1.　　　The state change from gas directly to solid is called:
　　A　　Condensation
　　B　　Evaporation
　　C　　Deposition
　　D　　Ionisation

Answer: C
Explanation: Condensation is the change from gas to liquid, evaporation is the change from liquid to gas and ionization is the loss of electrons. Deposition is the change from gas directly to solid. Many textbooks refer to this as sublimation, but the IB now uses the word sublimation to refer only to the change from solid directly to gas (i.e. the opposite of deposition).
Syllabus reference: 1.1

2.　　　The following equation is unbalanced:

$$\_\_NaOH + \_\_H_2O + \_\_P_4 \longrightarrow \_\_NaH_2PO_2 + \_\_PH_3$$
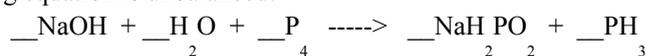
When balanced, the coefficient for PH_3 is:

　　A　　1

　　B　　2

　　C　　3

　　D　　4

Answer: A
Explanation: Start by looking at the metal; there is initially one Na on both sides of the equation. So far so good! Then look at non-metals, but always leave oxygen and hydrogen until last because they tend to be hardest to sort out. On the reactant side there are initially four P atoms and on the product side there are only two; this means it is necessary to add two more P atoms on the right hand side. There are three possible ways to achieve this – put 3 in front of NaH_2PO_2, or put a 3 in front of PH_3, or put a 2 in front of NaH_2PO_2 and a 2 in front of PH_3. There is no easy way to know which is the right way, so just pick one option and try it. Suppose you put a 3 in front of PH_3; this means the equation is now balanced for Na and P. There are 11 H on the r.h.s. and only 3 H on the l.h.s. This can be fixed by putting 5 in front of H_2O. Everything is now balanced apart from the oxygen – but there are 6 oxygens on the l.h.s. and only two on the r.h.s. It doesn't work! So try the next option – remove all the coefficients and start again. Try putting a 2 in front of NaH_2PO_2 and a 2 in front of PH_3. To balance the Na, put a 2 in front of NaOH. There are now three oxygens on the l.h.s. and four on the r.h.s., which can be fixed by putting a 2 in front of H_2O. Everything is now balanced apart from the hydrogen – but there are 6 hydrogens on the l.h.s. and 10 hydrogens on the r.h.s. It doesn't work! So try the last option. Put a 3 in front of NaH_2PO_2; to balance the Na, you now need to put a 3 in front of NaOH. There are now 4 oxygens on the l.h.s. and six on the r.h.s., so fix this by putting a 3 in front of H_2O. The equation is now balanced for Na, P and O, so check the hydrogens – 9 on both sides, so job done! The coefficient for PH_3 is therefore one.
Syllabus reference: 1.1

3.　　　A mixture that has the same composition throughout is described as
　　A　　homologous
　　B　　homogeneous
　　C　　heterogeneous
　　D　　homolytic

Answer: B
Explanation: A homologous series is a group of organic compounds with similar structural features and chemical reactions. When catalysts are in a different physical state to the substances being catalysed, they are described as heterogeneous. When catalysts are in the same physical state as the substances being catalysed, they are described as homogeneous; the word homogeneous when applied to a mixture means the same composition all the way through. Homolytic fission is where a covalent bond splits so that each of the bonded atoms takes back its own electron, forming free radicals.
Syllabus reference: 1.1

4.　　　Boiling point can be described as each of the following **except**:

A   the temperature at which liquid and gas are in equilibrium at atmospheric pressure
B   the temperature at which a liquid turns to vapour
C   the temperature at which the vapour pressure of a liquid equals atmospheric pressure
D   the highest temperature at which a substance can remain liquid at atmospheric pressure

Answer: B

Explanation: A liquid can turn to vapour at any temperature by evaporation. All the other descriptions given here apply to boiling point. Vapour pressure rises with temperature until it equals atmospheric pressure; at that point, the liquid boils.

Syllabus reference: 1.1

5.   Which of the following factors can affect the vapour pressure in a container half-filled with liquid?

        I   Size of container
        II   Surface area of liquid
        III   Temperature of liquid

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

Answer: D

Explanation: The size of the container does not matter; in a larger container more molecules will be in the space above the liquid than in a small container, but the concentration of vapour will be the same, so the pressure exerted by collisions with the sides of the container will be the same. As surface area increases, the rate of escape from the liquid increases, but the rate of return also increases by the same amount. At a higher temperature, a larger proportion of molecules have enough energy to enter the vapour phase, so the concentration of vapour and consequently the vapour pressure increases.

Syllabus reference: 1.1

6.   Which of the following is true?

A   Four moles of helium atoms weigh the same as eight moles of hydrogen molecules.
B   Two moles of carbon atoms contain as many atoms as two moles of oxygen gas.
C   There are 6×10^{23} atoms in 10 g of neon.
D   One mole of water contains Avogadro's number of hydrogen atoms.

Answer: A

Explanation: Two moles of carbon atoms is twice Avogadro's number but two moles of oxygen, which is diatomic, is four times Avogadro's number. 10 g of Ne is half a mole – don't confuse the atomic number 10 with the mass number 20! This means there are only 3×10^{23} Ne atoms. A mole of water contains 2 moles of H atoms because each molecule has two H atoms in it. Four moles of He weighs $4 \times 4 = 16$ g and eight moles of hydrogen molecules, (H_2) = $8 \times 2 = 16$ g.

Syllabus reference: 1.2

7.   A sample of a hydrocarbon is found to consist of 0.013 moles of carbon and 0.052 moles of hydrogen. Its empirical formula is:

A   CH
B CH_2
C CH_3
D CH_4

Answer: D

Explanation: 0.052 is four times 0.013, so there are four H atoms for every one C, giving empirical formula CH_4.

Syllabus reference: 1.2

8.   An organic compound is found to have the empirical formula C_3H_4. Which of the following relative molecular masses are possible?

        I   20
        II   40
        III   60
        IV   80

A   I only

B   II only

C   II, III and IV only

D   II and IV only

Answer: D

Explanation: The empirical formula would give a mass of 40; the molecular mass must be a whole-number multiple of this value.

Syllabus reference: 1.2

9.   478 g of a lead oxide can be formed from 414 g of lead. Find the empirical formula of this oxide.

A PbO

B PbO_2

C Pb_2O_3

D Pb_3O_4

Answer: B

Explanation: The relative atomic mass of Pb is 207, so 414 g of Pb = 2 moles. The amount of oxygen in the compound is 478 – 414 = 64 g. As the relative atomic mass of oxygen is 16, this means there are 4 moles of oxygen. The ratio is therefore 2:4 or 1:2, giving the formula PbO_2.

Syllabus reference: 1.2

10.   Which of the following could not be the empirical formula of a compound?

A CH

B C_2H

C CH_2

D CH_4

Answer: B

Explanation: As carbon has four outer shell (valence) electrons, it needs to form four bonds. CH_4 would be a possible formula – it is methane, the smallest alkane. CH is a possible empirical formula, because the compound could be C_2H_2, with a triple bond between the carbon atoms. CH_2 would also be possible, for example in C_2H_4, where there is a double bond between the carbons. C_2H would not be possible, because it would not permit the carbons to form four bonds.

Syllabus reference: 1.2

11.   Which of the following is true?

A   There are 6.02×10^{23} atoms in 16 grams of O_2 gas

B   Two moles of sodium atoms contain as many atoms as two moles of nitrogen molecules

C   Two moles of helium atoms weigh the same as two moles of hydrogen molecules

D   One mole of ammonia contains Avogadro's number of hydrogen atoms

Answer: A

Explanation: The relative atomic mass of oxygen is 16, so 16 g = 1 mole, which contains Avogadro's number of atoms; the fact that they are paired up in molecules is not relevant! Two moles of sodium atoms is twice Avogadro's number but two moles of nitrogen, which is diatomic, is four times Avogadro's number. Two moles of He weighs 2 x 4 = 8 g and two moles of hydrogen molecules, (H_2) = 2 x 2 = 4 g. One mole of ammonia contains three times Avogadro's number of hydrogen atoms, because each molecule contains 3 H atoms.

Syllabus reference: 1.2

12.   A sample of a hydrocarbon is found to consist of 0.024 moles of carbon, 0.096 moles of hydrogen and 0.048 moles of oxygen. Its empirical formula is

A CHO

B CH_2O

C CH_4O_2

D CH_2O_4

Answer: C

Explanation: 0.096 is four times 0.024 and 0.048 is twice 0.024, so there are four H atoms and two O atoms for every one C, giving empirical formula CH_4O_2.

Syllabus reference: 1.2

13. A certain compound has a relative molar mass of 60. A possible empirical formula could be

    A C_3H_8O

    B C_4H_{10}

    C C_3H_5N

    D $C_2H_2O_2$

Answer: A

Explanation: $C_3H_8O = (3*12)+(8*1)+16 = 60$. $C_4H_{10} = (4*12)+(10*1) = 58$. $C_3H_5N = (3*12)+(5*1)+14 = 55$. $C_2H_2O_2 = (2*12)+(2*1)+(2*16) = 58$.

Syllabus reference: 1.2

14. What mass in grams of solid barium sulfate can be precipitated when 25.0 cm^3 of 0.14 mol dm^{-3} aluminium sulfate solution is added to an excess of aqueous barium nitrate?

    A   (25.0 x 0.14 x 233.41) / (3 x 1000)

    B   (25.0 x 0.14 x 3 x 233.41) / 1000

    C   (3 x 0.14 x 233.41) / (25.0 x 1000)

    D   25.0 x 0.14 x 3 x 233.41 x 1000

Answer: B

Explanation: 1000 cm^3 of $Al_2(SO_4)_3$ contains 0.14 moles of $Al_2(SO_4)_3$, so it contains 0.14 x 3 moles of sulfate ions. This means that 1 cm^3 of $Al_2(SO_4)_3$ contains (0.14 x 3) / 1000 moles, so 25.0 cm^3 of $Al_2(SO_4)_3$ contains (25.0 x 0.14 x 3) / 1000 moles of sulfate ions. Each mole of $BaSO_4$ contains a mole of sulfate ions. One mole of $BaSO_4 = 233.41$ g, so mass of $BaSO_4$ is (25.0 x 0.14 x 3 x 233.41) / 1000

Syllabus reference: 1.3

15. For a fixed mass of gas

    A   Temperature is inversely proportional to volume at constant pressure

    B   Pressure is inversely proportional to temperature at constant volume

    C   Volume is proportional to pressure at constant temperature

    D   Volume is proportional to temperature at constant pressure

Answer: D

Explanation: As the temperature increases the gas expands, so the volume is proportional to the temperature.

Syllabus reference: 1.3

16. Which of the following molecules is non-polar?

    A NF_3

    B H_2S

    C CO_2

    D PH_3

Answer: C

Explanation: Carbon dioxide is linear, with its two double bonds at 180° angles. Whilst the individual C=O bonds are polar, the symmetry of this molecules means that the dipole moments cancel each other to give a non-polar molecule. NF_3 is trigonal pyramidal; there are four electron domains around the nitrogen, one of which is a lone pair; this means that the molecule is not symmetrical, so the dipoles do not cancel out. H_2S is angular; there are four electron domains around the sulfur, two of which are lone pairs; this means that the molecule is not symmetrical, so the dipoles do not cancel out. PH_3 is trigonal pyramidal; there are four electron domains around the phosphorus, one of which is a lone pair; this means that the molecule is not symmetrical, so the dipoles do not cancel out.

Syllabus reference: 1.3

17. If 20.00 cm^3 samples of 0.24 mol dm^{-3} solutions of the acids below are titrated against 0.38 mol dm^{-3}

sodium hydroxide solution, which requires a different volume from the others to reach complete neutralisation?

A   Hydrochloric acid

B   Nitric acid

C   Phosphoric acid

D   Ethanoic acid

Answer: C

Explanation: Phosphoric acid is a tribasic acid, so three moles of NaOH are required to neutralize one mole of it. The other three acids are all monobasic, so would require one mole of NaOH per mole of acid. The fact that ethanoic acid weak whilst hydrochloric and nitric are strong makes no difference.

Syllabus reference: 1.3

18.   If 46.0 g sodium is added to 71.0 g chlorine:

A   Chlorine is in excess

B   Chlorine is the limiting reagent

C   117.0 g of sodium chloride is formed

D   Only 23.0 g of the sodium reacts

Answer: C

Explanation: $2Na + Cl_2 ---> 2NaCl$, so 2 moles of Na (2 x 23.0 = 46.0 g) react with one mole of Cl_2 (35.5 + 35.5 = 71.0 g). The elements are therefore in the correct stoichiometric ratio, so there is no excess of either of them and 46.0 + 71.0 = 117.0 g of NaCl is formed.

Syllabus reference: 1.3

19.   What volume of oxygen would be required to combine with 8.4 dm³ of carbon monoxide and what volume

of carbon dioxide would be formed?

A   8.4 dm³ oxygen and 16.8 dm³ carbon dioxide

B   4.2 dm³ oxygen and 8.4 dm³ carbon dioxide

C   4.2 dm³ oxygen and 12.6 dm³ carbon dioxide

D   8.4 dm³ oxygen and 8.4 dm³ carbon dioxide

Answer: B

Explanation: $O_2 + 2CO ----> 2CO_2$. The reacting ratios of volumes of gases are based on the coefficients in the stoichiometric equation. This means that you need twice as much volume of carbon monoxide as oxygen and that the volume of CO_2 formed will equal the volume of CO used up. Thus half of 8.4 = 4.2 dm³ of oxygen are used and 8.4 dm³ of CO_2 are formed.

Syllabus reference: 1.3

20.   Two moles of methane are burned in excess oxygen in a sealed container, which is then allowed to cool back to room temperature.

A   Two moles of water are formed

B   Two moles of carbon monoxide are formed

C   72 g of water is formed

D   The pressure inside the container stays constant

Answer: C

Explanation: $CH_4(g) + 2O_2(g) ----> CO_2(g) + 2H_2O(l)$. This means that two moles of water are produced for every one mole of methane burned. Two moles of methane therefore give four moles of water, which would weigh 4 x 18 = 72 g. Carbon monoxide would not be formed because we are told there is excess oxygen. The pressure would drop because three moles of reactant gases become one mole of product gas – remember that water is a liquid, so takes up almost no volume compared to the gas.

Syllabus reference: 1.3

21.   When using the ideal gas equation, $PV = nRT$

A   P must always be measured in kPa

B   T must always be measured in K

C   V must always be measured in cm³

D   n must always be an integer

Answer: B

Explanation: The pressure and volume can be measured in any suitable units – just be consistent. The number of moles could be a fraction rather than an integer. However, the only temperature scale that has no

negative numbers is the Kelvin scale, so the temperature must always be measured in K for any calculations.
Syllabus reference: 1.3

22. Assuming ideal gas behaviour, which of the following statements is **untrue**?
    A   Equal volumes of hydrogen and carbon monoxide contain the same number of molecules at S.T.P.
    B   Equal masses of hydrogen and carbon monoxide contain the same number of molecules at S.T.P.
    C   200 cm^3 of hydrogen and 100 cm^3 of methane contain the same number of hydrogen atoms at S.T.P.
    D   The volumes occupied at S.T.P. by two moles of helium and two moles of nitrogen are equal.

    Answer: B
    Explanation: One mole of **any** gas at S.T.P. has a volume of 22.7 dm^3. As hydrogen has a molar mass of 2 and carbon monoxide has a molar mass of 28, equal masses would not contain the same number of molecules. Note that 200 cm^3 of H$_2$ has the same number of hydrogen atoms as 100 cm^3 of CH$_4$.
    Syllabus reference: 1.3

23. A sample of gas has a volume of 200 cm^3 at 17°C. Assuming no change in pressure, at what temperature would its volume be doubled? Give your answer in °C.
    A   580°C
    B   34°C
    C   8.5°C
    D   307°C

    Answer: D
    Explanation: V1/T1 = V2/T2 at constant pressure. V1 = 200 cm^3, T1 = 17 + 273 = 290 K (don't forget to convert to K). V2 = 400 cm^3. Thus 200/290 = 400/T2, so T2 = 580 K. Don't fall for the examiner's trick – 580°C is one of the options, but converting back into °C involves subtracting 273, so the answer is 580 – 273 = 307°C.
    Syllabus reference: 1.3

24. Under the same conditions, equal volumes of oxygen and carbon dioxide have equal
    A   Masses
    B   Numbers of atoms
    C   Numbers of molecules
    D   Numbers of covalent bonds

    Answer: C
    Explanation: Equal volumes of oxygen and carbon dioxide at the same temperature and pressure contain equal numbers of molecules, according to Avogadro's law. They have different numbers of covalent bonds, because oxygen has a double bond and carbon dioxide has two double bonds. Each CO$_2$ molecule contains 3 atoms whilst each O$_2$ molecule has 2.
    Syllabus reference: 1.3

25. For a fixed mass of gas:
    A   Volume is proportional to pressure at constant temperature
    B   Pressure is inversely proportional to temperature at constant volume
    C   Temperature is directly proportional to pressure at constant volume
    D   Volume is inversely proportional to temperature at constant pressure

    Answer: C
    Explanation: For a fixed mass of gas, the temperature is directly proportional to the pressure, provided the volume remains constant. Volume is inversely proportional to pressure at constant temperature (Boyle's law). Pressure is directly proportional to temperature at constant volume (Pressure law). Volume is directly proportional to temperature at constant pressure (Charles' law).
    Syllabus reference: 1.3

26. Which of the following liquids would be unaffected if a stream of it, released from a burette, was passed close to an electrostatically charged glass rod?
    A   Hexane
    B   Ethanol
    C   1,1,1-trichloroethane
    D   Water

Answer: A
Explanation: Hexane is a non-polar molecule due to symmetry; although individual carbon to hydrogen bonds are polar, the effects of the dipoles cancel each other out. The other molecules are polar and non-symmetrical, so they would be attracted to the glass rod.
Syllabus reference: 1.3

27. 8.00 g of hydrogen is mixed with 64.00 g of oxygen in a flask, then a spark is applied. After the reaction is
finished, the flask contains:
A   Only water
B   Water and oxygen
C   Water and hydrogen
D   Water, hydrogen and oxygen
Answer: A
Explanation: $2H_2 + O_2 ---> 2H_2O$. The stoichiometric ratio would be 2 x 2 = 4 g hydrogen with 2 x 16 = 32 g oxygen, so 8 g hydrogen react with 64 g oxygen. The flask contains only water at the end of the reaction.
Syllabus reference: 1.3

28. Which of the following graphs represents the relationship between PV/T and P?

A $\frac{PV}{T}$

B $\frac{PV}{T}$

C $\frac{PV}{T}$

D $\frac{PV}{RT}$
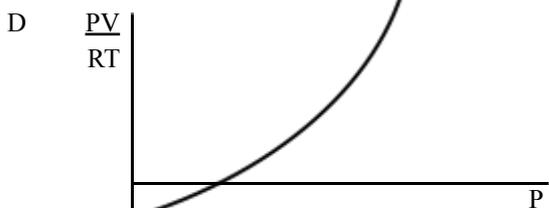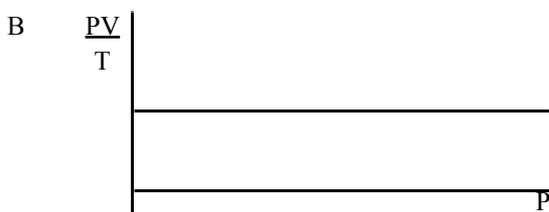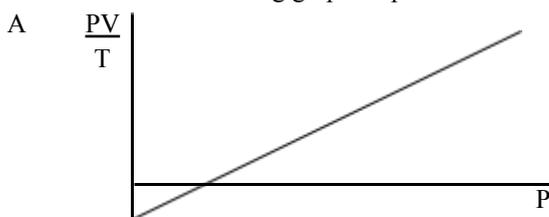
Answer: B
Explanation: P1V1/T1 = P2V2/T2, so the ratio of PV/T is constant, no matter what the pressure.
Syllabus reference: 1.3

29. If 25.00 cm^3 samples of 0.25 mol dm^{-3} solutions of the acids below are titrated against 0.25 mol dm^{-3} potassium hydroxide solution, which requires a different volume from the others to reach complete neutralisation?

A   Hydrochloric acid
B   Nitric acid
C   Ethanoic acid
D   Sulfuric acid

Answer: D

Explanation: Sulfuric acid is dibasic, so it requires twice as much base to neutralize it than the monobasic acids hydrochloric, nitric and ethanoic acid. Do not fall for the trap of thinking that this is about strong or weak acids; the examiner is trying to trick you into thinking that ethanoic acid, the only weak acid in the list, is the one that requires a different volume. In fact, it does not matter whether the acid is weak or strong – it will require the same amount of OH^- ions to neutralize.

Syllabus reference: 1.3

30.   Kinetic Theory does **not** assume that:
A   There are spaces between particles
B   Particles move faster as the temperature increases
C   Particles move by vibrating, rotating or translating
D   Particles have volume but no mass

Answer: D

Explanation: Just learn your Kinetic theory for this one – particles have spaces between them, move faster as the temperature rises, can vibrate, rotate or translate (move from one place to another). You could not have a particle with volume but no mass; all atoms and molecules have mass – even electrons have some mass, although it is really small.

Syllabus reference: 1.3

31.   In an ideal gas, the particles can be considered:
A   To have no mass
B   To have no volume
C   To have no kinetic energy
D   To lose energy when they collide

Answer: B

Explanation: The particles in an ideal gas would be point-masses, so they would have mass but no volume. If all the spaces between particles were removed, the volume of an ideal gas would fall to zero. Particles of a gas would only have zero kinetic energy at the lowest possible temperature, 0K. Collisions between ideal gas particles are perfectly elastic, so their total kinetic energy is conserved.
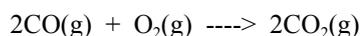
Syllabus reference: 1.3

32.   The concept of yield can be applied:
A   When collecting crystals precipitated from solution
B   When finding the pH of a solution with a pH meter
C   When determining the equilibrium constant for a reaction
D   When determining Avogadro's number by experiment

Answer: A

Explanation: "Yield" implies that you have made something and that its mass can be measured and compared with the amount that you should get in theory, if there were no sources of error. This does not include values for pH, equilibrium constant or Avogadro's number, none of which can be weighed on a balance.

Syllabus reference: 1.3

33.   Carbon monoxide burns to form carbon dioxide:
$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$$
If 16 dm^3 of carbon monoxide is burned with 10 dm^3 of oxygen, then returned to its original temperature and pressure, what will be the composition of the mixture formed?
A   26 dm^3 of carbon dioxide
B   16 dm^3 of carbon dioxide and 2 dm^3 of oxygen
C   6 dm^3 of carbon dioxide and 10 dm^3 of oxygen
D   10 dm^3 of carbon dioxide, 10 dm^3 of carbon monoxide and 6 dm^3 of oxygen

Answer: B

Explanation: As the gases CO and oxygen react in a 2:1 molar ratio, they also react in a 2:1 volume ratio. 16 dm^3 CO reacts with 8 dm^3 oxygen to form 16 dm^3 CO$_2$ and there will be 2 dm^3 of unused oxygen.
Syllabus reference: 1.3

34.   A 25.00 cm^3 sample of potassium hydroxide solution is neutralised in a titration by 18.65 cm^3 of 0.28 mol dm^{-3} sulfuric acid. The concentration of the potassium hydroxide solution is:

A $\dfrac{2 \times 25.00 \times 0.28}{18.65}$ mol dm^{-3}

B $\dfrac{18.65 \times 0.28}{25.00 \times 2}$ mol dm^{-3}

C $\dfrac{25.00}{2 \times 18.65 \times 0.28}$ mol dm^{-3}

D $\dfrac{2 \times 18.65 \times 0.28}{25.00}$ mol dm^{-3}

Answer: D
Explanation: 1000 cm^3 of the sulfuric acid contains 0.28 moles, so 18.65 cm^3 contains (18.5 x 0.28) / 1000 moles of sulfuric acid. The H$_2$SO$_4$ and KOH react in a 1:2 molar ratio, so 25.00 cm^3 KOH contains (2 x 18.5 x 0.28) /1000 moles, so 1 cm^3 KOH contains (2 x 18.5 x 0.28) /25.00 x 1000 moles, so 1 dm^3 KOH contains (2 x 18.5 x 0.28) /25.00 moles.
Syllabus reference: 1.3

35.   The pressure of 1 dm^3 of an ideal gas in a flexible container is quadrupled and its absolute temperature is tripled. The volume is then
A   4/3 dm^3
B   3/4 dm^3
C   12 dm^3
D   1/12 dm^3

Answer: B
Explanation: Quadrupling the pressure would reduce the volume to 1/4 dm^3, but tripling the temperature would then triple that volume to give 3/4 dm^3.
Syllabus reference: 1.3

36.   Which of the following will be closest to behaving as an ideal gas?
A   Nitrogen at low temperature and high pressure
B   Oxygen at high temperature and low pressure
C   Ammonia at low temperature and high pressure
D   Ammonia at high temperature and low pressure

Answer: B
Explanation: Molecules with the weakest intermolecular forces will behave most like ideal gases, so oxygen and nitrogen, which are non-polar molecules with weak London forces will behave more like ideal gases than ammonia, which can do hydrogen bonding. Ideal behaviour is most closely approached when molecules are moving fast and are widely separated. Thus oxygen at high temperature and low pressure will be the closest to ideal gas behaviour.
Syllabus reference: 1.3

37.   Which of the following will be closest to behaving as an ideal gas?
A   Neon at low temperature and high pressure
B   Oxygen at high temperature and low pressure
C   Ammonia at low temperature and high pressure
D   Oxygen at high temperature and high pressure

Answer: B
Ideal behaviour is most closely approached when particles are moving fast and are widely separated. Thus oxygen at high temperature and low pressure will be the closest to ideal gas behaviour. Ammonia molecules have hydrogen bonding, so it has strong intermolecular attractions.
Syllabus reference: 1.3

38.   Which of the following is **not** an assumption of the Kinetic Theory?
    A   Molecules in a gas experience negligible attractions between them
    B   The size of the molecules themselves is insignificant compared to the size of the gaps between them
    C   Molecules can move by vibration, rotation or translation
    D   All molecules in a sample of gas at 27°C have the same kinetic energy
    Answer: D
    Explanation: The **average** kinetic energy of molecules is the same at 27°C. The molecules are in constant random motion. On collision, energy is redistributed randomly, leading to a widely different amounts of kinetic energy in molecules. Only molecules with the activation energy or more can react on collision.
    Syllabus reference: 1.3

39.   Which of the following statements about electrons is **untrue**?
    A   Electrons can be diffracted
    B   Electrons have mass
    C   Electrons are transferred between substances during redox reactions
    D   Atoms of the same element with different numbers of electrons are called isotopes
    Answer: D
    Explanation: Atoms of the same element with different numbers of neutrons are called isotopes. Electrons have both wave and particle properties, so they can be diffracted and they have mass. Redox reactions involve the gain and loss of electrons between substances.
    Syllabus reference: 2.1

40.   One mole of 2+ ions is formed from the ^{24}Mg isotope. Which of the following is **untrue**?
    A   It contains 12 moles of protons
    B   It contains 12 moles of electrons
    C   It contains 12 moles of neutrons
    D   It has a mass of 24 g
    Answer: B
    Explanation: Magnesium has atomic number 12, so its atoms and ions contain 12 protons. ^{24}Mg has 12 protons plus 12 neutrons in each atom. One mole of ^{24}Mg weighs 24 g. When it forms 2+ ions, the Mg loses two electrons per atom, so a mole of Mg^{2+} ions contains 10 moles of electrons. It does not matter which isotope we are dealing with - this is a "red herring".
    Syllabus reference: 2.1

41.   Which of the following pairs of compounds would produce identical mass spectra:
    A   1,1-dichloroethene and 1,2-dichloroethene
    B   Cis-1,2-dibromoethane and trans-1,2-dibromoethane
    C   Ethanol and methoxymethane
    D   Hydrogen fluoride and neon
    Answer: B
    Explanation: Although in each case the molar masses of the two substances named are the same, some of the molecules would fragment in the spectrometer. For example, a CH_3 group (mass 15) could break off from 1,1-dichloroethene but not from 1,2- dichloroethene. Ethanol could lose an OH group (mass 17), but methoxymethane could not lose this fragment. Hydrogen fluoride could split to give 1 and 19 as fragments, but neon atoms would not split, so these fragments could not form. Cis and trans isomers break up to form the same fragments.
    Syllabus reference: 2.1

42.   Which of the following pairs are **not** isoelectronic?
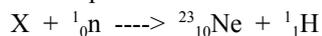   A Li^+ and K^+
    B   Ne and Na^+
    C S^{2-} and K^+

D Mg^{2+} and Al^{3+}

Answer: A

Explanation: Ne and Na^+ both have 10 electrons, S^{2-} and K^+ both have 18 electrons, Mg^{2+} and Al^{3+} both have 10 electrons. Li^+ has 2 electrons and K^+ has 18 electrons.

Syllabus reference: 2.1

43.   What is the particle X in the following nuclear reaction?

$$X + {}^{1}_{0}n \longrightarrow {}^{23}_{10}Ne + {}^{1}_{1}H$$

A ${}^{22}_{9}F$

B ${}^{24}_{12}Mg$

C ${}^{23}_{11}Na$

D ${}^{22}_{10}Ne$

Answer: C

Explanation: The total mass and the total proton number have to be the same on both sides of the equation. On the right hand side, the total mass is $23 + 1 = 24$ and the total proton number is $10 + 1 = 11$. On the left hand side, X must therefore have mass 23 and proton number 11, which makes it a sodium atom.

Syllabus reference: 2.1

44.   How many neutrons are there in 10 molecules of ${}^{19}_{9}F_2$?

A   90

B   180

C   200

D   380

Answer: C

Explanation: The atomic number of F is 9, so each F atom has 10 neutrons. Each F_2 molecule has 20 neutrons, so ten molecules contain 200 neutrons.

Syllabus reference: 2.1

45.   The number of electrons in a stable indium-115 ion is:

A   46

B   49

C   52

D   115

Answer: A

Explanation: The atomic number of indium is 49, so its atom would contain 49 electrons. As it is in group 13, it is a metal with three outer shell (valence) electrons; its ion will therefore be In^{3+} and it will have 46 electrons. The mention of indium-115 is a "red herring" because it does not matter which isotope we are dealing with here.

Syllabus reference: 2.1

46.   The atomic and mass numbers for four different nuclei are given in the table below. Which two are isotopes?

	atomic number	mass number
I	101	258
II	102	258
III	102	260
IV	103	259

A   I and II

B   II and III

C   II and IV

D   III and IV

Answer: B
Explanation: Isotopes are atoms of the same element with different numbers of neutrons. They therefore have the same number of protons but a different number of neutrons. This means that they have the same atomic number and a different mass number.
Syllabus reference: 2.1

47.   How many neutrons are there in 5 molecules of $^{19}_{9}F_2$?
    A   100
    B   190
    C   85
    D   50
Answer: A
Explanation: Each atom has 9 protons (atomic number shown as a subscript) and a total of 19 protons plus neutrons (mass number shown as a superscript). Each atom therefore has 19 – 9 = 10 neutrons. The fluorine is diatomic, so each molecule contains 20 neutrons. Five molecules therefore contain 5 x 20 = 100 neutrons.
Syllabus reference: 2.1

48.   Which one of the following atoms in its ground state has the greatest number of unpaired electrons?
    A   N
    B   C
    C   B
    D   O
Answer: A
Explanation: Nitrogen has atomic number 7, so it has the electron configuration $1s^2 2s^2 2p^3$; each p electron is singly occupying a p orbital, giving 3 unpaired electrons. Carbon has atomic number 6, so it has the electron configuration $1s^2 2s^2 2p^2$ giving 2 unpaired electrons. Boron has atomic number 5, so it has the electron configuration $1s^2 2s^2 2p^1$ giving one unpaired electron. Oxygen has atomic number 8, so it has the electron configuration $1s^2 2s^2 2p^4$. Two of its p electrons are paired, giving 2 unpaired electrons.
Syllabus reference: 2.2

49.   Which of the following transitions would produce a line in the visible part of the hydrogen emission spectrum?
    A   n = 5 to n = 3
    B   n = 4 to n = 1
    C   n = 6 to n = 2
    D   n = 2 to n = 3
Answer: C
Explanation: Transitions from outer shells back to the second shell give visible lines in the spectrum. Transitions from outer shells back to the third shell give infrared lines in the spectrum. Transitions from outer shells back to the first shell give ultraviolet lines in the spectrum. A transition from the second to the third shell would require the input of energy, so it would not produce any line in the emission spectrum.
Syllabus reference: 2.2

50.   Which of the following statements is true?
    A   Every shell has s, p, d and f orbitals
    B   P orbitals have a lower potential energy than the s orbital in the same shell
    C   4s orbitals are filled before 3d orbitals
    D   The maximum capacity of a p orbital is six electrons
Answer: C

Explanation: The first shell has only an s orbital; the second shell has s and p orbitals, the third shell has s, p and d orbitals and the fourth shell has s, p, d and f orbitals. The s orbital in a particular shell has a lower energy than the p orbitals in that shell. The maximum capacity of a p orbital (or any other orbital!) is 2 electrons. The 4s fills before the 3d, which is the reason why the transition metals follow potassium and calcium in the periodic table.
Syllabus reference: 2.2

51.   What is the condensed electron configuration for Fe^{2+}?
A $[Ar]\ 4s^2 3d^6$
B $[Ar]\ 4s^2 3d^4$
C $[Ar]\ 4s^0 3d^6$
D $[Ar]\ 4s^1 3d^5$

Answer: C
Explanation: Iron has atomic number 26, so it has the electron structure $1s^2 2s^2 2p^6 3s2 3p^6 4s^2 3d^6$. It loses the two 4s electrons when it forms the 2+ ion.
Syllabus reference: 2.2

52.   Which of the following is **not** involved in determining atomic structure?
A   Aufbau Principle
B   Hund's Law
C   Pauli Exclusion Principle
D   Le Châtelier's Principle

Answer: D
Explanation: The Aufbau Principle is that electrons occupy the lowest energy level orbital available. Hund's Law is that electrons singly occupy all orbitals at a particular energy level before pairing up. Pauli's Exclusion Principle is that a maximum of two electrons can occupy an orbital and paired up electrons have opposite spins.
Syllabus reference: 2.2

53.   The maximum capacity of any orbital is two electrons; if two electrons occupy the same orbital, they are spin-paired. Which of the following describes this?
A   Hund's Rule
B   Pauli's Exclusion Principle
C   Aufbau Principle
D   Charles' Law

Answer: B
Explanation: Hund's rule is that electrons prefer to singly occupy orbitals at a particular energy level and only double up when every orbital is partly filled. The Aufbau Principle is that electrons occupy the lowest energy orbitals available. Charles Law is that the volume of a fixed mass of gas is directly proportional to the absolute temperature, provided the volume remains constant. The Pauli Exclusion Principle is that no more than two electrons can occupy an orbital; if paired, they have to have opposite spins so that their magnetic effects cancel.
Syllabus reference: 2.2

54.   The electron configuration of the Ti^{2+} ion is:
A $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$
B $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^0$

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^0 4s^0$

Answer: C
Explanation: Ti has atomic number 22, so it is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$. The 2+ ion has lost the outer 4s electrons, so it is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^0$. Transition metals always lose their outer s electrons when forming ions; they also have the option to lose unpaired 3 electrons.
Syllabus reference: 2.2

55. The number of unpaired electrons in Fe^{3+} is:
 A   Five
 B   Four
 C   Three
 D   None

Answer: A
Explanation: Fe has atomic number 26, so it is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$. The 3+ ion has lost the outer 4s electrons and one of its 3d electrons, so it has five remaining 3d electrons. Hund's rule tells us that these will all singly occupy the five available 3d orbitals.
Syllabus reference: 2.2

56. Which of the following statements about flame tests is **incorrect?**
 A   Sodium gives yellow-orange
 B   Potassium gives lilac
 C   Copper gives blue
 D   Lithium gives green

Answer: D
Explanation: Lithium gives a red flame. You just have to learn flame test colours.
Syllabus reference: 2.2

57. The electron configuration of Ni^{2+} is:
 A $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
 B $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
 C $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$
 D $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^8$

Answer: D
Explanation: Nickel has atomic number 28, so the Ni^{2+} ion has 26 electrons and it will have lost its pair of 4s electrons, leaving $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^8$. Remember that transition metals always lose their outer shell electrons first when forming ions.
Syllabus reference: 2.2

58. The wavelengths of lines in spectra can be determined using:
 A   The Rydberg Equation
 B   Planck's Constant
 C   The Schrödinger Wave Equation
 D   Heisenberg's Uncertainty Principle

Answer: A
Explanation: The Rydberg Equation is used to determine the wavelengths of the lines in a spectrum. Planck's constant relates the energy of light to its wavelength, the Schrödinger Wave Equation is used to explain quantum mechanical behaviour and the Heisenberg Uncertainty Principle shows that it is not possible to determine simultaneously where an electron is and how much energy it has.
Syllabus reference: 2.2

59. Group 2 elements are called:
 A   Alkali metals
 B   Alkaline earths
 C   Halogens
 D   Noble gases

Answer: B
Explanation: Group 1 are alkali metals. Group 17 are halogens. Group 18 are noble gases. Group 2 are alkaline earths.
Syllabus reference: 3.1

60.   Which of the following ions is found in compounds?

A Si^{4+}

B Be^{2+}

C Al^{3+}

D Mg^+

Answer: C

Explanation: Silicon and beryllium form covalent compounds rather than ionic. The energy required to remove 4 electrons from Si is prohibitively high; the beryllium atom is very small, with only two shielding electrons, so removing two electrons to form 2+ ions is too difficult. Magnesium has two outer shell electrons, so it will form 2+ ions; a 1+ ion would leave it with one outer shell electron, so Mg^+ is not formed. Aluminium has three outer shell electrons so it can lose them to form Al^{3+}; this only happens when highly electronegative fluorine is bonded to the aluminium in AlF_3. Other aluminium compounds have a significant amount of covalent nature and are best considered as highly polar covalent rather than ionic.

Syllabus reference: 3.1

61.   Moving from left to right across period 3:

A   There is a steady increase in ionisation energy

B   There is a steady increase in melting point

C   There is a steady decrease in electronegativity

D   There is a steady decrease in density

Answer: A

Explanation: There is a steady increase in ionization energy because the amount of inner shell shielding stays constant across a period, but the nuclear charge steadily increases, making it increasingly difficult to remove an electron. There is no clear trend in melting points, since elements have different types of forces holding them together. Metals on the left of the table have metallic bonding, so the force to be overcome is due to attractions between the ions and the delocalized electrons. Metalloids have macromolecular structures, so large numbers of covalent bonds need to be broken for them to melt, giving them really high melting points. Non-metals form small molecules (or are monatomic in the case of group 18), so the forces of attraction to be overcome are van der Waals forces; these depend on the size of the molecules, which don't really follow a trend. Electronegativity generally rises from left to right across the periodic table. Density does not follow a clear trend because it depends on the type of forces holding the particles together; for example, a group 2 metal is denser than its neighbour in group 1 because it has the same amount of shielding but an extra proton in its nucleus. For non-metals, the strength of the van der Waals forces determines how strongly the molecules or atoms are attracted together.

Syllabus reference: 3.1

62.   Which of the following does **not** affect ionisation energy?

A   Distance of the outermost electron from the nucleus

B   Number of protons in the nucleus

C   Number of neutrons in the nucleus

D   Shielding effect of inner shell electrons

Answer: C

Explanation: The further the outer electrons from the nucleus, the weaker the attraction. The more protons in the nucleus the stronger the attraction. The more inner shells of electrons the greater the shielding effect. Neutrons do not affect the attraction of the nucleus for electrons, so varying the number of neutrons would not affect ionization energy.

Syllabus reference: 3.2

63.   The first electron affinity of bromine is represented by:

A $Br(l) + e^- \longrightarrow Br^-(g)$

B $\frac{1}{2}Br_2(l) + e^- \longrightarrow Br^-(g)$

C $Br(g) + e^- \longrightarrow Br^-(g)$

D $Br^+(g) + e^- \longrightarrow Br(g)$

Answer: C

Explanation: The first electron affinity represents the addition of one mole of electrons to a mole of gas atoms to form a mole of 1- ions. In answer A, the bromine is in the liquid state, so energy would be needed to separate the atoms into the gas state; answer B, even more energy would be needed because the bromine molecules would need to be broken. Positive bromine gas ions picking up electrons would be the opposite of ionization energy.
Syllabus reference: 3.2

64.   Which of the following has the largest atomic radius?
    A   N
    B   F
    C   Li
    D   Ne
Answer: C
Explanation: These elements are all in period 2 of the periodic table; they all have the same amount of shielding, but moving from left to right across the period, the number of protons increases.
Syllabus reference: 3.2

65.   Which of these elements is a metalloid?
    A   Selenium
    B   Indium
    C   Thallium
    D   Germanium
Answer: D
Explanation: Germanium is on the borderline between metallic and non-metallic behaviour. Indium and thallium are metals and selenium is a non-metal.
Syllabus reference: 3.2

66.   Which of these elements has the largest relative molecular mass?
    A   Phosphorus
    B   Sulfur
    C   Chlorine
    D   Iodine
Answer: B
Explanation: Phosphorus forms P_4, so its relative molecular mass is 4 x 31 = 124 g. Sulfur forms S_8, so its relative molecular mass is 8 x 32 = 256 g. Chlorine forms Cl_2, so its relative molecular mass is 2 x35.5 = 71 g. Iodine is I_2, so its relative molecular mass is 127 = 2 = 254 g.
Syllabus reference: 3.2

67.   Which of the following oxides forms the most strongly acidic aqueous solution?
    A   Magnesium oxide
    B   Phosphorus pentoxide
    C   Sulfur dioxide
    D   Nitrogen dioxide
Answer: D
Explanation: Magnesium oxide reacts to form weakly basic magnesium hydroxide. Phosphorus pentoxide reacts to form the weak acid phosphoric acid. Sulfur dioxide reacts to form the weak acid sulfurous acid. Nitrogen dioxide reacts to form the strong acid nitric acid.
Syllabus reference: 3.2

68.   An ionic structure with 8,8-coordination is:
    A   Sodium chloride
    B   Lithium bromide
    C   Potassium iodide
    D   Caesium chloride
Answer: D
Explanation: Caesium chloride has 8,8-coordination. The other halides have smaller cations, so there is only room for six anions to surround each cation, giving 6,6-coordination.
Syllabus reference: 3.2

69.   Which of the following elements are metalloids?
        I   Al

II   Ge

III   B

A   I and II only

B   I and III only

C   II and III only

D   I, II and III

Answer: C

Explanation: Metalloids are elements with giant covalent structures that have properties of both metals and non-metals. They are semiconductors.

Syllabus reference: 3.2

70.   The highest melting point of the following elements is:

A   Sodium

B   Magnesium

C   Aluminium

D   Silicon

Answer: D

Explanation: Silicon has a macromolecular structure, so melting it involves breaking huge numbers of strong covalent bonds. This is harder than overcoming the metallic bonding in sodium, magnesium or aluminium.

Syllabus reference: 3.2

71.   Which of the following aqueous solutions would be the best electrical conductor?

A 0.100 mol dm^{-3} NaCl

B 0.100 mol dm^{-3} $C_{12}H_{22}O_{11}$ (sucrose)

C 0.100 mol dm^{-3} CH_3COOH

D 0.100 mol dm^{-3} NH_3

Answer: A

Explanation: NaCl is fully ionised in aqueous solution, so there is a high concentration of mobile ions to carry the charge. Sucrose is covalent, so there are no ions to carry the charge (other than the very tiny amounts produced by the water itself). CH_3COOH and NH_3 are both weak, so they are only partially ionised in aqueous solution.

Syllabus reference: 3.2

72.   Melting points:

A   Decrease down each group

B   Increase down each group

C   Decrease down group 1 and increase down group 17

D   Increase down group 1 and decrease down group 17

Answer: C

Explanation: Melting points decrease down group 1 because increased shielding has a more significant affect than the increased nuclear charge; it becomes easier to overcome the attraction between the ion and the delocalized electrons. Down group 17, the elements form diatomic molecules; the melting points increase because it gets harder to overcome the van der Waals forces as molecules get larger.

Syllabus reference: 3.2

73.   The species with the largest radius is:

A   N

B N^{3-}

C Al^{3+}

D Mg^{2+}

Answer: B

Explanation: Positive ions have lost electrons, so their nuclei have a stronger pull on the remaining electrons, making the ions smaller than the parent atoms. Negative ions have gained electrons, so the amount of nuclear pull has stayed the same whilst the repulsion between electrons has increased, making the ions bigger than the parent atoms. N^{3-} has gained three electrons, so it is much larger than the parent atom. The actual radii are N 71×10^{-12} m, N^{3-} 146×10^{-12} m, Al^{3+} 54×10^{-12} m and Mg^{2+} 72×10^{-12} m.

Syllabus reference: 3.2

74.   The smallest difference in electronegativity would be between:
   A   Lithium and oxygen
   B   Gallium and germanium
   C   Barium and arsenic
   D   Nitrogen and iodine

Answer: B
Explanation: The closer elements are in the periodic table, the smaller the electronegativity difference between them. Ga and Ge are in groups 13 and 14 respectively; Li and O are in groups 1 and 16 respectively; Ba and As are in groups 2 and 15 respectively; N and I are in groups 15 and 17 respectively. Thus the nearest neighbours are Ga and Ge.
Syllabus reference: 3.2

75.   Which of the following would have the largest lattice enthalpy?
   A   sodium chloride
   B   potassium oxide
   C   aluminium nitride
   D   calcium sulfate

Answer: C
Explanation: Highly charged ions are most attractive. Aluminium nitride has Al^{3+} and N^{3-} ions, which attract each other very strongly, giving a large lattice enthalpy. Potassium oxide has K^+ and O^{2-} ions, sodium chloride has Na^+ and Cl^- ions and calcium sulfate has Ca^{2+} and SO_4^{2-} ions.
Syllabus reference: 3.2

76.   Which of the following electron configurations represents the atom with the largest first electron affinity?
   A $1s^2 2s^2 2p^6 3s^1$
   B $1s^2 2s^2 2p^6 3s^2 3p^5$
   C $1s^2 2s^2 2p^6 3s^2 3p^6$
   D $1s^2 2s^2 2p^6$

Answer: B
Explanation: Halogens have the largest first electron affinity values. Gaining one electron will give them noble gas structure.
Syllabus reference: 3.2

77.   Which of the following show a general trend moving from left to right across period 3 of the periodic table?
   A   Melting point increases
   B   Electronegativity increases
   C   First ionisation energy decreases
   D   Atomic radius increases

Answer: B
Explanation: Electronegativity increases as the number of protons in the nucleus increases but the amount of inner shell electron shielding remains the same. There is no steady melting point trend because Na, Mg and Al are metallic, Si is macromolecular, sulfur forms S_8, phosphorus forms P_4, chlorine forms Cl_2 and argon is monatomic; this means that different types of forces hold the elements together as solids. First ionisation energy generally increases as the nuclear charge increases whilst the shielding stays the same. Atomic radius generally decreases as the nuclear charge increases whilst the shielding stays the same.
Syllabus reference: 3.2

78.   An alkaline earth X bonding with a group 15 element Y could have the formula:
   A XY_3
   B X_2Y_3

C X_3Y_2

D   XY

Answer: C

Explanation: Alkaline earths are Group 2 elements; they lose their two outer shell (valence) electrons to form 2+ ions. A Group 15 element has five outer shell electrons, so it gains three electrons to form 3- ions. The compound formed is neutral, so it must have equal amounts of positive and negative charge. Thus three 2+ ions and two 3- ions are combined to give X_3Y_2.

Syllabus reference: 4.1

79.   Two moles of aluminium sulfate contain:

    A   Two moles of aluminium atoms

    B   Three moles of sulfur atoms

    C   Twelve moles of oxygen atoms

    D   Ten moles of ions

Answer: D

Explanation: Aluminium sulfate is $Al_2(SO_4)_3$, so 2 moles of $Al_2(SO_4)_3$ contain 2 x 2 = 4 moles Al^{3+} ions and 2 x 3 = 6 moles of SO_4^{2-} ions. Total number of ions is therefore 10 moles. There are 2 x 3 = 6 moles of sulfur atoms and 2 x 4 x 3 = 24 moles of oxygen atoms.

Syllabus reference: 4.1

80.   A group 2 metal X would form a phosphate with the formula:

    A XPO_4

    B $X_2(PO_4)_3$

    C $X_3(PO_4)_2$

    D $X(PO_4)_2$
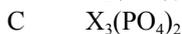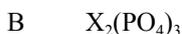
Answer: C

Explanation: A Group 2 metal forms 2+ ions. Phosphate is PO_4^{3-}, so the compound has three X^{2+} ions with two PO_4^{3-} ions.

Syllabus reference: 4.1

81.   Which of the following formulae is correct?

    A KCl_2

    B $Al_3(SO_4)_2$

    C Li_3PO_4

    D Na_2CO_4

Answer: C

Explanation: Li is in group 1, so forms 1+ ions; the phosphate ion is 3-, so three lithium atoms combine with one phosphate ion to give Li_3PO_4. Potassium is in group 1, so forms 1+ ions, whilst Cl is in group 17 and forms 1- ions; potassium chloride is therefore KCl. Al forms 3+ ions and sulfate is SO_4^{2-}, so aluminium sulfate is $Al_2(SO_4)_3$. Na forms 1+ ions and the carbonate ion is CO_3^{2-}, so sodium carbonate is Na_2CO_3.

Syllabus reference: 4.1

82.   Alkaline earth element X reacts with a group 15 element Y. Which of the following is true?

    A   Y is a non-metal

    B   Both elements are non-metals

    C   The compound is covalent

    D   The compound's formula is X_2Y_3

Answer: A

Explanation: Alkaline earths are group 2 metals, so they form 2+ ions.; thus X is a metal. Non-metals in group 15 form 3- ions when they react with metals. An ionic compound X_3Y_2 could form. Although group 15 also contains some metals (antimony and bismuth), these would not react with group 2 metals.

Syllabus reference: 4.1

83.   Ionic bonding results from electrostatic attraction:

A   Between atoms
B   Between cations and anions
C   Between molecules
D   Between nuclei

Answer: B
Explanation: Ionic bonding is the attraction between oppositely charged ions, i.e. cations and anions. Atoms would not have these charges. Nuclei would not attract each other because they are all positive. Only covalent substances are made of molecules.
Syllabus reference: 4.1

84.   Calcium hydrogen carbonate has the formula:
A $CaHCO_4$
B $Ca(HCO_3)_2$
C Ca_2HCO_3
D $Ca(HCO_4)_2$

Answer: B
Explanation: Calcium is in group 2 so forms Ca^{2+} ions. The hydrogen carbonate ion is HCO_3^-. One Ca^{2+} ion is balanced by two HCO_3^- ions to give the formula $Ca(HCO_3)_2$.
Syllabus reference: 4.1

85.   The formula of erbium carbonate is $Er_2(CO_3)_3$. The formula for erbium nitrate would be expected to be:
A Er_2N_3
B $Er(NO_2)_3$
C $Er_2(NO_3)_3$
D $Er(NO_3)_3$

Answer: D
Explanation: As the carbonate ion has a 2- charge, the compound $Er_2(CO_3)_3$ contains Er^{3+} ions. The nitrate ion has a 1- charge, so erbium nitrate is $Er(NO_3)_3$.
Syllabus reference: 4.1

86.   An alkaline earth element X reacts with a group 15 element Y. Which of the following is true?
A   Both elements are non-metals
B   Y is a non-metal
C   The compound's formula is X_2Y_3
D   The compound is covalent

Answer: B
Explanation: Alkaline earth elements are metals in group 2 with two outer shell (valence) electrons; they form 2+ ions. Group 15 elements have five outer shell (valence) electrons and form 3- ions; group 15 contains both metals and non-metals, but a metal would not react with an alkaline earth metal, so the element in group 15 must be a non-metal. The formula of the compound would be X_3Y_2 and it would be ionic.
Syllabus reference: 4.1

87.   Ionic bonding
A   is the electrostatic attraction between positive anions and negative cations
B   is the electrostatic attraction between positive and negative atoms
C   is the sharing of electrons between atoms with different electronegativities
D   involves the transfer of electrons from the less electronegative atom to the more electronegative atom

Answer: D
Explanation: Ionic bonding involves the transfer of electrons from the less electronegative atom to the more electronegative atom to form positive and negative ions. Answer A is wrong because anions are negative and cations are positive. Answer B is wrong because it is ions rather than atoms that are attracted together. Answer C is wrong because it describes polar covalent bonding rather than ionic.
Syllabus reference: 4.1

88.   Five moles of barium phosphate contains
A   Five moles of barium atoms
B   Twenty five moles of ions
C   Twenty moles of oxygen atoms
D   Fifteen moles of phosphorus atoms

Answer: B

Explanation: Barium phosphate is $Ba_3(PO_4)_2$, so each mole of $Ba_3(PO_4)_2$ contains 5 moles of ions (three Ba^{2+} and two PO_4^{3-}); thus 5 moles of $Ba_3(PO_4)_2$ contains 5 x 5 = 25 moles of ions
Each mole of $Ba_3(PO_4)_2$ contains 3 moles of Ba, 2 moles of P and 8 moles of O. Thus 5 moles of $Ba_3(PO_4)_2$ contains 15 moles Ba, 10 moles P and 40 moles of O.
Syllabus reference: 4.1

89.   A group 13 metal J would form a sulfate with the formula
   A JSO_4
   B J_3SO_4
   C $J_3(SO_4)_2$
   D $J_2(SO_4)_3$
 Answer: D
Explanation: If J is a metal in group 13, it forms 3+ ions. Sulfate is a 2- ion, so the formula is $J_2(SO_4)_3$.
Syllabus reference: 4.1

90.   Which of the following compounds is most ionic?
   A   RbCl
   B   NaCl
   C $AlCl_3$
   D   HCl
Answer: A
Explanation: The most ionic compound is formed between elements with the greatest difference in electronegativity.
Syllabus reference: 4.1

91.   Which of the following is true?
   A   A coordinate bond is formed when there is a large electronegativity difference between two elements
   B   Covalent bonding involves the electrostatic attraction between a pair of electrons and positively charged nuclei
   C   Covalent bonding generally happens between metals bond to non-metals
   D   Covalent substances generally have high melting points
Answer: B
Explanation: Covalent bonding involves the electrostatic attraction between a pair of electrons and positively charged nuclei. If there is a large electronegativity difference, the bonding is ionic. Covalent bonding usually happens between non-metals. Covalent substances generally have low melting points.
Syllabus reference: 4.2

92.   Covalent bonding is best described as:
   A   Electrostatic attraction between an electron pair and positively charged nuclei
   B   Two atoms sharing an electron
   C   Transfer of electrons between two non-metal atoms
   D   Equal sharing of an electron pair between elements
Answer: A
Explanation: Covalent bonding is the electrostatic attraction between an electron pair and positively charged nuclei. Two electrons are needed for the bond, not one. A transfer of electrons between atoms would be ionic, not covalent. Equal sharing of electrons can occur, but only when the two bonded atoms are of the same element and therefore have the same electronegativity.
Syllabus reference: 4.2

93.   Which of the following statements is correct?
   A   A coordinate bond is formed when there is a large difference in electronegativity between two

elements.

B   Covalent bonding involves the electrostatic attraction between a pair of electrons and positively charged nuclei.

C   Covalent bonding generally involves metals bonded to non-metals.

D   Covalent substances tend to conduct electricity well.

Answer: B

Explanation: A coordinate bond is formed when one atom has a lone pair and another atom is electron deficient. Covalent bonding generally involves non-metals bonded to other non-metals. Covalent substances have no delocalised electrons or ions to carry charge, so they are really bad electrical conductors.

Syllabus reference: 4.2

94.   Which of the following compounds contain both ionic and covalent bonds?

A   NaOH

B CH_3COOH

C SiO_2

D AlF_3

Answer: A

Explanation: There is a covalent bond between the O and H atoms in the hydroxide ion, but the bond between Na^+ and OH^- is ionic. Ethanoic acid is covalent. Silicon dioxide is macromolecular, so contains only covalent bonds. Aluminium fluoride is ionic.

Syllabus reference: 4.2

95.   The ammonium ion:

A   has the formula NH_3^+

B   contains covalent bonds

C   contains both covalent and coordinate bonds

D   is electron deficient

Answer: C

Explanation: The nitrogen atom has five outer shell (valance) electrons, so it forms three covalent bonds to hydrogen to form the molecule ammonia. The remaining electrons in the nitrogen's outer shell are a lone pair. These electrons can form a coordinate bond to a proton to form the ammonium ion, NH_4^+. The nitrogen in the ammonium ion has four electron domains, so it is not electron deficient.

Syllabus reference: 4.3

96.   Which of the following does **not** obey the octet rule?

A BH_3

B GeH_4

C Al_2Cl_6

D C_2H_4

Answer: A

Explanation: In BF_3, the boron has three electron domains, so the boron can count only three pairs of electrons, leaving it electron deficient. There are four electron domains in GeH_4. In Al_2Cl_6, each aluminium has three covalent bonds and one dative bond, making four electron domains. In C_2H_4, there is a double bond, so each carbon has two three sigma bonds and one pi bond.

Syllabus reference: 4.3

97.   Coordinate bonding between two atoms:

A   involves the transfer of an electron pair from one atom to another

B   is stronger than covalent bonding

C   is covalent bonding where both shared electrons come from the same atom

D   is intermediate between ionic and covalent bonding

Answer: C

Explanation: Coordinate bonding is covalent bonding where both of the shared electrons come from the same atom. It is a type of covalent bonding, not intermediate between ionic and covalent. A transfer of electrons between atoms would be ionic bonding. A coordinate bond, once formed is the same as a covalent bond; for example, in the ammonium ion, there are three covalent bonded hydrogens and one coordinate bonded hydrogen, but all four bonds are the same length and strength.

98.   Which of the following structures contains coordinate bonding?
   A   Ammonium chloride
   B   Ethanol
   C   Hydrogen cyanide
   D   Ethene
   Answer: A
   Explanation: Ammonium chloride has coordinate bonds (as well as covalent bonds) between the nitrogen and hydrogen atoms in the ammonium ion. Ethanol, hydrogen cyanide and ethane are covalent.
   Syllabus reference: 4.3

99.   The bond angle in water is:
   A   180°
   B   90°
   C   109.5°
   D   105°
   Answer: D
   Explanation: The oxygen in water has two bonds and two lone pairs, so it is angular with four electron domains. If all four electron domains were bonds, this would give 109.5° angles. Each lone pair reduces the bond angle by about two degrees, so the bond angle in water is about 105°.
   Syllabus reference: 4.3

100.   The bond angle in sulfur dioxide is:
   A   180°
   B   90°
   C   109.5°
   D   118°
   Answer: D
   Explanation: The bond angle is about 118°. The molecule is angular and can be represented with a lone pair on the sulfur and a double bond to one oxygen and a coordinate bond to the other. It is actually a resonance structure that can be represented with two Lewis structures. As the shape is based on three electron domains, one of which is a lone pair, the angles are reduced from 120 to 118°.
   Syllabus reference: 4.3

101.   The nitrate ion is a resonance hybrid. How many Lewis structures need to be drawn to show its structure?
   A   2
   B   3
   C   4
   D   6
   Answer: B
   Explanation: Three resonance structures are needed, because the "double bond" could be shown in three different places. It does not matter which of the other two bonds is shown as covalent and which is shown as coordinate, because covalent and coordinate bonds are the same length and strength.
   Syllabus reference: 4.3

102.   The Kekulé model of benzene can be used to explain why:
   A   Benzene undergoes substitution reactions
   B   The bond lengths between all six carbon atoms are equal
   C   Benzene is not very reactive
   D   Only one monosubstituted bromine derivative exists
   Answer: D

Explanation: In the Kekulé model, the three double bonds in the structure should encourage addition rather than substitution reactions. The bond lengths should be alternately long (single) and short (double). A substance with three double bonds should be highly reactive. As the Kekulé structure has all six carbons in equivalent positions, it would make no difference which one of the six carbons had its hydrogen replaced with a bromine atom.
Syllabus reference: 4.3

103.   Which of the following is **not** a resonance hybrid?
    A   The nitrate ion
    B   The sulphate ion
    C   The ozone molecule
    D   The ethanoic acid molecule
Answer: D
Explanation: In ethanoic acid, there is one C=O bond and one C-O-H bond; there is no resonance involved. All of the other three structures are resonance structures. In NO_3^-, there are effectively one and a third bonds between the C and each O, so three Lewis structures must be drawn. The SO_4^{2-} ion has six resonance structures as its two single and two double bonds can be drawn in different positions. Ozone has two resonance structures, with one coordinate bond and one double bond in each Lewis structure.
Syllabus reference: 4.3

104.   Which of the following is **not** macromolecular?
    A   Silicon dioxide
    B   Diamond
    C   Phenol
    D   Graphite
Answer: C
Explanation: Phenol is a discrete molecule C_6H_5OH. Silicon dioxide has a central Si bonded to four oxygens, each of which bonds to another silicon, building to a macromolecule. In diamond, each C bonds to four others, each of which is bonded to a total of four carbons, building a macromolecule. In graphite, each carbon bonds to three others in flat hexagonal layers of effectively infinite size, with delocalized electrons between layers holding them together, giving a macromolecule.
Syllabus reference: 4.3

105.   Which of these molecules has the smallest bond angles?
    A NH_3
    B H_2O
    C SF_6
    D CO_2
Answer: C
Explanation: SF_6 is octahedral with 90° bond angles. H_2O is angular with 105° angles. NH_3 is trigonal pyramidal with 107° angles. CO_2 is linear with 180° angles.
Syllabus reference: 4.3

106.   All the following molecules are linear **except:**
    A CO_2
    B   HCN
    C C_2H_2
    D SiO_2
Answer: D
Explanation: In CO_2, the carbon has two double bonds and no lone pairs, giving two electron domains that produce a linear molecule. In HCN, the carbon has a single bond to hydrogen and a triple bond to nitrogen, giving two electron domains that produce a linear molecule. In C_2H_2, each carbon has a single bond to hydrogen and a triple bond to the other carbon, giving two electron domains that produce a linear molecule. SiO_2 is a macromolecular structure in which each silicon atom forms bonds to four oxygen

atoms, each of which bonds to another silicon atom, building a diamond-like structure. The bond angles are 109.5° and the shape around each silicon is tetrahedral.
Syllabus reference: 4.3

107.   Which of the following are planar?
        I BF_3
        II NF_3
        III NO_3^-

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

Answer: D

Explanation: BF_3 is an electron deficient compound with three electron domains equally spaces out to give a trigonal planar structure with 120° angles. The nitrate ion is a resonance hybrid with three electron domains around the nitrogen and effectively one and a third bonds between the nitrogen and each oxygen; it is also trigonal planar. NF_3 has four electron domains due to the lone pair on the nitrogen, so it is trigonal pyramidal.
Syllabus reference: 4.3

108.   Which of the following species involve sp^3 hybridisation?
        I BCl_3
        II SiH_4
        III PH_3

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

 Answer: D

Explanation: B has electron configuration $1s^2 2s^2 2p^1$. It forms three bonds by promoting a 2s electron to 2p then hybridizing the s and both p to form sp^2. Si has electron configuration $1s^2 2s^2 2p^6 3s^2 2p^2$. It forms four bonds by promoting a 2s electron to 2p then hybridizing the s and all three p to form sp^3. P has electron configuration $1s^2 2s^2 2p^6 3s^2 2p^3$. It forms four bonds by hybridizing the s and all three p to form four sp^3 orbitals, one of which has a lone pair and the others form bonds.
Syllabus reference: 4.3

109.   Which of the following contain coordinate bonding?
A   Ammonium bromide
B   Water
C   Potassium chloride
D   Ammonia

Answer: A

Explanation: The ammonium ion contains a nitrogen forming covalent bonds to three hydrogen atoms and using its lone pair to forma coordinate bond to a proton, giving the NH_4^+ ion. Water and ammonia are both covalent, whilst potassium chloride is ionic.
Syllabus reference: 4.3

110.   The nitrate ion is a resonance hybrid. Which of the following is true?
A   Two Lewis structures must be drawn to show its structure
B   Three Lewis structures must be drawn to show its structure
C   The central nitrogen atom is electron deficient
D   The formula for this ion is NO_4^-

Answer: B

Explanation: The nitrate ion is NO_3^-. The central nitrogen atom bonds to three oxygens, effectively forming one and a third bonds with each of them. This means that Lewis structures can be drawn with a double bond in three possible locations.
Syllabus reference: 4.3

111. Which of the following does not obey the octet rule?

A BF_3
B SiH_4
C Al_2Cl_6
D C_2H_4

Answer: A
Explanation: Boron has atomic number 5, so it has two electrons in the first shell and three in the second. It uses these three outer shell electrons to form three covalent bonds, so it is electron deficient. The other compounds mentioned all meet the octet rule. Si forms 4 covalent bonds to hydrogen atoms. Each Al forms three covalent bonds and one coordinate bond in Al_2Cl_6. In C_2H_4, each carbon forms sigma bonds to two hydrogen atoms and the other carbon atom, plus one pi bond with the other carbon.
Syllabus reference: 4.3

112. Which of the following would have the greatest vapour pressure at room temperature?

A $CH_3CH_2OCH_2CH_3$
B $CH_3CH_2CHOHCH_2CH_3$
C CH_3CH_2COOH
D $CH_3CH_2CH_2CH_2NH_2$

Answer: A
Explanation: Ethoxyethane is an ether – it does not have hydrogen bonding between its molecules. Pentan-3-ol, propanoic acid and butanenitrile all have hydrogen bonding between molecules. Hydrogen bonding is a strong intermolecular force that reduces the volatility of a compound.
Syllabus reference: 4.4

113. A highly volatile substance is most likely to be

A   macromolecular
B   ionic
C   polar covalent
D   non-polar covalent

Answer: D
Explanation: A macromolecular substance will not vaporise easily because covalent bonds would need to break for it to do so. Ionic substances have strong attractions between the oppositely charged ions, so they do not vaporise easily. Polar covalent and non-polar covalent substances can both vaporise, but there is less attraction between non-polar molecules and therefore non-polar substances are the most likely to be highly volatile.
Syllabus reference: 4.4

114. Ice is less dense than liquid water because:

A   Each molecule in ice hydrogen bonds to two others
B   Each molecule in ice hydrogen bonds to three others
C   Each molecule in ice hydrogen bonds to four others
D   Ice has a smaller molecular mass than liquid water

Answer: C
Explanation: Each water molecule in ice forms two hydrogen bonds via its hydrogen atoms and another two via its lone pairs. Note that ice and liquid water have the same molecular mass!
Syllabus reference: 4.4

115. 2-nitrophenol has a lower boiling point than 4-nitrophenol because:

A   2-nitrophenol has intermolecular hydrogen bonding whilst 4-nitrophenol has intramolecular hydrogen bonding
B   2-nitrophenol has intramolecular hydrogen bonding whilst 4-nitrophenol has

intermolecular hydrogen bonding
C   2-nitrophenol has a lower molecular mass than 4-nitrophenol
D   2-nitrophenol does not have hydrogen bonding
Answer: B
Explanation: In 2-nitrophenol, the hydrogen in the OH group is next to the oxygen in the nitro group, so the hydrogen bond forms between two parts of the same molecule, making intramolecular hydrogen bonding. In 4-nitrophenol, the OH and NO_2 are on opposite sides of the molecule, so the hydrogen bonding occurs between one molecule and the next. Intermolecular hydrogen bonding leads to a stronger attraction between molecules and a higher boiling point. Note that 2-nitrophenol and 4-nitrophenol are isomers with the same molecular mass.
Syllabus reference: 4.4

116.   The vapour pressure of a liquid increases if:
A   The volume of the container is increased
B   The surface area of the liquid is increased
C   The volume of the liquid is increased
D   The temperature is increased
Answer: D
Explanation: Increasing the temperature increases the proportion of molecules within the liquid that achieve the activation energy needed to escape and this leads to an increase in the concentration and therefore pressure of the vapour. Increasing the volume of the container just means that the escaping molecules have to travel further before they collide with the walls of the container; eventually, however, the rate at which they leave will equal the rate at which they return to the liquid. Volume does not affect the pressure. Increasing surface area has an equal effect on the rates of escape and return. Increasing the volume of liquid has no effect because molecules can only escape at the surface.
Syllabus reference: 4.4

117.   Which substance has the highest solubility in water (in mol dm^{-3}) at 298K?
A $CH_3CH_2CH_2CH_3$
B $CH_3CH_2OCH_2CH_3$
C $CH_3CH_2CH_2CH_2OH$
D $CH_3CH_2CH_2OH$
Answer: D
Explanation: Butane is a non-polar gas, so its solubility is minimal in highly polar water. Ethoxyethane is a non-polar liquid with a low solubility in water. Propan-1-ol and butan-1-ol are both alcohols that can engage in hydrogen bonding, so both are soluble; the longer chain length in butan-1-ol makes it less soluble than propan-1-ol, which is actually infinitely soluble because it can mix with water in any ratio.
Syllabus reference: 4.4

118.   Metallic bonding involves:
A   Attractions between the nuclei and outer shell electrons
B   Attractions between protons and electrons
C   Attractions between positive ions and delocalised electrons
D   Attractions between positive ions and outer shell electrons
Answer: C
Explanation: This is a tricky question, because all four answers look very similar. The best answer is that metallic bonding involves attractions between positive ions and delocalized electrons. In a metal, the outer shell electrons are always delocalized.
Syllabus reference: 4.5

119.   Other than iron, which element is always present in all steels?
A   Silicon
B   Carbon
C   Chromium
D   Tungsten
Answer: B
Explanation: There is always some carbon in any steel. Silicon, chromium and tungsten are all used in the manufacture of some specialist steels, but are not in all steels.
Syllabus reference: 4.5

120.   Which of the following statements about metals is **<u>untrue</u>**?

    A   Metals are usually malleable and ductile

    B   A metallic lattice consists of positive ions in a sea of delocalised electrons

    C   The melting points of Group 1 metals increase down the group.

    D   Metals are good thermal and electrical conductors

Answer: C

Explanation: Most metals are malleable (can be hammered flat) and ductile (can be drawn into wires), although this is not true for all metals. A metallic lattice is a regular three-dimensional array of positive ions in layers with the attractions to delocalised electrons acting to hold them in place. The good thermal and electrical conductivity of metals is due to the ability of delocalised electrons to move about. Descending group 1, melting points decrease because the extra shielding and distance from the nucleus to the outer shells is more significant than the increase in nuclear charge.

Syllabus reference: 4.5

121.   Which of the following is **<u>untrue</u>**?

    A   Aluminium is a small atom with very little inner electron shielding, so it cannot fully delocalise three electrons

    B   Most aluminium compounds are covalent, but very polar

    C   Molten aluminium oxide is a poor electrical conductor

    D   Aluminium has a much higher melting point than magnesium

Answer: D

Explanation: Aluminium falls near the dividing line between metals and non-metals in the periodic table. It has atomic number 13, so it is a small atom with very little shielding. Removing three electrons to form genuine Al^{3+} ions is only achieved when it bonds to the most electronegative element, fluorine. All other simple aluminium compounds are covalent but highly polar. Effectively, each aluminium atom delocalises two and a bit electrons. When melted (molten), aluminium oxide is a poor conductor because it is polar rather than ionic. There is very little difference in the melting points of magnesium and aluminium; if aluminium formed 3+ ions and delocalised three electrons per atom, it would have a much higher melting point than magnesium (2+ ions and two delocalised electrons per atom). As the third electron is not fully delocalised and the ionic charge is less than 3+, aluminium's melting point is only 10 K higher than that of magnesium.

Syllabus reference: 4.5

122.   The enthalpy of formation for sodium chloride is shown by:

    A $Na(s) + \frac{1}{2}Cl_2(g)$ ----> $NaCl(s)$

    B $Na(g) + \frac{1}{2}Cl_2(g)$ ----> $NaCl(s)$

    C $Na(g) + Cl(g)$ ----> $NaCl(s)$

    D $Na^+(g) + Cl^-(g)$ ----> $NaCl(s)$

Answer: A

Explanation: The enthalpy of formation is the energy change when one mole of a substance is formed from its elements in their standard states. This means that sodium has to be a solid and chlorine has to be a diatomic gas.

Syllabus reference: 5.1

123.   The standard enthalpy change of combustion of graphite is given by:

    A $C(graphite) + O_2(g)$ ----> $CO_2(g)$

    B $C(graphite) + \frac{1}{2}O_2(g)$ ----> $CO(g)$

    C $2C(graphite) + O_2(g)$ ----> $2CO(g)$

    D $C(g) + O_2(g)$ ----> $CO_2(g)$

Answer: A

Explanation: The standard enthalpy change of combustion is the energy change when one mole of a substance in its standard state is burned in excess oxygen. This means that the carbon has to be graphite and the product has to be CO_2 rather than CO.

Syllabus reference: 5.1

124.   50 cm³ of 1.0 mol dm⁻³ HNO_3 is mixed with 50 cm³ of 1.0 mol dm⁻³ KOH and the temperature of the resultant solution rises by 6 K. What will be the temperature rise if 100 cm3 of each of these solutions are mixed?

    A   3 K

    B   6 K

C   12 K

D   24 K

Answer: B

Explanation: As the volumes have been doubled and the concentrations have been kept the same, twice as much heat will have been released. However, since that heat is warming double the volume, the temperature rise will be the same.

Syllabus reference: 5.1

125.   All of the following have enthalpy of formation values of zero **except:**

A $O_2(g)$

B $F_2(g)$

C $P_2(s)$

D $S_8(s)$

Answer: C

Explanation: The standard states of these elements are $O_2(g)$, $F_2(g)$, $P_4(s)$ and $S_8(s)$, so the only one of the four suggested answers that is not the element in its standard state is $P_2(s)$. Enthalpy of formation is the energy change when one mole of a substance is formed from its elements in their standard states.

Syllabus reference: 5.1

126.   The enthalpy change of formation of carbon dioxide is given by

A $C(diamond) + O_2(g) \longrightarrow CO_2(g)$

B $C(graphite) + O_2(g) \longrightarrow CO_2(g)$

C $C(g) + O_2(g) \longrightarrow CO_2(g)$

D $C(g) + 2O(g) \longrightarrow CO_2(g)$

Answer: B

Explanation: The enthalpy of formation involves one mole of a substance being formed from its elements in their standard states. Graphite is more stable than diamond. Carbon is not a gas under standard conditions.

Syllabus reference: 5.1

127.   Which of the following represents the enthalpy change of formation of methane?

A $C(graphite) + 2H_2(g) \longrightarrow CH_4(g)$

B $C(g) + 2H_2(g) \longrightarrow CH_4(g)$

C $C(g) + 4H(g) \longrightarrow CH_4(g)$

D $C^{4+}(g) + 4H^+(g) \longrightarrow CH_4(g)$

Answer: A

Explanation: The enthalpy of formation involves the formation of one mole of a substance from its elements in their standard states. The standard state for carbon is graphite and hydrogen is diatomic. Methane is covalent, so the suggestion of forming it from $C^{4+}(g)$ and $4H^+(g)$ is clearly wrong.

Syllabus reference: 5.1

128.   When 50 joules of heat are supplied to a piece of ice at -12°C, the temperature rises to -7°C. The specific

heat capacity of ice is 2.0 J g^{-1} K^{-1}. What is the mass of the ice?
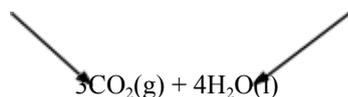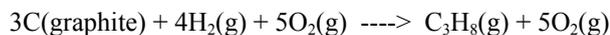
A   5.0 g

B   4.0 g

C   10.0 g

D   500.0 g

Answer: A

Explanation: $E = -mc\Delta T$, so $50 = m * 2.0 * 5$. Thus $m = 5.0$ g.

Syllabus reference: 5.1

129.   The enthalpy of formation of propane can be determined using an enthalpy cycle:

$$3C(graphite) + 4H_2(g) + 5O_2(g) \longrightarrow C_3H_8(g) + 5O_2(g)$$

$$3CO_2(g) + 4H_2O(l)$$

The enthalpy of combustion of graphite is -394 kJ mol^{-1}
The enthalpy of formation of water is -286 kJ mol^{-1}
The enthalpy of combustion of propane is -2202 kJ mol^{-1}

The enthalpy of formation of propane is given by:
A   3(-394) + 4(-286) - 2202
B   3(-394) + 4(-286) + 2202
C   3(-394) - 4(-286) - 2202
D   3(-394) - 4(-286) + 2202

Answer: B
Explanation: ΔH_{form} propane + ΔH_{comb} propane = 3 x ΔH_{comb} graphite + 4 x ΔH_{form} water. This is rearranged to give ΔH_{form} propane = 3(-394) + 4(-286) - (-2202) = 3(-394) + 4(-286) + 2202 kJ mol^{-1}
Syllabus reference: 5.2

130.   The enthalpy of formation of ethane can be found using an enthalpy cycle diagram:
$$2C(graphite) + 3H_2(g) + 3\tfrac{1}{2}O_2(g) \longrightarrow C_2H_6(g) + 3\tfrac{1}{2}O_2(g)$$

$$2CO_2(g) + 3H_2O(l)$$
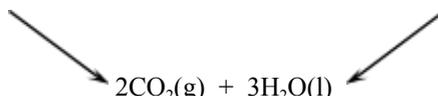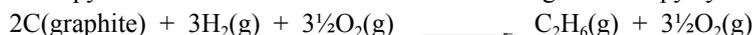
The enthalpy of combustion of graphite = -394 kJ mol^{-1}
The enthalpy of combustion of hydrogen = -286 kJ mol^{-1}
The enthalpy of combustion of ethane = -1561 kJ mol^{-1}
The enthalpy of formation of ethane is given by:
A   2(-394) + 3(-286) + 1561
B   2(-394) + 3(-286) - 1561
C   2(-394) - 3(-286) - 1561
D   2(-394) - 3(-286) + 1561

Answer: A
Explanation: According to Hess's Law, the energy change in converting graphite, hydrogen and oxygen into carbon dioxide and water equals the energy change in converting graphite, hydrogen and oxygen into ethane and oxygen and then converting that into carbon dioxide and water. So (2 x enthalpy of combustion of graphite) + (3 x enthalpy of combustion of graphite) = enthalpy of formation of ethane + enthalpy of combustion of ethane. Thus the enthalpy of formation of ethane = 2(-394) + 3(-286) + 1561.
Syllabus reference: 5.2

131.   Which of the following have an enthalpy of formation value that is zero?
A   ozone
B   diamond
C   buckminsterfullerene
D   graphite

Answer: D
Explanation: The enthalpy of formation involves forming one mole of a substance from the elements in their standard states. Ozone is not the standard state of oxygen; diamond and buckminsterfullerene are not the standard states of the carbon. Graphite is the standard state of carbon, so there is no energy change involved in converting a mole of graphite into a mole of graphite!

132. The enthalpy change for the reaction:

    $C_2H_4(g) + HI(g) \longrightarrow C_2H_5I(g)$
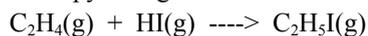
    can be found using bond enthalpy values (all in kJ mol^{-1}):

    | C-H 414 | C-C 346 | C=C 614 | H-I 298 | C-I 228 |

    A $\Delta H = [(4 \times 414) + 614 + 298] + [(5 \times 414) + 346 + 228]$
    B $\Delta H = [(4 \times 414) + 614 + 298] - [(5 \times 414) + 346 + 228]$
    C $\Delta H = [(5 \times 414) + 346 + 228] + [(4 \times 414) + 614 + 298]$
    D $\Delta H = [346 + 414 + 228] - [614 + 298]$

    Answer: B
    Explanation: Bonds broken: 4C-H, C=C and H-I = $(4 \times 414) + 614 + 298$. Bonds formed = 5C-H, C-C and C-I = $(5 \times 414) + 346 + 228$. ΔH = bonds broken – bonds formed = $[(4 \times 414) + 614 + 298] - [(5 \times 414) + 346 + 228]$.
    Syllabus reference: 5.3

133. Which statement about average bond enthalpies is **wrong**?
    A They are negative for bond breaking and positive for bond making
    B They are negative for bond making and positive for bond breaking
    C They are only valid for gases
    D They are measured in kJ mol^{-1}.

    Answer: A
    Explanation: Bond breaking requires energy so it is endothermic; this means that bond enthalpy values used when breaking bonds are positive. Bond enthalpies can only be applied when dealing with molecules in the gaseous state.
   **Syllabus reference:** 5.3

134. When a catalyst is used:
    A It increases the total kinetic energy of the particles
    B It increases the yield of product
    C It increases the total potential energy of the particles
    D It undergoes no permanent chemical change

    Answer: D
    Explanation: A catalyst does not increase the total kinetic energy of the particles, the yield of product or the total potential energy of the particles. The catalyst undergoes no permanent chemical change and can therefore be reused.
    Syllabus reference: 6.1

135. In the Haber Process, nitrogen reacts with hydrogen as follows:

    $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol^{-1}
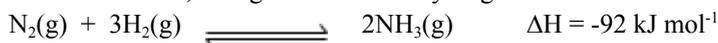
    Why do some collisions between nitrogen and hydrogen molecules not lead to the formation of the product?
    A The N_2 and H_2 molecules do not have sufficient energy
    B The system is at equilibrium
    C The reaction is exothermic
    D The activation energy for this reaction is very low

    Answer: A
    Explanation: The activation energy for this reaction is very high, so most colliding molecules do not have enough energy to react. It is true that the forward reaction is exothermic and that the reaction can reach equilibrium, but neither of these facts explain why some collisions do not lead to reaction.
    Syllabus reference: 6.1

136. A suitable method for following the rate of reaction between iodine and propanone would be:
    A Gravimetric analysis
    B Colorimetric analysis

C   Conductimetric analysis

D   Volumetric analysis

Answer: B

Explanation: Gravimetric analysis relies on weighing a precipitate – the products here are soluble. Conductimetric analysis relies on monitoring changes in electrical conductivity – there would be no variation during this reaction. Volumetric analysis involves measuring the volume of gas produced – but no gas is formed here. Colorimetric analysis will work because iodine is coloured but the 1-iodopropane formed is not.

Syllabus reference: 6.1

137.   Addition of a catalyst to a reacting mixture:

A   Increases the activation energy of the particles by providing an alternative pathway for the reaction

B   Increases the average kinetic energy of the particles by providing an alternative pathway for the reaction

C   Increases the yield of product at equilibrium by providing an alternative pathway for the reaction

D   Decreases the activation energy for the reaction by providing an alternative pathway for the reaction

Answer: D

Explanation: Addition of a catalyst decreases the activation energy for the reaction by providing an alternative pathway. It has no effect on the average energy of the particles or the yield of products.

Syllabus reference: 6.1

138.   Which of the following reactions will **not** be facilitated by the catalytic convertor fitted to a car?

A $2NO(g) \longrightarrow N_2(g) + O_2(g)$

B $2NO_2(g) \longrightarrow N_2(g) + 2O_2(g)$

C $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$

D $2NO_2(g) \longrightarrow 2NO(g) + O_2(g)$

Answer: D

Explanation: A catalytic convertor changes harmful gases like nitrogen oxides and carbon monoxide into nitrogen, oxygen and carbon dioxide.

Syllabus reference: 6.1

139.   The Haber Process is used in the industrial manufacture of ammonia:

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

Most collisions between hydrogen and nitrogen molecules are unsuccessful, which means that:

A   The system is already at equilibrium

B   The temperature is too high

C   The activation energy for this reaction is very low

D   Only a small fraction of molecules have the activation energy

Answer: D

Explanation: Only a small fraction of molecules have the activation energy. The activation energy for this reaction is very high. The higher the temperature, the more molecules would have the activation energy.

Syllabus reference: 6.1

140.   The addition of a catalyst:

A   Affects the equilibrium constant

B   Increases the yield of products at equilibrium

C   Increases the fraction of molecules with the activation energy

D   Provides an alternative reaction pathway with a lower activation energy

Answer: D

Explanation: The addition of a catalyst does not affect the equilibrium constant or the equilibrium yield of products, nor does it provide energy. However, by lowering the activation energy barrier, it increases the fraction of molecules that have enough energy to react.

Syllabus reference: 7.1

141.   In the Haber Process, ammonia is produced by reacting nitrogen with hydrogen:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$
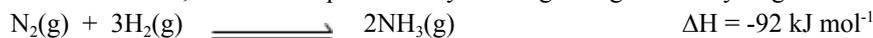
The yield of ammonia at equilibrium could be increased by:

A   Increasing the temperature
B   Increasing the pressure by adding more nitrogen
C   Using osmium instead of iron as a catalyst
D   Increasing the pressure by adding helium

Answer: B
Explanation: Increasing the temperature would drive the reaction in the endothermic direction, giving less ammonia. Changing the catalyst will not change the yield. The examiner is trying to trick you into thinking that adding helium will increase the pressure and drive the reaction to the right; this is not true! Adding helium has no effect because helium is not involved in the equilibrium. Helium atoms can be introduced into the container without having any measurable effect on the space available for the other gas particles – the container is so much bigger than the helium atoms that their volume is negligible. Adding more nitrogen will shift the equilibrium towards more ammonia, as the equilibrium shifts to cancel the effects of the change according to Le Châtelier's principle.
Syllabus reference: 7.1

142.   The Haber Process is used for producing ammonia:

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

The equilibrium expression for this reaction is given by

A $[NH_3]^2 / [N_2] [H_2]^3$
B $[N_2] [H_2]^3 / [NH_3]^2$
C $[2NH_3] / [N_2] [3H_2]$
D $2[NH_3] / [N_2] 3[H_2]$

Answer: A
Explanation: The equilibrium constant is the ratio of the concentrations of products over concentration of reactants, with each concentration raised to the power that corresponds to its coefficient in the stoichiometric equation. Note that $[2NH_3]$ and $[3H_2]$ are meaningless!
Syllabus reference: 7.1

143.   The value of K_c for a reaction is 10.0. What is the value of the inverse reaction?

A   10.0
B   -10.0
C   0.1
D   -0.1

Answer: C
Explanation: For the reverse reaction, the numerator and denominator are reversed, giving $K_c = 1/10.0 = 0.1$.
Syllabus reference: 7.1

144.   Consider the homogeneous equilibrium

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

where the equilibrium concentrations of H_2 and I_2 are both 0.300 mol dm^{-3} and the equilibrium concentration of HI is 3.00 mol dm^{-3}. Which of the following is true?

A K_c for the reaction is 10.0
B K_c for the inverse reaction is 0.0100
C   Increasing the pressure will increase the yield of HI
D K_c for the reaction could be increased by increasing the total pressure

Answer: B
Explanation: K_c would equal $3.00^2 / 0.300^2 = 100$. For the reverse reaction $K_c = 0.300^2 / 3.00^2 = 0.100$. Increasing the pressure would have no effect on yield, because there are equal numbers of moles of gas on

both sides of the equilibrium. Increasing pressure would have no effect of K_c – only temperature changes affect K_c.
Syllabus reference: 7.1

145. In the Contact Process, sulfur dioxide and oxygen react as follows:

$$2SO_2(g) \ O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -98 \text{ kJ mol}^{-1}$$

Which of the following is true?
A   Decreasing the pressure gives a higher equilibrium yield of sulfur trioxide
B   Increasing the temperature gives a higher equilibrium yield of sulfur trioxide
C   Adding vanadium (V) oxide as a catalyst gives a higher equilibrium yield of sulfur trioxide
D   Sulfur trioxide is continuously removed so the reaction is not allowed to reach equilibrium

Answer: D
Explanation: Decreasing the pressure would push the equilibrium towards the side with more moles of gas, giving less sulfur trioxide at equilibrium. As ΔH is negative, the forward reaction is exothermic, so increasing the temperature would decrease the yield of sulfur trioxide. Changing the catalyst would not affect the yield. Removing the SO_3 as it forms prevents equilibrium from being reached; the forward reaction is encouraged whilst the reverse reaction is prevented. In industry, the Contact Process is run as a continuous process that is never allowed to reach equilibrium and the SO_3 is continually removed.
Syllabus reference: 7.1

146. For the reaction:

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

A $K_c = \dfrac{[Cl_2]^2 \ [H_2O]^2}{[HCl]^4 \ [O_2]}$

B $K_c = \dfrac{[HCl]^4 \ [O_2]}{[Cl_2]^2 \ [H_2O]^2}$

C $K_c = \dfrac{[2Cl_2] \ [2H_2O]}{[4HCl] \ [O_2]}$

D $[HCl] = 2[Cl_2]$ at equilibrium

Answer: A
Explanation: The coefficients in the stoichiometric equation are the powers to which the concentrations need to be raised in the K_c equation. $K_c = [Cl_2]^2 \ [H_2O]^2/ [HCl]^4 \ [O_2]$. Answer (C) is wrong because $[2Cl_2]$ is meaningless – it is like saying "the concentration of two chlorines".
Syllabus reference: 7.1

147. Carbon monoxide and ~~hydrogen c~~an react as follows:

$$CO(g) + 3H_2(g) \qquad CH_4(g) + H_2O(g) \qquad \Delta H = -210 \text{ kJ mol}^{-1}$$
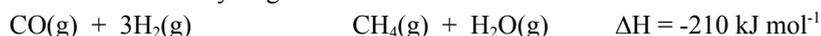
Which statement is always correct about this reaction when equilibrium has been reached?
A   The concentrations of carbon monoxide and steam are equal
B   The rate of the forward reaction is greater than the rate of the reverse reaction
C   The amount of hydrogen is three times the amount of methane
D ΔH for the reverse reaction is $+210$ kJ mol^{-1}

Answer: D
Explanation: At equilibrium, the rates of the forward and reverse reactions are equal, but this does not imply that there will be equal amounts of CO and steam, or that there will be three times as much hydrogen as methane, because the position of equilibrium is not known here. The reverse reaction will have the same magnitude for ΔH, but the opposite sign.
Syllabus reference: 7.1

148. Which of the following changes may affect the value of K_c for a reaction?
A   Increasing the concentration of the reactants
B   Increasing the pressure
C   Increasing the temperature
D   Changing from a heterogeneous catalyst to a homogeneous catalyst

Answer: C
Explanation: Only changes in temperature affect the value of K_c. Changes in pressure or concentration can change the position of equilibrium, but not the value of K_c. Changing from a heterogeneous to a homologous catalyst does not affect the value of K_c or the position of equilibrium – it just enables the equilibrium to be reached faster.
Syllabus reference: 7.1

149. Hydrogen and iodine react to form an equilibrium with hydrogen iodide:
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$
It is found that value of the equilibrium constant, K_c, for this reaction = 100. What is the value of the reverse reaction?

A   100
B   -100
C   0.01
D   -0.01

Answer: C
Explanation: K_c for the forward reaction is given by $[HI]^2 / [H_2][I_2] = 100$. For the reverse reaction, $K_c' = [H_2][I_2] / [HI]^2 = 1/100 = 0.01$.
Syllabus reference: 7.1

150. Which of the following **cannot** act as a Brønsted-Lowry acid?

A NH_4^+
B H_3O^+
C   HBr
D BF_3

Answer: D
Explanation: A Brønsted-Lowry acid is a proton donor, which means that it must contain a hydrogen atom in its molecule. BF_3 does not contain any hydrogen! NH_4^+ can donate a proton to form NH_3. H_3O^+ can donate a proton to form H_2O. HBr can donate a proton to become Br^-.
Syllabus reference: 8.1

151. A Brønsted-Lowry base:

A   is a proton donor
B   must also be a Lewis base
C   always has a pH above 7
D   will always turn phenolphthalein pink

Answer: B
Explanation: Brønsted-Lowry bases are a subset of Lewis bases, so all Brønsted-Lowry bases are Lewis bases, but not vice versa. The term "Brønsted-Lowry base" refers to the behaviour of the substance when it accepts protons from a Brønsted-Lowry acid – it does not indicate the relative amounts of the two substances, so it does not give any indication of what the pH would be or what colour an indicator will turn.
Syllabus reference: 8.1

152. An amphiprotic substance:

A   can also be classed as amphoteric
B   can resist pH changes when small amounts of acid are added
C   is defined according to the Lewis definition of acids and bases
D   does not necessarily contain any hydrogen atoms

Answer: A
Explanation: An amphiprotic substance can act as both a Brønsted-Lowry acid and a Brønsted-Lowry base, so it can be a proton donor or acceptor; it must therefore contain hydrogen. The word amphoteric is used for substances that can act as both Lewis acids and bases, i.e. substances that can both accept and donate an electron pair. As all Brønsted-Lowry acids are also Lewis acids, all amphiprotic substances could also be classified as amphoteric.
Syllabus reference: 8.1

153. The conjugate acid of ammonia is:

A H^+

B H_3O^+

C NH_2^-

D NH_4^+

Answer: D

Explanation: Conjugate partners always differ by one proton, so if NH_3 acts as a base by accepting a proton, its conjugate acid is NH_4^+.

Syllabus reference: 8.1

154. In which of the following reactions between stoichiometric quantities of reactants would the final pH be highest?

A $2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$

B $HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$

C $HCl(aq) + NH_3(g) \longrightarrow NH_4Cl(aq)$

D $HCOOCH_3(l) + H_2O(l) \longrightarrow HCOOH(aq) + CH_3OH(aq)$

Answer: A

Explanation: In answer (A), the product is the strong base potassium hydroxide. In answer (B), the product is neutral sodium chloride. In answer (C), the product is ammonium chloride, which is acidic because it is the salt of a weak base (ammonia) with a strong acid (HCl). In answer (D), the products are the weak acid methanoic acid and neutral methanol. The highest pH will therefore be potassium hydroxide.

Syllabus reference: 8.1

155. Which of the following aqueous solutions would have the highest pH?

A 0.10 mol dm^{-3} HCl

B 0.10 mol dm^{-3} NH_3

C 0.10 mol dm^{-3} CH_3COOH

D 0.10 mol dm^{-3} KOH

Answer: D

Explanation: KOH is a strong base, so it is fully ionised in aqueous solution, giving it a very high pH (about pH13). NH_3 is a weak base, so it has a lower [OH$^-$] and a lower pH than KOH (about pH9). CH_3COOH is a weak acid and HCl is a strong acid, so these solutions have pH of about pH5 and pH1 respectively.

Syllabus reference: 8.1

156. The $H_2PO_4^-$ ion:

A Is the conjugate acid of H_3PO_4

B Is the conjugate base of HPO_4^{2-}

C Is the conjugate acid of HPO_4^{2-}

D Is the conjugate base of H^+

Answer: C

Explanation: Conjugate acid-base partners differ by one proton. $H_2PO_4^-$ is the conjugate acid of HPO_4^{2-}, because $H_2PO_4^-$ is formed when HPO_4^{2-} acts as an acid by giving up a proton.

Syllabus reference: 8.1

157. When added to water, ammonia acts as a weak Brønsted-Lowry base. In this case

A the ammonium ion would act as a weak Brønsted-Lowry acid

B the ammonium ion would act as a strong Brønsted-Lowry acid

C hydroxide ions would act as a Lewis acid

D water would act as a Lewis base

Answer: B

Explanation: Ammonia is a weak base, which means that it exists mainly as NH_3 molecules in solution. This means that ammonium ions would have a strong tendency to release H^+ in solution to form NH_3 molecules, i.e. ammonium ions act as a strong Brønsted-Lowry acid. Hydroxide ions would behave in this reaction as a Lewis base, i.e. an electron pair donor, whilst water would act as a Lewis acid.

Syllabus reference: 8.1

158. Which of the following is true?

 A   Methyl orange turns blue in acidic solution

 B   Litmus turns yellow in acidic solution

 C   Phenolphthalein is colourless in acidic solution

 D   Universal indicator is blue in acidic solution

Answer: C

Explanation: You just have to learn the colour changes for the common indicators. Lots of indicators are listed in the Data Booklet, but you only need to learn the colour changes for methyl orange, litmus, phenolphthalein and universal indicator. Remember that the Data Booklet is only available for papers 2 and 3, so in multiple-choice questions, you need to know these colours!

Syllabus reference: 8.2

159. The reaction between strontium hydroxide and nitric acid is given by the equation:

 A $SrOH(aq) + HNO_4(aq) \longrightarrow SrNO_4(aq) + H_2O(l)$

 B $Sr(OH)_2(aq) + 2HNO_4(aq) \longrightarrow Sr(NO_4)_2(aq) + 2H_2O(l)$

 C $Sr(OH)_2(aq) + 2HNO_2(aq) \longrightarrow Sr(NO_2)_2(aq) + 2H_2O(l)$

 D $Sr(OH)_2(aq) + 2HNO_3(aq) \longrightarrow Sr(NO_3)_2(aq) + 2H_2O(l)$

Answer: D

Explanation: Strontium is a group 2 metal, so it forms 2+ ions. The hydroxide ion is OH^-. Thus strontium hydroxide is $Sr(OH)_2$. Nitric acid is HNO_3 and it reacts to form nitrate ions, NO_3^-. Strontium nitrate is therefore $Sr(NO_3)_2$. Be aware that nitrous acid, HNO_2, forms nitrites, NO_2^-.

Syllabus reference: 8.2

160. Which of the following methods for making copper(II) sulfate would **_not_** work?

 A $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$

 B $Cu(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2(g)$

 C $Cu(OH)_2(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + 2H_2O(l)$

 D $CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l) + CO_2(g)$

Answer: B

Explanation: Metal oxides, hydroxides and carbonates always react with acids to form salts. Only the more reactive metals will react with acids, however. Only metals above hydrogen in the reactivity series can displace it.

Syllabus reference: 8.2

161. An aqueous solution of which of the following reacts with magnesium metal?

 A   Ammonia

 B   Potassium carbonate

 C   Hydrogen chloride

 D   Sodium hydroxide

Answer: **C**

Explanation: Hydrogen chloride dissolves in water to form hydrochloric acid. Acids attack reactive metals to form salts and hydrogen. Ammonia solution and sodium hydroxide solution are alkaline; they do not react with magnesium. Potassium carbonate solution is also alkaline (salt of a strong base with a weak acid), so it doesn't react with magnesium either.

Syllabus reference: 8.2

162. A solution of pH 2:

 A   Has a $[H^+]$ of 1×10^{-2} mol dm^{-3}

 B   Turns phenolphthalein pink

 C   Has a pOH of 10

 D   Has a $[H^+]$ 1000 times greater than a solution of pH 4

Answer: A

Explanation: $pH = - lg[H^+]$, so a solution with pH 2 has $[H+] = 1 \times 10^{-2}$. Phenolphthalein would be colourless in acid solution. As pH + pOH, the pOH would be 12. Each pH unit represents a tenfold change in $[H^+]$, so a solution with pH4 has 100 times more H^+ ions than one with pH2.

Syllabus reference: 8.3

163. When the pH of a solution changes from 3.0 to 6.0, the hydrogen ion concentration

 A   increases by a factor of 1000

 B   decreases by a factor of 1000

 C   increases by a factor of 3

 D   decreases by a factor of 3

Answer: B
Explanation: pH = lg [H+]. Each pH unit represents a tenfold change in hydrogen ion concentration, so a change from pH 3.0 to 6.0 involves a decrease by a factor of 10 * 10 *10 = 1000.
Syllabus reference: 8.3

164.   In pure water at 40°C, $[H^+] = 1.71 \times 10^{-7}$ mol dm^{-3}. Which of the following is true?

A   Pure water at 40°C has a pH of 7

B   Pure water at 40°C is slightly acidic

C   Pure water at 40°C is slightly alkaline

D   Pure water at 40°C contains equal concentrations of H$^+$ and OH$^-$ ions

Answer: D
Explanation: Pure water only has a pH of 7 at 25°C – the examiner is trying to trick you here. Pure water is always neutral, because it always has equal concentrations of H$^+$ and OH$^-$ ions.
Syllabus reference: 8.3

165.   Which of the following is true?

A $[H^+]$ in 2.00 mol dm^{-3} HCl is 1.00 mol dm^{-3}

B $[H^+]$ in 2.00 mol dm^{-3} CH_3COOH is 2.00 mol dm^{-3}

C $[H^+]$ in 2.00 mol dm^{-3} H_2SO_4 is 2.00 mol dm^{-3}

D $[H^+]$ in 2.00 mol dm^{-3} HNO_3 is 2.00 mol dm^{-3}

Answer: D
Explanation: HCl is a strong monobasic acid, so 2.00 mol dm^{-3} HCl has $[H^+]$ = 2.00 mol dm^{-3}. Ethanoic acid is a weak monobasic acid, so the concentration of H$^+$ in 2.00 mol dm^{-3} CH_3COOH is a lot **less** than 2.00 mol dm^{-3}. Sulfuric acid is a strong dibasic acid, so the concentration of H$^+$ in 2.00 mol dm^{-3} H_2SO_4 is 4.00 mol dm^{-3}. HNO_3 is a strong monobasic acid, so 2.00 mol dm^{-3} HNO_3 has $[H^+]$ = 2.00 mol dm^{-3}.
Syllabus reference: 8.3

166.   The pH of a 0.01 mol dm^{-3} solution of KOH is:

A   2

B   8

C   10

D   12

Answer: D
Explanation: As KOH is a strong base, it is fully ionized, so $[OH^-]$ = 0.01, so pOH = $10^{-0.01}$ = 2. As pH + pOH = 14, this means that the pH = 12.
Syllabus reference: 8.3

167.   Which of the following 0.01 mol dm^{-3} aqueous solutions has the highest pH?

A CH_3COOH

B   KCl

C $FeCl_3$

D CH_3NH_2

Answer: D
Explanation: Methanamine is basic, so has a pH above 7. Ethanoic acid is a weak acid, KCl (salt of a strong acid and strong base) is neutral and iron (III) chloride (salt of strong acid and weak base) is acidic.
Syllabus reference: 8.3

168.   A strong acid:

A   Will neutralise more of a given sodium hydroxide solution than a weak acid of the same concentration

B   Always has a lower pH than a weak acid

C   Always conducts better than a weak acid

D   Has a K_a value that approaches infinity

Answer: D
Explanation: The strength of an acid does not affect the amount of NaOH needed to neutralise it – what counts is the concentration. The pH of a solution depends on both its strength and its concentration, so a strong acid may have a lower or higher pH than a weak acid, depending on their concentrations. Again, conductivity depends on both strength and concentration; a strong acid may have a lower or higher conductivity than a weak acid, depending on their concentrations. As a strong acid HA has almost completely ionized to form H$^+$ and A$^-$ ions, [HA] is almost zero. $K_a = [H^+] [A^-] / [HA]$, but dividing by zero gives infinity.
Syllabus reference: 8.4

169.   Which of the following is true?
   A   A dilute acid is always weak because it has a low concentration of $H_3O^+(aq)$ ions.
   B 0.1 mol dm^{-3} ethanoic acid is a worse electrical conductor than 0.1 mol dm^{-3} nitric acid.
   C 0.1 mol dm^{-3} hydrochloric acid and 0.1 mol dm^{-3} sulfuric acid are equally good as electrical conductors.
   D   If a weak base B is added to water, a high concentration of $BH^+(aq)$ ions will be formed.
   Answer: B
   Explanation: Dilution and strength are not related; a dilute acid has a low concentration, but it can be either strong (fully ionised) or weak (partially ionised). At equal concentrations, the strong acid nitric acid will have a higher concentration of ions than the weak acid ethanoic acid, so nitric acid is a better conductor. Although they are both strong, at equal concentrations, sulfuric acid has more ions than hydrochloric acid; this is because sulfuric acid is dibasic (can donate two protons) and hydrochloric acid is monobasic (can donate one proton), so there is a higher concentration of ions in sulfuric acid. A weak base B will form a low concentration of $BH^+(aq)$ ions.
   Syllabus reference: 8.4

170.   Which of the following is **untrue**?
   A   Rain could be classified as acid deposition
   B   Fog could be classified as acid deposition
   C   Acid deposition is classified as a primary pollutant
   D   Snow could be classified as acid deposition
   Answer: C
   Explanation: Rain, fog and snow are all forms of acid deposition. Acid deposition is a secondary pollutant, because the rain does not necessarily fall in the place where the source of the pollution occurs.
   Syllabus reference: 8.5

171.   Which of the following gases contributes to making rain acidic?
   A   CFCs
   B   Sulfur dioxide
   C   Methane
   D   Carbon monoxide
   Answer: B
   Explanation: CFCs, methane and carbon monoxide are all responsible for air pollution, but none of them are acidic – they are all neutral. Sulfur dioxide, however, dissolves in clouds to form sulfurous acid, which is then oxidized by atmospheric oxygen to produce sulfuric acid when it rains.
   Syllabus reference: 8.5

172.   In which of the following reactions is hydrogen behaving as an oxidizing agent?
   A $2K + H_2 \longrightarrow 2KH$
   B $H_2 + Cl_2 \longrightarrow 2HCl$
   C $HCHO + H_2 \longrightarrow CH_3OH$
   D $O_2 + 2H_2 \longrightarrow 2H_2O$
   Answer: A
   Explanation: When potassium reacts with hydrogen, the oxidation state of potassium goes from 0 to +1 and the oxidation state of hydrogen goes from 0 to -1; this means that hydrogen is acting as an oxidizing agent. When hydrogen reacts with chlorine, the chlorine is reduced from oxidation state 0 to -1. When hydrogen reacts with HCHO, the carbon is reduced from +2 to -2. When hydrogen reacts with oxygen, the oxygen is reduced from oxidation state 0 to -2.
   Syllabus reference: 9.1

173.   In H_3PO_4, the oxidation states of hydrogen, phosphorus and oxygen are, respectively
   A   +1, +5 and -2
   B   1+, 5+ and 2-
   C   I, V and II
   D   +1, +1 and -1
   Answer: A
   Explanation: Oxidation states are written with the sign before the number. Roman numerals are used when naming some compounds to specify the charges on ions. In H_3PO_4, both hydrogen and oxygen follow

their usual behaviour. Hydrogen is +1 in all compounds except the hydrides of group 1 and 2 metals, whilst oxygen is -2 in compounds except peroxides and OF_2. As the total of the oxidation states in a compound totals zero, phosphorus is +5 in this compound.
Syllabus reference: 9.1

174. The oxidation state of molybdenum in K_2MoO_4 is:
    A   +6
    B   6+
    C   6
    D   VI
    Answer: A
    Explanation: The two potassium atoms both have oxidation state +1 and the four oxygen atoms are each -2. To give a total of zero, the manganese has to be +6. Be really careful here; when writing oxidation states, the sign comes **before** the number. When writing the charges on ions, the sign goes after the number, e.g. Fe^{2+}. When writing the name of a compound, the oxidation state of the metal is sometimes indicated using Roman numerals, e.g. potassium manganite (VI). Just writing 6 would not show whether the oxidation state is positive or negative, so it is not good enough!
    Syllabus reference: 9.1

175. Which of the following is the strongest reducing agent?
    A   Li
    B   Mg
    C   Pb
    D Br^-
    Answer: A
    Explanation: Lithium is a strong reducing agent because it can easily be oxidized to Li^+. It is easier to remove electrons form lithium than from magnesium or lead, which is why lithium is a much more reactive metal. The bromide ion has a full outer shell, which it would lose if it gets oxidized to a bromine atom.
    Syllabus reference: 9.1

176. The oxidation numbers of the elements in potassium dichromate are:
    A   K = +1, Cr = +6, O = -2
    B   K = -1, Cr = +6, O = -2
    C   K = +1, Cr = +3, O = -2
    D   K = -1, Cr = -6, O = +2
    Answer: A
    Explanation: Group 1 metals always have oxidation number +1 in all compounds. Oxygen is always -2 except in peroxides or OF_2. There are two potassium atoms, each +1 and seven oxygen atoms, each -2. The total of this is -12, so the two chromium atoms are =6 each.
    Syllabus reference: 9.1

177. Which of the following does **not** involve redox?
    A $ReO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) ----> Re^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq)$
    B $PH_3(g) + HCl(aq) ----> PH_4Cl(aq)$
    C $2HClO(aq) + 2H^+(aq) + Mn(s) ----> Cl_2(g) + 2H_2O(l) + Mn^{2+}(aq)$
    D $H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) ----> 2H_2O(l) + I_2(aq)$
    Answer: B
    Explanation: In answer (B), the phosphorus remains at oxidation state -3, the hydrogen remains at oxidation state +1 and the chlorine remains at oxidation state -1, so this is not a redox reaction. In answer (A), Re is reduced from +7 in ReO_4^- to +2 in Re^{2+}, whilst Fe is oxidized from +2 in Fe^{2+} to =3 in Fe^{3+}. In answer (A), Re is reduced from +7 in ReO_4^- to +2 in Re^{2+}, whilst Fe is oxidized from +2 in Fe^{2+} to +3 in Fe^{3+}. In answer (C), Cl is reduced from +1 in HClO to 0 in Cl_2, whilst Mn is oxidized from 0 in Mn to +2 in Mn^{2+}. In answer (D), O is reduced from -1 in H_2O_2 to -2 in H_2O, whilst I is oxidized from -1 in I^- to 0 in I_2.
    Syllabus reference: 9.1

178.   What happens to chlorine when chlorate ions, ClO_3^-, are converted into chlorine molecules?
    A   It undergoes reduction and its oxidation state changes from -1 to 0
    B   It undergoes oxidation and its oxidation state changes from -1 to 0
    C   It undergoes reduction and its oxidation state changes from +5 to 0
    D   It undergoes oxidation and its oxidation state changes from +5 to 0
    Answer: C
    Explanation: In ClO_3^- the chlorine has an oxidation number of +5, whilst in Cl_2 it is zero; it is therefore reduced from +5 to 0.
    Syllabus reference: 9.1

179.   Which statement about the electrolysis of molten potassium bromide is correct?
    A   A red-brown gas is produced at the negative electrode
    B   A silvery metal is produced at the positive electrode
    C   Bromide ions are attracted to the positive electrode and undergo oxidation
    D   Potassium ions are attracted to the negative electrode and undergo oxidation
    Answer: C
    Explanation: Bromide ions have a 1- charge and so are attracted to the positive electrode, where they lose electrons to form the element bromine. This produces red-brown gas at the positive electrode and a silvery metal at the negative electrode. The potassium ions have a 1+ charge, so they are attracted to the negative electrode and reduced to potassium atoms.
    Syllabus reference: 9.1

180.   Which of the following **cannot** be added when balancing a half-equation?
    A   Electrons
    B H^+ ions
    C O_2 gas
    D   Water molecules
    Answer: C
    Explanation: You will just need to learn this. Only electrons, H^+ ions and water molecules can be added when balancing half-equations in acid or neutral solutions. In alkaline solutions, you could also add OH^- ions, but these are not on the current IB syllabus, so you won't need to remember that. You can't add O_2 gas.
    Syllabus reference: 9.1

181.   In which of the following does nickel have an oxidation number of zero?
    A $[Ni(OH)_2(H_2O)_4]^+$
    B $[Ni(H_2O)_6]^{3+}$
    C $NiCl_3$
    D $Ni(CO)_4$
    Answer: D
    Explanation: In answer (A), there are four neutral ligands and two 1- ligands; as the overall charge is +1, nickel has an oxidation number of +3. In answer (B), the ligands are all neutral, so the nickel has an oxidation number of +3. In answer (C), each Cl is -1, so nickel has an oxidation number of +3. In answer (D), the carbonyl group is neutral, so nickel has an oxidation number of zero.
    Syllabus reference: 9.1

182.   Which of the following should **not** feature in a half-equation?

A CH_3COOH
B HNO_3
C Cu^{2+}
D H_2O

Answer: B

Explanation: Weak acids remain mainly as molecules, so their full formulas are used when writing half-equations. Strong acids are fully ionized, so a strong acid HA should be represented as A⁻. Ethanoic acid is weak but nitric acid is strong. There is no reason why Cu_{2+} or water should not feature in a half-equation.

Syllabus reference: 9.1

183.   The biochemical oxygen demand (BOD) of pure water would be:
A   Less than 1 ppm
B   Between 1 and 5 ppm
C   Between 5 and 10
D   Between 300 and 400

Answer: A

Explanation: Just learn this! The BOD of pure water is less than 1 ppm. The more polluted the water becomes, the higher its BOD.

Syllabus reference: 9.1

184.   In which of the following is the oxidation state of oxygen -1?
A H_2O
B H_2O_2
C H_2SO_4
D HNO_3

Answer: B

Explanation: In H_2O_2, the bond between the two oxygens shares the electrons equally; the oxygen is more electronegative than the hydrogen, so each oxygen has gained control of one electron, giving it an oxidation number of -1. In all the other compounds mentioned, oxygen hs an oxidation number of -2. In water, each H is +1, so the oxygen is -2. In H_2SO_4, both H are +1, S is +6 and each O is -2. In HNO_3, the H is +1, the N is +5 and each O is -2.

Syllabus reference: 9.1

185.   What are the oxidation numbers of the elements in phosphoric acid, H_3PO_4?
A   Hydrogen +1, phosphorus +5, oxygen -2
B   Hydrogen -1, phosphorus +3, oxygen -2
C   Hydrogen +3, phosphorus +5, oxygen -8
D   Hydrogen -3, phosphorus -5, oxygen +8

Answer: A

Explanation: Both hydrogen atoms are +1 and each of the eight oxygen atoms is -2; this gives a total of -5, so the phosphorus is +5.

Syllabus reference: 9.1

186.   In an acidic hydrogen-oxygen fuel cell:
A   Hydrogen is oxidised into H^+ ions at the anode
B   Hydrogen is oxidised into H^+ ions at the cathode
C   Oxygen and hydrogen are reduced to water at the anode
D   Oxygen and hydrogen are oxidised to water at the cathode

Answer: A

Explanation: Just remember **RED CAT** (**red**uction always happens at the **cat**hode)! Hydrogen is oxidized at the anode: $2H_2(g) \longrightarrow 4H^+(aq) + 4e^-$

Syllabus reference: 9.2

187.   The cell diagram convention for the Daniell Cell is shown by
A $Zn(s) \mid Zn^{2+}(aq) \parallel Cu^{2+}(aq) \mid Cu(s)$
B $Cu^{2+}(aq) \mid Cu(s) \parallel Zn(s) \mid Zn^{2+}(aq)$
C $Zn^{2+}(aq) \mid Zn(s) \parallel Cu(s) \mid Cu^{2+}(aq)$
D $Cu(s) \mid Cu^{2+}(aq) \parallel Zn^{2+}(aq) \mid Zn(s)$

Answer: A

Explanation: Zinc is oxidised to $Zn^{2+}(aq)$ and $Cu^{2+}(aq)$ is reduced to copper

188.   Which of the following statements is true?
    A   A voltaic cell requires an external voltage
    B   A salt bridge connects the two half-cells in an electrolytic cell
    C   Oxidation occurs at the anode, which is positive in the voltaic cell
    D   Reduction occur at the cathode, which is negative in the electrolytic cell
    Answer: D
    Explanation: Oxidation occurs at the anode and reduction occurs at the cathode (RED CAT); the cathode is negative in an electrolytic cell (APE VAN). The voltaic cell produces an external voltage. A salt bridge connects the two half-cells in a voltaic cell.
    Syllabus reference: 9.2

189.   Which of the following statements is untrue about a voltaic cell?
    A   A salt bridge is used to connect the two half-cells
    B   If the electron flow is from the hydrogen electrode through the wire towards metal M, then M will have a negative standard electrode potential
    C   The cell potential depends on the difference between the electrode potential of the two component half-cells
    D   A high-resistance voltmeter is needed to accurately measure the cell potential
    Answer: B
    Explanation: If the electron flow is from the hydrogen electrode through the wire towards metal M, then M will have a **positive** standard electrode potential. In a voltaic cell, a salt bridge is needed to connect the two half-cells. The cell potential depends on the difference between the electrode potentials of the two component half-cells. A high-resistance voltmeter is needed to accurately measure the cell potential, because a low-resistance voltmeter would allow some current to flow and reduce the potential difference.
    Syllabus reference: 9.2

190.   The empirical formula of pent-2-ene is:
    A CH
    B CH_2
    C C_5H_{10}
    D C_5H_{12}
    Answer: B
    Explanation: Pent-2-ene has the structural formula $CH_3CHCHCH_2CH_3$, so it has five carbons and ten hydrogens. This gives a 1:2 ratio, so the empirical formula is CH_2.
    Syllabus reference: 10.1

191.   Which of the following molecules is an ester?
    A CH_3COOH
    B $CH_3CH_2COOCH_3$
    C $CH_3CH_2OCH_2CH_3$
    D $CH_3CH_2COCH_3$
    Answer: D
    Explanation: $CH_3CH_2COOCH_3$ is an ester. CH_3COOH is a carboxylic acid. $CH_3CH_2OCH_2CH_3$ is an ether. $CH_3CH_2COCH_3$ is a ketone.
    Syllabus reference: 10.1

192.   Which of the following compounds would be expected to have the highest boiling point?
    A $CH_3CH_2CH_2CH_3$
    B $CH_3CH_2OCH_2CH_3$
    C $CH_3CH_2CH_2CH_2OH$
    D $CH_3CH_2CH_2CH_2F$
    Answer: C
    Explanation: Butane, $CH_3CH_2CH_2CH_3$, ethoxyethane, $CH_3CH_2OCH_2CH_3$ and 1-fluorobutane, $CH_3CH_2CH_2CH_2F$, all have van der Waals forces between their molecules. Butan-1-ol, $CH_3CH_2CH_2CH_2OH$ has hydrogen bonds, which are stronger than van der Waals forces in molecules of similar relative molecular mass.
    Syllabus reference: 10.1

193.   What is the IUPAC name for $CH_3CH_2C(CH_3)_2Br$?
    A   2-bromo, 2-methylbutane
    B   2-bromopentane

C   2-bromo, 2-ethylpropane

D   1-bromo, 1,1-dimethylpropane

Answer: A

Explanation: The longest continuous chain is four carbon atoms and there are only single bonds, so the name is based on butane. There is a methyl group and a bromine on the second carbon in the chain, so the compound is 2-bromo, 2-methylbutane.

Syllabus reference: 10.1

194.   The number of isomers with formula C_5H_{12} is:

A   5

B   4

C   3

D   2

Answer: C

Explanation: The formula C_5H_{12} could be pentane, methylbutane or dimethylpropane.

Syllabus reference: 10.1

195.   Members of a homologous series:

A   Have the same molecular formula

B   Have the same empirical formula

C   Have the same general formula

D   Have the same structural formula

Answer: C

Explanation: Members of a homologous series have different lengths of carbon "skeleton". The molecules therefore have different molecular and structural formulas. The ratio of different elements may vary as the number of carbon atoms in the chain increases, so the empirical formulas are not the same. For example, the empirical formula of methane is CH_4 (also its molecular formula), whilst ethane has a molecular formula of C_2H_6 and an empirical formula of CH_3. All members of a homologous series have a general formula that can be used to generate the molecular formulas of all members of the group. For example, the alkanes are C_nH2_{n+2}, where n is an integer.

Syllabus reference: 10.1

196.   Saturated hydrocarbons:

A   Contain no double bonds

B   Easily undergo addition reactions

C   Rapidly decolourise bromine water

D   Can be oxidised using acidified potassium dichromate

Answer: A

Explanation: Saturated hydrocarbons have only singly bonded carbon atoms. As each carbon already has four strong covalent bonds, addition is impossible – they can react by substitution. Saturated hydrocarbons do not decolourise bromine water or undergo oxidation reactions.

Syllabus reference: 10.1

197.   Which substances are possible products of the incomplete combustion of pentane?

A   carbon dioxide and hydrogen

B   carbon monoxide and hydrogen

C   carbon dioxide and water

D   carbon monoxide and water

Answer: D

Explanation: When hydrocarbons burn, their hydrogen content reacts to form water. In excess oxygen, their carbon content burns to form carbon dioxide, but in a limited oxygen supply, incomplete combustion produces carbon monoxide.

Syllabus reference: 10.1

198.   How many isomers have the formula C_5H_{10}?

A   2
B   4
C   5
D   6
Answer: D
Explanation: One possibility is cyclopentane. There are two straight-chain alkenes: pent-1-ene and pent-2-ene. There are three branched-chain alkenes: 2-methylbut-1-ene, 2-methylbut-2-ene and 3-methylbut-1-ene.
Syllabus reference: 10.1

199.   In which of the following is the nitrogen to carbon bond shortest?
A CH_3CH_2CN
B $CH_3CH_2NH_2$
C $C_6H_5NH_2$
D $C_6H_5NO_2$
Answer: A
Explanation: There is a triple bond between N and C in CH_3CH_2CN. There are single N to C bonds in all the other compounds mentioned.
Syllabus reference: 10.1

200.   Which of the following is true?
A   A primary alcohol can be oxidised to form an aldehyde
B   A ketone can be reduced to form a primary alcohol
C   A tertiary alcohol can be oxidised to form a carboxylic acid
D   An aldehyde can be oxidised to form a secondary alcohol
Answer: A
Explanation: A primary alcohol can be oxidised to an aldehyde. A ketone can be reduced to form a secondary alcohol. A tertiary alcohol resists oxidation. An aldehyde can be oxidised to form a carboxylic acid.
Syllabus reference: 10.2

201.   Ethanol can be oxidised to ethanoic acid
A   by heating under reflux with acidified potassium dichromate
B   by adding acidified potassium dichromate and distilling the mixture
C   by heating under reflux with lithium aluminium hydride
D   by adding lithium aluminium hydride and distilling the mixture
Answer: A
Explanation: Ethanol is a primary alcohol, which can undergo a two-step oxidation process. In the first step, ethanol is oxidised to ethanol; as the latter has no hydrogen bonding, it has a much lower boiling point than ethanol. If the mixture is distilled, ethanol would separate from the oxidising agent and the second stage oxidation from ethanol to ethanoic acid would not occur. Thus, full oxidation is achieved by heating under reflux. A suitable oxidising agent is potassium dichromate, which itself gets reduced to form Cr^{3+} ions. Lithium aluminium hydride is a powerful reducing agent!
Syllabus reference: 10.2

202.   Methanol can be oxidised to methanoic acid by heating under reflux with acidified potassium dichromate.
What colour change would be observed?
A   pink to colourless
B   orange to green
C   green to orange
D   colourless to pink
Answer: B
Explanation: Potassium dichromate is orange; it is reduced to form green Cr^{3+} ions. The alternative oxidising agent potassium manganate(VII) would turn from pink to colourless.
Syllabus reference: 10.2

203.   To convert propan-1-ol into propanal:
A   Reflux with acidified potassium manganate (VII)
B   Reflux with acidified potassium dichromate
C   Distil with lithium aluminium hydride

D   Distil with acidified potassium dichromate

Answer: D

Explanation: Propan-1-ol can be oxidized by either acidified potassium manganate (VII) or acidified potassium dichromate. However, this oxidation is a two step process in which the propan-1-ol is first oxidized to propanal and then further oxidized to propanoic acid; propanal has a much lower boiling point than propan-1-ol because it does not have hydrogen bonding, so distillation would separate it from the oxidizing agent and prevent the second step in the oxidation process. Reflux would allow the oxidizing agent to further oxidize the propanal to form propanoic acid. Thus the mixture should be distilled rather than refluxed if the desired product is propanal.

Syllabus reference: 10.2

204.   Which of the following reagents would react with $CH_3CH_2CH_2CHO$?

    I $H^+(aq)$ with $MnO_4^-(aq)$

    II   Dilute sulfuric acid with potassium dichromate

    III $LiAlH_4(aq)$

A   I only

B   I and II only

C   I, II and III

D   III only

Answer: C

Explanation: $CH_3CH_2CH_2CHO$ is an aldehyde; it can be oxidized to butanoic acid by heating with H^+ (from dilute acid) and either MnO_4^- or $Cr_2O_7^{2-}$ ions. Aldehydes can also be reduced to primary alcohols by $LiAlH_4$. Thus, butanal reacts with all three of the proposed reagents.

Syllabus reference: 10.2

205.   The number 0.0012340 has:

A   8 significant figures

B   7 significant figures

C   5 significant figures

D   4 significant figures

Answer: C

Explanation: Initial non-zero digits do not count, but all other digits from first non-zero digit do count.

Syllabus reference: 11.1

206.   The enthalpy change of neutralisation can be determined by mixing equal volumes of KOH(aq) and HCl(aq) of the same concentration in a glass beaker. The maximum temperature change is recorded using an alcohol thermometer.

What is the biggest source of error in this experiment?

A   Random error in the thermometer readings

B   Heat absorbed by the thermometer

C   Systematic error in measuring the volumes of KOH(aq) and HCl(aq) using burettes

D   Heat loss to the surroundings

Answer: D

Explanation: A lot of heat will be lost to the surroundings because there is no lagging or lid on the beaker. Very little heat will be absorbed by the thermometer. The random error in thermometer readings will be small. Using burettes correctly should not produce systematic errors.

Syllabus reference: 11.1

207.   A burette reading is recorded as 24.30 ± 0.05 cm^3. Which of the following could be the actual value?

    I   24.32 cm^3

    II   24.24 cm^3

    III   24.29 cm^3

A   I and II only

B   I and III only

C   II and III only

D   I, II and III

Answer: B

Explanation: The actual value is between 24.25 and 24.35 cm^3.

Syllabus reference: 11.1

208. The number 0.0002370 has
   A   4 significant figures
   B   7 significant figures
   C   8 significant figures
   D   3 significant figures
   Answer: A
   Explanation: Initial zeroes are not significant, so the 2 is the first significant figure in this number. The final zero is significant, so there are a total of 4 significant figures.
   Syllabus reference: 11.1

209. When producing a graph:
   A   The independent variable should be on the y axis
   B   Both scales must start from zero
   C   The dependent variable should be on the y axis
   D   At least four data points are required to establish a trend
   Answer: C
   Explanation: The dependent variable should be on the y axis and the independent variable should be on the x axis. There is no requirement for both scales to start at zero. At least five data points are required to establish a trend.
   Syllabus reference: 11.2

210. When producing a graph
   A   The independent variable should be on the y axis
   B   Both scales must start from zero
   C   The dependent variable should be on the x axis
   D   At least five data points are required to establish a trend
   Answer: D
   Explanation: The independent variable should be on the x axis and the dependent variable on the y axis. If all of the data has values between, for example, 9.1 and 9.9, it is better to cover the range 9-10 rather than starting at zero; in this way, the trend can be more easily seen. At least five data points are needed to establish a trend.
   Syllabus reference: 11.2

211. The IHD of methylbenzene is:
   A   0
   B   1
   C   2
   D   4
   Answer: D
   Explanation: IHD = 0.5 (2c + 2 – h – x + n), where c = number of carbons, h = number of hydrogens, x = number of halogens and n = number of nitrogens. Here IHD = 0.5 (14 + 2 – 8 – 0 + 0) = 4. Another way to get this answer is to say that there is one aromatic ring, (which counts as three double bonds and a ring) giving 4.
   Syllabus reference: 11.3

212. In an IR spectrum, which of the following is **not** true?
   A   The region below 1500 cm^{-1} is called the fingerprint region
   B   The presence of hydrogen bonds can be shown by wide bands
   C   The lighter the bonded atoms, the higher the frequency of adsorption
   D   TMS is added to the sample being tested
   Answer: D
   Explanation: TMS is added during NMR spectroscopy, not IR spectroscopy. The other statements are true – learn them!
   Syllabus reference: 11.3

213.   An NMR spectrum
    A   Indicates the number of hydrogen atoms in the molecule
    B   Identifies the molar mass of the substance
    C   Shows how many different environments hydrogen has in the molecule
    D   Can distinguish between chlorine isotopes
    Answer: C
    Explanation: The NMR spectrum won't tell you how many hydrogens there are in the molecule or the mass of the molecule. It would not be a suitable technique for distinguishing between chlorine isotopes because they don't contain any hydrogen! The number of peaks in the spectrum shows how many different environments there are for hydrogen within the molecule and the size of peaks (technically the area under the peaks) shows the ratio of how many hydrogens are in each environment.
    Syllabus reference: 11.3

214.   Tetramethylsilane is used:
    A   As a solvent in IR spectroscopy
    B   As a lubricant in burette taps
    C   As a reference standard in IR spectroscopy
    D   As a reference standard in NMR spectroscopy
    Answer: D
    Explanation: Tetramethylsilane has twelve hydrogens in equivalent environments, so it gives one large peak, used as a reference in TMS to establish the 0 ppm mark. Burette taps are often lubricated with silicone-based grease. Don't confuse NMR with IR!
    Syllabus reference: 11.**3**

215.   Chemical shifts in NMR spectra are measured in:
    A   nm
    B cm^{-1}
    C   ppm
    D   m
    Answer: C
    Explanation: NMR shifts are measured in ppm (parts per million). Just learn this!
    Syllabus reference: 11.**3**

216.   Which of the following peaks would appear in the mass spectrum of propan-1-ol but **not** in the mass spectrum of methoxyethane?
    A   15
    B   17
    C   29
    D   31
    Answer: B
    Explanation: The peak at 17 represents an OH^+ group, which is present in propan-1-ol but not in methoxyethane. Both molecules could fragment to form a CH_3^+ group (peak at 15). A peak at 31 would appear in both spectra, representing CH_2OH^+ or OCH_3^+. A peak at 29 would appear in both spectra, representing $CH_3CH_2^+$. A peak at 46 would be formed by both molecules (i.e. the molecular mass without any fragmentation).
    Syllabus reference: 11.3

217. In the electromagnetic spectrum:
- A   γ rays have the highest frequency and the lowest energy
- B   Radio waves have the longest wavelength and the highest energy
- C   Radio waves have the lowest frequency and the highest energy
- D   γ rays have the shortest wavelength and the highest energy

Answer: D
Explanation: Gamma rays have very short wavelength (high frequency) and very high energy. Radio waves have long wavelength and relatively low energy.
Syllabus reference: 11.3

218. The first eight ionisation energies (in kJ mol^{-1}) of an element are as follows:

| 1680 | 3370 | 6040 | 8410 | 11000 | 15100 | 17900 | 91600 |

The element is in:
- A   Group 1
- B   Group 2
- C   Group 17
- D   Group 18

Answer: C
Explanation: The first seven electrons are removed with increasingly high energies, but the biggest jump between successive ionization energies comes between 17900 and 916600, which is the eighth ionization. This corresponds to an element with seven outer shell electrons, so the element is a halogen from group 17.
Syllabus reference: 12.1

219. The first eight ionisation energies of an element are as follows:

| 1000 | 2260 | 3390 | 4540 | 6990 | 8490 | 27100 | 31700 |

The element is in:
- A   Group 1
- B   Group 2
- C   Group 16
- D   Group 17

Answer: C
Explanation: A group 16 element has 6 outer shell electrons, each of which will take progressively more energy to remove. Removing a seventh electron breaks into the next shell, which is considerably more difficult, so the seventh ionisation energy is a much larger jump compared with previous increases.
Syllabus reference: 12.1

220. Which of the following statements is correct?
- A   The first ionisation energy of Li is greater than that of Be
- B   The first ionisation energy of Mg is greater than that of Al
- C   The first ionisation energy of Al is greater than that of Si
- D   The first ionisation energy of S is greater than that of Cl

Answer: B
Explanation: Moving from left to right across each period, there is a general increase in ionisation energies because elements in the same period have the same amount of shielding but an increasing number of protons. However, there is a special stability in filled orbitals. When Al loses an electron it achieves the stability of a filled 3s and an empty 3p orbital, but when Mg loses an electron, it loses the special stability of a full 3s orbital.
Syllabus reference: 12.1

221. What is the energy (in J) of a photon of light of wavelength 645.0 nm?
Planck's constant, $h = 6.626 \times 10^{-34}$ J s and the speed of light, $c = 2.998 \times 10^8$ m s^{-1}.
- A $\underline{6.626 \times 10^{-34} \times 2.998 \times 10^8}$

$$\frac{645.0 \times 10^9}{6.626 \times 10^{-34} \times 2.998 \times 10^8}$$

B $\dfrac{6.626 \times 10^{-34} \times 2.998 \times 10^8}{645.0 \times 10^{-9}}$

C $\dfrac{645.0 \times 10^{-9} \times 2.998 \times 10^8}{6.626 \times 10^{-34}}$

D $\dfrac{6.626 \times 10^{-34} \times 645.0 \times 10^{-9}}{2.998 \times 10^8}$

Answer: B

Explanation: To solve this, you need to know that 1 nm = 10^{-9} m, so 645.0 nm = 645.0 x 10^{-9} m. E = hν, so E = 6.626 x 10^{-34} x 2.998 x 10^8 /645.0 x 10^{-9} **Syllabus reference:** 12.1

222. Which of the following oxidation states are exhibited by transition metals?
    A   Scandium +4
    B   Chromium +1
    C   Iron +7
    D   Titanium +2

Answer: D

Explanation: Sc can lose its outer pair of 4s electrons and its single 3d electron to form Sc^{3+}. Cr can lose its outer pair of 4s electrons and can also lose its unpaired 3d electrons, but it cannot lose just one electron. Iron can lose its outer pair of 4s electrons and its unpaired 3d electrons; it has six 3d electrons, but two are paired and so cannot be lost. The maximum oxidation state for iron would therefore be +6. Titanium can lose its outer pair of 4s electrons and keep its two 3d electrons to form Ti^{2+}.

Syllabus reference: 13.1

223. The $[MoI_2(CN)_4]^{2-}$ ion is called
    A   Diiodotetracyanomolybdate (IV)
    B   Tetracyanodiiodomolybdate (IV)
    C   Diiodotetracyanomolybdenum (IV)
    D   Tetracyanodiiodomolybdenum (IV)

Answer: B

Explanation: When naming complex ions, ligands are named in alphabetical order, so "tetra**c**yano" comes before "di**i**odo". The metal is named in English if the overall ion is positive, but if it is negative overall, the ending "–ate" is used. Thus, this ion is tetracyanodiiodomolybdate (IV). Note that the (IV) refers to the 4+ charge of the central metal cation, not the overall charge of the complex ion.

Syllabus reference: 13.1

224. Which of the following properties is **not** typical of transition metals?
    A   Variable oxidation states
    B   Catalytic activity
    C   Coloured compounds
    D   Low density

Answer: D

Explanation: Transition metals are generally dense because they have strong metallic bonding that involves the delocalization of multiple electrons. They have variable oxidation states because they always lose their outer s electrons but they also have the option of losing some or all of their unpaired d electrons. They often have catalytic properties. When the catalyst is solid, it acts as a "docking station" for molecules to temporarily attach by donating electrons into vacant d orbitals, do their chemistry and then depart. When the catalyst is in solution, the catalyst works by being oxidized and then reduced (or vice versa) in two steps.

Syllabus reference: 13.1

225. What is the formula for the tetracyanodiiodomolybdate (IV) ion?
    A $[MoI_2(CN)_4]^{4-}$
    B $[MoI_2(CN)_4]^{2-}$
    C $[Mo(CN)_4I_2]^{4-}$
    D $[Mo(CN)_4I_2]^{2-}$

Answer: D

Explanation: When writing the formula for a complex ion, negative ligands are always written before neutral ligand, so "tetra**c**yano" comes before "di**i**odo. As each of the six ligands has a 1- charge and

molybdenum is 4+, the overall charge is 2-. The formula of the complex ion is therefore $[Mo(CN)_4I_2]^{2-}$.
Syllabus reference: 13.1

226. How many unpaired electrons are in an atom of nickel?
     A   0
     B   2
     C   3
     D   8
     Answer: D
     Explanation: Nickel has atomic number 28 and electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$. Six of its eight 3d electrons are paired and two are unpaired.
     Syllabus reference: 13.1

227. Which of the following ions would be likely to form coloured compounds?
     A Zn^{2+}
     B Sc^{3+}
     C Ti^{4+}
     D Ni^{2+}
     Answer: D
     Explanation: Colour appears when an ion is formed that has a partially filled set of d orbitals. In Zn^{2+}, the 3d is full because the outer pair of 4s electrons have been lost. In Sc^{3+}, both 4s electrons and the only 3d electron have been lost, so the 3d is empty. In Ti^{4+}, both 4s electrons and both 3d electrons have been lost, so the 3d is empty. In Ni^{2+}, the nickel has lost its outer 4s electrons, but still has eight 3d electrons. Splitting of the d orbitals into higher and lower energy orbitals means that electrons can transfer from lower to higher energy orbitals by absorbing energy that corresponds to frequencies in the visible part of the spectrum.
     Syllabus reference: 13.1

228. Transition metals include:
     A   Scandium and zinc
     B   Scandium but not zinc
     C   Zinc but not scandium
     D   Neither scandium nor zinc
     Answer: B
     Explanation: Zinc is not a transition metal because it only forms 2+ ions by losing its two 4s electrons; it does not form ions with partially filled d orbitals. Scandium usually forms the 3+ ion by losing its two 4s electrons and its single 3d electron, but it can also form a 2+ state by losing just the 4s electrons, leaving it one 3d electron. Scandium is therefore classified as a transition metal. Be careful – not all exam boards or textbooks go along with this decision – until 2015, the IB were not classifying scandium as a transition metal. From 2016 onwards, scandium is a transition metal (at least in the eyes of IB examiners!).
     Syllabus reference: 13.1

229. Unpaired electrons in an atom always give rise to:
     A   Ferromagnetism
     B   Diamagnetism
     C   Paramagnetism
     D   Coloured compounds
     Answer: C
     Explanation: Ferromagnetism is a strong magnetic effect only found in iron, cobalt and nickel. Paramagnetism occurs when an atom has unpaired electrons and is pulled into an external magnetic field. Diamagnetism occurs when all electrons are paired and the atom is weakly repelled by an external magnetic field. Coloured compounds are typical of transition metal ions with partially filled d orbitals.
     Syllabus reference: 13.1

230. Which of the following could not act as a ligand in forming a complex ion?
     A NO_2^-
     B NH_4^+

C Br⁻

D H_2O

Answer: **B**

Explanation: A ligand must have a lone pair that it can use to form a coordinate bond. The NH_4^+ ion does not have a lone pair.

Syllabus reference: 13.1

231. What is the coordination number of copper in $[Cu(NH_3)_4(H_2O)_2]^{2+}$?

A 0

B 2

C 4

D 6

Answer: D

Explanation: The Cu^{2+} central cation is coordinated to four NH_3 molecules and two H_2O molecules.

Syllabus reference: 13.1

232. Which of the following elements would be classified as a transition element?

A $1s^2 2s^2 2p^4$

B $1s^2 2s^2 2p^6 3s^2 3p^6$

C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

Answer: C

Explanation: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ represents nickel, which is classified as a transition element because it has partially filled d orbitals. A is a p block element, oxygen. B is a p block element, argon. D is a d block element, zinc. This is not classified as a transition metal because it does not form any compounds where it has partially filled d orbitals, since it loses only its 4s electrons when forming ions.

Syllabus reference: 13.1

233. Which of the following salts would you expect to form coloured aqueous solutions?

    I $ZnSO_4$

    II $FeBr_3$

    III $NiCl_2$

A I and II only

B I and III only

C II and III only

D I, II and III

Answer: C

Explanation: The energy levels of d orbitals in compounds are split. Colour can be due to partially filled d orbitals; electrons can absorb visible light to be promoted from lower to higher energy d orbitals. Zinc has its 3d subshell completely full, whilst Fe^{3+} and Ni^{2+} have partially filled d orbitals.

Syllabus reference: 13.1

234. Which of the following is true?

A Zinc forms 2+ ions that have completely filled d orbitals

B Scandium compounds are usually coloured

C Titanium(II) chloride is white

D Copper(I) chloride is blue

Answer: A

Explanation: Zinc loses its pair of outer shell 4s electrons, leaving the 3d orbitals completely filled. Colour results from partially filled d orbitals. Scandium compounds are usually white because their d orbitals are completely empty. Titanium loses its outer shell 4s electrons, leaving two unpaired 3d orbitals.

Be careful with answer D – copper(II) salts are blue, but copper(I) chloride is white, as the copper has lost its single outer shell 4s electron, leaving the 3d orbitals completely filled.
Syllabus reference: 13.2

235.   The formal charge on each bromine atom in CBr_4 is:
A   -1
B   +1
C   0
D   +2
Answer: C
Explanation: Formal charge equals number of valence electrons – number of bonds) – number of non-bonding electrons. For bromine, FC = 7 – 1 – 6 = 0.
Syllabus reference: 13.1

236.   The triple bond in ethyne, C_2H_2:
A   Consists of three σ bonds
B   Consists of two σ bonds and one π bond
C   Consists of one σ bond and two π bonds
D   Consists of three π bonds
Answer: C
Explanation: A triple bond consists of one sigma and two pi bonds.
Syllabus reference: 14.1

237.   Sulfur tetrafluoride is:
A   Square pyramidal
B   Square planar
C   Tetrahedral
D   Seesaw shaped
Answer: D
Explanation: Sulfur has 5 electron domains. It has sp^3d hybridization, so it forms four bonds to fluorine atoms and it has one lone pair, giving it a seesaw shape.
Syllabus reference: 14.1

238.   Which of the following has the smallest bond angles?
A CBr_4
B NCl_3
C SF_6
D BeH_2
Answer: C
Explanation: SF_6 has 90º angles, NCl_3 has 107º angles, CBr_4 has 109.5º angles and BeH_2 has 180º angles.
Syllabus reference: 14.1

239.   The formal charge on each fluorine atom in CF_4 is
A   0
B   +1
C   -1
D   -2
Answer: A
Explanation: Formal charge = number of valence electrons – number of bonds – number of non-bonding electrons = 7 – 1 – 6 = 0.
Syllabus reference: 14.1

240.   Sulfur tetrafluoride is
A   Square pyramidal

B   Octahedral

C   Tetrahedral

D   Seesaw shaped

Answer: D

Explanation: The sulfur in SF_4 is sp^3d hybridized to give four bonds and a lone pair. This gives a seesaw shape.

Syllabus reference: 14.1

241.   Which of the following has the smallest bond angles?

A NF_3

B CF_4

C H_2O

D SF_6

Answer: D

Explanation: NF_3 has 4 electron domains (3 bonds and a lone pair) giving bond angles of about 107°. CF_4 has 4 electron domains (4 bonds) giving bond angles of about 109.5°. H_2O has 4 electron domains (2 bonds and 2 lone pairs) giving bond angles of about 105°. SF_6 is octahedral, with bond angles of 90°.

Syllabus reference: 14.1

242.   The element xenon

A   forms no compounds

B   forms an ionic fluoride, XeF_4

C   forms a covalent fluoride, XeF_4

D   is soluble in polar solvents

Answer: C

Explanation: Xenon can make use of its vacant 4d orbitals by hybridising to form d^2sp^3 orbitals. Two of these are filled (giving lone pairs) whilst the other four are singly occupied and can form covalent bonds to fluorine atoms. This gives a square planar molecule. Xenon cannot form ionic compounds and it is insoluble in polar solvents.

Syllabus reference: 14.2

243.   The hybridisation in benzene and diamond are, respectively

A sp^2 and sp^3

B   sp and sp^2

C sp^3 and sp^2

D sp^3d and sp^3

Answer: A

Explanation: In benzene, each C is bonded to two others and a hydrogen, so there are 3 electron domains and this involves sp^2 bybridisation. In diamond, each C forms 4 bonds to other carbons, so there are 4 electron domains and this involves sp^3 hybridisation.

Syllabus reference: 14.2

244.   Benzene has:

A sp^3 hybridisation

B sp^2 hybridisation

C   sp hybridisation

D   no hybridisation

Answer: B

Explanation: Benzene has sp^2 hybridisation. One 2s electron in carbon is promoted into a vacant 2p orbital, then the s and two of the p orbitals are hybridized to form three sp^2 orbitals that can form bonds at 120° angles. Two of these will be to other carbons and one to a hydrogen. The remaining unhybridised p electrons from each of the six atoms in the ring are parallel and then overlap form a delocalized pi system called the benzene ring.

Syllabus reference: 14.2

245.   What is the hybridisation of the oxygen atom in propan-1-ol?

A   sp

B sp^2

C sp^3

D sp^3d

Answer: C

Explanation: Oxygen has atomic number 8, so it has a ground state of $1s^22s^22p^4$. The s and all three p orbitals are hybridised to form four sp^3 hybrid orbitals. Two of these are filled to give lone pairs, whilst the other two are singly occupied, allowing the oxygen to form single bonds with carbon and hydrogen.

Syllabus reference: 14.2

246.   The hybridisation in graphene and diamond are, respectively:

A sp^3 and sp^2

B sp^2 and sp^3

C sp and sp^2

D sp^3 and sp^3

Answer: B

Explanation: Graphene has three bonds at $120°$ and is sp^2 hybridised; diamond has four bonds at $109.5°$ angles and is sp^3 hybridised.

Syllabus reference: 14.2

247.   Fullerene, C_{60}, would be expected to have:

A sp hydridisation

B sp^2 hybridisation

C sp^3 hybridisation

D   One delocalised electron per carbon atom

Answer: B

Explanation: As each carbon in the C_{60} molecule is bonded to three others, there must be three orbitals hybridized, forming sp^2 hybrid orbitals.

Syllabus reference: 14.2

248.   The standard enthalpy change of hydration is the:

A   energy change when one mole of gaseous ions is added to a large excess of water

B   energy change when one mole of an ionic lattice is added to a large excess of water

C   energy change when one mole of gaseous ions is added to one mole of water

D   energy change when one mole of an ionic lattice is added to one mole of water

Answer: A

Explanation: Just learn the definitions!

Syllabus reference: 15.1

249.   For an oxygen atom:

A   The first electron affinity is positive

B   The second electron affinity is negative

C   The sum of the first and second electron affinities is positive

D   The sum of the first and second electron affinities is negative

Answer: C

Explanation: The first electron affinity of oxygen is exothermic, but the second electron affinity is very endothermic, because a 1- ion repels the approach of another electron. The total of the first and second electron affinities of oxygen is positive.

Syllabus reference: 15.1

250.   The lattice enthalpy of a substance is the energy change when:

A   one mole of an ionic lattice is formed from the elements, in their standard states

B   one mole of an ionic lattice is formed from gaseous ions

C   one mole of an ionic lattice is formed from gaseous atoms

D   one mole of an ionic lattice is formed from aqueous ions

Answer: B

251.   For sulfur
    A   The first electron affinity is positive
    B   The second electron affinity is negative
    C   The sum of the first and second electron affinities is positive
    D   The sum of the first and second electron affinities is negative
    Answer: C
    Explanation: The first electron affinity is negative because a neutral atom is taking on an electron, which is like bond formation. The second electron affinity is highly positive because a negative ion repels an approaching electron. The sum of the first and second ionisation energies is positive.
    Syllabus reference: 15.1

252.   The enthalpy of solution is best described as
    A $NaBr(s) \longrightarrow Na^+(aq) + Br^-(aq)$
    B $NaBr(aq) \longrightarrow Na^+(aq) + Br^-(aq)$
    C $Na^+(aq) + Br^-(aq) \longrightarrow NaBr(aq)$
    D $Na(s) + \frac{1}{2}Br_2(l) \longrightarrow Na^+(aq) + Br^-(aq)$
    Answer: A
    Explanation: The enthalpy of solution is the energy change when one mole of a solid dissolves in water to form a solution of infinite dilution.
    Syllabus reference: 15.1

253.   The lattice enthalpy of a substance is the energy change when
    A   one mole of an ionic lattice is formed from the elements, in their standard states
    B   one mole of an ionic lattice is formed from gaseous ions
    C   one mole of an ionic lattice is formed from gaseous atoms
    D   one mole of an ionic lattice is formed from aqueous ions
    Answer: B
    Explanation: The lattice enthalpy is the energy change when one mole of an ionic lattice is formed from gaseous ions. Learn your definitions!
    Syllabus reference: 15.1

254.   Which of the following is **<u>not</u>** required for the calculation of the lattice enthalpy of lithium fluoride using a
    Born-Haber cycle?
    A   First ionisation energy of lithium
    B   Electron affinity of fluorine
    C   Enthalpy of formation of lithium fluoride
    D   Enthalpy of hydration of lithium fluoride
    Answer: D
    Explanation: Lithium fluoride is not being reacted with water.
    Syllabus reference: 15.1

255.   The standard enthalpy change of hydration is the energy change when
    A   one mole of gaseous ions are added to a large excess of water
    B   one mole of a substance dissolves in a large excess of water
    C   one mole of gaseous ions are added to one mole of water
    D   one mole of a substance dissolves in one mole of water
    Answer: A
    Explanation: The enthalpy change of hydration is the energy change when one mole of gaseous ions are added to a large excess of water. The energy change when one mole of a substance dissolves in a large excess of water is called the enthalpy of solution.
    Syllabus reference: 15.1

256.　Which species are arranged in order of **increasing** entropy?
A　$CH_4(g) < CH_3OH(l) < Hg(l) < K(s)$
B　$Hg(l) < K(s) < CH_4(g) < CH_3OH(l)$
C　$K(s) < Hg(l) < CH_3OH(l) < CH_4(g)$
D　$CH_3OH(l) < CH_4(g) < K(s) < Hg(l)$
Answer: C
Explanation: Solids have lower entropy than liquids and gases have much higher entropy than liquids.
Syllabus reference: 15.2

257.　Which of the following is true for a spontaneous reaction?
A　ΔH must be negative but ΔS could be either positive or negative
B　ΔS must be positive but ΔG could be either positive or negative
C　ΔG must be negative but ΔH could be either positive or negative
D　ΔG must be positive but ΔH could be either positive or negative
Answer: C
Explanation: For a reaction to be spontaneous, ΔG must be negative. $\Delta G = \Delta H - T\Delta S$. If ΔH is positive and ΔS is positive, the reaction will become spontaneous at high temperatures as soon as the magnitude of $T\Delta S$ is greater than that of ΔH. If ΔH is negative and ΔS is negative, the reaction will be spontaneous at low temperatures, as soon as the magnitude of $T\Delta S$ is greater than ΔH.
Syllabus reference: 15.2

258.　In an exothermic reaction:
A　ΔH is positive
B　ΔG is always positive
C　ΔS is always positive
D　ΔS could be either positive or negative
Answer: D
Explanation: ΔH is negative for an exothermic reaction. If ΔG is positive, a reaction will not be spontaneous. ΔS could be either positive (an increase in chaos, for example due to an increase in the number of moles of gas present) or negative (a decrease in chaos, for example due to a reduction in the number of moles of gas present). Overall, the spontaneity of a reaction is decided by ΔG – the reaction will only work if ΔG is negative.
Syllabus reference: 15.2

259.　The decomposition of silver oxide
　　　$Ag_2O(s)$ ----> $2Ag(s) + \frac{1}{2}O_2(g)$
is spontaneous only above 460 K. This suggests that
A　ΔH is positive and ΔS is negative
B　ΔH is positive and ΔS is positive
C　ΔH is negative and ΔS is negative
D　ΔH is negative and ΔS is positive
Answer: B
Explanation: ΔG must be negative for a reaction to be spontaneous. $\Delta G = \Delta H - T\Delta S$. At low temperatures, the more significant factor is the positive ΔH, so the reaction is non-spontaneous. At high temperatures, the magnitude of $T\Delta S$ exceeds that of ΔH and the reaction becomes spontaneous.
Syllabus reference: 15.2

260.　In a spontaneous endothermic reaction:
A　The total energy needed for bond breaking is less than the total energy released on bond forming
B　The temperature rises
C　Energy is absorbed from the surroundings
D　ΔS must be negative
Answer: C

Explanation: In an endothermic reaction, more energy is required to break the old bonds than is released in forming the new bonds; this leads to a drop in temperature. If ΔH is positive and ΔS is negative, there is no temperature at which ΔG would be negative, so the reaction would never work; ΔS would have to be positive in order for ΔG to be negative.
Syllabus reference: 15.2

261.   For which of the following changes would ΔS be negative?

A $H_2O(l)$ ----> $H_2O(g)$

B $CuCO_3(s)$ ----> $CuO(s) + CO_2(g)$

C $HBr(g) + NH_3(g)$ ----> $NH_4Br(s)$

D $2CO_2(g)$ ----> $2CO(g) + O_2(g)$

Answer: C

Explanation: ΔS is negative when there is a decrease in chaos; this is often due to a decrease in the number of moles of gas present. Water turning to steam increases chaos as it is producing gas from liquid, so ΔS is positive. Decomposing copper carbonate to copper oxide and carbon dioxide also increases chaos as it is producing gas from liquid, so ΔS is positive. When carbon dioxide changes to carbon monoxide and oxygen, there is an increase in chaos as the number of moles of gas increases, so ΔS is positive. When the gases HBr and NH_3 combine to form solid ammonium bromide, there is a decrease in the number of moles of gas, so ΔS is negative.
Syllabus reference: 15.2

262.   For a particular reaction, ΔH = -610 kJ mol^{-1} and ΔS = -132 J K^{-1} mol^{-1}:

A   The reaction is only spontaneous at low temperatures

B   The reaction is only spontaneous at high temperatures

C   The reaction is spontaneous at all temperatures

D   The reaction is not spontaneous at any temperature

Answer: A

Explanation: $\Delta G = = \Delta H - T\Delta S$. At low temperatures, the magnitude of ΔH is greater than $T\Delta S$, so as ΔH is negative the reaction will be spontaneous (it won't matter whether ΔS is positive or negative). At high temperatures, the magnitude of ΔH is less than $T\Delta S$; as ΔS is negative, ΔG becomes positive and the reaction will not proceed. Thus, this reaction is spontaneous at low temperatures only.
Syllabus reference: 15.2

263.   Which reaction occurs with the largest increase in entropy?

A $Ba(NO_3)_2(aq) + Na_2SO_4(aq)$ ----> $2NaNO_3(aq) + BaSO_4(s)$

B $2CO(g) + O_2(g)$ ----> $2CO_2(g)$

C $H_2(g) + Br_2(g)$ ----> $2HBr(g)$

D $PbCO_3(s)$ ----> $PbO(s) + CO_2(g)$

Answer: D

Explanation: Reactions in which the total number of moles of gas increase have the largest increases in entropy. In reaction (A), there are no gases involved. In reaction (B) the number of moles of gas decreases and in (C) the number of moles of gas stays the same.
Syllabus reference: 15.2

264.   In which situation will a reaction only be spontaneous at low temperatures?

A ΔH is positive and ΔS is positive

B ΔH is positive and ΔS is negative

C ΔH is negative and ΔS is positive

D ΔH is negative and ΔS is negative

Answer: D

Explanation: Δ must be negative for a reaction to be spontaneous. $\Delta G = \Delta H - T\Delta S$. At low temperatures, the main factor affecting ΔG is ΔH, because the magnitude of $T\Delta S$ is small; this means that reactions will be spontaneous at low temperatures if ΔH is negative. At high temperatures, the magnitude of $T\Delta S$ is greater, so that the main factor affecting ΔG is ΔS. If ΔS is negative, then $-T\Delta S$ becomes positive. Thus, at high temperatures, reactions with negative ΔS become non-spontaneous.
Syllabus reference: 15.2

265.   For which of the following changes would ΔS be positive?

A $CaCO_3(s)$ ----> $CaO(s)$ + $CO_2(g)$

B $N_2(g)$ + $3H_2(g)$ ----> $2NH_3(g)$

C $H_2O(g)$ ----> $H_2O(l)$

D $Zn(s)$ + $S(s)$ ----> $ZnS(s)$
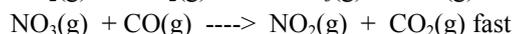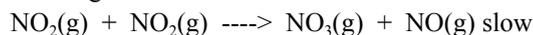
Answer: A

Explanation: An increase in chaos produces a positive ΔS; this often involves an increase in the number of moles of gas present. When calcium carbonate decomposes to calcium oxide and carbon dioxide, gas is formed from solid, so ΔS is positive. When nitrogen and hydrogen react to form ammonia, four moles of reactant gas form two moles of product gas, so ΔS is negative. When steam condenses to liquid water, ΔS is negative. When zinc and sulfur combine to form zinc sulfide, two solids become just one, which gives a very slight reduction is chaos, so ΔS is very slightly negative.

Syllabus reference: 15.2

266.   Carbon monoxide reacts with nitrogen dioxide as follows:

$$CO(g) + NO_2(g) ----> CO_2(g) + NO(g)$$
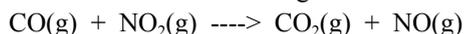
Further investigation shows that the mechanism for the reaction is:

$NO_2(g)$ + $NO_2(g)$ ----> $NO_3(g)$ + $NO(g)$ slow

$NO_3(g)$ + $CO(g)$ ----> $NO_2(g)$ + $CO_2(g)$ fast

The rate equation for the reaction is:

A   rate = $k[NO_2(g)] [NO_3(g)]$

B   rate = $k[CO_2(g)] [NO(g)]$

C   rate = $k[NO_2(g)]^2$

D   rate = $k[NO_2(g)]^2 [CO_2(g)]$

Answer: C

Explanation: Only the species that are involved in the slow step affect the rate of the overall reaction. As two NO_2 molecules are involved in the slow step, the reaction is second order with respect to NO_2. As CO is not involved in the slow step, the reaction is zero order with respect to CO.

Syllabus reference: 16.1

267.   Nitrogen monoxide reacts with hydrogen at high temperatures:

$$2NO(g) + 2H_2(g) ----> N_2(g) + 2H_2O(g)$$

Experiments show that rate = $k [NO]^2 [H_2]$. If the concentrations of nitrogen monoxide and hydrogen are both doubled, the rate increases by a factor of:

A   3

B   4

C   6

D   8

Answer: D

Explanation: The reaction is second order with respect to NO and first order with respect to oxygen. Doubling just the NO concentration would make the reaction four times faster, so doubling the oxygen concentration as well would make it eight times faster.

Syllabus reference: 16.1

268.   Nitrogen monoxide reacts with hydrogen at high temperatures:

$$2NO(g) + 2H_2(g) ----> N_2(g) + 2H_2O(g)$$

Experiments show that rate = $k [NO]^2 [H_2]$. Possible units for k are:

A $mol^{-2} dm^6 s^{-1}$

B $mol^2 dm^{-6} s^{-1}$

C $mol\ dm^{-3} s^{-1}$

D $mol^{-1}\ dm^3\ s^{-1}$

Answer: A

Explanation: If rate = k $[NO]^2$ $[H_2]$, then k = rate / $[NO]^2$ $[H_2]$. In terms of units k = mol dm^{-3} s^{-1} / (mol dm^{-3})^2 mol dm^{-3}, which cancels to s^{-1} / mol^2 dm^{-6} or mol^{-2} dm^6 s^{-1}. **Syllabus reference:** 16.1

269.   When investigating the activation energy of a reaction
    A   A graph of log k against 1/T gives a straight line with gradient E_a/R
    B   A graph of log k against 1/T gives a straight line with gradient $-E_a/R$
    C   A graph of ln k against 1/T gives a straight line with gradient E_a/R
    D   A graph of ln k against 1/T gives a straight line with gradient $-E_a/R$

Answer: D

Explanation: You just have to learn this one! The graph is based on taking the natural logarithm (ln) of both sides of the Arrhenius equation.

Syllabus reference: 16.2

270.   One mole of methanol and one mole of ethanoic acid are introduced into a sealed 1 dm^3 flask and left to reach equilibrium:

  $CH_3OH(l)\ +\ CH_3COOH(l)\ \rightleftharpoons\ CH_3COOCH_3\ +\ H_2O$

The equilibrium mixture is found to contain 0.6 moles of methyl ethanoate:
    A   The equilibrium mixture will contain 0.4 moles of water
    B   The equilibrium constant equals $0.6^2/0.4^2$
    C   The equilibrium constant equals $04^2/0.6^2$
    D   At equilibrium the rate of the forward reaction is greater than the rate of the reverse reaction

Answer: B

Explanation: If the equilibrium mixture contains 0.6 moles methyl ethanoate, it must also contain 0.6 moles of water, as they are formed together in a 1:1 molar ratio. If 0.6 moles of methyl ethanoate were formed, 0.6 moles of each reactant must have been used up, so $[CH_3OH]$ = $[CH_3COOH]$ = 0.4 mol dm^{-3}. K_c = $[CH_3COOCH_3]$ $[H_2O]$ / $[CH_3OH]$ $[CH_3COOH]$ = 0.6^2 / 0.4^2 **Syllabus reference:** 17.1

271.   Water can act in all of the following ways **except:**
    A   As a Lewis acid
    B   A a Brønsted-Lowry base
    C   As a solvent for polar compounds
    D   As a solvent for non-polar compounds

Answer: D

Explanation: Water can act as a Lewis acid, i.e. an electron pair donor, for example when it reacts with HCl to form oxonium ions. Water can react as a Brønsted-Lowry base when it donates protons, e.g. when it reacts with ammonia to form ammonium and hydroxide ions. Water is a solvent for polar compounds because water is also polar; the δ+ hydrogen attracts δ - ends of polar molecules, whilst the δ - oxygen attracts the δ + ends of polar molecules. With non-polar molecules, there are no δ + or δ - ends of the molecule to attract water molecules; the water molecules are much more strongly attracted to each other than they would be towards non-polar molecules.

Syllabus reference: 18.1

272.   A strong acid and a weak acid, respectively, are:
    A HNO_3 and HNO_2
    B H_2SO_4 and HCl
    C H_3PO_4 and CH_3COOH
    D   HCN and H_2SO_3

Answer: A

Explanation: Just learn the short list of strong acids – hydrochloric, nitric and sulfuric! These acids fully dissociate in aqueous solution. Any other acid that you encounter can be considered to be weak.

Syllabus reference: 18.2

273.   Which of the following is the K_b expression for the reaction of methylamine with water?
    A K_b = $[CH_3NH_3^+]$ $[OH^-]$

B $K_b = [CH_3NH_2] [H_2O]$

C $K_b = \dfrac{[CH_3NH_3^+] [H_2O]}{[CH_3NH_2]}$

D $K_b = \dfrac{[CH_3NH_3^+] [OH^-]}{[CH_3NH_2]}$

Answer: D

Explanation: $CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$, so $K_b = [CH_3NH_3^+] [OH^-] / [CH_3NH_2]$. Water does not feature in the expression for K_b because its concentration is effectively constant.

Syllabus reference: 18.2

274.   The pK_w value for water at 10°C is 14.54. What is the pH of pure water at this temperature?
   A   6.73
   B   7.00
   C   7.27
   D   7.54

   Answer: C

   Explanation: If $pK_w = 14.54$, then $K_w = 10^{-14.54}$. $K_w = [H^+][OH^-]$. If the water is pure, $[H^+] = [OH^-]$ at all temperatures so $K_w = [H^+]^2$. This means that $[H^+] = \sqrt{10^{-14.54}} = 10^{-7.27}$, so pH = 7.27. Do not fall for the examiner's trick – the pH of pure water is only 7.00 at 25°C.

   Syllabus reference: 18.2

275.   Which of these would have the highest pK_a value?
   A HCl
   B HNO_3
   C H_2SO_4
   D HNO_2

   Answer: D

   Explanation: The higher the pK_a, the lower the K_a and the weaker the acid. Hydrochloric, nitric and sulfuric acids are all strong, but nitrous acid is weak, so it will have the highest pK_a value.

   Syllabus reference: 18.2

276.   In an aqueous solution at 25°C
   A   the ionic product $K_w = 1 \times 10^{-14}$ mol dm^{-3}
   B   the ionic product $K_w = 1 \times 10^{-14}$ mol^2 dm^{-6}
   C   the value of K_w will depend on the pH
   D   the ionic product K_w has a higher value than the same solution at 35°C

   Answer: B

   Explanation: At 25°C, the concentration of both H^+ and OH^- ions is 1×10^{-7} mol dm^{-3}. The ionic product $K_w = [H^+] [OH^-] = (1 \times 10^{-7})^2 = 1 \times 10^{-14}$. The units are (mol dm^{-3})^2 = mol^2 dm^{-6}. K_w is not affected by pH and increases with temperature rise.

   Syllabus reference: 18.2

277.   The concentration of water does not feature in the equation for the acid dissociation constant of a weak acid because:
   A   the acid remains mainly as molecules in solution
   B   the pH of water is seven
   C   water is just acting as a solvent
   D   the concentration of water is virtually constant in all acid solutions

   Answer: D

   Explanation: The concentration of water in acid solutions is virtually constant. The other three statements are all true, but they don't explain why $[H_2O]$ does not feature in the expression for K_a.

   Syllabus reference: 18.2

278.   The higher the value of pK_b :
   A   the stronger the base
   B   the weaker the conjugate acid

C   the lower the pK_a of the conjugate acid

D   the greater the degree of dissociation of the base in aqueous solution

Answer: C

Explanation: The higher the value of pK_b, the lower the pK_a of the conjugate acid. The higher the pK_b, the weaker the base, the lower the degree of dissociation of the base in aqueous solution and the stronger the conjugate acid.

Syllabus reference: 18.2

279.   Which of the following, when added to water, would **not** affect the pH?

A NH_4NO_3

B   NaCN

C $FeCl_3$

D K_2SO_4

Answer: D

Explanation: Ammonium nitrate is acidic because it is the salt of a weak base (NH_3) with a strong acid (HNO_3). Sodium cyanide is basic because it is the salt of a strong base (NaOH) with a weak acid (HCN). Iron (III) chloride is acidic because it is the salt of a weak base ($Fe(OH)_3$) with a strong acid (HCl). Potassium sulfate is neutral because it is the salt of a strong base (KOH) with a strong acid (H_2SO_4).

Syllabus reference: 18.3

280.   Which of the following combinations would produce a buffer solution?

A   50 cm^3 of 0.20 mol dm^{-3} hydrochloric acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide

B   50 cm^3 of 0.20 mol dm^{-3} ethanoic acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide

C   25 cm^3 of 0.20 mol dm^{-3} hydrochloric acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide

D   25 cm^3 of 0.20 mol dm^{-3} ethanoic acid with 100 cm^3 of 0.10 mol dm^{-3} sodium hydroxide

Answer: B

Explanation: A buffer solution consists of a weak acid mixed with its conjugate base or a weak base mixed with its conjugate acid. Neither sodium hydroxide nor hydrochloric acid are weak, so no combination of these substances could form a buffer solution. Ethanoic acid is weak, so if the number of moles of NaOH added is less than the number of moles of ethanoic acid present, some ethanoic acid will remain as molecules and some will be converted into the conjugate base ethanoate ions. Equal volumes of the two solutions, where the concentration of the ethanoic acid is greater than that of the NaOH will therefore produce a buffer solution.

Syllabus reference: 18.3

281.   Methyl red changes colour from red to yellow in the pH range 4.4 to 6.2. Which of the following statements is true?

A   Molecules of methyl red, HIn, are yellow.

B   The pKa of methyl red is between 4.4 and 6.2.

C   Methyl red would be a suitable indicator for titrating methanoic acid against sodium hydroxide solution.

D   At pH values below 4.4, a solution of methyl red contains more ions, In$^-$, than molecules, HIn.

Answer: B

Explanation: Methyl red is a weak acid that sets up an equilibrium:

$$HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$$

Indicators are perceived to change colour when the position of equilibrium shifts enough for there to be about 10 times as much HIn than In$^-$ or vice versa. $K_a = [H^+][In^-] / [HIn]$, but at the end-point $[In^-] = [HIn]$, so at that point $K_a = [H^+]$. This means that at the end-point, $pK_a = pH$. If methyl red changes colour in the pH range 4.4 to 6.2, its pK_a must also be in that range. When acid is added, the extra H^+ shifts the equilibrium towards HIn; at pH below 4.4, the indicator turns red, so molecules of HIn are red. This would not be a suitable indicator for titration of methanoic acid against sodium hydroxide, because when a weak acid is titrated against a strong base, the equivalence-point is at a high pH; the indicator would not change colour at this pH.

Syllabus reference: 18.3

282.   Equal volumes and concentrations of nitric acid and methanoic acid are titrated with potassium hydroxide

solutions of the same concentration. Which of the following is true?

A   At the equivalence points, both titrations have pH values of 7

B   The same volume of potassium hydroxide is needed to reach the equivalence point in both titrations.

C	The initial pH values of both acids are equal.

D	The pH values of both acids increase equally until the equivalence points are reached.

Answer: B

Explanation: Both acids are monobasic, so they each react in a 1:1 molar ratio with KOH. The strength of the acid does not affect the amount of base required to neutralize it. At the equivalence point, nitric acid against KOH would have a pH of 7 because it is a strong acid-strong base titration. Methanoic acid is weak, so its equivalence point when titrated against KOH would be above 7. As the concentrations are the same, the stronger acid would have a higher [H$^+$] and therefore lower pH. The pH curves when strong and weak acids respectively are titrated against strong base give different shapes; with strong acid, there is very little pH change until just before the equivalence point, whilst with weak acid, the pH change is more gradual.

Syllabus reference: 18.3

283.	Which of the following mixtures of equimolar solutions produces a buffer solution with pH < 7 at 298 K?

A	100 cm^3 HCl(aq) and 300 cm^3 of NH$_3$(aq)

B	100 cm^3 CH$_3$COOH(aq) and 100 cm^3 of NH$_3$(aq)

C	100 cm^3 CH$_3$COOH(aq) and 50 cm^3 of KOH(aq)

D	40 cm^3 CH$_3$COOH(aq) and 40 cm^3 of NH$_3$(aq)

Answer: C

Explanation: Ethanoic acid and ammonia are both weak, so no combination of these substances would form a buffer solution. Hydrochloric acid and ammonia can produce a buffer if there are more moles of the ammonia than HCl; this is the case in answer (A), but this will give a **basic** buffer with a pH above 7. In answer (C), there are more moles of ethanoic acid than KOH, so some ethanoic acid molecules remain and some ethanoate ions are formed; this mixture is an acidic buffer with pH below 7.

Syllabus reference: 18.3

284.	The indicator HIn is used in a titration between an acid and a base. Which statement about the dissociation

of the indicator, HIn, is correct?

$$HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$$
colour A   colour B
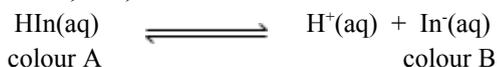
A	In a strongly acidic solution, colour B would be observed.

B	In a strongly alkaline solution, colour B would be observed

C	[In$^-$] is greater than [HIn] at the equivalence point

D	In a weakly alkaline solution, colour A would be observed.

Answer: B

Explanation: In acid solution, the increased [H$^+$] would push the equilibrium towards HIn, giving colour A. At the equivalence point, [In$^-$] = [H$^+$]. In an alkaline solution, the OH$^-$ ions would react with HIn molecules, pushing the equilibrium position towards the right, so colour B would be seen.

Syllabus reference: 18.3

285.	Which salt dissolves in water to form an acidic solution?

A	Potassium chloride

B	Sodium ethanoate

C	Ammonium nitrate

D	Sodium carbonate

Answer: C

Explanation: Potassium chloride is the salt of a strong acid and a strong base, so it is neutral. Sodium ethanoate is the salt of a weak acid with a strong base, so it is basic. Sodium carbonate is also the salt of a weak acid with a strong base, so it is basic. Ammonium nitrate is the salt of a strong acid with a weak base, so it is acidic.

Syllabus reference: 18.3

286.	A titration curve can be drawn for an acid-base titration. Which of the following is **untrue**?

A	The volume of 1.00 mol dm^{-3} acid needed to neutralise a sample of base depends on both the concentration and the strength of the base.

B	The volume of 1.00 mol dm^{-3} acid needed to neutralise a sample of base depends on the concentration of the base.

C	The strength of the base used can be judged from the shape of the curve.

D   The buffer zone is the region of the graph before the vertical drop.

Answer: A

Explanation: The volume of acid required to neutralize a sample of base depends on the concentration of the base but not its strength. The same volume of acid would be required to neutralize a certain number of moles of acid whether the acid is already fully ionized (strong) or only partially ionized (weak). The shape of the titration curve can be used to judge the strength of the base; a strong acid will give quite a sharp change in pH just before the equivalence point, whilst a weak base will show a more gradual pH change just before the equivalence point. The buffer zone is the region of the graph just before the vertical drop.

Syllabus reference: 18.3

287.   An equimolar aqueous mixture of ammonia and ammonium chloride is produced.

A   This will act as an acid buffer.

B   If H^+ ions are added, they will be "mopped up" by reacting mainly with OH^- ions.

C   If OH^- ions are added, they will be "mopped up" by reacting mainly with NH_3 molecules

D   If H^+ ions are added, they will be "mopped up" by reacting mainly with NH_3 molecules

Answer: D

Explanation: If H^+ ions are added, they are mainly mopped up by NH_3 molecules, which are converted into NH_4^+ ions. An equimolar aqueous mixture of ammonia and ammonium chloride acts as a **basic** buffer. If H^+ ions are added, they are mainly mopped up by ammonia molecules, which are converted into NH_4^+ ions. If OH^- ions are added, they are mainly mopped up by NH_4^+ ions, which are converted into NH_3 molecules.

Syllabus reference: 18.3

288.   When a weak acid is titrated against a strong base

A   the end point is above pH 7 and phenolphthalein is a suitable indicator

B   the end point is at pH 7 and litmus is a suitable indicator

C   the end point is below pH 7 and methyl orange is a suitable indicator

D   the reaction is endothermic

Answer: D

Explanation: The pH of the base starts high and drops rapidly just at the end point from about pH 10.5 to pH 7.5. It is therefore desirable to have an indicator such as phenolphthalein, that changes colour at a high pH value. The reaction is exothermic.

Syllabus reference: 18.3

289.   In an electrolytic cell:

A   The anode is negative

B   Oxidation occurs at the anode

C   Electrical energy is produced by chemical reactions

D   metals can be deposited on the anode

Answer: B

Explanation: Just remember **APE VAN** (**a**node **p**ositive in **e**lectrolytic, **v**oltaic **a**node **n**egative) and **RED CAT** (**red**uction always happens at the **cat**hode)! Electrical energy is required to run an electrolytic cell, so it does not produce energy. Metals can be deposited at the cathode (red cat!).

Syllabus reference: 19.1

290.   Here are the standard electrode potentials for two half-cells

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \quad E^o = -0.23V$$
$$Ag^+(aq) + e^- \rightleftharpoons Ag(s) \quad E^o = +0.80V$$
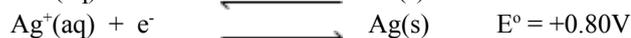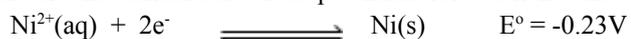
Which of the following is true?

A   Nickel will be reduced when the two half-cells are connected together

B   The silver electrode will gradually dissolve

C   The cell potential is 1.03V

D   Connecting the half-cells gives an electrolytic cell

Answer: C

Explanation: Using the "anti-clockwise rule", we see that the first reaction listed will be reversed so that nickel will become $Ni^{2+}(aq)$; the sign on E^o for the reaction is reversed to give +0.23V. Adding 0.23 and 0.80 gives the cell potential of 1.03V. Nickel is oxidized. Silver ions are reduced to silver, so the silver electrode grows. The two half-cells connected together form a voltaic cell.

Syllabus reference: 19.1

291. In a voltaic cell:
   A   Reduction occurs at the anode
   B   Electrons flow through the salt bridge
   C   The cathode is positive
   D   Both electrodes are in the same electrolyte
   Answer: C
   Explanation: Just remember **APE VAN** (**a**node **p**ositive in **e**lectrolytic, **v**oltaic **a**node **n**egative) and **RED CAT** (**red**uction always happens at the **cat**hode)! In a voltaic cell, ions flow through the salt bridge. The two electrodes are in different electrolytes.
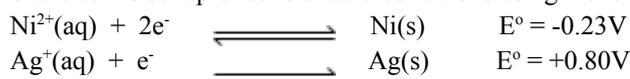   **Syllabus reference:** 19.1

292. During electrolysis of aqueous sodium chloride, the products formed depend on concentration.
   A   At low concentration, chlorine is formed at the anode and hydrogen and hydroxide ions are formed at the cathode.
   B   At low concentration, oxygen is formed at the anode and hydrogen and hydroxide ions are formed at the cathode.
   C   At low concentration, chlorine is formed at the anode and sodium is formed at the cathode.
   D   At high concentration, oxygen is formed at the anode and sodium is formed at the cathode.
   Answer: B
   Explanation: At low concentration, oxygen forms at the anode and hydrogen and hydroxide ions are formed at the cathode. Answers (C) and (D) are obviously wrong, because a reactive metal like sodium could not be formed in the presence of water.
   Syllabus reference: 19.1

293. A voltaic cell is set up under standard conditions using nickel and silver half-cells.
   $Ni^{2+}(aq) + 2e^-$ ⇌ $Ni(s)$ $E^o = -0.23V$
   $Ag^+(aq) + e^-$ ⇌ $Ag(s)$ $E^o = +0.80V$
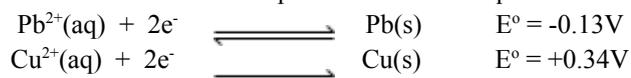   Which of the following is true?
   A   The cell potential is 0.14V
   B   The cell potential is 0.57V
   C   The cell potential is 1.03V
   D   The cell potential is 1.26V
   Answer: C
   Explanation: Using the "anti-clockwise rule", we see that the first reaction listed will be reversed so that nickel will become $Ni^{2+}(aq)$; the sign on E^o for the reaction is reversed to give +0.23V. Adding 0.23 and 0.80 gives the cell potential of 1.03V.
   Syllabus reference: 19.1

294. Here are the standard electrode potentials for half-equations involving nickel and copper.
   $Pb^{2+}(aq) + 2e^-$ ⇌ $Pb(s)$ $E^o = -0.13V$
   $Cu^{2+}(aq) + 2e^-$ ⇌ $Cu(s)$ $E^o = +0.34V$
   Which of the following is true?
   A   If a piece of copper is dipped into lead nitrate solution, it will get plated in lead
   B   If a piece of lead is dipped into copper (II) nitrate solution, it will get plated in copper
   C   If a voltaic cell is made by combining these two half-cells, it will have a cell potential of 0.21V
   D   If a voltaic cell is made by combining these two half-cells, electrons will flow through the wire from the copper towards the lead
   Answer: B
   Explanation: If lead is dipped into copper (II) nitrate solution, it will get plated in copper because lead can displace copper from solution; the reverse reaction cannot happen. The cell potential would be 0.13 + 0.24 = 0.37V. In a voltaic cell made from these two half-cells, electrons flow through the wire from lead towards the copper, because lead is better at releasing electrons than copper.
   Syllabus reference: 19.1

295. When aqueous sulfuric acid is electrolysed:
   A   Hydrogen ions are reduced at the anode
   B   Hydroxide ions are reduced at the cathode
   C   Hydroxide ions are oxidised at the anode
   D   Hydroxide ions are reduced at the cathode

Answer: C
Explanation: Hydroxide ions are oxidized at the anode; just remember **RED CAT** (**red**uction always happens at the **cat**hode)! The reaction is $4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$.
Syllabus reference: 19.1

296.   Platinum, graphite and copper are all used often to make the electrodes used in electrolytic cells. Which of

the following is true?
A   Platinum electrodes are inert, whilst graphite and copper electrodes are active
B   Platinum and copper electrodes are inert, whilst graphite electrodes are active
C   Platinum and graphite electrodes are inert, whilst copper electrodes are active
D   Graphite electrodes are inert, whilst platinum and copper electrodes are active
Answer: C
Explanation: Platinum and graphite electrodes are inert, whilst copper electrodes are active. You just have to learn this!
Syllabus reference: 19.1

297.   During the electrolysis of silver nitrate solution with platinum electrodes
A   oxygen is formed at the anode and hydrogen is formed at the cathode
B   oxygen is formed at the anode and silver is formed at the cathode
C   silver is formed at the anode and hydrogen is formed at the cathode
D   silver is formed at the anode and oxygen is formed at the cathode
Answer: B
Explanation: Oxygen is formed at the anode and silver is formed at the cathode; just remember **RED CAT** (**red**uction always happens at the **cat**hode)! Silver is formed at the cathode because it is easier to reduce Ag^+ than H^+ ions. Answers (C) and (D) are obviously wrong because metals never form at the anode; metals only form positive ions, so their formation is a reduction, which can only happen at the cathode (**RED CAT!**). **Syllabus reference:** 19.1

298.   During the electrolysis of sodium chloride with platinum electrodes
A   sodium and hydrogen compete to be discharged at the cathode
B   sodium and hydrogen compete to be discharged at the anode
C   chloride and hydroxide ions compete to be discharged at the cathode
D   the pH of the solution steadily falls
Answer: A
Explanation: Sodium and hydrogen compete to be discharged at the cathode; just remember **RED CAT** (**red**uction always happens at the **cat**hode)! The chloride and hydroxide ions compete to be discharged at the anode. The pH steadily rises as sodium hydroxide is formed in the solution.
Syllabus reference: 19.1

299.   Given that one faraday equals 96500 coulombs, what mass of magnesium in kg would be formed during the electrolysis of magnesium chloride solution, using a current of 0.1 amps for 2000 seconds?
A $\dfrac{0.1 \times 2000 \times 24.31}{96500 \times 1000}$ kg
B $\dfrac{0.1 \times 2000}{24.31 \times 96500 \times 1000}$ kg
C $\dfrac{0.1 \times 2000 \times 24.31 \times 1000}{2 \times 96500}$ kg
D $\dfrac{0.1 \times 2000 \times 24.31}{2 \times 96500 \times 1000}$ kg
Answer: D

Explanation: Each Mg^{2+} ion requires 2 electrons to form Mg. The charge on one mole of electrons is 96500 coulombs, so 2 x 96500 coulombs transfer 1 mole of Mg, which weighs 24.31 g. So 1 coulomb transfers (1 x 24.31) / (2 x 96500) g. We have 0.1 x 2000 coulombs, so we have (0.1 x 2000 x 24.31) / (2 x 96500) g, which means (0.1 x 2000 x 24.31) / (2 x 96500 x 1000) kg.
Syllabus reference: 19.1

300.   During the electrolysis of concentrated aqueous sodium chloride using platinum electrodes:
A   Hydrogen is produced at the cathode by oxidation
B   Chlorine is produced at the anode by reduction
C   Sodium is produced at the cathode by reduction
D   The pH of the solution rises
Answer: D
Explanation: Hydrogen is produced at the cathode, but by reduction not oxidation. Chlorine is produced at the anode, but by oxidation not reduction. Sodium would never be a product in the presence of water – it is a highly reactive metal! The pH of the solution rises as hydroxide ions are formed from water.
Syllabus reference: 19.1

301.   The reaction between 2-iodo,2-methylpropane and cyanide ions:
A   Proceeds mainly by an S_N2 mechanism
B   Proceeds mainly by an E2 mechanism
C   Proceeds mainly by electrophilic substitution
D   Produces dimethylpropanenitrile and iodide ions
Answer: D
Explanation: As 2-iodo,2-methylpropane is a tertiary halogenoalkane, it reacts with cyanide ions by an

S_N1 mechanism. This is due to the stability of the tertiary carbonium ion that forms when the $C^{\delta+}$-$I^{\delta-}$ bond

spontaneously breaks as the electrons in the bond transfer to the iodine to form an iodide ion. The carbonium ion is stabilised by the inductive effect of the three methyl groups that are attached to the carbon that bears the positive charge – these methyl groups push electrons towards the C+ and help to reduce the charge. As the carbonium ions form, they are quickly attacked by cyanide ions to form dimethylpropanenitrile.
Syllabus reference: 20.1

302.   When HBr reacts with propene:
A   The major organic product is 1-bromopropane
B   An electrophilic substitution reaction occurs
C   An electrophilic addition reaction occurs
D   A nucleophilic addition reaction occurs
Answer: C
Explanation: Alkenes do electrophilic addition reactions with hydrogen halides, because the electron-rich

double bond attracts the δ+ hydrogen in the polar $H^{\delta+}$-$X^{\delta-}$ molecule. In unsymmetrical alkenes, the

addition follows Markovnikoff's rule, which means that the major product has the hydrogen adding to the carbon that already has most hydrogens attached. In this case, this means that 2-bromopropane is the major product.
Syllabus reference: 20.1

303.   The nitration of benzene:
A   Is a nucleophilic substitution reaction
B   Is an electrophilic addition reaction
C   Is a nucleophilic addition reaction
D   Is an electrophilic substitution reaction
Answer: D
Explanation: The nitration of benzene is an electrophilic substitution reaction. A mixture of concentrated sulfuric and nitric acid is added to the benzene. The sulfuric acid forces the HNO_3 to behave as a base, accepting a proton to form $H_2^+NO_3$. This quickly breaks up to form H_2O and the nitronium ion NO_2^+, which is attracted by the benzene ring electrons. The NO_2 group bonds to one of the carbons in the ring, which means that that carbon is no longer able to participate in the delocalized ring system; a delocalized crescent consisting of electrons from the remaining five carbons in the ring is formed. Finally, the ring is re-established by dumping the hydrogen from the carbon bearing the NO_2 group. Nucleophilic substitution occurs when negative ions attack a positive centre, as in the reaction between hydroxide ions and a halogenoalkane. Alkenes do electrophilic addition reactions with hydrogen halides, because the

electron-rich double bond attracts the δ+ hydrogen in the polar $H^{\delta+}X^{\delta-}$ molecule.

Syllabus reference: 20.1

304.   "Nitrating mixture" is used in the nitration of benzene.
   A   This is a mixture of concentrated nitric and hydrochloric acids
   B   This is a mixture of concentrated nitric and sulfuric acids
   C   The reaction proceeds at room temperature
   D   The product is 1,3,5-trinitrobenzene

Answer: B

Explanation: "Nitrating mixture" contains a mixture of concentrated nitric and sulfuric acids. The electrophilic substitution reaction with benzene requires heating and forms nitrobenzene.

Syllabus reference: 20.1

305.   The reaction between 2-methylpent-2-ene and hydrogen chloride involves
   A   electrophilic addition
   B   nucleophilic addition
   C   electrophilic substitution
   D   nucleophilic substitution

Answer: A

Explanation: The hydrogen chloride molecule is polar, with the less electronegative hydrogen carrying a

δ+ charge. This is attracted to the double bond in the alkene. The hydrogen adds to one of the carbon

atoms in the double bond, mainly to the one that already has a hydrogen (the third carbon in the chain), forming a carbonium ion and a chloride ion. These rapidly combine to form 2-methyl, 3-chloropentane.

Syllabus reference: 20.1

306.   Which of the following is most likely to react with aqueous sodium hydroxide by an S_N2 mechanism?
   A $CH_3CH_2CH_3$
   B C_6H_6
   C $CH_3CH_2CH_2Br$
   D $(CH_3)_3CBr$

Answer: C

Explanation: $CH_3CH_2CH_2Br$ has a polar bond between C and Br, with the δ- charge on the Br and the δ+

charge on the carbon; this attracts the nucleophilic OH⁻ ion, so a transition state forms as the carbon to oxygen bond starts to form while the carbon to bromine bond starts to break. As both the halogenoalkane and the hydroxide ion are involved in the slow step, this is an S_N2 reaction. $CH_3CH_2CH_3$ is an alkane – it does nor react with NaOH. C_6H_6 is benzene, which does not react with NaOH. $(CH_3)_3CBr$ undergoes an S_N1 reaction with NaOH.

Syllabus reference: 20.1

307.   The reaction between propene and hydrogen bromide is an example of
   A   electrophilic addition
   B   electrophilic substitution
   C   nucleophilic addition
   D   nucleophilic substitution

Answer: A

Explanation: Alkenes are unsaturated and therefore do addition reactions rather than substitution reactions. The high electron density in the double bond gives a region of negative charge that attracts electrophiles.

Syllabus reference: 20.1

308.   Which of the following series of reactions could **NOT** be used to make propyl ethanoate?
   A   Step 1: reduce propanal to propan-1-ol using lithium aluminium hydride, then step 2: react the propan-1-ol with ethanoic acid to form propyl ethanoate.
   B   Step 1: react 1-bromopropane with aqueous sodium hydroxide to form propan-ol, then step 2: react the propan-1-ol with ethanoic acid to form propyl ethanoate.
   C   Step 1: oxidise ethanal to ethanoic acid using acidified potassium dichromate, then step 2: react the ethanoic acid with propan-1-ol to form propyl ethanoate.

D   Step 1: react propene with steam to form propan-2-ol, then step 2: react the propan-2-ol with ethanoic acid to form propyl ethanoate.

Answer: D

Explanation: Propene reacts with steam in the presence of a catalyst to produce propan-2-ol as the major product (according to Markoffnikov's Rule). This alcohol would react with ethanoic acid to form an ester, but in order for the final product to have a propyl group, the –OH in the alcohol must be on the end carbon in the chain, i.e. propan-1-ol. All the other steps indicated in the question would work.

Syllabus reference: 20.2

309.   Which of the following series of reactions would work?

A   Step 1: react but-2-ene with HCl to form butan-2-ol, then step 2: distil butan-2-ol with acidified potassium manganate(VII) to form butanoic acid.

B   Step 1: oxidise propan-1-ol to propanoic acid by refluxing with acidified potassium dichromate, then step 2: reduce the propanoic acid to propanone by heating with $LiAlH_4$.

C   Step 1: reduce propanal to propan-2-ol by heating with $LiAlH_4$, then step 2: react the propan-2-ol with methanoic acid to form an ester.

D   Step 1: heat ethene with hydrogen in the presence of a catalyst to make ethane, then step 2: react ethane with chlorine in uv light to produce a mixture that includes chloroethane and hydrogen chloride.

Answer: D

Explanation: The first step in answer A would work, but the second step would give butanone. The first step in answer B would work, but the second step would produce propanal rather than propanone. In answer C, the first step would produce propan-1-ol rather than propan-2-ol. In answer D, both steps work; in the first the alkene undergoes addition to form the alkane and in the second, the alkane undergoes substitution via a free radical mechanism.

Syllabus reference: 20.2

310.   Which of the following sequences of reactions is correct?

A   Heat benzene with a mixture of concentrated nitric and sulfuric acids to make nitrobenzene, then reflux the nitrobenzene with zinc and concentrated hydrochloric acid and finally add sodium hydroxide solution to form phenylamine.

B   Warm benzene with nitric acid to make nitrobenzene, then heat the nitrobenzene with hydrogen in the presence of a nickel catalyst to form phenylamine.

C   Propanoic acid can be reduced to propanone by heating with $LiAlH_4$.

D   2-methylpropan-2-ol can be oxidised to 2-methylpropanal by distilling with acidified potassium dichromate. If the experiment was set up for reflux instead of distillation, the final product would be 2-methylpropanoic acid.

Answer: **A**

Explanation: A mixture of concentrated nitric and sulfuric acids initially proton the nitric acid, because H_2SO_4 is a stronger acid than HNO_3, forcing the HNO_3 molecule to act as a base. The protonated nitric acid is unstable and decomposes to form water and nitronium ions, NO_2^+, which are then attacked by the benzene ring, forming nitrobenzene. This then reacts with zinc and hydrochloric acid to form phenylammonium ions, which are finally reacted with sodium hydroxide to give phenylamine. In answer B, benzene has no reaction with acids; furthermore, nitrobenzene would not react with hydrogen. In answer C, propanoic acid would be reduced to propanal and then further reduced to propan-1-ol. In answer D, 2-methylpropan-2-ol is a tertiary alcohol, which cannot be oxidised.

Syllabus reference: 20.2

311.   Which of the following exhibits optical activity?

A $CH_3CH_2CH_2CH_2CH_2Br$

B $CH_3CH_2CH_2CHBrCH_3$

C $CH_3CH_2CHBrCH_2CH_3$

D $CH_2BrCH_2CH_2CH_2CH_2Br$

Answer: B

Explanation: In order to exhibit optical activity, a molecule must possess a chiral carbon atom, i.e. a carbon atom bonded to four different atoms or groups. In answer (B), 2-bromopentane, the second carbon in the chain is bonded to Br, H, CH_3 and C_3H_7.

Syllabus reference: 20.3

312.   The Cahn-Ingold-Prelog rules are used

    A   in naming stereoisomers

    B   in naming complex ions

    C   in determining the mechanism of substitution reactions

    D   in determining electron configuration

Answer: A

Explanation: The Cahn-Ingold-Prelog system is used to name stereoisomers that could not be named using cis-trans nomenclature; molecules are classed as (E) or (Z) depending on whether the heavier groups are on opposite sides of the double bond (E form) or on the same side (Z form).

Syllabus reference: 20.3

313.   Which of the following peaks would appear in the mass spectrum of propan-1-ol but **not** in the mass spectrum of methoxyethane?

    A   15

    B   17

    C   29

    D   31

Answer: B

Explanation: The peak at 17 represents an OH^+ group, which is present in propan-1-ol but not in methoxyethane. Both molecules could fragment to form a CH_3^+ group (peak at 15). A peak at 31 would appear in both spectra, representing CH_2OH^+ or OCH_3^+. A peak at 29 would appear in both spectra, representing $CH_3CH_2^+$. A peak at 46 would be formed by both molecules (ie the molecular mass without any fragmentation).

Syllabus reference: 20.3

314.   The following compound is named:
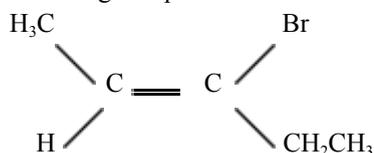
    A   cis-3-bromopent-2-ene

    B   trans-3-bromopent-2-ene

    C   (E)-3-bromopent-2-ene

    D   (Z)-3-bromopent-2-ene

Answer: D

Explanation: You can't use cis-trans nomenclature here. This is (Z)-3-bromopent-2-ene, because the heavier groups (CH_3 and Br being heavier than H and CH_2CH_3) are both on the same side of the double bond (drawn above on the question paper). If they were on opposite sides, the molecule would be the (E) or "entgegen" form (German for opposite). When the heavier groups are on the same side, the molecule is the (Z) or "zusammen" form (German for together). One way to remember is that the heavier groups are both on the **z**ame **z**ide in the (**Z**) isomer!

Syllabus reference: 20.3

315.   If a compound contains a chiral carbon atom:

A   It shows cis-trans isomerism
B   It has enantiomers
C   It has diastereomers
D   It is named using the Cahn-Ingold-Prelog system
Answer: B
Explanation: A chiral carbon is one that is bonded to four different atoms or groups; it leads to non-superimposable mirror image structures called enantiomers that rotate the plane of polarized light to the left or the right. Cis-trans isomerism occurs in molecules with a double bond or a ring, where substituents could be positioned above or below the double bond or ring. Diastereomers are stereoisomers that are not mirror images of each other; these do not give optical activity. The Cahn-Ingold-Prelog system is used to name stereoisomers that could not be named using cis-trans nomenclature; molecules are classed as (E) or (Z) depending on whether the heavier groups are on opposite sides of the double bond (E form) or on the same side (Z form).
Syllabus reference: 20.3

316.   Which of the following molecules would show optical activity?
A $CH_3CH_2CH_2CH_2I$
B $CH_3CH_2CHICH_3$
C $CH_3CH_2CH_2CN$
D $CH_3CH_2CBr_2COOH$
Answer: B
Explanation: An optically active compound contains a chiral carbon atom, i.e. a carbon bonded to four different atoms or groups. In compound B, the second carbon is bonded to I, H, CH_3 and CH_3CH_2.
Syllabus reference: 20.3

317.   Including (if appropriate) optical isomers, how many secondary alcohols have the molecular formula $C_5H_{12}O$?
A   3
B   4
C   5
D   7
Answer: C
Explanation: Pentan-2-ol has two optical isomers due to its chiral carbon, $CH_3CH_2C*HOHCH_3$. Pentan-3-ol, $CH_3CH_2CHOHCH_2CH_3$ does not have optical isomers. 2-methylbutan-3-ol, has two optical isomers due to its chiral carbon, $CH_3CHCH_3C*HOHCH_3$.
Syllabus reference: 20.3

318.   A high resolution NMR spectrum of ethyl ethanoate will show:
A   A singlet, a triplet and a quartet
B   A singlet, a doublet and a triplet
C   Two doublets and two triplets
D   A doublet and two triplets
Answer: A
Explanation: There is a singlet (relative intensity 3) due to the CH_3 part of the ethanoyl group, with no splitting because the neighbouring carbon has no hydrogens. There is a triplet (relative intensity 3) due to the CH_3 part of the ethyl group, with triplet splitting due to the neighbouring CH_2 group. There is a quartet (relative intensity 2) due to the CH_2 part of the ethyl group, with quartet splitting due to the neighbouring CH_3 group.
Syllabus reference: 21.1

319.   In high resolution ^1H NMR spectroscopy:
A   Chemical shift is given the symbol δ
B   The presence of a doublet indicates that the molecule contains 2 carbon atoms
C   The presence of a doublet shows that there are two different environments for hydrogen in the molecule

D   The integration trace shows the relative number of hydrogen atoms in each environment within the molecule

Answer: D

Explanation: The integration trace shows the relative number of hydrogen atoms in each environment within the molecule. Chemical shift is given the symbol δ. The presence of a doublet shows that the next carbon along bears one hydrogen atom.

Syllabus reference: 21.1

320.   The high resolution NMR spectrum of ethyl ethanoate would show

A   a triplet, a doublet and a singlet in the ratio 2:3:3

B   a quartet, a triplet and a singlet in the ratio 2:3:3

C   two triplets and a singlet in the ratio 2:2:1

D   a quartet, a doublet and a singlet in the ratio 2:3:3

Answer: B

Explanation: The three peaks in the ratio 2:3:3 represent one CH_2 group and two CH_3 groups. The CH_2 group is a quartet, so the adjacent carbon has three hydrogens attached. The CH_3 group on the adjacent carbon therefore is a triplet, because the neighbouring carbon has two hydrogens attached. The other CH_3 group is a singlet, because the neighbouring carbon has no hydrogens attached to it.

Syllabus reference: 21.1