SUCCINCT ANSWERS TO THE 2010 NATIONAL SCIENCE OLYMPIAD: CHEMISTRY

1. Freshly-prepared pancake batter (milk, flour and eggs) is always allowed to stand for some time before cooking to allow the batter to thicken. The reason the batter thickens is:

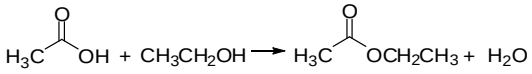
A. water evaporates from the mixture
B. disulfide bonds form between proteins in the flour
C. unsaturated lipids in the egg become saturated
D. all of the above

Answer: B
Flour proteins called glutenins and gliadins, when added to water, begin to cross-link and polymerise by connection of two cysteine residues through a disulfide bond to form gluten. This cross-linking results in thickening of the batter.

2. The compound type formed by reacting a carboxylic acid with an alcohol, with loss of water is:

A. an amide
B. an alkane
C. an ether
D. an ester

Answer: D
Carboxylic acids react with alcohols to form esters, with loss of water. An example of the reaction is shown below:



3. Which electronic configuration is most likely to give a stable -2 ion?

A. $1s^2 2s^2 2p^6$
B. $1s^2 2s^2 2p^6 3s^2 3p^4$
C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
D. none of the above

Answer: B
The electronic configuration for B has an unfilled 3p orbital, containing only 4 electrons. Gaining an additional two electrons allows the 3p orbital to be filled and gives the same configuration as that for a noble gas, with the outer shell full. This is a stable configuration and results in a stable -2 ion. A already has a stable configuration and C needs to lose 2 electrons (giving a +2 ion) to have a stable configuration.

4. The reaction of calcium carbide (CaC_2) with water involves the following steps:
$CaC_2\ (s) \rightarrow Ca^{2+}\ (aq) + C_2^{2-}\ (aq)$
$C_2^{2-}\ (aq) + H_2O \rightarrow C_2H^-\ (aq) + OH^-\ (aq)$
$C_2H^-\ (aq) + H_2O \rightarrow C_2H_2\ (g) + OH^-\ (aq)$
$Ca^{2+}\ (aq) + 2OH^-\ (aq) \rightarrow Ca(OH)_2\ (s)$
The overall reaction may be represented as:

A. $CaC_2\ (s) + 2H_2O \rightarrow Ca(OH)_2\ (s) + 2C\ (s)$
B. $C_2H^-\ (aq) + Ca^{2+}\ (aq) + 2OH^-\ (aq) \rightarrow Ca(OH)_2\ (s) + C_2H_2\ (g)$
C. $CaC_2\ (s) + 2H_2O \rightarrow Ca(OH)_2\ (s) + C_2H_2\ (g)$
D. None of the above

Answer: C
$CaC_2\ (s) \rightarrow \cancel{Ca^{2+}\ (aq)} + \cancel{C_2^{2-}\ (aq)}$
$\cancel{C_2^{2-}\ (aq)} + H_2O \rightarrow \cancel{C_2H^-\ (aq)} + \cancel{OH^-\ (aq)}$
$\cancel{C_2H^-\ (aq)} + H_2O \rightarrow C_2H_2\ (g) + \cancel{OH^-\ (aq)}$
$\cancel{Ca^{2+}\ (aq)} + \cancel{2OH^-\ (aq)} \rightarrow Ca(OH)_2\ (s)$

$CaC_2\ (s) + 2H_2O \rightarrow Ca(OH)_2\ (s) + C_2H_2\ (g)$

By cancelling the components that appear on both the left and right hand sides of the equations, we get the overall reaction:
$CaC_2\ (s) + 2H_2O \rightarrow Ca(OH)_2\ (s) + C_2H_2\ (g)$

5. Silver jewellery is usually made from an alloy of silver and copper. In order to check the silver content of a new batch of alloy, a jeweller dissolves 0.135 g of shaved alloy in 50.0 ml of concentrated HNO_3 and then adds 1.00 M KCl solution until no more precipitate forms. After filtration and drying the AgCl precipitate is found to weigh 0.156 g. What is the percentage silver in the alloy? [Hint: assume the AgCl precipitate is totally insoluble]

A. 75%
B. 100%
C. 50%
D. 90%

Answer: A
Treatment of silver with concentrated nitric acid gives $AgNO_3$. This reacts with KCl to give insoluble AgCl. In order to calculate the

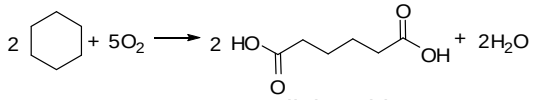
amount of silver present in the alloy sample, we must calculate how much silver is in the AgCl precipitate.

n (AgCl) = m/MW
= 0.156g/143.32g.mol^{-1}
= 1.089 x 10^{-3}mol of AgCl

Mass (Ag) = n x MW
= 1.089x10^{-3}mol x 107.87g.mol^{-1}
= 0.117 g of Ag

% Ag in alloy: (0.117g/0.135g) x 100
= 75%

6. What is the maximum mass of adipic acid that can be prepared from 320 kg of cyclohexane and 300 kg of oxygen in the reaction shown below?



adipic acid

A. 1370 kg
B. 556 kg
C. 1389 kg
D. 548 kg

Answer: D

First calculate the MW of the compounds:
MW Cyclohexane (C_6H_{12}) = 84.18 g.mol^{-1}
MW O_2 = 32.00 g.mol^{-1}
MW adipic acid ($C_6H_{10}O_4$) = 146.16 g.mol^{-1}
Next, determine whether cyclohexane or oxygen is the limiting reagent:

n (cyclohexane) = m/MW
=320 x 10^{3}g/84.18 g.mol^{-1}
= 3801 mol

n (O_2) = m/MW
= 300 x 10^{3}g/ 32.00 g.mol^{-1}
= 9375 mol

2 moles of cyclohexane react with 5 moles of oxygen, therefore for 3801 moles of cyclohexane you would need:
(3801/2) x 5 = 9503 mol O_2
BUT, you only have 9375 mol of O_2 and therefore O_2 is the limiting reagent.
5 moles of O_2 give 2 moles of adipic acid. Therefore from 9375 mol of O_2 you can get:
(9375/5) x 2 = 3750 mol adipic acid.

mass (adipic acid) = n x MW
= 3750 mol x 146.16g.mol^{-1}
= 548 100 g
= 548 kg

7. Which of the following processes is endothermic?

A. Addition of ammonium chloride to water
B. Neutralisation of an acid with a base
C. Addition of water to concentrated acid
D. Burning of magnesium metal in air to form magnesium oxide

Answer: A

Addition of ammonium chloride to water causes the solution to become very cold. This is an endothermic process, as heat is absorbed from the environment. The other processes are exothermic ie. heat is given off during the process.

8. Baking powder is used in baking to make cakes rise. Baking powder works in the following way:

A. Baking powder is magnesium carbonate and it gives off carbonic acid when heated, causing rising.
B. Baking powder is a mixture of sodium bicarbonate and tartaric acid and these two react together giving off CO_2 when water is added to cause rising.
C. Baking powder contains yeast, which releases CO_2 on heating, causing rising.
D. None of the above

Answer: B

Baking powder is a mixture of sodium bicarbonate and tartaric acid. When water is added, the acid and bicarbonate react to make a salt and carbonic acid. The carbonic acid decomposes to water and carbon dioxide gas. This carbon dioxide gas is what causes the cakes to rise.

9. Metalloids are elements that show some properties of both metals and non-metals. Which of the following is an example of a metalloid?

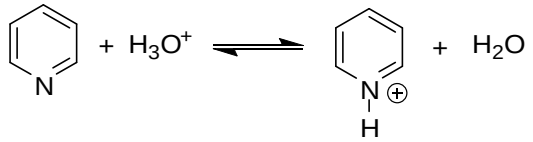
A. potassium
B. bromine
C. silicon
D. plutonium

Answer: C

Silicon is considered a metalloid. The properties of metalloids lie between those of metals and those of non-metals. In most respects, they behave as non-metals but in their most important physical property, electrical conductivity, they resemble metals slightly. They tend to be semiconductors ie.

they conduct electricity but not nearly as well as metals. This has led to many applications in manufacture. Other examples of metalloids are: boron, germanium, arsenic, antimony, polonium and tellurium.

10.



Pyridine Pyridinium ion

In the above reaction:

A. Pyridine is the acid and pyridinium ion is the conjugate base
B. H_3O^+ is the acid and pyridinium ion is the conjugate base
C. Pyridine is the base and pyridinium ion is the conjugate acid
D. H_3O^+ is the base and H_2O is the conjugate acid

Answer: C
In this reaction pyridine is acting as the base, as it is accepting a proton from H_3O^+ to become a pyridinium ion. Pyridinium ion is the conjugate acid. H_3O^+ is donating a proton and is thus acting as the acid in the reaction.

11. Emulsions are dispersions of one immiscible liquid in another. Everyday examples of emulsions include:

A. Mayonnaise
B. Brine
C. Dishwashing liquid
D. Petrol

Answer: A
Mayonnaise is an example of an oil-in-water emulsion. Microdroplets of oil are suspended in an aqueous solution. The protein in egg yolk acts as an emulsifying agent, preventing the oil droplets from combining or coalescing.

12. Which of the structures below are possible, keeping in mind the numbers of bonds that various atoms can form:

$CH_3CH=CH_2CH_2CH_3$ (a) $CH_3CH_2SCH_2CH_3$ (b)

$CH_3=CHCH_2CH_3$ (c) $CH_3CH=CHCH_2Br$ (d)

A. a and b
B. b and d
C. b and c
D. all of them

Answer: B
The structures b and d are correct. Structures a and c both contain carbon atoms bonded to 5 other atoms, these carbon atoms are underlined:
$CH_3CH=\underline{\mathbf{C}}H_2CH_2CH_3$
$\underline{\mathbf{C}}H_3=CHCH_2CH_3$

13. Metallic iron is produced in a blast furnace by smelting. This smelting process is best described as:

A. Heating iron ore with an oxidising agent such as molecular oxygen
B. Heating iron ore with a reducing agent such as carbon
C. Heating iron ore until it melts
D. An electrolysis reaction

Answer: B
Smelting of iron ore takes place in a blast furnace. Near the bottom of the furnace heated air is blown into the furnace where carbon (as coke) reacts with oxygen to form carbon dioxide. This is an exothermic reaction and this part of the furnace reaches temperatures of almost 2000℃. Hot CO_2 rises up the furnace and reacts with additional carbon to form carbon monoxide. This is an endothermic reaction. Carbon monoxide reacts with iron oxides in the ore and reduces them to free metal.

14. Carbon has two common allotropes: graphite and diamond. Which of the following statements describing these allotropes is true?

a. Graphite conducts electricity because of a network of delocalised pi electrons, while diamond with only sigma bonds, does not.
b. Diamond is thermodynamically less stable than graphite at ordinary pressures.
c. Industrial grade diamonds are made more cheaply from graphite than they can be mined.

d. The density of diamond is greater than that of graphite.

A. a and b
B. b and c
C. d
D. all are true

Answer: D
All the statements about diamond and graphite are true. At very high pressures and temperatures, graphite can be forced into the less stable form, diamond. Diamond's density is greater than that of graphite and thus the carbon atoms rearrange into the more dense diamond packing under conditions of high pressure.
Unlike diamond, graphite is an electrical conductor, and can be used, for instance, as the material in the electrodes of an electrical arc lamp. Graphite holds the distinction of being the most stable form of solid carbon ever discovered. It may be considered to be the highest grade of coal, just above anthracite, although it is not normally used as fuel because it is hard to ignite. Graphite is the substance used as the marking material ("lead") in common pencils. In its pure glassy (isotropic) synthetic forms, pyrolytic carbon and carbon fiber, graphite is an extremely strong, heat-resistant (to 3000℃) material, used in reentry shields for missile nosecones, solid rocket engines, pebble bed reactors, brake shoes, electric motor brushes and as electrodes in electrical discharge machines (EDM). Graphite also finds use as a matrix and neutron moderator within nuclear reactors. Its low neutron cross section also recommends it for use in proposed fusion reactors.

15. In the reaction below, _____ is the reducing agent and _____ is the oxidising agent. _____ is reduced and _____ is oxidised.

$2KCl + MnO_2 + 2H_2SO_4 \rightarrow$
$K_2SO_4 + MnSO_4 + Cl_2 + 2H_2O$

A. KCl, H_2SO_4, Cl, Mn
B. KCl, MnO_2, Mn, Cl
C. H_2SO_4, KCl, O_2, Mn
D. $MnSO_4$, K_2SO_4, Cl, Mn

Answer: B

The first thing we need to do is to assign oxidation numbers to each atom on both sides of the equation.
+1 -1 +4 -2 +1 +6 -2
$2KCl + MnO_2 + 2H_2SO_4 \rightarrow$
+1+6-2 +2+6-2 0 +1-2
$K_2SO_4 + MnSO_4 + Cl_2 + 2H_2O$

Now, we must look for changes in oxidation number. An increase in oxidation number is oxidation, while a decrease in oxidation number is reduction. The oxidation number for Cl changes from -1 to 0, therefore Cl is oxidised. The oxidation number of Mn changes from +4 to +2, therefore Mn is reduced.

16. What volume of a 0.16 M $AgNO_3$ solution is needed to react completely with 25 ml of a 0.45 M $CaCl_2$ solution according to the reaction:
$2AgNO_3$ (aq) + $CaCl_2$ (aq) $\rightarrow$ 2AgCl (s) + $Ca(NO_3)_2$ (aq)

A. 70.3 ml
B. 160.0 ml
C. 140.6 ml
D. 450.0 ml

Answer: C
We first need to calculate the number of moles of $CaCl_2$:
0.45 mol in 1000 ml
x mol in 25 ml
x = (0.45 x 25)/1000
= 0.01125 mol
1 mol of $CaCl_2$ reacts with 2 mol $AgNO_3$
number of moles $AgNO_3$ = 2 x 0.01125
= 0.0225 mol
0.16 mol in 1000 ml
0.0225 mol in x ml
x = (1000 x 0.0225)/0.16
=140.6 ml

17. The Haber-Bosch commercial synthesis of ammonia can be represented by the reaction below:

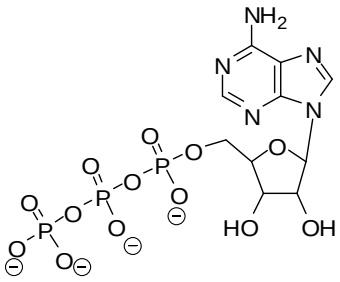
N_2 (g) + $3H_2$ (g) $\rightleftharpoons$ $2NH_3$ (g) ΔH = -92 kJ

The effect of increasing the pressure will be:

A. to favour the forward reaction
B. to favour the reverse reaction
C. no effect
D. to make the forward reaction endothermic

Answer: A
Le Chatelier's Principle states that if the conditions (e.g., temperature, pressure or concentration) of an equilibrium system are changed, the reaction which tends to cancel the effect of the changes will be favoured. In the above example, four moles of gas are converted into 2 moles of gas in the forward reaction and thus when the pressure is increased, the equilibrium will shift in such a way as to decrease the pressure, thus favouring the forward reaction which causes a pressure reduction by reducing the number of moles of gas.

18. Adenosine triphosphate (shown below) plays an important role in biological systems for storage and transfer of energy.



This molecule can be described as:

A. an amino acid
B. a sugar diphosphate
C. a nucleoside containing a pyrimidine base
D. a nucleotide containing a purine base

Answer: D
A nucleotide is made up of a base, sugar and phosphate group. A nucleoside, on the other hand, has only a base and sugar group.

19. A material that is used in paints, enamels and ceramics has the percentage composition: Ba, 69.58%; C, 6.09%; and O, 24.32%. What is its empirical formula?

A. $Ba_{11}CO_4$
B. $Ba(OH)_2$
C. $Ba(CO_3)_2$
D. $BaCO_3$

Answer: D

Consider 100 g of the material. It would contain: 69.58 g of Ba, 6.09 g of C and 24.32 g of O.

n (Ba) = m/MW
= 69.58g/137.33g.mol^{-1}
= 0.5067 mol
n (C) = m/MW
= 6.09g/12.01g.mol^{-1}
= 0.5071 mol
n (O) = m/MW
= 24.32g/16g.mol^{-1}
= 1.52 mol

From this it is evident that the number of moles of Ba and C are equal and that there are 1.52/0.5067 = 3 times the number of moles of O. Thus the empirical formula is $BaCO_3$.

20. Which of the following statements regarding petrol for fuelling cars is true?

A. Heptane makes the best fuel, with an octane rating of >95.
B. Straight-chain alkanes burn more smoothly than branched-chain alkanes.
C. Alkanes of chain length C_{11}-C_{14} are the major component of most petrol.
D. Isooctane (2,2,4-trimethylpentane) makes a very good fuel, with an octane rating of >95.

Answer: D
Heptane, a straight-chain alkane, is a very poor fuel and by definition has an octane rating of 0. Branched-chain alkanes burn more smoothly than straight-chain alkanes; and isooctane makes an excellent fuel, which by definition has an octane rating of 100.

21. Decompression sickness, or "the bends", occurs when deep-sea divers return too rapidly from the high-pressure ocean depths to the surface. This sickness results from:

A. too little oxygen in the bloodstream at normal pressure
B. higher solubility of nitrogen and oxygen at higher pressure
C. lower solubility of nitrogen and oxygen at higher pressure
D. none of the above

Answer: B

Both nitrogen and oxygen have increased solubility at high pressure, according to Henry's Law. Thus, deep-sea divers have increased levels of nitrogen and oxygen in their bloodstreams when they are at the high-pressure depths. If they return to the surface too rapidly, these gases are no longer soluble at the reduced pressure of the ocean surface and bubbles of nitrogen and oxygen form in the bloodstream. This can be extremely dangerous as blood flow to the brain and other major organs can be interrupted.

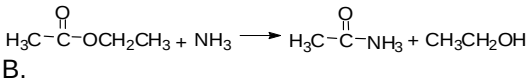
22. Which of the following is a liquid at room temperature and atmospheric pressure?

A. Bromine
B. Chlorine
C. Iodine
D. Ammonia

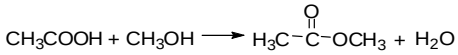
Answer: A
Bromine is liquid at room temperature. Ammonia and chlorine are gases at room temperature, while iodine is a solid.

23. Which of the following is a saponification reaction?

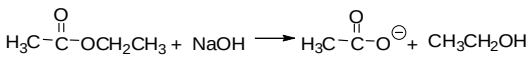
A.



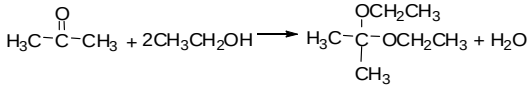
B.



C.



D.



Answer: C
The reaction in which an ester is hydrolysed by a strong base is called saponification.

24. There are _____ electrons, _____ protons and _____ neutrons in an atom of

$$^{35}_{17}\mathrm{Cl}^{1-}$$

A. 16, 17, 18
B. 18, 17, 18
C. 17, 17, 18
D. 17, 17, 35

Answer: B
The mass number (above and to the left of the element symbol) shown is 35. The mass number is equal to the number of protons plus the number of neutrons. The atomic number (below and to the left of the element symbol) given is 17. The atomic number is equal to the number of protons. Thus the number of neutrons is equal to the mass number minus the atomic number:

$$35 - 17 = 18$$

In a neutral atom the number of protons is equal to the number of electrons, but this atom has a charge of -1 so there is one extra electron than proton:

$$17 + 1 = 18 \text{ electrons.}$$

25. Most of the earth's crust is made up of two elements. These elements are:

A. iron and calcium
B. silicon and nitrogen
C. sodium and magnesium
D. silicon and oxygen

Answer: D
Oxygen and silicon make up about 75% of the mass of the earth's crust. They occur in the form of silicates, a family of minerals where the structure is based on a silicon atom surrounded by 4 oxygen atoms. These silicon-oxygen tetrahedrons are joined together by a network of bonds that makes the mineral extremely strong.

26. Which one of the following is not a fossil fuel?

A. Coal
B. Crude oil
C. Natural gas
D. None of the above

Answer: D
A fossil fuel is any of a class of materials of biological origin occurring within the Earth's crust that can be used as a source of energy. Fossil fuels include coal, natural gas, petroleum, shale oil, and bitumen. They all contain carbon and were formed as a result of geologic processes from the remains of organic matter produced by

photosynthesis hundreds of millions of years ago. Coal is a solid fossil fuel formed from the compressed remains of plant material. Crude oil is a liquid fossil fuel formed by the action of bacteria on organic matter. Natural gas is a gaseous fossil fuel also formed by the action of bacteria on organic matter.
All fossil fuels can be burned with air or with oxygen derived from the air to provide heat. This heat may be employed directly, as in the case of a home furnace, or utilized to produce steam with which to drive a turbo generator so that it can supply electricity. In still other cases, as, for example, gas turbines used in jet aircraft, the heat yielded by burning a fossil fuel can serve to increase both the pressure and the temperature of the combustion products to furnish motive power.

27. The most important step in the processes used by SASOL (South African Synthetic Oil) in the production of synthetic petrol is the Fisher-Tropsch process. This step involves:

A. Using a catalyst to break hydrocarbons into shorter hydrocarbons.
B. Using syngas (a mixture of carbon monoxide and hydrogen) to produce hydrocarbons.
C. Using steam to produce syngas from coal.
D. Using steam to produce syngas from natural gas.

Answer: B
Catalytic breaking of hydrocarbons into shorter hydrocarbons is Cracking. Producing syngas from coal with steam is Gasification. Producing syngas from natural gas with steam is called reforming.

28. The industrial process for the production of ammonia gas involves the reaction

$$N_2 + 3\ H_2 \rightleftharpoons 2\ NH_3$$

If the reaction is carried out at a lower pressure,

A. The forward reaction will be favoured.
B. The equilibrium concentration of nitrogen will decrease.
C. The yield of ammonia will increase
D. None of the above

Answer: D
There are 4 moles of gaseous reactants and only 2 moles of gaseous product. Lower pressure favours the reaction that loads to an increase in the number of gas molecules, i.e. the reverse reaction. Therefore the equilibrium concentration of nitrogen will increase and the yield of ammonia will decrease.

In the Haber Process, nitrogen (N_2) and hydrogen (H_2) gases are reacted over an iron catalyst (Fe^{3+}) in which aluminium oxide (Al_2O_3) and potassium oxide (K_2O) are used as promoters. The reaction is carried out under conditions of 250 atmospheres (atm), 450-500 ℃; resulting in a yield of 10-20%:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

ΔH^o = -92.4 kJ/mol, where ΔH^o is the standard heat of reaction or standard enthalpy change.

These conditions are chosen due to the high reaction rate which they foster despite the poor relative amount of ammonia produced. The conditions which are needed to make ammonia are 200 atmospheres, 450 degrees and an iron catalyst. There are two opposing considerations in this synthesis: the position of the equilibrium and the rate of reaction. At room temperature, the reaction is slow and the obvious solution is to raise the temperature. This may increase the rate of the reaction but, since the reaction is exothermic, it also has the effect, according to Le Chatelier's Principle, of favouring the reverse reaction and thus reducing equilibrium constant, given by:

$$K_{eq} = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

As the temperature increases, the equilibrium is shifted and hence, the constant drops dramatically according to the van't Hoff equation. Thus one might suppose that a low temperature is to be used and some other means to increase rate. However, the catalyst itself requires a temperature of at least 400 ℃ to be efficient. Pressure is the obvious choice to favour the forward reaction because there are 4 moles of reactant for every 2 moles of

product, and the pressure used (around 200 atm) alters the equilibrium concentrations to give a profitable yield. Economically, though, pressure is an expensive commodity. Pipes and reaction vessels need to be strengthened, valves more rigorous, and there are safety considerations of working at 200 atm. In addition, running pumps and compressors takes considerable energy. Thus the compromise used gives a single pass yield of around 15%. Another way to increase the yield of the reaction would be to remove the product (i.e. ammonia gas) from the system. In practice, gaseous ammonia is not removed from the reactor itself, since the temperature is too high; but it is removed from the equilibrium mixture of gases leaving the reaction vessel. The hot gases are cooled enough, whilst maintaining a high pressure, for the ammonia to condense and be removed as liquid. Unreacted hydrogen and nitrogen gases are then returned to the reaction vessel to undergo further reaction.

29. If 4 moles of nitrogen gas react with 6 moles of hydrogen gas in a 2 dm^3 reaction vessel at 250 K, and the equilibrium mixture is found to contain 1.5 moles of hydrogen, what is the equilibrium constant K_c at 250 K?

A. 1.6
B. 36
C. 4.27
D. 1.07

Answer: C
The balanced reaction equation is:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

	N_2	H_2	NH_3
Initial no of moles	4	6	0
Equilibrium no of moles	2.5	1.5	3
Equilibrium concentration (volume = 2 dm^3)	1.25 mol/dm^3	0.75 mol/dm^3	1.5 mol/dm^3

At equilibrium, 1.5 moles of hydrogen are still present, which means 6 – 1.5 = 4.5 moles were used to produce ammonia. From the balanced reaction equation, 4.5 moles of hydrogen must have reacted with 1.5 moles nitrogen (leaving 4-1.5 = 2.5 moles) at equilibrium. The amount of ammonia thus produced will be 4.5×2/3 = 3 moles.

$K_C = [NH_3]^2/[N_2][H_2]^3$
$= (1.5)^2/(1.25)(0.75)^3 = 4.27$

30. For the following chemical equilibrium

$6\ P\ (s) + BC_2\ (g) \rightarrow 2\ P_3C\ (s) + B\ (g)\ (\Delta H>0)$

Consider the following statements:
I. The reverse reaction is exothermic.
II. The equilibrium constant depends on the concentration of P_3C.
III. Increasing the pressure will favour the forward reaction.

Which of the statement(s) is/are correct?

A. I, II and III
B. I and II only
C. I only
D. III only

Answer: C
The forward reaction is endothermic ($\Delta H>0$) therefore the reverse reaction is exothermic. P_3C is a pure solid so its concentration does not appear in the equilibrium constant expression. Changes in pressure will have no effect on the position of the equilibrium as the number of mols of gaseous reactants equals the number of mols of gaseous products.

31. Consider the following statements:
I. The cathode of a galvanic cell is positive.
II. Electroplating of metals occur at the cathode.
III. Reduction takes place at the positive electrode of an electrolytic cell

Which statement(s) is/are true?

A. I only
B. I, II, and III
C. II only
D. III only

Answer: C
The cathode is negative. Metals ions, which are positively charged (cations), migrate to the negatively charged electrode (cathode)

where they undergo reduction and get deposited as solid.

32. Which of the following pollutants can cause the environmental problem known as eutrophication or dead zones?

A. Heavy metals such as Pb
B. Insecticides such as DDT
C. Phosphorus
D. None of the above

Answer: C
Eutrophication or dead zones is caused by the accumulation of plant nutrients such as phosphorus (as phosphates) and nitrogen (as nitrates) in water bodies, which lead to an explosion in algae growth and their subsequent death which in turn leads to a depletion of dissolved oxygen and light penetration. This ultimately results in the death of fish and other underwater life.

33. Which of the following is a chemical name for the common painkiller aspirin?

A. Isopropyl amide
B. Butyl ethanoate
C. Ethyl butanoate
D. Acetylsalicylic acid

Answer: D
Salicyclic acid is the bioactive compound in the extract from the bark of the willow plant which was known a long time ago to reduce aches, pains and fevers. Acetylsalicylic acid, which was produced by derivatising one of the hydroxyl functional groups in salicylic acid (the phenolic group) with an acetyl group to form an ester, is known as aspirin.
Aspirin also has anti-anti-inflammatory and anticoagulant ("blood-thinning") effects and is used in long-term low-doses to prevent heart attacks. The brand name *Aspirin* was coined by the Bayer company of Germany.

34. Which one of the following statements is true about an endothermic reaction?

A. The heat of reaction is negative
B. The system continuously releases energy to the surroundings
C. The reactants are at a lower energy level than the products
D. The activation energy is negative

Answer: C
By definition the heat of reaction for an endothermic reaction is positive, as the addition of heat to the system would be required to maintain all the substances present at the same temperature. The reactants gain energy to form the products, so the former must be at a lower energy level than the latter. Activation energy cannot be negative.

35. Which of the following processes can cause the pH of a basic solution to decrease?

I. Addition of water
II. Addition of acid
III. Addition of the same basic solution

A. I only
B. II only
C. I and II
D. I, II, and III

Answer: C
For the pH to decrease the concentration of hydroxide ions must decrease by either dilution (adding more water to increase the volume of solution) or neutralisation (adding hydronium ions (acid) to react with some of the hydroxide ions to form water).

36. Which one of the following salts will dissolve in water to give a basic solution?

A. $(NH_4)_2CO_3$
B. NH_4Cl
C. Na_2SO_4
D. Na_2CO_3

Answer: D
Na_2CO_3 results from the reaction of the strong base NaOH and the weak acid H_2CO_3

$$2\ NaOH + H_2CO_3 \rightarrow Na_2CO_3 + H_2O$$

The salt ionises in water to give hydroxide ions which render the solution basic:

$$Na_2CO_3 + H_2O \rightarrow 2\ Na^+ + CO_3^{2-} + H_2O$$

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$$

37. Which one of the following statements is true of the following chemical reaction:

$$2\ H_2S + SO_2 \rightarrow 3\ S + 2\ H_2O$$

A. SO_2 is the oxidising agent and H_2S is the reducing agent
B. SO_2 is the reducing agent and H_2S is the oxidising agent
C. H_2S is reduced and is also the reducing agent
D. None of the above

Answer: A
The oxidation number of sulphur in H_2S, SO_2 and S are -2, +4 and 0, respectively. Thus the oxidation number of S in H_2S increases (oxidation) whilst the oxidation number of S in SO_2 decreases (reduction). Hence SO_2 is the oxidising agent and H_2S is the reducing agent.

38. Which one of the following sequences correctly arranges the types of bonds between atoms, ions, and molecules in order of decreasing strength?

A. Covalent, ionic, van der Waals, hydrogen
B. Ionic, covalent, van der Waals, hydrogen
C. Covalent, ionic, hydrogen, van der Waals
D. Ionic, covalent, hydrogen, van der Waals

Answer: C
Intramolecular bonds (covalent) are stronger than intermolecular bonds (van der Waals). Hydrogen bonds are special intermolecular bonds that are slightly stronger than van der Waals bonds. Covalent bonds are generally stronger that ionic bonds.

39. All neutral atoms of a given element have

A. The same number of protons and electrons
B. The same number of neutrons
C. The same number of neutrons and electrons
D. The same mass

Answer: A
All atoms of a given element have the same atomic number (number of protons, also number of electrons in the neutral atom). Isotopic forms of an element have different numbers of neutrons and hence difference masses.

40. The element Y has three naturally occurring isotopes. The masses and percent abundances of the isotopes are given below:

Isotope Mass (amu)	% Abundance
^{221}Y 220.9	74.22
^{220}Y 220.0	12.78
^{218}Y 218.1	13.00

What is the average atomic mass of the element (in amu)?

A. 219.7
B. 220.4
C. 22042
D. 221.0

Answer: B
Average atomic mass = (0.7422 x 220.9) + (0.1278 x 220.0) + (0.1300 x 218.1) = 220.4

41. The name and formula of the ester formed when butanoic acid reacts with propanol are, respectively,

A. Butyl propanoate, $CH_3CH_2COOCH_2CH_3$
B. Butyl propanoate, $CH_3CH_2COOCH_2CH_2CH_2CH_3$
C. Propyl butanoate, $CH_3CH_2CH_2COOCH_2CH_2CH_3$
D. None of the above.

Answer: C
An ester's name is always two words, the first denoting the alcohol from which it was made, ending with *yl*, and the second word denoting the precursor acid, ending with *oate*.
$CH_3CH_2CH_2CO\mathbf{OH} + CH_3CH_2CH_2O\mathbf{H} \rightarrow$
Butanoic acid Propanol

$CH_3CH_2CH_2COOCH_2CH_2CH_3$ [+ $\mathbf{H_2O}$]
Propy*l* butan*oate*

42. The acronym IUPAC stands for

A. International Union of Physics and Chemistry
B. International Union of Physics and Applied Chemistry

C. International Union for Peace and Comradeship
D. International Union of Pure and Applied Chemistry

Answer: D
The International Union of Pure and Applied Chemistry (IUPAC) was formed in 1919 by academic and industrial chemists to address global issues involving chemistry and the chemical sciences and to contribute to the application of chemistry in the service of mankind. As a scientific, international, non-governmental and objective body, IUPAC can address many global issues involving the chemical sciences. IUPAC was formed in 1919 by chemists from industry and academia. Over nearly eight decades, the Union has succeeded in fostering worldwide communications in the chemical sciences and in uniting academic, industrial and public sector chemistry in a common language. IUPAC has long been recognized as the world authority on chemical nomenclature, terminology, standardized methods for measurement, atomic weights and many other critically evaluated data. The Union continues to sponsor major international meetings that range from specialized scientific symposia to CHEMRAWN meetings with societal impact. During the Cold War, IUPAC became an important instrument for maintaining technical dialogue among scientists throughout the world. IUPAC is an association of bodies, National Adhering Organizations, which represent the chemists of different member countries. There are 45 National Adhering Organizations, and 20 other countries are also linked to IUPAC in the status of Associate National Adhering Organizations. Almost 1000 chemists throughout the world are engaged on a voluntary basis in the scientific work of IUPAC, primarily through projects, which are components of eight Divisions and several other Committees.

43. Use the table of standard reduction potentials to determine the coefficient of the permanganate ion when the following equation is balanced.

$Br^- + MnO_4^- \rightarrow Mn^{2+} + Br_2$ (acidic solution)

A. 5
B. 10
C. 2
D. 1

Answer: C
The Br_2/Br^- and MnO_4^-/Mn^{2+} half-reactions involve 2 and 5 electrons, respectively. In order to equalize the number of electrons the half-reactions must be multiplied by 5 and 2, respectively.

44. Elemental nitrogen is used mainly in the manufacture of which one of the following?

A. Explosives
B. Plastics
C. Electrolyte in car batteries
D. Fertilizer

Answer: D
Although some nitrogen is converted to nitric acid for the manufacture of explosives, the main use of nitrogen is converting it to ammonia which is used extensively for making nitrogen-containing fertilizer.

45. What is the oxidation number of chromium in the dichromate ion $Cr_2O_7^{2-}$?

A. +7
B. -2
C. +6
D. +12

Answer: C
The total oxidation number for the ion is -2. The oxidation number of oxygen is -2 (except in elemental oxygen and peroxides). Let the oxidation number of chromium be x. Then (2)(x) + (7)(-2) = -2 and x = +6.

46. Which one of the following containers can be used to store a solution of lead (II) nitrate?
A. Zinc
B. Copper
C. Tin
D. Nickel

Answer: B
To ensure that the lead (II) ions remain in solution without being deposited, the (unbalanced) reaction $Pb + M^{n+} \rightarrow Pb^{2+} + M$ must be spontaneous. Therefore

$E^o_{cell} = E^o_{reduced} - E^o_{oxidised} = E^o_M – E^o_{Pb}$ must be positive.
For Cu: E^o_{cell} = -0.34 – (-0.13) = +0.47 V
For Zn: E^o_{cell} = -0.76 – (-0.13) = -0.63 V
For Sn: E^o_{cell} = -0.14 – (-0.13) = -0.01 V
For Ni: E^o_{cell} = -0.27 – (-0.13) = -0.14 V

47. The precipitate and the soluble salt produced in the reaction between magnesium nitrate and potassium sulphate in aqueous solution are:

	Precipitate	Soluble salt
A.	$MgSO_4$	K_2SO_4
B.	KNO_3	$MgSO_4$
C.	$MgSO_4$	K_2SO_4
D.	None of the above	

Answer: D
$Mg(NO_3)_2$ (aq) + K_2SO_4 (aq) → $MgSO_4$ (s) + 2 KNO_3 (aq)
KNO_3 is not a precipitate because all common nitrates are soluble.

48. The Nobel Prize in chemistry is the most prestigious prize that a chemist can win in recognition of his/her contribution to the advancement of scientific knowledge. The prize is named after Alfred Nobel, who is famous for his discovery of

A. Nuclear radiation
B. Aspirin
C. Dynamite
D. Computer chip

Answer: C
The Swedish scientist Alfred Bernard Nobel (1833-1896) made a huge fortune from armaments manufacturing after he invented dynamite. The Nobel Prizes were instituted in accordance with his last will, funded from his estate. The synthetic element Nobelium was named after him.

49. What is the percentage (by mass) nitrogen in ammonium nitrate?
[Relative atomic masses: N = 14.0; H = 1.0; O = 16.0]

A. 22.2%
B. 29.6%
C. 17.5%
D. 35.0%

Answer: D
Formula = NH_4NO_3
Molar mass = (2x14) + (4x1) + (3x16)
= 80
%N = [(2 x 14)/80] x 100 = 35%

50. What is the pH of a 0.10 $mol.dm^{-3}$ aqueous solution of a weak acid if its dissociation (ionisation) constant in water, $K_C = 4.50 \times 10^{-4}$

A. 1.00
B. 2.17
C. 2.19
D. None of the above

Answer: C
HA (aq) + $H_2O \rightarrow H_3O^+ + A^-$ (aq)
$K_C = [H_3O^+][A^-]/[HA]$
$= [H_3O^+]^2/[HA\} = x^2/(0.10 – x)$
$= 4.50 \times 10^{-4}$
Solving the quadratic equation yields:
$x = 6.49 \times 10^{-3}$ $mol.dm^{-3}$
pH = -log (6.49×10^{-3}) = 2.19