
ANSWERS
Gr 12
PHYSICAL SCIENCE
2025
CHEMISTRY
REVISION BOOK

Secondary Schools Directorate

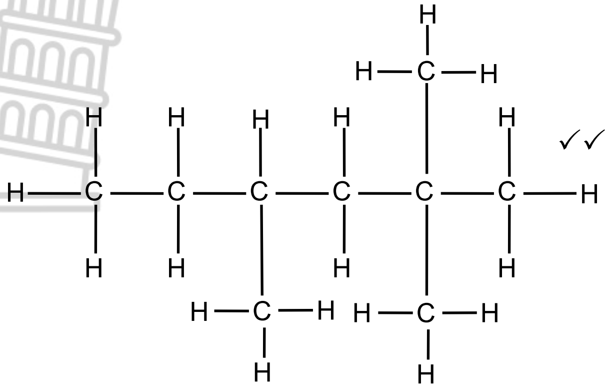
education
Department of Education
FREE STATE PROVINCE

TABLE OF CONTENTS

ORGANIC MOLECULES: NOMENCLATURE

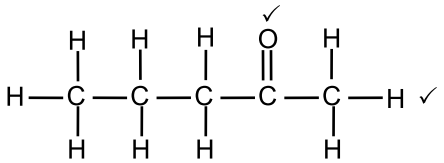
QUESTION 1 (November 2014)

1.1.1 B ✓ (1)
1.1.2 D ✓ (1)
1.2 2-bromo-3-chloro-4-methylpentane ✓✓✓ (3)
1.3.1



(2)

1.3.2

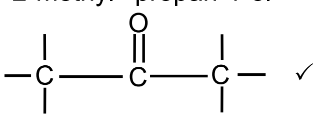


(2)

1.4.1 Compounds with the same molecular formula ✓ but DIFFERENT functional goups. ✓ (2)
1.4.2 <u>B & F</u> ✓ (1)
[12]

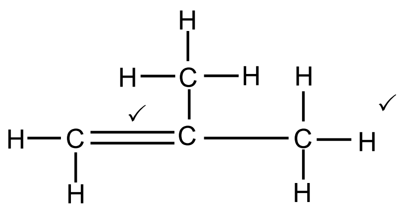
QUESTION 2 (June 2015)

2.1.1 B ✓ (1)
2.1.2 E ✓ (1)
2.1.3 A ✓ (1)
2.2.1 4-chloro-2,5-dimethylheptane ✓✓✓ (3)
2.2.2 2-methyl✓propan-1-ol ✓ (2)
2.2.3



(1)

2.3.1 Compounds with the <u>same molecular formula</u>✓ but <u>different POSITIONS of the functional group</u> / side chain / substituents on parent chain. ✓ (2)
2.3.2 <u>But</u>-1-<u>ene</u> ✓✓ **AND** <u>But</u>-2-<u>ene</u> ✓✓ (4)
2.3.3

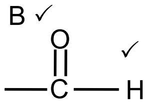


(2)

2.4.1 Cracking / elimination ✓ (1)
2.4.2 Ethene ✓ (1)
2.4.3 C_4H_{10} ✓ (1)
[20]

QUESTION 3 (November 2015)

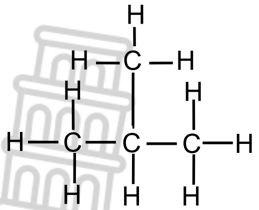
3.1.1 B ✓ (1)
3.1.2



(1)

3.1.3 C_nH_{2n-2} ✓ (1)
3.1.4 4-ethyl-5-methylhept-2-yne ✓✓ **OR** 4-ethyl-5-methyl-2-heptyne (2)
3.1.5 Butan-2-one / 2-butanone ✓✓ (2)
3.2.1 Alkanes ✓ (1)

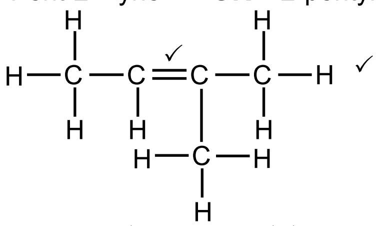
3.2.2 2-methyl✓propane ✓ **OR** methyl✓propane ✓


(4)

3.2.3 Chain ✓ (1)
3.3.1 Haloalkanes / Alkyl halides ✓ (1)
3.3.2 Substitution / halogenation / bromination ✓ (1)
[16]

QUESTION 4 (June 2016)

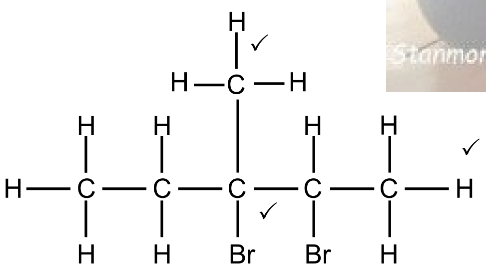
4.1.1 E ✓ (1)
4.1.2 C ✓ (1)
4.1.3 D ✓ (1)
4.2.1 Pent-2✓-yne✓ **OR** 2-pentyne (2)
4.2.2


(2)

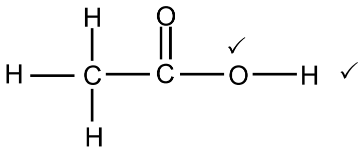
4.2.3 2-methyl✓but-1-ene ✓✓ **OR** 3-methylbut-1-ene (3)
4.3.1 Esters ✓ (1)
4.3.2 Sulphuric acid / H_2SO_4 ✓ (1)
4.3.3 Methyl✓ propanoate ✓ (2)
[14]

QUESTION 5 (November 2016)

5.1.1 A ✓ (1)
5.1.2 D ✓ (1)
5.1.3 E ✓ (1)
5.2.1


(3)

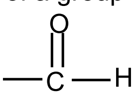
5.2.2


(2)

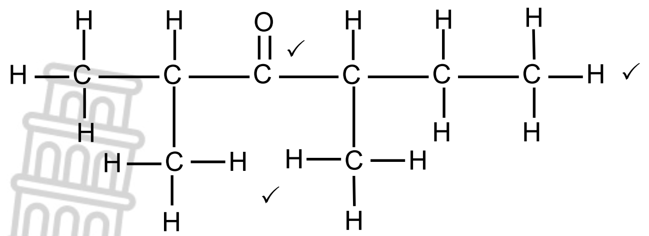
5.3.1 Hydrogen gas ✓ (1)
5.3.2 Addition / Hydrogenation ✓ (1)
[10]

QUESTION 6 (March 2017)

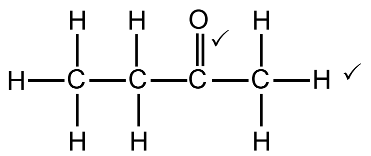
6.1 A bond or an atom or a group of atoms ✓ that determine(s) the (physical and chemical) properties of a group of organic compounds. ✓ (2)
6.2.1

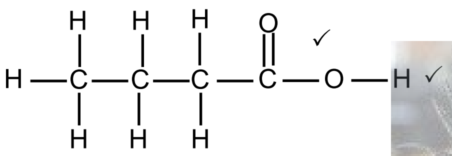

(1)

6.2.2 Carboxyl (group) ✓ (1)
6.3.1 Ketones ✓ (1)

6.3.2

(3)

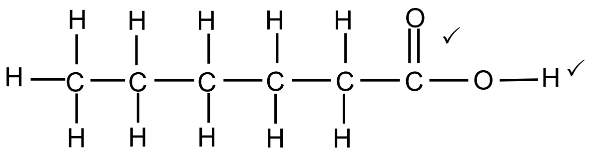
6.4.1 5-bromo-4-ethyl-2,2-dimethylhexane ✓✓✓ (3)
6.4.2 4-methyl✓pent-2-yne ✓ / 4-methyl-2-pentyne (2)
[13]

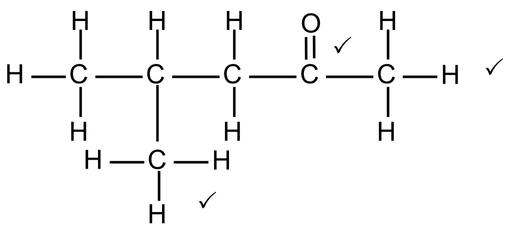
QUESTION 7 (June 2017)
7.1.1 B ✓ (1)
7.1.2 D **OR** E ✓ (1)
7.1.3 F ✓ (1)
7.2.1 Butanal ✓ (1)
7.2.2 2,3,3-trimethylbut-1-ene ✓✓✓ **OR** 2,3,3- trimethyl-1-butene (3)
7.3

(2)

7.4.1 Esterification / Condensation ✓ (1)
7.4.2 Propan-1-ol ✓✓ (1)
7.4.3



(3)

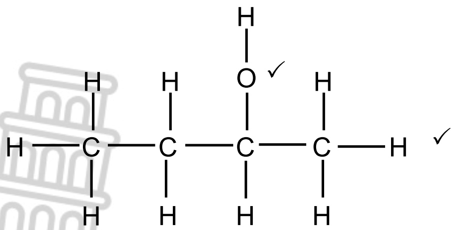
7.4.4 Propyl ✓ butanoate ✓ (2)
[16]

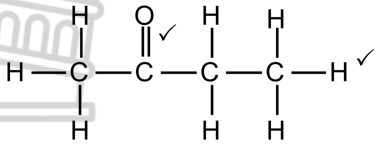
QUESTION 8 (November 2017)
8.1.1 Esters ✓ (1)
8.1.2 Ethyl ✓ butanoate ✓ (2)
8.1.3 Butanoic acid ✓ (1)
8.1.4

(2)

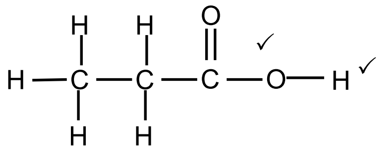
8.2

(3)

8.3.1 C_nH_{2n-2} ✓ (1)
8.3.2 5-ethyl-2,6-dimethylhept-3-yne ✓✓✓ **OR** 5-ethyl-2,6-dimethyl-3-heptyne (3)
[13]

QUESTION 9 (March 2018)
9.1.1 A ✓ (1)
9.1.2 B ✓ (1)
9.1.3 D ✓ (1)
9.1.4 D ✓ (1)
9.2.1 Butanal ✓ (1)
9.2.2 5-ethyl-6,6-dimethyl✓✓octan-3-ol ✓✓ **OR** 5-ethyl-6,6-dimethyl-3-octanol (4)
9.3 Compounds with the same molecular formula, ✓ but different positions of the side chain/substituents/functional groups on parent chain. ✓ (2)

9.4.1

(2)

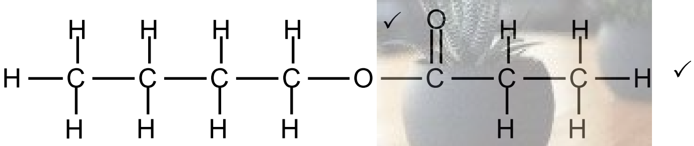
9.4.2

(2)

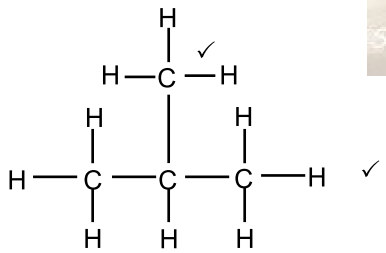
9.4.3

(2)
[17]

QUESTION 10 (June 2019)

10.1 Unsaturated✓
C/It has a <u>triple/multiple bond</u>. ✓ (2)

10.2.1 D ✓ (1)
10.2.2 B ✓ (1)
10.2.3 C ✓ (1)
10.2.4 E ✓ (1)
10.3.1 —C≡C— ✓ (1)

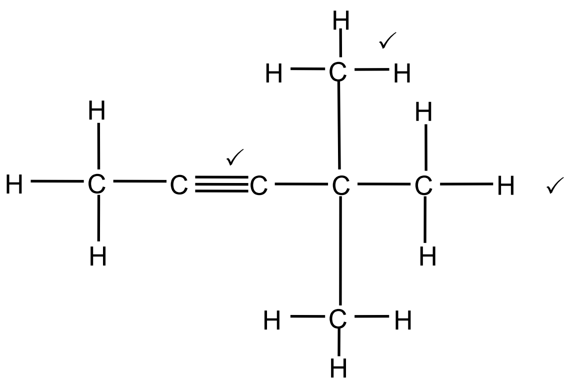
10.3.2

(2)

10.3.3

(2)

10.4.1 2,3-dibromo-5-methylheptane ✓✓✓ (3)
10.4.2 $2C_4H_{10}$ + $13O_2$ ✓ → $8CO_2$ + $10H_2O$ ✓ Bal ✓ (3)
[17]

QUESTION 11 (November 2019)

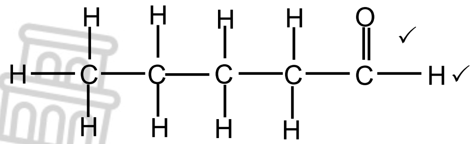
11.1.1 C_nH_{2n-2} ✓ (1)

11.1.2

(3)

11.2.1 Compounds with the <u>same molecular formula</u>, ✓ but <u>different positions of the side chain/substituents/functional groups</u> ✓on the parent chain. (2)

11.2.2 Pentan-3-one/3-pentanone ✓✓ (2)

11.2.3



(2)

11.3.1 Tertiary (alcohol) ✓
The C atom bonded to the functional group/hydroxyl (group)/-OH is bonded to three other C atoms. ✓ (2)

11.3.2 2-methylbutan-2-ol/2-methyl-2-butanol ✓✓ (2)

11.3.3 2-methylbut-2- ene/2-methyl-2-butene ✓✓ (2)

[16]

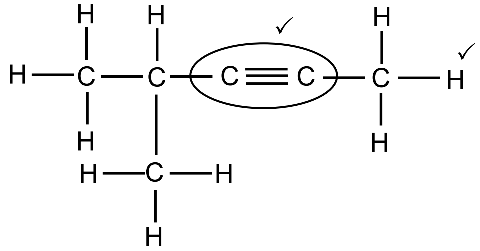
QUESTION 12 (November 2020)

12.1.1 Ketones ✓ (1)

12.1.2 Pentanal ✓✓ (2)

12.2.1 5-bromo-2,3-dimethylhexane ✓✓✓ (3)

12.2.2



(2)

12.3.1 The C atom bonded to the hydroxyl group is bonded to only one other C-atom. ✓✓ **(2 or 0)**
OR
The hydroxyl group/-OH/ is bonded to a C atom which is bonded to two hydrogens atoms. **(2 or 0)**
OR
The hydroxyl group/functional group/-OH is bonded to: a primary C atom / the first C atom. **(2 or 0)** (2)

12.3.2 Esterification/condensation ✓ (1)

12.3.3 Butanoic acid ✓ (1)

[12]

QUESTION 13 (June 2021)

13.1.1 F ✓ (1)

13.1.2 B & F ✓ (1)

13.1.3 C ✓ (1)

13.2.1 Haloalkane/alkyl halide ✓ (1)

13.2.2 3,5-dibromooctane ✓✓✓

Marking criteria
- Octane ✓
- Dibromo ✓
- Substituents (dibromo) correctly numbered, hyphens, commas correctly used. ✓ (3)

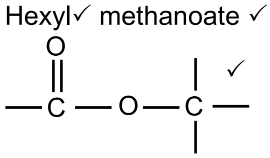
13.3.1 Pentan-3-one ✓✓

Marking criteria
- Pentanone ✓
- Correct position of functional group. ✓ (2)

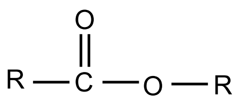
13.3.2 3-methyl✓butan-2-one✓ **OR** 3-methyl✓butanone✓ ✓ methyl✓butanone✓ (2)

13.4.1 Hexyl✓ methanoate ✓ (2)

13.4.2



OR



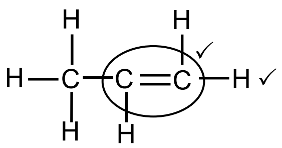
(1)

13.5

13.5.1 Cracking/Elimination ✓ (1)

13.5.2 C_7H_{16} ✓✓ (2)

13.5.3



Marking criteria
- Functional group ✓
- Whole structure correct. ✓

(2)

[19]

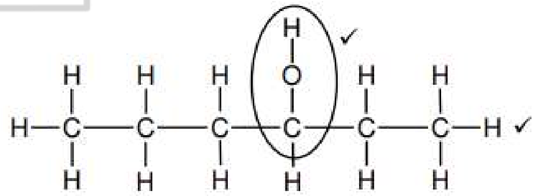
QUESTION 14 (September 2021)

14.1
14.1.1 C ✓ (1)
14.1.2 B/E ✓ (1)
14.1.3 E ✓ (1)
14.2
14.2.1 2-bromo-4-ethyl-3,3-dimethylhexane ✓✓✓

Marking criteria
- Correct stem i.e. hexane. ✓
- All substituents (bromo, ethyl and dimethyl) correctly identified. ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas.✓

(3)

14.2.2



Marking criteria
- Six carbons in longest chain. ✓
- Hydroxyl group on third carbon. ✓

(2)

14.2.3 Pentanal ✓✓

Marking criteria
- Correct functional group i.e. -al ✓
- Whole name correct. ✓

(2)

14.3
14.3.1 Oxidation/combustion ✓ (1)
14.3.2 C_8H_{18} ✓✓ **(2 or 0)** (2)

14.3.3

OPTION 1/OPSIE 1	**Marking criteria/*Nasienkriteria***
$V(CO_2) = 8 \times V_B$ $= 8(50)$ $= 400\ cm^3$ $V(H_2O) = \frac{18}{2}V_B$ $= 9(50)$ $= 450\ cm^3$ ✓ Total volume gas formed/ *Totale volume gas gevorm* ✓ $= 400 + 450$ $= 850\ cm^3$ ✓	• Use volume ratio/*Gebruik volume verhouding:* $V(CO_2) : V(B) = 2 : 1$ and/en $V(H_2O) : V(B) = 9 : 1$ ✓ • Add/*Tel bymekaar:* $V(CO_2)$ and/en $V(H_2O)$ ✓ • Final answer/*Finale antwoord:* $850\ cm^3$ ✓ **OPTION 2/*OPSIE 2*** ✓ 2 mol C_XH_Y .... 16 + 18 = 34 mol gas 50 mol C_XH_Y .... 25 x 34 ✓ mol gas Total moles gas formed/*Totale volume gas gevorm* = $850\ cm^3$ ✓

(3)
[16]

QUESTION 15 (November 2021)

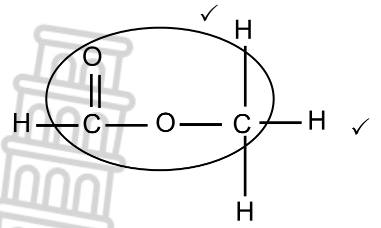
15.1 A compound that contains a double bond/multiple bond/no single bonds (between C atoms). ✓✓ (2)
15.2
15.2.1 B / E ✓ (1)
15.2.2 Carbonyl (group) ✓ (1)
15.2.3 F ✓✓ (2)
15.2.4 2,5-dichloro-3-methylhexane

Marking criteria
- Correct stem i.e. hexane. ✓
- All substituents (dichloro and methyl) correctly identified. ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas.✓ (3)

15.2.5 C_nH_{2n} ✓ (1)
15.3 Compounds with the same molecular formula, ✓ but different functional groups. ✓ (2)

15.4.1 Carboxylic acids ✓ (1)

15.4.2



Marking criteria
- Functional group ✓
- Whole structure correct. ✓

(2)

15.5

15.5.1 Ethanol ✓ (1)

15.5.2 E ✓ (1)

15.5.3 (Concentrated) sulphuric acid/H_2SO_4 ✓ (1)

[18]

QUESTION 16 (June 2022)

16.1

16.1.1 E ✓ (1)

16.1.2 F ✓ (1)

16.1.3 C ✓ (1)

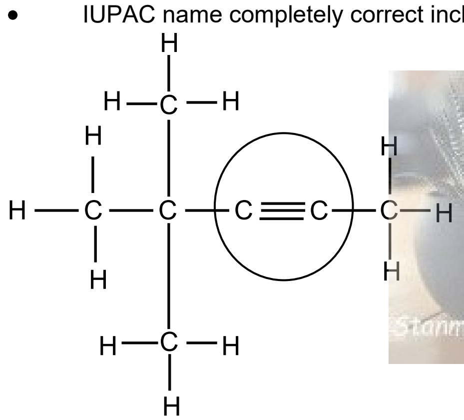
16.1.4 H ✓ (1)

16.2

16.2.1 2-bromo-2,4,5-trimethylhexane

Marking criteria
- Correct stem i.e. hexane. ✓
- All substituents (bromo and trimethyl) correctly identified. ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓ (3)

16.2.2



Marking criteria
- Five C atoms in longest chain + tripple bond. ✓
- Two methyl substituents. ✓
- Whole structure correct. ✓

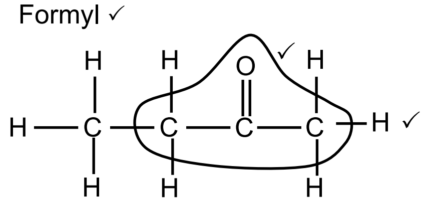
(3)

16.3

16.3.1 Aldehyde ✓ (1)

16.3.2 Formyl ✓ (1)

16.3.3



Marking criteria
- Functional group ✓
- Whole structure correct. ✓

(2)

16.4

16.4.1 Methyl✓propane✓/2-methylpropane (2)

16.4.2 $2C_4H_{10}$ + $13O_2$ ✓ → $8CO_2$ + $10H_2O$ ✓ Bal. ✓ (3)

[19]

QUESTION 17 (November 2022)

17.1

17.1.1 C & D ✓ (1)

17.1.2 Functional ✓ (1)

17.1.3 C_nH_{2n-2} ✓ (1)

17.1.4 Hydroxyl (group) ✓ (1)

17.2

17.2.1 4-bromo-3,3-dimethylhexane ✓✓✓

Marking criteria:
- Correct stem i.e. hexane. ✓
- All substituents (bromo and dimethyl) correctly identified. ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓

(3)

17.2.2 4,4-dimethylpent-2-yne/4,4-dimethyl-2-pentyne ✓✓

Marking criteria:
- Correct stem and substituents: dimethyl and pentyne ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓

(2)

17.2.3 Butanal ✓✓

Marking criteria
- Functional group: -al ✓
- IUPAC name correct. ✓

(2)

17.3

17.3.1 Esterification/condensation ✓ (1)

17.3.2 $M(C_3H_6O) = 58\ g{\cdot}mol^{-1}$

$$\frac{\text{molecular mass of molecular formula}}{\text{molecular mass of empirical formula}} = \frac{116}{58} = 2$$

Compound S = $C_6H_{12}O_2$ ✓

Carboxylic acid: $C_2H_4O_2$ ✓✓ (3)

[15]

QUESTION 18 (June 2023)

18.1 Compounds with one or more multiple/double/triple bonds between C atoms in the hydrocarbon chain. ✓✓

OR

Hydrocarbons containing not only single bonds between C atoms. (2)

18.2.1 D ✓ (1)

18.2.2 2,4-dimethylhexane ✓✓✓

Marking criteria:
- Correct stem i.e. hexane. ✓
- Substituents (dimethyl) correctly identified. ✓
- IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓

(3)

18.2.3 Propan-2-ol /2-propanol ✓✓

Marking criteria:
- *Correct stem i.e. propanol.* ✓
- *IUPAC name completely correct including numbering and hyphens.* ✓ (2)

18.2.4 Hept-1-ene/1-heptene ✓✓

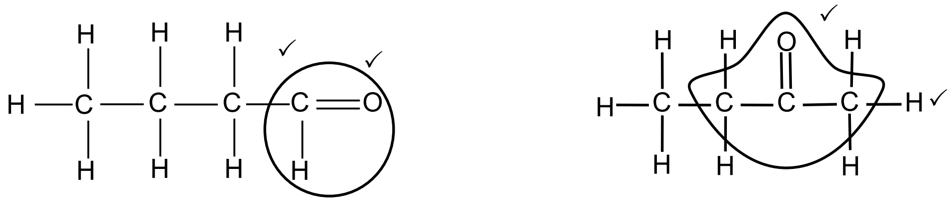
Marking criteria:
- *Correct stem i.e. heptene.* ✓
- *IUPAC name completely correct including numbering and hyphens.* ✓ (2)

18.2.5 $2C_8H_{18}$ ✓ + $25O_2$ → $16CO_2$ + $18H_2O$ ✓ Bal ✓

Marking criteria
- *Correct molecular formula: C_8H_{18}* ✓
- *Correct molecular formula of inorganic reactant and products.* ✓
- *Balancing* ✓ (3)

18.3.1 Compounds with the same molecular formula but different functional groups/homologous series. ✓✓ (2)

18.3.2



(4)

18.4

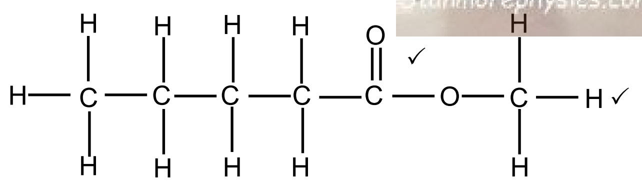
Marking criteria:
- Calculate the mass of oxygen ✓
- Substitute mass and molar mass for C and H into $n = \frac{m}{M}$. ✓
  NOTE: Any incorrect substitution – deduct 1 mark
- Substitute mass and molar mass for O into $n = \frac{m}{M}$. ✓
  NOTE: Any incorrect substitution – deduct 1 mark.
- Simplify ratio. ✓
- Correct molecular formula. ✓✓

	C	H	O
Mass	1,09	0,18	2 – (1,09 + 0,18) ✓ = 0,73
Moles	$n = \frac{m}{M}$ $= \frac{1,09}{12}$ = 0,0908	$n = \frac{m}{M}$ $= \frac{0,18}{1}$ ✓ = 0,18	$n = \frac{m}{M}$ $= \frac{0,73}{16}$ ✓ = 0,046
Simplest ratio	2	4	1 ✓
Empirical formula	C_2H_4O		

$M(C_2H_4O) = 88\ (g{\cdot}mol^{-1})$
$44n = 88$
$n = 2$
Molecular formula of compound **X**: $C_4H_8O_2$ ✓✓ (6)
[25]

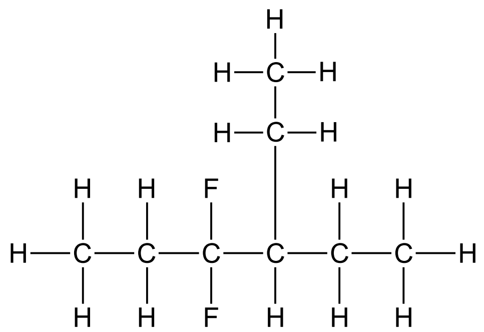
QUESTION 19 (November 2023)

19.1 Compounds containing carbon atoms. ✓ (1)
19.2
19.2.1 2,3-dimethylbut-1-ene ✓✓ (2)
19.2.2 Butan-2-one ✓✓ (2)
19.3
19.3.1



(2)

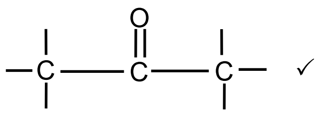
19.3.2



- Six C atoms in longest chain ✓
- Two F atoms on 3rd C atom ✓
- Ethyl group on 4th C atom ✓

(3)

19.3.3 C_nH_{2n} ✓ (1)
19.3.4

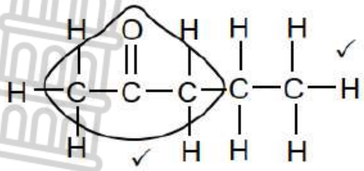


(1)

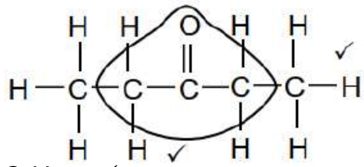
19.3.5 Methanol ✓✓ (2)
19.4
19.4.1 B (1)
19.4.2 D & G (1)
[16]

QUESTION 20 (June 2024)

20.1 Organic compounds that consist of hydrogen and carbon only. ✓✓(2 or 0) (2)
20.2.1 C and E ✓ (1)
20.2.2 D and H ✓✓ (2 or 0) (2)
20.2.3 A ✓ (1)
20.3.1



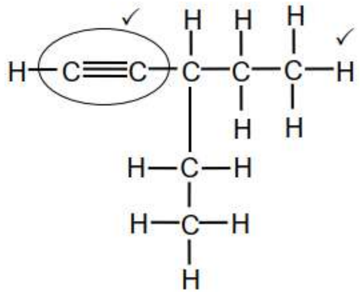
OR



Marking criteria:
Functional group ✓
Whole structure is correct. ✓
IF:
More than one functional group / wrong functional group: (0/2)
Condensed structural formulae are used. (1/2)

(2)

20.3.2 C_nH_{2n+2} ✓ (1)
20.3.3



Marking criteria:
As before.

(2)

20.4.1 3-ethylhex-3-ene ✓✓✓ **OR** 3-ethyl-3-hexene

Marking criteria:
Correct stem ✓
Substituent(s) correctly identified. ✓
IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓

(3)

20.4.2 2,5-dichloro-2,4-dimethylhexane ✓✓✓ Marking criteria as before. (3)
20.4.3 2,2-dimethyl✓propanal ✓ **OR** dimethylpropanal Marking criteria as before.
Note: 2,2-dimethylpropan-1-al (1/2) (2)
20.5 $C_7H_{16} + 11O_2$ ✓ $\rightarrow 7CO_2 + 8H_2O$ ✓ Balancing: ✓ (3)
[22]

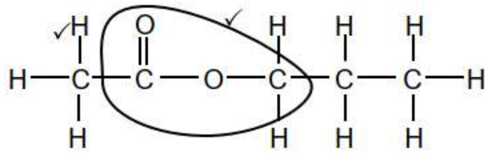
QUESTION 21 (November 2024)

21.1.1 D ✓ (1)
21.1.2 A ✓ (1)
21.1.3 E ✓ (1)
21.2.1 3,3-dibromo-4,4-dimethylhexane ✓✓✓

Marking criteria:
Correct stem ✓
Substituent(s) correctly identified. ✓
IUPAC name completely correct including numbering, sequence, hyphens and commas. ✓

(3)

21.2.2 4,4-dimethylpent-2-yne/4,4-dimethyl-2-pentyne ✓✓✓ Marking criteria as before. (3)
21.3.1 Compounds with the same molecular formula, ✓ but different functional groups / homologous series. ✓ (2)
21.3.2 A and C ✓ (1)
21.4.1 H_2SO_4/Sulhuric acid ✓ (1)
21.4.2 Esterification/Condensation ✓ (1)
21.4.3



Marking criteria:
Functional group ✓
Whole structure is correct. ✓

(2)

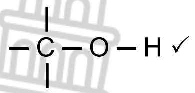
21.4.4 Propan-1-ol/1-propanal ✓✓ (2)
[18]

ORGANIC MOLECULES: PHYSICAL PROPERTIES

QUESTION 1 (November 2014)

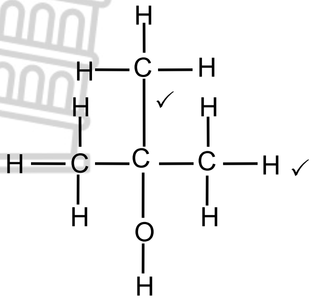
1.1 Alkanes have ONLY single bonds between C atoms. **OR** Alkanes have NO multiple bonds. (1)

1.2.1



(1)

1.2.2



(2)

1.3.1 **Criteria for investigative question*:***

The dependent and independent variables are stated.	✓
Ask a question about the relationship between the independent and dependent variables.	✓

Examples:
How does an increase in chain length influence boiling point?
What is the relationship between chain length and boiling point? (2)

1.3.2 **Structure:** The chain length increases. ✓
Intermolecular forces: Increase in strength of intermolecular. ✓
Energy: More energy needed to overcome intermolecular forces. ✓
OR
Structure: From propane to methane the chain length decreases. ✓
Intermolecular forces: Decrease in strength of intermolecular. ✓
Energy: Less energy needed to overcome intermolecular forces. ✓ (3)

1.4 Between propane molecules are London forces. ✓
Between propan-1-ol molecules are London forces, dipole-dipole forces and hydrogen bonds. ✓
Hydrogen bonds are stronger than London forces. ✓ (3)
[12]

QUESTION 2 (June 2015)

2.1 Saturated ✓
B has ONLY single bonds between C atoms. ✓ **OR** B has NO multiple bonds. (2)

2.2.1 – 42 °C ✓ (1)

2.2.2 78 °C ✓ (1)

2.3 Between molecules of C/propane are London forces / induced dipole forces. ✓
Between molecules of E/ethanol are (London forces / induced dipole forces and) hydrogen bonds. ✓
Hydrogen bonds / Forces between alcohol molecules are stronger. ✓ (3)

2.4 Decrease ✓
From A to D: Chain length increases. ✓
Strength of intermolecular forces increases. ✓
More energy needed to overcome intermolecular forces. ✓ (4)

2.5 Higher than ✓ (1)
[12]

QUESTION 3 (November 2015)

3.1 A bond / an atom / a group of atoms ✓ that determine(s) the (physical and chemical) properties of a group of organic compounds. ✓ (2)

3.2.1 D / ethanoic acid ✓
Lowest vapour pressure. ✓ (2)

3.2.2 A / butane ✓ (1)

3.3 Between molecules of A / butane are London forces. ✓
Between molecules of B / propan-2-one / ketones are dipole-dipole forces ✓ in addition to London forces.
Intermolecular forces in A are weaker than those in B. ✓ (3)

3.4 London forces / induced dipole forces / dipole-dipole forces. ✓
OR A and B do not have hydrogen bonding. / C and D have hydrogen bonding. (1)

3.5 D has more sites for hydrogen bonding than C. / D forms dimers. ✓
D has stronger intermolecular forces. ✓ (2)

3.6

$V(CO_2) = 4V(C_4H_{10})$ $= (4)(8)$ ✓ $= 32\ cm^3$	$V(H_2O) = 5V(C_4H_{10})$ $= (5)(8)$ ✓ $= 40\ cm^3$	$V(O_2$ reacted): $V(O_2) = (\frac{13}{2})V(C_4H_{10})$ $= (\frac{13}{2})(8)$ ✓ $= 52\ cm^3$ $V(O_2$ excess): $V(O_2) = 60 - 52$ ✓ $= 8\ cm^3$

$V_{tot} = 32 + 40 + 8 = 80\ cm^3$ ✓

(5)
[16]

QUESTION 4 (March 2016)

4.1 Temperature ✓ at which the vapour pressure equals atmospheric pressure. ✓ (2)

4.2 The stronger the intermolecular forces, the higher the boiling point. / The boiling point is proportional to the strength of intermolecular forces. ✓
NOTE: NOT DIRECTLY proportional! (1)

4.3.1 Between molecules of **A** / propane are London forces. ✓
Between molecules of **B** / propan-2-one are dipole-dipole forces ✓ in addition to London forces.
Intermolecular forces in **A** are weaker than those in **B**. ✓ (3)

4.3.2 Both **C** and **D**: hydrogen bonding ✓
D has two / more sites for hydrogen bonding. / **D** forms dimers. ✓
D has stronger intermolecular forces than **C**. ✓ (3)

4.4 Liquid ✓ (1)
[10]

QUESTION 5 (June 2016)

5.1 Temperature ✓at which the vapour pressure equals atmospheric pressure. ✓ (2)

5.2 **Criteria for conclusion:**
Dependent and independent variables correctly identified. ✓
Relationship between the independent and dependent variables correctly stated. ✓
Examples:
- Boiling point increases with increase in chain length.
- Boiling point decreases with decrease in chain length.
- Boiling point is proportional to chain length.

NOTE: Boiling point is **NOT** DIRECTLY proportional to chain length. (2)

5.3.1 P ✓ (1)

5.3.2 R ✓ (1)

5.4 Between alkane molecules are London forces. ✓
In addition to London forces and dipole-dipole forces each alcohol molecule has one site for hydrogen bonding. ✓
In addition to London forces and dipole-dipole forces each carboxylic acid molecule has two sites for hydrogen bonding. ✓
Intermolecular forces in carboxylic acids are stronger than intermolecular forces in alkanes and alcohols. ✓
More energy is needed to overcome intermolecular forces in carboxylic acids than in the other two compounds. ✓ (5)
[11]

QUESTION 6 (November 2016)

6.1 Compounds with the same molecular formula ✓ but different structural formulae. ✓ (2)

6.2 Chain ✓ (1)

6.3 **From A to C:**
Structure: Less branched / less compact / larger surface area (over which intermolecular forces act). ✓
Intermolecular forces: Stronger intermolecular forces. ✓
Energy: More energy needed to overcome intermolecular forces. ✓ (3)

6.4 A ✓
Lowest boiling point. ✓ (2)

6.5 $C_5H_{12} + 8O_2$ ✓ $\rightarrow 5CO_2 + 6H_2O$ ✓ Bal ✓ (3)
[11]

QUESTION 7 (June 2017)

7.1 The temperature ✓ at which the vapour pressure equals atmospheric (external) pressure. ✓ (2)

7.2 Flammable / Catch fire easily. / Volatile ✓ (1)

7.3.1 Use straight chain ✓ primary alcohols ✓ (2)

7.3.2. **Structure:** Chain length / more C atoms in chain / molecular size / molecular mass / surface area increases from top to bottom / butan-1-ol to hexan-1-ol. ✓
Intermolecular forces: Intermolecular forces / Van der Waals forces / London forces / dispersion forces increase from top to bottom / butan-1-ol to hexan-1-ol. ✓
Energy: Energy needed to overcome / break intermolecular forces increases from top to bottom / butan-1-ol to hexan-1-ol. ✓ (3)

7.4 Remains the same ✓ (1)

7.5.1 Functional group / Type of homologous series ✓ (1)

7.5.2 **Type of intermolecular forces:**
Between molecules of aldehyde / hexanal are dipole-dipole forces. ✓
Between molecules of alcohols / hexan-1ol are (in addition to dipole-dipole forces and London forces) hydrogen bonds. ✓
Strength of intermolecular forces:
Dipole-dipole forces are weaker than hydrogen bonds. ✓
OR Hydrogen bonds are stronger than dipole-dipole forces.
Energy:
More energy needed to overcome intermolecular forces in hexan-1-ol. ✓
OR Less energy needed to overcome intermolecular forces in hexanal. ✓ (4)
[14]

QUESTION 8 (November 2017)

8.1 They have ONLY single bonds between C atoms. /They have NO multiple bonds. ✓ (1)

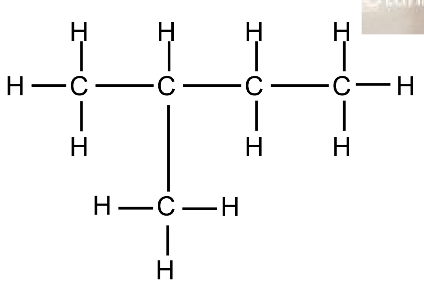
8.2 The pressure exerted by a vapour in equilibrium with its liquid in a closed system. ✓✓ (2)

8.3.1 Increases ✓ (1)

8.3.2 Q ✓
It is the temperature where the vapour pressure of compound Q equals atmospheric pressure/is equal to 760 (mmHg). /It is the temperature where the graph intercepts the dotted line. ✓ (2)

8.3.3 S ✓
At a given temperature/reference to any temperature. ✓
S has the lowest vapour pressure. ✓
Strongest intermolecular forces. / Highest energy needed to overcome the intermolecular forces. ✓ (4)

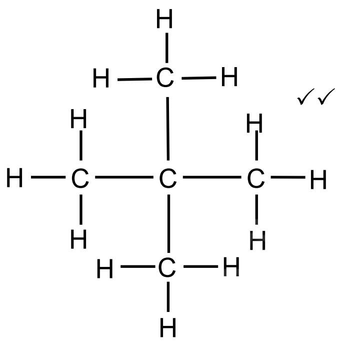
8.4.1



✓✓

2-methylbutane/methylbutane ✓

OR



✓✓

2,2-dimethylpropane/dimethylpropane ✓ (3)

8.4.2 Higher than ✓ (1)
[14]

QUESTION 9 (March 2018)

9.1 150 kPa ✓ (1)

9.2.1 The temperature ✓ at which the vapour pressure equals atmospheric/external pressure. ✓ (2)

9.2.2 55 °C ✓ (1)

9.3.1 Z ✓ (1)

9.3.2 Carboxylic acids have, in addition to London forces and dipole-dipole forces, two sites for hydrogen bonding between molecules. / Carboxylic acids can form dimers due to strong hydrogen bonding between molecules.✓
Alcohols have, in addition to London forces and dipole-dipole forces, one site for hydrogen bonding between molecules. ✓
Ketones has, in addition to London forces, dipole-dipole forces between molecules. ✓
Intermolecular forces in ethanoic acid is the strongest./Most energy needed to overcome/break intermolecular forces in ethanoic acid. ✓ (4)

9.3.3 Propanone ✓ **OR** propan-2-one **OR** 2-propanone (1)
[10]

QUESTION 10 (June 2018)

10.1 **Structure:** The chain length/molecular size/molecular mass/ surface area increases. ✓
Intermolecular forces: Increase in strength of intermolecular forces. ✓
Energy: More energy needed to overcome intermolecular forces. ✓
OR
Structure: From 4 C atoms to 1 C atom/bottom to top the chain length/molecular size/molecular mass/surface area decreases. ✓
Intermolecular forces*:* Decrease in strength of intermolecular forces. ✓
Energy: Less energy needed to overcome intermolecular forces. ✓ (3)

10.2 Alkanes have London forces. ✓
Alcohols have hydrogen bonding (in addition to London forces and dipole dipole forces). ✓
Hydrogen bonding are stronger intermolecular forces than London. / More energy needed to overcome intermolecular forces in alcohols ✓
Alcohols have higher boiling points than alkanes. ✓ (4)

10.3 Decrease ✓ (1)

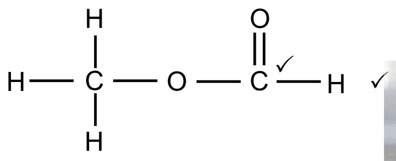
10.4 Lower than ✓
2-methylpropane is more branched/has a smaller surface area than butane/chain isomer. ✓
OR Butane/chain isomer is less branched /has larger surface area than 2-methylpropane. (2)
[10]

QUESTION 11 (November 2018)

11.1 The temperature ✓ at which the vapour pressure of a substance equals atmospheric/external pressure. ✓ (2)

11.2.1 Carboxyl group ✓ (1)

11.2.2 Propanoic acid ✓ (1)

11.2.3

(2)

11.3 A ✓
Lowest boiling point./Shortest chain length. ✓ (2)

11.4.1 The same molecular mass/molecular size. ✓ (1)

11.4.2 Primary ✓
OH group is bonded to a C atom bonded to one other C atom. ✓ (2)

11.4.3 - Both compounds/X and B have (in addition to London forces and dipole-dipole forces) hydrogen bonding. ✓
- Compound X/$CH_3CH_2CH_2OH$/propan-1-ol/alcohol has one site for hydrogen bonding and compound B/ethanoic acid/carboxylic acid has two/more sites for hydrogen bonding
OR: B/ethanoic acid/carboxylic acid has two/more sites for hydrogen bonding. ✓
- Intermolecular forces in compound B/ethanoic acid/carboxylic acid are stronger than intermolecular forces in compound X/$CH_3CH_2CH_2OH$/ propan-1-ol/alcohol. ✓
OR: Intermolecular forces in compound X/$CH_3CH_2CH_2OH$/ propan-1-ol/alcohol are weaker than intermolecular forces in compound B/ethanoic acid/carboxylic acid.
- More energy is needed to overcome intermolecular forces in compound B/ethanoic acid/carboxylic acid than in compound X/$CH_3CH_2CH_2OH$/ propan-1-ol/alcohol. ✓
OR Less energy is needed to overcome intermolecular forces in compound X/$CH_3CH_2CH_2OH$/ propan-1-ol/alcohol than in compound B/ethanoic acid/carboxylic acid. (4)
[15]

QUESTION 12 (June 2019)

12.1.1 Yes ✓
Compounds have the same molecular mass. ✓ (2)

12.1.2 Functional group/Homologous series/Type of (organic) compound ✓ (1)

12.2 A/butane ✓
Lowest boiling point/weakest intermolecular forces. ✓ (2)

12.3 - Between molecules of butane/compound A are London forces/dispersion forces/induced dipole forces. ✓
- Molecules of compound B/propan-1-ol have one site for hydrogen bonding. ✓
- Molecules of compound C/ethanoic acid have two/more sites for hydrogen bonding. ✓
- Strength of intermolecular forces increases from compound A/butane to compound B/propan-1-ol to compound C/ethanoic acid. ✓
- More energy is needed to overcome/break intermolecular forces in compound C than in the other two compounds. ✓ (5)

12.4 Butan-1-ol ✓
Longer chain length./Larger molecule./Larger molecular mass./ Larger molecular size./Stronger intermolecular forces./Larger surface area.✓✓ (2)
[12]

QUESTION 13 (November 2019)

13.1 The temperature ✓ at which the vapour pressure of a substance equals atmospheric/external pressure. ✓ (2)

13.2 **Q**, **R** and **S** have same molecular mass/same molecular formulae/number of carbon and hydrogen atoms. ✓ (1)

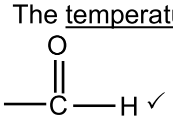
13.3 55 (°C) ✓
Compare compound R with compounds Q and S:
- Compound **R** is less branched/less compact/less spherical/has a larger surface area than compound **Q** and more branched/more compact/more spherical/has a smaller surface area than compound **S**. ✓**OR**
  Q is the most branched/compact /spherical/has the smallest surface area and **S** is least branched/compact/spherical/has the largest surface area.
- Intermolecular forces in compound **R** are stronger than in compound **Q** and weaker than in compound **S**. ✓
- More energy needed to overcome intermolecular forces in compound **R** than in compound **Q** and less energy needed to overcome intermolecular forces in compound **R** than in compound **S**. ✓ (4)

13.4.1 P ✓✓ (2)

13.4.2 In P/ pentanal/aldehydes: dipole-dipole forces (in addition to London forces/dispersion forces/ induced dipole forces). ✓
In **T**/pentan-1-ol: Hydrogen bonding (in addition to London forces/dispersion forces/induced dipole forces). ✓
Intermolecular forces in **P**/pentanal are weaker ✓ than in **T**/pentan-1-ol **OR** dipole-dipole forces are weaker than hydrogen bonds **OR** intermolecular forces in **T**/pentan-1-ol are stronger than in **P**/ pentanal. **OR** More energy needed to overcome intermolecular forces in **T**. (3)
[12]

QUESTION 14 (November 2020)

14.1 The temperature at which the vapour pressure equals atmospheric (external) pressure. ✓✓ (2)

14.2 
(1)

14.3 Increase in the number of C-atoms increases molecular mass/size/chain length/surface area. ✓
Strength of the intermolecular forces increases/More sites for London forces. ✓
More energy is needed to overcome/break intermolecular forces. ✓ (3)

14.4.1 C ✓ (1)

14.4.2 B ✓
- Aldehydes/B have (in addition to London forces) dipole-dipole forces which are stronger than London forces, but weaker than hydrogen bonds. ✓
- Therefore aldehydes/B have lower boiling points/require less energy to overcome intermolecular forces than alcohols/A, ✓ but higher boiling points / require more energy to overcome intermolecular forces than alkanes/C. ✓

OR
- Aldehydes/B have stronger intermolecular forces than alkanes, but weaker intermolecular forces than alcohols/A. ✓
- Therefore aldehydes/B have higher boiling points/ more energy required to overcome intermolecular forces than alkanes/C, ✓ but lower boiling points/ less energy to overcome intermolecular forces than alcohols/A. ✓ (4)

14.5 Butanal ✓✓ (2)

14.6 Pentan-1-ol ✓✓ (2)
[15]

QUESTION 15 (September 2021)

15.1 No ✓ (1)

15.2 There is more than one independent variable. ✓
OR Positions of functional groups and branching/chain length differ.
OR Compounds **A** and **B**/**C** are positional isomers and compounds **B** and **C** are chain isomers. (1)

15.3
- B/butan-2-ol is less branched / less compact / less spherical/ has a longer chain length / has a larger surface area (over which intermolecular forces act). ✓
- B/butan-2-ol has stronger / more intermolecular forces / Van der Waals forces / London forces / dispersion forces. ✓
- More energy needed to overcome or break intermolecular forces / Van der Waals forces in B/ butan-2-ol. ✓

OR
- C/2-methylpropan-2-ol is more branched / more compact / more spherical / has a smaller surface area (over which intermolecular forces act). ✓
- C/2-methylpropan-2-ol has weaker / less intermolecular forces / Van der Waals forces / London forces / dispersion forces. ✓
- Less energy needed to overcome or break intermolecular forces / Van der Waals forces in C/2-methylpropan-2-ol. ✓ (3)

15.4 Compounds with the same molecular formula, but different positions of the side chain/substituents/ functional groups on parent chain. (2)

15.5

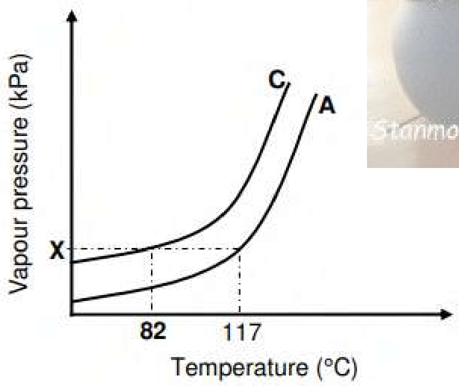
15.5.1 A & B ✓ (1)

15.5.2 C ✓
The C-atom bonded to the functional group/OH-group/hydroxyl (group) is bonded to three other C-atoms. ✓
OR
The functional group/OH-group/hydroxyl (group) is bonded to a tertiary C atom. (2)

15.6

15.6.1 101,3 (kPa) / 1,013 x 10^5 Pa / 1 atm / 760 mmHg ✓ (1)

15.6.2



Marking criteria:
- Curve C is above A.
- Value 82 °C on curve C where vapour pressure is X/ 101,3 kPa.

(2)
[13]

QUESTION 16 (November 2021)

16.1 The temperature at which solid and liquid phases are in equilibrium. ✓✓ (2)

16.2 As the chain length ✓ increases, the melting points increases. ✓ (2)

16.3 London forces/dispersion forces ✓ (1)

16.4.1 Liquid ✓ (1)

16.4.2 Solid ✓✓ (1)

16.5.1 Equal to ✓
Same molecular formula/Isomers ✓ (2)

16.5.2 Lower than ✓ (1)

16.5.3 **Marking criteria:**

- Compare structures. ✓
- Compare the strength of intermolecular forces. ✓
- Compare the energy required to overcome intermolecular forces. ✓

Hexane

- **Structure:**
  Longer chain length/less branched/less compact/less spherical/larger surface area (over which intermolecular forces act). ✓
- **Intermolecular forces:**
  Stronger/more intermolecular forces/Van der Waals forces/London forces/dispersion forces. ✓
- **Energy:**
  More energy needed to overcome or break intermolecular forces/Van der Waals forces. ✓
  OR

2,2-dimethylbutane:

- **Structure:**
  More branched/more compact more spherical/smaller surface area (over which intermolecular forces act). ✓
- **Intermolecular forces:**
  Weaker / less intermolecular forces/Van der Waals forces/London forces / dispersion forces. ✓
- **Energy:**
  Lesser energy needed to overcome intermolecular forces/Van der Waals forces. ✓ (3)

[13]

QUESTION 17 (June 2022)

17.1 The temperature at which the vapour pressure of a substance equals atmospheric/external pressure. (2)

17.2.1 Increases ✓ (1)

17.2.2
- Increase in molecular mass/size/chain length/surface area. ✓
- Strength of the intermolecular forces increases/More sites for London forces. ✓
- More energy is needed to overcome/break intermolecular forces. ✓

OR

From C to A:
- Decrease in molecular mass/size/chain length/surface area. ✓
- Strength of the intermolecular forces decreases/Less sites for London forces. ✓
- Less energy is needed to overcome/break intermolecular forces. ✓ (3)

17.3 No ✓
More than one independent variable./Molar mass and chain length are changing. ✓ (2)

17.4.1 Functional group/homologous series ✓ (1)

17.4.2 Dipole-dipole forces ✓ (1)

17.5 D / methylbutane ✓
Lower boiling point/Weaker intermolecular forces ✓ (2)

[12]

QUESTION 18 (November 2022)

18.1.1 Ketone ✓ (1)

18.1.2 Functional group/homologous series ✓ (1)

18.1.3

Marking criteria:
- Compare structures. ✓
- Compare the strength of intermolecular forces. ✓
- Compare the energy required to overcome intermolecular forces. ✓
- State the difference in melting point. ✓

Pentan-2-one/C

- **Structure:**
  Longer chain length/less branched/less compact/less spherical/larger surface area (over which intermolecular forces a
- **Intermolecular forces:**
  Stronger/more intermolecular forces/Van der Waals forces/London forces/ dipole-dipole forces. ✓
- **Energy:**
  More energy needed to overcome intermolecular forces/Van der Waals forces/dipole-dipole forces. ✓
- Higher melting point. ✓

OR
3-methylbutanone/D

- **Structure:**
  Shorter chain length/more branched/more compact more spherical/smaller surface area (over which intermolecular forces act). ✓
- **Intermolecular forces:**
  Weaker/less intermolecular forces/Van der Waals forces/London forces/ dipole-dipole forces. ✓
- **Energy:** Less energy needed to overcome intermolecular forces/Van der Waals force/dipole-dipole forces. ✓
- Lower melting point. ✓ (4)

18.2.1 The pressure exerted by a vapour at equilibrium with its liquid in a closed system. ✓✓ (2)

18.2.2

> **Marking criteria:**
> - Dependent and independent variables correctly identified. ✓
> - Correct relationship between dependent and independent variables stated. ✓

Vapour pressure decreases with increase in number of C atoms/chain length. ✓✓
OR
Vapour pressure increases with decrease in number of C atoms/chain length. (2)

18.2.3 Hexan-1-ol/1-Hexanol ✓✓✓
Marking criteria
Correct chain length i.e. hex ✓
Whole name correct. (3)

18.2.4 Increases ✓ (1)

[14]

QUESTION 19 (June 2023)

19.1 The temperature ✓ at which the vapour pressure equals atmospheric (external) pressure. ✓ (2)

19.2 Butan-1-ol ✓

- Has a longer chain length/is less branched./has a larger surface area./ contact area. ✓
- Strength of the intermolecular forces is greater./There are more sites for London forces. ✓
- More energy is needed to overcome/break intermolecular forces. ✓

OR

- 2-methylpropan-1-ol has a shorter chain length./is more branched./ has a smaller surface area/contact area.
- Strength of the intermolecular forces is weaker./There are fewer sites for London forces.
- Lesser energy is needed to overcome/break intermolecular forces.

19.3 Boiling point ✓

19.4

19.4.1 S ✓ (1)

19.4.2 P ✓ (1)

19.4.3 R ✓(1)

19.5 Propanoic acid/P has the strongest intermolecular forces. ✓
OR
Two sites for hydrogen bonding (which is stronger than other intermolecular forces)
OR
Most energy needed to separate the chains. (1)

[11]

QUESTION 20 (November 2023)

20.1 The temperature ✓ at which the vapour pressure equals atmospheric (external) pressure. ✓ (2)

20.2 **OPTION 1**

> **Marking criteria:**
> - Dependent and independent variables correctly identified. ✓
> - Correct relationship between dependent and independent variables stated. ✓
>
> **IF:** Directly proportional - Max 1 out of 2 marks

The higher the molecular mass the higher the boiling point. ✓✓
OR: As the molecular mass increases the boiling point increases.
OR: The longer the C-chain the higher boiling point
OR The boiling point and the molecular mass are proportional.

OPTION 2
Curve P represents carboxylic acids. ✓✓
OR For every molar mass, P has the highest boiling point. (2)

20.3 **For OPTION 1 in Q20.2**

Marking criteria:
- Strength of intermolecular forces. ✓
- Energy required to overcome intermolecular forces. ✓

Strength of the intermolecular forces increases / More sites for London forces with increase of molar mass/chain length/surface area. ✓
More energy is needed to overcome/break intermolecular forces. ✓

For OPTION 2 IN Q20.2

Marking criteria:
- Strength of intermolecular forces. ✓
- Energy required to overcome intermolecular forces. ✓

Curve P/carboxylic acids has strongest intermolecular forces. ✓
Most energy is needed to overcome/break intermolecular forces. ✓ (2)

20.4
20.4.1 Aldehyde ✓ (1)
20.4.2

Marking criteria:
- Comparing the strength of intermolecular forces of aldehydes/S with alcohols/R and/or carboxylic acids/P. ✓
- Linking the intermolecular forces to boiling point/energy needed. ✓

- Aldehydes/S have the weakest/weaker intermolecular forces. ✓
- Therefore, aldehydes/S have the lowest/lower boiling points / least/lower energy needed to overcome/break intermolecular forces. ✓

OR
- The strength of the intermolecular forces in aldehydes/S is weaker than in alcohols/R / carboxylic acids/P.
- Therefore, aldehydes/S have lower boiling points / need less energy than alcohols/carboxylic acids to overcome/break intermolecular forces

OR
- Carboxylic acids/P have the strongest intermolecular forces.
- Therefore, carboxylic acids/P have the highest boiling points / need most energy to overcome/break intermolecular forces.

OR
- Carboxylic acids/P and alcohols/R have stronger intermolecular forces than aldehydes/S.
- Therefore, carboxylic acids/P and/or alcohols/R have higher boiling points/ need more energy than aldehydes to overcome/break intermolecular forces. (2)

20.5
20.5.1 60 ($g \cdot mol^{-1}$) ✓
Range: 58 – 62 $g \cdot mol^{-1}$ (1)
20.5.2 Propan-1-ol/1-propanol ✓✓ (2)
20.6

Marking criteria:
- State that carboxylic acids have two sites for hydrogen bonding.
- State that alcohols have one site for hydrogen bonding. ✓
- Comparing the strength of IMFs / the energy needed to overcome IMFs. ✓

- Carboxylic acids/B/Propanoic acid have, (in addition to London forces and dipole-dipole forces), two sites for hydrogen bonding between molecules. ✓
  OR Carboxylic acid/B/Propanoic acid can form dimers due to strong hydrogen bonding between molecules.
- Alcohols/A/Butan-1-ol have, (in addition to London forces and dipole-dipole forces), one site for hydrogen bonding between molecules. ✓
- Intermolecular forces in carboxylic acids are stronger. ✓
  OR More energy needed to overcome/break intermolecular forces in carboxylic acid/B/ propanoic acid. (3)

[15]

QUESTION 21 (June 2024)

21.1 The temperature at which the vapour pressure (of a substance) equals atmospheric pressure. ✓✓ (2)

21.2 C ✓ (1)

21.3

Marking criteria:
Compare structures. ✓
Compare the strength of intermolecular forces. ✓
Compare the energy required to overcome intermolecular forces. ✓

Structure **A** has a longer chain length / larger surface area (over which intermolecular forces act) than structure **B**. ✓
A has stronger/more intermolecular forces / Van der Waals forces / London forces / dipole-dipole forces. ✓
A needs more energy to overcome or break intermolecular forces / Van der Waals forces / London forces / dipole-dipole forces. ✓
OR
Structure **B** has a shorter chain length /branched/ more spherical / smaller surface area (over which intermolecular forces act) than structure **A**. ✓
B has weaker/less intermolecular forces / Van der Waals forces / London forces / dipole-dipole forces. ✓
B needs less energy to overcome or break intermolecular forces / Van der Waals forces / London forces / dipole-dipole forces. ✓ (3)

21.4.1 75°C ✓ (1)

21.4.2

Marking criteria:
Compare the strength of intermolecular forces. ✓
Compare the energy required to overcome intermolecular forces. ✓

C has stronger intermolecular forces than **D**. ✓
More energy is needed to overcome or break the intermolecular forces. ✓
OR
D has weaker intermolecular forces than **C**.
Less energy is needed to overcome or break the intermolecular forces. (2)

21.5 Decrease ✓ (1)

[10]

QUESTION 22 (November 2024)

22.1 The pressure exerted by a vapour at equilibrium with its liquid in a closed system. ✓✓ (2)

22.2.1 146 kPa ✓ (1)

22.2.2

Marking criteria:
Compare structures. ✓
Compare the strength of intermolecular forces. ✓
Compare the energy required to overcome intermolecular forces. ✓

<u>Comparing compound **C** with compounds **A** and **B**</u>:
Structure: Compound **C** is more branched than compounds **A** and **B**. / shorter chain length / most compact / most spherical / smallest surface area (over which intermolecular forces act). ✓
Intermolecular forces: Compound **C** has weaker/less intermolecular forces / Van der Waals forces / London forces than **A** and **B**. ✓
Energy: Less energy needed to overcome/break intermolecular forces / Van der Waals forces / London forces in compound **C** than **A** and **B**. ✓ (3)

22.3.1 E (1)

22.3.2

Marking criteria:
Intermolecular forces in compounds **D** and **E**. ✓✓
Compare the strength of intermolecular forces. ✓
Compare the energy required to overcome intermolecular forces. ✓

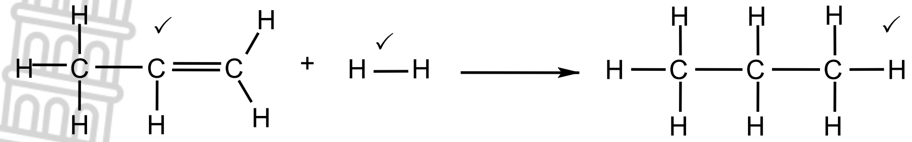
Compound **D** has hydrogen bonding (and dipole-dipole and London forces) between the molecules. ✓
Compound **E** has dipole-dipole forces (and London forces) between the molecules. ✓
The intermolecular forces between molecules of compound **D** are stronger than the intermolecular forces between molecules of compound **E**. ✓
More energy is needed to overcome/break the intermolecular forces between molecules of compound **D** than in compound **E**. ✓ (4)

[11]

ORGANIC MOLECULES: ORGANIC REACTIONS

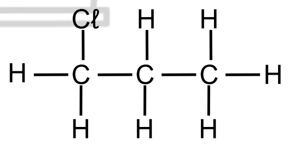
QUESTION 1 (November 2014)

1.1.1 Substitution / chlorination / halogenation ✓ (1)
1.1.2 Substitution / hydrolysis ✓ (1)
1.2.1 Hydrogenation ✓ (1)
1.2.2



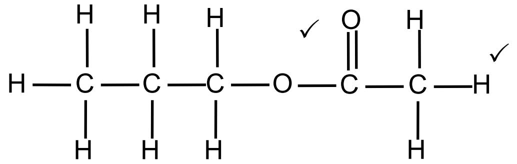
(3)

1.3



(2)

1.4.1 Esterification ✓ (1)
1.4.2 Concentrated H_2SO_4 / sulphuric acid ✓ (1)
1.4.3



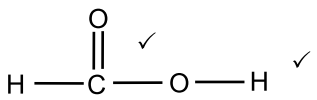
(2)

1.4.4 Propyl ✓ ethanoate ✓ (2)
1.5 Sulphuric acid / H_2SO_4 ✓ (1)

[15]

QUESTION 2 (June 2015)

2.1.1 Hydrolysis ✓ (1)
2.1.2 Mild heat ✓ AND dilute strong base ✓ (2)
2.1.3 Ethanol ✓ (1)
2.2.1 Esterification/Condensation (1)
2.2.2



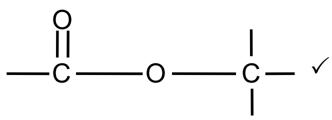
(2)

2.2.3 Ethyl✓ methanoate ✓ (2)

[9]

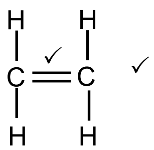
QUESTION 3 (November 2015)

3.1.1 Esterification / Condensation ✓ (1)
3.1.2



(1)

3.1.3 Propanoic acid ✓ (1)
3.1.4 Dehydration / elimination ✓ (1)
3.1.5 Concentrated H_2SO_4 / sulphuric acid ✓ (1)
3.1.6

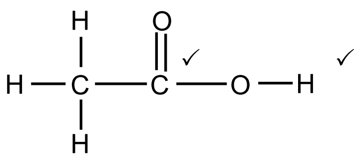


(2)

[7]

QUESTION 4 (March 2016)

4.1.1 Chloro✓ethane ✓ (2)
4.1.2 Hydrohalogenation/hydrochlorination ✓ (1)
4.2.1



(2)

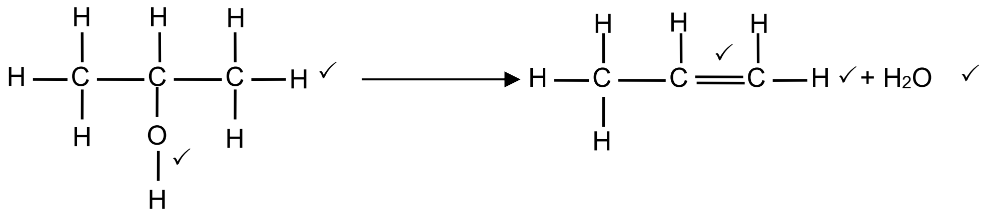
4.2.2 HCℓ / hydrogen chloride ✓ (1)

4.3.1	Saturated ✓ There are no double / multiple bonds between C atoms. ✓	(2)	
4.3.2	H_2 / hydrogen gas ✓	(1)	
4.3.3	$2C_2H_6 + 7O_2$ ✓ $\rightarrow$ $4CO_2 + 6H_2O$ ✓ Bal. ✓	(3)	
			[12]

QUESTION 5 (June 2016)

5.1.1	Addition / Hydrogenation ✓	(1)	
5.1.2	Elimination / Dehydrohalogenation / Dehydrobromination ✓	(1)	
5.1.3	Substitution / Halogenation / Bromination ✓	(1)	
5.2.1	Pt / platinum ✓	(1)	
5.2.2	H_2SO_4 / sulphuric acid ✓	(1)	
5.2.3	Hydration ✓	(1)	
5.2.4	2-bromopropane ✓✓	(2)	

5.3



(5)

5.4	Higher temperature ✓ Concentrated base ✓	(2)	
			[15]

QUESTION 6 (November 2016)

6.1.1	High temperature / heat / high energy / high pressure ✓	(1)	
6.1.2	C_6H_{12} ✓	(1)	
6.1.3	Alkenes ✓	(1)	

6.2 **X** / C_6H_{12} / Alkene ✓

<u>OPTION 1</u>

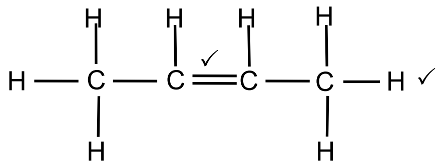
X has a double bond. / **X** is unsaturated.
X can undergo addition. ✓
X will react without light / heat. ✓

<u>OPTION 2</u>

Butane is an alkane **OR** butane is saturated. ✓
Butane can only undergo substitution. ✓
Butane will only react in the presence of light or heat. ✓ (4)

6.3.1	2-chloro✓butane ✓	(2)	
6.3.2	Substitution / Hydrolysis ✓	(1)	

6.3.3



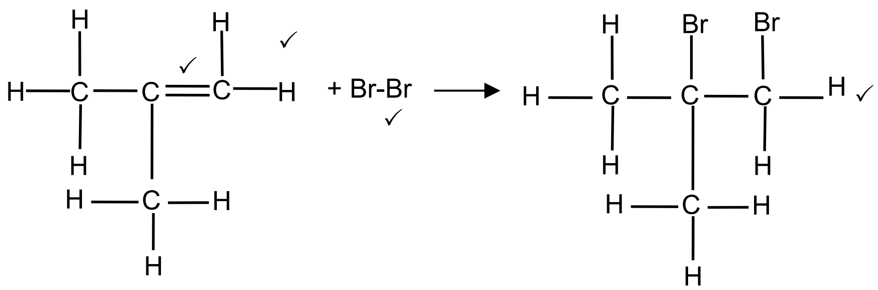
(2)

6.3.4	Hydration ✓	(1)	
			[13]

QUESTION 7 (June 2017)

7.1	Substitution / hydrolysis ✓	(1)	
7.2	H_2O/water ✓ **OR** Dilute sodium hydroxide /NaOH(aq) / Dilute potassium hydroxide/KOH(aq) ✓	(1)	
7.3	Tertiary ✓	(1)	
7.4	Elimination / dehydrohalogenation / dehydrobromination ✓	(1)	
7.5	2-methyl<u>prop-1-ene</u> / methylpropene / 2-methylpropene	(2)	
7.6	Halogenation / bromination ✓	(1)	

7.7

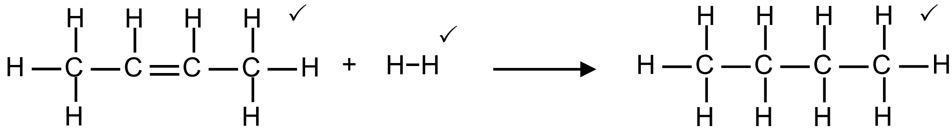


(4)

[11]

QUESTION 8 (November 2017)

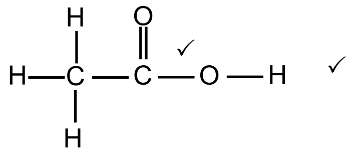
8.1 Secondary ✓
The C atom bonded to the (–)OH (group) is bonded to TWO other C atoms. ✓
OR One H atom is bonded to the C atom that the –OH group is bonded to. (2)
8.2.1 Dehydration ✓ (1)
8.2.2 Hydration ✓ (1)
8.2.3 Dehydrohalogenation/dehydrobromination ✓ (1)
8.3.1 Substitution/Hydrolysis ✓ (1)
8.3.2 Dilute strong base/ dilute sodium hydroxide/ dilute NaOH ✓ **OR** Add water.
Moderate temperature/mild heat ✓ (2)
8.3.3 2-bromo✓ butane ✓ (2)
8.4 NaOH/KOH ✓ (1)
8.5



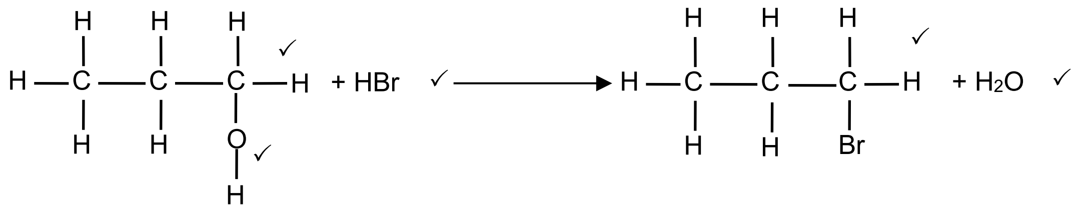
(3)
8.6 Butane ✓ (1)
[15]

QUESTION 9 (June 2018)

9.1.1 Substitution/halogenation/bromination ✓ (1)
9.1.2 Elimination/dehydration ✓ (1)
9.1.3 Esterification/condensation ✓ (1)
9.1.4 Addition/hydrohalogenation/hydrobromination ✓ (1)
9.2.1 Catalyst/dehydrating agent/speeds up reaction ✓ (1)
9.2.2 Propyl ✓ ethanoate ✓ (2)
9.2.3



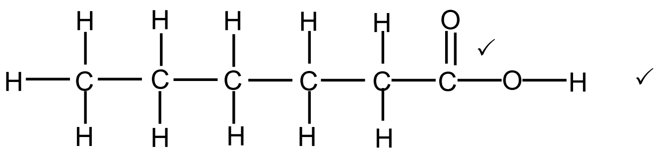
(2)
9.3



(5)
[14]

QUESTION 10 (November 2018)

10.1 Alcohol/ethanol is flammable/catches fire easily./To heat it evenly. ✓ (1)
10.2.1 Esterification/condensation ✓ (1)
10.2.2 H_2SO_4 ✓ (1)
10.2.3 Esters ✓ (1)
10.3 $\frac{M(\text{ester})}{M(C_4H_8O)} = \frac{144}{72} = 2$ ✓
$\therefore$ 2 x C_4H_8O = $C_8H_{16}O_2$ ✓ (2)
10.4 Ethyl ✓ hexanoate ✓ (2)
10.5



(2)
[10]

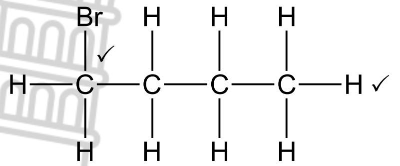
QUESTION 11 (November 2018)

11.1.1 (A series of organic) compounds that can be described by the same general formula/functional group. ✓✓
OR (A series of organic) compounds in which one member differs from the next by a CH_2 group (2)

11.1.2 Substitution/halogenation/bromination ✓ (1)

11.1.3 HBr ✓ (1)

11.1.4

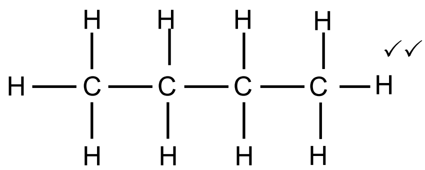


(2)

11.1.5 $C_5H_{12} + 8O_2$ ✓ → $5CO_2 + 6H_2O$ ✓ Bal ✓ (3)

11.1.6 The (chemical) process in which longer chain hydrocarbons/longer chain alkanes are broken down to shorter/more useful hydrocarbons/molecules/ chains/alkanes and alkenes. ✓✓ (2)

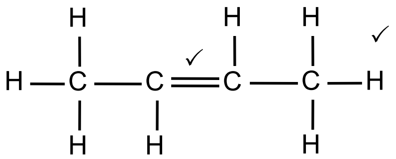
11.1.7



(2)

11.2.1 Butan-2-ol / 2-butanol ✓✓ (2)

11.2.2



(2)
[17]

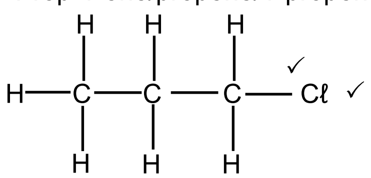
QUESTION 12 (June 2019)

12.1 Dehydration/elimination ✓ (1)

12.2 Catalyst/dehydrating agent/causes dehydration/removes water molecules ✓ (1)

12.3 Prop-1-ene/propene/1-propene ✓✓ (2)

12.4



(2)

12.5 Addition/Hydration ✓ (1)

12.6 Propan-2-ol/2-propanol ✓✓ (2)
[9]

QUESTION 13 (November 2019)

13.1 Haloalkane/alkyl halide ✓ (1)

13.2.1 Elimination/dehydrohalogenation ✓ (1)

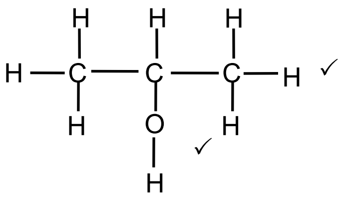
13.2.2 Substitution/hydrolysis ✓ (1)

13.2.3 Esterification/condensation ✓ (1)

13.3.1 Mild heat ✓
Dilute strong base/(NaOH/KOH/LiOH) **OR** Add water/H_2O ✓ (2)

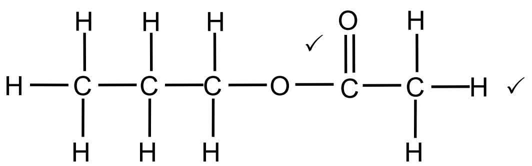
13.3.2 Propan-1-ol/1-propanol ✓✓ (2)

13.4



(2)

13.5.1



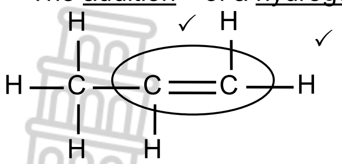
(2)

13.5.2 (Concentrated) sulphuric acid/H_2SO_4 ✓ (1)
[13]

QUESTION 14 (November 2020)

14.1 The <u>addition</u> ✓of a <u>hydrogen halide/HX</u> ✓ to an alkene. (2)

14.2



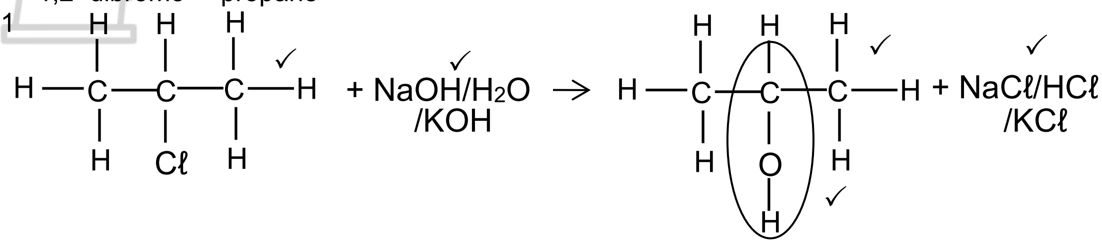
(2)

14.3.1 Cracking ✓ (1)

14.3.2 C_8H_{18} ✓ (1)

14.4 1,2–dibromo ✓ propane ✓ (2)

14.5.1



(5)

14.5.2 (Mild) heat ✓
Dilute strong base/NaOH/LiOH/KOH **OR** water/H_2O ✓ (2)

[15]

QUESTION 15 (September 2021)

15.1

15.1.1 Substitution/halogenation/bromination ✓ (1)

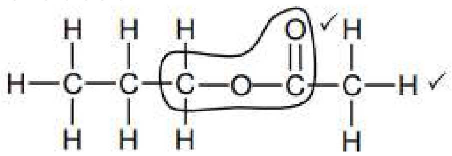
15.1.2 Substitution/hydrolysis ✓ (1)

15.1.3 1-bromopropane ✓✓ (2)

15.1.4 H_2SO_4/(concentrated) sulphuric acid ✓ (1)

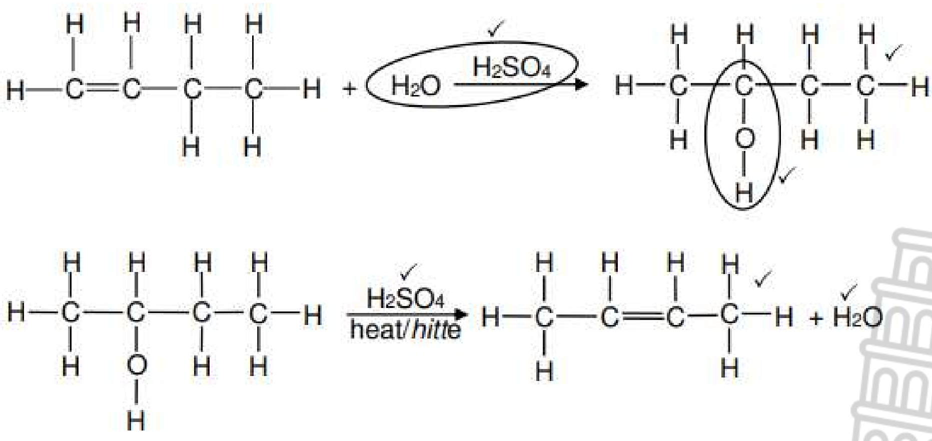
15.1.5 Ethanoic acid ✓✓ (2)

15.1.6



(2)

15.2



(6)

[15]

QUESTION 16 (November 2021)

16.1

16.1.1 Substitution/Hydrolysis ✓ (1)

16.1.2 Primary (alcohol) ✓

The C-atom bonded to the hydroxyl/OH /functional group is bonded to only one other C-atom. ✓

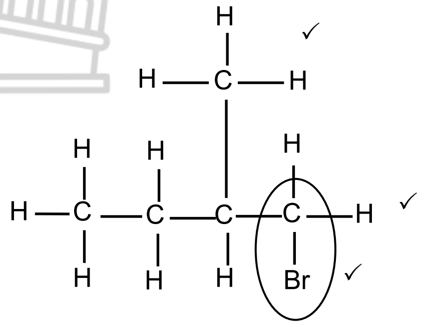
OR

The hydroxyl/OH /functional group is bonded to a C-atom which is bonded to two hydrogen atoms.

OR

The hydroxyl/OH /functional group is bonded to a primary C atom. (2)

16.1.3



Marking criteria:

- Four C atoms in longest chain. ✓
- One methyl substituent on C2. ✓
- Bromo substituent on C1. ✓

(3)

16.1.4 Elimination/dehydrohalogenation/dehydrobromination ✓ (1)

16.1.5 Alkenes ✓ (1)

16.1.6 Addition ✓ (1)

16.1.7 2-bromo-2-methyl✓butane ✓ (2)

16.2

16.2.1 **Marking criteria:**

- Correct condensed structure for but-2-ene. ✓
- React but-2-ene with H_2. ✓
- Indicate the catalyst Pt/Ni/Pd on arrow. ✓
- Correct condensed formula for butane as product. ✓

$CH_3CHCHCH_3 + H_2 \longrightarrow CH_3CH_2CH_2CH_3$ (4)

16.2.2 Elimination/Cracking ✓ (1)

16.2.3 Propene/Propeen ✓✓ (2)

16.2.4 **Marking criteria:**

- Correct condensed formula for propene as reactant. ✓
- React propene with Br_2. ✓
- Correct condensed formula for 1,2-dibromopropane as product. ✓

$CH_3CHCH_2 + Br_2 \longrightarrow CH_3CHBrCH_2Br$ (3)

[21]

QUESTION 17 (June 2022)

17.1

17.1.1 Dehydrohalogenation/elimination/dehydrobromination ✓ (1)

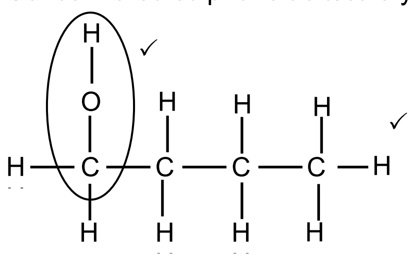
17.1.2 2-methyl ✓ but-2-ene ✓ / 2-methyl-2-butene (2)

17.1.3 Water/H_2O ✓ (1)

17.1.4 Heat/Hitte ✓

Concentrated sulphuric acid/catalyst ✓ (2)

17.1.5



(2)

17.2

17.2.1 Catalyst/Lowers the activation energy./Increases the rate of the reaction. ✓ (1)

17.2.2 The bromine water/Br_2 decolourises. ✓ (1)

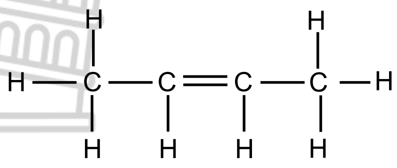
17.2.3 Addition/halogenation/bromination ✓ (1)

17.2.4 C_2H_6 ✓✓✓ **OR** C_4H_{10} **OR** C_6H_{14} **(3 or 0)** (3)

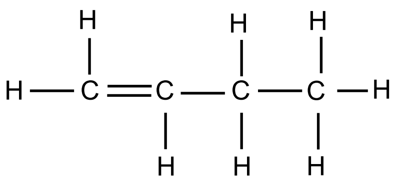
17.2.5

Marking criteria
Correct functional group i.e. double bond. ✓
Correct number of C atoms in relation to answer in Q17.2.4. ✓
Whole structure correct. ✓

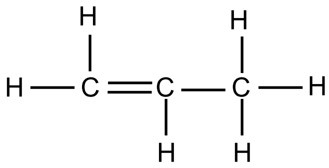
IF C_2H_6 in QUESTION 17.2.4



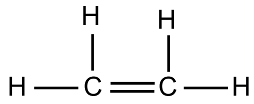
OR



IF C_4H_{10} in QUESTION 17.2.4



IF C_6H_{14} in QUESTION 17.2.4:



(3)
[17]

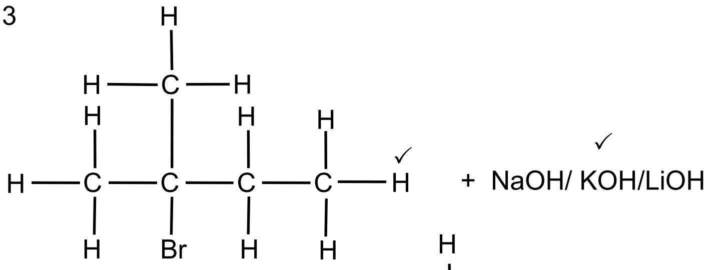
QUESTION 18 (November 2022)

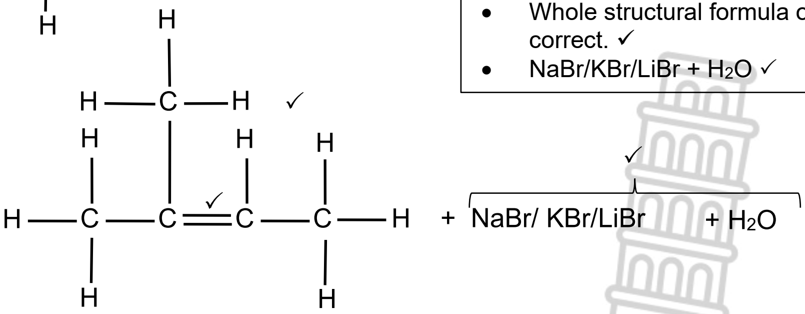
18.1 Tertiary ✓
The halogen/bromine/functional group (-X) is bonded to a C atom that is bonded to three other C atoms/ a tertiary C atom. ✓
OR: The functional group (— C —) is bonded to three other C atoms.
X/Br (2)

18.2.1 <u>Concentrated strong base</u> ✓
OR: <u>Concentrated NaOH</u>/KOH/LiOH/sodium hydroxide/potassium hydroxide/ lithium hydroxide
OR
<u>Strong base</u>/NaOH/KOH/LiOH/sodium hydroxide/potassium hydroxide/lithium hydroxide <u>in ethanol</u>. (1)

18.2.2 Elimination/dehydrohalogenation/dehydrobromination ✓ (1)

18.2.3

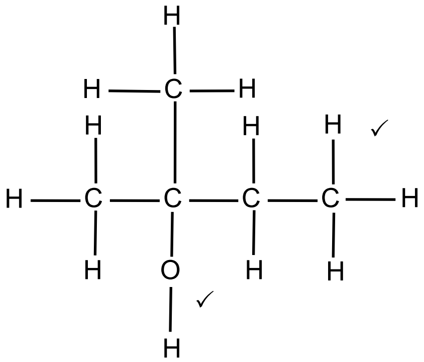




Marking criteria:
- Whole structural formula correct for compound A. ✓
- React (2-bromo-2-methylbutane) with NaOH/KOH/LiOH. ✓
- Functional group of alkene correct. ✓
- Whole structural formula of alkene correct. ✓
- NaBr/KBr/LiBr + H_2O ✓

(5)

18.3.1



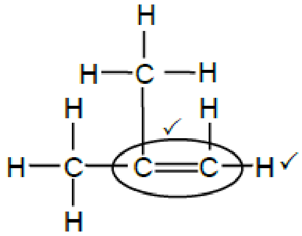
(2)

18.3.2 Water/H_2O ✓ (1)

18.3.3 Hydration ✓ (1)
18.4.1 Substitution/Hydrolysis ✓ (1)
18.4.2 Dilute strong base ✓
OR: Dilute NaOH/KOH/LiOH/sodium hydroxide/potassium hydroxide/lithium hydroxide
OR: NaOH(aq)/KOH(aq)/LiOH(aq)
OR: (Add) water/H_2O (1)
[15]

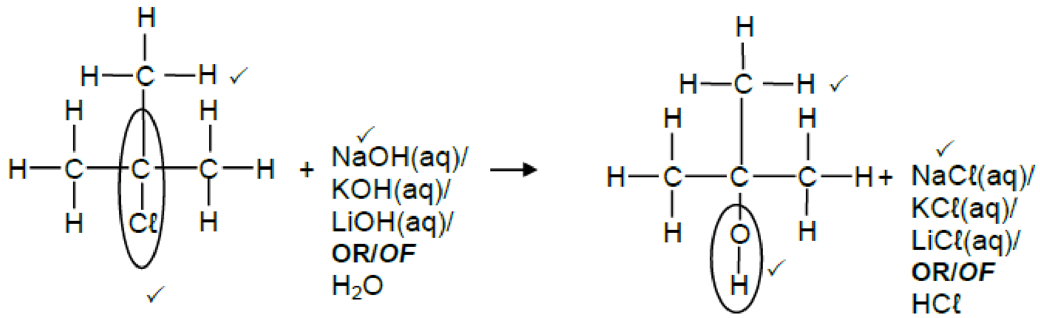
QUESTION 19 (June 2023)

19.1
19.1.1 Halogenation/Bromination ✓ (1)
19.1.2 The bromine water/Br_2/solution decolourises./Brown colour disappears. ✓
OR
Bromine water/Br_2 solution changes from brown/reddish to colourless. (1)
19.1.3



(2)
19.1.4 2-chloro-2-methyl✓propane✓ (2)
19.1.5 **Marking criteria:**

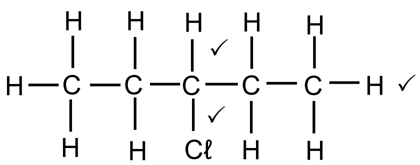
- Cℓ atom on second C atom of conpound R ✓
- Whole structure of compound R correct ✓
- React compound R with NaOH(aq)/ KOH(aq)/LiOH(aq) OR H_2O ✓
- OH-group replaces Cℓ ato at the same position. ✓
- Whole structure of alcohol correct. ✓
- NaCℓ(aq)/KCℓ(aq)/LiCℓ(aq) OR HCℓ(aq) ✓ (must correspond to the inorganic reactant used)



(6)
19.1.6 2-methyl✓propan-2-ol✓/2-methyl-2-propanol (2)
19.1.7 Dehydration ✓ (1)
19.2.1 Esterfication/Condensation ✓ (1)
19.2.2 Butyl✓propanoate ✓ (2)
[18]

QUESTION 20 (November 2023)

20.1
20.1.1 The chemical process/reaction in which longer chain hydrocarbon/alkane molecules/ are broken down to shorter (more useful) molecules. ✓✓ (2)
20.1.2 X = 12 ✓
Y = 2 ✓
Z = 4 ✓ (3)
201.3 $2C_6H_{14} + 19O_2$ ✓ → $12CO_2 + 14H_2O$ ✓ Bal ✓ (3)
20.2
20.2.1 Compounds with the same molecular formula, but different positions of the side chain / substituents / functional groups on the parent chain. ✓✓ (2)
20.2.2 Addition/hydrohalogenation/hydrochlorination ✓ (1)
20.2.3



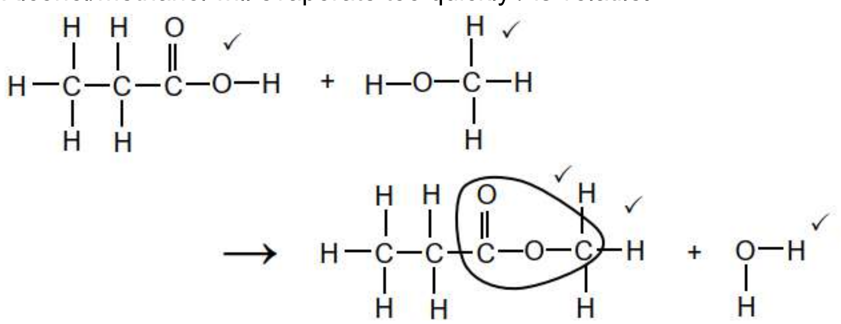
Marking criteria

- Chlorine atom bonded to any C-atom. ✓
- Correct functional group on third C-atom. ✓
- Whole structure correct. ✓

(3)

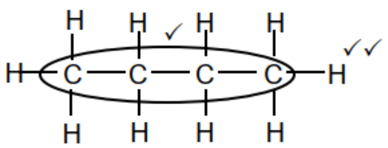
20.2.4 HCℓ ✓ (1)
20.2.5 (Concentrated/ conc.) H_2SO_4 / sulphuric acid / H_3PO_4 / phosphoric acid ✓ (1)
20.2.6 Concentrated strong base ✓
OR
Concentrated NaOH / KOH / LiOH / sodium hydroxide/ potassium hydroxide/ lithium hydroxide
OR
Strong base/NaOH/KOH/LiOH/sodium hydroxide/ potassium hydroxide/lithium hydroxide in ethanol. (1)
20.2.7 Elimination ✓
Dehydrohalogenation/dehydrochlorination ✓ (2)
[19]

QUESTION 21 (June 2024)
21.1.1 (Concentrated) sulphuric acid/$H_2SO_4(aq)$ ✓ (1)
21.1.2 Esterification/Condensation ✓ (1)
21.1.3 **ANY TWO:** ✓✓
Alcohol/methanol/reactant is flammable / catches fire easily.
To heat evenly. / A steady/controlled/gradual increase in temperature.
Alcohol/methanol will evaporate too quickly / is volatile. (2)
21.1.4



(5)
21.1.5 Methyl propanoate ✓✓ (2)
21.2.1 Hydrogen/ Hydrogen gas /H_2 ✓ (1)
21.2.2 3,3-dimethyl✓but-1-ene ✓/ 3,3-dimethyl-1-butene (2)
21.2.3 Elimination **OR** dehydrohalogenation ✓ (1)
21.2.4 H_2SO_4/H_3PO_4 **OR** Sulphuric acid/Phosphoric acid ✓ (1)
21.2.5 3,3-dimethyl✓butan-2-ol✓/ 3,3-dimethyl-2-butanol (2)
21.2.6 Addition/Hydration ✓ (1)
21.2.7 Secondary ✓ (1)
[20]

QUESTION 22 (November 2024)
22.1 The chemical process/reaction in which longer chain hydrocarbon/alkane molecules are broken down to shorter (more useful) molecules. ✓✓ (2)
22.2 Primary ✓
The halogen/bromine/functional group (-X) is bonded to a C atom that is bonded to one other C atom. ✓ (2)
22.3.1

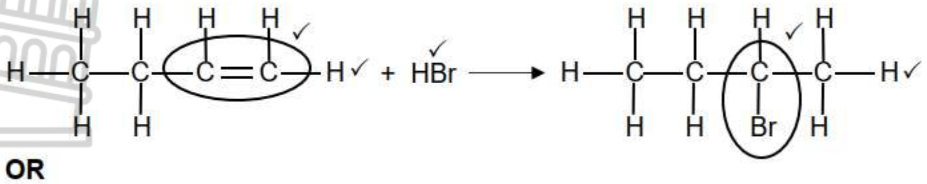


Marking criteria
Correct stem. ✓
Whole structural formula correct. ✓

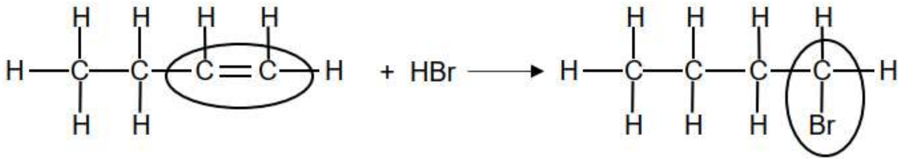
(3)
22.3.2 C_8H_{18} ✓ (1)
22.4.1 Br_2/Bromine ✓ (1)
22.4.2 Substitution ✓ (1)
22.4.3 UV/(Sun)light/Heat ✓ (1)
22.5 Dehydrohalogenation/Dehydrobromination ✓ (1)

22.6.1

Marking criteria:
Functional group of alkene on first C atom. ✓
Whole structural formula of alkene correct. ✓
HBr ✓
Functional group of haloalkane correct. ✓
Whole structural formula of haloalkane correct (halogen on second/first C-atom). ✓



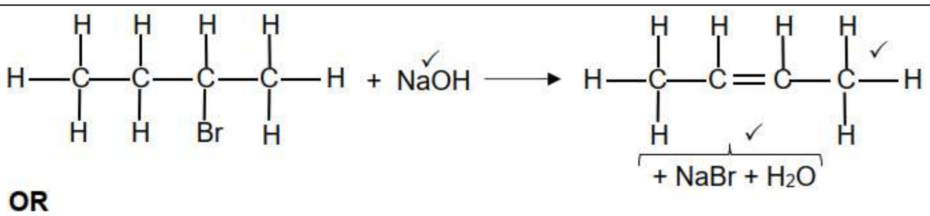
OR



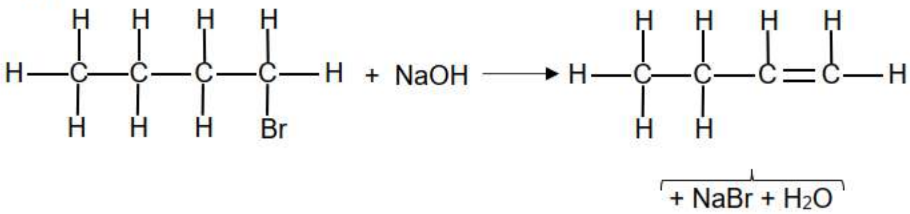
(5)

22.6.2

Marking criteria:
NaOH. ✓
Whole structural formula of alkene correct (functional group on second/first C atom). ✓
NaBr + H_2O ✓



OR



(3)

22.6.3 But-2-ene/2-butene/but-1-ene/1-butene ✓✓ (2)

[22]

REACTION RATE AND ENERGY IN CHEMICAL REACTIONS

QUESTION 1 (November 2014)

1.1 Change in concentration of products / reactants ✓ per unit time. ✓ (2)

1.2.1 Temperature ✓ (1)

1.2.2 Rate of reaction / Volume of gas formed per unit time ✓ (1)

1.3 Larger mass / amount / surface area. ✓
More effective collisions per unit time. / More particles collide with sufficient kinetic energy & correct orientation per unit time. ✓✓ (3)

1.4

Marking criteria		
Compare Exp.1 with Exp. 2:	Reaction in exp. 1 is faster than in exp. 2 due to higher acid concentration.	✓
	Therefore the gradient of the graph representing exp. 1 is greater / steeper than that of exp. 2.	✓
Compare Exp. 1 with Exp 3 & 4:	The reaction in exp. 3 is faster than that in exp. 1 due to the higher temperature.	✓
	The reaction in exp. 4 is faster than that in exp. 1 due to the higher temperature / larger surface area. **OR** Graph A represents exp. 4 due to the greater mass of $CaCO_3$ - greater yield of CO_2 at a faster rate.	✓
	Therefore the gradient of the graphs of exp. 3 & 4 are greater/steeper than that of exp. 1.	✓
Final answer	C	✓

(6)

1.5 $n(CO_2) = \frac{V}{V_m} = \frac{4,5}{25,7}$ ✓ = 0,17 mol

$n(CaCO_3) = n(CO_2) = 0,18$ mol ✓

$n(CaCO_3) = \frac{m}{M} \quad \therefore \quad 0,18 = \frac{m}{100}$ ✓ $\therefore m(CaCO_3) = 18$ g

$m(CaCO_3)$ not reacted: 25 – 18 ✓ = 7,00 g ✓ (5)

[18]

QUESTION 2 (March 2015)

2.1 Exothermic ✓ Temperature increases during reaction. / $T_i < T_f$ ✓ (2)

2.2 Larger surface area in experiment 2. ✓ (1)

2.3 More than one independent variable. ✓ **OR** Different concentrations and state of division. (1)

2.4 Faster than ✓
A catalyst is used in experiment 5. ✓
- A catalyst provides an alternative pathway of lower activation energy. ✓
- More molecules have sufficient kinetic energy. ✓
- More effective collisions per unit time. ✓ (5)

2.5 $(Zn) = \frac{m}{M}$ ✓ $= \frac{1,2}{65}$ ✓ = 0,018 mol

$n(HC\ell)_{reacted} = 2n(Zn) = 2(0,018) = 0,037$ mol ✓

$Rate = \frac{\Delta n}{\Delta t} = \frac{0,037 ✓}{8 ✓} = 4,63 \times 10^{-3}\ mol{\cdot}s^{-1}$ ✓ (6)

[15]

QUESTION 3 (June 2015)

3.1 Exothermic ✓ $\Delta H < 0$ / Energy is released. ✓ (2)

3.2.1

OPTION 1	**OPTION 2**
$n(HC\ell) = cV$ $= (1,5)$ ✓ (30×10^{-3}) ✓ $= 0,045$ mol $\text{Ave rate} = -\frac{\Delta n}{\Delta t} = -\frac{0-45 ✓}{60-1 ✓}$ $= 7,5 \times 10^{-4}\ mol{\cdot}s^{-1}$ ✓	$\text{Ave rate} = -\frac{\Delta n}{\Delta t} = -\frac{0-1,5 ✓}{60-1 ✓}$ $= 0,025\ mol{\cdot}dm^{-3}{\cdot}s^{-1}$ $\therefore$ average rate $= (0,025)(30 \times 10^{-3})$ ✓✓ $= 7,5 \times 10^{-4}\ (mol{\cdot}s^{-1})$ ✓

(5)

3.2.2(a) Increases ✓
- The reaction is exothermic, resulting in an increase in temperature. ✓
- More molecules have sufficient kinetic energy. ✓
- More effective collisions per unit time. ✓ (4)

3.2.2(b) Decreases ✓
Concentration of acid decreases. ✓ **OR** The surface area of magnesium decreases. (2)

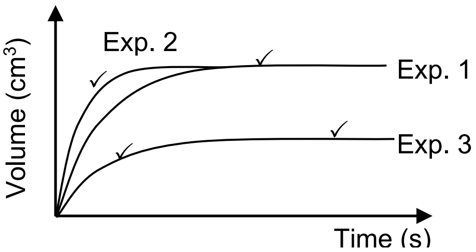
3.3 **ANY TWO**

- Higher temperature ✓
- Larger surface area/state of division/contact area of Mg. / Use Mg powder. ✓
- Addition of a catalyst. (2)

[15]

QUESTION 4 (November 2015)

4.1 Time: Stop watch ✓ Volume: Gas syringe / burette ✓ (2)
4.2.1 t_1 ✓ (1)
4.2.2 t_3 ✓ (1)
4.3 Between t_1 and t_2 ✓ (1)
4.4



Marking criteria		
Exp.2	Initial gradient higher than that of Exp.1.	✓
	Curve reaches same constant volume as for Exp. 1 (but earlier).	✓
Exp.3	Initial gradient lower than that of Exp.1.	✓
	Curve reaches a smaller constant volume as for Exp. 1 (later stage).	✓

(4)

4.5.1

OPTION 1	**OPTION 2**
n(HCℓ) = cV = (0,1)(100 x 10^{-3}) ✓ = 0,01 mol n(Zn reacted) = ½n(HCℓ) = ½(0,01) ✓ = 5 x 10^{-3} mol m(Zn reacted) = (5 x 10^{-3})(65) ✓ = 0,325 g m(Zn_f) = 0,8 – 0,325 ✓ = 0,48 g ✓ (0,475 g)	n(HCℓ) = cV = (0,1)(100 x 10^{-3}) ✓ = 0,01 mol n(Zn reacted) = ½n(HCℓ) = ½(0,01) ✓ = 5 x 10^{-3} mol $n(Zn)_i = \frac{m}{M} = \frac{0,8}{65}$ ✓ = 1,23 x 10^{-2} mol $n(Zn)_f$ = 1,23 x 10^{-2} – 5 x 10^{-3} ✓ = 7,3 x 10^{-3} mol m(Zn) = nM = (7,3 x 10^{-3})(65) = 0,47 g ✓

(5)

4.5.2 Smaller than ✓ (1)

[15]

QUESTION 5 (June 2016)

5.1 **ANY TWO:**
Temperature of reaction mixture ✓; Addition of a catalyst ✓ ; Concentration of reactants (2)
5.2 Sulphur / S ✓ (1)
5.3 Water is used to dilute/change the concentration of the $Na_2S_2O_3$(aq) ✓ (1)
5.4 **Criteria for investigative question***:*

- The dependent and independent variables are stated correctly. ✓
- Asks a question about the relationship between dependent and independent variables. ✓

Dependent variable: reaction rate
Independent variable: concentration
Examples*:* What is the relationship between concentration and reaction rate?
How does the reaction rate change with change in concentration? (2)

5.5 A ✓ (1)
5.6 **Experiment B***:*

- The concentration of $Na_2S_2O_3$(aq) is higher. / More $Na_2S_2O_3$ particles per unit volume. ✓
- More particles with correct orientation. ✓
- More effective collisions per unit time. ✓ (3)

5.7

OPTION 1

$c = \frac{m}{MV}$ ✓

$= \frac{62,5}{(158)(0,25)}$ ✓ ✓

$= 1,58\ mol\cdot dm^{-3}$

OPTION 2

$n = \frac{m}{M}$ ✓

$= \frac{62,5}{158}$ ✓

$= 0,396$ mol

$c = \frac{n}{V}$ ✓

$= \frac{0,396}{0,25}$ ✓

$= 1,58\ mol\cdot dm^{-3}$

OPTION 3

250 cm^3 ..... 62,5 g

10 cm^3 .....$\frac{10}{250}$ ✓ x 62,5✓

$\therefore$ m($Na_2S_2O_3$ in D) = 2,5 g

n($Na_2S_2O_3$ in D) = $\frac{m}{M}$

$= \frac{2,5}{158}$ ✓ ✓

= 0,0158 mol

(Options 1 and 2:) n($Na_2S_2O_3$ in D) = cV = (1,58)(0,01) ✓
= 0,0158 mol

n(S) = ($Na_2S_2O_3$) ✓ = 0,0158

$n = \frac{m}{M}$ $\therefore$ $0,0158 = \frac{m}{32}$ ✓ $\therefore$ m = 0,51 g✓

(7)

[17]

QUESTION 6 (June 2017)

6.1.1 To measure volume of gas/oxygen produced. ✓ (1)

6.1.2 Catalyst/Speeds up the reaction./Increases reaction rate. ✓ (1)

6.2 No more gas/bubbles produced.✓ (1)

6.3 CuO/Copper(II) oxide/catalyst ✓ (1)

6.4 A catalyst provides an alternative pathway of lower activation energy. ✓
More molecules have sufficient/enough kinetic energy. ✓
OR More molecules have kinetic energy equal to or greater than the activation energy.
More effective collisions per unit time./Frequency of effective collisions increases. ✓ (3)

6.5.1 Released ✓ Products at lower energy than reactant./Reaction is exothermic/ΔH < 0 ✓ (2)

6.5.2 B ✓ (1)

6.6 $n(O_2)_{produced} = \frac{V}{V_m} = \frac{0,4}{25}$ ✓ $= 0,016$ mol $\therefore$ $n(H_2O_2)_{used} = 2(0,016)$ ✓ $= 0,032$ mol

$[H_2O_2] = \frac{n}{V} = \frac{0,032}{0,05}$ ✓ $= 0,64\ mol\cdot dm^{-3}$ $\therefore$ Rate $= -\frac{\Delta c}{\Delta t} = -\frac{0 - 0,64}{5,8 - 0}$ ✓ ✓ $= 0,11\ (mol\cdot dm^{-3}\cdot min^{-1})$ ✓ (6)

[16]

QUESTION 7 (March 2017)

7.1 **ANY TWO**

- Increase temperature of HCℓ. ✓
- Add a catalyst. ✓
- Increase the concentration of HCℓ.
- Increase the state of division of $CuCO_3$. (2)

7.2 Accepted range: 42 s to 50 s ✓ (1)

7.3.1 average $= -\frac{\Delta m}{\Delta t} = -\frac{(169,76 - 170,00)}{(20 - 0)}$ ✓ ✓ $= 0,012\ (g\cdot s^{-1})$ ✓

If answer is negative (minus 1 mark) (3)

7.3.2 Pure sample: $m(CO_2)_{formed}$ = 170,00 – 169,73 ✓ = 0,27 g

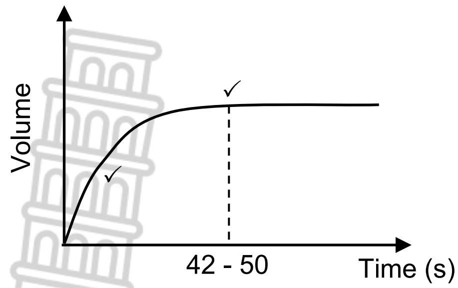
Impure sample: $m(CO_2)_{formed}$ = 170,00 - 169,78 ✓ = 0,22 g

$\%Purity = \frac{0,22}{0,27} \times 100$ ✓ = 81,48% ✓ (4)

7.3.3 $n(CO_2)_{formed} = \frac{m}{M} = \frac{0,27}{44}$ ✓ $= 6,13 \times 10^{-3}$ mol

$n(CO_2) = \frac{V}{V_m}$ $\therefore$ $6,13 \times 10^{-3} = \frac{V}{22,4}$ ✓ $\therefore$ V = 0,137 dm^3 ✓ (3)

7.4



Marking criteria for sketch graph:	
Graph drawn from origin with decreasing gradient.	✓
Constant volume after (42 -50) s. **or** graph stops at (42 -50) s.	✓
If no labels on axes: minus 1.	

(2)
[15]

QUESTION 8 (November 2017)

8.1 Change in concentration of products/reactants per (unit) time. ✓✓ (2)

8.2 **Marking criteria**

Independent (concentration) and dependent (reaction rate) variables correctly identified. ✓
Ask a question about the relationship between the independent and dependent variables. ✓

Examples:

- What is the relationship between concentration and reaction rate?
- How does the reaction rate change when the concentration changes/increases/ decreases?

IF the answer to the question is "YES" or "NO": Max. 1 mark
Examples: Does reaction rate increase with increase in concentration?
Is there a relationship between reaction rate and concentration? (2)

8.3 Q ✓

- Reaction **I** has the lower (HCℓ) concentration. ✓
- Smaller/less steep gradient. ✓
  OR Take longer to complete./Slower reaction rate./Produce less product per unit time./ Take longer for the maximum volume of gas to form. (3)

8.4

OPTION 1	**OPTION 2**
Ave rate = $\frac{\Delta V}{\Delta t}$ ∴ $15 = \frac{\Delta V}{30\ (-0)}$ ✓	Ave rate = $\frac{\Delta V}{\Delta t}$ ∴ $15 \times 10^{-3} = \frac{\Delta V}{30\ (-0)}$ ✓
$V(H_2)_{produced}$ = 450 cm^3	$V(H_2)_{produced}$ = 0,45 dm^3
$n(H_2)_{produced} = \frac{V}{V_m} = \frac{450}{24\ 000}$ ✓	$n(H_2)_{produced} = \frac{V}{V_m} = \frac{0,45}{24}$ ✓
= 0,0188 mol	= 0,0188 mol

$n(Zn) = n(H_2)$ = 0,0188 mol ✓

$n(Zn)_{used} = \frac{m}{M}$ ∴ $0,0188 = \frac{m}{65}$ ✓ ∴ m(Zn) = 1,22 g ✓

(5)

8.5.1 Equal to ✓ (1)

8.5.2 Equal to ✓ (1)

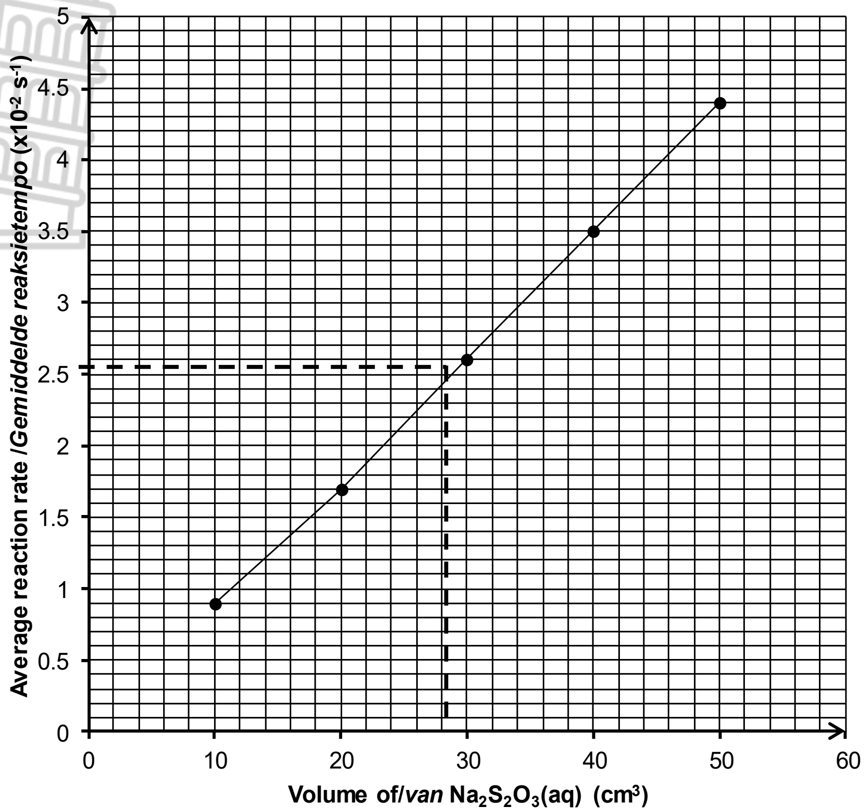
8.6 At higher temperature the (average) kinetic energy of particles is higher. ✓
More molecules have sufficient/enough kinetic energy. ✓
OR More molecules have kinetic energy equal to or greater than the activation energy.
More effective collisions per unit time. ✓ (3)
[17]

QUESTION 9 (March 2018)

9.1 Change in concentration ✓ of a reactant/product per unit time. ✓ (2)

9.2 Greater than ✓ (1)

9.3 **Graph of average reaction rate versus volume of $Na_2S_2O_3(aq)$**



Marking criteria
Any 3 points correctly plotted. ✓
All (5) points correctly plotted. ✓
Straight line drawn. ✓

(3)

9.4.1

Marking criteria
y axis/*y-as*: 2,5 x 10^{-2} s^{-1} ✓
Dotted line drawn from the y-axis to the x-axis as shown. ✓
V = 28 to 30 cm^3 ✓

(3)

11.4.2

Criteria for conclusion
Dependent and independent variables correctly identified. ✓
Relationship between the independent and dependent variables correctly stated. ✓

Examples:

- Reaction rate of reaction increases with an increase in concentration/volume of sodium thiosulphate.
- Reaction rate decreases with a decrease in concentration/volume of sodium thiosulphate.
- Reaction rate is (directly) proportional to concentration/volume of sodium thiosulphate.

(2)

9.5 More $Na_2S_2O_3$ particles per unit volume. ✓
More effective collisions per unit time./Higher frequency of effective collisions. ✓
Increase in reaction rate. ✓ (3)

9.6 $n(S)_{produced} = \frac{m}{M} = \frac{1,62}{32}$ ✓ $= 0,05$ mol

$n(Na_2S_2O_3) = n(S) = 0,05$ mol ✓

$n(Na_2S_2O_3) = \frac{m}{M}$ $\therefore$ $0,05 = \frac{m}{158}$ ✓

$\therefore$ $m(Na_2S_2O_3) = 7,90$ g ✓ (4)

[18]

QUESTION 10 (November 2018)

10.1 Temperature ✓ (1)

10.2 Change in concentration of products/reactants per (unit) time. ✓✓ (2)

10.3 14 min ✓✓ (2)

10.4.1 Graph **B** ✓
(Experiment **3)** has the highest (acid) concentration/more particles/higher number of moles. ✓ (2)

10.4.2 Graph **C** ✓
(Experiment 5) is at highest temperature/more particles with sufficient kinetic energy. ✓ (2)

10.5.1 Speeds up the reaction./Increases the reaction rate. ✓ (1)

10.5.2 Equal to ✓ (1)

10.6 $n(Zn) = \frac{m}{M} = \frac{1,5}{65 ✓} = 0,023$ mol

$\text{rate} = -\frac{\Delta n}{\Delta t} = -\frac{(0 - 0,023)✓}{14 - 0 ✓} = 1,65 \times 10^{-3}\ (\text{mol·min}^{-1})$ ✓ (4)

[15]

QUESTION 11 (June 2019)

11.1 Change in concentration ✓ of products/reactants per (unit) time. ✓ (2)

11.2.1 Rate of the reaction ✓ (1)

11.2.2

Marking criteria
Dependent (reaction rate) and independent (concentration) variables correctly identified. ✓
Relationship between the independent and dependent variables correctly stated. ✓

Example:
Reaction rate increases with increase in concentration.
IF: DIRECTLY proportional*:* Max. ½ (2)

11.3.1 Activation energy/(The boundary line for the) molecules with (adequate) kinetic energy to make effective collisions. ✓ (1)

11.3.2 B ✓ (1)

11.3.3 At a higher temperature particles move faster/have a higher kinetic energy. ✓
More molecules have enough/sufficient (kinetic) energy. ✓
OR: More molecules have (kinetic) energy equal to or greater than activation energy.
More effective collisions per unit time/second./Increased frequency of effective collisions. ✓
Reaction rate increases. ✓ (4)

11.4 Curve **Y** was obtained for the reaction where a catalyst was added. ✓ (1)

11.5

OPTION 1	**OPTION 2**
$n(HC\ell)_{used} = cV$ ✓ $= 0,2 \times 0,1$ ✓ $= 0,02$ mol $n(S)_{expected} = ½n(HC\ell)_{used} = ½(0,02)$ ✓ $= 0,01$ mol $n(S)_{produced} = \frac{m}{M} = \frac{0,18}{32} = 0,0056$ mol ✓ $\%yield = \frac{n(S)_{prod/berei}}{n(S)_{exp/verwag}} \times 100$ $= \frac{0,0056}{0,01} \times 100$ ✓ $= 56,25\%$ ✓	$n(HC\ell)_{used} = cV$ ✓ $= 0,2 \times 0,1$ ✓ $= 0,02$ mol $n(S)_{expected} = ½n(HC\ell)_{used} = ½(0,02)$ ✓ $= 0,01$ mol $m(S)_{expected} = nM = (0,01)(32)$ ✓ $= 0,32$ g $\%yield = \frac{m(S)_{prod/berei}}{m(S)_{exp/verwag}} \times 100$ $= \frac{0,18}{0,32} \times 100$ ✓ $= 56,25\%$ ✓

(6)
[18]

QUESTION 12 (November 2019)

12.1 Exothermic ✓
$\Delta H < 0$/Energy is released ✓ (2)

12.2 $\text{rate} = -\frac{\Delta m}{\Delta t}$ **OR** $\text{rate} = -\frac{\Delta m}{\Delta t}$

$= -\frac{0{,}25 - 2}{30}$ ✓ ✓ $= -\frac{-1{,}75}{30}$ ✓ ✓

$= 0{,}06\ (g \cdot s^{-1})$ ✓ $(0{,}0583\ g \cdot s^{-1})$ $= 0{,}06\ (g \cdot s^{-1})$ ✓ $(0{,}0583\ g \cdot s^{-1})$ (3)

12.3

OPTION 1	**OPTION 2**
$m(CaCO_3) = \frac{40}{100} \times 2$ ✓ $= 0{,}8$ g $n(CaCO_3)_{reacted} = \frac{m}{M}$ $= \frac{0{,}8}{100}$ ✓ $= 8 \times 10^{-3}$ mol $n(CO_2) = n(CaCO_3)$ ✓ $= 8 \times 10^{-3}$ mol $V(CO_2) = 8 \times 10^{-3} \times 22{,}4$ ✓ $= 0{,}18\ dm^3$ ✓	<u>For 2 g antacid</u>: 100 g ✓$CaCO_3$ ......22,4 dm^3 ✓ CO_2 2 g $CaCO_3$ .....0,448 dm^3 ✓ 100% CO_2 .... 0,448 dm^3 ✓ 40% CO_2 .... 0,18 dm^3 ✓ **OPTION 3** 100% $CaCO_3$ ....2 g 40% ....0,8 g ✓ 100 g ✓....... 1 mol 0,8 g .... 8×10^{-3} mol ✓ 1 mol ....22,4 dm^3 ✓ 8×10^{-3} mol ......0,18 dm^3 ✓

(5)

12.4 **ANY ONE**:
- Concentration (of acid) ✓
- Size/mass of tablet/Identical tablet /Type of tablet.
- State of division / Surface area. (1)

12.5

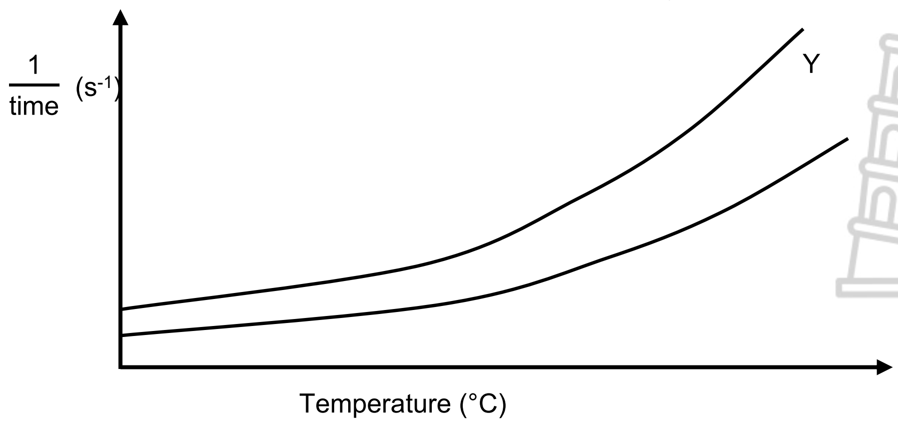
Criteria for conclusion:	
Dependent [reaction rate/time] and independent (temperature) variables correctly identified.	✓
Relationship between the independent and dependent variables correctly stated.	✓

<u>Examples:</u>
- Reaction rate ($\frac{1}{time}$) increases with increase in temperature.
- Time taken for reaction decreases when temperature increases.

IF*:* Reaction rate is DIRECTLY proportional to temperature: Max. 1 out of 2 marks (2)

12.6 Increase in temperature increases the average kinetic energy/molecules move faster. ✓
More molecules have enough/sufficient kinetic energy/More molecules have $E_k > E_a$. ✓
More effective collisions per unit time/second. /Frequency of effective collisions increases. ✓ (3)

12.7



<u>Marking guidelines</u>
- For each value of temperature, the CURVE Y must be above the given CURVE. ✓
- CURVE Y must have an increasing rate with an increase in temperature. ✓ (2)

[18]

QUESTION 13 (November 2020)

13.1.1 Reaction rate ✓ (1)

13.1.2 Surface area/state of division /particle size ✓ (1)

13.2.1 (Decreasing gradient indicates) rate of reaction is decreasing. ✓ (1)

13.2.2 (Gradient is zero, indicates) reaction rate is zero ✓
OR: Reaction stopped/is completed. / Reactants/$CaCO_3$ are used up. (1)

13.3 Ave rate = $\frac{\Delta V}{\Delta t}$

$= -\frac{500 - 0 \checkmark}{60 - 0 \checkmark}$

$= 8,33\ (cm^3\cdot s^{-1})$ ✓ (3)

13.4 Equal to ✓ (1)

13.5 Greater than/*Groter as* ✓

Experiment C:

- Surface area of $CaCO_3$ powder is greater than that of $CaCO_3$ granules./ More particles are exposed /More particles with correct orientation ✓
- More effective collisions per unit time/Higher frequency of effective collisions. ✓
- Increase in reaction rate.✓

OR

Experiment A

- Surface area of $CaCO_3$ granules is smaller/Fewer particles are exposed (than that of powdered $CaCO_3$). Less particles with correct orientation ✓
- Less effective collisions per unit time./Lower frequency of effective collisions. ✓
- Decrease in reaction rate. ✓ (4)

13.6

OPTION 1	**OPTION 2**
$n(CO_2) = \frac{V}{V_m} = \frac{0,5}{25,7}$ ✓ $= 0,0195$ mol $n(CaCO_3) = n(CO_2) = 0,0195$ mol ✓ $m(CaCO_3) = nM$ $= 0,0195(100)$ ✓ $= 1,95$ g ✓	25,7 dm^3 ....1 mol 0,5 dm^3 ....0,0195 mol ✓ 100 g ✓...........1 mol x ....0,0195 mol ✓ x = $m(CaCO_3) = 1,95$ g ✓
OPTION 3 $n(CO_2) = \frac{V}{V_m} = \frac{0,5}{25,7}$ ✓ $= 0,0195$ mol 0,0195 mol $CO_2 \equiv 0,856$ g CO_2 ✓ $m(CO_2)$ produced : $m(CaCO_3)$ 44 g : 100 g ✓ 0,856 : x x = 1,95 g ✓ $CaCO_3$	

(4)
[16]

QUESTION 14 (June 2021)

14.1 **ANY ONE**

- Change in concentration ✓ of products/reactants per (unit) time. ✓
- Change in amount/number of moles/volume/mass of products or reactants per (unit) time.
- Amount/number of moles/volume/mass of products formed/reactants used per (unit) time.
- Rate of change in concentration/amount/number of moles/volume/mass. ✓✓ **(2 or 0)** (2)

14.2 Time ✓
Volume of gas/CO_2/carbon dioxide ✓
OR Time taken for $A\ell_2(CO_3)_3$ to be used up. ✓✓ (2)

14.3 **Experiment II:**

- More ($HC\ell$) particles per unit volume./More particles with correct orientation. ✓
- More effective collisions per unit time./Higher frequency of effective collisions. ✓
- Higher reaction rate. ✓

OR: Experiment I:

- Less ($HC\ell$) particles per unit volume. ✓
- Less effective collisions per unit time./Lower frequency of effective collisions. ✓
- Lower reaction rate. ✓ (3)

14.4

$$\text{ave rate} = -\frac{\Delta n}{\Delta t}$$

$$4{,}4 \times 10^{-3} = -\frac{n_f - 0{,}016}{2{,}5(-0)} ✓ ✓$$

$n[A\ell_2(CO_3)_3] = 0{,}005$ (mol) ✓

Marking cirteria

- Substitute average rate and Δt. ✓
- Substitute Δn. ✓
- Final answer: 0,005 (mol) ✓

(3)

14.5

Marking criteria:

- Use mol ratio: $n(CO_2) : n(A\ell_2(CO_3)_3) = 3 : 1$ ✓
- Substitute 24 000 $cm^3\cdot mol^{-1}$/24 $dm^3\cdot mol^{-1}$ in $n = \frac{V}{V_M}$ or in ratio. ✓
- Final answer: 1 152 cm^3 / 1,152 dm^3 ✓

OPTION 1

$n(CO_2) = 3n[A\ell_2(CO_3)_3]$
$= 3(0{,}016)$ ✓
$= 0{,}048$ mol

$n(CO_2) = \frac{V}{V_M}$

$\therefore 0{,}048 = \frac{V}{24\ 000}$ ✓✓

$V(CO_2) = 1\ 152\ cm^3\ (1{,}152\ dm^3)$ ✓

OPTION 2

$n(CO_2) = 3n[A\ell_2(CO_3)_3]$
$= 3(0{,}016)$ ✓
$= 0{,}048$ mol

1 mol ………………24 000 cm^3
0,048 mol …………V

$V(CO_2) = \frac{0{,}048 \times 24000}{1}$ ✓
$= 1\ 152\ cm^3\ (1{,}152\ dm^3)$ ✓

(3)
[13]

QUESTION 15 (September 2021)

15.1
15.1.1 Kinetic energy ✓ (1)
15.1.2 Number of particles/molecules ✓ (1)
15.2
15.2.1 Activation energy ✓ (1)
15.2.2 Increase ✓ (1)
15.3 - A catalyst provides an alternative pathway of lower activation energy. ✓
- More molecules have sufficient kinetic energy. ✓
- More effective collisions per unit time./Frequency of effective collisions increases.
- Increase reaction rate. ✓ (4)

15.4
15.4.1 Temperature / Surface area / Amount or mass of $CaCO_3$ ✓ (1)
15.4.2 **Criteria for conclusion**:

- Dependent (reaction rate) and independent (concentration) variables correctly identified. ✓
- Relationship between the independent and dependent variables correctly stated. ✓

Example:
Reaction rate is directly proportional to concentration. (2)

15.4.3

Marking criteria/*Nasienkriteria:*

- Substitute 50 $cm^3 \cdot min^{-1}$ and 26 minutes in rate = $\frac{\Delta V}{\Delta t}$ ✓
- Substitute/ *Vervang* 1 300 cm^3 /1,3 dm^3 **OR/*OF*** 24 000 $cm^3 \cdot mol^{-1}$/ 24 $dm^3 \cdot mol^{-1}$ in $n = \frac{V}{V_m}$ ✓
- Use ratio/*Gebruik verhouding* $n(CO_2) = n(CaCO_3) = 1:1$ ✓
- Substitute/*Vervang* 100 $g \cdot mol^{-1}$ in $n = \frac{m}{M}$ ✓
- Calculate % purity/*Bereken % suiwerheid* = $\frac{m(CaCO_3)}{m(Sample/monster)}$ ✓ x 100
- Final answer/*Finale antwoord*: 90,33% ✓
  Range/*Gebied*: 83,33% to 90,33%

OPTION 1	**OPTION 2:**
Rate/*tempo* = $\frac{\Delta V}{\Delta t}$ $50 = \frac{\Delta V}{26}$ ✓ ΔV = 1 300 cm^3 $n(CO_2) = \frac{1300}{24\ 000}$ ✓ **OR** $\frac{1,3}{24}$ = 0,0542 mol $n(CaCO_3) = n(CO_2)$ = 0,0542 mol ✓ $m(CaCO_3) = nM$ = 0,0542 x 100 ✓ = 5,42 g % purity/*suiwerheid* = $\frac{5,42}{6}$ ✓ x 100 = 90,33% ✓	Rate/*tempo* = $\frac{50}{24\ 000}$ ✓ = 0,00208 $mol \cdot min^{-1}$ ✓ $n(CO_2)$ = 0,00208 x 26 = 0,0542 mol $n(CaCO_3) = n(CO_2)$ = 0,0542 mol ✓ $m(CaCO_3) = nM$ ✓ = 0,0542(100) = 5,42 g % purity/*suiwerheid* = $\frac{5,42}{6}$ ✓ x 100 = 90,33% ✓

(6)
[17]

QUESTION 16 (November 2021)

16.1 **ANY ONE**
- Change in concentration ✓ of products/reactants per (unit) time. ✓
- Change in amount/number of moles/volume/mass of products or reactants per (unit) time.
- Amount/number of moles/volume/mass of products formed/reactants used per (unit) time.
- Rate of change in concentration/amount/number of moles/volume/mass. ✓✓ **(2 or 0)** (2)

16.2 Reaction rate decreases./Concentration of HCℓ decreases./Reactants are used up. ✓ (1)

16.3

16.3.1 Exothermic ✓ (1)

16.3.2
- Gradient increases. ✓
- Reaction rate increases. ✓
- Temperature increases./Energy is released. ✓ (3)

16.4

Marking criteria

- m(pure $CaCO_3$) = $\frac{82,5}{100}$ x 15 ✓ / V(CO_2) = $\frac{82,5}{100}$ x V(CO_2) from 15 g $CaCO_3$
- Divide by 100 g·mol^{-1}. ✓
- Use mol ratio: n(CO_2) = n($CaCO_3$). ✓
- Multiply n(CO_2) by 24 000 cm^3. ✓
- Final answer: 2 976 cm^3 ✓

OPTION 1	OPTION 2
m(pure $CaCO_3$) = $\frac{82,5}{100}$ x 15 ✓ = 12,375 g n(pure $CaCO_3$) = $\frac{m}{M}$ = $\frac{12,375}{100}$ ✓ = 0,124 mol n(CO_2) = n($CaCO_3$) ✓ = 0,124 mol V(CO_2) = 0,124 x 24 000 ✓ = 2 976 cm^3 ✓	IF 15 g $CaCO_3$ reacts: n($CaCO_3$) = $\frac{m}{M}$ = $\frac{15}{100}$ ✓ = 0,15 mol n(CO_2) = n($CaCO_3$) ✓ = 0,015 mol n(CO_2) = $\frac{V}{V_M}$ 0,015 = $\frac{V}{24\ 000}$ ✓ V(CO_2) = 3,6 dm^3 Actual CO_2 formed: V(CO_2) = $\frac{82,5}{100}$ x 3,6 ✓ = 2 976 cm^3 ✓

(5)

16.5 Increases ✓ (1)

16.6
- More particles with correct orientation. ✓
- More effective collisions per unit time/Higher frequency of effective collisions. ✓ (2)

[15]

QUESTION 17 (June 2022)

17.1 **ANY ONE:**
- Change in concentration ✓ of products/reactants per (unit) time. ✓
- Change in amount/number of moles/volume/mass of products or reactants per (unit) time.
- Amount/number of moles/volume/mass of products formed/reactants used per (unit) time.
- Rate of change in concentration/amount/number of moles/volume/ mass. ✓✓ **(2 or 0)** (2)

17.2 Surface area / state of division / particle size (of $MgCO_3$) ✓
Concentration (of HCℓ) ✓ (2)

17.3
- At higher temperature particles move faster/have a higher kinetic energy. ✓
- More molecules have enough/sufficient kinetic energy for an effective collision. ✓
  OR More molecules have kinetic energy/Ek equal to or greater than the activation energy.
- More effective collisions per unit time/second. ✓
  OR Frequency of effective collisions increases.
- Reaction rate increases. ✓ (4)

17.4.1 **Marking criteria**
- Formula: n = $\frac{m}{M}$ ✓
- Substitution of 84 g·mol^{-1} in n = $\frac{m}{M}$ ✓
- Use mole ratio: n($MgCO_3$)$_{used}$ = n(CO_2)$_{produced}$ ✓
- Substitution of 44 g·mol^{-1} in n = $\frac{m}{M}$ **or** to calculate rate in mol·min^{-1}. ✓
- Correct substitution of 0,5 in rate equation. ✓
- Final answer: 5,238 to 5,28 min ✓

$n(MgCO_3) = \frac{m}{M}$ ✓

$= \frac{5}{84}$

= 0,06 mol ✓ (0,0595 mol)

$n(CO_2)_{produced}$ = $n(MgCO_3)$ ✓ = 0,06 mol

$n(CO_2) = \frac{m}{M}$ $0,06 = \frac{m}{44}$ ✓ $m(CO_2)$ = 2,64 g Ave rate = $\frac{\Delta m(CO_2)}{\Delta t}$ 0,5 ✓ = $\frac{2,64}{\Delta t}$ Δt = 5,28 min ✓	Ave rate in $mol \cdot min^{-1}$: $\frac{0,5✓}{44✓}$ = 0,0114 $mol \cdot min^{-1}$ Ave rate = $\frac{\Delta n(CO_2)}{\Delta t}$ $0,0114 = \frac{0,06}{\Delta t}$ Δt = 5, 28 min ✓

(6)

17.4.2

Marking criteria

- Substitution of $n(CO_2)$ AND 1,5 dm^3 in $n = \frac{V}{V_m}$. ✓
- Final answer: 25 to 25,21 $dm^3 \cdot mol^{-1}$ ✓

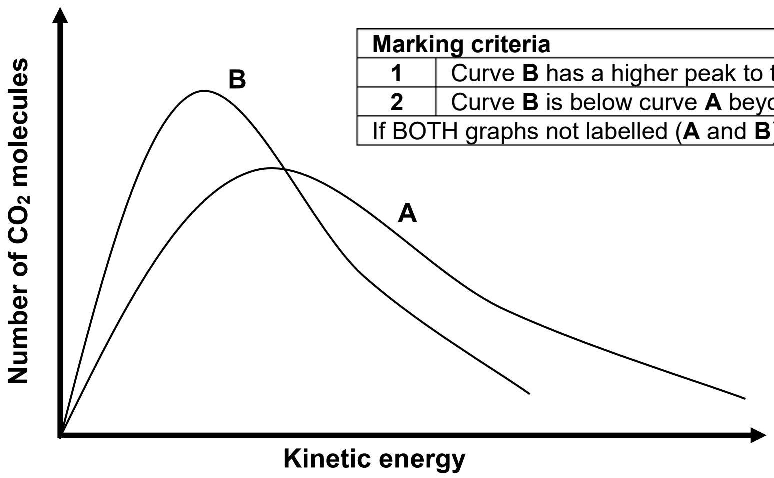
$n = \frac{V}{V_m}$

$0,06 = \frac{1,5}{V_m}$ ✓

V_m = 25 $dm^3 \cdot mol^{-1}$ ✓ (25,21 $dm^3 \cdot mol^{-1}$)

(2)

17.5



Marking criteria		
1	Curve **B** has a higher peak to the left of curve **A**.	✓
2	Curve **B** is below curve **A** beyond the peak of curve **A**.	✓
If BOTH graphs not labelled (**A** and **B**): no marks		

(2)
[18]

QUESTION 18 (November 2022)

18.1 B ✓

- The catalyst provides an alternative route of lower activation energy. ✓
- More molecules have enough/sufficient (kinetic) energy./More molecules have (kinetic) energy equal to or higher than the activation energy. ✓
- •More effective collisions per unit time./Higher frequency of effective collisions. ✓ (4)

18.2 Y ✓✓ (2)

18.3

18.3.1 560 cm^3 / 0,56 dm^3 ✓✓ (2)

18.3.2

Marking criteria:

(a) Substitute <u>24 000 and 560/24 and 0,56</u> in $n = \frac{V}{V_m}$ ✓

(b) USE mol ratio:
$n(H_2O) : n(O_2) = 2 : 1$ ✓

(c) Substitute <u>18 and $n(H_2O)$</u> in
m = nM ✓

(d) Final answer: 0,83 g ✓ Range: 0,72 to 0,9 g

OPTION 1	OPTION 2
$n(O_2) = \frac{V}{V_m}$ $= \frac{560}{24\ 000}$ ✓(a) = 0,023 mol (0,0233) $n(H_2O) = 2n(O_2)$ $n(H_2O) = 2(0,023)$ ✓(b) = 0,046 mol (0,0467) m = nM = <u>0,046 x 18</u> ✓(c) = 0,83 g ✓(d)	1 mol …….24 000 cm^3 x mol …….560 cm^3 } ✓(a) x = 0,023 mol (0,0233) $n(H_2O) = 2n(O_2)$ $n(H_2O) = 2(0,023)$ ✓(b) = 0,046 mol (0,0467) m = nM = <u>0,0466 x 18</u> ✓(c) = 0,83 g ✓(d)

(4)

18.4

18.4.1 0 ($g{\cdot}s^{-1}$) / zero ✓ (1)

18.4.2 Greater than ✓ (1)

18.4.3

Marking criteria

a) Substitute 0,9 g in $\frac{m}{M}$ ✓

b) Substitute 32 in $\frac{m}{M}$ ✓

c) USE mol /rate ratio:
$n(H_2O_2) : n(O_2) = 2 : 1$ ✓

d) Substitute <u>$2,1 \times 10^{-3}$ and $n(H_2O_2)$</u> in rate formula ✓
OR: Substitute <u>rate O_2</u> ($1,05 \times 10^{-3}$) <u>and $n(O_2)$</u> in rate formula
OR: Substitute rate O_2 (0,0336 $g{\cdot}s^{-1}$) in rate formula

e) Final correct answer: 26,67 (s) ✓ Range: 26,67 to 28,57 (s)

OPTION 1	OPTION 2
$n(O_2) = \frac{m}{M}$ ✓(a) $= \frac{0,9}{32}$ ✓(b) = 0,028 mol (0,0281) $n(H_2O_2) = 2n(O_2)$ = 2(0,028) ✓(c) = 0,056 rate = $\frac{\Delta n}{\Delta t}$ ✓(d) $2,1 \times 10^{-3} = \frac{0,056 - 0}{\Delta t}$ Δt = 26,67 (s) ✓(e)	1 mol ………………..32 g ✓(b) x mol ………………..0,9 g ✓(a) x = 0,0275 mol $n(H_2O_2) = 2n(O_2)$ = 2(0,0275) ✓(c) = 0,056 mol rate = $\frac{\Delta n}{\Delta t}$ ✓(d) $2,1 \times 10^{-3} = \frac{0,056 - 0}{\Delta t}$ Δt = 26,67 (s) ✓(e)

OPTION 3	**OPTION 4**
$n(O_2) = \frac{m}{M}$ $= \frac{0,9}{32}$ ✓(a) ✓(b) $= 0,028$ mol (0,0281) $Rate(O_2) = ½ rate(H_2O_2)$ $= ½ (2,1 \times 10^{-3})$ ✓(c) $= 1,05 \times 10^{-3}$ $rate = \frac{\Delta n}{\Delta t}$ $1,05 \times 10^{-3} = \frac{0,028}{\Delta t}$ ✓(d) $\Delta t = 26,67$ (s) ✓(e)	rate $H_2O_2 = 2,1 \times 10^{-3}$ mol·s^{-1} $Rate(O_2) = ½rate(H_2O_2)$ $= ½(2,1 \times 10^{-3})$ ✓(c) $= 1,05 \times 10^{-3}$ In one second: $n(O_2) = \frac{m}{M}$ $1,05 \times 10^{-3} = \frac{m}{32}$ ✓(b) $m(O_2) = 0,0336$ g rate = 0,0336 g·s^{-1} $rate = \frac{\Delta m}{\Delta t}$ $0,0336 = \frac{0,9 - 0}{\Delta t}$ ✓(d) ✓(a) $\Delta t = 26,79$ (s) ✓(e)

(5)
[19]

QUESTION 19 (June 2023)

19.1 Initial concentration is 0./Concentration increases./Curve starts at 0. ✓
OR
Curve B has an initial concentration and is the reactant as its concentration decreases. (1)

19.2 True ✓
1 mol of N_2O_5 forms 2 mol of NO_2 per unit time/per second. ✓
OR
Gradient of graph for NO_2 is twice the gradient of the graph for N_2O_5. (2)

19.3

19.3.1 **Marking criteria:**

- Formula: $c = \frac{m}{MV}$ / $n(NO_2) = cV$ / $n(NO_2) = \frac{m}{M}$
- Substitute change in concentration. ✓
- Substitute M and V. ✓
- Final correct answer: 1,84 g✓

OPTION 1	**OPTION 2**
$c(NO_2) = \frac{m}{MV}$ ✓ 200×10^{-4} ✓$= \frac{m}{(46)(2)}$ ✓ $m = 1,84$ g ✓	$n(NO_2) = cV$✓ $= (200 \times 10^{-4})(2)$ ✓ $= 4 \times 10^{-2}$ mol $n(NO_2) = \frac{m}{M}$ $4 \times 10^{-2} = \frac{m}{46}$ $m = 1,84$ g

(4)

19.3.2 **Marking criteria:**

- Substitute the change in concentration into rate formula. ✓
- Substitute time into the rate formula. ✓
- Use mol ratio: rate $(O_2) = ½$ rate (N_2O_5) / rate$(O_2) = ¼$ rate (NO_2) ✓
- Final correct answer: 1×10^{-5} (mol·dm^{-3}·s^{-1})✓

OPTION 1	**OPTION 2**
Ave rate $= -\frac{\Delta c(N_2O_5)}{\Delta t}$ $= -\frac{(60 \times 10^{-4} - 200 \times 10^{-4})}{700 (- 0)}$ ✓ ✓ $= 2 \times 10^{-5}$ (mol·dm^{-3}·s^{-1}) $Rate(O_2) = ½ rate(N_2O_5)$ $= ½(2 \times 10^{-5})$ ✓ $= 1 \times 10^{-5}$ (mol·dm^{-3}·s^{-1}) ✓	Ave rate $= \frac{\Delta c(NO_2)}{\Delta t}$ $= \frac{(280 \times 10^{-4} (- 0))}{700 (- 0)}$ ✓ ✓ $= 4 \times 10^{-5}$ (mol·dm^{-3}·s^{-1}) $rate(O_2) = ¼ rate(NO_2)$ $= ¼(4 \times 10^{-5})$ ✓ $= 1 \times 10^{-5}$ (mol·dm^{-3}·s^{-1}) ✓

OPTION 3

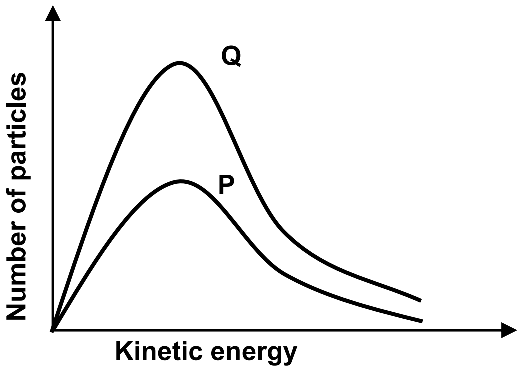
$\Delta c(O_2) = \frac{1}{2}\Delta c(N_2O_5)$
$= \frac{1}{2}(60 \times 10^{-4} - 200 \times 10^{-4})$ ✓
$= \frac{1}{2}(140 \times 10^{-4})$
$= 7 \times 10^{-3}\ mol \cdot dm^{-3}$

OR

$\Delta c(O_2) = \frac{1}{4}\Delta c(NO_2)$
$= \frac{1}{4}(280 \times 10^{-4}$ ✓ $- 0)$
$= 7 \times 10^{-3}\ mol \cdot dm^{-3}$
$= 7 \times 10^{-3}\ mol \cdot dm^{-3}$

$$\text{Ave rate} = \frac{\Delta c(O_2)}{\Delta t}$$
$$= \frac{(7 \times 10^{-3})\ ✓}{700\ (-\ 0)\ ✓}$$
$$= 1 \times 10^{-5}\ (mol \cdot dm^{-3} \cdot s^{-1})\ ✓$$

19.4
19.4.1



Marking criteria
- Curve Q must be above the given curve/P. ✓
- Curve Q must have the same shape as the given curve/P. ✓

(2)

19.4.2 Higher than ✓
- When the concentration of N_2O_5 is higher there are more N_2O_5 particles per unit volume. ✓
- More effective collisions per unit time/second. ✓
  OR
  Higher frequency of effective collisions. (3)

[16]

QUESTION 20 (November 2023)

20.1 **ANY ONE:**
- Change in concentration ✓ of products/reactants per (unit) time. ✓
- Change in amount/number of moles/volume/mass of products or reactants per (unit) time.
- Amount/number of moles/volume/mass of products formed/reactants used per (unit) time.
- Rate of change in concentration/amount/number of moles/volume/ mass. ✓ **(2 or 0)** (2)

20.2 Concentration (of $Na_2S_2O_3$) ✓ (1)

20.3 **Marking criteria**:

- Substitute 0,03 and 0,13 OR 30 and 0,13. ✓
- Substitute 0,05 OR 50. ✓
- Final correct answer: 0,078 mol·dm^{-3}. ✓
  Range 0,075 to 0,08 mol·dm^{-3}

OPTION 1

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

$0,13 = \frac{n}{0,03}$ ✓

$n = 3,9 \times 10^{-3}$ *mol*

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

$c = \frac{3,9 \times 10^{-3}}{0,05}$ ✓

$= 0,078$ (mol·dm^{-3}) ✓

OPTION 2

$c_1V_1 = c_2V_2$

(0,13)(0,030) ✓ = c_2 (0,050) ✓

c_2 = 0,078 (mol·dm^{-3}) ✓

OPTION 3 **Marking criteria**

- Substitute 0,05 and 0,13 OR 50 and 0,13 OR 0,05 and 0,10. ✓
- Substitute 0,05 OR 0,0550. ✓
- Final correct answer: 0,078 mol·dm^{-3}. ✓
  Range: 0,075 to 0,08 mol·dm^{-3}

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

$0,13 = \frac{n}{0,05}$ ✓

$n = 6,5 \times 10^{-3}$ moles

$V_2 : V_1$

3 : 5

$3,9 \times 10^{-3} : 6,5 \times 10^{-3}$

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

$c = \frac{3,9 \times 10^{-3}}{0,05}$ ✓

$= 0,078$ (mol·dm^{-3}) ✓

OR

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

$0,10 = \frac{n}{0,05}$ ✓

$n = 5 \times 10^{-3}$ moles

$V_2 : V_1$

3 : 4

$3,75 \times 10^{-3} : 5 \times 10^{-3}$

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

$c = \frac{3,75 \times 10^{-3}}{0,05}$ ✓

$= 0,075$ (mol·dm^{-3}) ✓

20.4 **Marking criteria:**

- Substitute M = 32 g·mol^{-1} in formula: $n(S) = \frac{m}{M}$ ✓
- Use mol/M ratio: $n(S) = n(Na_2S_2O_3)$ ✓
- Substitute M = 158 g·mol^{-1} in formula $n(Na_2S_2O_3) = \frac{m}{M}$ ✓
- Divide by 20,4 s. ✓
- Final correct answer: 0,051 (g·s^{-1}) ✓
  Range: 0,048 to 0,080 (g·s^{-1})

OPTION 1

$n(S) = \frac{m}{M}$

$= \frac{0,21}{32}$ ✓

$= 0,00656$ moles ($6,56 \times 10^{-3}$)

$n(S) = n(Na_2S_2O_3)$

$= 0,00656$ moles ✓

$n(Na_2S_2O_3) = \frac{m}{M}$

$0,00656 = \frac{m}{158}$ ✓

$m(Na_2S_2O_3) = 1,04$ g

OPTION 2

158 g $Na_2S_2O_3$ ✓ .... 2 g S ✓

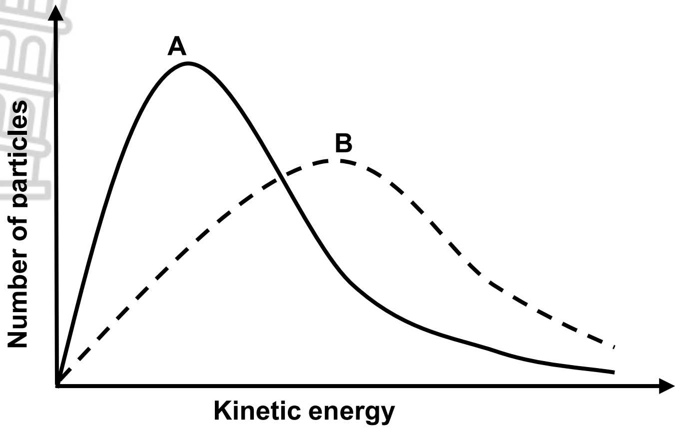
x g .... 0,21 g ✓

x = 1,04 g

$$\text{Rate} = \frac{\Delta m}{\Delta t} = \frac{1,04}{20,4} ✓ = 0,051 \text{ (g·s}^{-1}\text{)} ✓$$

(5)

20.5 **Marking criteria:**
- Both axis labelled correctly. ✓
- Both curves start at origin and have correct shape. ✓
- Peak of curve B must be lower than curve A. ✓
- Curve B must have higher kinetic energy than curve A from the peak up to end of curve B. ✓



(4)

20.6 **OPTION 1**
- At a higher temperature particles move faster/have higher kinetic energy. ✓
- More molecules have enough/sufficient kinetic energy for an effective collision. ✓
  OR
  More molecules have kinetic energy/Ek equal to or greater than the activation energy.
- More effective collisions per unit time/second. ✓
  OR
  Frequency of effective collisions increases.
- Reaction rate increases. ✓

OPTION 2
- At a lower temperature particles move slower/have lower kinetic energy. ✓
- Less molecules have enough/sufficient kinetic energy for an effective collision. ✓
  OR
  Less molecules have kinetic energy/Ek equal to or greater than the activation energy.
- Less effective collisions per unit time/second. ✓
  OR
  Frequency of effective collisions decreases
- Reaction rate decreases. ✓ (4)

[19]

QUESTION 21 (June 2024)

21.1.1 Exothermic ✓
Lower (potential) energy of the products than reactants. / $\Delta H < 0$ / ΔH negative / $\Delta H = -121{,}7$ kJ / More energy is released than absorbed. ✓ (2)

21.1.2 (The number of) particles with sufficient/enough (kinetic) energy (with a catalyst) **OR** $E_k \geq E_A$ (which can undergo effective collisions.) ✓ (1)

21.1.3 240,8 - 208,2 ✓= 32,6 (kJ) ✓ (2)

21.2.1 Decreases. ✓ (1)

21.2.2 Remains the same. ✓ (1)

21.2.3 Remains the same. ✓ (1)

21.3.1 Concentration (of sulphuric acid/H_2SO_4(aq)) ✓ (1)

21.3.2 More (H_2SO_4) particles per unit volume. ✓
More effective collisions per unit time. / Higher frequency of effective collisions. ✓
Higher reaction rate. ✓
OR
Less (H_2SO_4) particles per unit volume.
Less effective collisions per unit time. / Lower frequency of effective collisions.
Lower reaction rate. (3)

21.3.3

OPTION 1

$Rate = \frac{\Delta V_{H2}}{\Delta t}$

$40 = \frac{\Delta V_{H2}}{(2,6)(60)}$ ✓

$\Delta V_{H2} = 6\,240\ cm^3$

$n(H_2) = \frac{V}{V_m}$

$= \frac{6\,240}{27\,000}$ ✓

$= 0,23\ mol$

$n(A\ell) = \frac{2}{3}n(H_2)$

$n(A\ell) = \frac{2}{3}(0,23)$ ✓

$= 0,15\ mol$

$n(A\ell) = \frac{m}{M}$

$0,15 = \frac{m}{27}$ ✓

$m = 4,05\ g$

$\%\ purity$

$= \left[\frac{4,05}{5}\right](100)$ ✓

$= 81\%$ ✓

OPTION 2

$Rate\ V(H_2) = 40\ cm^3 \cdot s^{-1}$

$Rate\ n(H_2) = \frac{V}{V_m}$

$= \frac{40}{27\,000}$ ✓

$= 0,00148\ mol \cdot s^{-1}$

$Rate\ n(A\ell) = \frac{2}{3}n(H_2)$

$= \frac{2}{3}(0,00148)$ ✓

$= 9,87x10^{-4}\ mol \cdot s^{-1}$

$n(A\ell) = \frac{m}{M}$

$9,87x10^{-4} = \frac{m}{27}$ ✓

$m = 0,027\ g \cdot s^{-1}$

$Rate = \frac{\Delta m_{A\ell}}{\Delta t}$

$0,027 = \frac{\Delta m_{A\ell}}{(2,6)(60)}$ ✓

$m_{A\ell} = 4,212\ g$

$\%\ purity$

$= \left[\frac{4,212}{5}\right](100)$ ✓

$= 84,2\%$ ✓

(6)

[18]

QUESTION 22 (November 2024)

22.1.1 The change in concentration ✓ of products/reactants per (unit) time. ✓ **OR**
The change in the amount/number of moles/volume/mass of products or reactants per (unit) time. **OR**
The amount/number of moles/volume/mass of products formed/reactants used per (unit) time. **OR**
Rate of change in concentration/amount/number of moles/volume/ mass. (**2 or 0 here.**) (2)

22.1.2

$Rate = \frac{\Delta V(H_2)}{\Delta t}$

$0,033 = \frac{\Delta V(H_2)}{5}$ ✓

$\Delta V(H_2) = 0,165\ dm^3 = V(H_2\ produced)$

$n(H_2\ produced) = \frac{V}{V_m}$

$= \frac{0,165}{24,5}$ ✓

$= 6,735x10^{-3}\ mol$

$n(A\ell\ used) = \frac{2}{3}n(H_2\ produced)$

$= \frac{2}{3}(6,735\ x10^{-3})$ ✓

$= 4,49x10^{-3}\ mol$

OPTION 1

$n(A\ell\ used) = \frac{m(A\ell\ used)}{M}$

$4,49x10^{-3} = \frac{m(A\ell\ used)}{27}$ ✓

$m(A\ell\ used) = 0,121\ g$

$m(A\ell\ at\ t = 5\ min) = 0,5 - 0,121$ ✓

$= 0,38\ g$ ✓

OPTION 2

$n(A\ell\ begin) = \frac{m(A\ell\ begin)}{M}$

$= \frac{0,5}{27}$

$= 0,0185\ mol$

$n(A\ell\ at\ t = 5\ min) = 0,0185 - 4,49x10^{-3}$ ✓

$= 0,014\ mol$

$n(A\ell\ at\ t = 5\ min) = \frac{m(A\ell\ at\ t = 5\ min)}{M}$

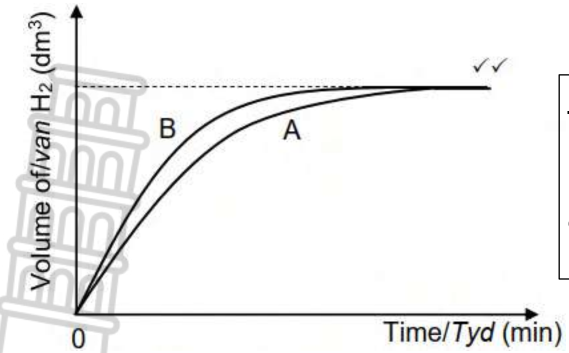
$0,014 = \frac{m(A\ell\ at\ t = 5\ min)}{27}$ ✓

$m(A\ell\ at\ t = 5\ min) = 0,38$ g ✓

(6)

22.1.3 The surface area / contact area /mass/size of aluminium decreases. ✓
Less particles are exposed. ✓
Less effective collisions per unit time/second. **OR** Lower frequency of effective collisions. ✓
Reaction rate decreases. / Lower reaction rate. / Reaction slows down. ✓ (4)

22.1.4



Marking criteria:
Curve **B** starts at the origin and ends at the same point as curve **A**. ✓
Gradient of curve **B** is steeper for the whole duration. ✓
Note: Graphs unlabelled: Max. ½

(2)

22.1.5 Equal to. ✓ (1)

22.2.1 An increase in temperature. ✓ (1)

22.2.2 Curve **Y** has a peak/maximum at a higher kinetic energy. / Peak shifted to the right. **OR** The (average) kinetic energy (of the particles) increases. / More particles with higher kinetic energy. / Larger area with higher kinetic energy. ✓ (1)

[17]

CHEMICAL EQUILIBRIUM

QUESTION 1 (November 2014)

1.1.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓
OR The stage in a chemical reaction when the concentrations of reactants and products remain constant. (2)

1.2

OPTION 1

$K_c = \frac{[N_2O_4]}{[NO_2]^2}$ ✓ $\therefore$ 171 ✓ = $\frac{[N_2O_4]}{(0,2)^2}$ ✓ $\therefore [N_2O_4] = 171 \times (0,2)^2 = 6,84\ mol{\cdot}dm^{-3}$

	NO_2	N_2O_4	
Initial quantity (mol)	1,11 ✓	0	
Change (mol) subtract ✓	1,094	0,55 ✓	ratio ✓
Quantity at equilibrium (mol)/	0,016	0,55	
Equilibrium concentration ($mol{\cdot}dm^{-3}$)	0,2	6,84	x 0,08 ✓

OPTION 2

$K_c = \frac{[N_2O_4]}{[NO_2]^2}$ ✓ $\therefore$ 171 ✓ = $\frac{[N_2O_4]}{(0,2)^2}$ ✓ $\therefore [N_2O_4] = 171 \times (0,2)^2 = 6,84\ mol{\cdot}dm^{-3}$

Equilibrium moles:
$n(N_2O_4) = (6,84)(0,080) = 0,55$ mol
$n(NO_2) = (0,2)(0,080) = 0,016$ mol } ✓ x 0,08 dm^3
$n(N_2O_4$ formed) = 0,55 – 0 = 0,55 mol ✓
Ratio: $n(NO_2$ reacted) = $2n(N_2O_4$ formed) = 2(0,55) = 1,094 mol ✓
Initial $n(NO_2)$ = 0,016 + 1,094 ✓ = 1,11 (mol) ✓

(8)

1.3.1 Concentration (of the gases) increases. / Molecules become more condensed or move closer to each other. ✓ (1)

1.3.2 Increase in pressure favours the reaction that leads to smaller number of moles of gas. ✓
Forward reaction is favoured. ✓
Number of moles/amount of N_2O_4 / colourless gas increases.✓
OR Number of moles/amount of NO_2 / brown gas decreases. ✓ (3)

1.4.1 Darker ✓ (1)

1.4. 2 Decreases ✓ (1)

[16]

QUESTION 2 (March 2015)

2.1 A reaction is reversible when products can be converted back to reactants. ✓ (1)

2.2 No change ✓ (1)

2.3.1 Temperature decreases ✓ (1)

2.3.2 Decrease in temperature decreases the rate of both forward and reverse reactions. ✓
Decrease in temperature favours the exothermic reaction. ✓
The rate of the reverse (exothermic) reaction is faster or the reverse reaction is favoured. ✓ (3)

2.4

OPTION 1/*OPSIE 1*

At equilibrium/*by ewewig*: $[H_2] = [I_2]$ ✓

$K_c = \frac{[H_2][I_2]}{[HI]^2}$ ✓

$\therefore 0,02$ ✓ $= \frac{(x)(x)}{\left(\frac{0,04}{2}\right)^2}$ ✓ Divide by 2 dm^3 ✓ / *Deel deur* 2 dm^3

$\therefore x = [H_2] = 2,83 \times 10^{-3}\ mol{\cdot}dm^{-3}$ ✓ ($0,0028\ mol{\cdot}dm^{-3}$)

OPTION 2/*OPSIE 2*

	HI	H_2	I_2	
Initial quantity (mol) *Aanvangshoeveelheid (mol)*	x	0	0	
Change (mol) *Verandering (mol)*	x - 0,04	$\frac{x-0,04}{2}$	$\frac{x-0,04}{2}$	ratio ✓ *verhouding*
Quantity at equilibrium (mol)/ *Hoeveelheid by ewewig (mol)*	0,04	$\frac{x-0,04}{2}$	$\frac{x-0,04}{2}$	
Equilibrium concentration ($mol{\cdot}dm^{-3}$) *Ewewigskonsentrasie ($mol{\cdot}dm^{-3}$)*	0,02	$\frac{x-0,04}{4}$	$\frac{x-0,04}{4}$	Divide by 2 dm^3 ✓ *Deel deur 2 dm^3*

$K_c = \frac{[H_2][I_2]}{[HI]^2}$ ✓

$\therefore 0,02$ ✓ $= \frac{(\frac{x-0,04}{4})(\frac{x-0,04}{4})}{(0,02)^2}$ ✓

$\therefore x = 0,05$

$[H_2] = \frac{x-0,04}{2}$

$= \frac{0,05-0,04}{2}$

$= 2,83 \times 10^{-3}\ mol{\cdot}dm^{-3}$ ✓

No K_c expression, correct substitution/*Geen K_c-uitdrukking, korrekte substitusie*: Max./*Maks.* $\frac{5}{6}$

Wrong K_c expression/*Verkeerde K_c-uitdrukking*: Max./*Maks.* $\frac{2}{6}$

(6)

2.5 $K_c = \frac{1}{0,02} = 50$ ✓ (1)

2.6 Increases ✓ (1)

[14]

QUESTION 3 (June 2015)

3.1 When the equilibrium (in a closed system) is disturbed, the system will re-instate a new equilibrium ✓ by favouring the reaction that will cancel the disturbance. ✓ (2)

3.2.1 Remains the same ✓ (1)

3.2.2 Increases ✓ (1)

3.3

OPTION 1

$K_c = [NH_3][H_2S]$ ✓

$\therefore 1,2 \times 10^{-4}$ ✓ $= [NH_3][H_2S]$

$\therefore [NH_3] = [H_2S] = 0,011\ mol{\cdot}dm^{-3}$

$n(NH_3) = cV = (0,011)(5)$ ✓ $= 0,06$ mol (0,06 mol)

$n(NH_4HS) = n(NH_3) = 0,06$ mol ✓

$m(NH_4HS) = nM = (0,06)(51)$ ✓ $= 2,81$ g ✓

OPTION 2

	NH_4HS	NH_3	H_2S	
Initial quantity (mol)		0	0	
Change (mol)	x	x ✓	x	
Quantity at equilibrium (mol)	-	x	x	
Equilibrium concentration ($mol{\cdot}dm^{-3}$)	-	$\frac{x}{5}$	$\frac{x}{5}$	Divide by 5 ✓

$K_c = [NH_3][H_2S]$ ✓

$\therefore 1,2 \times 10^{-4}$ ✓ $= (\frac{x}{5})(\frac{x}{5})$ $\therefore x = 0,0547$ mol

$m(NH_4HS) = nM = (0,0547)$ ✓ (51) ✓ $= 2,79$ g ✓

(6)

3.4 Decreases ✓
- Increase in pressure favours the reaction that leads to the smaller number of moles of gas. ✓✓
- The reverse reaction is favoured. ✓ (3)

[13]

QUESTION 4 (November 2015)

4.1 Equal to ✓ (1)

4.2 $K_c = \frac{[X_3]^2}{[X_2]^3}$ ✓ = $\frac{(0,226)^2 ✓}{(0,06)^3 ✓}$ = 236,46 ✓ (4)

4.3.1 Increases ✓ (1)

4.3.2 The increase in $[X_3]$ is opposed. / Change is opposed. ✓
The reverse reaction is favoured. / X_3 is used. / $[X_3]$ decreases. ✓ (2)

4.4 Higher than ✓ (1)

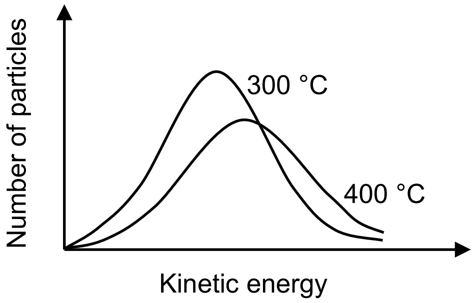
4.5 Exothermic ✓

- The concentration of the product / $X_3(g)$ is lower. / The concentration of the reactant / $X_2(g)$ is higher. ✓
- The increase in temperature favoured the reverse reaction. ✓
- According to Le Chatelier's principle an increase in temperature favours the endothermic reaction. ✓

OR

- $[X_3]$ decreases and $[X_2]$ increases. ✓
- K_c decreases if temperature increases. ✓
- Decrease in temperature favoured the forward reaction. ✓ (4)

4.6



Marking criteria	
Peak of curve at 400 °C lower than at 300 °C and shifted to the right.	✓
Curve at 400 °C has larger area at the higher E_k.	✓

(2)
[15]

QUESTION 5 (June 2016)

5.1 Reversible reaction ✓ (1)

5.2 Endothermic ✓ ΔH is positive. / ΔH > 0 ✓ (2)

5.3 Larger than ✓ $K_c > 1$ ✓ (2)

5.4 **<u>OPTION 1</u>**

$n = \frac{m}{M} = \frac{168}{28}$ ✓ = 6 mol

	CO_2	CO	
Initial quantity (mol)	x	0	
Change (mol)	3	6 ✓	ratio ✓
Quantity at equilibrium (mol)	x – 3 ✓	6	
Equilibrium concentration (mol·dm^{-3})	$\frac{x-3}{2}$	3	Divide by 2 ✓

$K_c = \frac{[CO]^2}{[CO_2]}$ ✓ ∴14 ✓ = $\frac{(3)^2}{\frac{x-3}{2}}$ ✓ ∴ x = 4,29 mol ✓

<u>OPTION 2</u>

$n = \frac{m}{M} = \frac{168}{28}$ ✓ = 6 mol and $c = \frac{n}{V} = \frac{6}{2}$ ✓ = 3 mol·dm^{-3}

	CO_2	CO	
Initial concentration (mol·dm^{-3})	x	0	
Change (mol·dm^{-3})	1,5	3 ✓	ratio ✓
Equilibrium concentration (mol·dm^{-3})	x – 1,5✓	3	

$K_c = \frac{[CO]^2}{[CO_2]}$ ✓ ∴ 14 ✓ = $\frac{(3)^2}{x - 1,5}$ ✓ ∴ x = 2,14 mol·dm^{-3}

$n(CO_2) = cV = (2,14)(2) = 4,29$ mol ✓ (9)

5.5.1 Remains the same ✓ (1)
5.5.2 Decreases ✓ (1)
5.5.3 Increases ✓ (1)
[17]

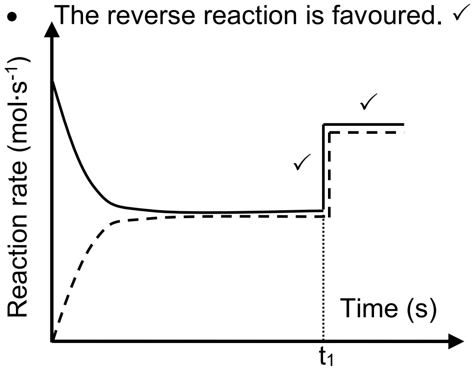
QUESTION 6 (November 2016)

6.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓
OR The stage in a chemical reaction when the concentrations / quantities of reactants and products remain constant. (2)

6.2.1 Remains the same ✓ (1)

6.2.2 Decreases ✓
- When the temperature is increased the reaction that will oppose this increase / decrease the temperature will be favoured. ✓ **OR** The forward reaction is exothermic.
- An increase in temperature favours the endothermic reaction. ✓
- The reverse reaction is favoured. ✓ (4)

6.3



Marking criteria
- Vertical parallel lines show a sudden increase in rate of both forward and reverse reactions. ✓
- Horisontal parallel lines showing a constant higher rate for both forward and reverse catalysed reactions after time t_1. ✓

(2)

6.4 **OPTION 1**

$n(PbS) = \frac{m}{M} = \frac{2,39}{239}$ ✓ = 0,01 mol

$n(H_2S)_{equilibrium}$ = n(PbS) ✓ = 0,01 mol

	H_2	H_2S	
Initial quantity (mol)	0,16	0	
Change (mol)	0,01	0,01 ✓	ratio ✓
Quantity at equilibrium (mol)	0,15 ✓	0,01	
Equilibrium concentration (mol·dm⁻³)	0,075	0,005	divide by 2 ✓

$K_c = \frac{[H_2S]}{[H_2]}$ ✓ $= \frac{0,005}{0,075}$ ✓ = 0,067 ≈ 0,07 ✓

OPTION 2

$n(PbS) = \frac{m}{M} = \frac{2,39}{239}$ ✓ = 0,01 mol

$n(H_2S)_{reacted}$ = n(PbS) ✓ = 0,01 mol = $n(H_2S)_{equilibrium}$

$n(H_2S)_{formed} = n(H_2S)_{equilibrium} – n(H_2S)_{initial}$ = 0,01 – 0 ✓ = 0,01 mol

$n(H_2)_{reacted} = n(H_2S)_{formed}$ ✓ = 0,01 mol

$n(H_2)_{equilibrium} = n(H_2)_{initial} - n(H_2)_{reacted}$ = 0,16 - 0,01 ✓ = 0,15 mol

$c(H_2) = \frac{n}{V} = \frac{0,15}{2}$ = 0,075 mol·dm⁻ ✓Divide by 2

$(H_2S) = \frac{n}{V} = \frac{0,01}{2}$ = 0,005 mol·dm⁻³

$K_c = \frac{[H_2S]}{[H_2]}$ ✓ $= \frac{0,005}{0,075}$ ✓ = 0,067 ✓ (9)

[18]

QUESTION 7 (March 2017)

7.1.1 Products can be converted back to reactants. ✓
OR Both forward and reverse reactions can take place. (1)

7.1.2 Endothermic ✓ (1)

7.1.3 K_c increases with increase in temperature. ✓
Forward reaction is favoured./Concentration of products increases./ Concentration of reactants decreases. ✓
Increase in temperature favours an endothermic reaction. ✓ (3)

7.1.4 Increases ✓ (1

7.1.5 Remains the same ✓ (1)

7.2.1

OPTION 1

	$C\ell_2$	Ti	
Initial quantity (mol)	6 ✓	7	
Change (mol)	2 ✓	1	Use mole ratio✓
Quantity at equilibrium (mol)	4	6 ✓	
Equilibrium concentration (mol·dm^{-3})	2		Divide by 2✓

$K_c = \frac{1}{[Cl_2]^2}$ ✓ $= \frac{1}{(2)^2}$ ✓ $= 0{,}25$ ✓

OPTION 2

$n(Ti)_{reacted} = \frac{m}{M} = \frac{48}{48}$ ✓ $= 1$ mol and $n(C\ell_2)_{reacted} = 2n(Ti) = 2(1)$ ✓ $= 2$ mol

$n(C\ell_2)_{initial} = \frac{m}{M} = \frac{426}{71}$ ✓ $= 6$ mol

$n(C\ell_2)_{equilibrium} = 6 - 2$ ✓ $= 4$ mol

$c = \frac{n}{V} = \frac{4}{2}$ ✓ $= 2$ mol·dm^{-3}

$K_c = \frac{1}{[Cl_2]^2}$ ✓ $= \frac{1}{(2)^2}$ ✓ $= 0{,}25$ ✓

(8)

7.2.2 Remains the same ✓ (1)

[16]

QUESTION 8 (June 2017)

8.1 Amount / number of moles / volume of (gas) reactants equals amount/number of moles/volume of (gas) products. ✓
OR A change in pressure will change the concentration of the reactants and products equally. (1)

8.2

OPTION 1

$K_c = \frac{[HI]^2}{[H_2][I_2]}$ ✓ $\therefore 55{,}3$ ✓ $= \frac{[HI]^2}{(0{,}014)(0{,}0085)}$ ✓ $\therefore [HI] = 0{,}08112$ mol·dm^{-3}

	H_2	I_2	HI	
Initial mass (g)		(0,09812)(254) ✓ = 24,92 g ✓		
Initial quantity (mol)	0,1091	0,09812	0	
Change (mol)	0,08112	✓ 0,08112	0,1622 ✓	Using ratio ✓
Quantity at equilibrium (mol)	0,028	0,017	0,1622	
Equilibrium concentration (mol·dm^{-3})	0,014	0,0085	0,08112	x 2

Divide by 2 ✓

OPTION 2

$K_c = \frac{[HI]^2}{[H_2][I_2]}$ ✓ $\therefore$ 55,3 ✓ = $\frac{x^2}{(0,014)(0,0085)}$ ✓ $\therefore$ x = 0,08112 mol·dm^{-3}

	H_2	I_2	HI
Initial quantity (mol)	x+0,028	x + 0,017	0
Change (mol)	x	x	2x✓
Quantity at equilibrium (mol)	0,028	✓0,017	2x
Equilibrium concentration (mol·dm^{-3})	0,014	0,0085	x

Using ratio ✓

x 2

Divide by 2 ✓

Initial quantity I_2(mol) = 0,08112 + 0,017 = 0,09812 mol

m(I_2) = nM = (0,09812)(254) ✓ = 24,92 g ✓

(9)

8.3 Chemical/dynamic equilibrium ✓ (1)

8.4 Addition of a catalyst. ✓ AND Increase in pressure. ✓ (2)

8.5.1 Endothermic ✓

- Rate of the forward reaction decreases more. / Rate of the reverse reaction decreases less. ✓
- A decrease in temperature favours the exothermic reaction. ✓ (3)

8.5.2 Decreases ✓ (1)

8.6 Reactants / H_2 / I_2 removed ✓ (1)

[18]

QUESTION 9 (November 2017)

9.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓

OR The stage in a chemical reaction when the concentrations/amount of reactants and products remain constant. (2)

9.2

OPTION 1

$n = \frac{m}{M} = \frac{1,12}{28}$ ✓ = 0,04 mol

	$COBr_2$	CO	Br_2
Initial quantity (mol)		0	0
Change (mol)	0,04	0,04	0,04
Quantity at equilibrium (mol)		0,04	0,04 ✓
Equilibrium concentration (mol·dm^{-3})		0,02	0,02

$K_c = \frac{[CO][Br_2]}{[COBr_2]}$ ✓ 0,19 ✓ = $\frac{(0,02)^2}{[COBr_2]}$ ✓ c($COBr_2$)$_{eq}$ = 2,11 x 10^{-3} mol·dm^{-3} ✓

OPTION 2

$n = \frac{m}{M} = \frac{1,12}{28}$ ✓ = 0,04 mol

	$COBr_2$	CO	Br_2
Initial quantity (mol)	x	0	0
Change (mol)	0,04	0,04	0,04
Quantity at equilibrium (mol)	x – 0,04	0,04	0,04 ✓
Equilibrium concentration	$\frac{x-0,04}{2}$	0,02	0,02

Divide by 2 ✓

$K_c = \frac{[CO][Br_2]}{[COBr_2]}$ ✓ $\therefore$ 0,19 ✓ = $\frac{(0,02)^2}{\frac{x-0,04}{2}}$ ✓ $\therefore$ x = 0,0442 mol

$\therefore$c($COBr_2$)$_{eq}$ = 2,11 x 10^{-3} mol·dm^{-3} ✓

(7)

9.3

OPTION 1	OPTION 2: From Q9.2 Option 2
$n(COBr_2)_{eq} = cV = 2,11 \times 10^{-3} \times 2$ ✓ $= 4,22 \times 10^{-3}$ mol $n(COBr_2)_{initial} = 0,04 + 4,22 \times 10^{-3}$ ✓ $= 0,044$ mol	$n(COBr_2)_{initial} = x = 0,0442$ mol ✓✓ $n(COBr_2)_{react} = 0,04$ mol

% decomposed = $\frac{0,04}{0,044}$ ✓ x 100 = 90,46% ✓ (90,3 – 90,9%)

(4)

9.4 $K_c < 0,19$ ✓ (1)

9.5 Decreases ✓
A decreases in pressure favours the reaction that produces the larger number of moles/ volume (units) of gas. ✓
The forward reaction will be favoured. ✓ (3)

[17]

QUESTION 10 (March 2018)

10.1.1 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will oppose the disturbance. ✓✓ (2)

10.1.2 Percentage yield increases with an increase in temperature. ✓
Forward reaction is favoured. ✓
Increase in temperature favours an endothermic reaction. ✓. (3)

10.1.3 When the pressure increases, the reaction that leads to a decrease in the number of moles will be favoured. ✓✓ (2)

10.1.4 I ✓✓ (2)

10.2

OPTION 1

	HCl	O_2	Cl_2	H_2O	
Initial quantity (mol)	0,2	0,11	0	0	
Change (mol)	0,15 ✓	0,0375	0,075	0,075	ratio ✓
Quantity at equilibrium (mol)	$\frac{1,825}{36,5} = 0,05$ ✓	0,0725	0,075	0,075	✓
Equilibrium concentration ($mol \cdot dm^{-3}$)	0,25	0,3625	0,375	0,375	Divide by 0,2✓

$K_c = \frac{[Cl_2]^2[H_2O]^2}{[HCl]^4[O_2]}$ ✓ $= \frac{(0,375)^2(0,375)^2}{(0,25)^4(0,3625)}$ ✓ ✓ $= 13,97$ ✓

OPTION 2

$n(HCl)_{equilibrium} = \frac{m}{M} = \frac{1,825}{36,5}$ ✓ $= 0,05$ mol
$n(HCl)_{reacted} = 0,2 – 0,05 = 0,15$ mol ✓
$n(O_2)_{reacted} = \frac{1}{4}n(HCl)_{reacted} = \frac{1}{4} \times 0,15 = 0,0375$ mol
$n(Cl_2)_{formed} = \frac{1}{2}n(HCl)_{reacted} = \frac{1}{2} \times 0,15 = 0,075$ mol
$n(H_2O)_{formed} = \frac{1}{2}n(HCl)_{reacted} = \frac{1}{2} \times 0,15 = 0,075$ mol } Using ratio ✓
$n(O_2)_{equilibrium} = 0,11 – 0,0375 = 0,0725$ mol
$n(Cl_2)_{equilibrium} = n(H_2O)_{equilibrium} = 0,075$ mol } ✓
$c(O_2)_{equilibrium} = \frac{n}{V} = \frac{0,0375}{0,2} = 0,3625\ mol \cdot dm^{-3}$
$c(Cl_2)_{equilibrium} = c(H_2O)_{equilibrium} = \frac{n}{V} = \frac{0,075}{0,2} = 0,375\ mol \cdot dm^{-3}$ } Divide by 0,2✓

$K_c = \frac{[Cl_2]^2[H_2O]^2}{[HCl]^4[O_2]}$ ✓ $= \frac{(0,375)^2(0,375)^2}{(0,25)^4(0,3625)}$ ✓ ✓ $= 13,97$ ✓

(9)
[18]

QUESTION 11 (June 2018)

11.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. ✓✓
OR The stage in a chemical reaction when the concentrations of reactants and products remain constant. ✓✓ (2)

11.2.1 2 ✓ (1)
11.2.2 1 ✓ (1)
11.2.3 3 ✓ (1)

11.3

OPTION 1

$[A] = \frac{8}{3} = 2{,}67\ mol{\cdot}dm^{-3}$ ✓
$[B] = \frac{4}{3} = 1{,}33\ mol{\cdot}dm^{-3}$ ✓
$[C] = \frac{12}{3} = 4\ mol{\cdot}dm^{-3}$ ✓
Divide by 3 dm³ ✓

$K_c = \frac{[C]^3}{[A]^2[B]}$ ✓ $= \frac{(4)^3}{(2{,}67)^2(1{,}33)}$ ✓ $= 6{,}75$ ✓

OPTION 2

	A	B	C
Initial quantity (mol)	16	8	0
Change (mol)	8	4	12
Quantity at equilibrium (mol)	8 ✓	4 ✓	12 ✓
Equilibrium concentration ($mol{\cdot}dm^{-3}$)	$\frac{8}{3}$	$\frac{4}{3}$	$\frac{12}{3}$

Divide by 3 dm³ ✓

$K_c = \frac{[C]^3}{[A]^2[B]}$ ✓ $= \frac{(4)^3 ✓}{(2{,}67)^2(1{,}33)} = 6{,}75$ ✓

(7)

11.4 Endothermic ✓
- (An increase in temperature) favours the reverse reaction. ✓
- An increase in temperature favours an endothermic reaction. ✓ (3)

[15]

QUESTION 12 (November 2018)

12.1 When the equilibrium in a closed system is disturbed, the system will re-instate a (new) equilibrium ✓ by favouring the reaction that will cancel/oppose the disturbance. ✓ (2)

12.2 Endothermic ✓
- Decrease in temperature favours the exothermic reaction. ✓
- The reverse reaction is favoured. ✓
  OR Number of moles/amount/concentration of N_2O_4/colourless gas increases.
  OR Number of moles/amount of NO_2/brown gas decreases. (3)

12.3.1 Increases ✓ (1)
12.3.2 Remains the same ✓ (1)
12.3.3 Increases ✓ (1)

12.4

OPTION 1

	N_2O_4	NO_2	
Initial amount (moles)	**x**	0	
Change in amount (moles)	0,2**x** ✓	0,4**x**	ratio ✓
Equilibrium amount (moles)	0,8**x**	0,4**x**	✓
Equilibrium concentration (mol·dm⁻³)	0,4**x**	0,2**x**	Divide by 2 dm³ ✓

$K_c = \frac{[NO_2]^2}{[N_2O_4]}$ ✓ $\therefore$ ✓ $0,16 = \frac{(0,2\mathbf{x})^2}{(0,4\mathbf{x})}$ ✓ $\therefore$ **x** = 1,6 mol ✓

OPTION 2

$\Delta n(N_2O_4) = \frac{20}{100}\mathbf{x}$ ✓ = 0,2**x** **AND** $\Delta n(NO_2) = 2\Delta n(N_2O_4)$ = 0,4 **x** ✓

$n(N_2O_4)_{eq}$ = **x** – 0,2**x** = 0,8**x** **AND** $n(NO_2)_{eq}$ = 0 + 0,4**x** ✓

$c(N_2O_4)_{eq} = \frac{0,8\mathbf{x}}{2} = 0,4\mathbf{x}$

$c(NO_2)_{eq} = \frac{0,4\mathbf{x}}{2} = 0,2\mathbf{x}$ ✓

$K_c = \frac{[NO_2]^2}{[N_2O_4]}$ ✓ $\therefore$ $0,16 = \frac{(0,2\mathbf{x})^2}{(0,4\mathbf{x})}$ ✓ $\therefore$ **x** = 1,6 mol ✓

(8)
[16]

QUESTION 13 (June 2019)

13.1 Reversible reaction/Both forward and reverse reactions can take place. ✓ (1)

13.2 To favour the forward reaction/production of ammonia./To increase the yield of ammonia. ✓ (1)

13.3 20% ✓ (1)

13.4.1 At 500 °C lower yield of ammonia: ✓
- The (forward) reaction is exothermic./Reverse reaction is endothermic. ✓
- An increase in temperature favours the endothermic reaction. ✓
- The reverse reaction is favoured. ✓

OR

At 350 °C higher yield of ammonia:
- The (forward) reaction is exothermic./Reverse reaction is endothermic. ✓
- A decrease in temperature favours the exothermic reaction. ✓
- The forward reaction is favoured. ✓ (3)

13.4.2 At 350 atm higher yield of ammonia:
- An increase in pressure favours the reaction that produces the lower number of moles/number of molecules/volume of gas. ✓
- The forward reaction is favoured. ✓ (2)

OR

At 150 atm lower yield of ammonia:
- A decrease in pressure favours the reaction that produces the higher number of moles/number of molecules/volume of gas. ✓
- Reverse reaction is favoured. ✓ (2)

13.5.1 1 mol N_2 reacts with 3 mol H_2 to produce 2 mol NH_3
2 mol N_2 reacts with 6 mol H_2 to produce 4 (mol) NH_3 ✓✓ (2)

13.5.2

$n(NH_3) = \frac{35}{100} \times 4$ ✓ = 1,4 mol

	N_2	H_2	NH_3	
Initial amount (moles)	6	6	0	
Change in amount (moles)	0,7	2,1	1,4	ratio ✓
Equilibrium amount (moles)	5,3	✓ 3,9	1,4	
Equilibrium concentration (mol·dm⁻³)	10,6	7,8	2,8	Divide by 0,5 dm³ ✓

$K_c = \frac{[NH_3]^2}{[H_2]^3[N_2]}$ ✓ $= \frac{(2,8)^2}{(7,8)^3(10,6)}$ ✓ = 0,002 ✓

(7)
[17]

QUESTION 14 (November 2020)

14.1 Products can be converted back to reactants. ✓
OR
Both forward and reverse reactions can take place.
OR
A reaction which can take place in both directions. (1)

14.2.1 Remains the same ✓ (1)

14.2.2 Increases ✓ (1)

14.3 (When pressure is increased) the reaction that leads to the smaller amount of gas / side with less molecules/number of moles is favoured. ✓
The reverse reaction is favoured. ✓ (2)

14.4 Endothermic ✓

- K_c decreases with decrease in temperature. ✓
- Reverse reaction is favoured. / Concentration of reactants increases. / Concentration of products decreases./Yield decreases ✓
- Decrease in temperature favours an exothermic reaction. ✓

OR

- K_c increases with increase in temperature. ✓
- Forward reaction is favoured. / Concentration of reactants decreases. / Concentration of products increases./Yield increases ✓
- Increase in temperature favours an endothermic reaction. ✓ (4)

14.5

Mark allocation

- Correct K_c expression (formulae in square brackets). ✓
- Substitution of equilibrium concentrations into K_c expression. ✓
- Substitution of K_c value. ✓
- Multiply equilibrium concentrations of I_2 and I by 12,3 dm³. ✓ (**OPTION 1**) / Multiply equilibrium concentrations of I by 12,3 dm³ and divide equilibrium mol of I_2 by 12,3 dm³. (**OPTION 2**)
- Change in n(I) = n(I at equilibrium). ✓
- **USING** ratio: $I_2 : I = 1 : 2$ ✓
- Initial $n(I_2)$ = equilibrium $n(I_2)$ + change in $n(I_2)$. ✓
- Substitute 254 g·mol⁻¹ as molar mass for I_2.✓
- Final answer: (26 g - 27,94 g). ✓

OPTION 1

$$K_c = \frac{[I]^2}{[I_2]} \checkmark$$

$$3{,}76 \times 10^{-3} \checkmark = \frac{(4{,}79 \times 10^{-3})^2}{[I_2]} \checkmark$$

$[I_2] = 6{,}102 \times 10^{-3}$ mol·dm⁻³

	I_2	I	
Initial mass (g)	(0,1045)(254) ✓ = 26,543 g ✓		
Initial quantity (mol)	0,1045	0	
Change (mol)	✓ 0,0295	0,0589 ✓	Using ratio ✓
Quantity at equilibrium (mol)	0,0751	0,0589	
Equilibrium concentration (mol·dm⁻³)	6,102 x 10⁻³	4,79 x 10⁻³	x12,3 ✓

OPTION 2

	I_2	I	
Initial amount (moles)	x	0	
Change in amount (moles)	0,0295	0,0589✓	Using ratio ✓
Equilibrium amount (moles)	✓x - 0,0295	0,0589	
Equilibrium concentration (mol·dm^{-3})	$\frac{x - 0,0295}{12,3}$	4,79 x 10^{-3}	x & divide by 12,3 ✓

$K_c = \frac{[I]^2}{[I_2]}$ ✓

$3,76 \times 10^{-3}$ ✓ $= \frac{(4,79 \times 10^{-3})^2}{\left[\frac{x - 0,0295}{12,3}\right]}$ ✓

x = 0,1045 mol

∴ m = nM

= (0,1045)(254) ✓

= 26,543 g ✓

(9)

[18]

QUESTION 15 (June 2021)

15.1 (The stage in a chemical reaction when the) rate of forward reaction equals the rate of reverse reaction. ✓✓ **(2 or 0)**

OR

(The stage in a chemical reaction when the) concentrations of reactants and products remain constant. **(2 or 0)** (2)

15.2

15.2.1 X ✓

ANY ONE

- The concentration of products increases (from 0 – 6 min.). ✓
- The concentration of reactants decreases (from 0 – 6 min.).
- No products were present initially. (2)

15.2.2 Higher than ✓ (1)

15.3

CALCULATIONS USING NUMBER OF MOLES

Marking criteria

- Calculate mol HI: $n(HI)_{ini}$ = 1(0,5). ✓
- Use mol ratio: 1:2 / n(HI) = $2n(H_2)$ = $2n(I_2)$. ✓
- $n(H_2)_{formed} = n(H_2)_{equilibrium}$; $n(I_2)_{formed} = n(I_2)_{equilibrium}$ ✓
- $n((HI)_{equilibrium} = n(HI)_{initial} - n(HI)_{change}$. ✓
- Divide $n(HI)_{equil}$ & $n(H_2)_{equil}$ & $n(H_2)_{equil}$ by 0,5 dm^3. ✓.
- Correct K_c expression (formulae in square brackets). ✓
- Substitute 0,04 into K_c expression. ✓
- Substitute equilibrium concentrations in K_c expression. ✓
- Final answer: 0,071 mol ✓
  Range: 0,071 – 0,072 mol

OPTION 1

n(HI) = 1(0,5) = 0,5 mol

	HI	H_2	I_2	
Initial quantity (mol)	0,5 ✓	0	0	
Change (mol)	2x	x	x	ratio ✓
Quantity at equilibrium (mol)	0,5-2x ✓	x	x ✓	
Equilibrium concentration ($mol \cdot dm^{-3}$)	$\frac{0,5-2x}{0,5}$	$\frac{x}{0,5}$	$\frac{x}{0,5}$	divide by 0,5 ✓

$$K_c = \frac{[H_2][I_2]}{[HI]^2} \checkmark$$

$$0,04 \checkmark = \frac{(\frac{x}{0,5})(\frac{x}{0,5})}{(\frac{0,5-2x}{0,5})^2} \checkmark$$

x = 0,071 mol ✓

No K_C expression, correct substitution: Max. $\frac{8}{9}$

Wrong K_C expression: Max.. $\frac{6}{9}$

CALCULATIONS USING CONCENTRATION

Marking criteria:

- Use initial c(HI) = 1 mol·dm^{-3}. ✓
- Use mol ratio: 1 : 2 / n(HI) = 2n(H_2) = 2n(I_2). ✓
- c(H_2)$_{formed}$ = c(H_2)$_{equilibrium}$; c(I_2)$_{formed}$ = c(I_2)$_{equilibrium}$ ✓
- c(HI)$_{equilibrium}$ = c(HI)$_{initial}$ - c(HI)$_{change}$. ✓
- Correct K_c expression (formulae in square brackets). ✓
- Substitution of 0,04 into K_c expression. ✓
- Substitution of equilibrium concentrations into K_c expression. ✓
- Multiply concentration by 0,5 dm^3. ✓ .
- Final answer: 0,071 mol ✓
  Range: 0,071 to 0,072 mol

OPTION 2/

	HI	H_2	I_2
Initial concentration (mol·dm^{-3})	1 ✓	0	0
Change (mol·dm^{-3})	2x	x	x
Equilibrium concentration (mol·dm^{-3})	1-2x ✓	x	x

ratio ✓ ✓

$K_c = \frac{[H_2][I_2]}{[HI]^2}$ ✓

$0,04 = \frac{(x)(x)}{(1-2x)^2}$ ✓ ✓

x = 0,143 mol·dm^{-3}

n(I_2) = cV
= 0,143 x 0,5 ✓
= 0,072 mol ✓

No K_C expression, correct substitution: Max. $\frac{6}{9}$

Wrong K_C expression: Max. $\frac{6}{9}$

(9)

15.4

15.4.1 Both forward and reverse ✓ (1)

15.4.2 Positive ✓

- The forward reaction is favoured. ✓
- An increase in temperature favours the endothermic reaction. ✓
- The forward reaction is endothermic. ✓ (4)

[19]

QUESTION 16 (September 2021)

16.1 The stage in a chemical reaction when the rate of forward reaction equals the rate of reverse reaction. **(2 or 0)**

OR

The stage in a chemical reaction when the concentrations of reactants and products remain constant. **(2 or 0)** (2)

16.2

CALCULATIONS USING NUMBER OF MOLES
BEREKENINGE WAT AANTAL MOL GEBRUIK

Marking criteria/*Nasienkriteria*

- Substitute/*Vervang* 18 g·mol⁻¹ in $n = \frac{m}{M}$ ✓
- $\Delta n(CO_2) = \Delta n(C)$ = 0,225 mol. ✓
- Use mole ratio/Gebruik n(C) : $n(H_2O)$: $n(CO_2)$: $n(H_2)$ = ! : 2 : 1 : 2 ✓
- Equilibrium/*Ewewig* $n(H_2O)$ = initial/*aanvaklike* $n(H_2O)$ - $\Delta n(H_2O)$
  Equilibrium/*Ewewig* $n(H_2)$ = initial/*aanvanklike* $n(H_2)$ + $\Delta n(H_2)$ ✓
  Equilibrium/*Ewewig* $n(CO_2)$ = initial/*aanvanklike* $n(CO_2)$ + $\Delta n(CO_2)$
- Divide equilibrium moles of H_2O, H_2 AND/*EN* CO_2 by/*deur* 2 dm^3. ✓
- Correct K_c expression (formulae in square brackets). ✓
  Korrekte K_c uitdrukking (formules in vierkantige hakies).
- Substitution of concentrations into correct K_c expression. ✓
  Vervanging van konsentrasies in korrekte K_c-uitdrukking.
- Final answer/*Finale antwoord*: 0,00948 ✓
  Range/*Gebied*: 0,00948 to/*tot* 0,01 ($9,48 \times 10^{-3}$ to/*tot* 1×10^{-2})

OPTION 1/*OPSIE 1*

$n(H_2O)_{initial/aanvanklik} = \frac{m}{M} = \frac{36}{18}$ ✓ = 2 mol

	H_2O	H_2	CO_2	
Initial amount (moles) *Aanvangs hoeveelheid (mol)*	2			
Change in amount (moles) *Verandering in hoeveelheid (mol)*	0,45	0,45	0,225 ✓	ratio ✓ *verhouding*
Equilibrium amount (moles) *hoeveelheid (mol)*	1,55	0,45	0,225	✓
Equilibrium concentration ($mol \cdot dm^{-3}$) *Ewewigskonsentrasie ($mol \cdot dm^{-3}$)*	0,775	0,225	0,1125	Divide by/ Deel deur 2 dm^3 ✓

$K_c = \frac{[H_2]^2[CO_2]}{[H_2O]^2}$ ✓

$= \frac{[0,225]^2[0,1125]}{[0,775]^2}$ ✓

= 0,00948 ✓

No K_c expression, correct substitution/*Geen K_c-uitdrukking, korrekte substitusie*: Max./*Maks.* $\frac{7}{8}$
Wrong K_c expression/*Verkeerde K_c-uitdrukking*: Max./*Maks.* $\frac{5}{8}$

CALCULATIONS USING CONCENTRATION
BEREKENINGE WAT KONSENTRASIE GEBRUIK

- Substitute/*Vervang* 18 g·mol^{-1} in $n = \frac{m}{M}$ ✓
- Divide initial/*Deel aanvanklike* $n(H_2O)$ AND $\Delta n(CO_2)$ by/*deur* 2 dm^3.✓
- $\Delta n(CO_2) = \Delta n(C) = $ 0,225 mol OR/*OF* $\Delta c(CO_2) = 0{,}1125$ mol·dm^{-3}. ✓
- Use mole ratio/*Gebruik molverhouding* $n(H_2O) : n(CO_2) : n(H_2) = 2 : 1 : 2$ ✓
- Equilibrium/*Ewewig* $c(H_2O)$ = initial/*aanvanklike* $c(H_2O)$ - $\Delta c(H_2O)$
  Equilibrium/*Ewewig* $c(H_2)$ = initial/*aanvanklike* $c(H_2)$ + $\Delta c(H_2)$
  Equilibrium/*Ewewig* $c(CO_2)$ = initial/*aanvanklike* $c(CO_2)$ + $\Delta c(CO_2)$ ✓
- Correct K_c expression (formulae in square brackets). ✓
  Korrekte K_c uitdrukking (formules in vierkantige hakies).
- Substitution of concentrations into correct K_c expression. ✓
  Vervanging van konsentrasies in korrekte K_c-uitdrukking.
- Final answer/*Finale antwoord*: 0,00948 ✓
  Range/*Gebied*: 0,00948 – 0,01)

OPTION 2/*OPSIE 2*

$n(H_2O)_{initial/aanvanklik} = \frac{m}{M} = \frac{36}{18}$✓ $= 2$ mol

	H_2O	H_2	CO_2	
Initial concentration (mol·dm^{-3}) Aanvangskonsentrasie (mol·dm^{-3})	1			Divide by/ *Deel deur* 2 dm^3 ✓
Change (mol·dm^{-3}) *Verandering* (mol·dm^{-3}) ✓	0,225	0,225	0,1125 ✓	ratio ✓ *verhouding*
Equilibrium concentration (mol·dm^{-3}) *Ewewigskonsentrasie (mol·dm^{-3})*	0,775	0,225	0,1125	

$K_c = \frac{[H_2]^2[CO_2]}{[H_2O]^2}$ ✓

$= \frac{[0{,}225]^2[0{,}1125]}{[0{,}775]^2}$ ✓

$= 0{,}00948$ ✓

No K_c expression, correct substitution/*Geen K_c-uitdrukking, korrekte substitusie*: Max./*Maks.* $\frac{7}{8}$
Wrong K_c expression/*Verkeerde K_c-uitdrukking*: Max./*Maks.* $\frac{5}{8}$

(8)

16.3.1 Steam is used up./Amount of steam decreases./Concentration of steam decreases./ Reactants are used up. (1)
16.3.2 Catalyst was added. (1)
16.3.3 Endothermic (1)
16.3.4 The forward reaction is favoured.
Increase in temperature favours the endothermic reaction. (2)
[15]

QUESTION 17 (November 2021)

17.1 (The stage in a chemical reaction when the) rate of forward reaction equals the rate of reverse reaction. ✓✓ **(2 or 0)**
OR
(The stage in a chemical reaction when the) concentrations of reactants and products remain constant. **(2 or 0)** (2)

17.2
17.2.1 Negative ✓ (1)
17.2.2
- Increase in temperature favours an endothermic reaction. ✓
- Reverse reaction is favoured./Concentration of reactants increases./ Concentration of products decreases. ✓
- Forward reaction is exothermic. ✓ (3)

17.2.3

CALCULATIONS USING NUMBER OF MOLES

Marking criteria:
a) Initial n(P) and n(Q_2) and n(PQ) from table. ✓
b) Change in n(P) = equilibrium n(P) – initial n(P). ✓
c) **USING** ratio: P : Q_2 : PQ = 2 : 1 : 2 ✓
d) Equilibrium n(Q_2) = initial n(Q_2) + change in n(Q_2); Equilibrium n(PQ) = initial n(PQ) - change in n(PQ) ✓
e) Divide **equilibrium** amounts of P and Q_2 and PQ by 2 dm^3. ✓
f) Correct K_c expression (formulae in square brackets). ✓
g) Substitution of equilibrium concentrations into K_c expression. ✓
h) Final answer: 10,889 ✓

OPTION 1

	P	Q_2	PQ	
Initial quantity (mol)	0,8	0,8	3,2	✓(a)
Change (mol)	0,4 ✓(b)	0,2	0,4	✓(c)
Quantity at equilibrium (mol)/	1,2	1,0	2,8	✓(d)
Equilibrium concentration (mol·dm^{-3})	0,6	0,5	1,4	✓(e)

$K_c = \frac{[PQ]^2}{[Q_2][P]^2}$ ✓(f)

$= \frac{1,4^2}{(0,5)(0,6)^2}$ ✓(g)

= 10,889 ✓ (h)

No K_c expression, correct substitution: Max. $\frac{7}{8}$

Wrong K_c expression: Max. $\frac{5}{8}$

CALCULATIONS USING CONCENTRATION

Marking criteria:
a) Initial c(P) and c(Q_2) and c(PQ) from table. ✓
b) Change in c(P) = equilibrium c(P) – initial c(P). ✓
c) **USING** ratio: P : Q_2 : PQ = 2 : 1 : 2 ✓
d) Equilibrium c(Q_2) = initial c(Q_2) + change in c(Q_2); Equilibrium c(PQ) = initial c(PQ) - change in c(PQ) ✓
e) Divide **initial** amounts of P and Q_2 and PQ by 2 dm^3. ✓
f) Correct K_c expression (formulae in square brackets). ✓
g) Substitution of equilibrium concentrations into K_c expression. ✓
h) Final answer: 10,889 ✓

OPTION 2

	P	Q_2	PQ	
Initial concentration (mol·dm^{-3})	0,4	0,4	1,6	✓(a) ✓(e)
Change in concentration (mol·dm^{-3})	0,2 ✓(b)	0,1	0,2	✓(c)
Equilibrium concentration (mol·dm^{-3}	0,6	0,5	1,4	✓ (d)

$K_c = \frac{[PQ]^2}{[Q_2][P]^2}$ ✓ (f)

$= \frac{1,4^2}{(0,5)(0,6)^2}$ ✓ (g)

= 10,889 ✓ (h)

No K_c expression, correct substitution: Max. $\frac{7}{8}$

Wrong K_c expression: Max. $\frac{5}{8}$

17.2.4 Remains the same ✓
Only temperature can change K_c. ✓ (2)

17.3
17.3.1 Increases ✓ (1)
17.3.2 Decreases (1)

[18]

QUESTION 18 (June 2022)

18.1.1 2 ($mol·dm^{-3}$) ✓ (1)

18.1.2 When the equilibrium in a closed system is disturbed, the system will re-instate a (new) equilibrium ✓ by favouring the reaction that will cancel/oppose the disturbance. ✓ (2)

18.1.3 Cooled ✓ (1)

18.1.4 A decrease in temperature favours the exothermic reaction./An increase in temperature favours the endothermic reaction. ✓
The forward reaction is favoured./HI concentration increases./Equilibrium (position) shifts to the right. ✓
The forward reaction is exothermic./Reverse reaction is endothermic. ✓ (3)

18.2.1 Products can be converted back to reactants. ✓
OR: Both forward and reverse reactions can take place.
OR: A reaction which can take place in both directions. (1)

18.2.2 **Marking criteria**

a) $\Delta n(N_2O_4) = n(N_2O_4)_{eq} - n(N_2O_4)_{ini}$. ✓
b) USING ratio:
$n(NO_2) : n(N_2O_4) = 2 : 1$ ✓
c) $n(NO_2)_{eq} = n(NO_2)_{ini} - \Delta n(NO_2)$ ✓
d) Divide BOTH by 1 dm^3 ✓
e) Correct K_c expression (formulae in square brackets). ✓

	NO_2	N_2O_4	
Initial amount (moles)	x	0	
Change in amount (moles)	1,62	0,81 ✓ (a)	ratio ✓ (b)
Equilibrium amount (moles)	x – 1,62 ✓ (c)	0,81	
Equilibrium concentration ($mol·dm^{-3}$)	x – 1,62	0,81	÷ dm^3 ✓(d)

$$K_c = \frac{[N_2O_4]}{[NO_2]^2} \checkmark(e)$$
$$= \frac{(0,81)}{(x-1,62)^2}$$

Wrong or no K_c expression: Max.. $^4/_5$

(5)

18.2.3

Marking criteria

a) Add 0,79 mol to $n(N_2O_4)_{ini}$. ✓
b) USING ratio: $n(NO_2) : n(N_2O_4) = 2 : 1$ to calculate $\Delta n(N_2O_4)$ as 0,6 mol. ✓
c) $n(NO_2)_{eq} = n(NO_2)_{ini} + \Delta n(NO_2)$ and $n(N_2O_4)_{eq} = n(N_2O_4)_{ini} - \Delta n(N_2O_4)$ ✓
d) Substitution of concentrations into correct K_c expression. ✓
e) Equating K_c expresssion from Q20.1.3 and Q20.2.3. ✓
f) Final answer: 12,42 ✓
(Range: 11,27 – 12,42)

	NO_2	N_2O_4
Initial amount (moles)	x – 1,62	0,81 + 0,79 ✓(a) = 1,6
Change in amount (moles)	1,2	0,6 ✓ (b)
Equilibrium amount (moles)	x – 1,62 +1,2	1 ✓(c)
Equilibrium concentration ($mol·dm^{-3}$)	x – 0,42	1

$$K_c = \frac{[N_2O_4]}{[NO_2]^2}$$
$$\frac{(0,81)}{(x-1,62)^2} \checkmark(e) = \frac{1}{(x-0,42)^2} \checkmark(d)$$
$$x = 12,42 \text{ (mol)} \checkmark(f)$$

Wrong K_c expression: Max. $^4/_6$
No K_c expression: $^6/_6$

(6)
[19]

QUESTION 19 (June 2023)

19.1 When the equilibrium in a closed system is disturbed, the system will re-instate a (new) equilibrium by favouring the reaction that will cancel/oppose the disturbance. ✓✓ (2)

19.2

19.2.1 $n[H_2(g)] = 0{,}11$ mol ✓ (1)

19.2.2

OPTION 1	**OPTION 2**
$n(HI) = 2n(I_2)$ $= 2(0{,}11)$ $n(HI)_{eqm} = 1 - 0{,}22$ $= 0{,}78$ mol ✓	$K_c = \frac{[H_2][I_2]}{[HI]^2}$ $0{,}02 = \frac{(0{,}11)(0{,}11)}{[HI]^2}$ $n[HI] = 0{,}78$ mol·dm^{-3} $n(HI) = 0{,}78$ mol ✓

(1)

19.3.1 Endothermic ✓ (1)

19.3.2 K_c increased:

- The concentration of the product/$H_2(g)$ and $I_2(g)$ is increased. ✓
  OR: The concentration of the reactant/HI decreased.
- The increase in temperature favoured the forward reaction. ✓
- (According to Le Chatelier's principle) an increase in temperature favours the endothermic reaction. ✓ (3)

19.3.3 **POSITIVE MARKING FROM Q19.2**

Marking criteria:

a) Correct K_c expression (formulae in square brackets). ✓
b) Substitution of 0,09 in K_c expression. ✓
c) USING ratio: $nHI(g) : 2nI_2(g) = 1:2$ ✓
d) Substitution of concentrations into correct K_c expression. ✓
e) Subtraction $[HI]_{ini} - \Delta[HI]$ ✓
f) Substitution of 1 dm^3 in the formula n = cV./ Divide by 1 dm^3. ✓
g) Substitution of 128 in m = nM. ✓
h) Final answer: 80,64 g ✓ (range: 79,36 - 80,64 g)

OPTION 1

$K_c = \frac{[H_2][I_2]}{[HI]^2}$ ✓(a)

$0{,}09$ ✓(b) $= \frac{(0{,}11 + x)(0{,}11 + x)}{(0{,}78 - 2x)^2}$ ✓(c) ✓(d) $\therefore x = 0{,}0775$

$\Delta[HI] = [HI]_{ini} - \Delta[HI] = 0{,}78 - 2(0{,}0775)$ ✓(e) $= 0{,}625$ mol·dm^{-3}

$n(HI) = cV$

$= (0{,}625)(1)$ ✓(f)

$= 0{,}625$ mol (0,63 mol)

$m(HI) = nM = (0{,}625)(128)$ ✓(g)

$= 80{,}64$ g ✓(h)

OPTION 2

	HI	I_2	H_2
Initial quantity (mol)	0,78	0,11	0,11
Change (mol)	2x	x	x
Quantity at equilibrium (mol)	0,78 - 2x	0,11 + x	0,11 + x
Equilibrium concentration (mol·dm^{-3})	$\frac{0{,}78 - 2x}{1}$	$\frac{0{,}11 + x}{1}$	$\frac{0{,}11 + x}{1}$

Ratio 1:2 ✓(c)

Divide by 1 ✓ (f)

$K_c = \frac{[H_2][I_2]}{[HI]^2}$ ✓(a)

$0{,}09$ ✓(b) $= \frac{(0{,}11 + x)(0{,}11 + x)}{(0{,}78 - 2x)^2}$ ✓(d) $\therefore x = 0{,}0775$

$\Delta[HI] = 0{,}78 - 2(0{,}0775)$ ✓(e) $= 0{,}625$ mol·dm^{-3}

$n(HI) = cV = (0{,}625)(1)$ ✓(f) $= 0{,}625$ mol (0,63 mol)

$m(HI) = nM = (0{,}625)(128)$ ✓(g)

$= 80{,}64$ g ✓(h)

(8)

[16]

QUESTION 20 (November 2023)

20.1 A reaction where products can be converted back to reactants ✓ (and vice versa).
OR Both forward and reverse reactions can take place.
OR A reaction which can take place in both directions.
OR Products can be converted back to reactants. (1)

20.2 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will cancel/oppose the disturbance. ✓✓ (2)

20.3

20.3.1 The amount/concentration of A_2(g) was increased./A_2 was added to the container. ✓ (1)

20.3.2

- Increase in A_2 /concentration favours the reaction that uses or decreases the amount/ concentration of A_2. ✓
- The reverse reaction is favoured. ✓
  OR Amount or concentration of products decreases
  OR Amount or concentration of reactants increases. (2)

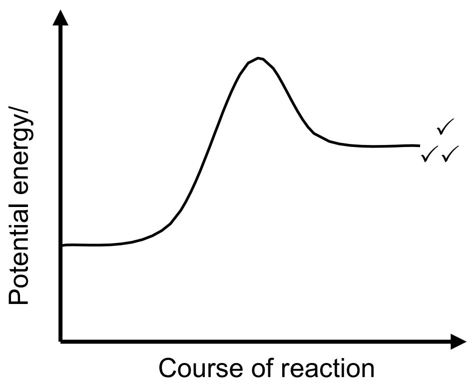
20.4

OPTION 1	**OPTION 2**
$K_c = \frac{[A_2][B_2]}{[AB]^2}$ ✓ $= \frac{\left(\frac{8}{4}\right)\left(\frac{2}{4}\right)}{\left(\frac{10}{4}\right)^2}$ ✓ = 0,16 ✓	$K_c = \frac{[A_2][B_2]}{[AB]^2}$ ✓ $= \frac{(2)(0,5)}{(2,5)^2}$ ✓ = 0,16 ✓
OPTION 3	**OPTION 4**
$K_c = \frac{[A_2][B_2]}{[AB]^2}$ ✓ $= \frac{\left(\frac{4}{4}\right)\left(\frac{4}{4}\right)}{\left(\frac{6}{4}\right)^2}$ ✓ = 0,44 ✓	$K_c = \frac{[A_2][B_2]}{[AB]^2}$ ✓ $= \frac{(1)(1)}{(1,5)^2}$ ✓ = 0,44 ✓

(2)

20.5

20.5.1



Marking criteria
- Both axes correctly labelled and shape of E_p curve. ✓
- Shape of E_p curve for endothermic reaction as shown. ✓✓

(3)

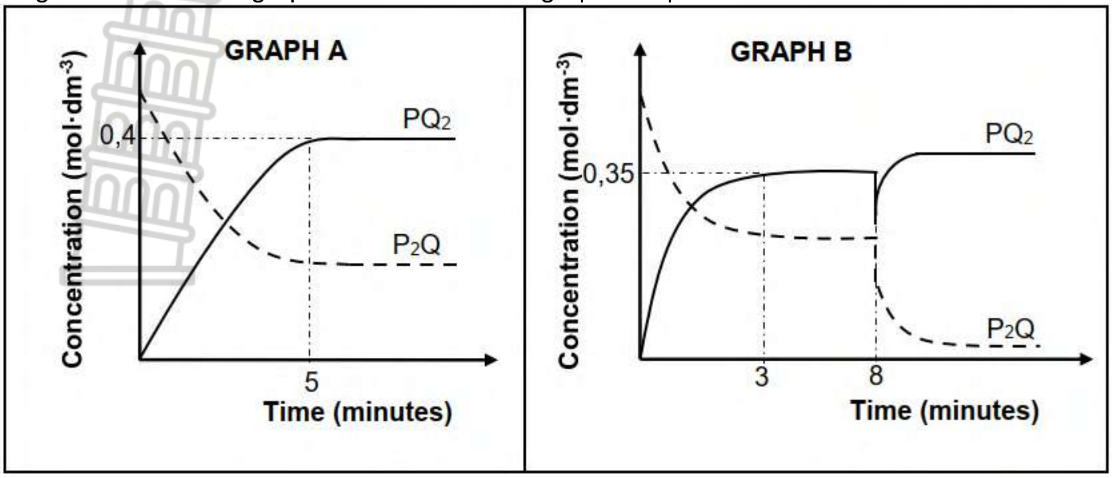
20.5.2 Less than ✓
Amount/concentration of products/B_2/A_2 decreases. ✓✓
OR: Amount/concentration of reactants/AB increases.
OR: The reverse reaction is favoured. / Equilibrium (position) shifts to the left (3)

20.6 Gradients (of all three curves) will be steeper ✓✓ and reach the same equilibrium ✓ values.
OR: Gradients of curve become zero ✓ at same equilibrium ✓ values before 40 s. ✓
OR: The curves are horizontal at same equilibrium values before 40 s / reaches same equilibrium sooner/less than 40 s.
IF curves are identified all three must be named. (3)

[19]

QUESTION 21 (June 2024)

Important note: Unfortunately, the labels for graph **B** in the revision book are incorrect. Here is the correct diagram with the two graphs. The solid line in graph **B** represents PQ_2.



21.1 When the equilibrium in a closed system is disturbed, the system will re-instate a new equilibrium by favouring the reaction that will cancel/oppose the disturbance. ✓✓
(If "isolated system" is used: -1) (2)

21.2 (Chemical) equilibrium. / Concentrations of reactants and products remain constant. / Rate of the forward and reverse reactions are equal. ✓ (1)

21.3 Exothermic ✓ (1)

21.4 With an increase in temperature the endothermic reaction is favoured. ✓
The reverse reaction is favoured. / Equilibrium shifts to the left. / Reactants/[P_2Q] increase(s). **OR** Products/[PQ_2] decrease(s) ✓ (2)

21.5 Less than ✓ (1)

21.6

OPTION 1: CONCENTRATION IS USED

	P_2Q	PQ_2
Initial concentration (mol·dm⁻³)	x	0
Change in concentration (mol·dm⁻³)	0,175 ✓	0,35
Equilibrium concentration (mol·dm⁻³)	x - 0,175 ✓	0,35

$K_c = \frac{[PQ_2]^2}{[P_2Q]}$ ✓✓

$0,49$ ✓ $= \frac{0,35^2}{x - 0,175}$ ✓

$x = 0,425\ mol \cdot dm^{-3}$

$n(P_2Q) = cV$
$= (0,425)(2)$ ✓
$= 0,85\ mol$ ✓

OPTION 2: CONCENTRATION IS USED

$K_c = \frac{[PQ_2]^2}{[P_2Q]}$ ✓✓

$0,49$ ✓ $= \frac{0,35^2}{[P_2Q]}$ ✓

$[P_2Q] = 0,25\ mol \cdot dm^{-3}$

	P_2Q	PQ_2
Initial concentration (mol·dm⁻³)	0,425 ✓	0
Change in concentration (mol·dm⁻³)	-0,175 ✓	0,35
Equilibrium concentration (mol·dm⁻³)	0,25	0,35

$n(P_2Q) = cV$
$= (0,425)(2)$ ✓
$= 0,85\ mol$ ✓

OPTION 3: NUMBER OF MOLES IS USED

	P_2Q	PQ_2
Initial quantity (mol)	x	0
Change (mol)	0,35 ✓	0,70
Equilibrium quantity (mol)	x - 0,35 ✓	0,70
Equilibrium concentration (mol·dm^{-3})	$\frac{x - 0,35}{2}$ ✓	0,35

$$K_c = \frac{[PQ_2]^2}{[P_2Q]} \checkmark\checkmark$$

$$0,49 \checkmark = \frac{0,35^2}{\left(\frac{x - 0,35}{2}\right)} \checkmark$$

$$x = n(P_2Q)$$

$$= 0,85\ mol \checkmark$$

OPTION 4: NUMBER OF MOLES IS USED

$$K_c = \frac{[PQ_2]^2}{[P_2Q]} \checkmark\checkmark$$

$$0,49 \checkmark = \frac{0,35^2}{[P_2Q]} \checkmark$$

$$[P_2Q] = 0,25\ mol \cdot dm^{-3}$$

	P_2Q	PQ_2
Initial quantity (mol)	0,85 ✓	0
Change (mol)	-0,35 ✓	0,70 ✓
Equilibrium quantity (mol)	0,5 ✓	0,70
Equilibrium concentration (mol·dm^{-3})	0,25	0,35

(8)

21.7 Pressure was decreased. / Volume of container was increased. ✓ (1)

21.8 The reaction that increases the number of moles (of gas) is favoured. ✓
$[P_2Q]$ increased. ✓ (2)

[18]

QUESTION 22 (November 2024)

22.1.1 Dynamic equilibrium is when the rate of the forward reaction equals the rate of the reverse reaction. ✓✓ **OR**
The stage in a chemical reaction when the concentrations of the reactants and products remain constant. (2)

22.1.2 X ✓ (1)

22.1.3 Decreased ✓ (1)

22.1.4 The concentrations of all the gases decreased. ✓ (1)

22.1.5 CO/carbon monoxide ✓ (1)

22.1.6 The concentration of **Z** (CO) decreased with a decrease in the concentration of **X** (O_2). **OR**
The concentration of **Z** (CO) increased with an increase in the concentration of **X** (O_2). **OR**
Z (CO) behaves like **X** (O_2). / **Z** (CO) follows the same trend as **X** (O_2). **OR**
Z (CO) and **X**(O_2) are both reactants. / **Y** (CO_2) is the product. ✓ (1)

22.1.7 Decreased ✓ (1)

22.1.8 Concentration of products/**Y**/CO_2 increases. **OR** Concentration of reactant/**Z**/**X**/CO/O_2 decreases. **OR**
The forward reaction is favoured. ✓
The forward reaction is exothermic. ✓
A decrease in temperature favours the exothermic reaction. ✓ (3)

22.2

OPTION 1: NUMBER OF MOLES IS USED (Change in amount is x)

	CO	H_2O	CO_2	H_2
Initial amount (mol)	0,6	0,6	0,1	0,1
Change in amount (mol) ✓	x	x	x	x
Equilibrium amount (mol) ✓	0,6 - x	0,6 - x	0,1 + x	0,1 + x
Equilibrium concentration (mol·dm^{-3}) ✓	$\frac{0,6 - x}{2}$	$\frac{0,6 - x}{2}$	$\frac{0,1 + x}{2}$	$\frac{0,1 + x}{2}$

$$K_c = \frac{[CO_2][H_2]}{[CO][H_2O]} ✓$$

$$4 ✓ = \frac{\left(\frac{0,1+x}{2}\right)\left(\frac{0,1+x}{2}\right)}{\left(\frac{0,6-x}{2}\right)\left(\frac{0,6-x}{2}\right)} ✓$$

$$x = 0,367\ (*)$$

$$n(CO)_{eq} = \frac{m}{M}$$

$$0,6 - 0,367 ✓ = \frac{m}{28} ✓$$

$$m(CO)_{eq} = 6,44\ g ✓$$

(*) Note: x = 1,3, the other value of x, cannot be used. It is greater than 0,6.

OPTION 2: NUMBER OF MOLES IS USED (Equilibrium amount of CO is x)

	CO	H_2O	CO_2	H_2
Initial amount (mol)	0,6	0,6	0,1	0,1
Change in amount (mol) ✓	-x +0,6	-x +0,6	-x +0,6	-x +0,6
Equilibrium amount (mol) ✓	x	x	0,7 - x	0,7 - x
Equilibrium concentration (mol·dm^{-3}) ✓	$\frac{x}{2}$	$\frac{x}{2}$	$\frac{0,7 - x}{2}$	$\frac{0,7 + x}{2}$

$$K_c = \frac{[CO_2][H_2]}{[CO][H_2O]} ✓$$

$$4 ✓ = \frac{\left(\frac{0,7-x}{2}\right)\left(\frac{0,7-x}{2}\right)}{\left(\frac{x}{2}\right)\left(\frac{x}{2}\right)} ✓$$

$$x = 0,233\ (*)$$

$$n(CO)_{eq} = \frac{m}{M}$$

$$0,233 ✓ = \frac{m}{28} ✓$$

$$m(CO)_{eq} = 6,52\ g ✓$$

(*) Note: x = -0,7, the other value of x, cannot be used. The equilibrium amount of CO cannot be negative.

(9)
[20]

ACIDS AND BASES

QUESTION 1 (November 2014)

1.1.1 Ionises / dissociates completely in water. ✓ (1)

1.1.2 NO_3^- / Nitrate ion ✓ (1)

1.1.3 pH = - log[H_3O^+] / - log[H^+] ✓ = -log(0,3) ✓ = 0,52 ✓ (1)

1.2.1 $c = \frac{n}{V}$ ✓ ∴ $2 = \frac{n}{0,1}$ ✓ ∴ n(HCℓ) = 0,2 mol ✓ (3)

1.2.2 Burette ✓ (1)

1.2.3 B ✓ Titration of strong acid and strong base. ✓✓ (3)

1.2.4 The number of moles of acid in the flask remains constant. ✓ (1)

1.2.5 $c = \frac{n}{V}$ ✓ ∴ $0,2 = \frac{n}{0,021}$ ✓ ∴ n = 4,2 x 10^{-3} mol ✓ n(HCℓ)$_{excess}$ = n(NaOH) = 4,2 x 10^{-3} mol (3)

1.2.6

OPTION 1	OPTION 2
n(HCℓ reacted): 0,2 – 4,2 x 10^{-3} ✓ = 0,196 mol n(MgO reacted): ½n(HCℓ) = ½(0,196) = 9,8 x 10^{-2} mol ✓ n(MgO reacted) = $\frac{m}{M}$ ∴ $0,098 = \frac{m}{40}$ ✓ ∴ m = 3,92 g % purity = $\frac{3,92}{4,5} \times 100$ ✓ = 87,11% ✓	n(HCℓ reacted) = 0,2 – 4,2 x 10^{-3} ✓ = 0,196 mol n(HCℓ reacted) = $\frac{m}{M}$ ∴ $0,196 = \frac{m}{36,5}$ ∴ m(HCℓ reacted) = 7,154 g 40 g MgO ✓ .... 73 g HCℓ ✓ x g MgO .... 7,154 g ∴ x = 3,92 g % purity = $\frac{3,92}{4,5} \times 100$ ✓ = 87,11% ✓

(5)
[21]

QUESTION 2 (March 2015)

2.1.1 An acid is a proton (H^+ ion) donor. ✓ (1)

2.1.2 It ionises to form 2 protons for each H_2SO_4 molecule. / It ionises to form 2 moles of H^+ ions. ✓
OR It donates 2 H^+ ions per H_2SO_4 molecule. (1)

2.2.1 Amphiprotic substance / Ampholyte ✓ (1)

2.2.2 H_2CO_3 ✓ (1)

2.3.1

$n(NaHCO_3) = \frac{m}{M}$ ✓

$= \frac{27}{84}$ ✓

= 0,32 mol (0,0321485 mol)

$n(H_2SO_4)$ = ½$n(NaHCO_3)$ = ½(0,32) ✓ = 0,16 mol (0,01607142 mol)

$c = \frac{n}{V}$ ✓

$6 = \frac{0,16}{V}$ ✓

∴ V = 0,03 dm^3 ✓ (30 cm^3/0,027 dm^3/27 cm^3) (6)

2.3.2

n_a(initial/*aanvanklik*) = n_a(final/*finaal*)

c_aV_a(initial/*aanvanklik*) = c_aV_a(final/*finaal*)

∴ $(6)V_a = (0,1)(1)$ ✓

∴ $V_a = 0,02\ dm^3$ ✓ (20 cm^3/0,0167 dm^3/16,7 cm^3) (2)

2.3.3 Shows end point of titration. / Shows when neutralisation occurs. ✓ (1)

2.3.4

n_a(initial/*aanvanklik*) = c_aV_a
= $(0,1)(25 \times 10^{-3})$ ✓
= $2,5 \times 10^{-3}$ mol

n_b(reacted/*gereageer*) = c_bV_b
= $(0,1)(30 \times 10^{-3})$ ✓
= 3×10^{-3} mol

$\frac{n_a}{n_b} = \frac{1}{2}$

∴ n_a(neutralised/*geneutraliseer*) = ½n_b = ½(3×10^{-3}) ✓= $1,5 \times 10^{-3}$ mol

n_a(left/*oorgebly*) = n_a(initial/*aanvanklik*) - n_a(neutralised/*geneutraliseer*)
= $2,5 \times 10^{-3} - 1,5 \times 10^{-3}$ ✓
= 1×10^{-3} mol

$c_a = \frac{n}{V}$
$= \frac{1 \times 10^{-3}}{(25 \times 10^{-3} + 30 \times 10^{-3})}$ ✓
$= 0,018 \text{ mol}\cdot\text{dm}^{-3}$

pH = $-\log[H_3O^+]$ ✓
= $-\log(2 \times 0,018)$ ✓
= 1,44 ✓

(8)
[22]

QUESTION 3 (June 2015)

3.1.1 Diprotic ✓ (1)

3.1.2 H_2O ✓ and $(COO)_2^{2-}$ ✓ (2)

3.1.3 $H(COO)_2^-$ / $HC_2O_4^-$ ✓ It acts as base (in reaction I) and as acid (in reaction II). ✓ (2)

3.2 Ionises / dissociates incompletely / partially. ✓ (1)

3.3

OPTION 1	OPTION 2
$c = \frac{m}{MV}$ ✓ ∴ $0,2 = \frac{m}{0,25 \times 90}$ ✓ ✓ ∴ m = 4,5 g ✓	$c = \frac{n}{V}$ ✓ ∴ $0,2 = \frac{n}{0,25}$ ✓ ∴ n = 0,05 mol $n = \frac{m}{M}$ ∴ $0,05 = \frac{m}{90}$ ✓ ∴ m = 4,5 g ✓

(4)

3.4.1

OPTION 1	OPTION 2
$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$ ✓ $\frac{0,2 \times 25}{c_b \times 36} = \frac{1}{2}$ ✓ ✓ ✓ ∴ c_b = 0,28 mol·dm^{-3} ✓	$n((COOH)_2)$ = cV ✓ = (0,2)(0,025) ✓ = 0,005 mol n(NaOH) = 2(0,005) ✓ = 0,01 mol $c = \frac{n}{V} = \frac{0,01}{0,0036}$ ✓ = 0,28 mol·dm^{-3} ✓

(5)

3.4.2 $(COO)_2^{2-}(aq) + 2H_2O(\ell)$ ✓ $\rightleftharpoons$ $(COOH)_2(aq) + 2OH^-(aq)$ ✓ Bal. ✓ (3)

[18]

QUESTION 4 (March 2016)

4.1 It is a proton donor. ✓✓ (2)

4.2.1 CO_3^{2-} (aq) ✓ (1)

4.2.2 H_2CO_3 + H_2O ✓ ⇌ HCO_3^- (aq) + H_3O^+(aq) ✓ Bal. ✓ (3)

4.2.3

OPTION/OPSIE 1	**OPTION/OPSIE 2**
pH =-log[H⁺] ✓ 3,4 =-log[H⁺] ✓ $[H^+] = 10^{-3,4}$ / $3,98 \times 10^{-4}$ mol·dm⁻³ $[H^+][OH^-] = 10^{-14}$ ✓ $\therefore [OH^-] = \frac{1\times 10^{-14}}{3,98\times 10^{-4}}$ ✓ $= 2,51\times 10^{-11}$ mol·dm⁻³ ✓	pH + pOH = 14 ✓ 3,4 + pOH = 14 ✓ pOH = 11,6 pOH =-log[OH⁻] ✓ 11,6 =-log[OH⁻] ✓ $[OH^-] = 10^{-11,6}$/$2,51\times 10^{-11}$ mol·dm⁻³ ✓

(5)

4.3.1 An acid that donates ONE proton / H^+ ion / H_3O^+ ion. ✓
OR An acid of which ONE mol ionises to form ONE mol of protons / H^+ ions / H_3O^+ ions. (1)

4.3.2

OPTION/OPSIE 1	**OPTION/OPSIE 2**
$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓ $\frac{c_a \times 25}{0,1 \times 27,5} = \frac{1}{1}$ ✓✓✓ $c_a = 0,11$ mol·dm⁻³ ✓	n(NaOH) = cV ✓ = 0,1 x 0,0275 ✓ = 0,00275 mol n(acid X) = n(NaOH) = 0,00275 mol ✓ $c(\text{acid X}) = \frac{n}{V}$ $= \frac{2,75\times 10^{-3}}{0,025}$ ✓ $= 0,11$ mol·dm⁻³ ✓

(5)

4.3.3 Weak ✓
The [H⁺] OR [H_3O^+] is lower than the concentration of acid X. ✓
Therefore, the acid is incompletely ionised. ✓ (3)

[20]

QUESTION 5 (June 2016)

5.1.1 An acid is a proton/ H^+ donor. ✓✓ **NOTE**: **NOT** H_3O^+ (2)

5.1.2 H_2O ✓ and H_2CO_3 ✓ (2)

5.1.3 H_2O ✓ **OR** HCO_3^- (1)

5.2.1 n(HCℓ) = cV ✓ = (0,1)(0,5) ✓ = 0,05 mol
n($NaHCO_3$) = cV = (0,25) (0,8) ✓ = 0,2 mol
n($NaHCO_3$)$_{reacted}$ = n(HCℓ) = 0,05 mol ✓
n($NaHCO_3$)$_{excess}$ = <u>0,2 – 0,05</u> ✓ = 0,15 mol
n(OH^-) = n($NaHCO_3$) ✓ = 0,15 mol
(OH^-) = $\frac{n}{V}$ = $\frac{0,15}{1,3}$ ✓ = 0,12 mol·dm⁻³ ✓ (8)

5.2.2

OPTION 1	**OPTION 2**
$K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$ $1 \times 10^{-14} = [H_3O^+](0,12)$ ✓ $[H_3O^+] = 8,33 \times 10^{-14}$ mol·dm⁻³ pH = - log [H_3O^+] ✓= - log($8,33 \times 10^{-14}$) ✓ = 13,08 ✓	pOH = -log[OH^-] ✓= -log(0,12) ✓ = 0,92 pH + pOH = 14 pH + 0,92 = 14 ✓ pH = 13,08 ✓

(4)

[17]

QUESTION 6 (November 2016)

6.1.1 Hydrolysis is the reaction of a salt with water. ✓✓ (2)

6.1.2 Smaller than 7 ✓

$NH_4^+ + H_2O$ ✓ → $NH_3 + H_3O^+$ ✓ (3)

6.2.1

OPTION 1	OPTION 2	OPTION 3
$n = \frac{m}{M} = \frac{7,35}{98}$ ✓= 0,08 mol ✓	98 g ✓: 1 mol 7,35 :0,08 mol ✓	$c = \frac{m}{MV} = \frac{7,35}{98 \times 0,5}$ ✓ = 0,15 mol·dm^{-3} n = cV = 0,15 x 0,5 = 0,08 mol ✓

(2)

6.2.2

OPTION 1	OPTION 2
pH = −log[H_3O^+] ✓ 1,3 ✓ = −log[H_3O^+] [H_3O^+] = 0,05 mol·dm^{-3} [H_2SO_4] = ½[H_3O^+] = ½ x 0,05 ✓ = 0,025 mol·dm^{-3} $n(H_2SO_4)_{excess}$ = cV ✓ = 0,025 x 0,5 ✓ = 0,0125 mol $n(H_2SO_4)_{react}$ = 0,075 – 0,0125 ✓ = 0,0625 mol n(NaOH) = 2n(H_2SO_4) = 2 x 0,0625 ✓ = 0,125 mol **OR** $n(NaOH) = \frac{m}{M}$ ✓ ∴ $0,125 = \frac{m}{40}$ ∴ m = 5 g ✓ **OR** 1 mol : 40 g ✓ 0,125 mol : 5 g ✓	$[H_2SO_4]_{in} = \frac{n}{V}$ ✓ $= \frac{0,075}{0,5}$ ✓ = 0,15 mol·dm^{-3} $[H_3O^+]_{initially}$ = 2[H_2SO_4] = 2 x 0,15 ✓ = 0,3 mol·dm^{-3} pH = −log[H_3O^+] ✓ ∴ 1,3 ✓ = -log[H_3O^+] [H_3O^+] = 0,05 mol·dm^{-3} $[H_3O^+]_{react}$ = 0,3 – 0,05 ✓ = 0,25 mol·dm^{-3} $[H_2SO_4]_{react}$ = ½[H_3O^+] = ½ x 0,25 = 0,125 mol·dm^{-3} (0,14) $n(H_2SO_4)_{react}$ = cV = (0,125)(0,5) = 0,0625 mol n(NaOH) = 2n(H_2SO_4) = 2 x 0,0625 ✓ = 0,125 mol $n(NaOH) = \frac{m}{M}$ ∴ $0,125 = \frac{m}{40}$ ∴ m = 5 g ✓

(9)
[16]

QUESTION 7 (March 2017)

7.1.1 Weak acid ✓ (1)

7.1.2 pH = -log[H_3O^+] ✓ ∴ 4 ✓ = -log[H_3O^+] ∴ [H_3O^+] = 1 x 10^{-4} mol·dm^{-3} ✓ (3)

7.2.1 A substance that produces hydroxide ions (OH^-) in water. ✓✓ (2)

7.2.2

OPTION 1	OPTION 2	OPTION 3
$\frac{c_a \times V_a}{c_a \times V_b} = \frac{n_a}{n_b}$ ✓ ✓ $\frac{0,16 \times 25}{c_b \times 12,5} = \frac{1}{1}$ ✓ ✓ c_b = 0,32 mol·dm^{-3} $c = \frac{m}{MV}$ $0,32 = \frac{m}{56 \times 0,25}$ ✓ ✓ m = 4,48 g ✓	$\frac{c_a \times V_a}{c_a \times V_b} = \frac{n_a}{n_b}$ ✓ ✓ $\frac{0,16 \times 25}{c_b \times 12,5} = \frac{1}{1}$ ✓ ✓ ∴c_b = 0,32 mol·dm^{-3} $c = \frac{n}{V}$ ∴ $0,32 = \frac{n}{0,25}$ ✓ ∴ n = 0,08 mol $n = \frac{m}{M}$ ∴ $0,08 = \frac{m}{56}$ ✓ ∴ m = 4,48 g ✓	$n(acid)_{used}$ = cV ✓ = (0,16)(0,025) ✓ = 4 x 10^{-3} mol n(KOH) = 4 x 10^{-3} mol ✓ In 12,5 cm^3: n(KOH) = 4 x 10^{-3} mol In 250 cm^3 $n(KOH) = \frac{250}{12,5} \times 4 \times 10^{-3}$ ✓✓ = 0,08 mol m(KOH) = nM = 0,08 x 56 ✓ = 4,48 g ✓

(7)

7.2.3 Greater than 7 ✓ (1)

7.2.4 $CH_3COO^-(aq) + H_2O(\ell)$ ✓ ⇌ $CH_3COOH(aq) + OH^-(aq)$ ✓ Bal. ✓ (3)
[17]

QUESTION 8 (June 2017)

8.1 A substance that ionises incompletely/to a small extent. ✓✓ (2)

8.2 Oxalic acid ✓ Higher K_a value ✓ **OR** Carbonic acid has a lower K_a value. (2)

8.3 H_2O ✓ and $(COO)_2^{2-}$ ✓ (2)

8.4

OPTION 1	**OPTION 2**
$K_w = [OH^-][H_3O^+]$ ∴ $1 \times 10^{-14} = (0,1)[H_3O^+]$ ✓ $[H_3O^+] = 1 \times 10^{-13}$ mol·dm^{-3} pH = $-\log[H_3O^+]$ ✓ = $-\log(1 \times 10^{-13})$ ✓ = 13 ✓	pOH = $-\log[OH^-]$ ✓ = $-\log(0,1)$ ✓ = 1 14 = pOH + pH ∴ 14 = 1 + pH ✓ pH = 13 ✓

(4)

8.5.1

OPTION 1	**OPTION 2**
$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓ ∴ $\frac{c_a \times 14,2}{0,1 \times 25,1}$ ✓ ✓ $= \frac{1}{2}$ ✓ ∴ c_a = 0,09 mol·dm^{-3} ✓	n(NaOH) = cV ✓ = (0,1)(0,0251) ✓ = 0,00251 mol $n(COOH)_2 = \frac{1}{2}(0,00251)$ ✓ = 0,00126 mol $c_a = \frac{n}{V} = \frac{0,00126}{0,0142}$ ✓ = 0,09 mol·dm^{-3} ✓

(5)

8.5.2 C/ phenolphthalein ✓
Titration of weak acid and strong base. ✓
OR The endpoint will be at pH > 7 which is in the range of the indicator. (2)

[17]

QUESTION 9 (March 2018)

9.1.1 H_2O ✓ & HSO_4^- ✓ (2)

9.1.2 Strong ✓ Completely ionised (in water). ✓ (2)

9.2.1

OPTION 1	**OPTION 2**
$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓ $\frac{0,15 \times 24}{c_b \times 26}$ ✓ ✓ $= \frac{1}{2}$ ✓ c(NaOH) = 0,28 mol·dm^{-3} ✓	$n(H_2SO_4)$ = cV ✓ = (0,15)(0,024) ✓ = $3,6 \times 10^{-3}$ mol n(NaOH) = 2($3,6 \times 10^{-3}$) ✓ = $7,2 \times 10^{-3}$ mol $c = \frac{n}{V} = \frac{7,2 \times 10^{-3}}{0,026}$ = 0,28 mol·dm^{-3} ✓

(5)

9.2.2

n(NaOH) = cV = 0,02 x 0,28 ✓ = 0,0056 mol $n(H_2SO_4)$ = 0,03 x 0,15 ✓ = 0,0045 mol $n(H_2SO_4)_{used}$ = ½n(NaOH) ✓ = 0,0028 $n(H_2SO_4)_{excess}$ = 0,0045 – 0,0028 ✓ = 0,0017 mol	$[H_2SO_4] = \frac{n}{V} = \frac{0,0017}{0,05}$ ✓ = 0,034mol·dm^{-3} $[H_3O^+] = 2[H_2SO_4]$ = 2 x 0,034 ✓ = 0,068mol·dm^{-3} pH = $-\log[H_3O^+]$ **OR** $-\log(0,068)$ ✓ = 1,17 ✓

(8)

[17]

QUESTION 10 (June 2018)

10.1 Titration/Volumetric analysis ✓ (1)

10.2 To measure the (exact) volume of acid needed to reach endpoint/to neutralise the base. ✓ (1)

10.3 Acids produce hydrogen ions (H^+)/hydronium ions (H_3O^+) in solution/water. ✓✓ (2)

10.4 H_2SO_4 ionises completely. ✓ (1)

10.5 Blue to yellow ✓ (1)

10.6

OPTION 1	**OPTION 2**
$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓ $\frac{(0,1)V_a}{(0,1)(25)}$ ✓ $= \frac{1}{2}$ ✓ ∴ V_a = 12,5 cm^3 ✓	$c_b = \frac{n}{V}$ ✓ ∴ $0,1 = \frac{n}{0,025}$ ✓ ∴ $n_b = 2,5 \times 10^{-3}$ mol $n_a = \frac{1}{2} n_b = \frac{1}{2}(2,5 \times 10^{-3})$ ✓ = $1,25 \times 10^{-3}$ mol $c_a = \frac{n}{V}$ ∴ $0,1 = \frac{1,25 \times 10^{-3}}{V}$ ∴ V_a = 0,0125 dm^3/12,5 cm^3 ✓

(4)

10.7

OPTION 1	OPTION 2
$n_{a(excess)} = cV$ ✓ $= (0,1)(0,005)$ ✓ $= 5 \times 10^{-4}$ mol $c_a = \frac{n}{V} = \frac{5\times10^{-4}}{4,25\times10^{-2}}$ ✓ $= 1,18 \times 10^{-2}$ mol·dm^{-3} $c(H^+) = 2c_a = 2(1,18 \times 10^{-2})$ ✓ $= 2,36 \times 10^{-2}$ mol·dm^{-3} pH = -log[H_3O^+] ✓= -log($2,36 \times 10^{-2}$)✓ = 1,63 ✓	$n_{a(final)} = cV$ ✓ $= (0,1)(0,0175)$ ✓ $= 1,75 \times 10^{-3}$ mol $n_{a(exs)} = n_{a(final)} - n_{a(react)}$ $= 1,75 \times 10^{-3} - 1,25 \times 10^{-3} = 5 \times 10^{-4}$ mol $c_a = \frac{n}{V} = \frac{5\times10^{-4}}{4,25\times10^{-2}}$ ✓ $= 1,18 \times 10^{-2}$ mol·dm^{-3} $c(H^+) = 2c_a = 2(1,18 \times 10^{-2})$ ✓ $= 2,36 \times 10^{-2}$ mol·dm^{-3} pH = -log[H_3O^+] ✓= -log ($2,36 \times 10^{-2}$) ✓= 1,63 ✓

(7)
[17]

QUESTION 11 (November 2018)

11.1.1 An acid is a <u>proton donor</u>. ✓✓ (2)
11.1.2 H_2O ✓ (1)
11.1.3 HSO_4^- ✓✓ (2)
11.2.1 Reaction of a salt with water/H_2O. ✓✓ (2)
11.2.2 CO_3^{2-}(aq) + $2H_2O$(ℓ) ✓ ⇌ H_2CO_3(aq) + $2OH^-$(aq) ✓
OR CO_3^{2-}(aq) + H_2O(ℓ) ⇌ HCO_3^-(aq) + OH^-(aq)
The formation of OH^- (aq) neutralises the excess acid. ✓ (3)
11.3.1 pH = -log[H_3O^+] ✓ ∴ 5 ✓ = -log[H_3O^+] ∴ [H_3O^+] = 1×10^{-5} mol·dm^{-3} ✓ (3)
11.3.2

OPTION 1	OPTION 2
$c(H_3O^+)_{ini.} = \frac{n}{V}$ ✓ ∴ $1 \times 10^{-5} = \frac{n}{4 \times 10^9}$ ✓ ∴$n_a = 4 \times 10^4$ mol $n(H_3O^+)_{react} = 4 \times 10^4 - 1,26 \times 10^3$ ✓✓ $= 3,87 \times 10^4$ mol $n(CaO) = ½n(H_3O^+) = ½ \times 3,87 \times 10^4$ ✓ $= 1,94 \times 10^4$ mol	$c(H_3O^+)_{fin} = \frac{n}{V}$ ✓$= \frac{1,26 \times 10^3}{4 \times 10^9}$ ✓ $= 3,15 \times 10^{-7}$ mol·dm^{-3} $c(H_3O^+)_{rea} = 1 \times 10^{-5} - 3,15 \times 10^{-7}$ ✓✓ $= 9,69 \times 10^{-6}$ mol·dm^{-3} $n(H_3O^+)_{rea} = cV = (9,65 \times 10^{-6})(4 \times 10^9)$ $= 3,87 \times 10^4$ mol $n(CaO) = ½n(H_3O^+) = ½ \times 3,87 \times 10^4$ ✓ $= 1,94 \times 10^4$ mol
$n(CaO) = \frac{m}{M}$ ∴ $1,94 \times 10^4 = \frac{m}{56}$ ✓ ∴ $m = 1,09 \times 10^6$ g ✓	**OR** 1 mol : 56 g ✓ $1,94 \times 10^4$ mol : m ∴ $m = 1,09 \times 10^6$ g ✓

(7)
[20]

QUESTION 12 (June 2019)

12.1 A base forms hydroxide ions (OH^-) in water/aqueous solution. ✓✓ (2)
12.2 A strong base ionises/dissociates completely ✓ and a weak base ionises/dissociates incompletely. ✓ (2)
12.3 HCO_3^-(aq) + H_2O(ℓ) ✓ ⇌ H_2CO_3(aq) + OH^-(aq) ✓ Bal. ✓ (3)
12.4.1 pH = -log[H_3O^+] ✓ = -log (0,2) ✓ = 0,70 ✓ (0,699) (3)
12.4.2 Titration of a weak base and a strong acid. ✓ **OR** The endpoint will be at pH < 7. (1)

12.4.3

OPTION 1

$c(HC\ell) = \frac{n}{V}$ ✓ ∴ $0{,}2 = \frac{n}{20 \times 10^{-3}}$ ✓ ∴ $n(HC\ell) = 4 \times 10^{-3}$ mol

$n(XHCO_3) = n(HC\ell)$ ✓

$= 4 \times 10^{-3}$ mol

$n = \frac{m}{M}$ ∴ $4 \times 10^{-3} = \frac{0{,}4}{M}$ ✓ ✓ $M = 100\ g \cdot mol^{-1}$ $M(XHCO_3) = M(X) + 61 = 100$ ∴ $M(X) = 39\ g \cdot mol^{-1}$ ✓ X = K /potassium ✓	1 mol → $M(XHCO_3)$ 4×10^{-3} mol → 0,4 g ✓ $M(XHCO_3) = 100\ g \cdot mol^{-1}$ ∴ $4 \times 10^{-3} = \frac{0{,}4}{M}$ $M(XHCO_3) = M(X) + 61$ $= 100$ ∴ $M(X) = 39\ g \cdot mol^{-1}$ ✓ X = K/potassium ✓

OPTION 2

$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓

$\frac{0{,}2 \times 20}{c_b \times 100}$ ✓ $= \frac{1}{1}$ ✓

$c_b = 0{,}04\ mol \cdot dm^{-3}$

$c(XHCO_3) = \frac{m}{MV}$

∴ $0{,}04 = \frac{0{,}4}{M(0{,}1)}$ ∴ ✓

$M(XHCO_3) = 100\ g \cdot mol^{-1}$

$M(XHCO_3) = M(X) + 61$

$= 100$

∴ $M(X) = 39\ g \cdot mol^{-1}$ ✓

X = K / potassium ✓

(6)

[17]

QUESTION 13 (November 2019)

13.1 Strong (acid) ✓

Large K_a value/ $K_a > 1$ / (HBr) ionises completely ✓ (2)

13.2 H_2O ✓ & Br^- ✓ (2)

13.3.1

OPTION 1

$n(NaOH)_{reacted} = cV$ ✓

$= 0{,}5(0{,}0165)$ ✓

$= 0{,}00825$ mol

$n(HBr)_{excess} = n(NaOH) = 0{,}00825$ mol ✓

$c(H_3O^+) = \frac{n}{V} = \frac{0{,}00825}{0{,}09}$ ✓ $= 0{,}092\ mol \cdot dm^{-3}$

$pH = -\log[H_3O^+]$ ✓ $= -\log(0{,}092)$ ✓ $= 1{,}04$ ✓

OPTION 2

$\frac{c_a V_a}{c_b V_b} = \frac{n_a}{n_b}$ ✓

$\frac{c_a (90)}{(0{,}5)(16{,}5)}$ ✓ ✓ $= \frac{1}{1}$ ✓

$c_a = 0{,}092\ mol \cdot dm^{-3}$

$pH = -\log[H_3O^+]$ ✓

$= -\log(0{,}092)$ ✓ $= 1{,}04$ ✓

(7)

13.3.2

OPTION 1

$n(HBr)_{initial} = cV = (0{,}45)(0{,}09)$ ✓ $= 0{,}0405$ mol

$n(HBr$ reacted with $Zn(OH)_2) = \underline{0{,}0405 - 0{,}00825}$ ✓✓ $= 0{,}03224$ mol

$n(Zn(OH)_2) = ½n(HBr) = ½(0{,}03224)$ ✓ $= 0{,}016125$ mol

$m(Zn(OH)_2) = nM = (0{,}016125)(99)$ ✓ $= 1{,}596$ g ✓

OPTION 2

$c(HBr) = 0{,}45 – 0{,}092$ ✓✓ $= 0{,}358\ mol \cdot dm^{-3}$

$n(HBr$ reacted$) = cV = 0{,}358 \times 0{,}09$ ✓ $= 0{,}0322$ mol

$n(Zn(OH)_2) = ½n(HBr) = ½(0{,}0322)$ ✓ $= 0{,}01611$ mol

$m(Zn(OH)_2) = nM = 0{,}01611 \times 99$ ✓ $= 1{,}595$ g ✓ (1,60 g)

(6)

[17]

QUESTION 14 (November 2020)

14.1.1 Weak ✓

Ionises/Dissociates incompletely/partially (in water) ✓ (2)

14.1.2 **OPTION 1**

$pH = -\log[H_3O^+]$ ✓

$3{,}85$ ✓ $= -\log[H_3O^+]$

$[H_3O^+] = 1{,}41 \times 10^{-4}\ mol \cdot dm^{-3}$ ✓

OPTION 2

$[H_3O^+] = 10^{-pH}$ ✓

$= 10^{-3{,}85}$ ✓

$= 1{,}41 \times 10^{-4}\ mol \cdot dm^{-3}$ ✓ (3)

14.1.3 Greater than ✓ (1)

14.1.4 $CH_3COO^-(aq) + H_2O(\ell)$ ✓ ⇌ $CH_3COOH(aq) + OH^-(aq)$ ✓

OR $CH_3COONa(aq) + H_2O(\ell)$ ✓ ⇌ $CH_3COOH(aq) + NaOH(aq)$ ✓

Due to formation of hydroxide/OH^-/ the solution is basic/alkaline /pH > 7. ✓ (3)

14.2.1

OPTION 1	**OPTION 2**
$n(NaOH)_{reacted} = cV$ $= 1(0,0145)$ ✓ $= 0,0145$ mol $n(CH_3COOH)_{diluted} = n(NaOH)$ ✓ $= 0,0145$ mol ✓	$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ $\frac{25 \times c_a}{1 \times 14,5}$ ✓ $= \frac{1}{1}$ ✓ $c_a(\text{unreacted}) = 0,58$ mol·dm^{-3} $n_a(\text{unreacted}) = cV = (0,58)(0,025)$ $= 0,0145$ mol ✓

(3)

14.2.2

$m(CH_3COOH) = \frac{4,52}{100} \times 25$ ✓ $= 1,13$ g

$n(CH_3COOH)_{ini.} = \frac{m}{M}$ ✓ $= \frac{1,13}{60}$ ✓ $= 0,01883$ mol

$n(CH_3COOH)_{rea} = 0,01883 – 0,0145$ ✓ $= 0,0043$ mol

$n(CaCO_3) = \frac{1}{2} n(CH_3COOH)$
$= 0,5(0,0043)$ ✓
$= 0,00217$ mol

$m(CaCO_3) = nM = 0,00217(100)$ ✓ $= 0,217$ g

$\% \ CaCO_3 = \frac{0,217}{1,2} \times 100$ ✓ $= 18,08 \%$ ✓

(8)
[20]

QUESTION 15 (September 2021)

15.1 A base forms hydroxide ions ($OH^–$) in water/aqueous solution/$OH^–(aq)$. ✓✓ (2)

15.2 $n(KOH) = cV = 0,1 \times 0,4$ ✓ $= 0,04$ mol
$n(OH^–) = n(KOH) = 0,04$ mol ✓ (2)

15.3

Marking criteria/*Nasienkriteria*
- Use formula/*Gebruik formule*: $pH = -\log[H_3O^+]$
- Substitute/*Vervang* pH = 13/pOH = 1
- Substitute/*Vervang* 1×10^{-13} in K_w/Calculate/*Bereken* pOH
- Substitute/*Vervang* of $0,1 \times 0,9$
- Calculate/*Bereken* $n(OH^-) = n(\text{in C}) – n(\text{in B})$ ✓
- Use mol ratio/*Gebruik molverhouding*: $n(Ba(OH)_2) : n(OH^-) = 1 : 2$. ✓
- Substitute/*Vervang* 0,5 dm^3. ✓
- Final answer/*Finale antwoord*: 0,05 mol·dm^{-3} ✓
  Range/*Gebied*: 0,05 to 0,06 mol·dm^{-3}

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
$pH = -\log[H_3O^+]$ **OR/*OF*** $[H_3O^+] = 10^{-pH}$ ✓ 13 ✓ $= -\log[H_3O^+]$ **OR/*OF*** $[H_3O] = 10^{-13}$ $[H_3O^+] = 1 \times 10^{-13}$ mol·dm^{-3} $[H_3O^+][OH^-] = 1 \times 10^{-14}$ $(1 \times 10^{-13})[OH^-] = 1 \times 10^{-14}$ ✓ $[OH^-] = 0,1$ mol·dm^{-3} $n(OH^-) = cV$ $= 0,1 \times 0,9$ ✓ $= 0,09$ mol	$pOH = 14 - 13 = 1$ ✓ $pOH = -\log[OH^-]$ ✓ 1 ✓ $= -\log[OH^-]$ $[OH^-] = 0,1$ mol·dm^{-3} $n(OH^-) = cV$ $= 0,1 \times 0,9$ ✓ $= 0,09$ mol

$n(OH^-)$ from/*van* $Ba(OH)_2$ in beaker/*beker* **C** $= 0,09 - 0,04$ ✓
$= 0,05$ mol

$n[Ba(OH)_2] = ½ \ n(OH^-)$
$= ½ \ (0,05)$ ✓
$= 0,025$ mol

$c[Ba(OH)_2] = \frac{n}{V}$
$= \frac{0,025}{0,5}$ ✓
$\therefore x = 0,05$ mol·dm^{-3} ✓ (8)

15.3.2 Weak (acid) ✓
Ionises/dissociates incompletely/partially. ✓ (2)

15.3.3

Marking criteria/*Nasienkriteria*

- Formula/*Formule*: $c = \frac{n}{V}$ / $\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$. ✓
- Substitution of/*Vervanging van* 0,1 x 15 / 0,1 x 0,015 ✓ **OR/*OF***
  Use/*Gebruik* V_a = 30 cm^3
- Use mol ratio/*Gebruik molverhouding* 1 : 1 ✓
- Final answer/*Finale antwoord*: 0,05 $mol{\cdot}dm^{-3}$.✓

OPTION 1/*OPSIE 1*	**OPTION 2/*OPSIE 2***
$n(OH^-) = cV$ ✓ $= 0,1 \times 0,015$ ✓ $= 0,0015$ mol $n(CH_3COOH) = n(OH^-)$ $= 0,0015$ mol ✓ $c = \frac{n}{V}$ $= \frac{0,0015}{0,03}$ $= 0,05\ mol \cdot dm^{-3}$ ✓	$\frac{c_a \times V_a}{c_b \times V_b} = \frac{n_a}{n_b}$ ✓ $\frac{c_a \times 30}{0,1 \times 15}$ ✓ $= \frac{1}{1}$ ✓ $c_a = 0,05\ mol{\cdot}dm^{-3}$ ✓

(4)
[18]

QUESTION 16 (November 2021)

16.1.1 (It is a) proton/H_3O^+ion/H^+ ion donor. ✓✓ (2)
16.1.2 HSO_4^-/hydrogen sulphate ion ✓
It <u>acts as base</u> in reaction **I** <u>and as acid</u> in reaction **II**. ✓ (2)
16.1.3 HSO_4^- ✓
Smaller K_a value/weaker acid ✓
Lower ion concentration/Incompletely ionised. ✓ (3)
16.2.1 $pH = -log[H_3O^+]$ ✓
1,02 ✓= $-log[H_3O^+]$
$[H_3O^+]$ = 0,0955 $mol{\cdot}dm^{-3}$ ✓ (0,096/0,1 $mol{\cdot}dm^{-3}$) (3)
16.2.2

Marking citeria:

- Calculate $n(Na_2CO_3)$: 0,075 x 0,025 ✓
- Calculate n(HCℓ): 0,095 x 0,05 ✓
- Use ratios: n(HCℓ) = 2$n(Na_2CO_3)$ ✓
- $n(HCℓ)_{excess} = n(HCℓ)_{initial} - n(HCℓ)_{used}$ = 0,00475 – 0,0038 ✓✓
- Formula: $c = \frac{n}{V}$ ✓
- Substitute0,075 dm^3 in $c = \frac{n}{V}$ ✓
- Final answer: 0,013 $mol{\cdot}dm^{-3}$ ✓ (1,3 x 10^{-2} $mol{\cdot}dm^{-3}$)

$n(Na_2CO_3)$ = 0,075 x 0,025 ✓
= 0,001875 mol (1,875 x 10^{-3}/0,002 mol)
$n(HCℓ)_{initial/aanvanklik} = cV$ ✓
= 0,095 x 0,05 ✓
= 0,00475 mol (4,75 x 10^{-3}/0,005 mol)
$n(HCℓ)_{used/gebruik} = 2n(Na_2CO_3)$ ✓
= 2(0,001875)
= 0,0038 mol (3,75 x 10^{-3}/0,004 mol)
$n(HCℓ)_{excess/oormaat}$ = 0,00475 – 0,0038 ✓✓
= 0,00095mol (9,5 x 10^{-4}/1 x 10^{-3} mol)
$c(HCℓ) = \frac{n}{V} = \frac{0,00095}{0,075}$ ✓ = 0,013 $mol{\cdot}dm^{-3}$ ✓

(8)
[18]

QUESTION 17 (June 2022)

17.1.1 An acid is a proton (H^+ ion) donor. ✓✓ (2)

17.1.2 HY ✓
For the same acid concentration,
the acid with the <u>lower pH has the higher H^+/H_3O^+ concentration/</u>is <u>more ionised</u>. ✓ (2)

17.1.3 Lower than. ✓
HX ionises incompletely./HX has a small K_a value./HX is a weak acid. ✓ (2)

17.2.1 $pH = -\log[H_3O^+]$/$[H_3O^+] = 10^{-pH}$ ✓
2 ✓ $= -\log[H_3O^+]$
$[H_3O^+] = 0{,}01\ mol\cdot dm^{-3}$ ✓ (3)

17.2.2

<u>Marking criteria:</u>
- Substitute $c(HC\ell)_{excess}$ and $0{,}35\ dm^3$ to calculate $n(HC\ell)_{excess}$.✓
- Substitute to calculate $n(HC\ell)_{initial}$ ✓
- $n(HC\ell)_{react} = n(HC\ell)_{ini} - n(HC\ell)_{excess}$.✓✓
- Use ratio: $n(NaOH) = n(HC\ell)$ ✓
- Substitute $0{,}15\ dm^3$. ✓
- Final answer: $0{,}02\ mol\cdot dm^{-3}$ ✓ **or** $0{,}0167\ mol\cdot dm^{-3}$ **or** $0{,}017\ mol\cdot dm^{-3}$

$n(HC\ell)_{excess} = cV = 0{,}01 \times 0{,}35$ ✓ $= 3{,}5 \times 10^{-3}$ mol

$n(HC\ell)_{initial} = cV = 0{,}03 \times 0{,}2$ ✓ $= 0{,}006$ mol

$n(HC\ell)_{reacted} = 0{,}006 - 3{,}5 \times 10^{-3}$ ✓✓
$= 0{,}0025$ mol

$n(NaOH)_{reacted} = n(HC\ell)_{reacted} = 0{,}0025$ mol ✓

$c = \frac{n}{V} = \frac{0{,}0025}{0{,}15 ✓} = 0{,}02\ mol\cdot dm^{-3}$ ✓ ($0{,}0167\ mol\cdot dm^{-3}$ **or** $0{,}017\ mol\cdot dm^{-3}$)

(7)
[16]

QUESTION 18 (November 2022)

18.1.1 An acid is a) proton donor/H^+ (ion) donor. ✓✓ **(2 or 0)** (2)

18.1.2 (Weak acids) ionise/dissociate incompletely/partially (in water)/have a low K_a value. ✓ (1)

18.1.3 H_2O ✓ and CH_3COO^- ✓ (2)

18.2.1 $n(NaOH) = cV$ ✓
$= \underline{(0{,}167)(0{,}300)}$ ✓
∴ $n(NaOH) = 0{,}05$ mol ✓ (5×10^{-2} mol) (3)

18.2.2

<u>Marking criteria:</u>
a) Any formula: $pH = -\log[H_3O^+]$ / $pH = -\log[H^+]$ / $pOH = -\log[OH^-]$ / $[H_3O^+][OH^-] = 10^{-14}$ / $pH + pOH = 14$ ✓
b) Substitute 11,4 in $pH = -\log[H_3O^+]$/$pH + pOH = 14$ ✓
c) Substitute calculated $[H_3O^+]$ in $[H_3O^+][OH^-]$ / 2,6 in $pOH = -\log[OH^-]$ ✓
d) Final answer: $2{,}51 \times 10^{-3}\ mol\cdot dm^{-3}$ ✓ ($0{,}003\ mol\cdot dm^{-3}$)

<u>OPTION 1</u>

$pH = -\log[H_3O^+]$
$11{,}4$ ✓**(b)** $= -\log[H_3O^+]$ **OR** $[H_3O^+] = 10^{-11{,}4}$
$[H_3O^+] = 3{,}98 \times 10^{-12}$

$[H_3O^+][OH^-] = 10^{-14}$

Any one ✓**(a)**

$(3{,}98 \times 10^{-12})$ ✓**(c)** $[OH^-] = 1 \times 10^{-14}$
$[OH^-] = 2{,}51 \times 10^{-3}\ mol\cdot dm^{-3}$ ✓**(d)** (0,003)

<u>OPTION 2</u>

$pH + pOH = 14$
$\underline{11{,}4 + pOH = 14}$ ✓**(b)**
$pOH = 2{,}6$

$pOH = -\log[OH^-]$ ✓

Any one ✓**(a)**

$2{,}6$ ✓**(c)** $= -\log[OH^-]$
$[OH^-] = 2{,}51 \times 10^{-3}\ mol\cdot dm^{-3}$ ✓**(d)** (0,003) (4)

18.2.3

Marking criteria:
a) Substitute [NaOH] = 0,00251 mol·dm^{-3} (answer from Q18.2.2) and 0,8 in $c = \frac{n}{V}$ ✓
b) Subtract: $n(NaOH)_{initial}$ (from Q7.2.1) – $n(NaOH)_{mixture}$ ✓✓
c) Use of ratio: $n(OH^-) = n(CH_3COOH)$ ✓
d) Substitute 0,5 and Δ$n(CH_3COOH)$[calculated by subtraction] into $c = \frac{n}{V}$ ✓
e) Final correct answer: 0,096 mol·dm^{-3} ✓
Range: 0,095 to 0,1 mol·dm^{-3}

n(NaOH)mixture = cV
= 0,00251 x 0,8 ✓**(a)**
= 0,002 mol (0,0024)

$n(NaOH)_{reacted}$ = 0,05 – 0,002 ✓✓**(b)**
= 0,048 mol (0,0476)

$n(NaOH)_{reacted} = n(CH_3COOH)_{used}$
= 0,048 mol ✓**(c)**

$[CH_3COOH] = \frac{n}{V}$
$= \frac{0,048}{0,5}$ ✓**(d)**
= 0,096 mol·dm^{-3} ✓**(e)** (0,0952)

(6)
[18]

QUESTION 19 (June 2023)

19.1

19.1.1 **ANY ONE:**
- A substance whose aqueous solution contains ions. ✓✓ **(2 or 0)**
- Substance that dissolves in water to give a solution that conducts electricity.
- A substance that forms ions in water/when melted. (2)

19.1.2 A ✓
H_2SO_4 is diprotic./donates more than one mole of H^+ ions per mole of acid ✓ (and both acids are of the same concentration)./H_2SO_4 has a higher K_a value.
OR
It ionises to produce more than one mole of protons/H+ ions for each mole of H_2SO_4./
H_2SO_4 has a higher Ka value. (2)

19.1.3 B ✓
Stroger acid/ionises completely ✓ (and both acids are of the same concentration)./HNO_3 has a higher Ka value.
OR
C is a weaker acid/ionises incompletely. (2)

19.2 **Marking criteria**
- Substitute 0,04 mol·dm^{-3} and 25 x 10^{-3} dm^3 or 25 cm^3 and 19,5 x 10^{-3} dm^3 or 19,5 cm^3. ✓
- USE mol ratio: $n(NaHCO_3) : n(HCℓ)$ = 1 : 2 ✓
- Final answer: 0,10 tot 0,103 mol·dm^{-3} ✓

OPTION 1	OPTION 2
$\frac{c_1V_1}{c_2V_2} = \frac{n_1}{n_2}$ $\frac{c_1(19,5)}{(0,04)(25)}$ ✓ $= \frac{2}{1}$ ✓ c_1 = 0,10 mol·dm^{-3} ✓(0,103)	$n(Na_2CO_3)$ = cV = 0,04 x 0,025 = 0,001 mol ✓ $n(HCℓ) = 2n(Na_2CO_3)$ = 0,002 mol ✓ $[HCℓ] = \frac{n}{V}$ $= \frac{0,002}{0,0195}$ = 0,10 mol·dm^{-3} ✓ (0,103)

(3)

19.2.2 Greater than ✓
The few drops of water will dilute the HCℓ, ✓ therefore greater volume of acid will be needed to neutralise the base. (2)

19.2.3 **POSITIVE MARKING FROM Q19.2.1**

Marking criteria:

- Substitute 0,1 mol·dm^{-3} and 18,7 x 10^{-3} dm^3 / 18,7 cm^3. ✓
- Use mole ratio: 1:1 ✓
- Calculate n(NH_3) / m(NH_3) in 250 cm^3: Substitute 0,25 dm^3 /250 cm^3 AND 0,022 dm^3/22 cm^3 ✓✓
- Substitute 20 cm^3 or 0,02 dm^3 to calculate mole/mass in initial solution.✓
- Use 17 g·mol^{-1} in $n = \frac{m}{M}$.✓
- Final answer: 18,06 g ✓ Range: 17 to 19,1 g

OPTION 1

n(HCℓ)= cV = (0,1)(18,7 x 10^{-3}) ✓ = 1,87 x 10^{-3} mol

$(NH_3)_{reacted}$ = n(HCℓ)$_{reacted}$ = 1,87 x 10^{-3} mol ✓

n(NH_3) in 22 cm^3 = 1,87 x 10^{-3} mol

n(NH_3) in 250 cm^3 = $\frac{(1,87 \times 10^{-3})(250) ✓}{22 ✓}$ = 0,021 mol (2,13 x 10^{-2})

n(NH_3) in initial 20 cm^3 = 0,021 mol

$n = \frac{m}{M}$ ∴ 0,021 = $\frac{m}{17 ✓}$ ∴ m(NH_3) = 0,357 g in 20 cm^3

m(NH_3) = $\frac{(0,357)(1000)}{20}$ = 17,85 g ✓ (18,06)

OPTION 2

n(HCℓ)= cV = (0,1)(18,7 x 10^{-3}) ✓
= 1,87 x 10^{-3} mol

$(NH_3)_{reacted}$ = n(HCℓ)$_{reacted}$
= 1,87 x 10^{-3} mol ✓

n(NH_3) in 22 cm^3 = 1,87 x 10^{-3} mol

$n = \frac{m}{M}$

1,87 x 10^{-3} = $\frac{m}{17 ✓}$

m(NH_3) = 3,72 x 10^{-3} g in 22 cm^3

m(NH_3) in 250 cm^3 = $\frac{(3,72 \times 10^{-3})(250) ✓}{22 ✓}$
= 0,361 g

m(NH_3) in initial 20 cm^3 = 0,361 g

m(NH_3) in 1 000 cm^3 = $\frac{(0,361)(1000)}{20 ✓}$
= 18,06 ✓

OPTION 3

$\frac{c_1V_1}{c_2V_2} = \frac{n_1}{n_2}$

$\frac{c_1(22)}{(0,1)(18,7) ✓} = \frac{1}{1}$ ✓

c_1 = 0,085 mol·dm^{-3}

[NH_3] in 22 cm^3 = 0,085 mol·dm^{-3}

[NH_3] in 250 cm^3 = 0,085 mol·dm^{-3} ✓

$c_1V_1 = c_2V_2$

c_1(0,02) ✓ = (0,085)(0,25) ✓

c_1 = 1,06 mol·dm^{-3}

n = cVM
= (1,06)(1)(17)✓
= 18,06 g ✓

(7)

19.2.4 Less than ✓

$NH_4^+(aq) + H_2O(\ell)$ ✓ → $NH_3(aq) + H_3O^+(aq)$ ✓ (2)

[21]

QUESTION 20 (November 2023)

20.1 A strong base (ionises) dissociates completely ✓ in water to form a high concentration of OH^- ions. ✓ (2)

20.2

20.2.1 $n(Ba(OH)_2) = cV$✓
$= (0,15)(0,02)$ ✓
$= 0,003$ mol ✓ (3)

20.2.2 **POSITIVE MARKING FROM QUESTION 20.2.1**

Marking criteria:
(a) Use ratio: $2nBa(OH)_2$ (7.2.1) = $nHNO_3$ ✓
(b) Substitute nH_3O^+ or $nHNO_3$ and 0,025 dm^3 in $c = \frac{n}{V}$ ✓
(c) Formula: $pH = -log[H_3O^+]$ ✓
(d) Substitute $[H_3O^+]$ in pH formula ✓
(e) Final correct answer: 0,62✓

$n(HNO_3)_{reacted} = 2nBa(OH)_2 = 2(0,003)$ ✓**(a)**
$= 0,006$ mol

OPTION 1
$n(H_3O^+) = n(HNO_3)$
$= 0,006$ mol
$[H_3O^+] = \frac{n}{V}$
$= \frac{0,006}{0,025}$✓**(b)**
$= 0,24$ mol·dm^{-3}

OPTION 2
$[HNO_3] = \frac{n}{V}$
$= \frac{0,006}{0,025}$ ✓**(b)**
$= 0,24$ mol·dm^{-3}
$[H_3O^+] = [HNO_3]$
$= 0,24$ mol·dm^{-3}

$pH = -log[H_3O^+]$ ✓**(c)**
$= -log(0,24)$ ✓**(d)**
$= 0,62$ ✓**(e)**

(5)

20.3 **POSITIVE MARKING FROM QUESTION 20.2.2**

Marking criteria:
(a) Substitute $[HNO_3] = 0,4$ mol·dm^{-3} and 0,025 dm^3 ✓
(b) Subtract: $n(HNO_3)_{ini} – n(HNO_3)_{excess}$ (20.2.2) / $[HNO_3]_{ini} – [HNO_3]_{excess}$ (20.2.2) ✓✓
(c) Use of ratio $n(MCO_3) = ½n(HNO_3)$ ✓
(d) Calculate the pure mass $m(MCO_3)$ ✓
(e) Substitute $n(MCO_3)$ and $m(MCO_3)$ in $n = \frac{m}{M}$ ✓
(f) Subtraction of 60 g·mol^{-1} from molar mass. ✓
Correct answer: Mg ✓

OPTION 1
$n(HNO_3)_{ini} = cV = (0,4)(0,025)$ ✓ **(a)**
$= 0,01$ mol

$n(HNO_3)_{react} = n(HNO_3)_{ini} – n(HNO_3)_{excess}$
$= 0,01 – 0,006$ ✓✓ **(b)**
$= 0,004$ mol

$n(MCO_3) = ½n(HNO_3)$
$= ½(0,004)$ ✓**(c)**
$= 0,002$ mol

$m(MCO_3) = \frac{85}{100} \times 0,198$ ✓**(d)**
$= 0,168$ g

$n(MCO_3) = \frac{m}{M}$
$0,002 = \frac{0,168}{M}$ ✓**(e)**
$M(MCO_3) = 84$ g·mol^{-1}

Molar mass (M) = 84 - 60 ✓**(f)**
= 2 g·mol^{-1}
Therefore metal M is Mg ✓**(g)**

OPTION
$[HNO_3]_{reacted} = [HNO_3]_{initial} - [HNO_3]_{excess}$
$= 0,4 – 0,24$✓✓ **(b)**
$= 0,16$ mol·dm^{-3}

In 1 dm^3 : 0,16 mol
In 0,025 dm^3 : 0,004 mol ✓ **(a)**

$n(MCO_3) = ½n(HNO_3)$
$= ½(0,004)$ ✓**(c)**
$= 0,002$ mol

$m(MCO_3) = \frac{85}{100} \times 0,198$ ✓**(d)**
$= 0,168$ g

$n(MCO_3) = \frac{m}{M}$
$0,002 = \frac{0,168}{M}$ ✓**(e)**
$M(MCO_3) = 84$ g·mol^{-1}

Molar mass (M) = 84 - 60 ✓**(f)**
= 24 g·mol^{-1}
Therefore, metal M is Mg ✓**(g)**

(8)
[18]

QUESTION 21 (June 2024)

21.1.1

OPTION 1

$c = \frac{m}{MV}$ ✓

$= \frac{10}{(106)(0,7)}$ ✓

$= 0,13\ mol \cdot dm^{-3}$ ✓

OPTION 2

$n = \frac{m}{M}$

$= \frac{10}{106}$ ✓

$= 0,094\ mol$

$c = \frac{n}{V}$ ✓

$= \frac{0,094}{0,7}$

$= 0,13\ mol \cdot dm^{-3}$ ✓

(3)

21.1.2 Greater than ✓ (1)

21.1.3 $CO_3^{2-}(aq) + H_2O(\ell)$ ✓ $\rightleftharpoons HCO_3^-(aq) + OH^-(aq)$ ✓ **OR**
$CO_3^{2-}(aq) + 2H_2O(\ell) \rightleftharpoons H_2CO_3(aq) + 2OH^-(aq)$ **OR**
$Na_2CO_3(aq) + H_2O(\ell) \rightleftharpoons NaHCO_3(aq) + NaOH(aq)$ **OR**
$Na_2CO_3(aq) + 2H_2O(\ell) \rightleftharpoons H_2CO_3(aq) + 2NaOH(aq)$ (2)

21.1.4 P ✓
Titration of a weak base and a strong acid. / The equivalence point is lower than pH 7. ✓ (2)

21.2.1 Dilute acids contain a small amount/number of moles of acid in proportion to the volume of water. ✓✓ (2)

21.2.2

OPTION 1

(*) [
$n(KOH)_{reacted} = 2n(H_2SO_4)_{reacted}$
$= 2(0,01)$ ✓
$= 0,02\ mol$

$n(KOH)_{excess} = 0,024 - 0,02$ ✓✓
$= 0,004\ mol$

$[OH^-] = \frac{n}{V}$
$= \frac{0,004}{0,2}$ ✓
$= 0,02\ mol \cdot dm^{-3}$
]

$[H_3O^+][OH^-] = 1x10^{-14}$
$[H_3O^+](0,02) = 1x10^{-14}$ ✓
$[H_3O^+] = 5x10^{-13} mol \cdot dm^{-3}$

$pH = -log[H_3O^+]$ ✓
$= -\log(5x10^{-13})$ ✓
$= 12,3$ ✓

OPTION 2

(**) [
$[KOH] = \frac{n}{V}$
$= \frac{0,024}{0,2}$
$= 0,12\ mol \cdot dm^{-3}$

$[H_2SO_4] = \frac{n}{V}$
$= \frac{0,01}{0,2}$
$= 0,05\ mol \cdot dm^{-3}$

✓ Both

$[KOH]_{reacted} = 2[H_2SO_4]_{reacted}$
$= 2(0,05)$ ✓
$= 0,10\ mol \cdot dm^{-3}$

$[KOH]_{excess} = 0,12 - 0,10$ ✓✓
$= 0,02\ mol.dm^{-3}$
]

$[H_3O^+][OH^-] = 1x10^{-14}$
$[H_3O^+](0,02) = 1x10^{-14}$ ✓
$[H_3O^+] = 5x10^{-13} mol \cdot dm^{-3}$

$pH = -log[H_3O^+]$ ✓
$= -\log(5x10^{-13})$ ✓
$= 12,3$ ✓

OPTION 3

Start with (*) or (**) ✓✓✓✓

$pOH = -\log[OH^-]$
$= -\log(0,02)$ ✓
$= 1,7$

$pH + pOH = 14$ ✓
$pH + 1,7 = 14$ ✓
$pH = 12,3$ ✓

(8)
[18]

QUESTION 22 (November 2024)

22.1 Weak bases dissociate/ionise incompletely/partially in water ✓ to form a low concentration of hydroxide/OH^- ions. ✓ (2)

22.2 HCO_3^- (aq) ✓ (1)

22.3.1 26,55 (cm^3) ✓ (1)

22.3.2 28,15 (cm^3) ✓ (1)

22.4 The titration's equivalence point/colour change is in the pH range of less than 7. / The solution is acidic. / The reaction of strong acid and weak base has an equivalence point at a pH of less than 7. ✓
The end point of this titration is within the pH range in which methyl orange / the indicator changes colour. / Methyl orange changes colour at a pH of less than 7. ✓ (2)

22.5

OPTION 1

$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$ ✓

$\frac{(0,1)(25)✓}{c_b(20,1)✓} = \frac{2}{1}$ ✓ (*)

$c_b = 0,0622\ mol \cdot dm^{-3}$ ✓

(*) Note that the **average** volume is used.

OPTION 2

$n(HC\ell) = cV$ ✓

$= (0,1)(0,025)$ ✓ (*)

$= 0,0025\ mol$

$n(K_2CO_3) = \frac{1}{2}n(HC\ell)$ ✓

$= \frac{0,0025}{2}$

$= 0,00125\ mol$

$n(K_2CO_3) = cV$

$0,00125 = c(0,0201)$ ✓ (*)

$c(K_2CO_3) = 0,0622\ mol \cdot dm^{-3}$ ✓

(*) Note that the **average** volume is used.

(5)

22.6

$c = \frac{m}{MV}$ ✓

$0,0622 = \frac{6,525✓}{M(0,6)✓}$

$M(K_2CO_3 \cdot xH_2O) = 174,839\ g \cdot mol^{-1}$

$2(39) + 12 + 3(16) + x(18)$ ✓ $= 174,839$

$x = 2$ ✓

(5)

[17]

GALVANIC CELLS

QUESTION 1 (November 2014)

1.1 Pressure: 1 atmosphere (atm) / 101,3 kPa / 1,013 x 10^5 Pa ✓
Temperature: 25 °C / 298 K ✓ (2)

1.2 Platinum is inert / does not react with the H^+ ions **OR** acid. ✓
Platinum is a conductor (of electricity). ✓ (2)

1.3.1 Salt bridge ✓ (1)

1.3.2 – 0,31 V ✓ (1)

1.3.3 $2H^+ + 2e^- \rightarrow H_2$ ✓✓ (2)

1.4.1 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ ∴ 2,05 ✓ = - 0,31 ✓– $E^\theta_{M/M^{2+}}$ ∴ $E^\theta_{M/M^{2+}}$ = -2,36 (V) ✓
∴ M is magnesium/ Mg. ✓ (5)

1.4.2 Exothermic ✓ (1)

1.5 The cell reaction reaches equilibrium. ✓ (1)
[15]

QUESTION 2 (March 2015)

2.1 A substance that is being reduced / that gains electrons / whose oxidation number decreases. ✓✓ (2)

2.2 Ag^+ is a stronger oxidising agent ✓ than Cu^{2+} ✓ and will oxidise Cu ✓ to (blue) Cu^{2+} ions. ✓
OR Cu^{2+} is a weaker oxidising agent ✓ than Ag^+ ✓ and Cu will be oxidised ✓ to Cu^{2+} ions. ✓ (4)

2.3 Chemical energy to electrical energy ✓ (1)

2.4 A ✓ (1)

2.5 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = -0,8 ✓ – 0,34 ✓ = 0,46 V ✓ (4)

2.6 $Cu + 2Ag^+(aq)$ ✓$\rightarrow Cu^{2+}(aq) + 2Ag(s)$ ✓ Balancing ✓ (3)

2.7 Remains the same ✓ (1)
[16]

QUESTION 3 (November 2015)

3.1 Temperature: 25 °C / 298 K ✓
Pressure: 101,3 kPa / 1,013 x 10^5 Pa / 1 atm / 100 kPa ✓
Concentration: 1 mol·dm^{-3} ✓ (3)

3.2.1 Cd(s) / Cadmium / Cd|Cd^{2+} / Cd^{2+}|Cd ✓ (1)

3.2.2 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓∴ 0,13 ✓= $E^\theta_{reduction}$ – (-0,40) ✓
$E^\theta_{reduction}$= - 0,27 V ✓ ∴ Q is Ni / nickel ✓ (3)

3.3.1 $Cd(s) \rightarrow Cd^{2+}(aq) + 2e^-$ ✓✓ (2)

3.3.2 Pt / Platinum ✓ (1)

3.4

Compare $\mathbf{Q^{2+}}$ & $\mathbf{Cd^{2+}}$	$\mathbf{Q^{2+}}$ is reduced / **Cd** is oxidised and therefore $\mathbf{Q^{2+}}$ is a stronger oxidising agent than $\mathbf{Cd^{2+}}$.	✓
Compare $\mathbf{R_2}$ & $\mathbf{Cd^{2+}}$	$\mathbf{R_2}$ is reduced / **Cd** is oxidised and therefore $\mathbf{R_2}$ is a stronger oxidising agent than Cd^{2+}. ✓	✓
Compare $\mathbf{R_2}$ & $\mathbf{Q^{2+}}$	The cell potential of combination **II** is higher than that of combination **I,** therefore $\mathbf{R_2}$ is a stronger oxidising agent than $\mathbf{Q^{2+}}$.	✓
Final answer	Cd^{2+}; Q^{2+};R_2 **OR** Cd^{2+} ; Ni^{2+} ; $C\ell_2$	✓

(4)
[16]

QUESTION 4 (March 2016)

4.1 B ✓ (1)

4.2.1 $C\ell_2(g) + 2e^- \rightarrow 2C\ell^-(aq)$ ✓✓ (1)

4.2.2 $C\ell_2$ / chlorine ✓ (1)

4.3 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = 6 ✓ – (-2,36) ✓ = 3,72 V ✓ (4)

4.4 The Mg electrode becomes smaller. / The mass of the Mg electrode decreases. / The Mg electrode being corroded. ✓
Magnesium is oxidised. / $Mg \rightarrow Mg^{2+} + 2e^-$ ✓ (2)
[10]

QUESTION 5 (June 2016)

5.1 Electrons are transferred. ✓
OR The oxidation number of Mg / H changes. **OR** Mg is oxidised / H^+ is reduced. (1)
5.2 H^+ ions / HCℓ / $H^+(aq)$ / HCℓ(aq) ✓ (1)
5.3 Ag is a weaker reducing agent ✓ than H_2 and will not be oxidised ✓ to Ag^+ ✓
OR H_2 is a stronger reducing agent ✓ than Ag and will be oxidised ✓ to H^+.✓ (3)
5.4 Electrode / Conductor of electrons in hydrogen half-cell ✓ (1)
5.5.1 Chemical energy to electrical energy ✓ (1)
5.5.2 Provides path for movement of ions./Completes the circuit./Ensures electrical neutrality in cell. ✓ (1)
5.5.3 $2H^+ + 2e^- \rightarrow H_2$ ✓✓ (2)
5.5.4 Mg(s) | $Mg^{2+}(aq)$ ✓ || ✓ $H^+(aq)$ | $H_2(g)$ | Pt ✓
OR Mg(s) | $Mg^{2+}(1\ mol\cdot dm^{-3})$ || $H^+(1\ mol\cdot dm^{-3})$ | $H_2(g)$ | Pt (3)
5.6 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = 0,00 ✓ – (-2,36) ✓ = 2,36 V ✓ (4)
5.7 Increases ✓ (1)
[18]

QUESTION 6 (November 2016)

6.1.1 $AgNO_3$ / Silver nitrate ✓ (1)
6.1.2 $Ni \rightarrow Ni^{2+} + 2e^-$ ✓✓ (2)
6.1.3 $Ni + 2Ag^+$ ✓ $\rightarrow Ni^{2+} + 2Ag$ ✓ Bal ✓ (3)
6.2.1 Ni ✓
Ni is a stronger reducing agent. / Ni is the anode. / Ni loses electrons. / Ni is oxidised. ✓ (2)
6.2.2 Ni (s) | Ni^{2+} (aq) ✓|| ✓ $Ag^+(aq)$ | Ag(s) ✓ **OR** Ni (s) | Ni^{2+} $(1\ mol\cdot dm^{-3})$ || $Ag^+(1\ mol\cdot dm^{-3})$ | Ag(s) (3)
6.2.3 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = 0,80 ✓ – (-0,27) ✓ = 1,07 V ✓ (4)
6.2.4 Increases ✓ (1)
[16]

QUESTION 7 (March 2017)

7.1.1 Salt bridge ✓ (1)
7.1.2 Voltaic / Galvanic cell ✓ (1)
7.2.1 Decreases ✓ (1)
7.2.2 Increases ✓ (1)
7.3 $Y(s) \rightarrow Y^{2+}(aq) + 2e^-$ ✓✓
OR $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ (2)
7.4 Y(s) |$Y^{2+}(aq)$ ||$Aℓ^{3+}(aq)$ | Aℓ(s) **OR** Mg(s) |$Mg^{2+}(aq)$ ||$Aℓ^{3+}(aq)$ | Aℓ(s
OR Y(s) | Y^{2+} $(1\ mol\cdot dm^{-3})$ || $Aℓ^{3+}(1\ mol\cdot dm^{-3})$ | Aℓ(s) (3)
7.5 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ ∴ 0,7 ✓ = - 1,66 ✓ - $E^\theta_{oxidation}$ ∴ $E^\theta_{oxidation}$ = -2,36 V
Y is Mg ✓ (5)
[14]

QUESTION 8 (November 2017)

8.1.1 Voltmeter/multimeter/galvanometer ✓ (1)
8.1.2 Anode ✓ (1)
8.1.3 $3Ag^+(aq)$ + Aℓ(s) ✓ → 3Ag(s) + $Aℓ^{3+}(aq)$ ✓ Bal. ✓ (3)
8.1.4 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = +0,80 ✓- (- 1,66) ✓ = 2,46 V ✓ (4)
8.2.1 Platinum/carbon ✓ (1)
8.2.2 **ANY TWO:** Concentration: 1 $mol\cdot dm^{-3}$ ✓; Temperature: 25 °C/298 K ✓ ;
Pressure: 101,3 kPa/1,01 x 10^5 Pa/1 atm (2)
8.2.3 Zinc/Zn ✓ (1)
8.2.4 PQ ✓ (1)
[14]

QUESTION 9 (March 2018)

9.1.1 A substance that loses/donates electrons. ✓✓ (2)
9.1.2 Platinum/Pt ✓ (1)
9.1.3 $Sn^{2+}(aq)$/tin(II) ions ✓ (1)
9.1.4 Pt | $Sn^{2+}(aq)$ | $Sn^{4+}(aq)$ ✓ || ✓$Ag^+(aq)$ | Ag(s) ✓
OR Pt| $Sn^{2+}(1\ mol\cdot dm^{-3})$ | Sn^{4+} $(1\ mol\cdot dm^{-3})$ || Ag^+ $(1\ mol\cdot dm^{-3})$ | Ag(s)) (3)
9.1.5 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓ = +0,80 ✓ - (+0,15) ✓ = 0,65 V ✓ (4)
9.2.1 Magnesium becomes smaller./Brown solid forms. ✓ (1)
9.2 2 Cu^{2+} is a stronger oxidising agent ✓(than Mg^{2+}) and will be reduced to ✓Cu. ✓
OR Mg is a stronger reducing agent ✓(than Cu) and will reduce Cu^{2+} to Cu. (3)
[15]

QUESTION 10 (June 2018)

10.1.1 Galvanic cell/Voltaic cell ✓ (1)
10.1.2 Indicates phase boundary./Interphase /phase separator✓ (1)
10.1.3 $Fe^{2+} \rightarrow Fe^{3+} + e^-$ ✓✓ (2)
10.1.4 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓ ∴ 0,03 ✓ = $E^{\theta}_{X/X^{2+}}$ - (0,77) ✓ ∴ $E^{\theta}_{X/X^{2+}}$ = 0,80 (V) ✓
X = Silver / Ag ✓ (5)
10.2.1 Pt ✓ (1)
10.2.2 Iron(III) ions ✓ (1)
10.2.3 $2Fe^{3+} + Cu$ ✓ $\rightarrow 2Fe^{2+} + Cu^{2+}$ ✓ Bal. ✓ (3)
[14]

QUESTION 11 (November 2018)

11.1.1 Loss of electrons. ✓✓ (2)
11.1.2 $Fe \rightarrow Fe^{3+} + 3e^-$ ✓✓ (2)
11.1.3 Reducing agent ✓ (1)
11.1.4 Fe is a stronger reducing agent ✓ than Cu ✓ and (Fe) will be oxidised ✓(to Fe^{3+}).
OR Cu is a weaker reducing agent ✓ than Fe ✓and (Cu) will not be oxidised. ✓ (3)
11.1.5 Zinc/Zn ✓ Stronger reducing agent than Fe. ✓ (2)
11.2.1 $3Cu^{2+} + 2Fe$ ✓ $\rightarrow 3Cu + 2Fe^{3+}$ ✓ Bal. ✓ (3)
11.2.2 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓ = 0,34 ✓ – (-0,06) ✓ = 0,40 V ✓ (4)
[17]

QUESTION 12 (June 2019)

12.1 It is a conductor of electricity/a solid to connect wires to./Pt is inert or unreactive. ✓ (1)
12.2.1 Chemical (energy) to electrical (energy) ✓ (1)
12.2.2 $C\ell_2 + 2e^- \rightarrow 2C\ell^-$ ✓✓ (2)
12.2.3 <u>$Cr(s) \mid Cr^{3+}(aq)$</u> ✓|| <u>$C\ell_2(g) \mid C\ell^-(aq) \mid Pt(s)$</u> ✓
OR $Cr(s) \mid Cr^{3+}(1\ mol \cdot dm^{-3}) \parallel C\ell_2(g) \mid C\ell^-(1\ mol \cdot dm^{-3}) \mid Pt(s)$ (3)
12.3 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓ = 1,36 ✓ – (-0,74) ✓ = 2,10 V ✓ (4)
12.4 Increases ✓✓ (2)
[13]

QUESTION 13 (November 2019)

13.1 Chemical (energy) to electrical (energy) ✓ (1)
13.2 Provides path for movement of ions./ Completes the circuit./Ensures electrical neutrality in the cell. ✓ (1)
13.3 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓
∴ 1,49 ✓ = 1,36 – $E^{\theta}_{oxidation}$ ∴ $E^{\theta}_{oxidation}$ = - 0,13 V ✓
X = Pb ✓ (5)
13.4 X/Pb/Lead ✓ (1)
13.5.1 Reaction reached equilibrium. ✓ (1)
13.5.2 Increases ✓ (1)
13.5.3 [$C\ell^-$] decreases. ✓
Forward reaction is favoured. ✓ (2)
[12]

QUESTION 14 (November 2020)

14.1 Provides path for movement of ions./Ensures(electrical)neutrality in the cell. ✓ (1)
14.2 (The electrode) where oxidation takes place/electrons are lost. ✓✓ (2)
14.3 Mg/Magnesium ✓ (1)
14.4.1 $2H^+ + 2e^- \rightarrow H_2$ ✓✓ (2)
14.4.2 Magnesium/Mg ✓ (1)
14.5 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$
= 0 - (-2,36)
= 2,36 V (Only the three formulae on the data sheet are accepted.) (4)
14.6 <u>H_2 is a stronger reducing agent</u> ✓ <u>than Cu</u> ✓ and therefore <u>Cu^{2+}/Cu ions are reduced/H_2 is oxidised</u> ✓
Electrons flow from H_2 to Cu. (3)
[14]

QUESTION 15 (September 2021)

15.1

15.1.1 Zinc/Zn ✓ (1)

15.1.2 Platinum/Pt /Carbon/C ✓ (1)

15.1.3 Iron(III) ions/Fe^{3+}(aq)/Fe^{3+} ions ✓ (1)

15.2

15.2.1 Conductor (to complete circuit). /Provides surface area for the reaction to take place. (1)

15.2.2 $Fe^{3+} + e^- \rightarrow Fe^{2+}$ ✓✓ (1)

15.2.3 $2Fe^{3+}(aq) + Zn$ ✓ $\rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$ ✓ Bal ✓ (3)

15.4 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓

$= 0{,}77$ ✓ $- (-0{,}76)$ ✓

$E^\theta_{cell} = 1{,}53$ ✓ (4)

15.4 Decreases (1)

… .**[14]**

QUESTION 16 (November 2021)

16.1 Chemical (energy) to electrical (energy) ✓ (1)

16.2

<table>
<tr><td colspan="2">

Marking criteria:

- Any formula: $c = \frac{m}{MV}$ / $c = \frac{n}{V}$ / $n = \frac{m}{M}$ ✓
- Substitute 1 mol·dm^{-3}.✓
- Substitute 170 g·mol^{-1} and 0,15 dm^3. ✓
- Final answer: 25,50 g ✓

</td></tr>
<tr><td>

OPTION 1
n = cV ✓
= 1 ✓ x 0,15
= 0,15 mol
m = nM
= (0,15)(170) ✓
= 25,50 g ✓

</td><td>

OPTION 2
$c = \frac{m}{MV}$ ✓
1 ✓ $= \frac{m}{170 \times 0{,}15}$ ✓
m = 25,50 g ✓

</td></tr>
</table>

(4)

16.3 **ANY ONE:**

- A substance that loses/donates electrons. ✓✓
- A substance that is oxidised.
- A substance whose oxidation number increases. (2)

16.4

16.4.1 Copper/Cu ✓ (1)

16.4.2 $Cu(s) + 2Ag^+(aq)$ ✓ $\rightarrow Cu^{2+}(aq) + 2Ag(s)$ ✓ Bal ✓ (3)

16.5 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$

$= 0{,}80$ ✓ $– (0{,}34)$ ✓

$= 0{,}46$ V ✓ (4)

16.6 Decreases ✓ (1)

[16]

QUESTION 17 (June 2022)

17.1.1 Temperature: 25 °C/298 K ✓

Pressure: 101,3 kPa/1 atmosphere ✓

Concentration: 1 mol·dm^{-3} ✓ (3)

17.1.2 $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ ✓

$2{,}89$ ✓ $= E^\theta_{reduction} – (-1{,}66)$ ✓

$E^\theta_{reduction} = 1{,}23$ V ✓ X is O_2 ✓ (5)

17.1.3 $A\ell$ ✓ (1)

17.1.4 $O_2(g) + 4H^+ + 4e^- \rightarrow H_2O$ ✓✓ (3)

17.1.5 $A\ell$ (s) | $A\ell^{3+}$(aq) ✓||✓ O_2(g) | H^+(aq) | $H_2O(\ell)$ | Pt(s) ✓

OR: $A\ell$ (s) | $A\ell^{3+}$(aq) ✓||✓ O_2(g) | H^+(aq) | $H_2O(\ell)$ | C(s) ✓

OR: $A\ell$ | $A\ell^{3+}$ ✓||✓ O_2 | H^+ | H_2O | Pt ✓ (3)

17.2 Copper ✓

Cu is a weaker reducing agent than Ni ✓ and <u>will not reduce Ni^{2+}</u> (to Ni). ✓

Zn is a stronger reducing agent than Ni ✓ and <u>will reduce Ni^{2+}</u> (to Ni).

(Any one of underlined used correctly – 1 mark) … ....(4)

[18]

QUESTION 18 (November 2022)

18.1.1 Zn/zinc ✓ (1)

18.1.2 MnO_4^- is a stronger oxidising agent ✓ than Zn^{2+}/Zn(II) ions ✓ and will oxidise Zn ✓ (to Zn^{2+}/Zn(II) ions).
OR
Zn^{2+}/Zn(II) ion is a weaker oxidising agent ✓ than MnO_4^- ✓ and therefore MnO_4^- will be reduced ✓ (to Mn^{2+}/Mn(II) ions). (3)

18.2.1 Provides path for movement of ions. / Completes the circuit. / Ensures electrical neutrality in the cell. / Restore charge balance. ✓ (1)

18.2.2 Mn to Ni ✓✓ (2)

18.2.3 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓
$= -0,27$ ✓ $- (-1,18)$ ✓
$= 0,91$ V ✓ (4)

18.2.4 $Ni^{2+} + Mn$ ✓ $\rightarrow Mn^{2+} + Ni$ ✓ Bal. ✓ (3)

18.2.5 Increase ✓ (1)

[15]

QUESTION 19 (June 2023)

19.1 Pressure: 1 atmosphere / 1,01 x 10^5 Pa ✓
Temperature: 25 °C / 298K ✓
Concentration of electrolytes: 1 mol·dm^{-3} ✓ (3)

19.2 To maintain electric neutrality/To complete the circuit ✓ (1)

19.3 $E^{\theta}_{cell} = E^{\theta}_{reduction} - E^{\theta}_{oxidation}$ ✓
1,20 ✓ $= E^{\theta}_{reduction} - 0$ ✓
$E^{\theta}_{reduction} = 1,20$ V ✓ X is platinum/Pt ✓ (5)

19.4 $H_2(g) \rightarrow 2H^+(aq) + 2e^-$ ✓✓ (2)

19.5 H^+, X^{2+} (Pt^{2+}), Au^{3+} ✓

- H_2 loses electrons to both Au and X/Pt. ✓
  OR: H_2 is the anode/is oxidised in both cells. Therefore H^+ is the weakest oxidising agent.
- The reduction potential of X│X^{2+} is 1,2 V and that of Au│Au^{3+} is 1,5 V. ✓
  OR: The reduction potential of X│X^{2+} is smaller than that of Au│Au^{3+}.
  OR: Au^{3+} is stronger oxidation agent than Pt^{2+} (from the Table of Standard Reduction Potentials).
  OR: The cell containing Au produces a higher emf than cell containing X. (3)

[14]

QUESTION 20 (November 2023)

20.1.1 Copper strip becomes thinner/corrodes/decreases in mass/solid/silver coloured particles in solution/ the copper becomes plated with silver. ✓ (1)

20.1.2 Ag^+ (ion) / Silver ion/ $AgNO_3$/silver nitrate ✓ (1)

20.2 Ag^+ (ion) is a stronger oxidising agent ✓ than Cu^{2+} ion ✓ and will oxidise Cu ✓ to Cu^{2+} ion.
OR
Cu^{2+} (ion) is a weaker oxidising agent ✓ than Ag^+ ion ✓ and Cu will be oxidised ✓ to Cu^{2+} ion.
OR
Cu/Copper is a stronger reducing agent ✓ than Ag/Silver ✓ and will reduce silver ✓ ions to silver. ✓ (3)

20.3.1 Silver/Ag ✓ (1)

20.3.2 $CuSO_4$/Cu^{2+} /Copper (II) ions/copper(II) sulphate ✓ (1)

20.3.3 $2Ag^+(aq) + Cu(s)$ ✓ $\rightarrow 2Ag(s) + Cu^{2+}(aq)$ ✓ Bal ✓ (3)

20.4 K^+ ✓
[Ag^+] decreases. ✓
OR: In silver half-cell concentration of positive ions decreases.
OR: The silver half-cell becomes negative. (2)

[12]

QUESTION 21 (June 2024)

21.1 Aluminium/Aℓ ✓ (1)
21.2 0,325 mol·dm^{-3} Range: 0,32 ~ 0,33 (mol·dm^{-3}) (2)
21.3 Decreases ✓ M^{2+} is reduced. / M^{2+} is used up. / M^{2+} is the oxidising agent. ✓ (2)
21.4 M ✓ (1)
21.5

OPTION 1

$E^{\theta}_{cell} = E^{\theta}_{oxidising\ agent} - E^{\theta}_{reducing\ agent}$ ✓ (or alternatives)

2 ✓✓ $= E^{\theta}_{oxidising\ agent} - (-1{,}66)$ ✓

$E^{\theta}_{oxidising\ agent} = 0{,}34\ V$ ✓

M is copper/Cu. ✓

OPTION 2

$M^{2+}(aq) + 2e^- \rightarrow M(aq)$	✓	$E^{\theta}_{oxidising\ agent}$ =	+x V	
$A\ell(s) \rightarrow A\ell^{3+}(aq) + 3e^-$		$E^{\theta}_{redusing\ agent}$ =	+1,66 V	✓
$2A\ell(s) + 3M^{2+}(aq) \rightarrow 2A\ell^{3+}(aq) + 3M(aq)$		E^{θ}_{cell} =	+2,00 V	✓✓

x = 0,34 (V) ✓; M is copper/Cu. ✓

(6)

21.6.1 Magnesium/Mg ✓ (1)
21.6.2 $A\ell^{3+}$ is a stronger oxidising agent than Mg^{2+} ✓. Therefore, Mg will be oxidised ✓ (to Mg^{2+}). **OR**
Mg^{2+} is a weaker oxidising agent than $A\ell^{3+}$. Therefore, Mg will be oxidised ✓ (to Mg^{2+}). (2)

[15]

QUESTION 22 (November 2024)

22.1.1 The oxidation number of H changes from +1 to 0 ✓AND the oxidation number of Mg changes from 0 to +2. ✓ **OR**
$H^+ \rightarrow H_2^0$ Oxidation number decreases.
$Mg^0 \rightarrow Mg^{2+}$ Oxidation number increases. (2)
22.1.2 H+/HCℓ ✓ (1)
22.1.3 Cu/copper is a weaker reducing agent ✓ than Mg/magnesium ✓ and will not reduce H^+/hydrogen ions to H_2. (2)
22.1.4 Yes ✓
NO_3^-/ The nitrate ion / Nitric acid is a stronger oxidising agent ✓ than Cu^{2+}/copper(II) ion ✓ (therefore Cu/copper will be oxidised to Cu^{2+}/copper(II) ion). (3)
22.2.1 $Pb(s) + 2Fe^{3+}(aq)$ ✓ $\rightarrow Pb^{2+}(aq) + 2Fe^{2+}(aq)$ ✓ Bal: ✓ **OR**
$Pb + 2Fe^{3+} \rightarrow Pb^{2+} + 2Fe^{2+}$ (3)
22.2.2 Increases ✓ (1)

[12]

ELECTROLYTIC CELLS

QUESTION 1 (November 2014)

1.1 Electrolytic ✓ (1)
1.2 Q ✓ & T ✓ $Cu^{2+} + 2e^- \rightarrow Cu$ ✓✓ (4)
1.3.1 $C\ell_2$ / chlorine gas ✓ (1)
1.3.2 Cu^{2+} ions / copper(II) ions / $CuC\ell_2$ / copper(II) chloride ✓ (1)
1.4 Cu is a stronger reducing agent ✓ than $C\ell^-$ ions ✓ and Cu will be oxidised ✓ to Cu^{2+}.
OR $C\ell^-$ ions is a weaker reducing agent ✓ than Cu ✓ and Cu will be oxidised ✓ to Cu^{2+}. (3)
[10]

QUESTION 2 (March 2015)

2.1 A solution that conducts electricity through the movement of ions. ✓✓ (2)
2.2 $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ✓✓ (2)
2.3 Chlorine gas / $C\ell_2$ ✓ (1)
2.4 H_2O is a stronger oxidising agent ✓ than Na^+ and will be reduced ✓ to H_2. (2)
[7]

QUESTION 3 (June 2015)

3.1 A solution that conducts electricity through the movement of ions. ✓✓ (2)
3.2 Plastic is a non-conductor of electricity. / Graphite is a conductor. ✓ (1)
3.3 $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$ ✓✓ (2)
3.4 Ni / nickel ✓ Ni is oxidised. ✓
OR: Ni loses electrons. **OR:** Ni is the anode. **OR:** Ni is the positive electrode. (2)
3.5 Ring ✓
Reduction takes place at the cathode. ✓ **OR:** Negative electrode. (2)
3.6 Decreases ✓
Ni^{2+} ions from the electrolyte will be reduced (to Ni). ✓ **OR** Ni^{2+} changes to Ni. (2)
[11]

QUESTION 4 (March 2016)

4.1 Electrolytic cell ✓ (1)
4.2 The substance/species which loses electrons. ✓✓ (2)
4.3 P ✓ (1)
4.4 $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ ✓✓ (2)
4.5 A ✓
$C\ell^-$ ions move to the positive electrode / anode where they are oxidised to $C\ell_2$. ✓✓ (3)
[9]

QUESTION 5 (June 2016)

5.1.1 Electrolyte ✓ (1)
5.1.2 Electrolytic cell ✓ (1)
5.2 A to B ✓ (1)
5.3.1 B ✓ (1)
5.3.2 A ✓ (1)
5.4 Decreases ✓
Copper (Cu) is oxidised to Cu^{2+} / Oxidation takes place at A. ✓ (2)
[7]

QUESTION 6 (June 2017)

6.1 Electrolytic cell ✓ (1)
6.2 P ✓ (1)
6.3.1 $Au(s) \rightarrow Au^{3+}(aq) + 3e^-$ ✓✓ (2)
6.3.2 +3 ✓ (1)
6.3.3 Electrical energy (is converted) to chemical energy ✓ (1)
6.3.4 Becomes smaller/thinner/eroded. ✓ (1)
6.4 Increase in value. ✓ **OR** Protection against rust. (1)
6.5 **ANY ONE:**
Replace $Au^{3+}(aq)$ / electrolyte with $Ag^+(aq)$ / silver(I) solution.; Replace P/anode with Ag(s). (1)
[9]

QUESTION 7 (November 2017)

7.1 DC/GS ✓ (1)

7.2 Cathode ✓

$Cu^{2+}(aq) + 2e^- \rightarrow Cu$ ✓✓ (3)

7.3 Cu^{2+} ions is a stronger oxidising agent ✓ than Zn^{2+} ions ✓ and therefore Zn^{2+} ions will not be reduced (to Zn). ✓

OR Zn^{2+} ions is weaker oxidising agent than Cu^{2+} ions and therefore Zn^{2+} ions will not be reduced (to Zn). (3)

7.4.1 (Chlorine) gas/bubbles is/are formed. ✓ (1)

7.4.2 Decreases ✓ (1)

[9]

QUESTION 8 (March 2018)

8.1 The chemical process in which electrical energy is converted to chemical energy. ✓✓

OR The use of electrical energy to produce a chemical change. (2)

8.2 B ✓ (1)

8.3 $Cu^{2+}(aq) + 2e^- \rightarrow Cu$ ✓✓ (2)

8.4 $\%\ purity = \frac{m(Cu)}{m(Cu)_{impure\ /\ onsuiwer}} \times 100$

$= \frac{4,4✓}{5✓} \times 100✓ = 88\%$ ✓ (4)

[9]

QUESTION 9 (June 2018)

9.1.1 Electrolyte ✓ (1)

9.1.2 Conduct electricity ✓ (1)

11.2 $Cu(NO_3)_2$ ✓ (1)

9.3 Iron rod ✓ Reduction takes place. ✓ (2)

9.4 $Cu \rightarrow Cu^{2+} + 2e^-$ ✓✓ (2)

9.5.1 Copper(II) (ions)/Cu^{2+} ✓and silver (ions)/Ag^+ ✓ (2)

9.5.2 Ag^+/silver(I) ions is a stronger oxidising agent ✓ than Cu^{2+}/Copper(II) ions and will be reduced (more readily) ✓ to form silver/Ag on the iron rod. (2)

[11]

QUESTION 10 (November 2018)

10.1 A cell in which electrical energy is converted to chemical energy. ✓✓

OR A cell in which electrical energy/electricity is used to obtain a chemical change/reaction. (2)

10.2 Any soluble copper(II) salt e.g. $CuSO_4/Cu(NO_3)_2/CuC\ell_2$ ✓ (1)

10.3 B ✓ $Cu^{2+} + 2e^- \rightarrow Cu$ ✓✓ (3)

10.4 Platinum/Pt ✓

AND

silver/Ag ✓ (2)

[8]

QUESTION 11 (June 2019)

11.1 Electrolytic ✓ (1)

11.2 $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ✓✓ (2)

11.3.1 Chlorine (gas) / $C\ell_2$ ✓ (1)

11.3.2 P ✓ & Y ✓ (2)

11.4 Cathode ✓

Reduction takes place here./Gains electrons. ✓ (2)

11.5 $CuC\ell_2(aq)$ ✓ $\rightarrow Cu(s) + C\ell_2(g)$✓ Bal ✓

OR

$Cu^{2+}(aq) + 2C\ell^- \rightarrow Cu(s) + C\ell_2(g)$ (3)

[11]

QUESTION 12 (November 2019)

12.1 The chemical process in which electrical energy is converted to chemical energy. ✓✓

OR

The use of electrical energy to produce a chemical change. (2)

12.2.1 $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ✓✓ (2)

12.2.2 Water/ H_2O ✓ (1)

12.3 H_2O is a stronger oxidising agent ✓ than Na^+ ✓ and will be reduced ✓ (to H_2).

OR

Na^+ is a weaker oxidizing agent ✓than H_2O ✓and therefore H_2O will be reduced ✓ (to H_2) (3)

[8]

QUESTION 13 (November 2020)

13.1 **ANY ONE (2 or 0):**

- The chemical process in which electrical energy is converted to chemical energy. ✓✓
- The use of electrical energy to produce a chemical change.
- Decomposition of an ionic compound by means of electrical energy.
- The process during which and electric current passes through a solution/ionic liquid/molten ionic compound. (2)

13.2 Battery/cell/ power source ✓ (1)

13.3 Silver nitrate/$AgNO_3$/ Silver ethanoate/CH_3COOAg / Silver fluoride /AgF/ Silver perchlorate $AgC\ell O_4$. ✓ (1)

13.4 Remains the same ✓
Rate of oxidation is equal to the rate of reduction. ✓ (2)

13.5 $Ag \rightarrow Ag^+ + e^-$ ✓✓ (2)

[8]

QUESTION 14 (June 2021)

14.1 Electrolytic (cell) ✓
Cells have a battery/Electrical energy is converted to chemical energy. ✓ (2)

14.2.1 $2C\ell^- \rightarrow C\ell_2 + 2e^-$ ✓✓ (2)

14.2.2 $A\ell^{3+} + 3e^- \rightarrow A\ell$ ✓✓ (2)

14.2.3 Cu/copper ✓ (1)

[7]

QUESTION 15 (September 2021)

15.1 **ANY ONE:**

- The chemical process in which electrical energy is converted to chemical energy. ✓✓
- The use of electrical energy to produce a chemical change.
- Decomposition of an ionic compound by means of electrical energy.
- The process during which an electric current passes through a solution/ionic liquid/molten ionic compound. (2)

15.2 Copper(II) ions/Cu^{2+} ✓
Zinc(II) ions/Zn^{2+} ✓ (2)

15.3 $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ ✓✓ (2)

15.4 Zn^{2+} is a weaker oxidising agent ✓ than Cu^{2+} ✓and will not be reduced to Zn. ✓ (3)

15.5 n(Cu) = ½n(electrons) ½(0,6) ✓ = 0,3 mol
m = nM = 0,3 x 63,5 ✓ = 19,05 g ✓ (3)

[12]

QUESTION 16 (November 2021)

16.1 **ANY ONE:**

- A substance whose aqueous solution contains ions. ✓✓
- Substance that dissolves in water to give a solution that conducts electricity.
- A substance that forms ions in water / when melted. (2)

16.2 Anode ✓
Chromium is oxidised./Oxidation takes place (at the anode). ✓ (2)

16.3 $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$ ✓✓ (2)

16.4

Marking criteria:

- Substitute 52 g·mol^{-1} in $n = \frac{m}{M}$/ratio ✓
- Use mol ratio: n(electrons) : n(Cr) = 3 : 1. ✓
- Number of electrons = n x 6,02 x 10^{23}/ratio. ✓
- Total charge = number of electrons x 1,6 x 10^{-19}/ratio. ✓
- Final answer: 11 113,85 C ✓
  Range: 11 113 to 11 558,4 C

$n = \frac{m}{M} = \frac{2}{52}$ ✓ = 0,038 mol
n(electrons) = 3n(Cr) ✓ = 3(0,038) = 0,115 mol

Number of electrons = 0,115 x 6,02 x 10^{23} ✓ = 6,95 x 10^{22} Q = 6,95 x 10^{22} x 1,6 x 10^{-19} ✓ = 11 113,85 C ✓	1 mol ………… 96 500 C ✓ 0,0385 mol ……11 145,74 C ✓✓

(5)

[11]

QUESTION 17 (June 2022)

17.1 **ANY ONE:**

- The chemical process in which electrical energy is converted to chemical energy. ✓✓ **(2 or 0)**
-
- The use of electrical energy to produce a chemical change.
- Decomposition of an ionic compound by means of electrical energy.
- The process during which an electric current pass through a solution/ionic liquid/molten ionic compound. (2)

17.2.1 X ✓ (1)

17.2.2 $2H_2O(\ell) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ✓✓ (2)

17.2.3 X to Y ✓ (1)

17.2.4 $2H_2O(\ell) + 2C\ell^-(aq)$ ✓ $\rightarrow C\ell_2(g) + H_2(g) + 2OH^-(aq)$ ✓ Bal ✓

OR

$2H_2O(\ell) + 2NaC\ell(aq) \rightarrow C\ell_2(g) + H_2(g) + 2NaOH(aq)$ (3)

17.3 Increases ✓ (1)

17.4 Solution becomes basic / OH^- ions form ✓ (1)

[11]

QUESTION 18 (June 2023)

18.1 A cell in which electrical energy is converted into chemical energy. ✓ (2)

18.2 R ✓

Oxidation takes place. ✓ (2)

18.3

18.3.1 $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ ✓✓ (2)

18.3.2 Zinc/Zn ✓ (1)

18.3.3 Zn^{2+} ions are reduced/[Zn^{2+}] decreases. ✓

Zn^{2+} ions must be replaced by oxidation of the Zn electrode. ✓ (2)

[9]

QUESTION 19 (November 2023)

19.1 **ANY ONE**:

- The chemical process in which electrical energy is converted to chemical energy. ✓✓ **(2 or 0)**
- The use of electrical energy to produce a chemical change.
- Decomposition of an ionic compound by means of electrical energy.
- The process during which an electric current pass through a solution/ionic liquid/molten ionic compound. (2)

19.2 $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ ✓✓ (2)

19.3 R to Q ✓ (2)

19.4 **Marking criteria:**

- Substitution of 63,5 into n = ✓
- Substitute 6,02 x 10^{23} mol^{-1} ✓
- N(electrons) = N(Cu atoms) x 2 **OR** N(electrons) = N(Cu atoms) x 1 ✓
- Calculate t = (5)(60)(60) ✓
- Final correct answer: 2,68 A ✓
- Range: 1,34 to 2,70 A

USING Cu^{2+}	**USING Cu^{+}**
$n(Cu) = \frac{m}{M}$	$n(Cu) = \frac{m}{M}$
$n(Cu) = \frac{16}{63,5}$ ✓**(a)** = 0,25 mol	$n(Cu) = \frac{16}{63,5}$ ✓**(a)** = 0,25 mol
$n(Cu) = \frac{N}{N_A}$	$n(Cu) = \frac{N}{N_A}$
$0,25 = \frac{N}{6,02 \times 10^{23}}$ ✓**(b)** ∴N = 1,5 x 10^{23} atoms	$0,25 = \frac{N}{6,02 \times 10^{23}}$ ✓**(b)** ∴N = 1,5 x 10^{23} atoms
N(electrons) = (1,5 x 10^{23})(2) ✓**(c)** = 3 x 10^{23} electrons	N(electrons) = (1,5 x 10^{23})(1) ✓**(c)** = 1,5 x 10^{23} electrons
$N(electrons) = \frac{Q}{e}$ **OR** $\frac{Q}{q_e}$	$N(electrons) = \frac{Q}{e}$ **OR** $\frac{Q}{q_e}$
$3 \times 10^{23} = \frac{Q}{1,6 \times 10^{-19}}$ = 48 160 C	$1,5 \times 10^{23} = \frac{Q}{1,6 \times 10^{-19}}$ = 24 080 C
$I = \frac{Q}{\Delta t}$	$I = \frac{Q}{\Delta t}$
$= \frac{48\ 160}{(5)(60)(60)}$ ✓**(d)** = 2,68 A ✓**(e)**	$= \frac{24\ 080}{(5)(60)(60)}$ ✓**(d)** = 1,34 A ✓**(e)**

19.5 Ag/silver is a weaker reducing agent ✓ than Cu/coper or Zn/zinc ✓ and will not be oxidised.
OR
Cu/coper or Zn/zinc is a stronger reducing agent ✓ than Ag/silver ✓ and Ag will not be oxidised. ..(2)
[12]

QUESTION 20 (June 2024)

20.1 Electrical to chemical (energy). ✓ (1)

20.2 P ✓ (1)

20.3 $Ag^+ + e^- \rightarrow Ag$ ✓✓ (2)

20.4

$$n(Ag) = \frac{m}{M}$$
$$= \frac{3,25}{108} ✓$$
$$= 0,03\ mol$$

$$n(electrons) = \frac{N(electrons)}{N_A}$$
$$0,03 ✓ = \frac{N(electrons)}{6,02x10^{23}} ✓$$
$$N(electrons) = 1,81x10^{22}$$

$$I = \frac{Q}{\Delta t}$$
$$= \frac{(1,81x10^{22})(1,6x10^{-19})}{(30)(60)} ✓$$
$$= 1,61\ A ✓$$

(5)
[9]

QUESTION 21 (November 2024)

21.1

<u>OPTION 1</u>

$E^{\theta}_{cell} = E^{\theta}_{oxidising\ agent} - E^{\theta}_{reducing\ agent}$ ✓

$= -0{,}13$ ✓ $- (0{,}80)$ ✓

$= -0{,}93\ V$ ✓

Non-spontaneous ✓

<u>OPTION 2</u>

$Pb^{2+} + 2e^- \rightarrow Pb$	} ✓	$E^{\theta}_{oxidising\ agent}$ =	-0,13 V	✓
$2Ag \rightarrow 2Ag^+ + 2e^-$		$E^{\theta}_{redusing\ agent}$ =	-0,80 V	✓
$Pb^{2+} + 2Ag \rightarrow Pb + 2Ag^+$		E^{θ}_{cell} =	-0,93 V	✓

Non-spontaneous ✓

(5)

21.2.1 ANY ONE: (2 or 0)
A substance of which the (aqueous) solution contains ions. ✓✓
A substance that dissolves in water to give a solution that conducts electricity.
A substance that forms ions in water / when melted.
A solution/substance that conducts electricity through the movement of ions. (2)

21.2.2 $2C\ell^- \rightarrow C\ell_2 + 2e^-$ ✓✓ (2)

21.2.3 OH^-/Hydroxide ions/Sodium hydroxide/NaOH ✓
H_2/Hydrogen ✓ (2)

21.2.4 Water/H_2O is a stronger oxidising agent ✓ than Na^+/ the sodium ion and water/H_2O will be reduced. ✓ **OR**
Na^+/ The sodium ion is a weaker oxidising agent than water/H_2O and water/H_2O will be reduced. (2)

[13]

BIBLIOGRAPHY

Department of Basic Education, *National Senior Certificate Physical Sciences Question Papers*, 2014 – 2024, Pretoria