BioMedical Admissions Test (BMAT)

Section 2: Chemistry

Questions by Topic

C9 - Acids, Bases and Salts

C9: Acids, Bases and Salts - Question by Topic

(Mark Scheme and explanations at the end)

1 One example of a redox reaction is that between calcium and hydrochloric acid. As this reaction progresses, the effervescence of a colourless gas can be observed.

What is the ionic equation for this reaction?

A $Ca\ (s) + H^+\ (aq) \rightarrow Ca^+\ (aq) + ½\ H_2\ (g)$
B $Ca\ (s) + 2H^+\ (aq) \rightarrow Ca^{2+}\ (aq) + H_2\ (aq)$
C $Ca\ (s) + 2H^+\ (aq) \rightarrow Ca^{2+}\ (aq) + H_2\ (g)$
D $Ca\ (s) + 2H^+\ (aq) + 2Cl^-\ (aq) \rightarrow CaCl_2\ (aq) + H_2\ (g)$
E $Ca\ (s) \rightarrow Ca^{2+}\ (aq) + 2e^-$

2 Acids are proton donors; they release hydrogen ions when mixed with water. Acids can differ between each other in strength and in concentration.

Which of the following statements about Sulfuric Acid are correct?

1 One mole of Sulfuric Acid donates more than one mole of H^+ (aq) ions.
2 A solution of Ethanoic Acid, at equal concentration, will react less readily with a metal carbonate and produce a smaller volume of carbon dioxide gas.
3 4.905 g of Sulfuric Acid is dissolved in 10 dm^3 of distilled water and 1 cm^3 of this solution is transferred to a larger volumetric flask. When made up to 1 dm^3 using distilled water, the pH of this new solution is 5.3 at 25°C.
[A_r values: H = 1.0, S = 32.1, O = 16.0]
4 Sulfuric Acid will fully dissociate in water.

A 1 and 2 only
B 1, 2, 3 and 4
C 1 and 4 only
D 1, 2 and 3 only.

3 Which of the following statements regarding acids is incorrect?

A The reaction between an acid and a metal carbonate is a redox reaction.
B On the pH scale, an increase/decrease of 1 corresponds to a change by a factor of 10 in the concentration of hydrogen ions.
C An acid will produce the same byproduct(s) when reacting with a metal hydroxide and a metal oxide.
D Reactions between metals and acids will occur only if the metal is more reactive than hydrogen.
E Sodium metal and dilute hydrochloric acid should not be reacted in the laboratory as the reaction may be violent.

4 Metal oxides are bases, so will react with acids in a neutralisation reaction.

20 cm^3 of dilute hydrochloric acid is reacted with an excess of solid copper (II) oxide. 2.69g of copper salt is formed.

Calculate the concentration of the hydrochloric acid used.

[A_r values: H = 1.0, Cl = 35.5, Cu = 63.5, O = 16.0]

A 0.020 mol dm^{-3}
B 1.000 mol dm^{-3}
C 0.002 mol dm^{-3}
D 2.000 mol dm^{-3}
E 0.100 mol dm^{-3}

5 Which of the following statements is correct?

A The simplest half equation for all reactions between aqueous acids and alkalis is:

$$H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$$

B Carbon reacts with water to produce carbonic acid.

C 20.0 cm^3 of 2.0 mol dm^{-3} calcium hydroxide solution is neutralised by 10.0 cm^3 hydrochloric acid.
The concentration of this acid will be twice that of the calcium hydroxide solution.
[A_r: H = 1.0, Ca = 40.1, O = 16.0, Cl = 35.5]

D The following equation for the reaction between phosphorus (V) oxide and water is correct:

$$P_4O_{10} (s) + 6H_2O (l) \rightarrow 4H_3PO_4 (aq)$$

E If silver metal is added to dilute hydrochloric acid under standard conditions, effervescence of a colourless gas may be observed and silver sulfate will be produced.

6 9.58kg of sodium hydroxide was mixed with an excess of sulfuric acid, H_2SO_4. The reaction occurred at RTP (room temperature and pressure). The aqueous product is sodium sulfate, Na_2SO_4. It has a density of 2.66 g/cm.

Using the balanced equation for this reaction, determine the expected volume of aqueous sodium sulfate produced.

(Molecular weights: Na = 23, S =32, H = 1, O = 16)

A 5610 cm^3
B 5607 cm^3
C 9800 cm^3
D 6393 cm^3
E 7524 cm^3

7 An excess of hydrochloric acid is reacted with calcium carbonate. The initial mixture of reactants weights 10.71g, and the final (open) product mixture weighs 9.31g.

Assuming that the only gaseous product formed was carbon dioxide, what percentage by mass of the initial mixture was made up by calcium carbonate?

(Molecular weights: C = 12, O = 16, Cl = 35, Ca = 40)

A 26.3%
B 95.2%
C 0.1%
D 29.9%
E 53.4%

8 5.5g of a carbonate X is isolated. It is titrated with hydrochloric acid, and it is found that the substance reacts completely in a 1:1 molar ratio with exactly 1.60g of hydrochloric acid. The resulting chloride is reacted with potassium to obtain a metal.

When this metal is placed in a flame, what colour is observed?

(Molecular weights: C = 12, O = 16, Cl = 35, Ca = 40, Cu = 64, Li = 7, Na = 23, Mg = 24, K = 39, H = 1)

A Brick red
B Orange
C Lilac
D Yellow
E Green

9 9.3 cm^3 of sulfuric acid reacts completely with 1g of sodium.

What concentration is the sulfuric acid?

(Molecular weights: S = 32, O = 16, H = 1, Na = 23)

A 2.26 mol dm^{-3}
B 2.34 mol dm^{-3}
C 1.77 mol dm^{-3}
D 9.63 mol dm^{-3}
E 1.12 mol dm^{-3}

10 An industrial chemical engineer reacts an excess of concentrated sulfuric acid, H_2SO_4, with extremely dilute aqueous copper hydroxide.

What is the most likely observation?

A Effervescence giving way to a clear solution
B A white precipitate is formed
C Effervescence giving way to a blue solution
D A blue precipitate is formed
E Effervescence giving way to a yellow solution

Answers and Explanations

1 **C is the answer**

Full Chemical Equation:
$Ca\,(s) + 2HCl\,(aq) \rightarrow CaCl_2\,(aq) + H_2\,(g)$

In forming an ionic equation, we keep only the reacting particles; write out the ions formed in the solution and remove the spectator ions- those that appear on either side of the equation.

$Mg(s) + 2H^+(aq) + \cancel{2Cl^-(aq)} \rightarrow Mg^{2+}(aq) + H_2(g) + \cancel{2Cl^-(aq)}$

A is incorrect as it worked under the assumption that calcium was a Group 1 metal and therefore would donate only one electron.

B is incorrect as it states that the hydrogen product is aqueous- it was even stated in the question that a colourless **gas** was produced.

D includes the chloride ions (spectator)- ionic equations should only include the reacting particles.

E is the half-equation, showing the oxidation of calcium.

2 **C is the answer**

1 **is correct** as H_2SO_4 is a diprotic acid- i.e. one mole can produce two moles of hydrogen ions.

2 is incorrect; while ethanoic acid is a weaker acid and will therefore react less readily/slowly, it will not ultimately produce a different volume of gas.

3 is incorrect…

Number of moles of H_2SO_4 = mass / M_r
= 4.905 g / 98.1 = 0.05 moles of acid.

As sulfuric acid is diprotic, it will form twice the moles of H^+ (aq) ions...
0.05 x 2 = 0.1 moles of H^+ ions.

[H^+ (aq)] in original solution will be…
c = n / v
= 0.1 / 10
= 0.01 mol dm^{-3}

The moles of hydrogen ions transferred can therefore be calculated by…
n = c x v
= 0.01 x 1/1000

= 0.00001 moles

So the concentration of the new solution will be
c = n / v
= 0.00001 / 1
= 1 x 10^{-5} mol dm^{-3}
So the actual pH of this solution will be 5.0.

4 **is correct** as Sulfuric Acid is a strong acid.

Therefore statements 1 and 4 only are correct so C is the correct answer..

3 **A is the answer.**

A This is not a redox reaction as there isn't electron transfer.
B correctly explains the relationship between the concentration of H^+ (aq) ions and the pH value.
C Both reactions result in the production of a salt (different) and water.
D is correct - the metal needs to displace the hydrogen.
E is correct; the reaction is too dangerous to carry out in the laboratory due to its violent nature. It is highly exothermic, resulting in the potential ignition of a bright flame.

4 **D is the answer**

Write out the equation:
$CuO\ (s) + 2HCl\ (aq) \rightarrow CuCl_2\ (aq) + H_2O\ (l)$
*remember to balance!

Find the molecular masses:
HCl = 36.5, $CuCl_2$ = 134.5

First, find the number of moles of copper salt,
n = mass / molecular mass
= 2.69 / 134.5
= 0.02 moles of $CuCl_2$

We know that there are twice the amount of moles of hydrochloric acid as there are moles of copper (ii) chloride…
0.02 x 2 = 0.04 moles of HCl

We can therefore calculate the concentration of the hydrochloric acid using

c = n / v
= 0.04 / 0.02
= 2 mol dm^{-3}.

A is incorrect.

B is incorrect as the equation was not balanced, so it was assumed the ratio of moles of hydrochloric acid to copper (ii) chloride was 1:1. The final calculation was therefore done using n = 0.02 rather than 0.04.

C is incorrect as it didn't convert 20 cm^3 to 0.02 dm^3 for final calculation.

E is incorrect.

5 **D is the answer** - it is the correct equation for the reaction between phosphorus (V) oxide and water.

A is incorrect as this is the simplest ionic equation used not half! A half equation will involve oxidation/reduction of an element.

B is incorrect.

Carbon dioxide will react with water to produce carbonic acid.

$$CO_2\ (g) + H_2O\ (l) \rightarrow H_2CO_3\ (aq)$$

Carbon itself won't react with water under standard conditions.

C is incorrect.

First, construct the equation:
$Ca(OH)_2\ (aq) + 2HCl\ (aq) \rightarrow CaCl_2\ (aq) + 2H_2O\ (l)$
You can work out the moles of calcium hydroxide…
n = c x v
= 0.02 x 2
= 0.04
We know there is twice the amount of moles of hydrochloric acid, so the actual concentration of the acid is…
c = n / v
= 0.08 / 0.01
8 mol dm^{-3}
The statement in the question would be correct if you had forgotten to balance the equation and double the moles for the acid.

E is incorrect; this reaction wouldn't actually occur under standard conditions as silver is less reactive than hydrogen.

6 **The answer is D**

The balanced equation for this reaction is:

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$.

- 9580g NaOH / (23 + 16 + 1) = **239.5 mol NaOH**
- Divide by 2 = **119.75 mol Na_2SO_4**
- Molar mass of Na_2SO_4 is 46 + 32 + 64 = 142
- 119.75 x 142 = **17004.5g Na_2SO_4**
- 17004.5/2.66 = **6392.7cm^3**

7 **The answer is D**

In this reaction, 1.40g were lost, and this is assumed to be all CO_2. This is equivalent to 1.40/44 = 0.032mol CO_2.

The balanced equation for this reaction is:
$CaCO_3 + 2HCl \rightarrow CaCl_2 + 2H_2O + CO_2$.

Hence $CaCO_3$ and CO_2 are present in a 1:1 ratio, and there are also 0.032 moles of $CaCO_3$.
0.032 x 100 = 3.20g $CaCO_3$.
3.20g / 10.71g * 100 = **29.87%.**

8 **The answer is E**

The flame colour produced is green.
Working backwards, 1.60g of HCl = 1.60 / 36 = 0.0444mol.
Given the 1:1 molar ratio stated in the question, there are therefore 0.0444mol of the substance X.
5.5/0.0444 = 123.7.
The carbonate X, by deduction, must be copper carbonate, $CuCO_3$. As CO_3 has a molecular weight of 60.
Hence the flame colour of the metal (copper) will be green.

9 **The answer is B**

Full balanced equation: $H_2SO_4 + 2Na \rightarrow Na_2SO_4 + H_2$.
1.00g / 23 = **0.0435 mol Na.**
2:1 molar ratio with H_2SO_4,
so 0.0435 / 2 = 0.02175 mol H_2SO_4.
0.02175 / 0.0093dm^3 = **2.34 mol dm^3 H_2SO_4.**

10 **The answer is A**

Although solid copper sulfate is blue in colour, copper sulfate is very soluble in water. Therefore, it will dissolve in the water formed, and the final solution will be colourless.