Mark Scheme

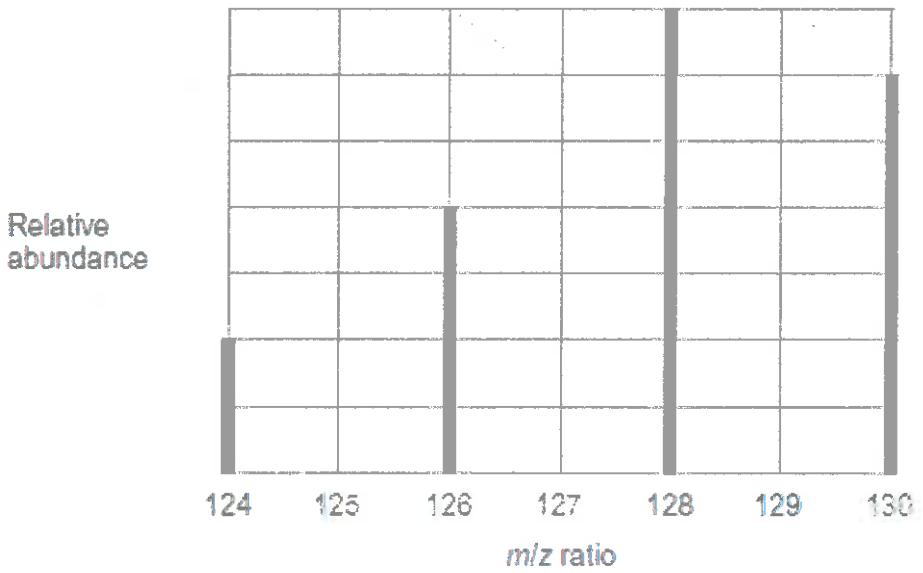
Q1. Tellurium is the element with atomic number of 52

(a) Using information from the Periodic Table, complete the electron configuration of tellurium.

[Kr] $5s^2\ 4d^{10}\ 5p^4$

(1)

(b) The mass spectrum of a sample of tellurium is shown in the graph.



(i) Use the graph to calculate the relative atomic mass of this sample of tellurium. Give your answer to one decimal place.

$$\frac{(124 \times 2) + (126 \times 4) + (128 \times 7) + (130 \times 6)}{19}$$

$= 127.8$

(3)

(ii) Suggest what might cause the relative atomic mass of this sample to be different from the relative atomic mass given in the Periodic Table.

A different abundance of isotopes are present in the sample.

(1)

(c) Write an equation for the reaction that occurs when a tellurium ion hits the detector.

$Te^+ + e^- \rightarrow Te$ [Remember the Te^+ ions gain an electron and become atoms.]

(1)

(d) State the *m* / *z* value of the ions that produce the biggest current at the detector when the spectrum in the graph is recorded.
Give a reason for your answer.

m / *z* value 128

Reason This is the most abundant ion.

(2)

(e) The mass spectrum of tellurium also has a small peak at *m* / *z* = 64

Explain the existence of this peak.

Some of the Te^{128} became 2+ ions hence giving a m/z value of 64 $\left(\frac{128}{2}\right)$.

(2)

(f) Predict whether the atomic radius of ^{124}Te is larger than, smaller than or the same as the atomic radius of ^{130}Te
Explain your answer.

Atomic radius of ^{124}Te compared to ^{130}Te Same

Explanation They both have same number of protons and electrons.

(2)
(Total 12 marks)

Q2. This question is about the elements in Period 3 of the Periodic Table.

(a) State the element in Period 3 that has the highest melting point.
Explain your answer.

Element ... Silicon ...

Explanation ... It has many strong covalent bonds which need to be broken to to melt - this requires large amounts of energy. ...

(3)

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element ... Argon. ...

Explanation ... Largest number of protons in period 3 and similar shielding. ...

(3)

(c) Suggest the element in Period 3 that has the highest electronegativity value.

... Chlorine ...

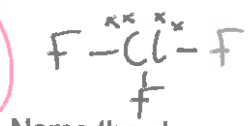
(1)

(d) Chlorine is a Period 3 element. Chlorine forms the molecules ClF_3 and CCl_2

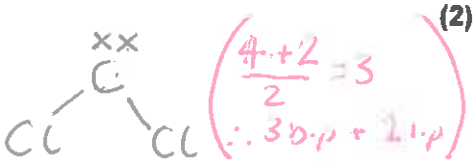
(i) Use your understanding of electron pair repulsion to draw the shape of ClF_3 and the shape of CCl_2
Include any lone pairs of electrons that influence the shape.

Shape of ClF_3

$\frac{7+3}{2} = 5$
$\therefore 3 b.p + 2 l.p$



Shape of CCl_2



$\frac{4+2}{2} = 3$
$\therefore 3 b.p + 2 l.p$

(2)

(ii) Name the shape of CCl_2

Bent

(1)

Remember the dynamic nature of the bonding!! Also forming one mole so no multiples.

(iii) Write an equation to show the formation of one mole of ClF_3 from its elements.

$\frac{1}{2}Cl_2 + \frac{1}{2}F_2 \longrightarrow ClF_3$

(1)
(Total 11 marks)

Q3. A sample of hydrated nickel sulfate ($NiSO_4.xH_2O$) with a mass of 2.287 g was heated to remove all water of crystallisation. The solid remaining had a mass of 1.344 g.

(a) Calculate the value of the integer x.
Show your working.

$2.287 - 1.344 = 0.943$ g of H_2O

this is the mr of $NiSO_4$ → $\frac{1.344}{154.8} = 0.00868$

$\frac{0.943}{18} = 0.0524$ ← mr of H_2O

$\frac{0.0524}{0.00868} = x = 6$

(4)

(b) Suggest how a student doing this experiment could check that all the water had been removed.

Reheat the sample to a constant mass.

if there was any water left reheating it would cause it to evaporate and hence the mass would decrease.

(2)
(Total 6 marks)

Q4. Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

moles = mass / Mr 550 / 65 = 8·46 moles ← Mr of NaN_3

This is the tricky bit. If 8·46 is 95% we need to know what 100% is!

→ 8·46 / 95 × 100 = 8·91 moles ← this is the theoretical no. of NaN_3

8·91 × 2 = 17·82 moles of $NaNH_2$

← × 2 because of the equation telling us the ratio by numbers

Mr of $NaNH_2$ →

17·82 × 39 = 695 g of $NaNH_2$

(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

150 kPa = 150000 Pa 35°C = 308K

PV = nRT PV / RT = n 150000 × 7·5×10⁻² / 8·31 × 308

Use the balanced equation. 3 moles of N_2 from 2 moles of NaN_3

n = 4·395 moles of N_2 ∴ 4·395 / 3 × 2 = 2·93 moles of NaN_3

2·93 × 65 = 190·45 g

Mr of NaN_3 →

(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

150 / 65 = 2.31 moles of NaN_3 — Conc. = Moles / Volume

No of NaN_3 →

2.31 / (500/1000) = 4.62 moldm^{-3}

Remember to convert your cm^3 to dm^3!

(3)

(ii) Nitrous acid decomposes on heating.

Balance the following equation for this reaction.

3 HNO_2 ⟶ ..... HNO_3 + 2 NO + ... H_2O

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding Ionic ← sodium a metal and nitrogen a non metal.

Reason for high melting point strong electrostatic attractions between positive and negative ions.

(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as N ≡ N – N^-
One of these bonds is a co-ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co-ordinate bond.

(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

Anything with 22 electrons! CO_2

(1)

(iii) Which is the correct formula of magnesium azide?

Tick (✓) **one** box.

Mg_3N	☐
MgN	☐
MgN_6	✓
Mg_3N_2	☐

Mg forms $2+$ ions and an azide (N_3) has a -1 charge ∴ MgN_6

(1)
(Total 21 marks)

Q5.(a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

$C_{(s)} + 2F_{2(g)} \rightarrow CF_{4(g)}$ MUST have state symbols!

(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

Tetrahedral shape consisting of 4 bond pairs that all have equal replusion and spread apart as far as possible.

(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	$HF(g)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

$C_2H_6 + 7f_2 \xrightarrow{-2889} 2Cf_4 + 6Hf$

? $C + H_2 + f_2$ $2\times -680 = -1360$ $6\times -269 = -1614$

$(-1360)+(-1614) = -2974$

$-2974 + (+2889) = -85$

Standard enthalpy of formation of $C_2H_6(g)$ = −85 kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C–H	C–F	H–F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F–F bond.

Is the student correct? Justify your answer with a calculation using these data.

$CH_4 + 4f_2 \longrightarrow Cf_4 + 4HF$

$412 \times 4 = 1648$

$484 \times 4 = 1936$

$562 \times 4 = 2248$

total = 4184

$\therefore$ $1904 + 1648 = 3552$

$4184 - 3552 = 632$

$4 \times F\text{-}f = 632$

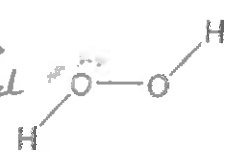
so: $\frac{632}{4} = 158$

Yes the student is correct as each f-f bond is only 158kjmol^{-1} which is much lower than the C-H bond.

(4)
(Total 10 marks)

Q6. A hydrogen peroxide molecule can be represented by the structure shown.

the lone pairs would repel it greater than the expected 109.5°!



(a) Suggest a value for the H–O–O bond angle.

104.5°

(1)

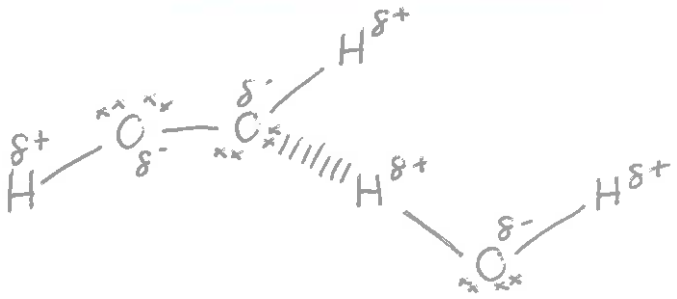
(b) Hydrogen peroxide dissolves in water.

(i) State the strongest type of interaction that occurs between molecules of hydrogen peroxide and water.

Hydrogen bonding

(1)

(ii) Draw a diagram to show how one molecule of hydrogen peroxide interacts with one molecule of water.
Include all lone pairs and partial charges in your diagram.



Remember the hydrogen bond goes between the lone pair and the delta positive hydrogen ($\delta^+ H$).

(3)

(c) Explain, in terms of electronegativity, why the boiling point of H_2S_2 is lower than H_2O_2.

Because Oxygen is more electronegative than Sulfur - this means there is hydrogen bonding in H_2O_2 but not in H_2S_2. In H_2S_2 there is only dipole-dipole + van der waals.

(2)
(Total 7 marks)

Q7.(a) Calcium phosphate reacts with aqueous nitric acid to produce phosphoric acid and calcium nitrate as shown in the equation.

$$Ca_3(PO_4)_2 + 6HNO_3 \longrightarrow 2H_3PO_4 + 3Ca(NO_3)_2$$

(i) A 7.26 g sample of calcium phosphate reacted completely when added to an excess of aqueous nitric acid to form 38.0 cm^3 of solution.

Calculate the concentration, in mol dm^{-3}, of phosphoric acid in this solution.
Give your answer to 3 significant figures.

No of $Ca_3(PO_4)_2$ → $\frac{7.26}{310.3} = 0.0234$ moles

$0.0234 \times 2 = 0.0468$ moles of H_3PO_4

Remember to turn cm^3 to dm^3 → $\frac{0.0468}{(38.0/1000)} = 1.23\ mol\,dm^{-3}$ ← 3 s.f.

(5)

(ii) Calculate the percentage atom economy for the formation of calcium nitrate in this reaction.
Give your answer to 1 decimal place.

$H_3PO_4 = 98 \times 2 = 196$

$Ca(NO_3)_2 = 164.1 \times 3 = 492.3$

$196 + 492.3 = 688.3$

Wanted products → $\frac{492.3}{688.3} = 0.715 \times 100 = 71.5\%$

All products →

(2)

(b) Write an equation to show the reaction between calcium hydroxide and phosphoric acid to produce calcium phosphate and water.

$3Ca(OH)_2 + 2H_3PO_4 \longrightarrow Ca_3(PO_4)_2 + 6H_2O$

(1)

(c) Calcium dihydrogenphosphate can be represented by the formula $Ca(H_2PO_4)_x$ where x is an integer.
A 9.76 g sample of calcium dihydrogenphosphate contains 0.17 g of hydrogen, 2.59 g of phosphorus and 5.33 g of oxygen.

Calculate the empirical formula and hence the value of x.
Show your working.

$9.76 - (0.17 + 2.59 + 5.33) = 1.67\text{g of Calcium}$

Do not forget to calculate Calcium

Ca	H	O	P
$\frac{1.67}{40.1}$ =	$\frac{0.17}{1}$ =	$\frac{5.33}{16}$ =	$\frac{2.59}{31}$ =
$\frac{0.0416}{0.0416}$	$\frac{0.17}{0.0416}$	$\frac{0.333}{0.0416}$	$\frac{0.0835}{0.0416}$
= 1	= 4	= 8	= 2

Divide by the lowest number

$\therefore \quad CaH_4O_8P_2 \quad \text{or} \quad Ca(H_2PO_4)_2$

$x = 2$

(4)
(Total 12 marks)

Q8. Which one of the following does **not** have a pair of s electrons in its highest filled electron energy sub-level?

A H^-

B Mg

C P^{3+} ← finishes 3p6.

(D) Ar

(Total 1 mark)

Q9. Assuming that chlorine exists as two isotopes, and that hydrogen and carbon exist as one isotope each, how many molecular ion peaks will be shown in the mass spectrum of $C_4H_8Cl_4$?

A 2

B 3

C 4

(D) 5

two Cl isotopes means

Cl35 Cl35
Cl35 Cl37
Cl37 Cl35
∴ three

So 4 for C
1 for H
3 for Cl

(Total 1 mark)

Q10. An atom in which the number of protons is greater than the number of neutrons is

A ^{234}U

B ^{6}Li

(C) ^{3}He ← 2 protons 1 neutron

D ^{2}H

(Total 1 mark)

Q11. Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^{+}(s) + Ag^{+}(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass dark glass

Which one of the following is a correct electron arrangement?

A Cu^{+} is $[Ar]3d^{9}4s^{1}$

B Cu is $[Ar]3d^{10}4s^{2}$

C Cu^{2+} is $[Ar]3d^{8}4s^{1}$

(D) Cu^{+} is $[Ar]3d^{10}$

Cu is $4s^1$ $3d^{10}$ so for the Cu^+ ion it will lose the $4s^1$ electron.

(Total 1 mark)

Q12. Which change requires the largest amount of energy?

(A) $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ○

B $Li(g) \longrightarrow Li^+(g) + e^-$ ○

C $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ○

D $N(g) \longrightarrow N^+(g) + e^-$ ○

← electrons very close to the nucleus hence highest energy needed.

(Total 1 mark)

Q13. An ester is hydrolysed as shown by the following equation.

$$RCOOR' + H_2O \longrightarrow RCOOH + R'OH$$

What is the percentage yield of RCOOH when 0.50 g of RCOOH (M_r = 100) is obtained from 1.0 g of RCOOR' (M_r = 150)?

A 33% ○

B 50% ○

C 67% ○

(D) 75% ○

DO NOT forget the recurring 6!!

$\frac{1}{150} = 0.006^{\bullet} \times 100 = 0.6^{\bullet}g$ ← theoretical yield

$0.5g$ ← actual yield

$\frac{0.5}{0.6^{\bullet}} \times 100 = 75\%$

(Total 1 mark)

Q14. Which of these samples of gas contains the largest number of molecules?
The gas constant R = 8.31 J K^{-1} mol^{-1}.

A 5.0×10^{-4} m^3 at 1.0×10^6 Pa and 300 K ○ $n = 0.2$

(B) 4.0×10^{-3} m^3 at 2.0×10^5 Pa and 400 K ○ $n = 0.24$

C 3.0×10^{1} dm^3 at 3.0×10^4 Pa and 500 K ○ $n = 0.216$

D 2.0×10^{2} dm^3 at 4.0×10^3 Pa and 600 K ○ $n = 0.16$

$PV = nRT$

$n = \frac{PV}{RT}$

these two have volumes in dm^3. Be careful!

(Total 1 mark)

Q15. Which of the following contains the most chloride ions?

A 10 cm^3 of 3.30×10^{-2} mol dm^{-3} aluminium chloride solution ( )

B 20 cm^3 of 5.00×10^{-2} mol dm^{-3} calcium chloride solution ( )

C 30 cm^3 of 3.30×10^{-2} mol dm^{-3} hydrochloric acid ( )

D 40 cm^3 of 2.50×10^{-2} mol dm^{-3} sodium chloride solution ( )

$C = \frac{n}{V}$

example

B

$5 \times 10^{-2} \times \left(\frac{20}{1000}\right) =$

1×10^{-3} moles

$\times 2 = 2 \times 10^{-3}$

from table

(Total 1 mark)

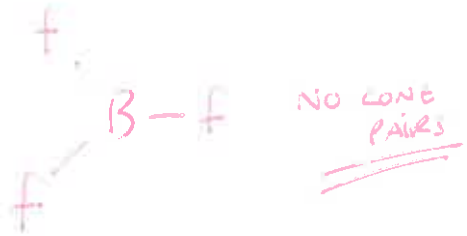
Q16. Which one of the following has a shape which is **not** influenced by a lone pair of electrons?

A CH_3OH

B H_2F^+

C BF_3

D NF_3



(Total 1 mark)

Q17. Which one of the following bond polarities is **not** correct?

A $\overset{\delta-}{C}-\overset{\delta+}{H}$ in ethane ← Not considered polar if charges were put on it it would be $C^{\delta-} - H^{\delta+}$ as carbon has the higher electronegativity.

B $\overset{\delta+}{C}-\overset{\delta-}{Br}$ in bromoethane

C $\overset{\delta+}{C}-\overset{\delta-}{O}$ in ethanol

D $\overset{\delta+}{C}=\overset{\delta-}{O}$ in ethanal

(Total 1 mark)

Q18. When ethanamide (CH_3CONH_2) burns in oxygen the carbon is converted into carbon dioxide, the hydrogen is converted into water and the nitrogen forms nitrogen gas.

Substance	ethanamide	carbon dioxide	water
Enthalpy of formation ($\Delta H_f^\ominus$) / kJ mol^{-1}	−320	−394	−286

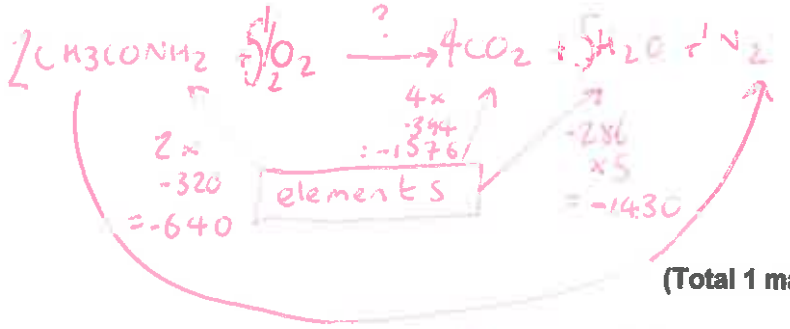
Using the data above, which one of the following is a correct value for the enthalpy of combustion of ethanamide?

A −1823 kJ mol^{-1}

B −1183 kJ mol^{-1}

C −1000 kJ mol^{-1}

D −360 kJ mo1^{-1}



(Total 1 mark)

640 + (-3006) = -2366

But my balance is for two moles of ethanamide

Therefore: -2366 / 2 = -1183