SOUTH AFRICAN AGENCY FOR SCIENCE AND TECHNOLOGY ADVANCEMENT
56th SCIENCE OLYMPIAD GRADES 10 -12
2021 MEMORANDUM

1. **Answer: C**

Analysis: In using the ion–electron method, there's not much to analyze. It's necessary to know the steps and to follow them in sequence.

Assembling the Tools: Follow the seven steps of the ion–electron method for acidic solutions to balance the equation.

Solution:

Step 1. Divide the skeleton equation into two half-reactions.

$$MnO_4^- \rightarrow Mn^{+2}$$
$$H_2SO_3 \rightarrow SO_4^{-2}$$

Step 2. Balance atoms other than H and O. There is nothing to do for this step. All the atoms except H and O are already in balance.

Step 3. Add H_2O to balance oxygens.

$$MnO_4^- \rightarrow Mn^{+2} + 4H_2O$$
$$H_2O + H_2SO_3 \rightarrow SO_4^{-2}$$

Step 4. Add H^+ to balance H.

$$8H^+ + MnO_4^- \rightarrow Mn^{+2} + 4H_2O$$
$$H_2O + H_2SO_3 \rightarrow SO_4^{-2} + 4H^+$$

Step 5. Balance the charge by adding electrons to the more positive side.

$$5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{+2} + 4H_2O$$
$$H_2O + H_2SO_3 \rightarrow SO_4^{-2} + 4H^+ + 2e^-$$

Step 6. Make electron loss equal to electron gain, then add the half-reactions.

$$2(5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{+2} + 4H_2O)$$
$$5(H_2O + H_2SO_3 \rightarrow SO_4^{-2} + 4H^+ + 2e^-)$$

$$10e^- + 16H^+ + 2MnO_4^- + 5H_2O + 5H_2SO_3 \rightarrow 2Mn^{+2} + 8H_2O + 5SO_4^{-2} + 20H^+ + 10e^-$$

Step 7. Cancel $10e^-$, $16H^+$, and $5H_2O$ from both sides. The final equation is

$$2MnO_4^- + 5H_2SO_3 \rightarrow 2Mn^{+2} + 3H_2O + 5SO_4^{-2} + 4H^+$$

2. **Answer: A**

Analysis This problem requires that we calculate the energy needed to heat a cup of tea. Once we know the total energy, we can determine the number of photons. Then we can calculate the moles of photons.

Strategy We have delineated three parts for this calculation:
(1) calculate the total energy needed,
(2) calculate the
number of photons needed, and
(3) convert the number of photons to moles of photons

PART
PART 1

Heat energy (J) = (specific heat)(mass)(temperature change)

We know that the specific heat of water is 4.184 J g^{-1} $°C^{-1}$, and the mass is determined by converting 237 mL of water to 237 g of water using the density of water.

The change in temperature is 85.5 °C - 25.0 °C or 60.5 °C. Putting this together we get

Heat energy (J) = (4.184 J g^{-1} $°C^{-1}$) (237 g) (60.5 °C) = 5.999×10^4 J
Notice that we will keep one extra significant figure until the final result is calculated.
PART 2

PART 2

We can calculate the energy of one photon using E = hf combined with c = fλ
to get

$$E = \frac{hc}{\lambda}$$

Then we divide that into the total energy from Part 1 to determine the number of photons. The energy of one photon is

$$E = \frac{(6.626x10^{-34}J.s)(2.998x10^{8}m.s^{-1})}{12.24x10^{-2}m} = 1.623\ x\ 10^{-24}J.photon^{-1}$$

The number of photons is

$$number\ of\ photons = \frac{(5.999x10^{4}J)}{(1.623\ x\ 10^{-24}J.photon^{-1})} = 3.696x10^{28}\ photons$$

PART 3

We use the tool for converting between elementary particles to moles, more commonly known as Avogadro's number.
1 mole photons = 6.022×10^{23} photons

We use our conversion factor to calculate moles from elementary units:

$$3.696x10^{28}\ photons\ \left(\frac{1\ mol.photon}{6.022\ x\ 10^{23}\ photons}\right) = 6.138\ x\ 10^{4}\ mol.photon$$

Correctly rounded the answer is 6.14×10^4 mol photons.

3. Answer: C

STRATEGY Using trigonometry, find the vector force exerted by each horse on the barge. Add the *x*-components together to get the *x*-component of the resultant force, and then do the same with the *y*-components. Divide by the mass of the barge to get the accelerations in the *x*- and *y*-directions.

SOLUTION

Compute the *x*-components of the forces exerted by the horses.

$$F_{1x} = F_1 \cos\theta_1 = (6.00x10^2 N)\cos(30.0^0) = 520\ N$$

$$F_{2x} = F_2 \cos\theta_2 = (6.00x10^2 N)\cos(-45.0^0) = 424\ N$$

Find the total force in the *x*-direction by adding the *x*-components:

$$F_{1x} + F_{2x} = 520N + 424\ N = 944\ N$$

Compute the *y*-components of the forces exerted by the horses:

$$F_{1y} = F_1 \sin\theta_1 = (6.00x10^2 N)\sin(30.0^0) = 300\ N$$

$$F_{2y} = F_2 \sin\theta_2 = (6.00x10^2 N)\sin(-45.0^0) = -424\ N$$

Find the total force in the *y*-direction by adding the *y*-components:

$$F_{1y} + F_{2y} = 300\ N - 424\ N = -124\ N$$

Obtain the components of the acceleration by dividing each of the force components by the mass:

$$a_x = \frac{F_x}{m} = \frac{944\ N}{2000\ N} = 0.472\ m.s^{-2}$$

$$a_y = \frac{F_y}{m} = \frac{-124\ N}{2000\ N} = 0.062\ m.s^{-2}$$

Calculate the magnitude of the acceleration:

$$a = \sqrt{a_x^2 + a_y^2} = \sqrt{(0.472)^2 + (-0.062)^2} = 0.476\ m.s^{-2}$$

Calculate the direction of the acceleration using the tangent function:

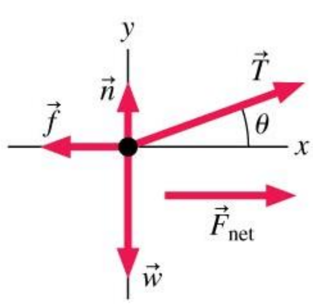
$$\tan\theta = \frac{a_y}{a_x} = \frac{-0.062}{0.472} = -0.131$$

Therefore $\theta = \tan^{-1}(-0.131) = -7.46^0$

REMARKS Notice that the angle is in fourth quadrant, in the range of the inverse tangent function, so it is not necessary to add 180° to the answer. The horses exert a force on the barge through the tension in the cables, while the barge exerts an equal and opposite force on the horses, again through the cables. If that were not true, the horses would easily move forward, as if unburdened.

4. Answer: D

Solution:



Known

$x_i = 0m$
$(v_x)_i = 0\ m/s$

$t_i = 0, \theta = 20°$
$m = 1500kg$
$f = 320N$
$(v_x)_f = 12\ m.s^{-1}$
$t_f = 10s$
T = ?

Newton's second law in component form is

$\Sigma F_x = n_x + T_x + f_x + w_x = ma_x$

$\Sigma F_y = n_y + T_y + f_y + w_y = ma_y = 0$

$T\cos\theta - f = ma_x$
$n + T\sin\theta - w = 0$

Because the car speeds up from rest to 12 m/s in 10 s, we can use kinematics to find the acceleration:

$$a_x = \frac{\Delta v_x}{\Delta t} = \frac{(v_x)_f - (v_x)_i}{t_f - t_i} = \frac{(12\ m.s^{-1} - 0\ m.s^{-1})}{(10s - 0s)} = 1.2\ m.s^{-2}$$

We can now use the first Newton's law equation above to solve tension. We have

$$T = \frac{ma_x + f}{\cos\theta} = \frac{(1500\ kg)(1.2\ m.s^{-2}) + 320\ N}{\cos 20°} = 2300\ N$$

5. Answer: D

SOLUTION:

First we calculate the volume of the room as $5.00m\ x\ 10.00m\ x\ 3.50m = 175\ m^3$

Converting 175 m^3 to Liters, we get $175x10^3\ L = 175x10^3\ dm^3$

We now calculate the amount of CO_2 using the concentration and volume to calculate moles.

$$n = CV = (1.00 \times 10^{-6} mol.dm^{-3})(175x10^3\ dm^3) = 0.175\ mol\ NaOH$$

We know that Formula or Molar mass of NaOH = 39.997 g/mol

$$m = nM_r = (0.175\ mol)(39.997\ g/mol) = 7.00g$$

6. **Answer: B**

Analysis: We start by determining the formulas for the reactants and products and then balancing the chemical equation. Phosphorus is represented as P(s) and chlorine gas is Cl_2(g) and the product is PCl_3(s). The balanced equation is

$2P(s) + 3Cl_2(g) \rightarrow 2PCl_3(s)$

Now we notice that the masses of both reactants are given, so this must be a limiting reactant problem.

The first step is to figure out which reactant, P or Cl_2, is the limiting reactant, because we must base all calculations on the limiting reactant. When we know the limiting reactant, we can calculate the theoretical yield of product, PCl_3(s).

Finally we calculate the percentage yield.

Assembling the Tools: To solve the first two steps, our basic tools are the relationships

$$1\ mol\ P\ =\ 30.97\ g\ P$$

$$1\ mol\ Cl_2\ =\ 70.90\ g\ Cl_2$$

$$3\ mol\ Cl_2 \Leftrightarrow\ 2\ mol\ P$$

Solution: In any limiting reactant problem, we can arbitrarily pick one reactant and do a calculation to see whether it can be entirely used up. We'll choose phosphorus and see whether there is enough to react with 35.0 g of chlorine. The following calculation gives us the answer.

$$12.0\ g\ P\ \times \frac{1\ mol\ P}{30.97\ g\ P} \times \frac{3\ mol\ Cl_2}{2\ mol\ P} \times \frac{70.90\ g\ Cl_2}{1\ mol\ Cl_2} = 41.2\ g\ Cl_2$$

Thus, with 35.0 g of Cl_2 provided but 41.2 g of Cl_2 needed, there is not enough Cl_2 to react with all 12.0 g of P. The Cl_2 will be all used up before the P is used up, so Cl_2 is the limiting reactant. We therefore base the calculation of the theoretical yield of PCl_3 on Cl_2.

(We must be careful to use the 35.0 g of Cl_2 given in the problem, not the 41.2 g calculated while we determined the limiting reactant.)
To find the theoretical yield of PCl_3, we calculate how many grams of PCl_3 could be made from 35.0 g of Cl_2 if everything went perfectly according to the equation given.

$$35.0\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.90\ g\ Cl_2} \times \frac{2\ mol\ PCl_3}{3\ mol\ Cl_2} \times \frac{137.32\ g\ PCl_3}{1\ mol\ PCl_3} = 45.2\ g\ PCl_3$$

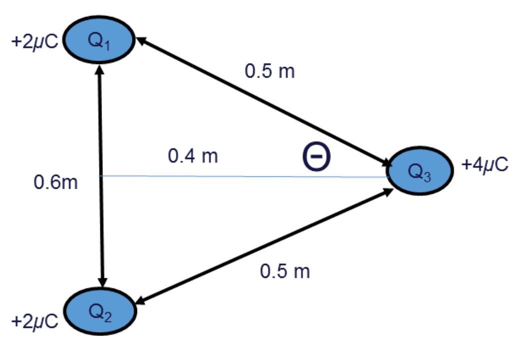
The actual yield was 42.4 g of PCl_3, not 45.2 g, so the percentage yield is calculated as follows

$$Percentage\ yield = \frac{42.4g\ PCl_3}{45.2g\ PCl_3} \times 100\% = 93.8\%$$

Thus 93.8% of the theoretical yield of PCl_3 was obtained.

7. **Answer: D**

Notice that vertical components of Q_1 and Q_2 don't have an effect on Q_3. Therefore we only need to pay attention to Horizontal components of Q1 and Q_2 which have the same value.



Using the **Theorem of Pythagoras** we can calculate the distance from the mid-point to charge Q_3 we have:

$(0,5)^2 - (0,3)^2 = (0.16)^2 = 0,4$ m

By Coulomb's Law: $F = k\frac{Q_1Q_3}{r^2} = \frac{(9x10^9)(2x10^{-6})(4x10^{-6})}{0.5^2} = 0,29\ N$
The horizontal component for Q_1 = horizontal component for Q_2
$= F\ \mathrm{Cos}\theta = (0,29)(\frac{0,4\ m}{0,5m}) = 0,23$ N
Therefore; the net electrostatic force on Q_3 = 0,23 N + 0,23 N = 0,46 N

8. **Answer: A**

Electric field strength due to Q:

$$E = \frac{kQ}{r^2} = \frac{9\times10^9\times10\times10^{-6}}{2^2} = 2{,}25\times10^4\,N.C^{-1}\ \ to\ the\ left$$

Electric field strength due to P:

$$E = \frac{kP}{r^2} = \frac{(9\times10^9)(-7\times10^{-6})}{1^2} = 6{,}3\times10^4\,N.C^{-1}\ \ to\ \ the\ \ left$$

E_{net}= $2{,}25x10^4$ $N.C^{-1}$ + $6{,}3 \times 10^4$ $N.C^{-1}$ = 85 500 $N.C^{-1}$

9. **Answer: A**

Analysis: Let's first translate the question into an equation:

0.635 g tungsten = ? atoms tungsten

Here we do not have any tool that directly relates grams of tungsten to atoms of tungsten. However, we can start with the grams of tungsten and make the following *sequence of conversions.*

grams tungsten → moles tungsten → atoms tungsten

Assembling the Tools: The first tool we need is the mass-to-moles tool,

183.84 g W = 1 mol W which lets us construct conversion factors between grams of tungsten and moles of tungsten.

Next we need the tool for Avogadro's number that allows us to construct conversion factors between the moles of tungsten atoms and the number of tungsten atoms,

1 mol W = 6.022 × 1023 atoms W

Solution: Having expressed the question as an equation, we can use it along with the two tools for the conversions to construct the two conversion factors.

We multiply the original 0.635 grams of tungsten by the conversion factors to get

$$0.635\ g\ W\ \times \left(\frac{1\ mol\ W}{183.84\ g\ W}\right) \times \left(\frac{6.022\ \times\ 10^{23}\ atoms\ W}{1\ mol\ W}\right) = 2.08\ \times 10^{21}\ atoms\ W$$

10. Answer: C

Analysis: Let's begin, as usual, by restating the problem as follows.

0.0011 g Mg ⇔ ? g C

Our first step is to convert the mass of Mg to moles of Mg. Once we know the moles of Mg, we can convert that to the moles of C using the formula of the compound. Finally, we can calculate the mass of the second substance, C, from the moles using the molar mass again. The sequence of calculations can be summarized as

0.0011 g Mg → mol Mg → mol C → g C

Assembling the Tools: From the sequence of steps above we see that we will need the mass-to-moles tool to convert the mass of Mg to moles of Mg. The tool states that 24.3050 g Mg = 1 mol Mg

Next we need a mole ratio to convert moles of Mg to moles of C. This is 1 mol Mg ⇔ 55 mol C (these are exact numbers)

Finally, the mass-to-moles tool for carbon is 1 mol C = 12.011 g C

Solution: We now set up the solution by forming conversion factors so the units cancel.

$$0.0011\ g\ Mg\ \times \frac{1\ mol\ Mg}{24.3\ g\ Mg} \times \frac{55\ mol\ C}{1\ mol\ Mg} \times \frac{12.0\ g\ C}{1\ mol\ C} = 0.030\ g\ C$$

A plant cell must supply 0.030 g C for every 0.0011 g Mg to completely use up the magnesium in the synthesis of chlorophyll.

11. **Answer: C .**

The object is travelling at the same velocity as the truck. Relative to each other their velocities are zero.

12. Answer: B

Solution:

For series connection: Total Resistance $= 12\ \Omega + 12\ \Omega + 12\ \Omega = 36\ \Omega$
For parallel connection: Effective resistance $= \frac{(12)(12)(12)}{(12)(12)+(12)(12)+(12)(12)} = \frac{1728}{432} = 4\ \Omega$
For mixed connection: Total resistance $= \frac{(12)(12)}{12+12} + 12 = 6 + 12 = 18\ \Omega$
Therefore $48\ \Omega$ cannot represent the total resistance

13. Answer: C

PART 1

Analysis: Our goal here is to break the problem down into parts that we already know how to solve. The approach is to read the problem carefully and extract from it the various pieces to the puzzle.

First, we're dealing with the stoichiometry of a chemical reaction, so we know we're going to need a balanced chemical equation. We will also need to determine the concentrations of ions, so we will have to be prepared to write an ionic equation, or at least to take into account the dissociation of each solute.
Notice that we've been given the volume and molarity for *both* solutions.
We have been given the number of moles of two reactants, this means we have a limiting reactant problem.

The problem also asks for the concentrations of the ions in the final mixture. The easiest way to find the answers here is to determine the number of moles of each of the ions present before and after the reaction, and then divide the latter by the total final volume of solution to calculate the molar concentrations. Because this is an ionic reaction, two of the ions will be reactants. One will be completely used up, but some of the other will be left over, and we will have to calculate how much. The other two ions are spectator ions and their amounts will not change. In summary, this is what we will be doing:

Part 1: Write a balanced molecular equation and then convert it to an ionic equation. (This comes first because all the rest of the reasoning is based on the equation.)
Part 2: Calculate the number of moles of each ion present before reaction, determine the limiting reactant, and then use it to calculate the moles and grams of $Mg(OH)_2$ formed.
Part 3: We already know the moles of the spectator ions from Part 2, but we have to calculate the moles of unreacted Mg^{2+} or OH^-. We also need to determine the total volume of the mixture and then calculate the molarities of the ions.

Assembling the Tools We need to set up a metathesis equation and balance it., making use of the solubility rules.

Solution

The balanced molecular equation for the reaction is
$MgCl_2(aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(s) + 2NaCl(aq)$ from which we construct the ionic and net ionic equations.
$Mg^{2+}(aq) + 2Cl^-(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s) + 2Na^+(aq) + 2Cl^-(aq)$
$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$
These are the equations we will use in Part 2.

PART 2

Assembling the Tools For each reactant solution, molarity × volume(L) = moles of solute

The chemical formulas of the reactants will be used to find the number of moles of each ion prior to reaction. The method of finding the limiting reactant will be applied. A tool we will use is the set of coefficients in the equation, which relates moles of the reactants and product. The molar mass tool will be used to convert moles of $Mg(OH)_2$ to grams.

58.31 g $Mg(OH)_2$ = 1 mol $Mg(OH)_2$

Solution Let's begin by determining the number of moles of NaOH and $MgCl_2$ supplied by the volumes of their solutions. The conversion factors are taken from their molarities: 0.200 *M* NaOH and 0.300 *M* $MgCl_2$.

$$0.0400\ L\ NaOH\ soln \times \frac{0.200\ mol\ NaOH}{1.00\ L\ NaOH\ soln} = 8.00 \times 10^{-3}\ mol\ NaOH$$

$$0.0250\ L\ MgCl_2\ soln \times \frac{0.300\ mol\ MgCl_2}{1.00\ L\ MgCl_2\ soln} = 7.500 \times 10^{-3}\ mol\ MgCl_2$$

From this information, we obtain the number of moles of each ion present *before* any reaction occurs. In doing this, notice that we take into account that 1 mol of $MgCl_2$ gives 2 mol Cl^-. Here is a summary of the data.

Moles of Ions before Reaction

Mg^{2+}	7.50×10^{-3} mol	Cl^-	15.0×10^{-3} mol
Na^+	8.00×10^{-3} mol	OH^-	8.00×10^{-3} mol

Now we refer to the net ionic equation, where we see that only Mg^{2+} and OH^- react. From the coefficients of the equation, 1 mol Mg^{2+} ⇔ 2 mol OH

This means that 7.50×10^{-3} mol Mg^{2+} (the amount of Mg^{2+} *available*) would require 15.0 × 10-3 mol OH^-. But we have only 8.00 × 10-3 mol OH^-. Insufficient OH^- is available to react with all of the Mg^{2+}, so OH^- must be the limiting reactant. Therefore, all of the OH^- will be used up and some Mg^{2+} will be unreacted. The amount of Mg^{2+} that *does* react to form $Mg(OH)_2$ can be found as follows.

$$8.00 \times 10^{-3}\ mol\ OH^{-}\ \times \frac{1\ mol\ Mg^{+2}}{2\ mol\ \ OH^{-}} = 4.00\ \times 10^{-3}\ mol\ Mg^{+2}\ (this\ amount\ reacts)$$

One mole of Mg^{2+} gives 1 mole of $Mg(OH)_2$. Therefore, the amount of $Mg(OH)_2$ that forms is

$$4.00\ \times 10^{-3}\ Mol\ Mg^{+2}\ \times \frac{1\ mol\ Mg\ (OH)_2}{1\ mol\ Mg^{+2}} \times \frac{58.32g\ Mg\ (OH)_2}{1\ mol\ Mg\ (OH)_2} = 0.233g\ Mg\ (OH)_2$$

The reaction mixture will produce 0.223 g $Mg\ (OH)_2$

PART 3

Assembling the Tools To calculate the concentrations of the ions, we can use the number of moles of each present in the final mixture divided by the *total volume* of the solution. This tool is the defining equation for molarity,

$$molarity = \frac{number\ of\ moles\ of\ solute}{volume\ of\ solution\ in\ L}$$

Solution Let's begin by tabulating the number of moles of each ion left in the mixture *after* the reaction is complete. For Mg^{2+}, the amount remaining equals the initial number of moles minus the moles that react (which we found in Part 2). Let's put all of the numbers into one table to make them easier to understand.

Ion	**Initial moles**	**Moles that react**	**Moles present after reaction**
Mg^{+2}	7.50 x10^{-3} mol	4.00 x10^{-3} mol	3.50 x 10^{-3} mol
Cl^{-}	15.0 x10^{-3} mol	0.00 x10^{-3} mol	15.0 x 10^{-3} mol
Na^{+}	8.00 x10^{-3} mol	0.00 x10^{-3} mol	8.00 x 10^{-3} mol
OH^{-}	8.00 x10^{-3} mol	8.00 x10^{-3} mol	0.00 x 10^{-3} mol

The problem asks for the concentrations of the Mg^{+2} ions in the final reaction mixture, so we must now divide the quantity in the last column by the *total volume of the final solution* (40.0 mL + 25.0 mL = 65.0 mL). This volume must be expressed in liters ($0.0650dm^{-3}$).

For Mg^{2+}, its concentration is $\frac{3.5\times10^{-3}\ mol\ Mg^{+2}}{0.0650\ dm^{-3}\ soln} = 0.0538\ mol.dm^{-3}\ Mg^{+2}$

14. Answer: A

Solution: The compound $KMnO_4$ provides MnO_4^- and the K^+ is a spectator ion and is not included in balancing the equation. The skeleton equation for the reaction is

$$Fe^{+2} + MnO_4^- \rightarrow Fe^{+3} + Mn^{+2}$$

Balancing it by the ion–electron method for acidic solutions gives

$$5Fe^{+2} + MnO_4^- + 8H^+ \rightarrow 5Fe^{+3} + Mn^{+2} + 4H_2O$$

The number of moles of MnO_4^- consumed in the reaction is calculated from the volume of the solution used in the titration and its concentration.

$$0.02745\ dm^3\ MnO_4^-\ soln\ \times \frac{0.100\ mol\ MnO_4^-}{1.00\ dm^3\ MnO_4^-\ soln} = 0.00275\ mol\ MnO_4^-$$

Next, we use the coefficients of the equation to calculate the number of moles of Fe^{2+} that reacted. The balanced chemical equation tells us five moles of Fe^{2+} react per mole of MnO_4^- consumed.

$$0.02745\ mol\ MnO_4^-\ \times \frac{5\ mol\ Fe^{+2}}{1\ mol\ MnO_4^-} = 0.0137\ mol\ Fe^{+2}$$

The chemical formula for the iron oxide gives us

1 mol Fe_2O_3 $\Leftrightarrow$ 2 mol Fe

This provides the conversion factor we need to determine how many moles of Fe_2O_3 were present in the sample. Working with the number of moles of Fe,

$$0.0137\ mol\ Fe\ \times \frac{1\ mol\ Fe_2O_3}{2\ mol\ Fe} = 0.00685\ mol\ Fe_2O_3$$

This is the number of mol%es of Fe_2O_3 in the sample. The formula mass of Fe_2O_3 is 159.69 g mol^{-1}, so the mass of Fe_2O_3 in the sample was

$$0.00685\ mol\ Fe_2O_3\ \times \frac{159.69\ g\ Fe_2O_3}{1\ mol\ \ Fe_2O_3} = 1.094\ g\ Fe_2O_3$$

Finally, the percentage of Fe_2O_3 in the sample was

$$\% \, Fe_2O_3 = \frac{1.094 \ g \ Fe_2O_3}{2.00 \ g \ sample} \times 100\% = 54.7\% \, Fe_2O_3$$

The ore sample contained 54.7% Fe_2O_3

15. Answer: A

Solution: 45^0

16. Answer: B

Reasoning In arriving at $I = {}^{P}/_{(4\pi r^2)}$, it was assumed that the sound spreads out uniformly from the source and passes only once through the imaginary surface that surrounds it (see given Figure above). In the Figure above, only part of this imaginary surface (colored blue) is shown, but nonetheless, if $I = {}^{P}/_{(4\pi r^2)}$ is to apply, the same assumption must hold.

Answers (A) and (C) are incorrect. $I = {}^{P}/_{(4\pi r^2)}$ cannot overestimate the sound intensity, because it assumes that the sound passes through the imaginary surface only once and, hence, does not take into account the reflected sound within the shower stall. For the same reason, neither can $I = {}^{P}/_{(4\pi r^2)}$ give the correct sound intensity.

Answer (B) is correct. The above Figure illustrates three paths by which the sound passes through the imaginary surface. The "direct" sound travels along a path from its source directly to the surface. It is the intensity of this sound that is given by $I = {}^{P}/_{(4\pi r^2)}$. The remaining paths are two of the many that characterize the sound reflected from the shower stall. The total sound power that passes through the surface is the sum of the direct and reflected powers. Thus the total sound intensity at a distance r from the source is greater than the intensity of the direct sound alone, so Equation $I = {}^{P}/_{(4\pi r^2)}$ underestimates the sound intensity from the singing. People like to sing in the shower because their voices sound so much louder due to the enhanced intensity caused by the reflected sound.

17. ANSWER: D

Solution- Directed radially inward

18. Answer: C

Reasoning
To find the age of the wine, it is necessary to determine the ratio of the current activity **A** to the initial activity **A$_0$**. If the age of the sample is very small relative to the half-life of the nuclei, relatively few of the nuclei would have decayed during the wine's life, and the measured activity would have changed little from its initial value

To obtain an accurate age from such a small change would require prohibitively precise measurements. On the other hand, if the age of the sample is many times greater than the half-life of the nuclei, virtually all of the nuclei would have decayed, and the current activity would be so small that it would be virtually impossible to detect.

Answer (A) is incorrect. The expected age of the wine is about 5 years. This period is only a tiny fraction of the 5730-yr half-life of ${}^{14}_{6}C$. As a result, relatively few of the ${}^{14}_{6}C$ nuclei would have decayed during the wine's life, and the current activity would be nearly the same as the initial activity thus requiring prohibitively precise measurements.

Answer (B) is incorrect. The ${}^{15}_{8}O$ isotope is not very useful either, because of its relatively short half-life of 122.2 s. During a 5-year period, so many half-lives of 122.2 s would have occurred that the current activity would be vanishingly small and undetectable.

Answer (C) is correct. The only remaining option is the ${}^{3}_{1}H$ isotope. The expected age of 5 yr is long enough relative to the half-life of 12.33 yr that a measurable change in activity will have occurred, but not so long that the current activity will have completely vanished for all practical purposes.

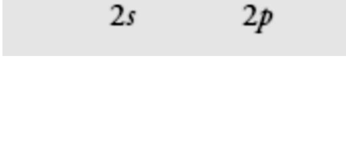
19. Answer: C

Solution: Centrifugation

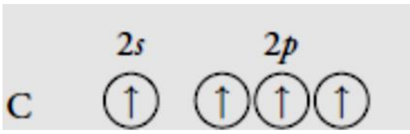
20. Answer :A

Analysis: No pure atomic orbitals have the correct orientations to form a tetrahedral molecule, so we expect hybrid orbitals will be used.

Solution: The tetrahedral structure of the molecule suggests that sp^3 hybrid orbitals are involved in bonding. Let's examine the valence shell of carbon.

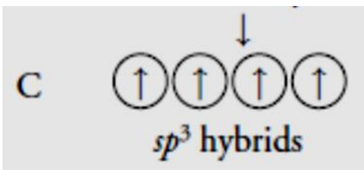


To form four $C–H$ bonds, we need four half-filled orbitals. Unpairing the electrons in the $2s$ and moving one to the vacant $2p$ orbital satisfies this requirement. Then we can hybridize all the orbitals to give the desired sp^3 set.

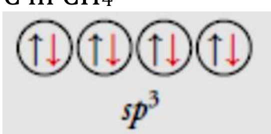


(Electrons become unpaired)

These become hybridized



Then we form the four bonds to hydrogen 1s orbitals.
C in CH_4



(Coloured arrows are H electrons)

21. Answer: B

Assembling the Tools: We can ignore the reaction of HCO_3 with water, so the only relevant equilibrium is

$CO_3^{-2} + H_2O \rightleftharpoons HCO_3^- + OH^-$ $\qquad\qquad K_{b1} = \frac{[HCO_3^-][OH^-]}{[CO_3^{-2}]} = 1.8 \times 10^{-4}$

	CO_3^{-2}	HCO_3^-	OH^-
Initial concentrations ($mol.dm^{-3}$)	0.11	0	0
Change in concentrations ($mol.dm^{-3}$)	$-x$	$+x$	$+x$
Equilibrium concentrations ($mol.dm^{-3}$)	$(0.11 - x) \approx 0.11$	x	x

$$\frac{[HCO_3^-][OH^-]}{[CO_3^{-2}]} = \frac{(x)(x)}{0.11 - x} \approx \frac{(x)(x)}{0.11} = 1.8 \times 10^{-4}$$

$$x = [OH^-] = 4.4 \times 10^{-3}\ mol.dm^{-3}$$

And

$$P^{OH} = -\log(4.4 \times 10^{-3}) = 2.36$$

Finally, $P^H = 14.00 - 2.36 = 11.64$

22. Answer: D

While Lewis theory is useful to explain the bonding behavior in many molecules, it does not work for complex molecules involving d or f electron species such as $[PtCl_2(NH_3)_2]$ or even simpler molecules such as PF_5 which can be hypervalent.

Similarly the simple heteronuclear species NO is electron deficient or electron rich if two (to satisfy the O) or three (to satisfy the nitrogen) are shared. This illustrates some of the limitations of Lewis theory and why more advanced theories have since been developed.

N_2 is the only molecule in this set that is fully explained by Lewis theory, if each nitrogen shares three electrons, a triple bond is created and both nitrogen atoms have an octet.

23. Answer: A

A catalyst remains unchanged in the reactions, so it did not undergo a permanent change

24. Answer: B

Reasoning To penetrate a nucleus, a particle such as a neutron, a proton, or an $\boldsymbol{\alpha}$ particle must have enough kinetic energy to do the work of overcoming any repulsive force that it encounters. A repulsive force can arise because protons in the nucleus are electrically charged. Since a neutron is electrically neutral, however, it encounters no electrostatic force of repulsion as it approaches the nuclear protons, and, hence, needs relatively little energy to reach the nucleus.

Answers (A) and (C) are incorrect. A proton and an $\boldsymbol{\alpha}$ particle each carry a positive charge, so that each would encounter an electrostatic force of repulsion as it approached the nuclear protons, a force that a thermal neutron does not encounter. These answers ignore the additional kinetic energy that a proton or an $\boldsymbol{\alpha}$ particle would need to overcome the repulsion.

Answer (B) is correct. A proton and an $\boldsymbol{\alpha}$ particle, each being positively charged, would each require much more kinetic energy than a neutron does, in order to overcome the electrostatic force of repulsion from the nuclear protons. It is true that each would also experience the attractive strong nuclear force from the nuclear protons and neutrons.

However, this force has an extremely short range of action and, therefore, would come into play only after an impinging particle reached the target nucleus. In comparison, the electrostatic force has a long range of action and is encountered throughout the entire journey to the target.

25. Answer: C

The forces must be in the same direction as on the original diagram.
F to right, T pulling up, W down ∴ NOT A or D. Forces must be head-to-tail ∴ not A. Angle θ is wrong in B; it should be between the horizontal and T.
Use original diagram to obtain the correct triangle. Extend W up so that it is head- to-tail to T and move F to close triangle.

26. Answer: C

Electrons are negative ∴ will accelerate in the opposite direction to the field, which is in the direction that a positive charge would move (+ to -).

27. Answer: D

$F = G\frac{mM}{r^2}$

Thus $F \propto \frac{m}{r^2} = \frac{(\frac{9}{10}m)}{(\frac{3}{4}r)^2} = 1.6$ F

28. **Answer : B**

Solution: When a magnesium atom becomes a magnesium ion, it must lose two electrons, and they appear in the products when we express the reaction as an equation.

$Mg \rightarrow Mg^{+2} + 2e^-$

By losing electrons, *magnesium is oxidized*, *so it is the reducing agent*.

When oxygen reacts to yield O^{2-} ions, each oxygen atom must gain two electrons, so an O_2 molecule must gain four electrons; these electrons appear on the reactant side of the equation.
$O_2 + 4e^- \rightarrow 2O^{2-}$
By gaining electrons, *O_2 is reduced* and *must be the oxidizing agent*.

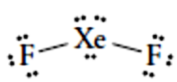
29. Answer: B

Solution In solution, K_3PO_4 dissociates into K^+ and PO_4^{-3} ions and $Ca(NO_3)_2$ dissociates into Ca^{+2} and NO_3^- ions. Calcium ions (Ca^{+2})and phosphate ions (PO_4^{-3}) will form an insoluble compound, calcium phosphate [$Ca_3(PO_4)_2$], while the other product, KNO_3, is soluble and remains in solution. Therefore, this is a precipitation reaction.

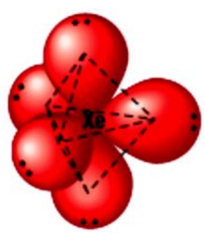
30. **Answer : D**

Analysis: The first step will be to correctly write the formula of the compound. Then we can construct the Lewis formula, from which we can derive the shape of the molecule by applying the VSEPR model

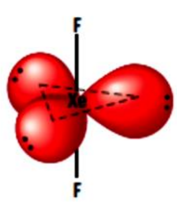
Solution: The outer shell of xenon, of course, has a noble gas configuration, which contains 8 electrons. Each fluorine has 7 valence electrons. Using this information we obtain the following Lewis structure for XeF_2.



Next we count domains around xenon; there are five of them, three nonbonding and two bonding. When there are five domains, they are arranged in a trigonal bipyramid.



Now we must add the fluorine atoms. In a trigonal bipyramid, the nonbonding domains always occur in the equatorial plane through the center, so the fluorines go on the top and bottom. This gives



The three atoms, $F–Xe–F$, are arranged in a straight line, so the molecule is linear

31. Answer: B

$P = V^2R$

If V is halved, then $P = \left(\frac{1}{2}V\right)^2 R = \frac{1}{4}P$

32. Answer: D

Impulse: $F_{net} = \frac{m[v-(-v)]}{\Delta t}$ $(towards\ the\ wall + ve\ and\ away\ from\ the\ wall - ve)$

$$\Delta t = \frac{2mv}{F}$$

33. Answer: A

$$W = G\frac{m_1 m_2}{r^2}$$

$$W_{new} = G\frac{m_1 \frac{1}{2} m_2}{3^2 r^2} = \frac{W}{18}$$

34. Answer: A

Bulb X gets 2 x more current than bulb Y.

$P_Y = I^2R$ $\qquad$ $PX = (2I)^2R = 4\ I^2R$

$P_X : P_Y$ $\qquad$ $4\ I^2R : 1\ I^2R$

∴ **4:1**

35. Answer: D

$$\frac{[NO_2]^2}{[N_2O_4]} = 4.50$$

	$N_2O_4(g)$	$2NO_2(g)$
Initial concentrations $(mol.dm^{-3})$	0.150	0.00
Change in concentrations $(mol.dm^{-3})$	$-x$	$+2x$
Equilibrium concentrations $(mol.dm^{-3})$	$0.150 - x$	$2x$

To obtain the solution, we substitute the equilibrium quantities into the mass action expression.

$$\frac{[NO_2]^2}{[N_2O_4]} = 4.50$$

$$\frac{(2x)^2}{(0.150-x)} = 4.50$$

$$4x^2 + 4.50x - 0.675 = 0$$

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

$$x = \frac{-4.50 \pm \sqrt{(4.50)^2-4(4)(-0.675)}}{2(4)} = \frac{-4.50 \pm 5.57}{8}$$

Because of the $\pm$ term, there are two values of x that satisfy the equation, $x = 0.134$ and $x = -1.26$. However, only the first value, $x = 0.134$, makes any sense chemically, as described below. Using $x = 0.134$, the equilibrium concentrations are

$$[N_2O_4] = 0.150 - 0.134 = 0.016\ mol.dm^{-3}$$

$$[NO_2] = 2(0.134) = 0.268\ mol.dm^{-3}$$

36. Answer: C

Solution:

(i) Adding H_2O will cause the equilibrium to shift to the right, in a direction that will consume some of the added H_2O. The amount of CO will increase.
(ii) When the pressure in the system drops, the system responds by producing more molecules of gas, which will tend to raise the pressure and partially offset the change. If the reaction goes from left to right, we use up two molecules (one CH_4 and one H_2O) and form four molecules (one CO and three H_2). This yields a net increase in the number of molecules, so some CH_4 and H_2O react and the amount of CO at equilibrium will increase.
(iii) Because the reaction is endothermic, we write the equation showing heat as a reactant:

$$\text{Heat} + CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

Raising the temperature is accomplished by adding heat, so the system will respond by absorbing heat. This means that the equilibrium will shift to the right and the amount of CO at equilibrium will increase.

(d) A catalyst causes a reaction to reach equilibrium more quickly, but it has no effect on the position of chemical equilibrium. Therefore, the amount of CO at equilibrium will not be affected.
Finally, the *only* change that alters K is the temperature change. Raising the temperature (adding heat) will increase K_c for this endothermic reaction.

37. Answer : B

Solution: First, we will write two half-reactions (in the form of reduction half reactions) for Cu^{2+} reduced to Cu(*s*) and for Al^{3+} reduced to Al(*s*). Our tool for predicting spontaneous reactions indicates that the half-reaction with the more positive standard reduction potential will occur as a reduction; the other will occur as an oxidation. In this cell, then, Cu^{2+} is reduced and Al is oxidized. To obtain the cell reaction, we add the two half-reactions, remembering that the electrons must cancel. This means we must multiply the copper half-reaction by 3 and the aluminum half-reaction by 2.

$3[Cu^{+2}(aq) + 2e^- \rightarrow Cu\ (s)]$ (Reduction)

$2[Al\ (s) \rightarrow Al^{+3}(aq) + 3e^-]$ (Oxidation)

$3Cu^{+2}\ (aq) + 2Al\ (s) \rightarrow 3Cu\ (s) + 2Al^{+3}\ (aq)$

$$E^\circ_{cell} = E^\circ_{Cu^{+2}} - E^\circ_{Al^{+3}}$$

$$= (0.34\ V) - (-1.66\ V) = 2.00\ V$$

An important point to notice here is that *although we multiply the half-reactions by factors to make the electrons cancel,* ***we do not multiply the standard reduction potentials by these factors.*** To obtain the standard cell potential, we simply subtract one standard reduction potential from the other.

38. Answer: B

Strategy : The half-reactions for the process are:

Anode (Oxidation) : $2H_2O\ (l) \rightarrow O_2\ (g) + 4H^+\ (aq) + 4e^-$

Cathode (Reduction): $4\left[H^+\ (aq) + e^- \rightarrow \frac{1}{2}H_2(g)\right]$

Overall: $2H_2O\ (l) \rightarrow 2H_2(g) +\ O_2\ (g)$

We carry out the following conversion steps to calculate the quantity of O_2 in moles:

$$current\ \times time\ \rightarrow charge\ \rightarrow moles\ of\ e^- \rightarrow moles\ of\ O_2$$

Then, using the ideal gas equation we can calculate the volume of O_2 in litres at STP.
A similar procedure can be used for H_2.

Solution First we calculate the number of coulombs of electricity that pass through the cell:

$$?\,C = 1.26A\ \times 7.44h\ \times \frac{3600\ s}{1\ h} \times \frac{1\ C}{1\ A.s} = 3.37\ \times\ 10^4\ C$$

Next, we convert number of coulombs to number of moles of electrons

$$3.37\ \times\ 10^4\ C\ \times \frac{1\ mol\ e^-}{96.500\ C} = 0.349\ mol\ e^-$$

From the oxidation half-reaction we see that 1 mol O_2 $\cong$4 mol e^-. Therefore, the number of moles of O_2 generated is

$$0.349\ mol\ e^-\ \times \frac{1\ mol\ O_2}{4\ mol\ e^-} = 0.0873\ mol\ O_2$$

The volume of 0.0873 mol O_2 at STP is given by

$$V = \frac{nRT}{P}$$

$$= \frac{(0.0873\ mol)(0.0821\ L.atm.K^{-1}.mol)(273\ K)}{1\ atm} = 1.96\ L$$

The procedure for hydrogen is similar. To simplify, we combine the first two steps to calculate the number of moles of H_2 generated:

$$3.37\ \times\ 10^4\ C\ \times \frac{1\ mol\ e^-}{96.500\ C} \times \frac{1\ mol\ H_2}{2\ mol\ e^-} = 0.175\ mol\ H_2$$

The volume of 0.175 mol H_2 at STP is given by

$$V = \frac{nRT}{P}$$

$$= \frac{(0.175\ mol)(0.0821\ L.atm.K^{-1}.mol)(273\ K)}{1\ atm} = 3.92\ L$$

39. Answer: B

Given -

900 = 0,9 kW

2,5 minutes = 2,5 / 60 = 4,17 $\times 10^{-2} h$

The electrical power is $E = Pt$= (0,9)(4,17 $\times 10^{-2}$)= 3,75 $\times 10^{-2}$ kWh

The cost for the electrical power $C = E \times price$= (3,75 $\times 10^{-2}$)(61,6)= 2,31 c

40. Answer: B

about 13% of 7.5 billion.

41. Answer: C

Global CO_2 emissions must decline rapidly to 50% of the current level.

42. Answer: A

Assembling the Tools: All we need is the mole ratio tool that relates P to the chemical formula $Ca_3(PO_4)_2$. We write it as

2 mol P ⇔ 1 mol $Ca_3(PO_4)_2$

Solution: Starting with the equation we expressed above, our tool is rearranged into a conversion factor so that the mol P cancels and we are left with the mol $Ca_3(PO_4)_2$.

Applying that ratio, we get

$$0.864\, mol\ P \times \frac{1\, mol\ Ca_3(PO_4)_2}{2\, mol\ P} = 0.432\, mol\ Ca_3(PO_4)_2$$

43. Answer: D

Solution: first we find the number of grams of C in the CO_2 as

$$1.039\ g\ CO_2 \times \frac{1\ mol\ CO_2}{44.009\ g\ CO_2} \times \frac{1\ mol\ C}{1\ mol\ CO_2} \times \frac{12.011\ g\ C}{1\ mol\ C} = 0.2836\ g\ C$$

For the number of grams of H in 0.6369 g of H_2O we calculate

$0.6369\ g\ H_2O \times \frac{1\ mol\ H_2O}{18.015\ g\ H_2O} \times \frac{2\ mol\ H}{1\ mol\ H_2O} \times \frac{1.0079\ \ g\ H}{1\ mol\ H} = 0.07127\ g\ H$

$The\ total\ mass\ of\ C\ and\ H\ \ =\ 0.2836g\ C + 0.07127\ g\ H = 0.3549\ g$

$Mass\ of\ O\ = 0.5438$ g – 0.3549 g = 0.1889 g O

Now we can convert the masses of the elements to an empirical formula

$$For\ C: 0.2836\ g\ C\ \times \frac{1\ mol\ C}{12.011\ g\ C} = 0.02361\ mol\ C$$

$$For\ H: 0.07127\ g\ H\ \times \frac{1\ mol\ H}{1.0079\ g\ H} = 0.07071\ mol\ H$$

$$For\ O: 0.1889\ g\ O\ \times \frac{1\ mol\ O}{15.999\ g\ O} = 0.01181\ mol\ O$$

Our preliminary empirical formula is thus $C_{0.02361}H_{0.070701}O_{0.1181}$. We divide all these subscripts by the smallest number which is 0.01181, we then get

$$C_{1.999}H_{5.987}O_1$$

The results are acceptably close to integers, to conclude that the empirical formula is C_2H_6O

44. **Answer: C**

Let's set up the problem using dimensional analysis to be sure of our procedure. We will use the fact that 1 mol $Al_2(SO_4)_3$ yields 3 mol SO_4^{-2} *in solution*

$$1\ mol\ Al_2(SO_4)_3\ \Leftrightarrow 3\ mol\ SO_4^{-2}$$

Therefore,

$$\frac{0.9\ mol\ SO_4^{-2}}{1.0\ L\ soln} = \frac{1\ mol\ Al_2(SO_4)_3}{3\ mol\ SO_4^{-2}} = \frac{0.30\ mol\ Al_2(SO_4)_3}{1.0\ L\ soln} = 0.3 mol.dm^{-3}\ Al_2(SO_4)_3$$

The concentration of $Al_2(SO_4)_3\ is\ 0.3 mol.dm^{-3}$

45. Answer: C

Solution: First we apply the nomenclature rules. The ions in potassium nitrate are K^+ and NO_3^-, so the salt has the formula KNO_3. In ammonium chloride, the ions are NH_4^+ and Cl^-, so the salt is NH_4Cl.
Next we write the molecular equation, being sure to construct correct formulas for the products.

$KNO_3 + NH_4Cl \rightarrow KCl + NH_4NO_3$

Looking over the substances in the equation, we don't find any that are weak acids or that decompose to give gases. Next, we check solubilities, both KNO_3 and NH_4Cl are soluble and again both products are also soluble in water.
The anticipated molecular equation is therefore

$KNO_3(aq) + NH_4Cl(aq) \rightarrow KCl(aq) + NH_4NO_3(aq)$
Soluble soluble soluble soluble
and the ionic equation is

$K^+(aq) + NO_3^-(aq) + NH_4^+(aq) + Cl^-(aq) \rightarrow K^+(aq) + Cl^-(aq) + NH_4^+(aq) + NO_3^-$

Notice that the right side of the equation is the same as the left side except for the order in which the ions are written. When we eliminate spectator ions, everything goes. There is no net ionic equation, which means there is no net reaction.

46. Answer: B
RADAR: Radio Detection and Ranging. It uses radio waves. This is an instrument to find out the precise location of distant objects (especially ships and aircraft) by means of radio waves.

47. Answer: B

$$M_A = \frac{F_L}{F_E} = 2.33$$
$$\frac{F_L}{15} = 2.33, therefore\ F_L = 34.95\ N$$

48. Answer: C

An LED is a type of diode that makes one color of light when electricity is sent through it in the expected direction (electrically biased in the forward direction). When the polarity of the battery is such that electrons are allowed to flow through the diode, the diode is said to be forward-biased. Conversely, when the battery is "reversed" and the diode blocks current, the diode is said to be reverse-biased

49. Answer: A

Stars are beautiful, wondrous things. Much like planets, planetoids and other stellar bodies, they come in many sizes, shapes, and even colors. And over the course of many centuries, astronomers have come to discern several different types of stars based on these fundamental characteristics.

For instance, the color of a star – which varies from bluish-white and yellow to orange and red – is primarily due to its composition and effective temperature. And at all times, stars emit light which is a combination of several different wavelengths. On top of that, the color of a star can change over time.

50. Answer: C

In general, refrigerators are cooled through the evaporation of a volatile liquid—that is, they use a liquid that evaporates very easily, and this evaporation creates the cooling effect. They then compress the gas into a liquid again, and the whole process starts over

51. Solution: A

52. Solution: A

53. Answer: B

Newton's Third law as the pressure of the gases exerts a force on the rear of the barrel the rear of the barrel exerts a force on the gases and thus the bullet.

54. Answer: B

The fermentation of sugar is used to produce alcohol not hydrogen.

55. Answer: B

Hypervalent molecules have an expanded octet. In these examples only SF_4 is hypervalent and would have 10 electrons in its outer shell; 6 from the sulfur and one each from the four fluorine. Of the rest, both CF_4 and NF_3 have 8 electrons, but BF_3 is electron poor with only 6 (three from the boron and one each from the three fluorine)

56. Answer: A

<u>Fermentation</u> is used to produce bioethanol

And <u>Transesterification</u> is used to produce biodiesel

57. Answer: C

VSEPR theory predicts that the anion $TeBr_6^{2-}$ has a shape based on a pentagonal bipyramid with one site containing a lone pair.

However, this is not the shape observed. Crystallographic measurements show that the ion is octahedral. This is explained by the lone pair occupying an s orbital. This electron pair is described as stereochemically inactive as it does not influence the geometry.

The assumption of VSEPR theory that all of the valence electrons contribute to the shape is incorrect in this case

58. Answer: A

Solution: Tracers

59. Answer: D

Alpha radiation is a helium nucleus (He^{2+}) which is larger than the other types of radiation and can be stopped by the skin.

60. Answer: B

$$\Delta H = \sum heat\ added\ to\ break\ old\ bonds - \sum heat\ released\ when\ new\ bonds\ are\ made$$

$$\begin{aligned} &= \left[\left(1(Br\text{–}Br) + 3\,(F\text{–}F)\right) - (6(BrF))\right] \\ &= [(1 \times 192) + (3 \times 158) - (6 \times 197)] \\ &= -516\ kJ \end{aligned}$$

61. **Answer: B**

Amine: An organic compound whose molecules contain the group NH_2, NHR, or NR_2.

62. Answer: B

The first indication that atoms had internal structure was the discovery of the electron. When a high voltage electric current was passed through a gas at low pressure, negatively charged particles were observed to travel between the electrodes. These so-called cathode rays were the same whatever gas was used, and we now know them as electrons. J.J. Thomson applied electric and magnetic fields to a beam of electrons and used the deviations from a straight line to calculate the ratio of charge to mass for the particles.

63. Answer: D

Reasoning Since both vehicles move at a constant velocity, each constitutes an inertial reference frame. According to the speed-of-light postulate, all observers in inertial reference frames measure the speed of light in a vacuum to be c.

Answers (A) and (B) are incorrect. Since the renegades' spacecraft constitutes an inertial reference frame, the velocity of the laser beam relative to it can only have a value of $v_{LS} = +c$,according to the speed-of-light postulate.

Answer (C) is incorrect. The velocity at which the renegades see the laser beam move away from the cruiser cannot be $v = +0.7c$, because they see the cruiser moving at a velocity of +0.7c and the laser beam moving at a velocity of only +c (not +1.4c).

Answer (D) is correct. The renegades see the cruiser approach them at a relative velocity of $v_{CS} = +0.7c$ and see the laser beam approach them at a relative velocity of $v_{LS} = +c$. Both these velocities are measured relative to the same inertial reference frame—namely, that of their own spacecraft. Therefore, the renegades see the laser beam move away from the cruiser at a velocity that is the difference between these two velocities, or$+c - (+0.7c) = +0.3c$.

The velocity-addition formula does not apply here because both velocities are measured relative to the same inertial reference frame. velocity-addition formula is used only when the velocities are measured relative to different inertial reference frames.

64. Answer: B

Explanation:

Remember that, the combined ideal gas is simply a combination of the other gas laws that works when **everything** except <u>temperature, pressure, and volume</u> are held constant.

There are a couple of common equations for writing the combined gas law. The classic law relates Boyle's law and Charles' law to state:

$$\frac{PV}{T} = k$$

where P = pressure, V = volume, T = absolute temperature, and k = constant.
The constant k is a true constant if the <u>number of moles of the gas doesn't change. Otherwise, it varies</u>.

65. Answer: B

The induced emf is proportional the rate of change of flux. Thus, it is a minimum at the peaks of the waveform. At the time interval 2s – 3s the plane of the coil is perpendicular to the magnetic field, the induced emf is a minimum.

66. Answer: C

Q = I x t
4 = 2 x t
thus t = 2 s
W = VIt = 12 x 2 x 2 = 48 J

67. Answer: A

Current is flowing from pos. to neg. terminal. Using right hand rule, thumb indicates north pole on far end away from **X** (and your four fingers point in the direction of the current), so **X** is south pole and current going into page

68. Answer: C

Solution: We now restate the problem as
1.50 L N_2 ⇔ ? L H_2
We use the volume ratio, now in L units, to express the equivalence
3 L H_2 ⇔ 1 L N_2
This volume equivalence is used to construct the conversion factor, and our solution is

$$1.5 L\ N_2 \times \frac{3\ L\ H_2}{1\ L\ N_2} = 4.50\ L\ H_2$$

69. Answer: C

Solution: Any use of the ideal gas law requires the correct units. The pressure given is already in atmospheres and the volume is in liters, but we must convert degrees Celsius into kelvins. Gathering our data, we have

$P = 0.757$ atm

$V = 0.220$ L

$T = 298$ K (25.0 °C + 273)

$$n = \frac{PV}{RT}$$

$$n = \frac{(0.757\ atm)(0.220\ L)}{(0.0821\ L.atm.mol^{-1}.K^{-1})(298\ K)} = 6.81\ \times 10^{-3}\ mol$$

The molar mass is obtained from the ratio of grams to moles:

$$molar\ mass = \frac{0.299\ g}{6.81\ \times\ 10^{-3}\ mol} = 43.9\ mol^{-1}$$

We now know the measured molar mass is 43.9, but what gas could this be?

What gases do we know are given off when a substance reacts with acids? We find some options, the gases might be H_2S, HCN, CO_2, or SO_2, using atomic masses to calculate their molar masses, we get

$H_2S = 34\ g.mol^{-1}$

$CO_2 = 44\ g.mol^{-1}$

$HCN = 27\ g.mol^{-1}$

$SO_2 = 64\ g.mol^{-1}$

The only gas with a molar mass close to 43.9 is CO2, and that gas would be evolved if we treat a carbonate with an acid. The rock probably contains a carbonate compound. (Limestone and marble are examples of such minerals.)

70. Answer: A

Strategy: Classify the species into three categories: ionic, polar (possessing a dipole moment), and nonpolar. Keep in mind that dispersion forces exist between all species.

(i) Both HBr and H_2S are polar molecules. Therefore, the intermolecular forces present are dipole-dipole forces, as well as dispersion forces.

(ii) Both Cl_2 and CBr_4 are nonpolar, so there are only dispersion forces between these molecules.

(iii) I_2 is a homonuclear diatomic molecule and therefore nonpolar, so the forces between it and the ion NO_3^{-2} are ion-induced dipole forces and dispersion forces.

(iv) NH_3 is polar, and C_6H_6 is nonpolar. The forces are dipole-induced dipole forces and dispersion forces.

71. Answer: A

$2NaNO_3\ (s) \rightarrow 2NaNO_2\ (s) + O_2\ (g)$
Splinter bursts into flames because of oxygen gas being liberated.

72. Answer: B

A transformer is an electrical apparatus designed to convert alternating current from one voltage to another. It can be designed to "step up" or "step down" voltages and works on the magnetic induction principle. It consists of two or more coils of insulated wire wound on a laminated steel core. When voltage is introduced to one coil, called the primary, it magnetizes the iron core. A voltage is then induced in the other coil, called the secondary or output coil. The change of voltage (or voltage ratio) between the primary and secondary depends on the turns ratio of the two coils.

73. Answer: A

$[Cr(NH_3)_6](NO_3)_3$

74. Answer: C

The power in the wind is proportional to the cube of the wind velocity.

75. Answer: A

STRATEGY
To predict the direction of reaction, use the balanced equation to identify the proton donors (acids) and proton acceptors (bases), and then identify the stronger acid and the stronger base. When equal concentrations of reactants and products are present, proton transfer always occurs from the stronger acid to the stronger base.
SOLUTION

(i) $H_2SO_4(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + HSO_4^-(aq)$

in this reaction, H_2SO_4 and NH_4^+ are the acids, AND NH_3 and HSO_4^- are the bases.

H_2SO_4 is a stronger acid than NH_4^+

NH_3 is a stronger base than HSO_4^-

Therefore, NH_3 gets the proton, and the reaction proceeds from left to right.

(ii) $HCO_3^-(aq) + SO_4^{2-}(aq) \rightleftharpoons HSO_4^-(aq) + CO_3^{2-}(aq)$

In this reaction,

HSO_4^- is stronger acid than HCO_3^-
CO_3^{-2} is stronger base than SO_4^{-2}

Therefore, CO_3^{-2}gets the proton, and the reaction proceeds from right to left

76. Answer: D

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.0 \times 10^{-14}}{2.5 \times 10^{-3}} = 4.0 \times 10^{-12}\ mol.dm^{-3}$$

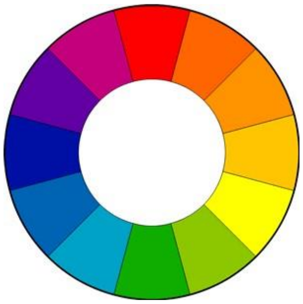
Because $[H_3O^+] > [OH^-]$, the solution is acidic

77. Answer: C

$$average\ speed = \frac{90\ km}{\frac{45}{60}h} = 120\ km.h^{-1}$$

78. Answer: A

The colour of organic pigments such as Lycopene (red) is due to their ability to absorb electromagnetic radiation in the visible region of the spectrum. The colour a pigment appears, is the complement of the colour its molecules absorb. So a molecule, such as Lycopene, that absorbs light in the Blue-Green region of the visible spectrum will appear as Orange-Red. Colours on opposite sides of the Colour Wheel are complementary. Complementary colours are provided by the standard Colour Wheel:

 **http://www.tigercolor.com/color-lab/color-theory/color-theory-intro.htm**

79. Answer: D

Sunlight travels at the speed of light. Photons emitted from the surface of the Sun travel across the vacuum of space and take an average of 8 minutes and 20 seconds to reach Earth

80. Answer: C

Solution: C

81. Answer: D

Each of these atoms or ions has 18 electrons. The greater positive charge in the Ca^{+2} nucleus (20 protons) has a greater pull on the electrons than do the smaller charges in Ar (18 protons) and Cl^{-}(17 protons). Thus, Ca^{+2} is the smallest and $Cl^{-}$is the largest of these three.

82. Answer: C
Mass number = number of protons + number of neutrons
Where number of protons = Atomic number = x
Therefore; Number of Neutrons = $(2x + 4) - x = x + 4$

83. Answer: B

Expansion of biomass use is limited by concerns about competition for land use for food production and hydropower expansion is limited by environmental concerns.

84. Answer: B
Although high voltage AC is normally used for land-based transmission lines it is difficult to use for undersea cables

85. Answer: B

Reasoning We can analyze this problem by disassembling the pattern into separate tiles, heating them, and then reassembling the pattern. What happens to each of the individual tiles can be explained using what we know about linear expansion.
Answer (A) is incorrect. When a tile is heated both its length and width expand. It is tempting to think, therefore, that the hole in the pattern decreases as the surrounding tiles expand into it. However, this is not correct, because any one tile is prevented from expanding into the hole by the expansion of the tiles next to it.
Answer (B) is correct. Since each tile expands upon heating, the pattern also expands, and the hole along with it. In fact, if we had a ninth tile that was identical to the others and heated it to the same extent, it would fit exactly into the hole. Thus, not only does the hole expand, it does so exactly as each of the tiles does. Since the ninth tile is made of the same material as the others, we can predict that the hole expands just as if it were made of the material of the surrounding tiles. The thermal expansion of the hole and the surrounding material is analogous to a photographic enlargement: everything is enlarged, including holes.

86. Answer: D

Reasoning

An object is in equilibrium when it has no acceleration. If the object's velocity remains constant, both in magnitude and direction, its acceleration is zero.

Answer (B) is incorrect. As the car goes around the turn, the direction of travel changes, so the car has a centripetal acceleration that is characteristic of uniform circular motion. Because of this acceleration, the car is not in equilibrium during the turn.

Answers (A) and (C) are correct. As the car either approaches the turn or moves away from the turn it is traveling along a straight line, and both the speed and direction of the motion are constant. Thus, the velocity vector does not change, and there is no acceleration. Consequently, for these parts of the motion, the car is in equilibrium.

87. Answer: C

$R_1 : R_1$
$1 : \frac{1}{2}$
$2 : 1 \; (Total\ of\ ratio = 3)$
$since\ I \propto \frac{1}{R}\ (resistors\ in\ parallel)$
$\therefore\ ^2/_3$ of I total will flow through R_2 and $^1/_3$of Itotal will flow through R_1
Hence , Iacross $R_1 = 1A$ and Iacross $R_2 = 2A$

88. Answer: A

Reasoning : To answer this question, we need to examine the nature of the job done by the pump in each place. The pump at the bottom of the well pushes water up the pipe, while the pump at ground level does not push water at all. Instead, the ground-level pump removes air from the pipe, creating a partial vacuum within it. (It's acting just like you do when drinking through a straw. You draw some of the air out of the straw, and the external air pressure pushes the liquid up into it.)

Answer (B) is incorrect. As the pump at ground level removes air from the pipe, the pressure above the water within the pipe is reduced. The greater air pressure outside the pipe pushes water up the pipe. However, even the strongest pump can only remove all of the air. Once the air is completely removed, an increase in pump strength does not increase the height to which the water is pushed by the external air pressure. Thus, the ground-level pump can only cause water to rise to a certain maximum height and cannot be used for very deep wells.

Answer (A) is correct. For a very deep well, the column of water becomes very tall, and the pressure at the bottom of the pipe becomes large. However, as long as the pump can push with sufficient strength to overcome the large pressure, it can shove the next increment of water into the pipe, so the method can be used for very deep wells.

89. Answer: D

F = mg $\quad\quad\quad\quad$ $\boldsymbol{F = G\frac{mM}{r^2}}$

Equating the two equations we get,

$mg = G\frac{mM}{r^2}$

Or $g = G\frac{m}{r^2}$ $(G\ and\ r\ are\ constant)$

$\therefore g = 5g$

90. Answer: C

Reasoning The variables T, P, and n are related to the volume V of a bubble by the ideal gas law (V = nRT/P). We assume that this law applies and use it to guide our thinking. According to this law, an increase in temperature, a decrease in pressure, or an increase in the number of moles could account for the growth in size of the upward-moving bubbles.

Answers (A) and (B) are incorrect. Temperature can be eliminated immediately, since it is constant throughout the beer. Pressure cannot be dismissed so easily. As a bubble rises, its depth decreases, and so does the fluid pressure that a bubble experiences. Since volume is inversely proportional to pressure according to the ideal gas law, at least part of the bubble growth is due to the decreasing pressure of the surrounding beer. However, some bubbles double in volume on the way up. To account for the doubling, there would need to be two atmospheres of pressure at the bottom of the glass, compared to the one atmosphere at the top. The pressure increment due to depth is ρgh, so an extra pressure of one atmosphere at the bottom would mean 1.01×10^5 Pa = ρgh. Solving for h with ρ equal to the density of water reveals that h = 10.3 m. Since most beer glasses are only about 0.2 m tall, we can rule out a change in pressure as the major cause of the change in volume.

Answer (C) is correct. The process of elimination brings us to the conclusion that the number of moles of CO_2 in a bubble must somehow be increasing on the way up. This is, in fact, the case. Each bubble acts as a nucleation site for CO_2 molecules dissolved in the surrounding beer, so as a bubble moves upward, it accumulates carbon dioxide and grows larger.

91. Answer: B

Reasoning : When the truck is stationary, the air outside and inside the cargo area is stationary, so the pressure is the same in both places. This pressure applies the same force to the outer and inner surfaces of the canvas, with the result that the tarpaulin lies flat.

When the truck is moving, the outside air rushes over the top surface of the canvas, and the pressure generated by the moving air is different than the pressure of the stationary air.

Answer (A) is incorrect. A higher pressure outside and a lower pressure in the cargo area would cause the tarpaulin to sink inward, not bulge outward.

Answer (C) is incorrect. A heating effect would not disappear every time the truck stops and reappear only when the truck is moving.

Answer (B) is correct. According to Bernoulli's principle, the moving air outside the canvas has a lower pressure than does the stationary air inside the cargo area. The greater inside pressure generates a greater force on the inner surface of the canvas, and the tarpaulin bulges outward.

92. Answer: B

$$x \propto t^2$$

If t is double, then x is four times larger

93. Answer: D

All other chemistry facts are TRUE

94. Answer: A

When fats and oils are oxidised, they became rancid and the smell and taste changes. Usually substances which prevent oxidation are added to foods containing fats and oil to preserve them and extend the shelf life

95. Answer: B

Solution: Potassium

96. Answer: A

Mg gains electrons more readily than Fe, keeping the Fe from oxidising.

97. Answer: C

Some colors of glass are widely known. Perhaps the best example of this is "cobalt blue" that is produced by adding cobalt oxide to the glass melt. "Vaseline glass" is a fluorescent yellow-green glass that contains small amounts of uranium oxide. "Ruby gold" and "cranberry glass" are red glasses produced by the addition of gold. "Selenium ruby" is a red color caused by the addition of selenium oxide, and "Egyptian blue" is produced by the addition of copper.

98. Answer: A

Bond lengths can be measured using diffraction techniques.

Diffraction is a type of interference between waves, and it occurs when the wavelength is similar to the size of the object involved.

The best technique for studying molecules in the gas phase is electron diffraction. This is because the wavelength of a beam of electrons is of the same order as the distance between the atoms in the molecules. The electron beam wavelength can be tuned to the value required, as the wavelength depends on the velocity of the electrons.

99. Answer: B

The mass of sodium ions in 4.57×10^{-3} mol = 0.105 g = 105 mg.

Therefore, in 1 dm^3 of water (= 1 kg), there are 105 mg, hence the concentration is 105 ppm.

100. Answer: D

All of the above are true