the lowest electronegativity?
A fluorine
B chlorine
C bromine
D iodine
E astatine (At)

12) An element has successive ionization energies as shown in the graph below.



Which one of the following is most likely to be the element?
A aluminium
B sodium
C magnesium
D calcium
E fluorine

13) Which one of the following compounds is most likely to exhibit hydrogen bonding?
A CH_3OH
B HBr
C CH_4
D H_2S
E LiH

14) Which one of the following molecules is expected to be the most polar?
A Cl_2
B IBr
C ICl
D IF
E F_2

15) Which one of the following molecules is electron deficient?
A NH_3
B HCl
C $BeCl_2$
D CH_4
E H_2O

16) In which of the following molecules does an atom have a valence shell with more than eight electrons in it?
A N_2O_5
B XeF_2
C PCl_3
D H_3O^+
E $PbCl_4$

17) Which group of elements shows the greatest tendency for its atoms to accept an electron?
A group 1
B group 2
C group 3
D group 6
E group 7

18) An element with an electronegativity of 1·0 combines with another element with an electronegativity of 3·9. The compound formed is most likely to be
A non-polar covalent.
B polar covalent.
C covalent with ionic character.
D ionic.
E metallic

19) When hydrogen gas is cooled sufficiently it turns into a liquid because of attractive forces between the molecules. These forces are best described as
A hydrogen bonding.
B dipole/dipole interactions.
C ion/dipole interactions.
D covalent bonding.
E London dispersion forces.

20) A balloon filled with air deflates in 56 hours as air escapes through tiny pores. Roughly how long does it take for a similar balloon filled with hydrogen to deflate given the following information: RMM of air = 28 and of hydrogen = 2? (Assume the deflation takes place by effusion; temperature and pressure are constant.)
A 2 hours
B 4 hours
C 15 hours
D 210 hours
E 784 hours

21) Ammonia burns in oxygen according to the equation

$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$

If 60 cm^3 of ammonia is burned completely in oxygen (all volumes being measured at the same temperature and pressure) then the volume of nitrogen produced is

A 30cm^3
B 45cm^3
C 55cm^3
D 80cm^3
E 120cm^3

22) A flask contains 0·5mol of oxygen and 0·3mol of nitrogen. What is the partial pressure of the nitrogen if the pressure of the mixture is 8atm?

A 3 atm
B 5 atm
C 8 atm
D 12·8 atm
E 21⅓ atm

23) 15cm^3 of a certain gaseous hydrocarbon was mixed with an excess of oxygen and ignited. The volume of the carbon dioxide produced was 60cm^3 when measured at the same temperature and pressure as the hydrocarbon. It may be concluded that one molecule of the hydrocarbon contained which of the following numbers of carbon atoms?

A 1
B 2
C 3
D 4
E 60

24) A certain volume of oxygen gas (molar mass 32gmol^{-1}) weighs 2.00g. An equal volume of another gas, X, weighs 1.75g under identical conditions of temperature and pressure. What is the relative molecular mass of X?

A 112
B 64
C 56
D 36½
E 28

25) X and Y are two gases which behave ideally. The mass of 1dm^3 of X is twice that of 1dm^3 of Y at room temperature and pressure. Which of the following is true for the gases under these conditions?

A The number of molecules in 1dm^3 of X is twice the number of molecules in 1dm^3 of Y.
B The average kinetic energy of the molecules of X is twice the average kinetic energy of the molecules of Y.
C On mixing equal volumes of the gases, the partial pressure of X is twice that of Y.
D The molar mass of X is twice that of Y.
E The volume occupied by 1 mole of X is half that occupied by 1 mole of Y.

26) A sample of nitrogen occupies 11200cm^3 at s.t.p. How may moles of this gas are present?

A 0·002
B 0·5
C 1
D 500
E 11 200

27) What is the *total number of ions* present in 5.85g of sodium chloride (RFM = 58·5)?

A 0·1
B 0·2
C $6·02 \times 10^{22}$
D 1.20×10^{23}
E $6·02 \times 10^{23}$

28) 300cm^3 of a 1·2M solution of KNO_3 is mixed with 200cm^3 of water. The concentration of the resulting solution (expressed in moldm^{-3}) is

A 0·72
B 0·80
C 1·8
D 2·0
E 3·0

29) For which one of the following equations is the enthalpy of reaction also the standard enthalpy of formation of water?

A $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$
B $H_2(g) + ½O_2(g) \rightarrow H_2O(g)$
C $2H_2(l) + O_2(l) \rightarrow H_2O(l)$
D $2H_2(g) + O_2(g) \rightarrow H_2O(g)$
E $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$

30) Which one of the following processes is exothermic?

A $O(g) + e^- \rightarrow O^-(g)$
B $O^-(g) + e^- \rightarrow O^{2-}(g)$
C $O_2(g) \rightarrow 2O(g)$
D $O(g) \rightarrow O^+(g) + e^-$
E $O^+(g) \rightarrow O^{2+}(g) + e^-$

31) Given the following information:
$C(graphite) + O_2(g) \rightarrow CO_2(g)$
$\Delta H = -393{\cdot}5 kJ\ mol^{-1}$
and
$C(diamond) + O_2(g) \rightarrow CO_2(g)$
$\Delta H = -395{\cdot}4 kJ\ mol^{-1}$
What is the enthalpy change for
$C(graphite) \rightarrow C(diamond)$ in $kJ\ mol^{-1}$?
A -788·87
B -395·4
C -393·5
D -1·9
E +1.9

32) A colourless solution gives a white precipitate when treated with either sodium hydroxide or ammonia solution. In both cases the precipitate redissolves in excess. The original solution contained
A sodium ions.
B ammonium ions.
C copper(II) ions.
D iron(III) ions.
E zinc ions.

33) A colourless solution gives a dense white precipitate when a little barium chloride solution is added. The precipitate does not dissolve on the addition of dilute nitric acid. The original solution contained
A sodium ions.
B calcium ions.
C sulfate ions.
D sulfite ions.
E chloride ions.

34) A pale green solution gives a pale green precipitate when treated with sodium hydroxide solution. The precipitate is insoluble in excess and turns brown on standing. Which one of the following ions must be present?
A iron(II) ions
B iron(III) ions
C dichromate ions
D copper(II) ions
E sulfite ions

35) A blue solution gives a precipitate on treatment with silver nitrate solution, but none on treatment with barium nitrate solution. When the precipitate is washed with water it is found to be white. Addition of a little dilute ammonia results in the dissolution of the precipitate. The original solution contained
A bromide ions.
B sulfate ions.
C iron(II) ions.
D calcium ions.
E chloride ions.

SECTION II: EQUATIONS

Answer this question in the spaces provided on the question paper.

1) Write balanced net ionic equations (including states) to illustrate ANY FOUR of the following. Two equations are required in each case. If you are unable to write an equation, partial marks may be awarded for a correct explanation in words. (4 marks each part)
a) When dilute sodium hydroxide is added to a solution of iron(II) nitrate a green precipitate is observed. The precipitate turns brown on standing.
b) When dilute sodium hydroxide is added to a solution of lead(II) chloride a white precipitate results. Upon addition of excess the precipitate redissolves to form a colourless solution.
c) When dilute ammonia is added to a solution of copper(II) nitrate a pale blue precipitate is obtained. Upon addition of excess dilute ammonia, a violet solution results.
d) When barium nitrate solution is added to a solution of sodium sulfite a dense white precipitate results. Upon addition of dilute hydrochloric acid the precipitate redissolves to form a colourless solution.
e) When silver nitrate solution is added to a solution of copper(II) bromide a cream coloured precipitate results. The precipitate redissolves in concentrated ammonia solution.
f) When dilute sodium hydroxide is added to a solution of potassium dichromate, the solution turns from orange to yellow. When dilute barium chloride solution is added to the original solution of potassium dichromate a yellow precipitate results.

SECTION III: Structured Questions

Answer **ANY THREE** of the following questions in the spaces provided on the question paper. Full marks can only be given to calculations where working is included and the final answer is clearly underlined. Clear and concise expression is an essential part of a good answer. If you answer more than three questions, only the first three answers will be marked.

1) a) i) How is the pressure of a mixture of gases related to the partial pressures of the components? (1)

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ii) A flask of volume 400cm^3 contains a gas, A, at 80.0mmHg pressure. A second flask of volume 800cm^3 contains gas B at 170mmHg pressure. The two flasks are connected and the gases are allowed to mix. Find the final pressure of the mixture given that the temperature remains constant throughout. (4)

b) i) In an experiment to determine the value of the gas constant, about 2g of potassium permanganate were heated in a test tube. The initial mass of the test tube and contents was 143·6153g. 76·5cm^3 of oxygen gas were collected over water at 102 000Pa pressure and a temperature of 28°C. After cooling the mass of the tube and contents was 143·5142g. The saturated vapour pressure of water at this temperature is 3170Pa. Calculate the value of the gas constant according to this experiment in Jmol^{-1}K^{-1}. Comment briefly on your result. (6)

2) a) i) What is the value of the standard enthalpy of formation of any element in its standard state? (1)

ii) Given that the standard enthalpies of formation of propane gas (C_3H_8), carbon dioxide (CO_2), and water (H_2O) are $-104 kJmol^{-1}$, $-393 kJmol^{-1}$, and $-286 kJmol^{-1}$ respectively, find the standard enthalpy of combustion of propane. (4)

b) Write a thermochemical equation to represent each of the following statements:

i) The first ionization energy of magnesium is $738 kJmol^{-1}$. (2)

ii) The second ionization energy of magnesium is $1451 kJmol^{-1}$. (2)

c) Explain why the second ionization energy of an element is always larger than the first. (2)

3) Nitrite ions (NO_2^-) react with permanganate ions in acidic solution as follows.

$$2MnO_4^-(aq) + 5NO_2^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 3H_2O(l) + 5NO_3^-(aq)$$

In a typical experiment $25{\cdot}00 cm^3$ of 0·02000M potassium permanganate solution were found to be equivalent to $23{\cdot}75 cm^3$ of sodium nitrite solution.

a) Calculate the concentration, in $moldm^{-3}$, of nitrite ions in the solution. (3)

b) The potassium permanganate solution may be standardised with ammonium iron(II) sulfate 6-water [$FeSO_4.(NH_4)_2SO_4.6H_2O$ RFM=392]. What mass of ammonium iron(II) sulfate 6-water would be used to prepare 500cm^3 of a 0·100M solution? (2)

c) Explain the meaning of the term *primary standard.* Mention one reason why potassium permanganate cannot be used as a primary standard. (3)

d) Briefly describe how you would make up a standard solution of a primary standard such as anhydrous sodium carbonate. (3)

4) An effervescent antacid tablet contains 5·00g of magnesium carbonate and 5·00g of citric acid $C_3H_4OH(COOH)_3$. Citric acid is a triprotic acid. No reaction occurs until the tablet is added to water and the citric acid dissolves. The equation for the reaction is as follows:

$2C_3H_4OH(COOH)_3(aq) + 3MgCO_3(s) \rightarrow 3H_2O(l) + 3CO_2(g) + C_3H_4OH(COO)_3(Mg)_3$ 1)

b) Determine which is the limiting reagent. (4)

c) Calculate the mass of magnesium citrate (RFM 451) produced. (2)

d) Calculate the molarity of the magnesium citrate if the total volume of solution is $300cm^3$. (2)

e) Calculate the volume (in cm^3) of carbon dioxide produced at 30°C and 1·02atm pressure. (3)

SECTION IV: ESSAY QUESTIONS

Answer **ONE** of the following questions on a separate sheet of paper. Your answer should be brief and to the point. Answers which contain irrelevant or incorrect material may be penalised.

1) Give *detailed* explanations for the following. Diagrams may strengthen your answers. (4 marks each)
   a) Water has a much higher boiling point than methane (CH_4) although the relative molecular masses of the two compounds is almost the same.
   b) Silicon dioxide is a high melting point solid whereas carbon dioxide is a gas at room temperature.
   c) The third period of the periodic table consists of only eight elements (sodium to argon) although the third shell can hold up to 18 electrons.
   d) The first ionization energies of elements generally increase from lithium to neon.

2) What is meant by the term *orbital*? (2) Draw diagrams of one s- and one p- atomic orbital, indicating the co-ordinate axes and the position of the nucleus. Label the following features on your diagram of a p-orbital: lobe, nodal plane. (6) By referring to the quantum numbers, n, l and m, explain the number of p-orbitals that are found in the second shell (4), and why p-orbitals do not appear in the first shell (2). How are the p-orbitals related to one another? (1) In what shell do d-orbitals first appear? (1).