# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 1

**1** B <u>Experiment I</u>

| Test tube *a* | Test tube *b* |
|---|---|
| Absence of water | Tap water (Water is present) |

Therefore, the manipulated variable for Experiment I is the presence and absence of water.

<u>Experiment II</u>

| Test tube *c* | Test tube *d* |
|---|---|
| Boiled water (Boiling removes oxygen. Oxygen is absent) | Tap water (Oxygen is present) |

Therefore, the manipulated variable for Experiment II is the presence and absence of oxygen.

**2** A The same volume of hydrogen peroxide is poured into two test tubes.
Then, the same amounts of magnesium oxide and manganese(IV) oxide are added to the test tubes respectively.
Glowing wooden splinters is put near the mouth of each of the test tube and which test tube releases oxygen earlier is observed. This is signaled by the rekindling of the glowing wooden splinter.
Therefore, the manipulated variable is adding magnesium oxide or manganese(IV) oxide added to each test tube.

**3** B The concentration and temperature of reactants affect the rate of a reaction.
The higher the concentration, the higher the rate of collisions between the hydrogen peroxide particles. Thus, the rate of reaction is higher.
The higher the temperature, the faster the hydrogen peroxide molecules move, resulting in a higher rate of collisions between the molecules. Thus, the rate of reaction is higher.
Thus, if we want to study if MgO and $MnO_2$ affect the rate of decomposition of hydrogen peroxide, the mass of MgO and $MnO_2$, and the concentration and temperature of hydrogen peroxide must be kept constant.

**4** A The experiment is carried out by pouring hydrochloric acid of different concentrations into different beakers. Then, a length of magnesium ribbon is added to the first beaker and the stopwatch is started. The time for the magnesium ribbon to dissolve is recorded.
The experiment is repeated by adding magnesium ribbons of the same length to the HCl solutions in the different beakers.
Thus, the length of the magnesium ribbon must be the same for each experiment (I is correct) but the concentration of hydrochloric acid is manipulated (II is incorrect).
The kinetic energy of the hydrogen ions is higher when the temperature of the hydrochloric acid is higher. Therefore, the rate of collisions between the hydrogen ions from HCl and the surface of the magnesium ribbon is higher making the rate of reaction is higher.
Thus, the temperature of the HCl solution must be kept constant (III is correct).
The size of beakers used will not affect the rate of reaction (IV is incorrect).

**5** B The volume and temperature of water used affect the solubility of salt. If we want to study the effect of volume of water on the solubility of salt, we need to manipulate the volume of water used in each beaker but the temperature of water in each beaker must be kept constant.

**6** D If we want to study which solvent can dissolve polystyrene, we pour the different solvents, water and benzene, into two different boiling tubes (manipulated variable). Then, we add polystyrene to each boiling tube and stir the mixture with a glass rod. The mass of polystyrene added must be fixed (fixed variable).

**7** C Adding an alkali to an acid will neutralise the acid to produce salt and water.

**8** A A more reactive metal takes a shorter time to react completely with an acid solution

compared to a less reactive metal.
Magnesium ribbon takes the shortest time to react. Thus, magnesium is the most reactive metal.
Iron takes the longest time to react. Thus, iron is the least reactive.
To arrange metals in increasing order of reactivity, arrange them from least reactive metal to the most reactive metal.

**9** A The experiment can be carried out by pouring the same volume of water into two boiling tubes (fixed variable).
Then, add the same mass of potassium hydroxide and magnesium hydroxide into each boiling tube and stir the mixtures with glass rods and observe which substance dissolve in water (manipulated variable).

**10** C The symbol is used to show that a chemical is a flammable chemical. Such chemicals must be stored away from sources of fire and fire.

**11** B According to the chemical equation, chlorine gas is one of the products of the reaction. Chlorine gas is poisonous and to avoid inhaling the gas, the experiment must be carried out in a fume chamber.

**12** A Diluting concentrated acid is an exothermic process where a lot of heat energy is released. Adding water to a solution of concentrated acid may cause the water to boil and causes the solution to splash out (B is false).
Concentrated acid solutions are denser than water. If we pour concentrated acid solutions into water, the acid particles will flow slowly into the water. There is less risk of the resulting acid solution spilling out (A is true).

**13** D Based on the diagram, one conical flask contains bigger-sized marble chips whereas the other conical flask contains smaller-sized marble chips. The size of the marble chips is the manipulated variable. The smaller the marble chips, the bigger the total surface area of the marble exposed to acid. Therefore, the rate of collisions of acid particles with the surface of the marble chips is higher.
Based on the chemical equation, the reaction between HCl and marble chips releases carbon dioxide gas. As the reaction progresses, within the same amount of time, the mass of the conical flask containing the smaller-sized marble chips decreases more rapidly and releases a higher amount of carbon dioxide gas compared to the conical flask with the bigger-sized marble chips.

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 2

**1** A Ionic compounds consist of metallic and non-metallic elements.
Covalent compounds are made of molecules formed by two or more non-metallic elements that are chemically bonded.
The following compounds consist of ions:

| Compound | Cation | Anion |
|---|---|---|
| Copper(II) sulphate, $CuSO_4$ | $Cu^{2+}$ | $SO_4^{2-}$ |
| Potassium chloride, KCl | $K^+$ | $Cl^-$ |
| Magnesium nitrate, $Mg(NO_3)_2$ | $Mg^{2+}$ | $NO_3^-$ |
| Sodium carbonate, $Na_2CO_3$ | $Na^+$ | $CO_3^{2-}$ |

**2** D Covalent compound are made of molecules formed by two or non-metallic elements that are chemically bonded.
The following compounds consist of molecules:

| Compound | Formula |
|---|---|
| Sulphur dioxide | $SO_2$ |
| Glucose | $C_6H_{12}O_6$ |
| Ammonia | $NH_3$ |
| Naphthalene | $C_{10}H_8$ |

**3** C All metals and inert gases (elements of Group 18) consist of atoms.
Iron, tin and copper are metals while helium is an inert gas.
Chlorine and nitrogen exist as diatomic molecules, $Cl_2$ and $N_2$.
A sulphur molecule consists of 8 sulphur atoms, $S_8$ that are chemically bonded.
A phosphorus molecule consists of 4 phosphorus atoms, $P_4$ that are chemically bonded.

**4** B Melting is the process in which a solid changes to liquid.
Heat energy is absorbed to overcome the forces of attraction between the particles of a substance before it can melt (I is true, II and III are false).
The distance between the particles of a liquid is further that the distance between particles of a solid (IV is correct).

**5** C The heavier the gas molecules, the lower the rate of diffusion of the gas out of the balloon, as a result, the balloon remains its initial size for longer.
The lighter the gas molecules, the higher the rate of diffusion of the gas out of the balloon, as a result, the balloon reduces in size faster.

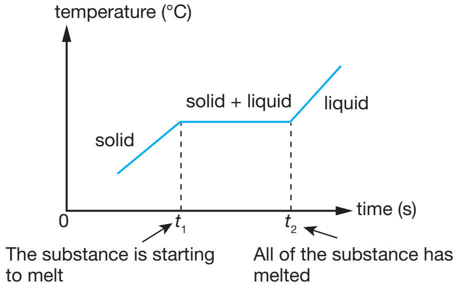
| Gas | Relative molecular mass | Rate of diffusion | Size of balloon |
|---|---|---|---|
| $C_4H_{10}$ | 58 | Low | Big |
| $NH_3$ | 17 | High | The smallest |
| $SO_2$ | 64 | Lowest | The biggest |
| $N_2$ | 28 | Low | Small |

**6** B During time $t_1$ to $t_2$, the acetamide is melting where heat energy is absorbed to overcome the forces of attraction between the molecules and the molecules move further apart. The further the molecules, the weaker the forces of attraction between the molecules. Chemical bonds are only broken during a chemical reaction, not during melting.

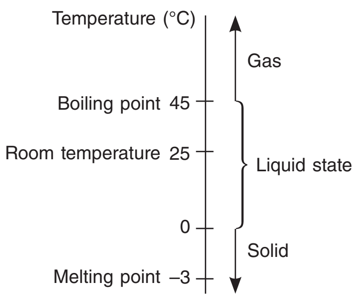
**7** A Based on the diagram, before the process, the particles are arranged in a regular manner (solid state), while after the process, the particles are further apart but still in contact with each other (liquid state). Thus, the process is melting during which heat energy is absorbed to overcome the forces of attraction between the particles.

**8** D Ice (solid) is heated until it boils (steam / gaseous state). During melting, ice turns into water and the temperature is constant. The constant temperature is reflected on the graph as a flat line. During the boiling of water to steam, the temperature also remains constant. The constant temperature is reflected on the graph as a flat line.

**9** A




**10** C




Below –3°C, the substance exists as a solid. Above 45°C, the substance exists as gas.

**11** B After some time, the solution turned orange. This shows that the orange dichromate(VII) ions are in random motion and diffuse throughout the solution.

**12** D Air is colourless whereas bromine is a dark brown gas. Once the gas jar cover is removed, the air and bromine molecules in the jars diffuse randomly until they are evenly distributed between the gas jars. Thus, both gas jars contain light brown gas as the bromine molecules are distributed evenly between the gas jars.

**13** D Atomic model I shows an atom with a nucleus and electrons embedded around it. This model is suggested by Rutherford. After he bombarded a thin gold foil with alpha particles, he found that some particles are deflected which led him to suggest that protons in the nucleus of atoms repel the positively charged alpha particles.
Thomson discovered electrons and suggested that electrons are distributed throughout an atom as shown by atomic model II.

**14** A Thomson discovered electrons when he carried out an experiment using a discharge tube.
Rutherford discovered protons when he bombarded a thin gold foil with alpha particles.
James Chadwick discovered neutral particles which he then calls neutrons.
Niels Bohr showed that electrons are arranged in shells around the nucleus of atoms.

**15** B Niels Bohr carried out an experiment that studies the emission spectra of elements and found that each element emits emission spectra with a specific wavelength. He then suggested that electrons in atoms are arranged in shells around the nucleus.

**16** C The electron arrangement given is 2.8.18.5.
The total number of electrons = 33
Thus, arsenic has 33 electrons and 33 protons.
The number of neutrons given is 42.
Therefore, the nucleon number = 33 + 42
= 75

**17** D Atom *X* releases two valence electrons during a chemical reaction and forms an ion with the charge +2.

$$X \rightarrow X^{2+} + 2e^-$$
2.8.18.18.8.2   2.8.18.18.8

Thus, both atom *X* and ion $X^{2+}$ have 56 protons in their nucleus.
The number of neutrons in the nucleus = 81
Therefore, the nucleon number = 56 + 81
= 137

**18** B Atom *Y* has 7 valence electrons.
During a chemical reaction, atom *Y* accepts an electron to achieve the stable octet electron arrangement and forms ion $Y^-$ with the charge –1.

$$Y + e^- \rightarrow Y^-$$
2.8.18.18.7   2.8.18.18.8

Thus, both atom *Y* and ion $Y^-$ have 53 protons.
The number of neutrons = 74
Therefore, the nucleon number = 53 + 74
= 127

**19** A Aluminium atom has 13 protons, 13 electrons and 14 neutrons.
During a chemical reaction, an aluminium atom releases 3 valence electrons and forms aluminium ion, $Al^{3+}$ that has a stable octet electron arrangement.

$$Al \rightarrow Al^{3+} + 3e^-$$
2.8.3   2.8

The number of protons and neutrons in the nucleus of the atom do not change during a chemical reaction. An aluminium ion has 13 protons, 10 electrons and 14 neutrons.

**20** A Selenium atoms have 6 valence electrons.
During chemical reactions, the atoms accept 2 electrons and forms selenide ions to achieve the stable octet electron arrangement.

$$Se + 2e^- \rightarrow Se^{2-}$$
2.8.18.6   2.8.18.8

Thus, a selenium atom has 34 protons.

**21** C The nucleon number of *X* is 17 and the proton number is 7. (I is true)
The electron arrangement of *X* is 2.5. It has 5 valence electrons. (II is true)
*X* belongs to group 15 in the Periodic Table. (III is true)
Elements with the proton number 17 have 7 valence electrons and belong in Group 17. Elements of different Groups have different chemical properties. (IV is false)

**22** D

| Particle | Proton number | Electron arrangement | Total number of electrons | Charge of particle |
|---|---|---|---|---|
| *P* | 9 | 2.8 | 10 | –1 |
| *Q* | 19 | 2.8.8 | 18 | +1 |

**23** C Atoms with the same number of valence electrons have the same chemical properties.

| Element | *P* | *Q* | *R* | *S* |
|---|---|---|---|---|
| Proton number | 3 | 5 | 13 | 17 |
| Electron arrangement | 2.1 | 2.3 | 2.8.3 | 2.8.7 |

Elements *Q* and *R* each has 3 valence electrons and therefore they have the same chemical properties.

**24** B A positively charged ion is formed when an atom releases its valence electron(s) during a reaction.

$$W \rightarrow W^+ + e^-$$
2.8.1   2.8

Both atom *W* and ion $W^+$ have 11 protons
Nucleon number
= (number of protons) + (number of neutrons)
= 11 + 12
= 23 (A is correct)

$$Y \rightarrow Y^{2+} + 2e^-$$
2.8.8.2   2.8.8

Both atom *Y* and ion $Y^{2+}$ have 20 protons
Nucleon number
= (number of protons) + (number of neutrons)
= 20 + 20
= 40 (C is correct)

A negatively charged ion is formed when an atom accepts electron(s) during a reaction.

$$X + 2e^- \rightarrow X^{2-}$$
2.6   2.8

Both atom *X* and ion $X^{2-}$ have 8 protons.
Nucleon number = 8 + 8
= 16 (B is incorrect)

$$Z + e^- \rightarrow Z^-$$
2.8.7   2.8.8

Both atom *Z* and ion $Z^-$ have 17 protons.
Nucleon number = 17 + 18
= 35 (D is correct)

**25** B The electron arrangement of *X* is 2.7.
The electron arrangement of *Y* is 2.8.7.
Both *X* and *Y* have the same chemical properties as both elements have 7 valence electrons.

**26** C Gamma rays are electromagnetic waves with a short wavelength that can kill microbes.
The ray is used to sterilise plastic hypodermic syringes and surgical gloves.

**27** A Living plants take in carbon dioxide during photosynthesis. Some of the carbons in carbon dioxide are radioactive carbon-14. Carbon-14 is incorporated in the bodies of animals that eat the plants. When the plants or animals die, the carbon-14 will decay. The longer the plants or animals have died, the lesser the carbon-14 content that remains in the organisms.

**28** D The electron arrangement of both $^{127}_{53}I$ and $^{131}_{53}I$ is 2.8.18.18.7.
I-127 and I-131 have different physical properties. (I is incorrect)
Each isotope has 7 valence electrons. Thus, they have the same chemical properties. (II is correct)
Isotopes of the same element have different numbers of neutrons. (III is false)
Isotopes of the same element have the same number of protons. (IV is correct)

**29** D Isotopes have the same number of protons but different numbers of neutrons.

| $^{35}_{17}Cl$ | $^{37}_{17}Cl$ |
|---|---|
| 17 protons | 17 protons |
| 18 neutrons | 20 neutrons |

**30** C Sodium-24 is injected in pipes carrying flammable gas and is carried along the pipe. A Geiger Muller tube is used to detect the part of the pipe that has a leak. The part of the pipe that is leaking will show a high radiation reading on the Geiger Muller tube.

**31** D Cobalt-60 disintegrates and releases gamma radiations with a short wavelength. These high energy electromagnetic waves can kill cancer cells.

**32** B RAM of magnesium

$$= \frac{(79 \times 24) + (10 \times 25) + (11 \times 26)}{100}$$

$= 24.32$

**33** A Assume the percentage abundance of boron-11 $= x\%$

Percentage abundance of boron-10 $= (100 - x)\%$

$$\frac{10(100 - x) + 11x}{100} = 10.8$$

$$1000 - 10x + 11x = 1080$$

$$x = 1080\text{-}1000$$

$$x = 80\%$$

**34** C Assume the percentage abundance of lithium-7 $= x\%$

Percentage abundance of lithium-6 $= (100 - x)\%$

$$\frac{7x + 6(100 - x)}{100} = 6.925$$

$$x = 92.5$$

**35** A RAM of potassium $= \frac{39(93.26) + 41(6.74)}{100}$

$= 39.13$

**36** A Assume the percentage abundance of gallium-71 $= x\%$

Percentage abundance of gallium-69 $= (100 - x)\%$

$$\frac{71x + 69(100 - x)}{100} = 69.8$$

$$x = 40\%$$

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 3

**1** D The charge of nitrate ions is –1.
Thus, the charge of metal *X* ion is +3.
The charge of sulphate ions is –2.
Therefore, the formula of *X* sulphate is $X_2(SO_4)_3$.
Check: Net charge 2(+3) + 3(–2) = 0

**2** C RFM of $CuSO_4.5H_2O$ = 64 + 32 + 4(16) + 5(18)
= 250
Percentage mass of water from crystallisation
$= \frac{90}{250} \times 100\%$
= 36%

**3** B Assume the relative atomic mass of element *X* = *m*
Given RFM of $K_2X_2O_7$ = 294
Therefore, 2(39) + 2*m* + 7(16) = 294
*m* = 52

**4** A Given the RFM of $Al_2O_3.2SiO_2.xH_2O$ = 258
2(27) + 3(16) + 2[28 + 2(16)] + 18*x* = 258
54 + 48 + 120 + 18*x* = 258
18*x* = 36
*x* = 2

**5** C Given the RFM of $M_4Fe(CN)_6$ = 368
Assume the relative atomic mass of element *M* = *a*
Therefore, 4*a* + 56 + 6(12 + 14) = 368
4*a* + 56 + 156 = 368
*a* = 39

**6** B Given the RFM of $Z_2CO_3.10H_2O$ = 286
Assume RAM of metal *Z* = *a*
2*a* + 12 +3(16) + 10(18) = 286
2*a* + 12 + 48 + 180 = 286
2*a* = 46
*a* = 23
Percentage mass of metal $Z = \frac{46}{286} \times 100\ \%$
= 16.08 %

**7** A Carbon form many compounds, thus is it reactive. (A is false)

**8** B Carbon-12 is used as a standard for mole.
Thus, 1 mole of a substance contains the same number of particles as 12.00 g of carbon-12.

**9** C RMM of urea, $CO(NH_2)_2$ = 12 + 16 + 2[(14 +2(1)]
= 60
There are 2 nitrogen atoms in urea.
The percentage mass of nitrogen $= \frac{28}{60} \times 100\%$
= 46.67%

**10** D $Fe_2O_3 \rightarrow 2Fe$
$2(56) + 3(16) \rightarrow 2 \times 56$
160 g of $Fe_2O_3$ produce 112 g Fe
Therefore, 8 g of iron(III) oxide should produce
$\frac{8}{160} \times 112$ g of iron = 5.6 g iron
But 4.48 g of iron was obtained in the experiment.
Thus, the percentage yield of iron
$= \frac{\text{experimental yield}}{\text{theoretical yield}} \times 100\%$
$= \frac{4.48}{5.6} \times 100\%$
= 80%

**11** A

| Compound | $C_2H_4$ | $C_3H_8$ | $CH_3COOCH_3$ | $C_2H_5OH$ |
|---|---|---|---|---|
| RMM | 28 | 44 | 74 | 46 |
| Percentage mass of carbon | $\frac{24}{28} \times 100\%$ = 85.7% | $\frac{36}{44} \times 100\%$ = 81.8% | $\frac{36}{74} \times 100\%$ = 48.6% | $\frac{24}{46} \times 100\%$ 52.2% |

**12** A The RMM of tartaric acid, $C_4H_6O_6$ = 150
The number of moles in 0.75 g tartaric acid
$= \frac{0.75}{150}$ mol
= 0.005 mol
The number of molecules in 0.005 mole of tartaric acid = $0.005 \times 6.02 \times 10^{23}$
$= 3.01 \times 10^{21}$ molecules

**13** D The RMM of methane, $CH_4$ = 16
The number of moles in 0.8 g of $CH_4 = \frac{0.8}{16}$ mol
= 0.05 mol
The number of molecules in 0.05 mole of $CH_4 = 0.05 \times 6.02 \times 10^{23}$
One $CH_4$ molecule has one carbon atom and 4 hydrogen atoms, a total of 5 atoms.
Thus, the total number of atoms in methane
$= 5 \times 0.05 \times 6.02 \times 10^{23}$
$= 1.505 \times 10^{23}$ atoms

**14** C The RMM of sucrose, $C_{12}H_{22}O_{11}$ = 342
The number of moles containing 7.525 x $10^{22}$ sucrose molecules $= \frac{7.525 \times 10^{22}}{6.02 \times 10^{23}}$ mol
= 0.125 mol
1 mole of sucrose = 342 g
0.125 mole of sucrose = $0.125 \times 342$ g
= 42.75 g

**15** B The RMM of methyl isocyanate, $CH_3NCO$ = 57
1 mole of gas occupies 22.4 $dm^3$ at STP
1.12 $dm^3$ methyl isocyanate gas $= \frac{1.12}{22.4}$ mol
= 0.05 mol
1 mole of $CH_3NCO$ = 57 g
0.05 mole of $CH_3NCO = 0.05 \times 57$ g
= 2.85 g

**16** A 1 mole of carbon monoxide, CO = 28 g
700 g of CO $= \frac{700}{28}$ mol
= 25 mol
1 mole of gas occupies 24 $dm^3$ at room conditions.
25 moles of CO = $25 \times 24$ $dm^3$
= 600 $dm^3$

**17** B 0.005 mole of paracetamol = 0.755 g
Thus, 1 mole of paracetamol
$= \frac{1 \text{ mol}}{0.005 \text{ mol}} \times 0.755$ g
= 151 g
The relative molecular mass of paracetamol = 151
RMM of $C_8H_9NO_2$ = 8(12) + 9(1) + 14 + 2(16)
= 151

**18** C 0.02 mole of allicin, $C_6H_{10}OX_2$ = 3.24 g
1 mole of allicin $= \frac{1}{0.02} \times 3.24$ g
= 162 g
Thus, the RMM of allicin, $C_6H_{10}OX_2$ = 162
Assume the relative atomic mass of element $X$ is $m$
$6(12) + 10 + 16 + 2m = 162$
$2m = 64$
$m = 32$

**19** B Substances with the same number of moles contain the same number of molecules.
4.5 g of water, $H_2O = \frac{4.5}{18}$ mol
= 0.25 mol

| **Substance** | $CO_2$ | $C_2H_5OH$ | $CH_3COOH$ | $CCl_2F_2$ |
|---|---|---|---|---|
| **RMM** | 44 | 46 | 60 | 121 |
| **Mass** | 8.8 g | 11.5 g | 12.0 g | 30.25 g |
| **Number of moles** | $\frac{8.8}{44}$ = 0.2 mol | $\frac{11.5}{46}$ = 0.25 mol | $\frac{12}{60}$ = 0.2 mol | $\frac{30.25}{121}$ = 0.25 mol |
| | I is incorrect | II is correct | III is incorrect | IV is correct |

**20** A 1.2 $dm^3$ of gas $X$ = 3.2 g

1 mole of gas (24 $dm^3$) $= \frac{24}{1.2} \times 3.2$ g

$= 64$ g

| Gas | $SO_2$ | $CO_2$ | $C_3H_8$ | $C_4H_{10}$ |
|---|---|---|---|---|
| RMM | 32 + 2(16) = 64 | 12 + 2(16) = 44 | 3(12) + 8(1) = 44 | 4(12) + 10(1) = 58 |

**21** D 1 mole of gas occupies 22.4 $dm^3$ at STP.

5.6 $dm^3$ $SO_2$ $= \frac{5.6}{22.4}$ mol

$= 0.25$ mol

RMM of $SO_2$ = 64

Mass of 0.25 mole of $SO_2$ 0.25 × 64 g = 16 g

RMM of $CO_2$ = 44

Mass of 8.4 $dm^3$ $CO_2$ $= \frac{8.4}{22.4} \times 44$ g

$= 16.5$ g

RMM of CO = 28

Mass of 14 $dm^3$ CO $= \frac{14}{22.4} \times 28$ g

$= 17.5$ g

RMM of $CH_4$ = 16

Mass of 16.8 $dm^3$ $CH_4$ $= \frac{16.8}{22.4} \times 16$ g

$= 12.0$ g

(*Note: Error in the answer section. The correct answer is D)

**22** C $3.01 \times 10^{22}$ morphine molecules has a mass of 14.25 g

$6.02 \times 10^{23}$ morphine molecules has a mass of

$\frac{6.02 \times 10^{23}}{3.01 \times 10^{22}} \times 14.25$ g = 285 g

1 mole of morphine has mass of 285 g

RMM of morphine, $C_xH_{19}NO_3$ = 285

$12x + 19(1) + 14 + 3(16) = 285$

$12x = 204$

$X = \frac{204}{12}$

$= 17$

**23** D $1.204 \times 10^{26}$ chlorine molecules

$= \frac{1.204 \times 10^{26}}{6.02 \times 10^{23}}$ mol

= 200 mol

Volume of 200 moles of chlorine gas

= 200 × 24 $dm^3$ at room conditions

= 4800 $dm^3$

**24** A 1 mole of gas occupies a volume of 22 400 $cm^3$ at STP

Number of moles in 280 $cm^3$ of $CO_2$

$= \frac{280}{22\,400}$ mol

= 0.0125 mol

Number of gas molecules $= 0.0125 \times 6.02 \times 10^{23}$

$= 7.525 \times 10^{21}$

**25** A The molecular formula for malic acid is $C_4H_6O_5$

RMM of malic acid is 4(12) + 6 + 5(16) = 134

The number of moles in 0.335 g of malic acid

$= \frac{0.335}{134}$ mol = 0.0025 mol

The number of molecules in 0.0025 mol

$= 0.0025 \times 6.02 \times 10^{23}$

$= 1.505 \times 10^{21}$

**26** D The molecular formula for a vitamin A molecule is $C_{20}H_{30}O$

RMM of vitamin A is 20(12) + 30 + 16 = 286

The number of moles containing $4.515 \times 10^{22}$

molecules $= \frac{4.515 \times 10^{22}}{6.02 \times 10^{23}}$ mol

= 0.075 mol

1 mole of vitamin A = 286 g

Therefore, 0.075 mole of vitamin A

= 0.076 × 286 g

= 21.45 g

**27** C The relative formula mass of $Ba(OH)_2$

= 137 + 2(16 + 1)

= 171

3.42 g of $Ba(OH)_2$ $= \frac{3.42}{171}$ mol

= 0.02 mol

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$

1 mol 1 mol 2 mol

1 mole of barium hydroxide ionises in water to produce a total of 3 moles of ions.

0.02 mole of barium hydroxide ionises to produce 0.02 × 3 mol of ions = 0.06 mol

The number of ions in the solution

$= 0.06 \times 6.02 \times 10^{23}$

$= 3.612 \times 10^{22}$ ions

**28** B 3 g of carbon contain $\frac{3}{21}$ mol = $\frac{1}{4}$ mol

2 g magnesium contain $\frac{2}{24}$ mol = $\frac{1}{21}$ mol

$\frac{1}{4}$ mol carbon contains $m$ atoms

$\frac{1}{12}$ mol magnesium contains $\frac{\frac{1}{12}}{\frac{1}{4}} \times m$ atoms $= \frac{1}{12} \times \frac{4}{1}\ m$ atoms

$= \frac{m}{3}$ atoms

**29** A RFM of NaF = 23 + 19 = 42

5.25 g of NaF = $\frac{5.25}{24}$ mol

= 0.125 mol

From the eqaution NaF $\rightarrow$ $Na^+$ + $F^-$,

0.125 mol of sodium fluoride produces 0.125 mol of fluoride ions.

The mass of 0.125 mol of fluoride ions = 0.125 × 19 g

= 2.375 g

**30** B

| Element | H | B | O |
|---|---|---|---|
| Percentage | 4.8% | 17.7% | 77.5 % |
| Number of mole | $\frac{4.8}{1}$ mol = 4.8 mol | $\frac{17.7}{11}$ mol = 1.61 mol | $\frac{77.5}{16}$ mol = 4.84 mol |
| Simplest ratio | $\frac{4.8}{1.61}$ = 3 mol | $\frac{1.61}{1.61}$ = 1 mol | $\frac{4.84}{1.61}$ = 3 mol |

The empirical formula is $H_3BO_3$

**31** D $M$ oxide = Metal $M$ + oxygen

3.8 g = 2.6 g + mass of oxygen

= 1.2 g

| Element | $M$ | O |
|---|---|---|
| Mass | 2.6 g | 1.2 g |
| Number of mole | $\frac{2.6}{52}$ = 0.05 mol | $\frac{1.2}{16}$ = 0.075 mol |
| Simplest ratio | $\frac{0.05}{0.05}$ = 1 mol<br>2 × 1 = 2 mol | $\frac{0.075}{0.05}$ = 1.5 mol<br>2 × 1.5 = 3 mol |

The empirical formula is $M_2O_3$

**32** C Assume relative atomic mass of metal $Y = m$

| Element | $Y$ | Cl |
|---|---|---|
| Mass | 5.76 g | 17.04 g |
| Number of mole | $\frac{5.76}{m}$ mol | $\frac{17.04}{35.5}$ = 0.48 mol |
| Simplest ratio | 1 mol | 4 mol |

The empirical formula is $YCl_4$

$$\frac{\frac{5.76}{m}}{0.48} = \frac{1}{4}$$

$$\frac{5.76}{m} = \frac{0.48}{4}$$

$$\frac{5.76}{m} = 0.12$$

$$m = \frac{5.76}{0.12}$$

$$= 48$$

**33** C

| Element | $M$ | O |
|---|---|---|
| Mass | $a$ g | 4.8 g |
| Number of mole | $\frac{a}{55}$ mol | $\frac{4.8}{16}$ = 0.3 mol |
| Simplest ratio | 2 mol | 3 mol |

The empirical formula is $M_2O_3$

$$\frac{\frac{a}{55}}{0.3} = \frac{2}{3}$$

$$\frac{a}{55} = \frac{2}{3} \times 0.3$$

$$\frac{a}{55} = 0.2$$

$$a = 0.2 \times 55 \text{ g}$$
$$= 11 \text{ g}$$

**34** B Combustion of hydrocarbon produces carbon dioxide and water.

$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$
1 mol 2 mol

From the equation, 1 mole of ethene produces 2 moles of carbon dioxide.
Thus, 28 g of $C_2H_4$ produces $2 \times 24$ dm$^3$ of $2CO_2$ at room conditions.
If 9.6 ddm$^3$ of $CO_2$ is produced, the mass of ethene burned $= \frac{9.6 \text{ dm}^3}{2 \times 24 \text{ dm}^3} \times 28$ g
$= 5.6$ g

**35** D Reactions between metals and acids produce salts and hydrogen gas.
Zinc reacts with hydrochloric acid to produce zinc chloride salt and hydrogen gas.
$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
From the equation, 1 mole of zinc produces 1 mole of hydrogen gas.
Thus, 65 g of Zn produces 22.4 dm$^3$ (22 400 cm$^3$) $H_2$ gas at STP.
448 cm$^3$ of $H_2$ gas is produced by $\frac{448 \text{ cm}^3}{22\,400 \text{ cm}^3}$ $\times$ 65 g of Zn when it reacts with excess HCl.
$= 1.300$ g

**36** A The molecular formula of potassium oxide is $K_2O$
Equation: $4K(s) + O_2(g) \rightarrow 2K_2O(s)$
4 moles of potassium produce 2 moles of potassium oxide.
$(4 \times 39)$ g of K produces $2(39 + 39 + 16)$ g of $2K_2O$ = 156 g of K produces 188 g of $2K_2O$
7.8 g of K will produce $= \frac{7.8}{156} \times 188$ g
$= 9.4$ g of $2K_2O$

**37** B Hydrogen peroxide, $H_2O_2$ decomposes to produce water and oxygen gas.
Equation: $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
2 moles of $H_2O_2$ produce 1 mole of $O_2$ gas.
2 moles of $H_2O_2$ produce 24 dm$^3$ of $O_2$ gas at room conditions.
Thus, 0.2 mole of $H_2O_2$ will produce
$= \frac{0.2 \text{ mol}}{2 \text{ mol}} \times 24$ dm$^3$
$= 2.4$ dm$^3$ of $O_2$ gas

**38** D During a combustion reaction, a chemical reacts with oxygen from the atmosphere.
Equation:
$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$
1 mole of $C_2H_5OH$ needs 3 moles of $O_2$ for a complete combustion.
Therefore, 46 g of $C_2H_5OH$ need $3 \times 22.4$ dm$^3$ of $O_2$ for complete combustion

Thus, 9.2 g of $C_2H_5OH$ need
$= \frac{9.2 \text{ g}}{46 \text{ g}} \times 3 \times 22.4$ dm$^3$ of $O_2$ for complete combustion
$= 13.44$ dm$^3$

**39** C The chemical formula of chromium(III) oxide is $Cr_2O_3$
Equation:
$2Cr_2O_3(s) + 3C(s) \rightarrow 4Cr(s) + 3CO_2(g)$
2 moles of $Cr_2O_3$ produce 4 moles of Cr metal.
2[2(52) + 3(16)] of $Cr_2O_3$ produce 4 x 52 g of Cr = 304 g of $Cr_2O_3$ produce 208 g of Cr
Thus, 7.6 g of $Cr_2O_3$ will produce $= \frac{7.6}{304} \times 208$
$= 5.20$ g of Cr

**40** A *Note*: Potassium hydroxide is an alkali whereas carbon dioxide is an acidic gas.
The neutralisation reaction will produce potassium carbonate salt and water.
Equation: $2KOH(aq) + CO_2(g) \rightarrow K_2CO_3(s) + H_2O(l)$
2 moles of KOH produce 1 mole of $K_2CO_3$
2(39 + 16 + 1) g of KOH produce
2(39) + 12 + 3(16) g of $K_2CO_3$
= 112 g of KOH produces 138 g of $K_2CO_3$
When 11.2 g of KOH reacts with carbon dioxide, the mass of potassium carbonate produced is $\frac{11.2}{112} \times 138$ g of $K_2CO_3 = 13.8$ g

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 4

**1** D Johann Dobereiner suggested that there are groups of 3 elements whereby the relative atomic mass of the middle element is close to the average of the relative masses of the first and third elements. He called these groups of 3 elements as triads.

**2** A John Newland arranged elements according to increasing RAM and found that the chemical properties of the eighth elements are similar to the first elements. He called this the Law of Octave.

| Group | 1 | 2 | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | *Q* |
| | *P* | | | | | | | | |
| | | *R* | Transition metals | | | | | *S* | |

**3** C Group 1 elements are called alkali metals
Group 2 elements are called alkali earth metals
Group 17 elements are called halogens
Group 18 elements are called inert gases

**4** B The proton number of element *Y* is
27 – 14 = 13
Element *Y* have 13 protons and therefore has 13 electrons.
The electron arrangement of atom *Y* is 2.8.3.
It has 3 valence electrons.

**5** C The 'x' in the diagram represents the electrons of element *W*.
Element *W* have 6 valence electrons.
Thus, element *W* belongs to Group 10 + 6 = 16

**6** B The proton number of element *X* is
31 – 16 = 15
Element *X* has 15 protons and therefore has 15 electrons.
Its electron arrangement is 2.8.5.
The group number of element *X* is 10 + 5 = 15
Element *X* belongs to Period 3 because it has three filled electron shells.

**7** D

| Element | $_{2}W$ | $_{8}X$ | $_{18}Y$ | $_{20}Z$ |
|---|---|---|---|---|
| Proton number | 2 | 8 | 18 | 20 |
| Number of electrons | 2 | 8 | 18 | 20 |
| Electron arrangement | 2 | 2.6 | 2.8.8 | 2.8.8.2 |
| Group | 18 Inert | 16 | 18 Inert | 2 |

*Note:* Element *W* is helium, *X* is oxygen, *Y* is argon and *Z* is calcium. It is advised to memorise the atomic number of the first 20 elements to be able to identify the elements.
*X* is diatomic/oxygen exist as diatomic molecule, $O_2$.
*Y* is inert and will not react with element *X*.
*W* is inert and will not react with element *X*.
*W* and *Y* are inert and will not react with each other.

**8** B Incandescent bulbs have tungsten filaments. When electricity is passed through the filament, it gets heated up and the tungsten atom will sublime causing the filament to break.
To increase the lifespan of the filament, the bulb is filled with argon gas. Argon gas reduces the rate of sublimation of the tungsten filament.

**9** C The element below krypton is xenon. Both elements are Group 18 elements.
All Group 18 elements are chemically inert and thus exist as monoatomic because its outermost electron shell are fully filled.
All Group 18 elements are gases at room conditions.

**10** A As we go down group 18, the relative atomic mass increases. As density is $\frac{\text{mass of atom}}{\text{volume of atom}}$, density increases down the Group. (I is true)
All Group 18 elements are inert. (II is false)
Group 18 elements do not have free moving valence electrons unlike metals. They cannot conduct electricity. (III is true)
Electronegativity is the measurement of tendency of an element to attract electron(s). All Group 18 elements have filled their outermost electron shells and do not attract electrons from other elements to form chemical bonds. They are not electronegative. (IV is false)

**11** D

| Element | $_{11}X$ | $_{18}Y$ |
|---|---|---|
| Electron arrangement | 2.8.1 | 2.8.8 |
| Group | 1 (Alkali metals) | 18 (Inert gas) |
| Period | 3 (3 electron shells) | 3 (3 electron shells) |

*Y* is inert but *X* is not inert. (A is false)
The outermost electron shell of element *Y* is filled with 8 electrons and it has achieved the octet electron arrangement. However, *X* has one valence electron and has not achieved the octet electron arrangement. (B is false)
*X* belongs to Group 1 while *Y* belongs to Group 18. (C is false)
*X* donates one valence electron during chemical reactions. However, *Y* has achieved an octet electron arrangement and will not accept the electron from *X*. These two elements will not react with each other. (D is true)

**12** B Electron arrangement of argon is 2.8.8.
Its outermost electron shell is filled with 8 electrons and do not need to accept, donate or share electron(s) with other elements to form a compound.

**13** B Potassium oxide is basic and it dissolves in water to form potassium hydroxide solution which is alkaline and changes phenolphthalein solution from colourless to red.
$K_2O(s) + H_2O(l) \rightarrow 2KOH(aq)$
Alkaline solution

**14** D Electron arrangement of Na = 2.8.2 and K = 2.8.8.1
Na and K each has one valence electron.
During chemical reactions, each will release one valence electron to achieve a stable octet electron arrangement.
The atomic radius of potassium is larger than sodium. The electrostatic forces of attraction between the nucleus and valence electrons in potassium atoms is weaker compared to sodium atom. Potassium atoms release their valence electrons more easily.

**15** C
$^{7}Li$ 2.1
$^{23}Na$ 2.8.1
$^{39}K$ 2.8.8.1
As we go down the Group, the atomic mass increases. Thus, density also increases. (I is true)
As we go down the Group, the atomic radius increases. Electrostatic forces of attraction between valence electrons and nucleus become weaker. Elements below the Group release their valence electrons more easily; therefore reactivity increases down the Group. (II is true)
Metallic bonding between atoms become weaker as we go down the Group. Thus, boiling point decreases down the Group. (III is false)
Electropositivity is the measurement of how easily an atom releases electron(s) to form a positively charged ion (cation). As the elements towards the bottom of the Group release their valence electrons more easily, electropositivity increases down the Group. (IV is true)

**16** A Element *X* is lithium with the electron arrangement 2.1.
Lithium burns in air to form lithium oxide which is soluble in water. (I is true)
Lithium reacts with water to produce lithium, LiOH and hydrogen. (II is false)

Lithium reacts with chorine to form lithium chloride salt, LiCl. (III is true)
Lithium is in Period 2 because it has two filled electron shells. (IV is false)

**17** D Alkali metals are very reactive and react with oxygen in the air to form metal oxides.

**18** A Aqueous copper(II) sulphate solution contains water. When sodium is added, it reacts with water to form sodium hydroxide and hydrogen gas.
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
Sodium will not displace the copper.

**19** B For example, sodium atom releases one valence electron during reactions.

$^{23}_{11}Na \rightarrow ^{23}_{11}Na^+ + e^-$

| | |
|---|---|
| 2.8.1 | 2.8 |
| 11p | 11p |
| 12n | 12n |
| $11e^-$ | $10e^-$ |

Sodium ions have 10 electrons and 11 protons.

**20** C Element *P* with proton number 17 is chlorine.
Chlorine is a non-metallic element and form acidic oxide. (A is true)
Chlorine exist as diatomic molecule, $Cl_2$ (B is true)
Chlorine reacts with iron o form iron(III) chloride which is brown. (C is false)
Chlorine reacts with sodium to form sodium chloride salt, NaCl. (D is true)

**21** A Fluorine is an element is Group 17.
It has 7 valence electrons and accepts an electron during chemical reactions.

$^{19}_{9}F + e^- \rightarrow ^{19}_{9}F^-$

| | |
|---|---|
| 2.7 | 2.8 |
| 9p | 9p |
| 10n | 10n |
| $9e^-$ | $10e^-$ |

Fluoride ions have 10 electrons and 9 protons.

**22** D Group 17 elements accept an electron during chemical reactions. As we go down the Group, atomic radius increases. Electrostatic forces of attraction between nucleus and electrons become weaker. Elements towards the bottom of the Group have lower tendencies to attract electrons. Reactivity decreases down the Group. (I is false)
As we go down the Group, the size of the molecules increases. The bigger the molecules, the stronger the Van der Waals force of attraction. More heat (energy) is needed to overcome the forces of attraction. Boiling point increases down the Group. (II is true)
As the forces of attraction become stronger, the molecules are harder to separate by water/ to dissolve. (III is true)
Elements towards the bottom of the Group have lower tendencies to attract electrons compared to the elements towards the top of the Group. Electronegativity decreases down the Group. (IV is true)

**23** B An example of Group 16 element is oxygen, $O_2$ which when dissolved in water does not produce acidic solution.
An example of Group 17 element is chlorine, $Cl_2$ which when dissolved in water produces hydrochloric acid and hypochlorous(I) acid.
$Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HOCl(aq)$
Hydrogen ions from the acids react with carbonate ions to produce carbon dioxide gas.
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$
Group 1 elements (such as Na) react with water to produce alkali solutions which do not react with carbonate ions.

**24** B All sodium halide salts are soluble in water. (I is true)
Bromine is a liquid at room temperature. (II is false)
Bromine dissolves in water producing hydrobromic acid and hypobromous(I) acid.
$Br_2(g) + H_2O(l) \rightarrow HBr(aq) + HOBr(aq)$
Hypobromous acid bleach/decolourise litmus papers. (III is true)
Bromine reacts with iron to produce brown iron(III) bromide salt. (IV is true)
$2Fe(s) + 3Br_2(g) \rightarrow 2FeBr_3(s)$

**25** A Density and melting point do not show a regular increase. (I and II false)
Atomic radius decreases across the Period because proton number increases. The electrostatic forces of attraction between protons and electrons become stronger causing the atomic radius to decrease. (III is false)
Elements on the left are metals and donate electrons during reactions, making them electropositive.
Elements on the right are non-metals and accept electrons during reactions, making them electronegative. (IV is true)

**26** C

| Group | 1 | 2 | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | *X* (Such as $_{9}F$) | *Y* (Such as $_{10}Ne$) |
| | *Z* (Such as $_{11}Na$) | | Transition metals | | | | | | |

Fluorine/*X* is more electronegative than sodium. (I is true)
Sodium/*Z* is a metal and conducts electricity whereas fluorine/*X* is a non-metal and cannot conduct electricity. (II is true)
Metallic oxide is basic whereas non-metallic oxide is acidic. (III is true)
Sodium/*Z* and fluorine/*X* reacts to form sodium fluoride, NaF. (IV is false)

**27** C Group 1 elements have one valence electron and release the valence electron during reactions.
As we go down the Group, atomic radius increases. The electrostatic forces of attraction between nucleus and valence electrons become weaker. The elements towards the bottom of the Group release their valence electrons more easily. Reactivity increases down the Group.

**28** D Amphoteric oxides react with acid and alkali solutions. Thus, the elements that form amphoteric oxides are between metals (elements on the left side of the Periodic Table) and non-metals (elements on the right side of the Periodic Table). Some elements in Groups 13 and 14 form amphoteric oxides.

**29** D Protons are positively charged whereas electrons are negatively charged. As the number of protons increases, the forces of attraction between the protons in the nucleus and electrons become stronger, causing the atomic radius to decrease across a Period.

**30** B *X*, *Y*, *Z* are elements in the same Period. As the proton number increases, atomic radius decreases.
The smaller the atomic radius of an element, the higher its tendency to accept electron(s).

**31** A Transition elements catalyse chemical reactions, form coloured compounds, have variable oxidation states and form complex ions.

**32** C $QCl_2$: Oxidation state of element *Q* is +2.
$QCl_3$: Oxidation state of element *Q* is +3.
*Q* has more than one oxidation number. Thus, it is a transition element.

**33** D Manganate(VII) ions are purple. Manganese(II) ions are pink.

**34** B All metals conduct electricity. The difference between transition metals and other Group metals is transition metals have high densities.

**35** A Pure transition metals are soft because their atoms slide over each other easily. During the alloying process, different elements are added to pure metals. The foreign atoms prevent the pure metal atoms from sliding over each other easily, making alloys harder than their pure metals.

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 5

**1** C Argon is in Group 18 and it has an octet electron arrangement. Argon does not form chemical bonds.

**2** B Electron arrangement of *P* is 2.8.8.2. Hence, atom *P* forms $P^{2+}$ ions by losing 2 electrons.

**3** B Electron arrangement of $Q^{2-}$ is 2.8. Hence the electron arrangement of atom *Q* is 2.6 before it accepts 2 electrons to form an anion.

**4** D The electron arrangement of *Z* is 2.6. *Z* accepts 2 electrons while *T* donates 3 valence electrons to achieve the stable octet to form $T_2Z_3$

**5** C *P* has 5 valence electrons. It shares 3 valence electrons to form a covalent bond.
*R* has 7 valence electrons. It shares 1 valence electron to form $PR_3$.

**6** B *U* and *T* are both non-metal atoms and share valence electrons to achieve octet electron arrangement. *U* will share 3 valence electrons while *T* will share 1 valence electron to form $UT_3$

**7** B Electron arrangement of *P* is 2.4 while *R* is 2.6. Both are non-metals that will share valence electrons to achieve the octet electron arrangement. *P* shares 4 valence electrons while *R* shares 2 valence electrons (their valence electron shells overlapping) to form $PR_2$

**8** C $X + 2e^- \rightarrow X^{2-}$

**9** C The electron arrangement of option C is 2.8.6, the element shares 2 valence electrons or donates 2 valence electrons to achieve the octet electron arrangement. The element in option A can only form covalent bonds, while the elements from options B and D are metals that form ionic bonds.

**10** C The electron arrangement of *X* is 2.5. *X* shares 3 valence electrons to form a triple bond which is represented by 3 pairs of electrons.

**11** A Only nitrogen, N is electronegative enough to produce a partial positive charge when bonded to hydrogen, H to form hydrogen bonds.

**12** **D** Nitrogen, N shares a pair of unshared valence electrons with hydrogen, H from hydrochloric acid, HCl to form a dative bond.

**13** C Covalent compounds such as glucose are soluble in water because these compounds form hydrogen bonds with water molecules.

**14** B Butane has only weak Van der Waals force of attraction between its molecules. Oxygen is very electronegative and induces partial positive charge in hydrogen, H in water molecules to form hydrogen bonds.

**15** C The atoms of copper form metallic bonds which comprises of positive metal ions immersed in a sea of delocalised valence electrons.

**16** A *P* (with the electron arrangement 2.8.5) and *Q* (with the electron arrangement 2.8.7) are non-metals. They form covalent compounds which are soluble in organic solvents and insoluble in water, have low melting points and do not conduct electricity in any state.

**17** A *W* is a metal and *Z* is a non-metal that react to form an ionic compound with a high melting point.

**18** D *E* (with the electron arrangement 2.8.8.1) and *D* (with the electron arrangement 2.8.7) react to form an ionic compound that conducts electricity in its liquid state.

**19** C *P* (with the electron arrangement 2.8.2) and *Q* (with the electron arrangement 2.8.6) react to form *PQ*.
Relative molecular mass = the sum of the nucleon numbers of respective element
= 24 + 32
= 56

**20** C *S* (2.8.1) is a metal and *U* is a non-metal (2.8.6) that react to form an ionic compound with a high melting point and boiling point. *T* (2.8.4) can only form covalent compounds.

**21** D Electrical conductivity in liquid state can be used to differentiate between potassium chloride (an ionic compound) and glucose (a covalent compound).

**22** B The compound formed shows shared electrons in their overlapped valence electron shells, indicating it is a covalent compound.

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 6

**1** A Ammonia does not dissociate to ions, and exists as molecules in organic solvents (such as propanone).

**2** B Sulphuric acid is used in all of the listed uses. Nitric acid is not used in the making of detergents.

**3** D Limewater is calcium hydroxide, which is alkaline (pH more than 7)

**4** C pH 13 indicates that *X* is an alkali, which produces a red coloured solution when tested with phenolphthalein, and produces ammonia gas when heated with an ammonium salt (ammonium sulphate)

**5** B pH = –log [$H^+$]
= –log 0.001
= 3

**6** D 0.1 mol of $Ba(OH)_2$ produces 0.2 mol of $OH^-$
pOH = -log [$OH^-$]
= –log (0.1 × 2)
= 0.7
pH = 14 – 0.7 = 13.3

**7** B pH = –log [$H^+$],
2 = –log [$H^+$]
[$H^+$]= 0.01 mol $dm^{-3}$

**8** B Only NaOH is a strong alkali that undergoes complete dissociation to produce a high concentration of $OH^-$ ions, hence the highest pH value. The rest are weak bases that undergo partial dissociation.

**9** B Strong acids undergo complete dissociation to produce a high concentration of $H^+$ ions with a low pH value.

**10** D Ethanoic acid is a weak acid that has a lower degree of ionisation, a lower concentration of $H^+$ ions and a higher pH value compared to HCl. But both aids are monoprotic acids that react with the same number of moles of $OH^-$ ions.

**11** C Only KOH is a strong alkali that undergoes complete dissociation to produce a high concentration of $OH^-$ ions. The rest are weak bases that undergo partial dissociation.

**12** D The lower the pH value, the higher the concentration of $H^+$ ions, and hence the higher the degree of dissociation. Ascending order of dissociation is associated with descending order of pH values.

**13** C Molecular mass of NaOH = 23 + 16 + 1 = 40

$$\text{Mass of NaOH} = \frac{MV}{1000} \times 40 = \frac{0.5 \times 250}{1000} \times 40 = 5.0 \text{ g}$$

**14** C $M_1V_1 = M_2V_2$

$2.0 \times 30 = M_2 \times 250$

$$M_2 = \frac{2.0 \times 30}{250} = 240 \text{ cm}^3 = 0.24 \text{ dm}^3$$

**15** A Addition of water dilutes an acid and decreases the concentration of $H^+$ ions, hence increasing the pH value. The number of moles of $H^+$ ions remains the same.

**16** A $2KOH + H_2SO_4 \rightarrow K_2SO_4 + H_2O$

$$\frac{M_A \times 25}{1.0 \times 20} = \frac{1}{2}$$

$$M_A = \frac{1.0 \times 20}{25 \times 2} = 0.4 \text{ mol dm}^{-3}$$

**17** B Number of mol of $X = \frac{0.5 \times 25}{1000} = 0.0125$

Number of mol of NaOH $= \frac{1.0 \times 25}{1000} = 0.025$

0.0125 mol of *X* reacts with 0.025 mol of NaOH
Hence 1 mol of *X* reacts with 2 mol of NaOH
This means *X* is a diprotic acid. $H_2SO_4$ is the only diprotic acid in the answer options.

**18** B Magnesium nitrate is a soluble salt that can be prepared by reacting nitric acid and an oxide (or metals/carbonates).

**19** B $PbSO_4$ is an insoluble salt that can be prepared by the double decomposition reaction. The rest are soluble salts.

**20** A Magnesium chloride is a soluble salt that can be prepared by the reaction between an acid and a metal. Silver chloride and lead(II) sulphate are insoluble salts.

**21 C** *R* as a residue, indicating that it is an insoluble salt formed by the double decomposition reaction between solution *P* and solution *Q*. $MgCO_3$ is the only insoluble salt.

**22 C** Lead(II) chloride is an insoluble salt formed in the reaction.

$2HCl + Pb(NO_3)_2 \rightarrow PbCl_2 + 2HNO_3$

Magnesium sulphate (formed in A), ammonium sulphate (formed in B) and zinc chloride (formed in D) are all soluble salts.

**23 C** Let the molarity of $Pb(NO_3)_2$ solution $= x$ mol $dm^{-3}$

Number of mol of $Pb^{2+} = \frac{x \times 5}{1000} = 0.005x$

Number of mol of $I^- = \frac{0.4 \times 20}{1000} = 0.008$

Mol ratio of $Pb^{2+} : I^- = 0.005x : 0.008$

From the equation, 1 mol of $Pb^{2+}$ reacts with 2 mol of $I^-$

Relating the mol ratio from the equation to the mol ratio from the calculation,

$$\frac{0.005x}{0.008} = \frac{1}{2}$$

$$x = \frac{\frac{1}{2} \times 0.008}{0.005}$$

$$= 0.80$$

**24** B Ammonia is an alkaline gas with a pH of more than 7

**25** A Sodium carbonates do not decompose when heated

**26** B An ammonium salt solution produces ammonia gas (which turns red litmus blue) when heated with an alkali (sodium hydroxide).

**27** A The residue which is brown when hot and yellow when cold is PbO. The brown gas is nitrogen dioxide, released from heating lead(II) nitrate.

**28** B Zinc chloride solution forms white precipitate which is soluble in excess aqueous ammonia. Aluminum nitrate solution forms white precipitate which is insoluble in excess aqueous ammonia. Both solutions do not react with barium nitrate and barium chloride solutions and both form white precipitate that are soluble in excess sodium hydroxide.

**29** C Chloride forms white precipitate (AgCl) when it reacts with $AgNO_3$. Zinc nitrate is absent since the white precipitate is insoluble in excess aqueous ammonia.

**30** A Only $Pb^{2+}$ forms white precipitate ($PbCl_2$) when reacted with hydrochloric acid, HCl and forms white precipitate ($PbSO_4$) when reacted with sulphuric acid, $H_2SO_4$.

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 7

**1** D Rusting takes days or even months to be noticeable. The other reactions are very fast.

**2** D The change in the size of a solid reactant is not measurable.

**3** C For reactions that involve the liberation of gases, the volume of gas liberated per unit time is the easiest to measure using a gas syringe or by the displacement of water method (for gases that are insoluble in water).

**4** D The average rate of reaction during the second minute

$= \frac{13.6 \times 7.8}{120 - 60}$

$= 0.097\ cm^3\ s^{-1}$

The reaction is complete at 180 s, the average rate of reaction

$= \frac{14.7}{180}$

$= 0.8\ cm^3\ s^{-1}$

The initial and instantaneous rate of reaction need to be obtained from the gradient of the graph of volume of gas against time.

**5** B 120 s = 2 min

The average rate of reaction $= \frac{0.2}{2}$

$= 0.10\ g\ min^{-1}$

or $\frac{100}{2} = 50\ cm^3\ min^{-1}$

**6** C The rate at $t_2$ is lower than at $t_1$ as the rate of a reaction decreases as the reaction proceeds.

The average rate of reaction $= \frac{V}{t_1}\ cm^3\ s^{-1}$

The instantaneous rate of reaction at $t_2$ = gradient of graph at $t_2 = 0$

**7** C The graph of a product (mass of sulphur or volume of sulphur dioxide) against time is an increasing curve.

The graph of a reactant (concentration of $Na_2S_2O_3$) against time is a decreasing curve.

**8** C Lead is less reactive than zinc; therefore its rate of reaction with an acid is lower.

Adding copper(II) sulphate or using sulphuric acid increases the rate of reaction.

The volume of hydrochloric acid used does not affect the rate of reaction.

**9** D *Y* has a higher rate of reaction (steeper gradient) than *X* due to a higher concentration of $H^+$ ions. The concentration of $H^+$ ions in 1 mol $dm^{-3}$ sulphuric acid is twice the amount in 1 mol $dm^{-3}$ hydrochloric acid as sulphuric acid is a diprotic acid.

The total volume of gas produced in *Y* is the same as in *X* , hence the total number of mol of $H^+$ ions (calculated from $\frac{MV}{1000}$) is the same for both *X* and *Y*.

**10** C The rate of a reaction decreases with time. (A is incorrect)

The volume of acid used does not affect the rate of the reaction. (B is incorrect)

Increasing the mass of zinc (increases the concentration of the reactant) increases the rate of reaction. (C is correct)

Increasing the size of zinc decreases the total surface area and therefore decreasing the rate of reaction. (D is incorrect)

**11** B Using hot hydrochloric acid increases the temperature of the reactants, which increases the rate of reaction. (B is correct)

Bigger sized marbles (decreases the total surface area of the reactant) as well as adding water (decreasing the concentration of the reactants) decreases rate. (A and D are incorrect)

The volume of acid used does affect the rate of reaction. (C is incorrect)

**12 B** Increasing the size of magnesium ribbon decreases the total surface area of the reactant, therefore decreasing the rate of reaction.

**13 C** Curve *N* has a higher rate of reaction (steeper gradient) than *M* due to the higher concentration of hydrogen peroxide (0.30 mol $dm^{-3}$ in *N* compared to 0.20 mol $dm^{-3}$ in *M*).

The total volume of gas produced depends on the number of mol of hydrogen peroxide used. Curve *N* has a smaller number of mol hydrogen peroxide $\left(\frac{0.20 \times 30}{1000}\right)$ than curve *M* $\left(\frac{0.20 \times 50}{1000}\right)$.

**14** C Increased pressure (compress) and temperature (heat) as well as the presence of a catalyst (powdered iron) increase the rate of formation of ammonia. (II, III and IV are correct)
The reaction does involve 1 mol (1 volume of nitrogen) and 3 mol (3 volumes of hydrogen), thus the rate of reaction is not changed. (I is incorrect)

**15** D A higher concentration (2.0 mol $dm^{-3}$ of hydrochloric acid) and a bigger total surface area (powdered marble) increase the rate of reaction.

**16** B The chemical composition of a catalyst is the same before and after a reaction.
A catalyst lowers the activation energy and increases the frequency of effective collisions.
The frequency of collisions is affected by the temperature or concentration of the reactants.
The yield depends on the number of mol of reactants.

**17** B The kinetic energy of reactants (not products) increases when temperature increases, causing the reactant particles to collide more frequently. Activation energy is only affected by a catalyst.

**18** C The frequency of collisions depends on the number of reactant particles per unit volume. The increase in the total number of reactant particles may not increase the rate of reaction if it is accompanied by an increase in the volume. The rate does not depend on the number of product particles.

**19** B Activation energy is the difference in the energy level between the reactants and the maximum point of the energy profile.

**20** A A catalyst provides an alternative pathway with lower activation energy, so that more reactant particles have the energy greater than the activation energy.

# Explanation for Multiple-choice Questions

## FORM 4

### Summative Practice 8

**1** C

| **Alloy** | Bronze | Brass |
|---|---|---|
| **Composition** | 90% copper, 10 % tin | 70% copper, 30% zinc |

*X* and *Y* are foreign atoms added to copper.
X = Tin; *Y* = Zinc

**2** B Stainless steel contains 18% chromium, 8% nickel, 0.08% carbon and 73.92% iron. Thus, element *M* is chromium.

**3** D Foreign atoms occupy the empty spaces between metal atoms. They disrupt the regular arrangement of metal atoms and prevent the metal atoms from sliding easily, increasing the hardness of the metal.

**4** B Foreign atoms make the arrangement of atoms less regular. This causes the metallic bonds between metal atoms to be weaker. Thus, alloys have lower melting point that pure metal.

**5** A The alloy of copper and nickel is called cupronickel alloy. This alloy is shiny and does not corrode easily. It is suitable to be used to make coins.

**6** A Solder is 50% tin and 50% lead.

**7** C Glass is made from silica sand or silicon(IV) oxide.

**8** D An aeroplane flies from sea level to a height of about 10 000 meter. The plane is exposed to extreme changes in temperature from an average of 25°C to –45°C. Normal glass will break due to this extreme changes in temperature. However, borosilicate glass has a low coefficient of expansion and can withstand extreme changes in temperature.

**9** C Bottles come in different shapes. These bottles are made from soda lime glass which has a low softening point of about 700°C, unlike fused glass which has a softening point of 1700°C.
After heating soda lime glass to its softening point, the molten glass is blown into different shapes to make bottles, bulbs etc.

**10** C Boron trioxide in borosilicate glass lowers the coefficient of expansion.

**11** B Lead metal sheets prevent the penetration of X-rays through it. Lead glass is made from silica and lead(II) bromide. The glass is transparent. However, the lead content in the glass absorbs high energy X-ray radiations.

**12** B Silicon carbide is a very hard substance with the MOH value of 9. Diamond is the hardest substance. It has the MOH value of 10. Therefore, silicon carbide can be used to cut metals.

**13** D A superconductor has no resistance to the flow of electricity. Yttrium copper oxide is a ceramic which is a superconductor.

**14** C Glass fibres are hard but not flexible. Polyester plastics are soft and flexible and but have limited uses. By adding glass fibres to polyester plastics (called matrix), a composite material called glass fibres which is strong and flexible is produced.

**15** A Ceramic is an electrical insulator. It is used as insulator in high tension wires.

**16** B Besides being a good electrical insulator, ceramic is also a good heat insulator. It is used to shield astronauts inside space shuttles during their re-entry phase during which the temperature can go up to 1500°C.

**17** D Silicon(IV) oxide is used to make glass. Glass is an electrical insulator.
Silicon is a semiconductor used to make diodes and transistors.
Aluminosilicate is white clay used to make traditional ceramics such as plates and cups.
Molybdenum disilicide is a ceramic which can conduct electricity and is used to make the heating filaments in water heaters and electrical ovens.

**18** A Tiles and bricks are made from wet clay which after being heated in a furnace, hardens and ceramic is produced.
Beams in buildings are made from steel reinforced concrete which is a composite material.

Windowpanes are made from silica/silicon(IV) oxide.

**19** C Photochromic glass contains silver halide salts. When exposed to sunlight, the compound decomposes to silver atoms and halogens. The silver atoms darken the glass.

**20** C Modern badminton rackets are made from carbon fibres and polyester plastic composite. This material is light, strong and does not break easily.

**21** B Racing bikes are used in races, so it must be light but hard.
Fiberglass is light but not hard enough for this purpose.
Manganese steel is made mainly from iron (RAM of Fe = 56). This material is hard but heavy.
Duralumin alloy is made mainly from aluminium (RAM of Al = 27). The alloy is hard and light, making it suitable to be used to make racing bikes.

**22** D The telecommunication industry uses optical fibres to transmit light pulses along glass fibres. The data transmitted is in the form of light, unlike copper wire which uses electricity. Resistance in copper also slows down the speed of data transmission.
To transmit light through optical fibres without the light escaping, optical fibres consist of two glasses with two different refractive indexes. This enables a total internal reflection to occur.

**23** B Concrete contains cement, sand and gravel. Once hardened, it is hard but it cannot withstand tremors such as due to earthquake.
To strengthen it, concrete steel rods are tied together before the concrete is poured into the column. Once hardened, steel reinforced concrete is obtained which is a composite material. Steel has a high tensile strength and prevents beams from breaking easily during tremors.

**24** A

**25** B

**26** D Yttrium copper oxide is a superconductor, but its use is limited because it is brittle and breaks easily. By combining it with a polymer, it becomes more flexible and more bendable.

**27** C Wind turbine blades must be strong and light so that when strong winds rotate the blades, they do not break. Steel, duralumin and ceramic are heavy and not suitable to be used to make wind turbine blades. Fiberglass is not only strong but it is also light.

**28** B Endoscopes enable doctors to see the inside of organs such as the stomach or the ears of a patient. Light is transmitted through the optical fibres in endoscopes and due to the total internal reflection and it travels along the glass core.

**29** C Tooth composites contain ceramic and Perspex polymer. Once the material is applied to a tooth as a filling and exposed to ultraviolet light, the polymerisation process takes place. The polymer will harden together with the ceramic materials.

**30** D All are made of fiberglass as it is strong, flexible and light.

# Explanation for Multiple-choice Questions

## FORM 5

### Summative Practice 1

**1** B $C + 2CuO \rightarrow CO_2 + 2Cu$
The oxidation number of carbon increases from 0 in C to +4 in $CO_2$.
Copper(II) oxide acts as the oxidising agent that oxidises carbon to $CO_2$.
Oxide ions remain unchanged in the reaction.

**2** B In this reaction, $Fe^{2+} \rightarrow Fe^{3+} + e^-$
$Cl_2$ is reduced and its oxidation number decreases from 0 to –1.

**3** A Bromide ions, $Br^-$ donate electrons and the electrons are received by $Cl_2$.

**4** A $2HNO_3 + Zn \rightarrow H_2 + Zn(NO_3)_2$
$H^+$ ions are reduced to $H_2$ (the oxidation number decreases) while Zn is oxidised to $Zn^{2+}$ ions (the oxidation number increases).
The rest are non-redox reactions as the oxidation number of all of the species on the reaction remain unchanged.

**5** C Chlorine is an oxidising agent that oxidises $Fe^{2+}$ ions (green) to $Fe^{3+}$ ions (brown).
Potassium dichromate(VI) is also an oxidising agent. Potassium bromide and potassium iodide are reducing agents. Iron(III) sulphate does not react with $Fe^{2+}$.

**6** A Potassium iodide is the reducing agent.
Chlorine and iodine are the oxidising agents.

**7** D Let the oxidation number of Cl = $x$

$NaClO_4$

$+1 + x + 4(-2) = 0$

$x = +7$

**8** C The oxidation number of sulphur, S in both $Na_2\underline{S}O_3$ and $\underline{S}O_2$ is +4
In option A, the oxidation number of chlorine, Cl changes from –1 to +1
In option B, the oxidation number of manganese, Mn changes from +7 to +6
In option D, the oxidation number of chlorine, Cl changes from –1 to +1

**9** B Let the oxidation number of Mn = $x$
In $MnO_4^{2-}$: $x + 4(-2) = -1$
$x = +7$
The oxidation number of Mn in $MnO_4^{2-}$ is +7, the oxidation number of Mn in $Mn^{2+}$ is +2

**10** C Solution $X$ is an oxidising agent that oxidises iodide ions to iodine which is brown.
Potassium dichromate(VI) is an oxidising agent.
Potassium bromide and potassium chloride are reducing agents.

**11** B $X$ has been oxidised (by $Y^{2+}$) to $X^{2+}$ ions and $Y^{2+}$ ions are reduced (by $X$) to $Y$ in the reaction.
Hence, $X$ is a reducing agent while $Y^{2+}$ is an oxidising agent.
$X$ is more electropositive than $Y$ because $X$ has a higher tendency to release electrons.

**12** D Cu is oxidised to $Cu^{2+}$ by donating electron to $Ag^+$.
Cu is the reducing agent (electron donor) while $Ag^+$ is the oxidising agent (electron acceptor).

**13** B $Fe^{3+}$ ions are reduced to $Fe^{2+}$ ions in the reaction; hence sodium sulphite is the reducing agent. Zinc metal is the reducing agent while bromine water and $Cu^{2+}$ ions from copper(II) sulphate are the oxidising agents. $Cl^-$ ions from potassium chloride cannot reduce $Fe^{3+}$ ions they are below $Fe^{3+}$ ions in the redox series (the $E^\theta$ value is more positive).

**14** B In option B, $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$.
Therefore, Cu is oxidised to $Cu^{2+}$ ions.
In option A, $C + 2CuO \rightarrow CO_2 + 2Cu$.
Therefore, $Cu^{2+}$ ions are reduced to Cu.
In option C, at the carbon cathode $Cu^{2+} + 2e^- \rightarrow Cu$. Therefore, $Cu^{2+}$ ions are reduced to Cu.

**15** D The decolourising of the blue colour indicates that $Cu^{2+}$ ions are reduced by accepting electrons. $Cu^{2+} + 2e^- \rightarrow Cu$
The oxidation number of copper decreases from +2 to 0.
$X$ is the reducing agent and $Cu^{2+}$ ions (not Cu) undergo reduction.

**16** B $N$ with a more negative $E^\theta$ value than $M$ indicates that $N$ has a higher tendency to release electrons compared to $M$; hence metal $N$ is the stronger reducing agent than $M$.
$M$ with a more positive $E^\theta$ value indicates the ions of $M$ have a higher tendency to accept electrons than ions of $N$; hence $N$ ions are stronger oxidising agents than $M$ ions.

**17 C** Metals with more negative $E^\theta$ values are stronger reducing agents while the metal ions are weaker oxidising agents. Metals with more positive $E^\theta$ values are weaker reducing agents while the metal ions are stronger oxidising agents. Hence, $Ag^+$ is the strongest oxidising agent (the most positive $E^\theta$ value).

**18** B The half-cell with the more negative $E^\theta$ value (Al) acts as the anode to release electrons.
$E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$
$= -0.13\ V - (-1.66\ V)$
$= +1.53\ V$

**19** B Oxidation occurs at the anode, whereby the metal with the smaller $E^\theta$ value releases electrons, and the electrons flow to the cathode.

**20** B The order of the metals arranged according to a decreasing potential difference compared to silver is *S*, *Q*, *P*, *R*, Ag.
The further apart the distance between two metals, the bigger the potential difference. Hence, metal pairs *S* and *R* will produce the biggest potential difference.

**21** C Zinc acts as the negative terminal of the voltaic cell because it has a more negative $E^\theta$ value compared to copper, and releases electrons to form $Zn^{2+}$ ions.
The positive ions, $Zn^{2+}$, $K^+$ and $H^+$ ions (from aqueous KCl) move to the anode.
$H^+$ ions accept electrons to form $H_2$ gas ($E^\theta$ values of $Zn^{2+}$ and $K^+$ ions are negative, therefore they are less likely to accept electrons compared to $H^+$ ions).

**22** B The copper electrode connected to the positive terminal of the battery is the anode while the carbon electrode is the cathode.
Oxidation occurs at copper anode.
$Cu \rightarrow Cu^{2+} + 2e^-$ (Factor: Active electrode)
Reduction occurs at the carbon cathode:
$Cu^{2+} + 2e^- \rightarrow Cu$ (Factor: $E^\theta$ value)
Mass of the copper electrode decreases, copper (brown deposit) is formed at the cathode and the concentration of $Cu^{2+}$ ions remains constant.

**23** B Both cations, $Mg^{2+}$ and $H^+$ ions, are attracted to the cathode, but only $H^+$ ions are discharged, producing hydrogen gas because of its higher $E^\theta$ value.

**24** C The electrolysis of copper(II) sulphate produces copper metal at the cathode (factor: $E^\theta$ value). As for the rest of the solutions, $H^+$ ions and $OH^-$ ions are discharged, producing hydrogen gas at the cathode and oxygen gas at the anode repectively.

**25** C If a concentrated potassium chloride solution is electrolysed, chloride ions are discharged at the anode, producing chlorine gas (factor: concentration of electrolyte). The other factors do not affect the selective discharge of ions during electrolysis.

**26** B When an impure copper is used as the anode and aqueous copper(II) salt is used as the electrolyte, copper loses its electrons to form copper(II) ions at the anode (factor: active electrode).

**27** C To electroplate an iron key with silver, the iron key must be the cathode (connected to the negative terminal of the battery), silver foil as the anode (connected to the positive terminal of the battery) and silver ion solution (silver nitrate) as the electrolyte.

**28** B Iron, which is less reactive than carbon, is extracted by reducing hematite using carbon. Aluminium, which is more reactive than carbon, is extracted by the electrolysis of molten bauxite. Copper ores which consists of copper metal and a little amount of copper sulphide, is extracted by heating the ores in air.

**29** C $3C + 2Fe_2O_3 \rightarrow 3CO_2 + 4Fe$
Carbon undergoes oxidation and iron(III) oxide is the oxidising agent. The oxidation number of iron decreases from +3 to 0 while $O^{2-}$ ions remain unchanged.

**30** C *y* which is at the center of the iron block, lacks oxygen. *y* acts as the anode in the electrolytic process of rusting.
Oxidation occurs at the anode (at *y*):
$Fe \rightarrow Fe^{2+} + 2e^-$

**31** A The intense blue colour indicates a high concentration of Fe ions.
$Fe \rightarrow Fe^{2+} + 2e^-$
This means iron has a smaller $E^\theta$ value than *P* (higher tendency to release electrons) and iron acts as the anode while *P* acts as the cathode. Electrons flow from iron to *P*.

# Explanation for Multiple-choice Questions

## FORM 5

### Summative Practice 2

**1** A Organic compounds contain carbon and hydrogen, and may contain other elements such as nitrogen, sulphur and oxygen.

**2** C Alkenes have carbon-carbon double bonds and alkynes have carbon-carbon triple bonds. Both are unsaturated hydrocarbons.

**3** C $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$
$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

**4** A Propene and propane have 3 carbon atoms per molecule. Both produce 3 mol (3 volumes) of $CO_2$ in combustion reactions. However, propane produces more $H_2O$ because it has more hydrogen atoms per molecule compared to propene. Propene produces more soot because of its higher percentage of carbon by mass compared to propane.

**5** D Butyne, $C_4H_6$ has the highest percentage of carbon by mass. It produces the most unburned carbon (soot) in an incomplete combustion.

**6** C The general formula of alkyne is $C_nH_{2n-2}$

**7** B $C_2H_4$ belongs to the homologous series alkene with the general formula $C_nH_{2n}$. The members of the same homologous series have the same functional group. $C_3H_6$ and $C_6H_{12}$ both satisfy the general formula $C_nH_{2n}$.

**8** C Alkanes have the general formula $C_nH_{2n+2}$ and undergo substitution reactions with halogens.

**9** B The equation shows the substitution of one H atom in ethane by a Cl atom. Sunlight or ultraviolet light is required for the substitution of alkanes.

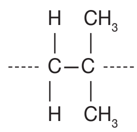
**10** A A diol is formed when ethene is added to acidified potassium manganate(VII).
$C_2H_4 + H_2O + [O] \rightarrow C_2H_4(OH)_2$

**11** D Cyclohexene is an alkene with a carbon-carbon double bond as its functional group although it does not satisfy the general formula $C_nH_{2n}$. It is insoluble in water and reacts with hydrogen to produce cyclohexane.

**12** D Butene is an alkene, it undergoes addition reactions with steam, bromine and hydrogen gas. It does not react with hydrochloric acid but undergoes addition reaction with hydrogen chloride gas.

**13** B Propene undergoes addition reaction with hydrogen chloride gas to produce 2-chloropropane.

**14** D The repeating unit of the polymer is:




To obtain the structural formula of the monomer, change the single bond between the two carbon atoms to a double bond and then remove the two single bonds attached to the carbon atoms.

**15** A The structural formula of *M* shows a carbon-carbon double bond (C=C), indicating *M* is an alkene. Alkenes undergo addition reactions with acidified potassium manganate(VII) to form diols, decolourising the potassium manganate(VII) in the process.

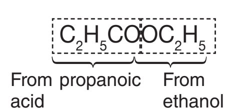
**16** C Propan-1-ol undergoes dehydration to form propene, which then undergoes addition reaction with acidified potassium manganate(VII) to form a diol.

**17** C Propanol (an alcohol) is oxidised to propanoic acid (a carboxylic acid) when heated with acidified potassium manganate(VII).

**18** C Methanol has only one carbon atom in a molecule. It cannot undergo dehydration to form an alkene. All alcohols can be oxidised to carboxylic acids in oxidation reactions and react with carboxylic acids (not alcohols) to form esters.

**19** D Compound *Y* is a carboxylic acid as it produces carbon dioxide gas with sodium carbonate.

**20** B Ethanol provides the ethyl group and propanoic acid forms propanoate in the esterification reaction.



**21 C** Pentyl ethanoate

From pentanol | From ethanoic acid

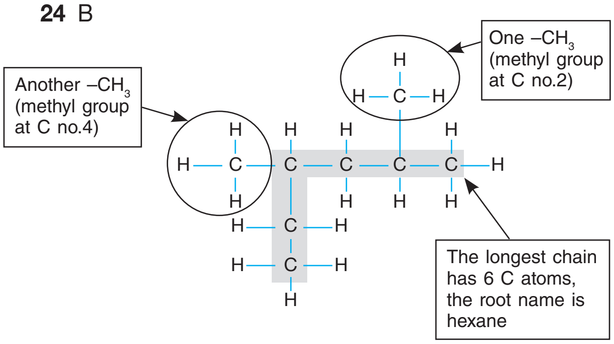
**22** D $Q$ is an ester formed from the reaction between a carboxylic acid and an alcohol.

$C_2H_5COOCH_3$

From propanoic acid | From methanol

**23 C** Ethanol reacts with ethanoic acid to form an ester with a sweet smell.
Water flows in from *Q* and flows out from *P*.
The Liebig condenser is used to prevent evaporation of volatile reactants before the reaction completes.

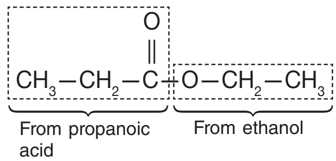
**24** B




**25** C Compound $Q$ is an alkane with 5 C atoms and 12 H atoms (molecular formula $C_5H_{12}$).
Structural formula of the compound in option C also has the molecular formula $C_5H_{12}$.

**26** B Compound $Z$ is an alcohol since it reacts with ethanoic acid to form an ester (a sweet smelling compound).
Alcohol $Z$ has a $-CH_3$ (methyl) group attached to the second C atom of the parent chain to form 2-methylpropene.
Alcohol in option A produces propene in dehydration.
Alcohol in option C produces but-1-ene in dehydration.

**27** C



# Explanation for Multiple-choice Questions

## FORM 5

### Summative Practice 3

**1** D Dissolving ammonium chloride and sodium thiosulphate in water are both endothermic reactions and the temperature of the water drops.
Dissolving calcium chloride and anhydrous copper(II) sulphate are both exothermic reactions and the reactions release heat.

**2** B The activation energy of a reaction is the minimum energy that the reactants need to have to react and form products. The heat of a reaction, $\Delta H$ is the heat change during a reaction.
This reaction is an endothermic reaction as the product has higher energy content than the reactant.
For endothermic reactions, the value of $\Delta H$ is a positive value.
Heat of reaction, $\Delta H = +(110 - 60)$ kJ mol$^{-1}$
$= +50$ kJ mol$^{-1}$ (I is true)
Activation energy $= 110$ kJ mol$^{-1}$ (IV is true)

**3** A The product of the reaction, *C*, has a lower energy content. Thus, the reaction is an exothermic reaction, where heat is released and the temperature of the surroundings increases. (I is true and IV is false)
The energy level diagram does not tell us whether a catalyst is used or not in the reaction. (II is false)
Breaking the bonds in reactants before they can react is an endothermic reaction, where heat is absorbed. Forming the bonds in products is an exothermic reaction where heat is released. As the reaction is exothermic, more energy is released during the formation of the bonds of the products than the energy absorbed to break the bonds of the reactants. (III is true)

**4** C The energy profile does not tell us whether the reaction is reversible or not. (I is false)
The reaction is exothermic as the products have lower energy content. For exothermic reactions, the value of $\Delta H$ is negative. For this reaction, $\Delta H = -(T_2 - T_1)$. (II is true)
The reactants, *A* and *B*, must overcome $(T_3 - T_2)$ kJ mol$^{-1}$ before they can form product *C*. (III is true)

**5** D The value of $\Delta H$ is positive. Thus, the reaction is endothermic where heat is absorbed from the surroundings. The temperature of the surroundings decreases. (A is false)
Since energy is absorbed from the surroundings, the products have higher energy content than the reactants. (B is false)
The $\Delta H$ value $= +18$ kJ mol$^{-1}$ is the heat of reaction, not the activation energy. (C is false)
More heat is absorbed to break the bonds of the reactants than the heat energy released during the formation of the bonds of the products. Thus, the overall $\Delta H$ value is positive. (D is true)

**6** C $Pb^{2+} + 2I^- \rightarrow PbI_2$ $\Delta H$ = negative
Reactants — Product
Since the reaction is exothermic, the value of $\Delta H$ is negative.
Also, the product, $PbI_2$ has lower energy content than the reactants.

**7** A $P + Q \rightarrow PQ$ $\Delta H = -x$ kJ mol$^{-1}$
From the equation, 1 mole of *P* reacts with 1 mole of *Q* and releases *x* kJ of heat.
If 2 moles of *P* (excess reactant) are reacted with 1 mole of *Q* (the limiting reactant), only 1 mole of *P* will react with 1 mole of *Q* to release *x* kJ of heat. The excess 1 mole of unreacted *P* will not contribute to any heat released.

**8** B Reaction I is the decomposition of ammonium chloride to ammonia gas and hydrogen chloride gas. Before ammonium chloride could decompose, it must absorb energy from the surroundings. Reaction I is endothermic. (I is false)
The reaction between metals and acids release heat. The reaction is exothermic. (II is true)
Before copper(II) carbonate can decompose to copper(II) oxide, carbon dioxide and water, it must absorb heat from the surroundings. Reaction III is endothermic. (III is false)

All displacement reactions of metals from their salt solutions by more electropositive metals are exothermic reactions. (IV is true)

**9** C The number of moles of reactants in 50 cm$^3$ 0.1 mol dm$^{-3}$, $n = \frac{50 \times 0.1}{1\ 000} = 0.001$ mol

When 0.001 mol of $AgNO_3$ reacts with 0.001 mol of NaCl, the temperature increases by $t$°C.

The number of moles of reactants in 50 cm$^3$ 0.2 mol dm$^{-3}$, $n = \frac{50 \times 0.2}{1\ 000} = 0.002$ mol

When 0.002 mol of $AgNO_3$ reacts with 0.002 mol of NaCl, the heat released is double the amount released in the first experiment. As the total volume of the solution used is the same for both experiments (100 cm$^3$), the temperature of the mixture in experiment II is $2t$°C.

**10** A When 1 mole of lead(II) sulphate is produced, 50 kJ or 50 000 J of heat is released.

If 250 J of heat is released, the number of moles of lead(II) sulphate produced

$= \frac{250}{50\ 000} \times 1$ mol

= 0.005 mol

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

0.005 mol    0.005 mol    0.005 mol

Number of moles, $n = \frac{MV}{1000}$, where

$M$ = molarity of solution, $V$ = volume of solution

$$0.005 = \frac{MV}{1000}$$

$$V = 50 \text{ cm}^3$$

**11** C Number of moles, $n = \frac{MV}{1000}$, where

$M$ = 2 mol dm$^{-3}$, $V$ = 100 cm$^3$

The number of moles of magnesium chloride and sodium carbonate, $n = \frac{2 \times 100}{1000}$

= 0.2 mol

Heat absorbed during a reaction, $H = mc\theta$, where $m$ = (100 + 100) cm$^3$,

$c$ = 4.2 J$^{-1}$ °C$^{-1}$, $\theta$ = 3°C

$H = 200 \times 4.2 \times 3$ J

$= \frac{200 \times 4.2 \times 3}{1000}$ kJ

When 0.2 mole of $MgCl_2$ reacts with 0.2 mole of $Na_2CO_3$, the heat absorbed

$= \frac{200 \times 4.2 \times 3}{1000}$ kJ

If one mole of reactants react, heat absorbed

$= \frac{1 \text{ mol}}{0.2 \text{ mol}} \times \frac{200 \times 4.2 \times 3}{1000}$ kJ

Heat of reaction, $\Delta H = + \frac{200 \times 4.2 \times 3}{1000}$ kJ mol$^{-1}$

**12** B Experiment A: Excess NaCl (25 cm$^3$)

Experiment B: Excess $AgNO_3$ (5 cm$^3$)

Experiment C: Excess NaCl (10 cm$^3$)

Experiment D: Excess $AgNO_3$ (10 cm$^3$)

Excess solution will absorb the heat released during a reaction and causes the temperature to increase less. In experiment B, the excess solution is only 5 cm$^3$. Thus, the mixture will show the highest rise in temperature.

**13** C Heat released during the experiment, $H = mc\theta$, where $m$ = 50 + 50 = 100 cm$^3$, $\theta$ = 3°C

$H = 100 \times 4.2 \times 3$ J

= 1260 J

= 1.26 kJ

Given that $\Delta H$ = –50.4 kJ mol$^{-1}$

When 1 mole of lead(II) sulphate is produced, 50.4 kJ of heat is released.

If 1.26 kJ of heat is released, the number of moles of lead(II) sulphate produced

$= \frac{1.26 \text{ kJ}}{50.4 \text{ kJ}} \times 1$ mol

= 0.025 mol

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

0.025 mol    0.025 mol    0.025 mol

Number of moles, $n = \frac{MV}{1000}$, where

$M$ = molarity of solution, $V$ = 50 cm$^3$

$$0.025 = \frac{M \times 50}{1000}$$

$M$ = 0.5 mol dm$^3$

**14** D The number of moles of reactant used,

$n = \frac{MV}{1000}$, where $M$ = 2 mol dm$^{-3}$, $V$ = 25 cm$^3$

$n = \frac{2 \times 25}{1000}$ mol

= 0.05 mol

Given that $\Delta H$ = –59 kJ mol$^{-1}$

When 1 mole of reactants reacts, 59 kJ of heat is released.

Thus, if 0.05 mole of reactants is reacted, the heat released = 0.05 × 59 kJ

= 2.95 kJ

= 2950 J

Heat, $H = mc\theta$, where $m$ = 25 + 25 = 50 cm$^3$

$2950 = 50 \times 4.2 \times \theta$

$\theta = \frac{2950}{50 \times 4.2}$

= 14°C

**15** B The heat released is due to the precipitation of calcium carbonate.

$Ca^{2+}$ (aq) + $\cancel{2NO_3^-}$ (aq) + $\cancel{2Na^+}$ (aq) + $CO_3^{2-}$ (aq)
$CaCO_3$ (s) + $\cancel{2Na^+}$ (aq) + $\cancel{2NO_3^-}$ (aq)
$Ca^{2+}$ (aq) + $\cancel{2Cl^-}$ (aq) + $\cancel{2K^+}$ (aq) + $CO_3^{2-}$ (aq)
$CaCO_3$(s) + $\cancel{2K^+}$(aq) + $\cancel{2Cl^-}$ (aq)

Sodium ions, potassium ions, nitrate ions and chloride ions are observer ions and do not participate in the reaction.

**16** A Number of moles of copper(II) sulphate,

$n = \frac{MV}{1\ 000}$, where $M$ = 0.1 mol dm$^{-3}$, $V$ = 50 cm$^3$

$n = \frac{0.1 \times 50}{1000}$ mol

$= 0.005$ mol

Given that $\Delta H = -210$ kJ mol$^{-1}$

When 1 mole of copper(II) sulphate reacts, 210 kJ of heat is released.

Thus, if 0.005 mole of copper(II) sulphate is reacted, the heat released

= 0.005 × 210 kJ
= 1.05 kJ
= 1050 J

Heat, $H = mc\theta$, where $m$ = 50 cm$^3$, $H$ = 1050 J

$1050 = 50 \times 4.2 \times \theta$

$\theta = 5°C$

**17** B Heat, $H = mc\theta$, where $m$ = 50 cm$^3$,

$\theta$ = 32.0 – 28.0°C = 4.0°C

$H = 50 \times 4.2 \times 4$ J
= 840 J
= 0.84 kJ

The number of moles of $Y$ sulphate,

$n = \frac{MV}{1\ 000}$, where $M$ = 0.2 mol dm$^{-3}$, $V$ = 50 cm$^3$

$n = \frac{0.2 \times 50}{1000}$ mol

= 0.01 mol

When 0.01 mol of metal $Y$ is displaced, 0.84 kJ of heat is released.

If 1 mole of metal $Y$ is displaced, the heat

released $= \frac{1}{0.01} \times 0.84$ kJ

= 84 kJ

$\Delta H = -84$ kJ mol$^{-1}$

**18** C Heat released during the experiment, $H = mc\theta$, where $m$ = 50 cm$^3$, $\theta$ = 6.2°C

$H = 50 \times 4.2 \times 5.2$ J
= 1302 J
= 1.302 kJ

Given that $\Delta H = -104.16$ kJ mol$^{-1}$

When 1 mole of copper is displaced by tin, 104.16 kJ of heat is released.

If 1.302 kJ of heat is released, the number of moles of copper displaced

$= \frac{1.302}{104.16} \times 1$ mol

= 0.0125 mol

The number of moles of copper nitrate,

$n = \frac{MV}{1000}$, where $M$ = molarity of solution,

$V$ = 50 cm$^3$

$n$ = 0.0125 mol

$0.0125 = \frac{M \times 50}{1000}$

$M$ = 0.25 mol dm$^{-3}$

**19** A Given that $\Delta H = -168$ kJ mol$^{-1}$

When 1 mole of copper (64 g) is displaced, 168 kJ of heat is released.

Thus, if 4.2 kJ of heat is released, the mass of

copper displaced $= \frac{4.2}{168} \times 64$ g

= 1.60 g

**20** D I $P$ + $R$ nitrate → $R$ + $P$ nitrate

[Metal $P$ is more reactive than $R$]

II $Q$ + $R$ nitrate → $R$ + $Q$ nitrate

[Metal $Q$ is more reactive than $R$]

III $P$ + $Q$ nitrate → No reaction

[Metal $Q$ is more reactive than $P$]

IV $S$ + $R$ nitrate → No reaction

[Metal $R$ is more reactive than $S$]

From equations I and II, we conclude that metal $P$ and Q are above metal $R$ in the electrochemical series as they can displace metal $R$ from its salt solution.

From equation III, we can conclude that metal $P$ is below metal $Q$ in the electrochemical series as it cannot displace metal $Q$ from its salt solution.

From equation IV, we can conclude that metal $S$ is below metal $R$ in the electrochemical series as it cannot displace metal $R$ from its salt solution. Therefore,

More electropositive ↓ $Q$
$P$
$R$
Less electropositive $S$

The further apart the metals in the electrochemical series, the higher the heat of displacement. The distance between metal $Q$ and $S$ is the furthest.

Thus, adding 1 g of metal $Q$ to $S$ nitrate solution will produce the highest increase in temperature.

**21** D I $W + X$ nitrate $\rightarrow X + W$ nitrate $\Delta H_1$
II $W + Y$ nitrate $\rightarrow Y + W$ nitrate $\Delta H_2$
III $X + Y$ nitrate $\rightarrow Y + X$ nitrate $\Delta H_3$
IV $X + Z$ nitrate $\rightarrow Z + X$ nitrate $\Delta H_4$
The further two metals in the electrochemical series, the higher the heat of reaction.
Given $\Delta H_2 > \Delta H_1 > \Delta H_4 > \Delta H_3$
From equations I and II, metal $W$ can displace metals $X$ and $Y$ from their salt solutions. This shows that metal $W$ is above metals $X$ and $Y$ is the electrochemical series.
The value of $\Delta H_2$ is higher than $\Delta H_1$. Thus, the distance between metals $W$ and $Y$ is further than the distance between metals $W$ and $X$.
From equations III and IV, metal $X$ can displace metals $Y$ and $Z$ from their salt solutions. This means that metal $X$ is above metals $Y$ and $Z$ in the electrochemical series.
Given $\Delta H_4 > \Delta H_3$. This means that the distance between metals $X$ and $Z$ is further than distance between metal $X$ and $Y$.

More electropositive $W$
$X$ — Decreasing order
$Y$ — of reactivity
Less electropositive $Z$ ↓

Thus, the decreasing order of reactivity is $W$, $X$, $Y$, $Z$

**22** A Given $\Delta H = -210$ kJ mol$^{-1}$
When 1 mole of copper (64 g) is displaced, 210 kJ of heat is released.
Thus, if 0.64 g of copper is displaced, the heat released $= \dfrac{0.64}{64} \times 210$ kJ heat
$= 2.10$ kJ
$= 2100$ J
Heat, $H = mc\theta$, where $\theta = 25°C$
$2100 = m \times 4.2 \times 25$
$m = 20$ g
As the density of the solution is 1 g cm$^{-3}$, the volume of the solution is 20 cm$^3$.

**23** B Strong acids and strong alkalis dissociate totally in water to produce high concentrations of hydrogen ions and hydroxide ions. These ions neutralise each other to produce water and produce heat of neutralisation which is $\Delta H = -57$ kJ mol$^{-1}$.
Hydrochloric acid and sulphuric acid are strong acids while sodium hydroxide and sodium hydroxide are strong alkalis.

**24** C The heat of neutralisation between a weak acid and a weak alkali is the lowest. Ethanoic acid is a weak acid and ammonia is a weak alkali.

**25** B The number of moles of methanoic acid or sodium hydroxide used, $n = \dfrac{MV}{1000}$, where
$M = 2.0$ mol dm$^{-3}$ and $V = 50$ cm$^3$
$n = \dfrac{2 \times 50}{1000}$
$= 0.1$ mole
Given that $\Delta H = -52.5$ kJ mol$^{-1}$.
When 1 mole of acid reacts with 1 mole of alkali, 52.5 kJ of heat is released.
Thus, if 0.1 mole of acid reacts with 0.1 mole of alkali, the heat released
$= 0.1 \times 52.5$ kJ
$= 5.25$ kJ
$= 5250$ J
Heat, $H = mc\theta$, where $m = (50 + 50)$ cm$^3$
$5250 = 100 \times 4.2 \times \theta$
$\theta = 12.5°C$

**26** A Heat released during the experiment, $H = mc\theta$, where $m = (25 + 25)$ cm$^3$, $\theta = 3.4°C$
$H = 50 \times 4.2 \times 3.4$ J
$= 714$ J
$= 0.714$ kJ
Given that $\Delta H = -57.12$ kJ mol$^{-1}$.
When 1 mole of water is produced, 57.12 kJ of heat is released.
Thus, if 0.714 kJ of heat is released, the number of moles of water produced
$= \dfrac{0.741}{57.12}$ mol
$= 0.0125$ mol
Number of moles, $n = \dfrac{MV}{1000}$, where
$n = 0.0125$ mole, $V = 25$ cm$^3$, $M$ = molarity of solution
$0.0125 = \dfrac{M \times 25}{1000}$
$M = 0.5$ mol dm$^{-3}$

**27** C Volume, $V = 1$ dm$^3$ $= 1000$ cm$^3$
Molarity of solution, $M = 2$ mol dm$^{-3}$
The number of moles of acid neutralised,
$n = \dfrac{2 \times 1\,000}{1000}$ mol
$= 2$ mol
Given that $\Delta H = -48$ kJ mol$^{-1}$.
When 1 mole of acid is neutralised, the heat released is 48 kJ.
Thus, if 2 moles of acid is neutralised, the heat released is $2 \times 48$ kJ.

**28** D Ethanoic acid, $CH_3COOH$ is a weak acid. It dissociates partially in water to produce low concentrations of hydrogen ions. Heat energy is needed to ionise the acid molecules (not dissociated) before the hydrogen ions can be neutralised.
Thus, the heat of neutralisation between a weak acid and an alkali is lower.

**29** D Heat released during the combustion, $H = mc\theta$, where $m$ = 500 cm$^3$, $\theta$ = 20°C
$H = 500 \times 4.2 \times 20$ J
= 42000 J
= 42 kJ
Combustion of 0.8 g of fuel released 42 kJ of heat.
Thus, combustion of 1 mole of fuel (16 g) will release $\frac{16 \cancel{g}}{0.8 \cancel{g}} \times 42$ kJ of heat = 840 kJ
Heat of combustion $\Delta H$ = –840 kJ mol$^{-1}$

**30** C Given $\Delta H$ = –735 kJ mol$^{-1}$
When 1 mole of methanol, $CH_3OH$ (32 g) is burned, 735 kJ of heat is released.
Thus, if 0.64 g of methanol is burned, the heat released = $\frac{0.64 \text{ g}}{32 \text{ g}} \times 735$ kJ
= 14.7 kJ
= 14 700 J
Heat, $H = mc\theta$ where $m$ = volume of water heated, $\theta$ = (42 – 28) = 14°C
$14\,700 = m \times 4.2 \times 14$
= 250 cm$^3$

**31** B Heat released during the experiment, $H = mc\theta$, where $m$ = 1 dm$^3$ or 1000 cm$^3$, $\theta$ = (46 – 30)
= 16°C
$H = 1000 \times 4.2 \times 16$
= 67 200 J
= 67.2 kJ
Given $\Delta H$ = –8400 kJ mol$^{-1}$
When 1 mole of heptane, $C_7H_{16}$ is burned, 8400 kJ of heat is released.
When 100 g of $C_7H_{16}$ is burned, 8400 kJ of heat is released.
Thus, 67.2 kJ of heat is released from the combustion of = $\frac{67.2 \cancel{kJ}}{8400 \cancel{kJ}} \times 100$ g
= 0.8 g of $C_7H_{16}$

**32** A Heat released during the experiment, $H = mc\theta$, where $m$ = 500 cm$^3$, $\theta$ = 37°C
$H = 500 \times 4.2 \times 37$ J
= 77 700 J
= 77.7 kJ
Combustion of 1.5 g of fuel released 77.7 kJ of heat.
Given $\Delta H$ = –1554 kJ mol$^{-1}$
When 1 mole of fuel $R$ is burned, 1554 kJ of heat is released.
The mass of fuel needed to be burned to release 1554 kJ of heat = $\frac{1\,554 \cancel{kJ}}{77.7 \cancel{kJ}} \times 1.5$ g
= 30 g
Relative molecular mass of fuel $R$ is 30.

**33** C Given $\Delta H$ = –882 kJ mol$^{-1}$
When 1 mole (16 g) of fuel $X$ is burned, 882 kJ of heat is released.
The heat released when 0.4 g of the fuel is burned = $\frac{0.4}{16} \times 882$ kJ
= 22.50 kJ
= 22 050 J
Heat released during the experiment, $H = mc\theta$, where $m$ = 250 cm$^3$, $\theta$ = rise in the temperature of the water
$22\,050 = 250 \times 4.2 \times \theta$
$\theta$ = 21°C

**34** D Given $\Delta H = -x$ kJ mol$^{-1}$
When 1 mole of fuel is burned, $x$ kJ of heat is released.
If $0.025x$ kJ of heat is released, the number of moles of the fuel burned
= $\frac{0.025x}{x} \times 1$ mol
= 0.025 mol
From the equation, combustion of 1 mole of toluene produces 7 moles of $CO_2$
Combustion of 1 mole of toluene produces $7 \times 24$ dm$^3$ of $CO_2$ at room conditions.
Thus, if 0.025 mole of toluene is burned, the volume of carbon dioxide produced is $0.025 \times 7 \times 24$ dm$^3$ = 4.2 dm$^3$

**35** A The alcohols listed are methanol, $CH_3OH$, ethanol, $C_2H_5OH$, propanol $C_3H_7OH$ and butanol, $C_4H_9OH$.
Each alcohol has one oxygen atom. However, from one alcohol to the next consecutive alcohol, there is an increase of one carbon atom and two hydrogen atoms.

**36** B

| Fuel | $C_2H_5OH$ | $C_4H_{10}$ | $CH_3OH$ | $C_7H_{16}$ |
|---|---|---|---|---|
| RMM | 46 | 58 | 32 | 100 |

Fuel value is defined as the heat released when 1 gram of fuel is burned.
Given heat of combustion of ethanol, $\Delta H$ is –1380 kJ mol$^{-1}$
When 1 mole of ethanol (46 g) is burned, 1380 kJ of heat is released.

If 1 gram of ethanol is burned, the heat released is $\frac{1}{46} \times 1380 \text{ kJ} = 30 \text{ kJ}$

Given heat of combustion of butane, $\Delta H$ is –2968 kJ $mol^{-1}$

When 1 mole of butane (58 g) is burned, 2968 kJ of heat is released.

If 1 gram of butane is burned, the heat released is $\frac{1}{58} \times 2968 \text{ kJ} = 51.17 \text{ kJ}$

Given heat of combustion of methanol, $\Delta H$ is –890 kJ $mol^{-1}$

When 1 mole of methanol (32 g) is burned, 890 kJ of heat is released.

If 1 gram of methanol is burned, the heat released is $\frac{1}{32} \times 890 \text{ kJ} = 27.81 \text{ kJ}$

Given heat of combustion of heptane, $\Delta H$ is –4818 kJ $mol^{-1}$

When 1 mole of heptane (100 g) is burned, 4818 kJ of heat is released.

If 1 gram of heptane is burned, the heat released is $\frac{1}{100} \times 4818 \text{ kJ} = 48.18 \text{ kJ}$

**37** C The most cost effective fuel is the fuel that is the least expensive for every kJ of heat released when it is burned.

| **Fuel** | *W* | *X* | *Y* | *Z* |
|---|---|---|---|---|
| **Heat of combustion, kJ $g^{-1}$** | 90 | 10 | 50 | 30 |
| **Cost per gram, cent $g^{-1}$** | 12 | 2 | 4 | 3 |
| **Cost per kJ of heat released, cent $kJ^{-1}$** | 0.133 | 0.2 | 0.08 | 0.1 |

Fuel *W*

$$\text{Cost per kJ of heat} = \frac{12 \text{ cent/g}}{90 \text{ kJ/g}} = \frac{12 \text{ cent}}{90 \cancel{\text{g}}} \times \frac{\cancel{\text{g}}}{\text{kJ}} = 0.133 \text{ cent kJ}^{-1}$$

Fuel *X*

$$\text{Cost per kJ of heat} = \frac{2 \text{ cent/g}}{10 \text{ kJ/g}} = 0.2 \text{ cent kJ}^{-1}$$

Fuel *Y*

$$\text{Cost per kJ of heat} = \frac{4 \text{ cent/g}}{50 \text{ kJ/g}} = 0.08 \text{ cent kJ}^{-1}$$

Fuel *Z*

$$\text{Cost per kJ of heat} = \frac{3 \text{ cent/g}}{30 \text{ kJ/g}} = 0.1 \text{ cent kJ}^{-1}$$

**38** A Coal produces smog due to incomplete combustion.

# Explanation for Multiple-choice Questions

## FORM 5

### Summative Practice 4

**1** B Definition of polymer.
**2** A
**3** D Both *J* and *K* have the same empirical formula.
**4** C Neoprene is a synthetic rubber.
**5** A The monomer of starch is glucose.
**6** D Plastics release poisonous gas when burned.
**7** C *Y* is polyvinyl chloride.
**8** B
**9** B
**10** A
**11** D Polymer *X* is a condensation polymer.
**12** C Poly(2-methylbut-1,3-diene) is natural rubber.
**13** D Latex contains polymer of natural rubber.
**14** A Coagulation of latex can be prevented by adding alkaline solutions such as aqueous ammonia.
**15** B Coagulation speeds up when an acid is added to latex.
**16** C
**17** C Vulcanised rubber is harder and more resistant to oxidation and heat than unvulcanised rubber.
**18** D Neoprene and styrene-butadiene rubber are examples of synthetic rubber.
**19** A SBR only contains carbon and hydrogen. It is produced when styrene and but-1,3-diene monomers undergo addition polymerisation.
**20** B

# Explanation for Multiple-choice Questions

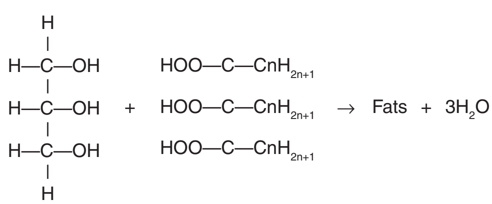
## FORM 5

### Summative Practice 5

**1** D Saturated fats satisfy the formula $C_nH_{2n+1}$. Unsaturated fats do not satisfy the formula $C_nH_{2n+1}$.

| Fat | I | II | III | IV |
|---|---|---|---|---|
| Hydrocarbon chain | $–C_{13}H_{27}$ | $–C_{16}H_{31}$ | $–C_{17}H_{35}$ | $–C_{12}H_{23}$ |
| General formula $C_nH_{2n+1}$ | Satisfy | Does not satisfy | Satisfy | Does not satisfy |
| Conclusion | Saturated | Unsaturated | Saturated | Unsaturated |

**2** D Fats are made up of one glycerol and three fatty acid molecules.



**3** C To make margarine, hydrogen gas is bubbled into an unsaturated plant oil in the presence of nickel as the catalyst. Hydrogen is added to the C = C double bonds to produce saturated fat.
The process of adding hydrogen to the C = C double bond is called hydrogenation.

**4** A Glycerol is an alcohol. It contains the –OH group.
Sodium stearate $C_{17}C_{35}COO^-Na^+$ is a salt of fatty acid.
Glyceryl tripalmitate is a natural ester produced in plants from esterification of one glycerol and three palmitic acid molecules.

**5** B Sodium chloride reduces the solubility of soap so that more soap can precipitate out. Therefore, increasing the yield of the soap produced.

**6** C Calcium ions and magnesium ions will react with soap to produce insoluble salts called scum.
$2RCOO^-(aq) + Ca^{2+}(aq) \rightarrow (RCOO)_2Ca(s)$ Scum
$2RCOO^-(aq) + Mg^{2+}(aq) \rightarrow (RCOO)_2Mg(s)$ Scum

**7** B Soaps do not form lather in hard water because they form scum with the $Ca^{2+}$ or $Mg^{2+}$ ions present in hard water.
$2RCOO^-(aq) + Ca^{2+}(aq) \rightarrow (RCOO)_2Ca(s)$ Scum
$2RCOO^-(aq) + Mg^{2+}(aq) \rightarrow (RCOO)_2Mg(s)$ Scum
(A is false)
All soaps are biodegradable because their hydrocarbon chains consist of hydrogen atoms bonded to carbon atoms. Enzymes from the microorganisms present in the water can penetrate the hydrocarbon chains and break the chains. (B is true)
Soaps are ineffective in acidic solutions because they react with the hydrogen ions to form insoluble fatty acids.
$RCOO^-(aq) + H^+(aq) \rightarrow RCOOH(s)$
Insoluble fatty acid
(C is false)
To make soaps, sodium chloride is added to precipitate out the soaps. (D is false)

**8** C Step I involves incorporating sulphuric acid molecules into the hydrocarbon. The process is called sulphonation.
Step II involves neutralising another hydrogen ion from the sulphuric acid with sodium hydroxide.

**9** A Both soap and detergent consist of hydrophobic hydrocarbon chains ($C_nH_{2n+1}$) which dissolve in grease. (A is true)

| $C_nH_{2n+1}COO^-$ | $\rightarrow$ | $C_nH_{2n+1}OSO_3^-$ |
|---|---|---|
| Soap | | Detergent |
| Alkyl carboxylate | | Alkyl sulphate |

Soap is an alkyl carboxylate salt whereas detergent is an alkyl sulphate salt. (B is false)
Soaps form scum in hard water whereas detergents do not. (C is false)
Soaps are ineffective in acidic water; whereas detergents are effective in acidic water. (D is false)

**10** B Lipase is an enzyme that dissolves fatty acids stains. (A is false)
Sodium tripolyphosphate contains phosphate ions which react with $Ca^{2+}$ and $Mg^{2+}$ ions present in hard water. Thus, it reduces the hardness of water.
$3Ca^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Ca_3(PO_4)_2(s)$
(B is true)
Sodium perborate is a bleaching agent. (C is false)
Anhydrous sodium sulphate keeps the detergent powder dry (prevent clumping). (D is false)

**11** A Sodium benzoate, $C_6H_5COONa$ and potassium nitrite, $KNO_2$ are food preservatives. (I and III are correct)
Pectin is a thickening agent added to jam. (II is incorrect)
Lecithin is an emulsifier to prevent oil and water from separating out. (IV is incorrect)

**12** D Ascorbic acid is an antioxidant, aspartame is an artificial sweetener, monosodium glutamate is a food enhancer.

**13** D Different food colour dye move at different speeds along a chromatography paper.
So this process can be used to separate the dyes.

**14** C Ascorbic acid slows down the oxidation of fats in foods so that they will not turn rancid.

**15** D Ringworm is caused by fungal infection. Thus, we apply antifungal lotions to treat it.

**16** C Aspirin contains the functional group –COOH. This functional group ionises to produce $H^+$ ions, making the medicine acidic. The intestinal walls in children are thin and the acid can cause the intestinal walls to bleed.

**17** D

**18** A Some people are allergic to eggs, nuts, pollens and dust. These reactions can be remedied or prevented by taking anti allergy medications.

**19** A Rejuvenating cosmetics are cosmetics that make skin look healthier. Toners, serum and sunscreens are all rejuvenating cosmetics.

**20** B Fragrances are volatile organic esters. It vapourises easily. If inhaled in excess, it may cause injury to lung tissues.

**21** D Carbon has 4 valence electrons. In carbon nanotubes, three electrons of each carbon atom is used to form bonds while one electron is highly mobile and can conduct electricity. Thus, electrical cables coated with carbon nanotubes are better electrical conductor and have lower resistance.

**22** B Wind turbine blades are made from the composite of carbon nanotubes (RAM of carbon = 12) and epoxy is lighter than those made from the composite of glass fibre (silicon dioxide, RMM = 60) and epoxy.

**23** A Nano-sized pesticides are smaller compared to conventional pesticides. They penetrate through the skin of pests more easily.
Since they can penetrate faster, we need to spray less pesticide, reducing pesticide residue on food.
As less pesticide is sprayed, the amount of pesticides that will leech through the ground and contaminate ground waters is also reduced.

**24** C Clay produces ceramics when heated. Ceramic has a high melting point.
Fireman's uniforms have these ceramic particles to protect their skin from burning when putting out fires that are very hot.

**25** A Nano-sized particles can be used to deliver drugs to specific cells such as cancer cells, reducing damage to healthy cells.
Vitamins which are enclosed in nano-sized particles do not degenerate quickly as they are not exposed to air and microorganisms. As they are nano-sized, they can be absorbed by the body more efficiently.

**26** D Nanosensors can detect small amounts of molecules present in the exhaled breaths of patients.

| Compound detected | Disease |
|---|---|
| Acetone | Diabetes |
| Hydrogen sulphide | Halitosis (Bad breath) / Oral disease |
| Ammonia | Kidney malfunction |
| Toluene | Lung cancer |

**27** B Electrolysis can remove heavy metal ions from wastewater.
For example, chromium(III) ions in wastewater will move to the cathode and discharge.

$$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$$

Another method is to pass the wastewater through a series of biofilms that contain microorganisms that can remove the heavy metal ions.

**28** C Green Technology is the technology that reduces the negative impacts of human activities on the environment such as water and land pollution as well as global warming.
It also uses renewable energies like solar, wind and wave energy to produce electricity.
Green Technology may also be in the form of repairing the damages already done to the environment.