Lisachem Materials

Chemistry Physics Biology
Psychology

VCE CHEMISTRY 2006
TRIAL EXAM YEAR 12
UNIT 4

Time allowed: 90 minutes
Total marks: 83

SECTION A
Contains 20 multiple choice questions
22 minutes, 20 marks

SECTION B
7 Extended response questions
68 minutes, 63 marks

A data sheet and multiple choice answer sheet are provided. Answer extended response questions in the space provided. Use the marks and time allowed as a guide to how much time you should spend answering each question.

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						relative atomic number symbol name relative atomic mass	1 H Hydrogen 1.0										2 He Helium 4.0
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 44.9	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.9	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.6	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yittrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium 98.1	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Ha Hahnium (262)	106 Sg Seaborgium (266)	107 Ns Neilsbohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (272)	111 Rg Roentgenium (272)	112 Uub Ununbium (277)		114 Uuq Ununquadium (289)				

Lanthanide series	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.3	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinide series	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium 237.1	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (255)	103 Lr Lawrencium (256)

DATA SHEET

Physical Constants

F	$= 96\ 500$ C mol^{-1}	**Ideal gas equation**
R	$= 8.31$ JK^{-1} mol^{-1}	$pV = nRT$
V_m (STP)	$= 22.4$ L mol^{-1}	
V_m (SLC)	$= 24.5$ L mol^{-1}	

Specific heat of water = 4.184 J mL^{-1} $^oC^{-1}$

The Electrochemical Series

		$E°$ in volt
$F_2(g) + 2e^-$	$\rightarrow 2F^-(aq)$	+ 2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^-$	$\rightarrow 2H_2O(l)$	+ 1.77
$Au^+(aq) + e^-$	$\rightarrow Au(s)$	+ 1.68
$MnO_4^-(aq) + 8H^+(aq) + 5e^-$	$\rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+ 1.50
$Cl_2(g) + 2e^-$	$\rightarrow 2Cl^-(aq)$	+ 1.36
$O_2(g) + 4H^+(aq) + 4e^-$	$\rightarrow 2H_2O(l)$	+ 1.23
$Br_2(l) + 2e^-$	$\rightarrow 2Br^-(aq)$	+ 1.09
$Ag^+(aq) + e^-$	$\rightarrow Ag(s)$	+ 0.80
$Fe^{3+}(aq) + e^-$	$\rightarrow Fe^{2+}(aq)$	+ 0.77
$I_2(s) + 2e^-$	$\rightarrow 2I^-(aq)$	+ 0.54
$O_2(g) + 2H_2O(l) + 4e^-$	$\rightarrow 4OH^-(aq)$	+ 0.40
$Cu^{2+}(aq) + 2e^-$	$\rightarrow Cu(s)$	+ 0.34
$CO_2(g) + 8H^+(aq) + 8e^-$	$\rightarrow CH_4(g) + 2H_2O(l)$	+ 0.17
$S(s) + 2H^+(aq) + 2e^-$	$\rightarrow H_2S(g)$	+ 0.14
$2H^+(aq) + 2e^-$	$\rightarrow H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^-$	$\rightarrow Pb(s)$	- 0.13
$Sn^{2+}(aq) + 2e^-$	$\rightarrow Sn(s)$	- 0.14
$Ni^{2+}(aq) + 2e^-$	$\rightarrow Ni(s)$	- 0.23
$Co^{2+}(aq) + 2e^-$	$\rightarrow Co(s)$	- 0.28
$Fe^{2+}(aq) + 2e^-$	$\rightarrow Fe(s)$	- 0.44
$Zn^{2+}(aq) + 2e^-$	$\rightarrow Zn(s)$	- 0.76
$2H_2O(l) + 2e^-$	$\rightarrow H_2(g) + 2OH^-(aq)$	- 0.83
$Mn^{2+}(aq) + 2e^-$	$\rightarrow Mn(s)$	- 1.03
$Al^{3+}(aq) + 3e^-$	$\rightarrow Al(s)$	- 1.67
$Mg^{2+}(aq) + 2e^-$	$\rightarrow Mg(s)$	- 2.34
$Na^+(aq) + e^-$	$\rightarrow Na(s)$	- 2.71
$Ca^{2+}(aq) + 2e^-$	$\rightarrow Ca(s)$	- 2.87
$K^+(aq) + e^-$	$\rightarrow K(s)$	- 2.93
$Li^+(aq) + e$	$\rightarrow Li(s)$	- 3.02

Student Name...

VCE Chemistry 2006 Year 12 Trial Exam Unit 4

SECTION A
MULTIPLE CHOICE ANSWER SHEET

Instructions:
For each question choose the response that is correct or best answers the question.
Circle the chosen response on this answer sheet.
Only circle **one** response for each question.

Question 1.	A	B	C	D
Question 2.	A	B	C	D
Question 3.	A	B	C	D
Question 4.	A	B	C	D
Question 5.	A	B	C	D
Question 6.	A	B	C	D
Question 7.	A	B	C	D
Question 8.	A	B	C	D
Question 9.	A	B	C	D
Question 10.	A	B	C	D
Question 11.	A	B	C	D
Question 12.	A	B	C	D
Question 13.	A	B	C	D
Question 14.	A	B	C	D
Question 15.	A	B	C	D
Question 16.	A	B	C	D
Question 17.	A	B	C	D
Question 18.	A	B	C	D
Question 19.	A	B	C	D
Question 20.	A	B	C	D

VCE Chemistry 2006 Year 12 Unit 4 Trial Exam

Section A

Section A consists of 20 multiple-choice questions.
Section A is worth approximately 24 per cent of the marks available.
You should spend approximately ***22 minutes*** *on this section.*
Choose the response that is ***correct*** *or* ***best answers*** *the question.*
Indicate your choice on the answer sheet provided.

Question 1.

Elements that form basic oxides may be expected to

A. be strong oxidants
B. have low electronegativity
C. have high first ionisation energies
D. exhibit a variety of oxidation states in their compounds.

Question 2.

The first four ionisation energies, in $kJ \cdot mol^{-1}$ of 4 elements with successive atomic numbers are shown in the table below.

Element	Ionisation Energy No.			
	1	2	3	4
A.	2081	3952	6122	9370
B.	496	4563	6913	9544
C.	738	1451	7733	10541
D.	578	1817	2745	11578

Which element is most likely to form a stable ion with a charge of +2?

A. A
B. B
C. C
D. D

Question 3.

Consider the series of E^o values for the reduction of various forms of vanadium

$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$ 1.0 V
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$ 0.32 V
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$ -0.26 V
$V^{2+}(aq) + 2e^- \rightarrow V(s)$ -1.2 V

Which of the following species could reduce the oxidation state of vanadium from +4 to +3 without reducing it to +2?

A. Cu
B. Fe
C. Co
D. H_2

Question 4.
In 1871, the 'periodic law' was stated by Mendeleev as '*The properties of the elements, as well as the forms and properties of their compounds … form a periodic function of the atomic weights of the elements'*.
Which of the following was **not** a key feature of Mendeleev's periodic table?

A. The elements were arranged in order of increasing atomic number
B. Elements with similar chemical properties were placed in vertical groups
C. Gaps were left for then undiscovered elements
D. The properties of undiscovered elements were accurately predicted.

Question 5.
A mass spectrometer is commonly used to identify, and determine the relative abundance of, the isotopes present in a naturally occurring sample of an atom. The property of the isotopes that is the key to their separation in the spectrometer is that

A. they all have the same atomic number
B. they contain different numbers of neutrons
C. they have similar chemical properties
D. they all have the same mass on a scale where carbon-12 has a mass of 12 exactly.

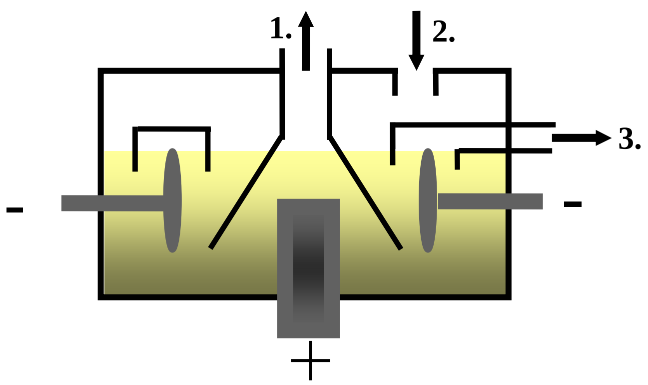
Question 6.
The elements of the first column on the periodic table are known as the 'alkali metals' whilst those immediately to the left of the noble gases are known as the 'halogens'.
Compared to atoms of the halogen in the same period, atoms of an alkali metal would

A. have a larger radius
B. be stronger oxidants
C. be higher on the electrochemical series
D. form more covalent compounds.

Question 7.
The Sun is the original source of the energy which we access on Earth. Energy is produced in the Sun as a result of

A. nuclear fission reactions during which the mass of the Sun increases
B. nuclear fusion reactions during which the mass of the Sun increases
C. nuclear fission reactions during which the mass of the Sun decreases
D. nuclear fusion reactions during which the mass of the Sun decreases.

Question 8.
A cross-section of an industrial cell used in the production of sodium is shown below:



The substances involved at points **1.**, **2.**, and **3.** are best represented by the chemical formulae

A. **1.** – Na(g), **2.** – Cl_2(g), **3.** – NaCl(s)
B. **1.** – Cl_2(g), **2.** – NaCl(s), **3.** – Na(l)
C. **1.** – Na (l), **2.** – NaCl(s), **3.** – Cl_2(g)
D. **1.** – Cl_2(g), **2.** – NaCl(l), **3.** – Na(s)

Question 9.
When an unsaturated fat is digested, the molecular formula of an expected product of the hydrolysis reaction would be

A. $C_6H_{12}O_6$
B. $C_3H_8O_3$
C. $C_{18}H_{36}O_2$
D. H_2O

Question 10.
When a cell of the lead acid-accumulator, used as a common car battery, is being recharged, it converts electrical energy into chemical energy via the electrode reactions.

$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$ and

$PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$

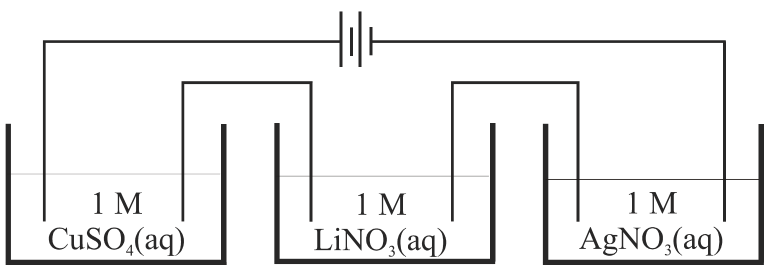
When the lead acid accumulator is providing electrical energy for the lights or radio in a car

A. Pb is produced at the negative electrode
B. the pH decreases
C. $PbSO_4$ is produced at the positive electrode
D. the oxidation number of lead increases at both electrodes.

Question 11.
In their ground state configuration atoms of a particular element, X, have electrons in eight subshells with the highest energy subshell containing 5 electrons. Element X is

A. nitrogen
B. bromine
C. manganese
D. chlorine

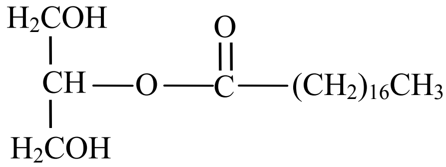
Question 12.
A current of 2.5 A is passed for 50 minutes through three cells connected in series. As indicated on the diagram below, these cells contained 1 M solutions of copper (II) sulfate, lithium nitrate and silver nitrate respectively. Each cell also contains a pair of platinum electrodes.



The ratio of the number of mole of metal deposited at the negative electrode in each cell,
ie ***n*(Cu) : *n*(Li) : *n*(Ag)** is

A. 1 : 0 : 2
B. 2 : 1 : 1
C. 1 : 2 : 2
D. 2 : 0 : 1

Question 13.
Food additive 471 has the structure shown below



The most likely reason for adding this additive to a food would be for it to

A. increase the levels of monounsaturated fats
B. act as an emulsifier
C. act as an antioxidant
D. absorb atmospheric moisture

Question 14
A 'breeder' reactor is a nuclear fission reactor that converts non-fissionable U-238 into a fissionable product. On neutron bombardment, U-238 undergoes the following nuclear transformations.

$$^{238}U + {}^{1}_{0}n \rightarrow X \rightarrow {}^{0}_{-1}e + Y \rightarrow {}^{0}_{-1}e + Z$$

The chemical symbol of the element represented by Z is

A. Pu
B. Ra
C. Th
D. Cm

Question 15.
A 1.154 g sample of a food was completed reacted with oxygen in bomb calorimeter. The initial temperature of the water in the calorimeter was 28.31ºC and the final temperature was 46.75ºC.
The energy content of the food sample was calculated to be 31.3 kJ per gram.
The most abundant food group present in the sample must have been

A. fat
B. protein
C. carbohydrate
D. sugar

Question 16.
The half-equation for the reaction occurring at the negative electrode during the production of fluorine by electrolysis would most likely be

A. $2F^{-}(aq) \rightarrow F_2(g) + 2e^{-}$
B. $2H_2O(l) + 2e^{-} \rightarrow H_2(g) + 2OH^{-}(aq)$
C. $2H_2O(l) \rightarrow O_2(g) + 4H^{+}(aq) + 4e^{-}$
D. $K^{+}(l) + e^{-} \rightarrow K(l)$

Question 17.
The presence of sugars in food may be shown by testing a sample with Benedict's reagent, which is an aqueous solution of copper II sulfate, sodium citrate and sodium carbonate. If disaccharides such as lactose are present in the food sample a red precipitate of copper (I) oxide, Cu_2O is produced. Therefore, this test shows that

A. sugars present in foods are oxidising agents
B. lactose is a disaccharide
C. sugars present in foods are reducing agents
D. lactose hydrolyses to glucose molecules during digestion.

Question 18.
The amino acid lysine may be represented by the structural formula shown below

$$\begin{array}{c} NH_2CHCOOH \\ | \\ (CH_2)_4 \\ | \\ NH_2 \end{array}$$

In an aqueous solution of pH 2, lysine molecules will be converted to

A. ions carrying a charge of –2
B. ions carrying a charge of –1
C. ions carrying a charge of +1
D. ions carrying a charge of +2

Question 19.
The combustion of octane can be represented by the equation
$2C_8H_{18}(g) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$; ΔH = -10108 kJ mol^{-1}
When a sample of pure octane undergoes complete combustion at, 100 % efficiency, 2.0×10^5 J of energy is released. What was the mass of the octane sample?

A. 4.5 g
B. 4.5 kg
C. 2.3 kg
D. 9.0 g

Question 20.
On November 1, 2004, element 111 was formally recognised as roentgenium, symbol Rg. Which of the following correctly describes an expected characteristic of roentgenium atoms?

A. they belong to the actinide series
B. they have their highest energy electrons in the 6d-subshell
C. they exhibit oxidation states as high as +5
D. they readily accept electrons in chemical reactions.

Section B

Section B consists of 7 short answer questions.
You should answer all of these questions.
This section is worth approximately 76 per cent of the total marks available.
*You should spend approximately **68 minutes** on this section of the examination.*
The marks allotted are shown at the end of each part of each question.
Questions should be answered in the spaces provided.

Question 1.

The food additive sorbitol, $C_6H_{14}O_6$, is produced by reduction of glucose according to the equation

$$C_6H_{12}O_6(aq) + H_2(g) \rightarrow C_6H_{14}O_6(aq)$$

When sorbitol reacts with oxygen, the equation describing the reaction is

$$C_6H_{14}O_6(aq) + 3O_2(g) \rightarrow 6CO_2(g) + 7H_2(g)$$

(a) Write a balanced equation describing the production of glucose in plants.

2 marks

(b) Give the names of

(i) two disaccharides that can be produced from glucose

1 mark

(ii) three biopolymers that can be produced from glucose

2 marks

(iii) explain why only two of the biopolymers listed in (ii) act as energy sources in the body

1 mark

(c) What type of reaction occurs when glucose is converted into disaccharides and biopolymers?

1 mark

(d) Why does the conversion of biopolymers to glucose require the involvement of proteins?

1 mark

(e) Explain why the oxidation of sorbitol does not actually increase overall atmospheric CO_2 levels.

2 marks

Total 10 marks

Question 2

Explain why

(a) when a 100 g sample of a protein was completely hydrolysed and the individual amino acids isolated collected and weighed, the total mass of the amino acids collected was 107.8 g.

2 marks

(b) the commercial production of Al is done by electrolysis of Al_2O_3 dissolved in molten cryolite and not by electrolysis of an aqueous solution of aluminium chloride?

2 marks

(c) the calorimeter constant for a well-insulated bomb calorimeter containing 500 mL of water should be greater than 2090 J °C^{-1}.

2 marks

(d) the electrolysis of 5 M NaCl(aq) produces three commercially valuable products.

3 marks

Total 9 marks

Question 3.

In 1894 William Ramsay, identified from its emission spectrum, a previously unidentified element present in air. During the next three years, 4 more related elements were discovered.

(a) The five elements referred to are all located in the same group of the periodic table. Which group?

1 mark

(b) Why had none of these elements been discovered earlier?

1 mark

(c) What are emission spectra and how are they produced?

4 marks

(d) Why could these five elements be identified from their respective emission spectra?

1 mark

Total 7 marks

Question 4.

In an experiment to determine the value of Avogadro's constant, the charge carried by one mole of electrons was determined by electrolysis and divided by the charge carried by one electron ($1.6x10^{-19}$ C). As part of the experiment an aqueous solution of copper sulfate was electrolysed for one hour, using a current of 3.25 A. As a result of the electrolysis, 4.17 g of Cu was deposited on the cathode.

(a) Determine the total charge passed through the cell.

1 mark

(b) Determine the number of mole of electrons needed to deposit 4.17 g Cu on the cathode.

2 marks

(c) On the basis of the experimental data, what is the charge carried by one mole of electrons?

1 mark

(d) What is the value of Avogadro's constant?

1 mark

(e) Give a reason why the calculated value of Avogadro's constant is different to the value supplied on the data sheet.

1 mark
Total 6 marks

Question 5.

In the absence of oxygen, bacteria may derive energy by causing a reaction between nitrates and glucose in organic matter according to the equation

$5C_6H_{12}O_6(s) + 24NO_3^-(aq) \rightarrow 30CO_2(g) + 18H_2O(l) + 24OH^-(aq) + 12N_2(g)$; $\Delta H = -11\ 925$ kJ mol^{-1}

(a) What mass of glucose would be consumed during the derivation of 2.00×10^6 J of energy by the bacteria?

3 marks

(b) What type of bacteria would cause this reaction?

1 mark

(c) What is the change in oxidation state of nitrogen that occurs during nitrogen fixing by bacteria in the soil?

1 mark

(d) Write a balanced half-equation describing the conversion of ammonium ions to nitrate ions by nitrifying bacteria.

2 marks

(e) Give the name and structural formula of the nitrogen containing compound which is one of the end-products of the body's use of food.

1 mark

Total 8 marks

Question 6.
A fuel may be defined as any substance that evolves energy in a controlled chemical or nuclear reaction.
(a) State two ways in which nuclear reactions differ from chemical reactions.

2 marks

(b) Both chemical and nuclear 'fuels' are used in power stations to generate electricity. Give the specific names of the reactions in which each fuel releases thermal energy.

(i) chemical fuel –

(ii) nuclear fuel –

2 marks

(c) How is the thermal energy produced in power stations converted in to electrical energy?

2 marks

(d) Give the names of chemical and nuclear fuels most commonly used to generate electricity in power stations.

1 mark

(e) Why are fuel cells more efficient than common power stations?

1 mark

(f) Aboard the space shuttle, fuel cells generate electrical energy from the flameless combustion of hydrogen gas. The only reaction product is water which the astronauts use for drinking. Consider a hydrogen-oxygen fuel cell in which the electrolyte is KOH(aq)
(i) Write the half-equation for the reaction occurring at the (-) electrode.

1 mark

(ii) Write the half-equation for the reaction occurring at the (+) electrode.

1 mark

(iii) What voltage would this cell generate at 25°C, using 1 M KOH and gases at 101.3 kPa.

1 mark

(g) An alternative form of electricity generation for domestic purposes is the use of methanol from a biogas digester in a methanol-O_2 fuel cell using an acid electrolyte. Write half-equations for the oxidation and reduction reactions occurring in this fuel-cell.

2 marks

Total 13 marks

Question 7.

Manganese and copper are both members of the first transition series.

a. Referring to its electron configuration, explain why manganese is classified as a transition element.

2 marks

b. Like most of the first row transition metals, this element manganese will react with dilute hydrochloric acid, but copper will not.

(i) Write a balanced equation for the reaction between manganese and dilute hydrochloric acid.

1 mark

(ii) Explain why copper does not react with dilute hydrochloric acid.

1 mark

(c) Manganese forms the compounds manganese dioxide, MnO_2, which is black and potassium permanganate, $KMnO_4$, which is purple.
What two chemical properties characteristic of transition metals which are exhibited by manganese in these compounds?

2 marks

(d) Copper (II) hydroxide is relatively insoluble in water but will dissolve on addition to 2 M ammonia solution according to the equilibrium
$Cu(OH)_2(s) + 4NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$.
Explain what characteristics of transition metals is evident in this equilibrium and identify all the types of bonding associated with $Cu(NH_3)_4^{2+}$.

3 marks

(e) What is the property associated with the transition metals iron, cobalt and nickel but not exhibited by either copper or manganese?

1 mark
Total 10 marks

Suggested Solutions VCE Chemistry 2006 Year 12 Unit 4 Trial Exam

Section A

Q1. B Using Period 3 as an example, the oxides range from basis (Na_2O, MgO) through amphoteric (Al_2O_3) to acidic (SO_3).
Considering the accepted trends in properties:
- oxidising strength increases across a period
- electronegativity increases across a period
- ionisation energy increases across a period

elements that form basic oxides will be weak oxidants, **have low electronegativity**, and have low first ionisation energy.
Only the transition metals exhibit multiple oxidation states.

Q2. C The most noticeable change in the sets of ionisation energies is the big jump between the first and second ionisation energies for element B. This suggests that atoms of element B have one outer-shell electron and the second electron was being removed from a shell closer to the nucleus. Since element B would occupy Group I on the Periodic Table, **element C must be in Group II. This is supported by the big jump between the second and third ionisation energies for element C** suggesting that atoms of element C have 2 outer-shell electrons**.**
Being in Group II, and having two outer-shell electrons, element C would form +2 ions.
The 'successive' atomic numbers is further supported by the ionisation energies for element D suggesting that it has three outer-shell electrons.

Q3. D Expand the electrochemical series to include Cu, Fe, Pb and H_2

$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	1.0 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	*0.34 V*
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	0.32 V
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	***0.00 V***
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	-0.26 V
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	*-0.13 V*
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	*-0.44 V*
$V^{2+}(aq) + 2e^- \rightarrow V(s)$	-1.2 V

The oxidation states of vanadium are +5 (VO_2^+), +4 (VO^{2+}), +3 (V^{3+}), +2 (V^{2+}) and 0 (V).
Since the reduction of the oxidation number from +4 to +3 is spontaneous, the reductant must be lower on the electrochemical series than the oxidant VO^{2+}.
H_2, Co and Fe will all reduce VO^{2+}, however the only species that will reduce VO^{2+} (+4) to V^{3+} (+3) without further reducing V^{3+} is **H_2(g).**

Q4. A **Mendeleev arranged the elements in order of increasing atomic mass.** He was unable to arrange them in order of increasing atomic number because when he did his work the 'structure' of the atom had not been established.
All the other alternatives are correct characteristics of Mendeleev's periodic table.

Q5. B The **mass spectrometer separates atoms according to their mass**. When a sample of an element is injected into a mass spectrometer, the atoms are ionised by an electron beam, accelerated through an electric field and separated in a magnetic field where the **lightest ions are most deflected**.
Isotopes of a particular element have **different masses** (on a scale where carbon-12 has a mass of 12 exactly) because they contain **different numbers of neutrons** (but have the same number of protons).

Q6. A Since atomic radius decreases across a period, the **alkali metal has a larger radius than the halogen**. Alkali metals are stronger reductants (weaker oxidants) than halogens so the alkali metals are lower on (the right hand side of) the electrochemical series. Also alkali metals form ionic compounds.

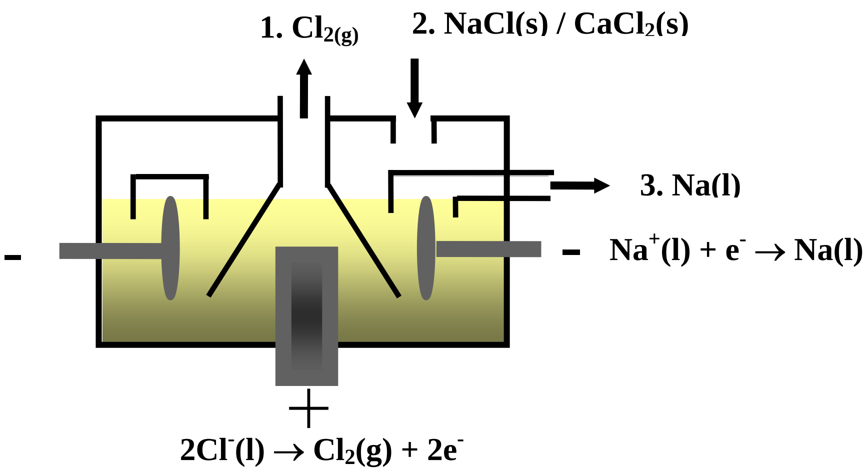
Q7. D The main nuclear reaction occurring in the Sun is generally represented by the equation

$$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{1}e$$

As a result of this nuclear fusion reaction, the mass of the products is less than the mass of the reactants as a result of the conversion of a small amount of mass into energy consistent with Einstein's $E = mc^2$.

The equation also shows that the number of nuclei present is decreasing.

Q8. B



In the Down's cell, **gaseous Cl_2** comes off the anode and **molten Na** is collected at the cathode. A mixture of NaCl and $CaCl_2$ is fed into the cell where it liquefies. The $CaCl_2$ serves to lower the melting temperature of NaCl.

Q9. B The products of digestion of one unsaturated fat molecule would be expected to be three unsaturated fatty acid molecules and one glycerol molecule.

The general molecular formula of a saturated fatty acid is $C_nH_{2n}O_2$, so $C_{18}H_{36}O_2$ is a saturated fatty acid.

Glycerol $CH_2OHCHOHCH_2OH$ has the **molecular formula $C_3H_8O_3$.**

Q10. C When the lead-accumulator is converting chemical energy to electrical energy the half-reactions occurring are:

$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$ at the anode (-)

$PbO_2(s) + SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$ at the cathode (+)

Pb is consumed at the (-) electrode, the pH increases as the $[H^+]$ decreases, **$PbSO_4$ is produced at both electrodes**, the oxidation number of Pb increases at the (-) electrode, from 0 to +2, and decreases at the (+) electrode, from +4 to +2.

Q11. B The electron configuration is:

$1s^22s^22p^63s^23p^64s^23d^{10}4p^5$ or $1s^22s^22p^63s^23p^63d^{10}4s^24p^5$.

Atoms of the element contain 35 electrons and, since they are neutral atoms, have an atomic number of 35. Hence according to the periodic table, the element is **bromine**.

Q12. A Considering the relevant half-equations on the electrochemical series.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	1.23 V
$Ag^+(aq) + e^- \rightarrow Ag(s)$	0.80 V
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.34 V
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	-0.83 V
$Li^+(aq) + e^-$	-3.02 V

Since the strongest oxidant present will react at the cathode in each cell, the reduction half-reactions occurring in the three cells can be deduced

1 M $CuSO_4$(aq) – strongest oxidant is $Cu^{2+}(aq)$

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

1 M $LiNO_3$(aq) – strongest oxidant is $H_2O(l)$

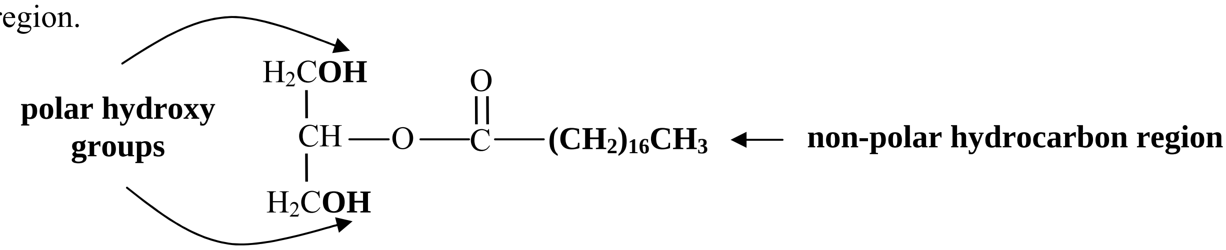
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

1 M $AgNO_3$(aq) – strongest oxidant is $Ag^+(aq)$

$Ag^+(aq) + e^- \rightarrow Ag(s)$

No metal will be deposited during the electrolysis of 1 M $LiNO_3$(aq).
Since the same amount of charge passes through each cell, the same $n(e^-)$ is available for the reduction of Cu^{2+}in $CuSO_4$(aq) and Ag^+ in $AgNO_3$(aq).
n(Ag) deposited = $n(e^-)$
***n*(Cu) deposited = ½ x *n*(e⁻)**
Hence the ***n*(Cu)** deposited = ½ x ***n*(Ag)** deposited
Ratio ***n*(Cu) : *n*(Ag) = 1 : 2**
Ratio ***n*(Cu) : *n*(Li) : *n*(Ag) = 1 : 0 : 2**

Q13. B The structure of the molecule shows significant polar regions and a significant non-polar region.



These are characteristics of an **emulsifier**.

Q14. A The atomic number of uranium, U, can be obtained from the periodic table. It is 92. Nuclear equations are balanced for atomic number and mass number.

$$^{238}_{\mathbf{92}}U + ^{1}_{0}n \rightarrow ^{\mathbf{239}}_{92}X \rightarrow ^{0}_{-1}e + Y \rightarrow ^{0}_{-1}e + Z$$

$$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}X \rightarrow ^{0}_{-1}e + ^{\mathbf{239}}_{\mathbf{93}}Y \rightarrow ^{0}_{-1}e + Z$$

$$^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}X \rightarrow ^{0}_{-1}e + ^{239}_{93}Y \rightarrow ^{0}_{-1}e + ^{\mathbf{239}}_{\mathbf{94}}Z$$

Element Z has atomic number 94 and according to the periodic table is plutonium, **Pu**

Q15. A The energy available from each of the three major food groups is
Carbohydrate – 16 kJ g^{-1}
Fat – 37 kJ g^{-1}
Protein – 17 kJ g^{-1}
So a food sample with an experimentally determined energy content of 31.3 kJ g^{-1} must contain a high proportion of fat.

Q16. D Fluorine is produced by the electrolysis if salts containing the fluoride ions. However according to the electrochemical series, particularly

$F_2(g) + 2e^- \rightarrow 2F^-(aq)$ +2.87 V

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ +1.23 V

aqueous solutions of fluoride salts cannot be used because $H_2O(l)$ is a stronger reductant than $F^-(aq)$ and would be preferentially oxidised.

Fluorine is produced by the electrolysis of molten salts such as KF(l), for which the electrode half-equations are

(+) oxidation: $2F^-(l) \rightarrow F_2(g) + 2e^-$

(-) reduction: $\mathbf{K^+(l) + e^- \rightarrow K(l)}$

Q17. C The conversion of $CuSO_4$ (Cu^{2+}) to Cu_2O (Cu^+) involves the reduction of Cu^{2+} to Cu^+. Since this occurs in the presence of lactose then lactose is acting as a reductant.

The reducing nature of sugars is also evident in respiration

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

where glucose is the reductant.

Q18. D In acidic solution (pH 2) the amino acid will act as a base and the basic amino ($-NH_2$) groups will each accept a proton and be converted to $-NH_3^+$. So the structure of the amino acid will then look like

$^+NH_3CHCOOH$
|
$(CH_2)_4$
|
$^+NH_3$

Consequently the lysine molecules will assume a charge of +2

Q19. A Energy released = 2.0×10^5 J = 2.0×10^2 kJ

Energy available from one mole of C_8H_{18} = 10108 / 2 = 5054 kJ mol^{-1}

$n(C_8H_{18})$ = energy released / energy per mole C_8H_{18}

= 2.0×10^2 kJ / 5054 kJ mol^{-1}

= 4.0×10^{-2} mol

$\boldsymbol{m(C_8H_{18})}$ = 4.0×10^{-2} mol x 114 g mol^{-1}

= **4.5 g**

Q20. B According to the periodic table element 111 is clearly located in the d-block in the fourth transition series. All elements in the d-block have their highest energy electrons in a d-subshell:-

3d – first transition series

4d – second transition series

5d – third transition series

6d – fourth transition series.

Roentgenium would be expected to exhibit similar properties to Cu, Ag and Au. Hence it is unlikely to have oxidation states as high as +5 and is more likely to donate electrons in chemical reactions.

Section B
Question 1.
(a) $6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$ ❶ *for balanced equation*; ❶ *for states*

(b) (i) maltose, sucrose, lactose, galactose ❶ *for two correct*

(ii) starch, cellulose, glycogen ❶❶ *for all 3 correct,* (❶ *for two correct*)

(iii) The human body does not contain the enzyme necessary for the digestion of cellulose ❶, hence it cannot be broken down into the glucose which is the source of the energy released during respiration.

(c) Condensation reaction ❶. Water is released as hydroxy groups on adjacent molecules react to produce ether links. —(C)—**O**—(C)—

(d) Enzymes control the reactions (speed up the hydrolysis) and enzymes are proteins. ❶

(e) The equation for the oxidation or sorbitol $C_6H_{14}O_6(aq) + 3O_2(g) \rightarrow 6CO_2(g) + 7H_2(g)$ shows that the oxidation of **1 mol of sorbitol produces 6 mol of CO_2.**
Since 1 mol of sorbitol is produced from 1 mol of glucose, and **6 mol of CO_2 is used in the production of 1 mol of glucose** during photosynthesis, the **oxidation of 1 mol of sorbitol releases back to the atmosphere the same amount of CO_2 that was consumed in its production.** ❶❶

Question 2
(a) **Proteins are converted into their constituent amino acids during hydrolysis** reactions in which **water reacts across the peptide –CONH links** and converts them into carboxy –COOH and amino $–NH_2$ groups. This 'addition' of water means that the **total mass of amino acids produced will be greater than the mass of protein undergoing hydrolysis.** ❶❶

(b) According to the electrochemical series,
$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ -0.83 V
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$ -1.67 V
$H_2O(l)$ is a stronger oxidant than $Al^{3+}(aq)$ and would be preferentially reduced at the cathode in an aqueous solution of $AlCl_3$. ❶ So Al^{3+} ions are reduced from molten alumina, Al_2O_3. Because Al_2O_3 has hight melting temperature (>2000°C) it is dissolved in molten cryolite which effectively lowers its melting temperature. ❶

(c) The specific heat capacity of water is 4.18 J mL^{-1} °C^{-1}. So to **increase the temperature of 500 mL of water by 1°C requires 4.18 x 500 = 2090 J** ❶
However, during calibration enough must also be added to increase the temperature of components such as the bomb, thermometer, stirrer and container. So **to raise the temperature of all the components of a bomb calorimeter containing 500 mL of water more than 2090 J of energy must be added for each 1 degree in temperature**. Consequently the calorimeter constant will be > 2090 J °C^{-1}. ❶

(d) In any aqueous solution of NaCl there are two oxidants – $Na^+(aq)$ and $H_2O(l)$ – and two reductants – $Cl^-(aq)$ and $H_2O(l)$. The stronger oxidant, $H_2O(l)$ is always preferentially reduced at the cathode, according to $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ❶
However, in concentrated NaCl(aq), despite the fact that $H_2O(l)$ is the stronger reductant, the similar reductant strength of $Cl^-(aq)$ and its high concentration means that it is oxidised according to
$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ ❶
The overall redox reaction occurring during the electrolysis of 5 M NaCl(aq) is
$2Cl^-(aq) + 2H_2O(l) \rightarrow H_2(g) + Cl_2(g) + 2OH^-(aq)$ *or*
$2NaCl(aq) + 2H_2O(l) \rightarrow \mathbf{H_2}(g) + \mathbf{Cl_2}(g) + 2\mathbf{NaOH}(aq)$
The three 'commercial' products are H_2, Cl_2 and NaOH ❶

Question 3.
(a) Group VIII or Group 18 ❶

(b) Identification of elements had depended mainly on their chemical reactivity. The **'noble gases'** being **unreactive** simply could be identified ❶

(c) Emission spectra are sets of **coloured lines on a black background**. Each coloured line corresponds to a **specific wavelength of light**. ➊ To produce an emission spectrum, **electrons must first have been excited, ie absorbed energy and moved to higher energy levels**. ➊ When the **electrons return to return to lower energy levels closer to the nucleus they emit, as light, energy equal to difference between the energy levels.**➊ So, the **coloured lines** on the black background occur at **specific wavelengths corresponding to the difference in energy between the starting and finishing levels of the electrons** moving back closer to the nucleus. ➊

(d) Because each element has a unique electron configuration and so produces a **unique emission spectrum**. ➊

Question 4.

(a) $Q = It$
$= 3.25 \times 1 \times 60 \times 60$
$= \mathbf{1.17 \times 10^4\ C}$ ➊

(b) Copper is deposited by reduction of $Cu^{2+}(aq)$, ie $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
$n(e^-) = 2 \times n(Cu)$
$= 2 \times 4.17\ g / 63.6\ g\ mol^{-1}$ ➊
$= 2 \times 0.0656$
$= \mathbf{0.131\ mol}$ ➊

(c) Charge on 1 mol electrons $= Q / n(e^-)$
$= 1.17 \times 10^4 / 0.131$
$= \mathbf{8.93 \times 10^4\ C\ mol^{-1}}$ ➊

(d) N_A = charge on 1 mol electrons / charge on 1 electron
$= 8.93 \times 10^4\ C\ mol^{-1} / 1.6 \times 10^{-19}$
$= \mathbf{5.6 \times 10^{23}}$ ➊

(e) During electrolysis, the transformation of electrical energy to chemical energy is not 100 per cent efficient.➊ So the amount of Cu produced is lower than what is theoretically possible from the charge passed through the cell. Also some of the Cu may fall off the cathode.

Question 5.

(a) 5 mol glucose $\rightarrow$ 11925 kJ
1 mol glucose $\rightarrow$ 11925 / 5 = **2385 kJ** ➊
Energy derived by bacteria = 2.00×10^6 J = 2.00×10^3 kJ
$n(C_6H_{12}O_6)$ = energy derived by bacteria / energy available from 1 mol $C_6H_{12}O_6$
$= 2.00 \times 10^3\ kJ / 2385\ kJ\ mol^{-1}$
$= 0.839$ mol ➊
$m(C_6H_{12}O_6) = 0.839\ mol \times 180\ g\ mol^{-1}$
$= \mathbf{151\ g}$ ➊

(b) Denitrifying bacteria ➊

(c) During nitrogen fixing by nitrogen fixing bacteria, N_2 is converted to NH_4^+.
So the oxidation state of nitrogen changes **from 0 to -3** ➊

(d) $NH_4^+(aq) + 3H_2O(l) \rightarrow NO_3^-(aq) + 10H^+(aq) + 8e^-$ ➊ *for all species correct,* ➊ *for balancing*

(e) urea, $CO(NH_2)_2$ or NH_2CONH_2 ➊

Question 6.

(a) In **chemical reactions** there is **no change in mass**, ie the total mass of reactants equals the total mass of products. In most **nuclear reactions mass is converted into energy** so the total mass of products is less than the total mass or reactants. ➊
In **chemical reactions no 'different' elements are produced**, the atoms are rearranged. In **nuclear reactions different elements are produced**, i.e. the products contain different elements to the reactants. ➊

(b) (i) combustion ➊
(ii) nuclear fission ➊

(c) Thermal energy is used to boil water to produce steam which drives turbines, so the thermal energy is converted to mechanical energy. ➊ The turbines drive generators so the mechanical energy is converted to electrical energy. ➊

(d) chemical fuel – **coal**; (oil, natural gas) nuclear fuel – **uranium** ➊

(e) In power stations, the pathway from chemical energy to electrical energy involves a number of conversions and a significant amount of energy is lost as heat energy along the way. Fuel cells are more efficient because the **chemical energy of the fuel is converted directly to electrical energy**. ➊

(f) (i) Oxidation occurs at the negative electrode

$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$ ➊ *from the electrochemical series*

(ii) Reduction occurs at the (+) electrode

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ ➊ *from the electrochemical series*

(iii) Cell voltage $= E^0(\text{oxidant}) - E^0(\text{reductant})$

$= 0.40 - (-0.83)$

= **1.23 V** ➊

(g) The products of the reaction between CH_3OH and O_2 in the fuel cell are the same as for the combustion of CH_3OH, ie CO_2 and H_2O.

CH_3OH is oxidized to CO_2 at the anode

$\mathbf{CH_3OH(aq) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-}$ ➊

O_2 is reduced to H_2O at the cathode

$\mathbf{O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)}$ ➊

Question 7.

(a) $_{25}Mn - 1s^22s^22p^63s^23p^64s^23d^5$ *or* $1s^22s^22p^63s^23p^63d^54s^2$ ➊

Manganese is a transition metal because its **highest energy electrons are in a d-subshell**. ➊

(b) (i) The electrochemical series shows that Mn is oxidized to Mn^{2+} and H^+ is reduced to H_2

$Mn(s) + 2H^+(aq) \rightarrow Mn^{2+}(aq) + H_2(g)$ *or* $Mn(s) + 2HCl(aq) \rightarrow MnCl_2(aq) + H_2(g)$➊

(ii) According to the half-equations on the electrochemical series.

$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ $E^0 = 0.34$ V

$2H^+(aq) + 2e^- \rightarrow H_2(g)$ $E^0 = 0.00$ V

Cu will not react spontaneously with $H^+(aq)$ because the **oxidant, H^+, is lower on the series than the reductant, Cu.** ➊

(c) Manganese forms **coloured compounds**. ➊

Manganese **exhibits a variety of oxidation states** - +4 in MnO_2; +7 in $KMnO_4$ ➊

(d) $Cu(NH_3)_4^{2+}$ is a **complex ion** ➊ in which the central cation is surrounded by ligands, in this case polar NH_3 molecules.

In each complex ion, the bonding between the Cu^{2+} ion and the NH_3 molecules is **ion-dipole bonding** ➊. Within the NH_3 molecule, there are **covalent bonds** ➊ between the N atom and the H atoms.

(e) **Magnetism** ➊