BioMedical Admissions Test (BMAT)

Section 2: Chemistry

Questions by Topic

C6 - Chemical Bonding, Structure and Properties

C6: Chemical Bonding, Structure and Properties - Question by Topic

(Mark Scheme and explanations at the end)

1 Below is a table of 6 hazard symbols, the warnings they give, and one example of each. One of the hazard symbols has an incorrect warning and example matched to its name.

Which hazard symbol is incorrectly described?

	Hazard Symbol	Warning	Example
A	Flammable	Easily ignites	Petrol
B	Explosive	Substance may explode if not handled carefully	Some peroxides
C	Health Hazard	Can cause breathing problems, cancer or other serious health concerns	Benzene
D	Oxidising	Gets oxidised in redox reactions	Iron(II) sulfate
E	Corrosive	Contact can damages clothes and burn skin and eyes	Concentrated sulfuric acid
F	Toxic	A very poisonous substance which can prove fatal if consumed, inhaled or comes into contact with skin	Hydrogen cyanide

2 The following statements are about acids and alkalis.

1 Acidic substances have a pH from 1-8.
2 An alkali forms H+ ions in water.
3 An acid forms OH- ions in water.
4 Acids and alkalis react to form neutral solutions.
5 Universal indicator confirms the precise pH of a substance.

Which of the above statements are incorrect?

A 1, 2, 3, 4 and 5
B 1, 2, 3 and 5
C 1, 2, 4 and 5
D 1, 2 and 3
E 2, 3 and 5
F 1 and 5
G 4 and 5
H 2 and 3

3 Ethanoic acid (CH_3COOH) is a weak acid. The following statements concerning ethanoic acid are all correct except:

A Ethanoic acid does not fully ionise in water. Only a small number of its acid molecules give off protons.
B The equation for the ionisation of ethanoic acid is: $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$
C Weak acids like ethanoic acid are less concentrated acids.
D Hydrochloric acid is a better electrical conductor than ethanoic acid.
E H_2 is produced in the electrolysis of ethanoic acid.

4 A student decided to perform an experiment reacting aluminium and sulfuric acid in a test-tube.

1 The reaction produces a salt and hydrogen, like all reactions of acids and metals.
2 The salt produced in this reaction is called aluminium sulfate.
3 Placing a burning splint in the test-tube makes no sound.
4 Copper would have a more explosive reaction than aluminium with the sulfuric acid.

Which of the above statements are true concerning the student's experiment reacting aluminium with sulfuric acid?

A 1, 2, 3 and 4
B 1, 2, and 3
C 2, 3 and 4
D 1, 2 and 4
E 1 and 2
F 3 and 4
G 2 and 3
H 1 and 4

5 When acids react with metal or compounds, they always make a salt. Some of these reactions also produce water.

1 Acid + metal oxide
2 Acid + metal carbonate
3 Acid + metal hydroxide
4 Acid + metal

Which of the above acid + metal/metal compound reactions result in the formation of salt and water only?

A 1 and 2
B 2 and 3
C 3 and 4
D 2 and 4
E 1 and 3
F 1 and 4

6 John wants to produce a soluble salt by reacting hydrochloric acid with potassium hydroxide (an alkali). He first adds a bit of potassium hydroxide to the hydrochloric acid in a flask. He was expecting to see a precipitate form at the bottom of the flask which he would then filter out to be left with a solution of salt and water only. However, no solid formed at the bottom of the glass. What is the most important mistake John has made in his experiment?

A He should have used a beaker instead of a flask. The flask does not provide enough surface area for the gas produced in the reaction to escape and therefore the reaction did not go to completion.

B He followed the procedure for the reactions of acids with insoluble bases. He should have performed a titration to determine the exact amount of base needed to neutralise the acid. Potassium hydroxide is soluble and produces a soluble salt when it reacts with acid, so no precipitate will form at the bottom of the flask to indicate that all the acid has been neutralised.

C He should have used a weak acid like ethanoic acid rather than hydrochloric acid. Strong acids like hydrochloric acid do not react with metal hydroxides, because they release too many protons.

D He forgot to heat the insoluble base before adding it to the acid. Heating the insoluble base would have enabled it to react with the acid to form a solid at the bottom of the flask.

7 Tina added 2g of a substance to a beaker of water. She watched the reaction and noticed that after some stirring, the substance had fully dissolved.

1 Sodium chloride
2 Lead nitrate
3 Barium sulfate
4 Ammonium carbonate
5 Iron(III) hydroxide

Which of the above substances could have been what Tina added to the beaker in her experiment?

A 1, 2, 3, 4 and 5
B 1, 2, and 4
C 2, 3 and 4
D 1, 3 and 5
E 4 and 5
F 1 and 4
G 3 and 5
H 2 and 3

8 Copper(II) oxide reacts with hydrogen in a redox reaction.

Copper(II) oxide + hydrogen → copper + water

$CuO + H_2 \rightarrow Cu + H_2O$

The following statements refer to this reaction.

1 Copper oxide is the reducing agent and hydrogen is the oxidising agent.
2 The half equations for this redox reaction are:
$CuO + 2\ e^- \rightarrow Cu + O^{2-}$ and $H_2 + O^{2-} \rightarrow H_2O + 2\ e^-$
3 The hydrogen donates 2 electrons, while the copper oxide accepts 2 electrons.
4 This reaction only involves oxidation, as reduction and oxidation cannot happen at the same time.

Which of the above statements are correct concerning this redox reaction?

A 1, 2, 3 and 4
B 1, 2, and 3
C 2, 3 and 4
D 1 and 2
E 2 and 3
F 3 and 4
G 2 and 4
H 1 and 4

9 The following statements refer to the rusting of iron and ways to prevent it.

1 Iron rusting is a redox reaction.
2 Iron rusts on exposure to nitrogen in the air and water.
3 Producing alloys such as stainless steel - made of iron, carbon and chromium - can help to prevent rust.
4 Galvanizing involves coating objects in tin to prevent rust.
5 Galvanizing is an example of a displacement reaction.

Which of the above statements are correct concerning rusting of iron?

A 1, 2, 3, 4 and 5
B 1, 2, and 3
C 2, 3 and 4
D 2, 4 and 5
E 4 and 5
F 1 and 3
G 2 and 5
H 1 and 4

10 The group 7 elements increase in reactivity. Of iodine, bromine and chlorine, iodine is the least reactive, and chlorine is the most reactive.

(Least reactive) Iodine→bromine→chlorine (most reactive)

1 Chlorine + sodium bromide
2 Iodine + potassium bromide
3 Bromine + potassium chloride
4 Iodine + sodium iodide
5 Chlorine + potassium iodide

In which of the above reactions will a displacement reaction occur?

A 1, 2, 3, 4 and 5
B 1, 2, and 3
C 2, 3 and 4
D 2, 4 and 5
E 4 and 5
F 1 and 5
G 2 and 3
H 1 and 4

11 Which of the following four lists of compounds contains exactly **two** compounds that contain ionic bonds?

A $MgCl_2$ (s) , CO_2 (g), $SiCl_4$ (s), H_2S (g)
B H_2SO_4 (aq), Cl_2O (s), CF_4 (g), $MgCO_3$ (s)
C SO_2 (g), $Fe(NO_3)_2$ (aq), $ZnSO_4$ (aq), $MgCl_2$ (s)
D NH_4Cl (aq), CH_4 (g), NaBr (aq), $SiCl_4$ (s)

12 Graphite is a compound that forms a particular type of structure. Which of the properties below are commonly found in this type of structure?

1 Very high melting point
2 Very high hardness
3 Varying electrical conductivity
4 Water soluble
5 Hexane soluble

A 1 and 2 only
B 1, 2 and 3 only
C 2 and 3 only
D 1, 3 and 5 only
E 2, 3 and 4 only
F 1 and 4 only
G 1 and 3 only

Answers and Explanations

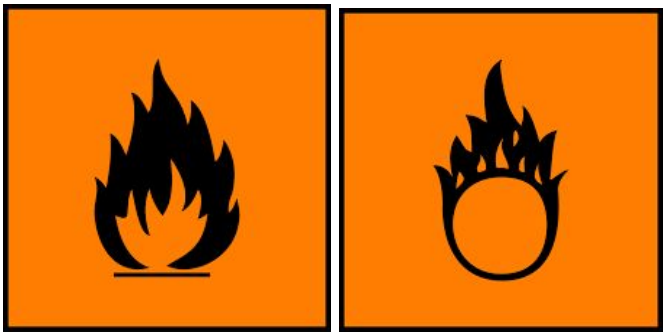
1 **The answer is D**

Answering this question requires basic knowledge of redox reactions which can be found in Topic 6 of the BMAT Chemistry Guide. You need to be very clear about the difference between substances that **get oxidised** and substances that are **oxidising agents.** The “oxidising” sign refers to oxidising agents. These are substances which, usually providing oxygen as the oxidising agent, cause another substance to set on fire. If you recall **OILRIG**, you will know that this means the oxidising agents bring about combustion of other substances by **losing electrons**.

Iron (III) sulfate is not an example of a substance labelled as “oxidising”, but if you answered this question hastily you may have just remembered reading about iron(III) sulfate in the redox reaction section and thought that it fits. Instead, a common example of an oxidising agent labelled with the “oxidising” hazard symbol is **liquid oxygen.**

Exam Tip - Make sure you are clear on a common point of confusion about oxidising substances. Unlike flammable substances, oxidising substances don’t actually burn themselves; they just provide the fuel for other substances to ignite.

Both hazard symbols show a flame, but you can distinguish them by remembering that the “oxidising” hazard symbol has a big O for “oxidising” in the flame.



Flammable Oxidising

2 The answer is B

1 is incorrect - acidic substances have a pH ranging from **1-6**. 7 is the neutral pH. Basic substances have a pH ranging from 8-14.

2 is incorrect - the answer options for alkalis and acids have been swapped. Alkalis actually **form OH- ions in water**.

3 is incorrect - **acids form H+ ions** in water, as they **ionise.**

4 **is correct**- this is the **neutralisation reaction**, an example can be as simple as $H^+ + OH^- \rightarrow H_2O$

5 is incorrect - Universal indicator only allows us to **estimate** the pH of a substance; it is not a way of confirming the exact pH. Make sure you don't get tripped up by this point!

3 The answer is C

A common **misconception** about weak and strong acids is that weak acids must also be dilute acids, and strong acids must also be concentrated acids. However, acid strength is very different to acid concentration. **Acid strength** refers to an acid's **ability to completely ionise** (that is, release the protons from all of its acid molecules) in water. Stronger acids fully ionise whereas weaker acids only partially ionise. **Acid concentration**, on the other hand, describes the **number of acid molecules in 1 litre of water**. Both strong and weak acids can be concentrated or dilute: this has nothing to do with acid strength. The BMAT may try to trip you up on this point, so make sure you learn the difference between acid strength and acid concentration.

Exam Tip - There are a few key facts you should remember about **weak acids**:

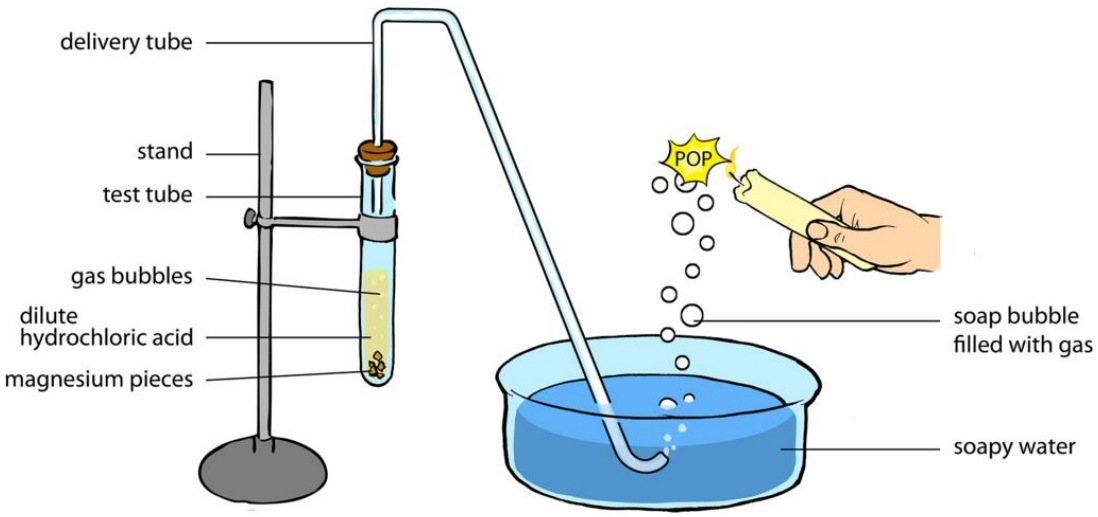
- They **don't fully ionise** (only some of the acid molecules release their H^+ ions in water).
- They have **lower electrical conductivity** than strong acids (partially-ionising weak acids have a lower concentration of ions in solution, and it is the ions which are able to carry charge and conduct electricity).
- The ionisation of weak acids is a **reversible reaction,** and the **equilibrium** is to the **left** (very few protons are given off).

4 **The answer is E**

3 is incorrect - the **hydrogen test** (placing a burning splint in a test-tube after a reaction) would make a **squeaky pop** in this experiment. If you knew that **1** was correct because reactions between metals and acids always produce a salt plus **hydrogen,** then you would immediately know that **3** is false, because any hydrogen produced will cause the burning splint to make a sound when placed in the test-tube.

4 is incorrect - **copper** is an exception to the **metal + acid → salt + hydrogen** rule. **Copper does not react with dilute acids** at all (and subsequently produces no sound during the hydrogen test). The reason that copper does not react with dilute acids is that it is less reactive than hydrogen.

Exam Tip - Remember, the **more reactive the metal, the faster and more explosive the reaction** between the acid and the metal. **Magnesium** will make the **loudest pop**, with aluminium coming in second place and zinc and then iron following behind with a small squeak. **Copper will not make any sound** in the hydrogen test because it does NOT react with dilute acids.



5 **The answer is E**

1 and **3** produce salt and water only.

Concerning **2,** reactions between acids and metal carbonates also produce **carbon dioxide.** You should be able to see bubbles of gas being given off during the reaction.

Regarding **4,** reactions between acids and a metal produce **no water**: they produce a salt and **hydrogen**. This is why the **hydrogen test** (placing a burning splint in a test-tube to see if it lights up) is useful in these reactions. The loudness (or absence of) of the **squeaky pop** sound in the hydrogen test can give you an indication of how reactive the metal is. Very unreactive metals like copper won't react with acid at all and will produce no sound!

Exam Tip - Make sure you know these key reactions of acids with metals and metal compounds, as they are easily testable:

- Acid + metal oxide → salt + water
- Acid + metal hydroxide → salt + water
- Acid + metal carbonate → salt + water + **carbon dioxide**
- Acid + metal → salt + **hydrogen**

6 **The answer is B**

John was following the method for producing soluble salts from an acid and an **insoluble reactant.** This was an error because he was using potassium hydroxide, an alkali. An alkali is a **soluble base.**

It is fine to add an **unmeasured** amount of **insoluble** base to acid, because the **excess base** that wasn't needed for neutralisation will settle as a solid at the bottom of the flask. This can then be **filtered out** and the remaining mixture heated to evaporate off the water and leave the salt to crystallise.

With **soluble** bases, however, the excess base will not sink to the bottom of the flask as a solid, so there is **no visible indication that the acid has been neutralised**. For this reason, a **titration** has to be performed beforehand to **calculate the exact amount of base** needed to neutralise the acid. Then, once the acid has been neutralised, **no filter paper is needed**, and the solution can simply be heated to evaporate off the water, leaving the salt.

Exam Tip - Remember, the key difference in methods between making a soluble salt using an acid an insoluble base versus using an acid and a soluble base, is that in the latter, you need to perform a **titration** to calculate the exact amount of base needed to neutralise the acid.

7 **The answer is B**

1, 2 and **4** are all soluble in water.
3 and **5** are **insoluble,** and would have formed a **precipitate,** so they cannot be the substance that Tina used.
Knowledge of the **solubility rules** is essential to answering this question.

1 is soluble - the common chlorides are all soluble, apart from silver chloride and lead chloride.
2 is soluble - nitrates are all soluble. There are no exceptions.
3 is **insoluble** - common sulfates are all soluble, apart from lead sulfate, **barium** sulfate and calcium sulfate.
4 is soluble - common carbonates are all **insoluble**, apart from sodium, potassium and **ammonium** carbonates.
5 is **insoluble** - common hydroxides are all **insoluble**, apart from sodium, potassium and ammonium carbonates.

8 **The answer is E**

1 is incorrect - copper oxide is the **oxidising** agent and hydrogen is the **reducing** agent. Recall **OILRIG.** Copper oxide **loses** 2 electrons, so it must be getting oxidised. Hydrogen **gains** electrons so it must be getting reduced.
4 is incorrect - redox reactions are named RED-OX because **both reduction and oxidation occur simultaneously**. By definition, in every redox reaction there must be both reduction and oxidation. Think about it: if one compound is losing electrons, where are they going to go? Something needs to accept them. Conversely, if a substance is accepting electrons, where are they coming from?

9 **The answer is F**

1 and **3** are correct.

2 is incorrect - iron rusts on exposure to **oxygen** in the air and water, **not nitrogen.**
Iron + oxygen + water → hydrated iron (III) oxide
This is a **redox reaction** in which iron gets oxidised (each atom loses 3 electrons) and oxygen gets reduced (each atom gains 2 electrons).

4 is incorrect - **galvanizing** involves coating objects in **zinc** to prevent rust. Some objects that tend to be galvanized are corrugated iron roofs and steel buckets.

5 is incorrect - galvanizing is **not** an example of a displacement reaction. Although it does involve placing a **more reactive metal** (zinc), with a **less reactive metal** (iron), this is not a reaction between a metal and a metal salt as is the case with classic displacement reaction. The two reactants in the case of galvanization are **zinc** and **oxygen: oxygen reacts with the more reactive zinc** instead of the less reactive iron, thereby preventing rust.

10 **The answer is F**

Reactions between the elements and compounds in **1** and **5** will be displacement reactions. In cases **2, 3** and **4, no visible reaction** will occur.

Displacement reactions are a type of reaction where a **more reactive element kicks out a less reactive element from its compound**.

Given that chlorine is **more reactive** than bromine, chlorine will **replace** bromine in the sodium bromide compound to form sodium chloride:
Chlorine + sodium bromide → bromine + sodium chloride.

Likewise, since bromine is **more reactive** than iodine, bromine will **replace** the iodine in the potassium iodide compound to produce potassium bromide:
Bromine + potassium iodide → iodine + potassium bromide.

2 will not be a displacement reaction because iodine is **less reactive** than bromine. **No visible reaction** will occur if you try to react these two substances.

3 will also not be a displacement reaction because bromine is **less reactive** than chlorine.

4 will not be a displacement reaction as iodine is being added to a compound containing the **same element,** which has the same reactivity.

Exam Tip - Remember that **displacement reactions also occur between metals and metal compounds**. A more reactive metal will kick out a less reactive metal from its metal compound. Don't forget: these are not only displacement reactions, but also **redox reactions.** The metal ion will get reduced and the metal atom will be oxidised.

11 **The answer is D**

Covalent bonding occurs between two non-metal elements, whereas ionic bonding usually occurs between a non-metal and a metal. The exception is NH_4Cl in D which is classified as an ionic compound.

12 **The answer is G**

Graphite is a **giant covalent structure**. These have very high melting points, but varying hardness and electrical conductivity. For example, diamond is very hard but graphite is very soft. Diamond also does not conduct electricity but graphite is widely used as a semiconductor (partial conductor of electricity) due to the presence of free electrons in its structure. No giant covalent structures are soluble in either water or organic solvents, due to the extremely high strength of the covalent bonds in the structure.