The amount of energy needed to change a sample of a substance of mass m from a solid to a liquid or vice versa without any change in its temperature is proportional to its mass with the following formula \[Q_f=\pm mL_f\] where L_f is called the latent heat of fusion of that substance. Plus sign indicates that heat must be added to the substance during the melting process. Minus sign shows that heat must be removed from the substance during the freezing process. The SI units of latent heat of fusion are J/kg or cal/kg. It is also known as the enthalpy of fusion. The latent heat of fusion of water is $333.5\,{\rm kJ/kg}$. This number indicates that to melt one kilogram of solid water (ice) into liquid water, we must extract $333.5\,{\rm kJ}$ heat from the ice. In all heat problems, first, identify whether there is a temperature change or not. If there was, then use the equation $Q=mC\Delta T$ to solve the unknown. If not, then read this article. Further solving: Specific heat problems with answers Heat examples problems with solutions Latent Heat of Fusion Example Problems with Answers: Problem (1): How much heat is needed to change $2\,{\rm kg}$ of ice at ${\rm -20^\circ C}$ into ${\rm 100^\circ C}$ water? (specific heats of ice and water are $2.05\,{\rm kJ/kg\cdot ^\circ \!C}$ and $4.18\,{\rm kJ/kg\cdot ^\circ \!C}$, respectively) Solution: this is the simplest example of a latent heat problem. The total heat needed to change ice into steam breaks into four parts: Q_1, is the heat required to change its temperature from ${\rm -20^\circ C}$ to ${\rm 0^\circ C}$. Q_2 is the heat needed to melt the ice or phase change. Q_3 is the heat required to increase the temperature from $0^\circ C$ to $100^\circ C$ and Q_4 is the heat needed to vaporize the water. Now, we calculate each part as follows: In the part one, there is a change in temperature so we have \begin{align*}Q_1&=mc_{ice}(T_f-T_i)\\&=(2)(2.05)(0-(-20))\\&=82\quad {\rm kJ}\end{align*}In the next level, there is a phase change (solid to liquid) so we have \begin{align*} Q_2&=mL_f\\&=(2)(333.5)\\&=667\quad {\rm kJ}\end{align*}In the final level, the temperature changes so \begin{align*}Q_3&=mc_{water}\Delta T\\&=(2)(4.18)(100-0)\\&=836\quad{\rm kJ}\end{align*}By adding the above heats together, the total heat required is found \[Q=Q_1+Q_2+Q_3=1585\,{\rm kJ}\] Problem (2): How much heat is needed to transform $2\,{\rm kg}$ of ice at ${\rm -15 ^\circ C}$ into $2\,{\rm kg}$ of water at ${\rm 70^\circ C}$? Solution: first, the ${\rm -15^\circ C}$-ice must absorb the following heat Q_1 to reach ${\rm 0^\circ C}$-ice. \begin{align*}Q_1&=mc_{ice}\Delta T\\&=(2)(2.05)(0-(-15))\\&=61.5\quad{\rm kJ}\end{align*}Then, it must transform into ${\rm 0^\circ C}$-water by absorbing the heat Q_2 as below \begin{align*} Q_2&=mL_f\\&=(2)(333.5)\\&=667\quad{\rm kJ}\end{align*}In the final stage, the heat Q_3 is needed to increase the temperature of the water (melted ice) from ${\rm 0^\circ C}$ to ${\rm 70^\circ C}$ as following \begin{align*} Q_3&=mc_{water}\Delta T\\&=(2)(4.18)(70-0)\\&=585.2\quad {\rm kJ}\end{align*}Summing up the above heats get the total heat needed to ${\rm -15^\circ C}$-ice absorbs and transforms into ${\rm 70^\circ C}$-water. \[Q=Q_1+Q_2+Q_3=1313.7\quad {\rm kJ}\] As you can see, the heat required to melt the ice is the smallest amount. Since in the solid phase (ice) the molecules are very close together thus given heat quickly spread across the whole solid and consequently much less heat is needed. Problem (3): In an isolated container, we add $4\,{\rm kg}$ of ice at ${\rm -10^\circ C}$ to the 40 liters of existing water at ${\rm 40^\circ C}$. When the water reaches equilibrium, what is its temperature? Solution: here, we have two materials: ice gains heat, warms, and then melts. Water releases its heat (because of its higher temperature) and cools down to a lower temperature. To see, whether the heat released by water can melt the whole ice we must first find the gained and released heat as below: Ice gains the heat Q_1+Q_2 to reaches ${\rm 0^\circ C}$-water where Q_1 is for ${\rm -10^\circ C}\rightarrow {\rm 0^\circ C}$ and Q_2 is for ${\rm 0^\circ C}$-ice to ${\rm 0^\circ C}$-water, thus \begin{align*}Q_1&=m c_{ice}\Delta T\\&=(4)(2.05)(0-(-10))\\&=82\quad {\rm kJ}\\ \\ Q_2&=mL_f\\ &=(4)(333.5)\\&=1334\quad{\rm kJ}\end{align*}Consequently, the energy gained by the ice is \[Q_{gained}=Q_1+Q_2=1416\,{\rm kJ}\] Next, we must find how much heat energy Q_3 is released during the water cooling process: ${\rm 40^\circ C}$-water to ${\rm 0^\circ C}$-water. Keep in mind that in the problem the volume of the water is given so using the definition of density, $\rho=mV$, we can find its mass as below \begin{align*} m&=\rho V\\ &={\rm \left(1000\,\frac{kg}{m^3}\right)(40\,L)\left(\frac{1\,m^3}{1000\,L}\right)}\\ \\&=40\quad {\rm kg}\end{align*}Where the last parenthesis is the conversion factor from $L\rightarrow m^3$. Now we compute the heat Q_3 as below \begin{align*}Q_3&=mc_{water}\Delta T\\&=(\rho V)c\Delta T\\&=(40)(4.18)(0-40)\\&=-6688\quad{\rm kJ}\end{align*} The minus sign indicates that the heat is leaving the water. The comparison between those two heats shows that the heat released by the water is enough to melt the ice totally (reaches the ${\rm 0^\circ C}$-water) and its remaining causes the temperature of the water to reach the final point T_f. Thus, the remaining heat $Q_{net}=6688-1416=5272\,{\rm kJ}$ changes the temperature of $40\,{\rm kg}$ of water at ${\rm 0^\circ C}$ to some temperature T_f as below \begin{align*} Q_{net}&=mc_{w}\Delta T\\5272&=(40)(4.18)(T_f-0)\\\Rightarrow T_f&={\rm 31.53^\circ C}\end{align*} In the above, we used the absolute value of the heat released by the water. The negative is a sign of the input or the output of heat and does not affect solving the heat problems. There is also another solution for this example problem with the help of the conservation of energy. See the next problem. Problem (4): A $200-g$ ice cube at ${\rm 0^\circ C}$ is dropped into ${\rm 1-kg}$ of water initially at ${\rm 10^\circ C}$. What is the final temperature of the mixture? (Assume no heat is released to the surroundings) Solution: Method (I): the heat Q_{gain} is the absorbed heat by the ice to transform from ${\rm 0^\circ C}$-ice to ${\rm 0^\circ C}$-water as below \begin{align*}Q_{gained}&=m_{ice}L_f\\ &={\rm (0.200\,kg)(333.5\,kJ/kg)}\\ &=66.7\quad{\rm kJ}\end{align*} The heat released by the $1\,{\rm kg}$ of water to transform from ${\rm 10^\circ C}\rightarrow {\rm 0^\circ C}$ is calculated as below \begin{align*}Q_{lost}&=m_{w}c\Delta T\\&=(1)(4.18)(0-10)\\&=-41.8\quad {\rm kJ}\end{align*} As you can see, ice needs more heat to completely melts and transforms into ${\rm 0^\circ C}$-ice since \[Q_{gained}>|Q_{lost}|\] Where $|\cdots|$ gets the absolute value of the heat lost. Thus, the ice can not be totally melted and there be some ice cubes in the mixture. Method (II): using conservation of energy At first, we assume that all of the ice melts and transforms at ${\rm 0^\circ C}$ into the water at temperature T_f. Ice gains the thermal energy released by the water. Since there is no heat exchange with the environment so according to the conservation of energy sum of those heat must be zero. Therefore, \begin{gather*} Q_{gained}+Q_{lost}=0 \\ \\ \underbrace{m_{ice}L_f}_{Q_1}+\underbrace{m_{ice}c_{ice}(T_f-0)}_{Q_2}+\underbrace{m_wc_w(T_f-10)}_{Q_3}=0\\ \\ (0.200)(333.5)+(0.200)(2.09)(T_f-0)+(1)(4.18)(T_f-10)=0 \\ \\ \Rightarrow T_f={\rm -5.5^\circ C}\end{gather*} A final temperature of below ${\rm 0^\circ C}$ is not correct because no amount of ice at ${\rm 0^\circ C}$ can decrease the temperature of a substance at higher temperature T to below ${\rm 0^\circ C}$. As a rule of thumb, in all heat problems, the final (equilibrium) temperature is always between the initial temperatures of the given materials. Consequently, at the final, we have a mixture of ice and water with the equilibrium temperature of ${\rm 0 ^\circ C}$. Problem (5): A ${\rm 80-g}$ ice cube at ${\rm 0^\circ C}$ is dropped into ${\rm 725-g}$ of water originally at ${\rm 24^\circ C}$. What is the final temperature of the mixture? ($c_{water}=4.18\,{\rm kJ/kg\cdot ^\circ C}$, $c_{ice}=2.090\,{\rm kJ/kg\cdot ^\circ C}$, and $L_f=333.5\,{\rm kJ/kg}$). Solution: water has a higher temperature so it releases its heat as $Q_{released}=Q_1$ and the ice absorbs it $Q_{abs}=Q_2+Q_3$. Initially, we assume that all of the ice melts and converts to ${\rm 80-g}$ of water at a temperature of T_f. By energy conservation, the algebraic sum of those heats must be zero. Thus, we have \begin{gather*} Q_{released}+Q_{gained}=0\\ \\ \underbrace{m_w c_w(T_f-24)}_{Q_1}+\underbrace{m_{ice}L_f}_{Q_2}+\underbrace{m_{ice}c_{ice}(T_f-0)}_{Q_3}=0\\ \\ (0.725)(4.180)(T_f-24)+(0.080)(333.5)+(0.080)(4.18)(T_f-0)=0\\ \\ -(3.0305)(T_f-24)+26.68=0\\ \\ \Rightarrow T_f= {\rm 13.6^\circ C}\end{gather*} Therefore, at the final the equilibrium temperature is ${\rm 13.6^\circ C}$. Problem (6): Into a aluminum container with mass of ${\rm 400-g}$ and specific heat of $c_{Al}=0.900\,{\rm kJ/kg\cdot ^\circ C}$ at ${\rm 25^\circ C}$ is poured ${\rm 5\,kg}$ of ethyl alcohol at ${\rm 30^\circ C}$ and is dropped a ${\rm 200\,g}$ ice cube at ${\rm -15^\circ C}$. Assume the system is isolated from the surrounding. What is the final equilibrium temperature of the mixture? Solution: Since the container is isolated, there is no heat exchange with the surrounding. According to the conservation of energy, some of the heat gained and lost must be zero. Aluminum container and alcohol lose their thermal energies since they are at a higher temperature and the ice gains those heat. As before, we assume that all of the ice melts and reaches a temperature of T_f higher than zero. During this process \[\underbrace{-15^\circ C}_{ice}\stackrel{Q_1}{\longrightarrow} \underbrace{0^\circ C}_{ice}\stackrel{Q_2}{\longrightarrow}\underbrace{0^\circ C}_{water}\stackrel{Q_3}{\longrightarrow} \underbrace{T_f}_{water}\] the amount of thermal heats gained by the ice is computed as below \begin{align*} Q_1&=m_{ice}c_{ice}(0-(-15))\\&=(0.200)(2.090)(15)\\&=6.27\quad {\rm kJ} \\ \\ Q_2&=m_{ice}L_f\\&=(0.200)(333.5)\\&=66.7\quad {\rm kJ} \\ \\ Q_3&=m_{ice}c_{water}(T_f-0)\\&=(0.200)(4.18)(T_f)\end{align*} Therefore, the total thermal energy gained is \begin{align*} Q_{gained}&=Q_1+Q_2+Q_3\\&=72.97+0.836T_f\end{align*} On the other side, the container and the water release their thermal heats and reaches at final temperature of T_f below their initial temperatures as \begin{align*} Q_{lost}&=Q_{Al}+Q_{ethyl}\\ \\&=m_{Al}c_{Al}(T_f-25)+m_{ethyl}c_{ethyl}(T_f-30)\\ \\&=(0.400)(0.9)(T_f-25)+(5)(2.4)(T_f-30)\\\\&=12.36T_f-369\end{align*} According to the principle of the conservation of energy all heat lost must be absorbed by the ice so \begin{align*} Q_{lost}+Q_{gained}&=0\\\\ \Rightarrow\quad Q_{gained}&=-Q_{lost} \\ \\ 72.97+0.836T_f&=-(12.36T_f-369)\\ \\ \Rightarrow \quad T_f&={\rm 22.43^\circ C}\end{align*} Problem (7): How much thermal energy does a freezer have to remove from ${\rm 2\, kg}$ of water at a temperature of ${\rm 25^\circ C}$ to make ice at ${\rm -15^\circ C}$? (Assume the ice specific heat capacity is $c_{ice}=2.090\,{\rm kJ/kg\cdot ^\circ C}$ and the water is $c_{w}=4.180\,{\rm kJ/kg\cdot ^\circ C}$). Solution: the process involved is outlined in the below \[\underbrace{25^\circ C}_{water}\stackrel{Q_1}{\longrightarrow}\underbrace{0^\circ C}_{water}\stackrel{Q_2}{\longrightarrow}\underbrace{0^\circ C}_{ice}\stackrel{Q_3}{\longrightarrow}\underbrace{-15^\circ C}_{ice}\] Using the definition of heat capacity, $Q=mc\Delta T$, and heat of fusion, $Q=mL_f$, we have, \begin{align*}Q_1&=mc_w(0-25)\\ &=(2)(4.18)(-25)\\&=-209\quad {\rm kJ}\\ \\ Q_2&=-mL_f\\&=-(2)(333.5)\\&=-667\quad {\rm kJ}\\ \\ Q_3&=mc_{ice}(-15-0)\\&=(2)(2.090)(-15)=-62.7\quad {\rm kJ}\end{align*} Next, summing those heats get the total thermal energy must be removed from the water to lower its temperature from ${\rm 25^\circ C}$ to ${\rm -15^\circ C}$. \begin{align*} Q_{tot}&=Q_1+Q_2+Q_3\\ &=-209-667-62.7\\&=-938.7\quad {\rm kJ}\end{align*} Note that stage two is a freezing process so we must use the definition of the heat of fusion as $Q=-mL_f$ since the heat must be removed from the water. In all heat problems, the negatives show that the thermal energy flows out of the system as we expected. Problem (8): A chunk of ice is taken from the freezer at ${\rm -15^\circ C}$ and is dropped into ${\rm 200\,g}$-an aluminum container filled with ${\rm 450\,g}$ of water at a temperature of ${\rm 24^\circ C}$. After a while, all we have left is water at ${\rm 5^\circ C}$. What was the mass of the ice cubes? Solution: first identify which material loses its heat and which gains it. Because the container and the water inside it are at a higher temperature than the ice cubes, they release their heat and ice absorbs it. The process of reaching ${\rm -15^\circ C}$-ice to water at ${\rm 5^\circ C}$ is as below \[\underbrace{{\rm -15^\circ C}}_{ice}\stackrel{Q_1}{\longrightarrow}\underbrace{{\rm 0^\circ C}}_{ice}\stackrel{Q_2}{\longrightarrow}\underbrace{{\rm 0^\circ C}}_{water}\stackrel{Q_3}{\longrightarrow}\underbrace{{\rm 5^\circ C}}_{water}\] By applying definitions of specific heat and latent heat of fusion the heats are determined as below \begin{align*} Q_1&=m_{ice}c_{ice}(0-(-15))\\&=m_{ice}(2.090)(15)\\&=31.35m_{ice}\\ \\ Q_2&=m_{ice}L_f\\&=m_{ice}(333.5)\\ \\Q_3&=m_{ice}c_{water}(5-0)\\&=m_{ice}(4.180)(5)\\&=20.9m_{ice}\end{align*} Summing those get the absorbed (gained) heat by the ice \[Q_{abs}=385.75m_{ice}\] Next, the container and the water inside it release the heat Q_{lost} and reach from ${\rm 24^\circ C}$ to ${\rm 5^\circ C}$ as below \begin{align*} Q_{lost}&=(m_{cont}c_{Al}+m_{water}c_{water})(5-24)\\&=(0.2\times 0.9+0.450\times 4.18)(-19)\\ &=-39.159\quad {\rm kJ}\end{align*} A negative heat obtained as we expected for a heat lost in a system. Now, setting the heat lost equal to the heat absorbed (conservation of energy) and solving for the unknown mas m_{ice}, we get \begin{align*} \text{gained heat}&=-\text{lost heat} \\ 385.75m_{ice}&=-(-39.159) \\ \Rightarrow \quad m_{ice}&=0.101\quad {\rm kg}\end{align*} Therefore, a ${\rm 101\,g}$-chunk of ice can lower the temperature of the water and the container to the ${\rm 5^\circ C}$. For solving more problems you can also check out the following page: Thermodynamics problems with solutions for AP physics Date Published: 4/11/2021 Author: Ali Nemati When a substance changes its state from a liquid to steam or vice versa, the heat absorbed or released during this process does not lead to a change in the temperature of the substance. In physics the amount of heat lost or gained by a substance when it changes from a gas to liquid (condensing) or liquid to gas (boiling) depends on the total mass m of the substance and its latent heat of vaporization L_v whose formula is \[Q=\pm mL_v\] where plus ($+$) is for a change from liquid to gas and negative ($-$) is for gas to liquid. The SI unit of latent heat of vaporization is joule per kilogram J/kg. For example, The latent heat of vaporization of water is 2260 kJ/kg which indicates the heat required to transform 1 kg of water completely into 1 kg of steam is 2260 kJ. In the following practice problems, by applying latent heat of vaporization, some heat problems involving phase changes are answered. The heat of Vaporization Problems: Problem (1): A 10-g chunk of liquid lead at 1750°C takes 8580 joules of heat to turn into 10-g of gaseous lead at 1750°C. What is the latent heat of vaporization of the lead? (a) 858 kJ/kg (b) 296 kJ/kg (c) 4726 kJ/kg (d) 879 kJ/kg Solution: a liquid stage is being converted into a gaseous state so there is a phase change (boiling). Substitute the known values into the heat of vaporization formula (with plus sign) as below \begin{align*} Q&=+mL_v\\ rm 8580\, {\rm J}&=(0.010\,{\rm kg})L_v \\ \Rightarrow L_v&=858\quad{\rm kJ/kg}\end{align*} Thus, the heat of vaporization of the lead is 858 joules per kilogram or the correct answer is (a). Problem (2): How much thermal energy is needed to change a $30-g$ ice initially at ${\rm -5^\circ C}$ to steam at ${\rm 110^\circ C}$? (Assume $c_{ice}=2.090\,{\rm kJ/kg\cdot ^\circ C}$, $c_{water}=4.18\,{\rm kJ/kg\cdot ^\circ C}$, $c_{steam}=2.010\,{\rm kJ/kg\cdot ^\circ C}$, $L_f=333.5\,{\rm kJ/kg}$ and $L_v=2260\,{\rm kJ/kg}$) (a) 91 kJ (b) 102 kJ (c) 84 kJ (d) 125 kJ Solution: The path from ice at ${\rm -5^\circ C}$ to steam at ${\rm 110^\circ C}$ is as following \[\underbrace{\rm -5^\circ C}_{ice}\stackrel{Q_1}{\longrightarrow}\underbrace{\rm 0^\circ C}_{ice}\stackrel{Q_2}{\longrightarrow}\underbrace{\rm 0^\circ C}_{water}\stackrel{Q_3}{\longrightarrow}\underbrace{\rm 100^\circ C}_{water}\stackrel{Q_4}{\longrightarrow}\underbrace{\rm 100^\circ C}_{steam}\stackrel{Q_5}{\longrightarrow}\underbrace{\rm 110^\circ C}_{steam}\] The amount of heats are calculated as below \begin{align*} Q_1&=mc_{ice}(0-(-5))\\&=(0.030)(2.090)(5)\\&=0.3135 \quad {\rm kJ}\\ \\Q_2&=mL_f\\&=(0.030)(333.5)\\&=10.005 \quad {\rm kJ}\\ \\Q_3&=mc_{water}(100-0)\\&=(0.030)(4.18)(100)\\&=12.54 \quad {\rm kJ}\\ \\Q_4&=mL_v\\&=(0.03)(2260)\\&=67.8 \quad {\rm kJ}\end{align*} For the phase change occurred, the amount of heat required Q_4 was obtained using latent heat of vaporization formula $Q_v=mL_v$. Finally, adding more thermal energy leads increasing in the temperature of the steam whose amount is determined as below \begin{align*} Q_5&=mc_{steam} \Delta T\\&=(0.030)(2.010)(110-100)\\&= 0.603\quad {\rm kJ}\end{align*} In the above, there are two-phase changes, one is due to the ice $\stackrel{Q_2}{\rightarrow}$ water, and the other is water $\stackrel{Q_4}{\rightarrow}$ steam. The total heat absorbed by the ice is the sum of the partial heat above \[Q_{tot}=91.2\quad {\rm kJ}\] so the correct answer is (a). To better understand the physics of the melting stage (Q_2), check out the following page: The heat of fusion Problems with answers Problem (3): How much heat must be released by the 200 g of steam at ${\rm 175^\circ C}$ to turn into 200 g of water at ${\rm 0^\circ C}$? (a) 283 kJ (b) 326 kJ (c) 483 kJ (d) 525 kJ Solution: Here, steam wants to change its phase and turns into water (condense). The path for this process is as follows: \[\underbrace{\rm 175^\circ C}_{steam}\stackrel{Q_1}{\longrightarrow}\underbrace{\rm 100^\circ C}_{steam}\stackrel{Q_2}{\longrightarrow}\underbrace{\rm 100^\circ C}_{water}\stackrel{Q_3}{\longrightarrow}\underbrace{\rm 0^\circ C}_{water}\] In the first stage, there is a change in the temperature of the steam so we use the specific heat formula as below to find the heat Q_1 \begin{align*} Q_1&=m_s c_s \Delta T\\&=(0.200)(2010)(100-175)\\&=-30150\quad {\rm J}\\&=-30.15\quad {\rm kJ}\end{align*} In the second stage, the steam cools and turns into the water so there is a phase change, and the required thermal energy is found using the latent heat of vaporization formula below \begin{align*} Q_2&=-mL_V\\&=-{\rm (0.200\, kg)\left(2260\,kJ/kg\right)}\\&=-452\quad {\rm kJ}\end{align*} Note that since the steam has lost its heat so we must add a negative in front of latent heat of vaporization as above. In the third stage, the water cools and its temperature drops so we must use the specific heat capacity formula to find the heat lost during this stage, \begin{align*} Q_3&=m_s c_{w} \Delta T\\ &={\rm (0.200\,kg)(4.186\,kJ/kg\cdot ^\circ C)(0-100)}\\&=-0.8372\,{\rm kJ}\end{align*} Now, sum the above heats lost to find the total heat lost by the steam to convert from ${\rm 175^\circ C}$ to ${\rm 0^\circ C}$. \[Q_{tot}=483\quad{\rm kJ}\] Thus, the correct answer is (c). Problem (4): A ${\rm 10-g}$ chunk of ice at ${\rm -10^\circ C}$ is placed in a sealed container so that there is no heat exchange with the environment. How much heat is required to change it into steam at ${\rm 180^\circ C}$? (a) 23.3 kJ (b) 30.3 kJ (c) 54.1 kJ (d) 13.2 kJ Solution: As above, the process is as follows \[\underbrace{\rm -10^\circ C}_{ice}\stackrel{Q_1}{\longrightarrow}\underbrace{\rm 0^\circ C}_{ice}\stackrel{Q_2}{\longrightarrow}\underbrace{\rm 0^\circ C}_{water}\stackrel{Q_3}{\longrightarrow}\underbrace{\rm 100^\circ C}_{water}\stackrel{Q_4}{\longrightarrow}\underbrace{\rm 180^\circ C}_{steam}\] Use the equation $Q=mc\Delta T$ to find the heat needed to increase the temperature of the ice from ${\rm -10^\circ C}$ to ${\rm 0^\circ C}$ \begin{align*}Q_1&=mc_{ice}(0-(-10))\\&=(0.010)(2.090)(10)\\&=0.2090\quad {\rm kJ}\end{align*} There is a phase change in the next stage as the ice wants to turns into its liquid phase that is water. Thus, use the latent heat of fusion formula, $Q=mL_f$, to find the required heat \begin{align*} Q_2&=mL_f\\&=(0.010)(333.5)\\&=3.335\quad{\rm kJ}\end{align*} In the third stage, the additional heat would causes the temperature of the water increases. Thus, \begin{align*}Q_3&=mc_{water}(100-0)\\&=(0.010)(4.18)(100)\\&=4.18\quad{\rm kJ}\end{align*} In the final stage, the water wants to turn from liquid state into gas state so there is a phase change and we must use the latent heat of vaporization to find the needed heat as below \begin{align*}Q_4&=mL_v\\&=(0.010)(2260)\\&=22.6\quad{\rm kJ}\end{align*} Summing up the above heats, we get the total thermal energy required as \[Q_{tot}=30.315\quad {\rm kJ}\] The correct answer is (b). For the third stage, you can solve more problems on the following page: Practice problems on the specific heat Problem (5): 20-g of aluminum at ${\rm 200^\circ C}$ and 35-g of lead are dropped into a ${\rm 45\,cm^3}$ container full of ethyl alcohol at ${\rm 15^\circ C}$. After a while, the mixture reaches equilibrium with a temperature of ${\rm 25^\circ C}$. What was the initial temperature of the lead? (density and specific heat capacity of ethyl alcohol are $\rho_{ethyl}={\rm 790\,kg/m^3}$, $c_{ethyl}={\rm 2400\,J/kg\cdot ^\circ C}$, respectively. $c_{Al}=900\,{\rm J/kg\cdot \circ C}$, $c_{Pb}=128\,{\rm J/kg\cdot \circ C}$). (a) -230°C (b) -487°C (c) +487°C (d) +230°C Solution: First of all, using the definition of density find the mass of the ethyl alcohol in the container. \begin{align*}m&=\rho V\\&={\rm \left(790\,\frac{kg}{m^3}\right)(45\times 10^{-6}\,m^3)}\\&=0.035550\quad{\rm kg}\\&=35.55\quad{\rm g}\end{align*} In all latent heat problems, one substance lost its thermal energy and the other absorbs it (assuming there is no heat exchange with the environment). In such processes, the conservation of energy states that heat lost must be equal to the heat absorbed. In this problem, the equilibrium temperature is higher than the temperature of the ethyl alcohol so it must gain heat whose value is obtained as below \begin{align*}Q_{gained}&=m_{ethyl}c_{ethyl}(T_f-T_i)\\&=(0.03555)(2400)(25-15)\\&=853.2\quad {\rm J}\end{align*} Aluminum must release heat to decrease its temperature. Therefore, \begin{align*}Q_{lost-Al}&=m_{Al}c_{Al}(T_f-T_i)\\&=(0.020)(900)(25-200)\\&=-3150\quad{\rm J}\end{align*} The initial temperature of the lead is unknown, so we can assume it is higher than the final temperature of the mixture. Thus, the amount of heat lost by the lead is as below \begin{align*}Q_{lost-Pb}&=m_{Pb}c_{Pb}(T_f-T_i)\\&=(0.035)(128)(25-T_i)\\&=4.48(25-T_i)\end{align*} Applying conservation of energy as below and solving for the initial temperature of the lead, we have \begin{align*}{-heat \ lost}&={heat \ gained}\\ \\ -(-3150+4.48(25-T_i))&=853.2\\ \\ 4.48(25-T_i)&=4003.2 \\ \\ \Rightarrow T_i&=-{\rm 487^\circ C}\end{align*} As you can see, the lead's initial temperature obtained much more below the equilibrium temperature of the mixture which contradicts the original assumption, $T_i>{\rm 25^\circ C}$. Now, assume $T_i< {\rm 25^\circ C}$ so the lead must gain heat. Applying again the conservation of energy, we get \begin{align*}{-heat \ lost}&={heat\ gained}\\ \\ -(-3150)&=853.2+4.48(25-T_i)\\ \\ \Rightarrow T_i&=-{\rm 487^\circ C}\end{align*} which is consistent with the initial assumption. Therefore, the correct answer is (b). Problem (6): In a 100-g glass container, there is 200 g of water initially at ${\rm 27^\circ C}$. How much steam at ${\rm 150^\circ C}$ is needed to raise the temperature of the container and water inside it to ${\rm 45^\circ C}$? ($c_{w}=4186\,{\rm J/kg\cdot ^\circ C}$, $c_{g}=837\,{\rm J/kg\cdot ^\circ C}$, heat of vaporization of water is $2260\,{\rm kJ/kg}$). (a) 5.5 g (b) 3.8 g (c) 4.5 g (d) 6.5 g Solution: First of all, we calculate the amount of heat required to raise the temperature of container+water from ${\rm 27^\circ C}$ to ${\rm 45^\circ C}$ as below \begin{align*} Q_{gain}&=(m_{g}c_{g}+m_{w}c_{w})\Delta T\\ &=(0.100\times 837+0.200\times 4186)(45-27)\\&=16576.2\quad {\rm J}\end{align*} In above the subscript g and w indicate "glass'' and "water'', respectively. Thus, the combination of water+container must absorb $16.576\,{\rm kJ}$ heat to increase its temperature. The amount of heat released by the steam to reach from ${\rm 150^\circ C}$ to ${\rm 45^\circ C}$ is composed of the following processes \[\underbrace{{\rm 150^\circ C}}_{steam}\stackrel{Q_1}{\longrightarrow}\underbrace{{\rm 100^\circ C}}_{steam}\stackrel{Q_2}{\longrightarrow}\underbrace{{\rm 100^\circ C}}_{water}\stackrel{Q_3}{\longrightarrow}\underbrace{{\rm 45^\circ C}}_{water}\] In the third stage, the steam changes phase and turns into the water. The heat Q_1 is found as \begin{align*} Q_1&=m_s c_s \Delta T\\&=m_s (2.09)(100-150)\\&=-104.5m_s\quad {\rm kJ}\end{align*} The heat Q_2 is due to the phase change so using latent heat of vaporization formula, we have \begin{align*} Q_2&=-m_{s} L_v\\&=-m_s (2260)\quad {\rm kJ}\end{align*} The heat Q_3 causes a change in temperature so we have \begin{align*} Q_3&=m_s c_w \Delta T\\&=m_s (4.186)(45-100)\\&=-230.23m_s \quad {\rm kJ}\end{align*} Summing those heats get the thermal energy lost by the steam as \[Q_{lost}=-2594.73m_s\quad{\rm kJ}\] According to conservation of energy heat lost must be equal with the heat gained \begin{align*} -{lost\ heat}&={gained\ heat}\\ 2594.73\,m_s&=16.576 \\ \Rightarrow m_s&=0.0063\quad {\rm kg}\end{align*} Thus, about $6.5\,{\rm g}$ of steam at ${\rm 150^\circ C}$ can raise the temperature of the container+water to ${\rm 45^\circ C}$. The correct answer is (d). Author: Ali Nemati Page Published: 4/17/2021 Thermodynamic phase transition energy ThermodynamicsThe classical Carnot heat engine Branches Classical Statistical Chemical Quantum thermodynamics Equilibrium / Non-equilibrium Laws Zeroth First Second Third Systems Closed system Open system Isolated system State Equation of state Ideal gas Real gas State of matter Phase (matter) Equilibrium Control volume Instruments Processes Isobaric Isochoric Isothermal Adiabatic Isentropic Isenthalpic Quasistatic Polytropic Free expansion Reversibility Irreversibility Endoreversibility Cycles Heat engines Heat pumps Thermal efficiency System propertiesNote: Conjugate variables in italics Property diagrams Intensive and extensive properties Process functions Work Heat Functions of state Temperature / Entropy (introduction) Pressure / Volume Chemical potential / Particle number Vapor quality Reduced properties Material properties Property databases Specific heat capacity c = {\displaystyle c=} T {\displaystyle T} ∂ S {\displaystyle \partial S} N {\displaystyle N} ∂ T {\displaystyle \partial T} Compressibility β = − {\displaystyle \beta =-} 1 {\displaystyle 1} ∂ V {\displaystyle \partial V} V {\displaystyle V} ∂ p {\displaystyle \partial p} Thermal expansion α = {\displaystyle \alpha =} 1 {\displaystyle 1} ∂ V {\displaystyle \partial V} V {\displaystyle V} ∂ T {\displaystyle \partial T} Equations Carnot's theorem Clausius theorem Fundamental relation Ideal gas law Maxwell relations Onsager reciprocal relations Bridgman's equations Table of thermodynamic equations Potentials Free energy Free entropy Internal energy U (S , V) {\displaystyle U(S,V)} Enthalpy H (S , p) = U + p V {\displaystyle H(S,p)=U+pV} Helmholtz free energy A (T , V) = U − T S {\displaystyle A(T,V)=U-TS} Gibbs free energy G (T , p) = H − T S {\displaystyle G(T,p)=H-TS} HistoryCulture History General Entropy Gas laws "Perpetual motion" machines Philosophy Entropy and time Entropy and life Brownian ratchet Maxwell's demon Heat death paradox Loschmidt's paradox Synergetics Theories Caloric theory Vis viva ("living force") Mechanical equivalent of heat Motive power Key publications An Inquiry Concerning theSource ... Friction On the Equilibrium ofHeterogeneous Substances Reflections on theMotive Power of Fire Timelines Thermodynamics Heat engines ArtEducation Maxwell's thermodynamic surface Entropy as energy dispersal Scientists Bernoulli Boltzmann Bridgman Carathéodory Carnot Clapeyron Clausius de Donder Duhem Gibbs von Helmholtz Joule Kelvin Lewis Massieu Maxwell von Mayer Nernst Onsager Planck Rankine Smeaton Stahl Tait Thompson van der Waals Waterston Other Nucleation Self-assembly Self-organization Categoryvte Latent heat (also known as latent energy or heat of transformation) is energy released or absorbed, by a body or a thermodynamic system, during a constant-temperature process—usually a first-order phase transition, like melting or condensation. Latent heat can be understood as hidden energy which is supplied or extracted to change the state of a substance without changing its temperature or pressure. This includes the latent heat of fusion (solid to liquid), the latent heat of vaporization (liquid to gas) and the latent heat of sublimation (solid to gas).[1][2] The term was introduced around 1762 by Scottish chemist Joseph Black. Black used the term in the context of calorimetry where a heat transfer caused a volume change in a body while its temperature was constant. In contrast to latent heat, sensible heat is energy transferred as heat, with a resultant temperature change in a body. Graph of temperature of phases of water heated from −100 °C to 200 °C – the dashed line example shows that melting and heating 1 kg of ice at −50 °C to water at 40 °C needs 600 kJ The terms sensible heat and latent heat refer to energy transferred between a body and its surroundings, defined by the occurrence or non-occurrence of temperature change; they depend on the properties of the body. Sensible heat is sensed or felt in a process as a change in the body's temperature. Latent heat is energy transferred in a process without change of the body's temperature, for example, in a phase change (solid/liquid/gas). Both sensible and latent heats are observed in many processes of transfer of energy in nature. Latent heat is associated with the change of phase of atmospheric or ocean water, vaporization, condensation, freezing or melting, whereas sensible heat is energy transferred that is evident in change of the temperature of the atmosphere or ocean, or ice, without those phase changes, though it is associated with changes of pressure and volume. The original usage of the term, as introduced by Black, was applied to systems that were intentionally held at constant temperature. Such usage referred to latent heat of expansion and several other related latent heats. These latent heats are defined independently of the conceptual framework of thermodynamics.[3] When a body is heated at constant temperature by thermal radiation in a microwave field for example, it may expand by an amount described by its latent heat with respect to volume or latent heat of expansion, or increase its pressure by an amount described by its latent heat with respect to pressure.[4] Latent heat is energy released or absorbed by a body or a thermodynamic system during a constant-temperature process. Two common forms of latent heat are latent heat of fusion (melting) and latent heat of vaporization (boiling). These names describe the direction of energy flow when changing from one phase to the next: from solid to liquid, and liquid to gas. In both cases the change is endothermic, meaning that the system absorbs energy. For example, when water evaporates, an input of energy is required for the water molecules to overcome the forces of attraction between them and make the transition from water to vapor. If the vapor then condenses to a liquid on a surface, then the vapor's latent energy absorbed during evaporation is released as the liquid's sensible heat onto the surface. The large value of the enthalpy of condensation of water vapor is the reason that steam is a far more effective heating medium than boiling water, and is more hazardous. In meteorology, latent heat flux is the flux of energy from the Earth's surface to the atmosphere that is associated with evaporation or transpiration of water at the surface and subsequent condensation of water vapor in the troposphere. It is an important component of Earth's surface energy budget. Latent heat flux has been commonly measured with the Bowen ratio technique, or more recently since the mid-1900s by the eddy covariance method. William Cullen In 1748, an account was published in The Edinburgh Physical and Literary Essays of an experiment by the Scottish physician and chemist William Cullen. Cullen had used an air pump to lower the pressure in a container with diethyl ether. No heat was withdrawn from the ether, yet the ether boiled, but its temperature decreased.[5][6] And in 1758, on a warm day in Cambridge, England, Benjamin Franklin and fellow scientist John Hadley experimented by continually wetting the ball of a mercury thermometer with ether and using bellows to evaporate the ether.[7] With each subsequent evaporation, the thermometer read a lower temperature, eventually reaching 7 °F (−14 °C). Another thermometer showed that the room temperature was constant at 65 °F (18 °C). In his letter Cooling by Evaporation, Franklin noted that, "One may see the possibility of freezing a man to death on a warm summer's day."[8] Joseph Black The English word latent comes from Latin latēns, meaning lying hidden.[9][10] The term latent heat was introduced into calorimetry around 1750 by Joseph Black, commissioned by producers of Scotch whisky in search of ideal quantities of fuel and water for their distilling process to study system changes, such as of volume and pressure, when the thermodynamic system was held at constant temperature in a thermal bath. It was known that when the air temperature rises above freezing—air then becoming the obvious heat source—snow melts very slowly and the temperature of the melted snow is close to its freezing point.[5] In 1757, Black started to investigate if heat, therefore, was required for the melting of a solid, independent of any rise in temperature. As far Black knew, the general view at that time was that melting was inevitably accompanied by a small increase in temperature, and that no additional heat was needed beyond what this increase in temperature would require in itself. Soon, however, Black was able to show that much more heat was required during melting than could be explained by the increase in temperature alone.[11][12] He was also able to show that heat is released by a liquid during its freezing; again, much more than could be explained by the decrease of its temperature alone.[13] Black would compare the change in temperature of two identical quantities of water, heated by identical means, one of which was, say, melted from ice, whereas the other was heated from merely cold liquid state. By comparing the resulting temperatures, he could conclude that, for instance, the temperature of the sample melted from ice was 140 °F lower than the other sample, thus melting the ice absorbed 140 "degrees of heat" that could not be measured by the thermometer, yet needed to be supplied, thus it was "latent" (hidden). Black also deduced that as much latent heat as was supplied into boiling the distillate (thus giving the quantity of fuel needed) also had to be absorbed to condense it again (thus giving the cooling water required).[14] In 1762, Black announced the following research and results to a society of professors at the University of Glasgow.[15] Black had placed equal masses of ice at 32 °F (0 °C) and water at 33 °F (0.6 °C) respectively in two identical, well separated containers. The water and the ice were both evenly heated to 40 °F by the air in the room, which was at a constant 47 °F (8 °C). The water had therefore received 40 – 33 = 7 "degrees of heat". The ice had been heated for 21 times longer and had therefore received 7 × 21 = 147 "degrees of heat".[a] The temperature of the ice had increased by 8 °F. The ice had thus absorbed 8 "degrees of heat", which Black called sensible heat, manifest as a temperature increase, which could be felt and measured. In addition to that, 147 – 8 = 139 "degrees of heat" were absorbed as latent heat, manifest as phase change rather than as temperature change.[16][17] Black next showed that a water temperature of 176 °F was needed to melt an equal mass of ice until it was all 32 °F. So now 176 – 32 = 144 "degrees of heat" seemed to be needed to melt the ice. The modern value for the heat of fusion of ice would be 143 "degrees of heat" on the same scale (79.5 "degrees of heat Celsius").[18][15] Finally, Black increased the temperature of a mass of water, then vaporized an equal mass of water by even heating. He showed that 830 "degrees of heat" was needed for the vaporization; again based on the time required. The modern value for the heat of vaporization of water would be 967 "degrees of heat" on the same scale.[19] Later, James Prescott Joule characterised latent energy as the energy of interaction in a given configuration of particles, i.e. a form of potential energy, and the sensible heat as an energy that was indicated by the thermometer,[20] relating the latter to thermal energy. A specific latent heat (L) expresses the amount of energy in the form of heat (Q) required to completely effect a phase change of a unit of mass (m), usually 1kg, of a substance as an intensive property: L = Q m . {\displaystyle L={\frac {Q}{m}}.} Intensive properties are material characteristics and are not dependent on the size or extent of the sample. Commonly quoted and tabulated in the literature are the specific latent heat of fusion and the specific latent heat of vaporization for many substances. From this definition, the latent heat for a given mass of a substance is calculated by Q = m L {\displaystyle Q={m}{L}} where: Q is the amount of energy released or absorbed during the change of phase of the substance (in kJ or in BTU), m is the mass of the substance (in kg or in lb), and L is the specific latent heat for a particular substance (in kJ kg−1 or in BTU lb−1), either Lf for fusion, or Lv for vaporization. The following table shows the specific latent heats and change of phase temperatures (at standard pressure) of some common fluids and gases.[citation needed] Substance SLH of fusion (kJ/kg) Melting point (°C) SLH of vaporization (kJ/kg) Boiling point (°C) Boiling point (K) SLH of Sublimation (kJ/kg) Ethyl alcohol 108 −114 855 78.3 351.45 Ammonia 332.17 −77.74 1369 −33.34 239.81 Carbon dioxide 184 −78 574 −78.46 194.69 570 [21] Helium 21 −268.93 4.22 Hydrogen(2) 58 −259 455 −253 20.15 Lead[22] 23.0 327.5 871 1750 2023.15 Methane 59 −182.6 511 −161.6 111.55 Nitrogen 25.7 −210 200 −196 77.15 Oxygen 13.9 −219 213 −183 90.15 Refrigerant R134a −101 215.9 −26.6 246.55 Refrigerant R152a −116 326.5 −25 248.15 Silicon[23] 1790 1414 12800 3265 3538.15 Toluene 72.1 −93 351 110.6 383.75 Turpentine 293 154 427.15 Formic Acid[24] 275.46 8.35 1010 100.75 373.9 1300 Water 334 0 2264.705 100 373.15 2840 The specific latent heat of condensation of water in the temperature range from −25 °C to 40 °C is approximated by the following empirical cubic function: L water (T) ≈ (2500.8 − 2.36 T + 0.0016 T 2 − 0.00006 T 3) J/g , {\displaystyle L_{\text{water}}(T)\approx \left(2500.8-2.36T+0.0016T^{2}-0.00006T^{3}\right)~{\text{J/g}},} [25] where the temperature T {\displaystyle T} is taken to be the numerical value in °C. For sublimation and deposition from and into ice, the specific latent heat is almost constant in the temperature range from −40 °C to 0 °C and can be approximated by the following empirical quadratic function: L ice (T) ≈ (2834.1 − 0.29 T − 0.004 T 2) J/g . {\displaystyle L_{\text{ice}}(T)\approx \left(2834.1-0.29T-0.004T^{2}\right)~{\text{J/g}}.} [25] Temperature-dependency of the heats of vaporization for water, methanol, benzene, and acetone. As the temperature (or pressure) rises to the critical point, the latent heat of vaporization falls to zero. Bowen ratio Eddy covariance flux (eddy correlation, eddy flux) Sublimation (physics) Specific heat capacity Enthalpy of fusion Enthalpy of vaporization Ton of refrigeration – the power required to freeze or melt 2000 lb of water in 24 hours ^ These "degrees of heat" were context-dependent and could only be used when circumstances were identical—except for the one differing factor to be investigated. When Black investigated specific heat, the "degrees of heat" were based on change in temperature multiplied by mass. When Black investigated latent heat, they were based on change in temperature multiplied by time passed. Clearly these units were not equivalent.

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Retrieved September 14, 2010. ^ "Founders Online: From Benjamin Franklin to John Lining, 17 June 1758". founders.archives.gov. Retrieved June 30, 2021. ^ Harper, Douglas. "latent". Online Etymology Dictionary. ^ Lewis, Charlton T. (1890). An Elementary Latin Dictionary. Entry for latens. ^ Ramsay, William (1918). The Life and letters of Joseph Black, M.D. Constable. p. 44. ^ Black, Joseph (1807). Robison, John (ed.). Lectures on the Elements of Chemistry: Delivered in the University of Edinburgh. Mathew Carey. pp. 111–112. ^ Black, Joseph (1807). Robison, John (ed.). Lectures on the Elements of Chemistry: Delivered in the University of Edinburgh. Mathew Carey. p. 112. ^ Burke, James (1979). "Credit Where It's Due". The Day the Universe Changed. Episode 6. Event occurs at 50 (34 minutes). BBC. ^ a b Black, Joseph (1807). Robison, John (ed.). Lectures on the Elements of Chemistry: Delivered in the University of Edinburgh. Mathew Carey. p. 120. ^ Ramsay, W. (1918). 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(1884), The Scientific Paper of James Prescott Joule, The Physical Society of London, p. 274, I am inclined to believe that both of these hypotheses will be found to hold good,—that in some instances, particularly in the case of sensible heat, or such as is indicated by the thermometer, heat will be found to consist in the living force of the particles of the bodies in which it is induced; whilst in others, particularly in the case of latent heat, the phenomena are produced by the separation of particle from particle, so as to cause them to attract one another through a greater space., Lecture on Matter, Living Force, and Heat. May 5 and 12, 1847 ^ Chickos, James S.; Acree, William E. (2002). "Enthalpies of Sublimation of Organic and Organometallic Compounds. 1910–2001". Journal of Physical and Chemical Reference Data. 31 (2): 537–698. doi:10.1063/1.1475333. ISSN 0047-2689. ^ Yaws, Carl L. (2011). Yaws' Handbook of Properties of the Chemical Elements. Knovel. ^ Elert, Glenn (2021). "Latent Heat". The Physics Hypertextbook. ^ "Formic acid". NIST WebBook. National Institute of Standards and Technology. Retrieved 2024-07-31. ^ a b Polynomial curve fits to Table 2.1. R. R. Rogers; M. K. Yau (1989). A Short Course in Cloud Physics (3rd ed.). Pergamon Press. p. 16. ISBN 0-7506-3215-1. Retrieved from " Specific heat capacity measures the heat energy needed to raise the temperature of one unit of mass by one degree Celsius or Kelvin. This guide includes practice problems with solutions to help students strengthen their understanding of heat transfer calculations. This guide provides several practice problems with solutions to help the students grasp this concept. Definition: If a substance of mass m (in kilogram) absorbs Q joules of heat energy from a heat source, and its temperature changes by: $\Delta T=T_{final}-T_{initial}$, then its specific heat capacity is given by: \[c=\frac{Q}{m\Delta T}\] This equation is only applicable a temperature change occurs. However, for the phase change process, this equation does not apply because the temperature remains constant, even though energy is being absorbed or released. Since specific heat capacity depends on temperature change, a different approach is required for such processes. For a deeper understanding of these thermal processes and how energy calculations work during phase changes, refer to the following resources: Heat of fusion: formula and solved problems Heat of vaporization: formula and solved problems With this information in mind, we can now solve some specific heat problems to understand its definition further. Specific Heat Problems Problem (1): A chunk of steel with a mass of 1.57 kg absorbs a net thermal energy of 2.5×10^{5} J and increases its temperature by 355°C. What is the specific heat of the steel? Solution: The specific heat of a substance is defined as the energy transferred (Q) to a system divided by the mass (m) of the system and the change in its temperature (ΔT). Its formula is \[c\equiv \frac {Q}{m\Delta T}\] Substituting the given numerical values into the above formula, we have \begin{align*} c&=\frac {Q}{m\Delta T}\\ \\ &=\frac{2.5\times 10^{5}}{(1.57)(273+355)}\\ \\&=4485.51\quad{\rm J/kg\cdot ^\circ C}\end{align*} Where ${\rm J/kg\cdot ^\circ C}$ is the SI unit of specific heat. Problem (2): The temperature of a 200-g sample of an unknown substance changed from 40°C to 25°C. In the process, the substance released 569 calories of energy. What is the specific heat capacity of the substance? Solution: again applying the specific heat definition, we have \begin{align*} c&=\frac{Q}{m\Delta T}\\ \\ &=\frac{-569\, {\rm cal}}{200\,{\rm g}\,(25-40)}\\ \\&=0.19 \quad {\rm cal/g\cdot K}\end{align*} Since thermal energy has left the substance, a negative sign is included to indicate heat loss. Problem (3): m kilogram of ice is heated, and its temperature increases from -10°C to -5°C. A larger amount of energy is added to the same mass of water, and the change in its temperature is from 15°C to 20°C. From these observations, compare the specific heat capacities of ice and water. Solution: The heat added to the ice and water is given by: $Q_i=m_ic_i \Delta T_i$ and $Q_w=m_wc_w \Delta T_w$, respectively. Since the problem states that both samples have the same mass, we set $m_i=m_w$, which allows us to equate their respective heat expressions. Solving for the ratio of specific heat capacities, gives us: \begin{align*} m_i &= m_w\\\frac{Q_i}{c_i\Delta T_i}&=\frac{Q_w}{c_w \Delta T_w}\\ \\ \Rightarrow \frac{c_i}{c_w} &= \Big(\frac{Q_i}{Q_w}\Big)\Big(\frac{\Delta T_w}{\Delta T_i}\Big)\\ \\ &=\Big(\frac{Q_i}{Q_w}\Big) \Big(\frac{20-15}{-5-(-10)}\Big)\\ \\&=\Big(\frac{Q_i}{Q_w}\Big)\end{align*} Since $Q_i < Q_w$, we conclude that the specific heat capacity of ice is lower than that of water. A quick check of a specific heat table confirms this. $c_i= 2090\,{\rm J/kg \cdot K}$ and $c_w=4190\,{\rm J/kg \cdot K}$. Problem (4): A 1.5-kg copper block is initially at 25°C. If 45 kJ of energy are added to the block, what is its final temperature? Solution: Using the specific heat formula and rearranging and solving for T_f, we have: \[T_f=T_i+ \frac{Q}{mc}\] Substituting the numerical values into this gives: \begin{align*} T_f &=25+ \frac{45000}{1.5 \times 385} \\\\ \Rightarrow T_f &\approx \boxed{\rm 103 ^\circ C} \end{align*} Thus, the final temperature of the copper block is approximately 103°C. Problem (5): (a) How much energy is required to heat 1.5 L of water from 15°C to 95°C? (b) For how long could this amount of energy power a 75-W lightbulb? Solution: (a) Since water has a density of 1 kg/L, the mass of 1.5 L of water is 1.5 kg. Substituting the given values into the heat transfer energy equation, we have: \begin{align*} Q&=mc\Delta T \\\\ &=(1.5)(4190)(95-15) \\\\ &=\boxed{502800\,\rm J} \end{align*} Thus, 502.8 kJ of energy is required to heat the water. (b) Power is defined as energy per unit time, $P=\frac{Q}{t}$. Rearranging to solve for t, and substituting the known values, we get: \begin{align*} t &=\frac{Q}{P} \\\\ &=\frac{502800}{75} \\\\ &=\boxed{6704\,\rm s} \end{align*} Converting to minutes: \[t \approx 112\quad\rm minutes\] Thus, the same amount of energy could power a 75-W lightbulb for about 112 minutes. In another type of problem, specific heat capacity is determined through calorimetry. In calorimetry problems, the specific heat of a sample is measured by placing it into a known quantity of water at a specific temperature. Since this system is isolated, the total energy gained or lost by all objects within it sums to zero, expressed as $\Sigma Q_i=0$, where Q_i represents the energy of the ith object. By measuring the equilibrium temperature, we can solve the equation above to determine the unknown specific heat. Below, some problems for finding the heat capacity using this method are presented. Problem (6): A 125-g block of a substance with unknown specific heat at a temperature of 90°C is placed in an isolated box containing 0.326 kg of water at 20°C. The equilibrium temperature of the system is 22.4°C. What is the block's specific heat? Solution: Since the block's temperature is higher than the water's, the block loses thermal energy while the water absorbs it. Applying the principle of energy conservation ($Q_{gain}=-Q_{lose}$), and solving for the unknown specific heat, gives us: \begin{align*} m_w c_w (T-T_w) &= -m_x c_x (T-T_x)\\ \\ \Rightarrow c_x&=\frac{m_w c_w (T-T_w)}{m_x (T_x-T)}\\ \\ &=\frac{(0.326)(4190)(22.4-20)}{(0.125)(90-22.4)}\\ \\&=388\quad {\rm J/kg\cdot ^\circ C}\end{align*} In calorimetry problems, thermal energy is transferred from the warmer substance to the cooler one. A negative sign is placed in front of the heat lost by the warmer object to ensure both sides of the equation remain positive. For more practice about this, check out the page on thermodynamics problems and solutions. Problem (7): A piece of metal of unknown specific heat, weighing 25 g and temperature of 90°C, is dropped into 150 g of water at 10°C. They finally reach thermal equilibrium at a temperature of 24°C. Calculate the unknown specific heat capacity. (Specific heat of water is 1.0 cal/g°C) Solution: Since the equilibrium temperature T_f is lower than that of the metal, the metal loses heat given by: $Q_m=-m_m c_m (T_f-T_m)$ while the water gains heat: $Q_w=m_w c_w (T_f-T_w)$. A useful rule of thumb is that when an object loses heat, a negative sign should be placed in front of its heat expression to indicate energy loss. Conservation of energy tells us $Q_w=Q_m$, thus we have \begin{align*} m_w c_w (T_f-T_w)&= -m_m c_m (T_f-T_m) \\ \\ \Rightarrow c_m &= \frac{m_w c_w (T_f-T_w)}{m_m \,(T_m-T_f)}\\ \\ &=\frac{(150)(1)(24-10)}{25\times(90-24)}\\ \\&=1.27\quad {\rm cal/g\cdot ^\circ C}\end{align*} Problem (8): A piece of unknown substance with a mass of 2 kg and a temperature of 280 Kelvin is brought into thermal contact with a 5-kg block of copper initially at 320 K. This system is in isolation. After the system reaches thermal equilibrium, its temperature becomes 290 K. What is the specific heat of the unknown substance in cal/g.°C? (Specific heat of the copper is 0.093 cal/g.°C). Solution: To solve for the specific heat of the unknown substance, we will use the principle of conservation of energy. In an isolated system, the heat lost by the copper is equal to the heat gained by the unknown substance. As previous questions, we get \begin{align*} m_s c_s (T_f-T_s)&= -m_c c_c (T_f-T_c) \\ \\ \Rightarrow c_s &= \frac{m_c c_c (T_c-T_f)}{m_s \,(T_f-T_s)}\\ \\&=\frac{(5000)(0.093)(320-290)}{2000\times(290-280)}\\ \\ &=0.6975 \quad {\rm cal/g\cdot K}\end{align*} In the above, the subscripts s and c denote the substance and copper, respectively. Note: In calorimetry equations where a temperature change appears, it's possible to use either Celsius or Kelvin temperatures because a change in Celsius equals a change in Kelvin. Problem (9): A 20-g block of a solid initially at 70°C is placed in 100 g of a fluid with a temperature of 20°C. After a while, the system reaches thermal equilibrium at a temperature of 30°C. What is the ratio of the specific heat of the solid to that of the fluid? Solution: The solid loses heat while the fluid absorbs it, so we express this as $Q_f=-Q_s$ where f and s denote the fluid and solid, respectively. Using the definition of specific heat, we can find the heat transferred during this process as follows: \begin{align*} m_f c_f (T-T_f) &= -m_s c_s (T-T_s)\\ \\ \Rightarrow \frac{c_f}{c_s} &=\frac{m_s (T_s-T)}{m_f (T-T_f)}\\ \\ &= \frac{(20)(70-30)}{(100)(30-20)}\\ \\ &=0.8\end{align*} Thus, the specific heat capacity of fluid is lower than that of the solid. Problem (10): A chunk of metal with a mass of 245.7 g at 75.2°C is placed in 115.43 g of water initially at a temperature of 22.6°C. The metal and water reach the final equilibrium temperature of 34.6°C. If no heat is exchanged between the system and its surroundings, what is the specific heat of the metal? (Specific heat of water is 1 cal/g °C). Solution: Since no heat is lost to the surroundings, the conservation of energy principle gives $Q_{water}=-Q_{metal}$. Using the definition of specific heat, the heat transfer equation is as follows. Solving this for c_{meta} and substituting the given numerical values into it, we have: \begin{align*}Q_{water}&=-Q_{metal}\\ \\m_w c_w (T_f-T_w) &=-m_{metal} \, c_{metal} (T_f-T_{metal})\\ &\\ \Rightarrow c_{metal}&=\frac{m_w c_w (T_f-T_w)}{m_{metal}(T_{metal}-T_f)}\\&\\ &=\frac{(115.43)(1)(34.6-22.6)}{(245.7)(75.2-34.6)}\\ \\&=0.13 \quad {\rm cal/g\cdot^\circ C}\end{align*} where T_f is the equilibrium temperature. Problem (11): How many liters of water at 80°C should be mixed with 40 liters of water at 10°C to have a mixture with a final temperature of 40°C? Solution: conservation of energy tells us that $\Sigma Q=0$ that is $Q_{lost}+Q_{gain}=0$. By considering no heat exchange with the environment, hotter objects lose heat and colder ones gain it. Thus, the amount of heat lost by 80°C - water is \begin{align*} Q_{lost}&=mc(T_f-T_i)\\&=mc(40-80)\\&=-40mc\end{align*} and also the heat gained by 40°C - water is \begin{align*} Q_{gain}&=m'c(T_f-T_i)\\&=40\times c\times (40-10)\\&=1200c\end{align*}Therefore, by equating those two heats, we get the unknown mass of the water \begin{align*} Q_{gain}&=-Q_{lost}\\1200c&=-(-40mc)\\1200&=40m \Rightarrow m&=30,{\rm Lit}\end{align*} Problem (12): 200 g of water at 22.5°C is mixed with 150 g of water at 40°C. After reaching the thermal equilibrium, what is the final temperature of the water? Solution: Using the principle of conservation of energy, we have $Q_{lost}+Q_{gain}=0$. Substituting the specific heat equation into it, we get \begin{gather*} m_1 c_w (T_f-T_1)+m_2 c_w (T_f-T_2)=0\\ \\ 200 (T_f-22.5)+150 (T_f-40)=0\\ \\ \Rightarrow 350T_f=10500 \\ \\ \Rightarrow T_f= 30^{\circ}C \end{gather*} where T_f is the equilibrium (final) temperature of the mixture. Also, the specific heat capacity of the water is specified in the thermal equilibrium. Problem (13): In a container, 1000 g of water and 200 g of ice are in thermal equilibrium. A piece of metal with a specific heat capacity of 0.300 J/kg.K and a temperature of 250°C is dropped into the mixture. How much should the minimum mass of the metal be to melt down all of the ice? (heat of fusion of ice is $L_f=336\,{\rm \frac{kJ}{kg}}$). Solution: The minimum mass of the metal ensures that it has just enough heat energy to completely melt the ice without raising the temperature of the system. The amount of heat energy released by m grams of the metal as it cools from 250°C to 0°C is given by $Q_{lost}=mc(T_f-T_i)$ where T_f is the equilibrium temperature, 0°C. Meanwhile, the energy required to melt 200 g of ice is: \[Q_{gain}=m_{ice} L_f=200\times 336\times 10^{3}\,{\rm \frac{J}{kg}}\] where L_f is the latent heat of fusion for ice. By the conservation of energy principle, equating the heat lostby the metal to the heat gained by the ice, we have: \begin{gather*} m_{metal}\,c(T_f-T_i)+m_{ice}L_f=0 \\ \\ m_{metal} \times 400\times (0-250)+200\times 336 \times 10^{3}=0 \\ \\ \Rightarrow m_{metal}=672 \quad {\rm g}\end{gather*} Thus, the minimum mass of the metal required to melt the ice is 672 g. In this case, the final system temperature to rise above 0°C. For more practice, you can practice these heat problems. In the end, we provide you with specific heat capacities of some materials. Substance Specific heat J/kg.K Specific heat cal/g.K Brass 0.380 0.092 Copper 386 0.0923 Glass 840 0.20 Aluminum 900 0.215 Mercury 140 0.033 Water 4187 1.00 Sea Water 3900 0.93 Ice (-10°C) 2220 0.530 Ethyl Alcohol 2430 0.58 Author: Dr. Ali Nemati Last Update: April 17, 2025 , the free encyclopedia that anyone can edit. 110,144 active editors 7,022,918 articles in English School in Sketty, Swansea, photographed in 1854 The period between 1701 and 1870 saw an expansion in access to formal education in Wales, though schooling was not yet universal. Several philanthropic efforts were made to provide education to the poor during the 18th century. In the early to mid-19th century, charitable schools were established to provide a basic education. Private schools aimed at the working classes also existed. State funding was introduced to schools from 1833. Some use of the Welsh language was made in 18th-century charitable schools, at a time when most agricultural workers in Wales spoke only Welsh, and public opinion was keen for children to learn English. Many schools punished children for speaking Welsh, despite government studies that found such methods ineffective. The government did little to promote bilingual education. Grammar schools experienced difficulties and, by the end of the period, secondary education and colleges offered higher education. (Full article...) Recently featured: White dwarf Battle of Groix Scott Carpenter Archive By email More featured articles About Sae Kitamura ... that Sae Kitamura (pictured) has had her university students contribute to the Japanese Wikipedia as part of their coursework? ... that the lead actress of The Grub-Stake brought her personal menagerie—which included bears and wolves—to the set for use as extras? ... that James Patrick Shea thought that an invitation to meet with Pope Benedict XVI at the White House was a hoax? ... that Robby Krieger was unable to record his guitar solo for "You're Lost Little Girl" until he got stoned on hashish? ... that all three podium finishers at the 2024 Tour de France were members of cycling's Big Four? ... that the directors of Final Destination Bloodlines "debated the ethics" of a character being killed by an MRI machine? ... that one newspaper described the mansions of Riverside Drive as "glitter[ing] like a wedding cake"? ... that Galdor has been described as Lego's biggest failure? ... that the Irish Post questioned whether a film that complained that its marriage plot focused too much on love? Archive Start a new article Nominate an article Vera Rubin Observatory The Vera C. Rubin Observatory (pictured) in Chile releases the first light images from its new 8.4-meter (28 ft) telescope. In basketball, the Oklahoma City Thunder defeat the Indiana Pacers to win the NBA Finals. An attack on a Greek Orthodox church in Damascus, Syria, kills at least 25 people. The United States conducts military strikes on three nuclear facilities in Iran. In rugby union, the Crusaders defeat the Chiefs to win the Super Rugby Pacific final. Ongoing: Gaza war Iran–Israel war Russian invasion of Ukraine timeline Sudanese civil war timeline Recent deaths: Lucien Nedzi Anne Burrell Frederick W. Smith Ron Taylor Mohammad Kazemi Marita Camacho Quirós Nominate an article June 25 Original rainbow flag 1658 – Anglo-Spanish War: The largest battle ever fought on Jamaica, the three-day Battle of Rio Nuevo, began. 1910 – The United States Congress passed the Mann Act, which prohibited the interstate transport of females for "immoral purposes". 1944 – World War II: U.S. Navy and Royal Navy ships bombarded Cherbourg, France, to support U.S. Army units engaged in the Battle of Cherbourg. 1978 – The rainbow flag (original version pictured) representing gay pride was first flown at the San Francisco Gay Freedom Day parade. 2009 – Singer Michael Jackson died as a result of the combination of drugs in his body. Giovanni Battista Riccioli (d. 1671)Eloisa Diaz (b. 1866)George Michael (b. 1963)Farrah Fawcett (d. 2009) More anniversaries: June 24 June 25 June 26 Archive By email List of days of the year About 1795 Turban Head eagle with heraldic eagle reverse 1797 Turban Head eagle with heraldic eagle reverse The Turban Head eagle is a ten-dollar gold piece, or eagle, struck by the United States Mint from 1795 to 1804. The piece was designed by Robert Scot, and was the first in the eagle series, which continued until the Mint ceased striking gold coins for circulation in 1933. The common name is a misnomer; Liberty does not wear a turban but a cap, believed by some to be a pileus or Liberty cap: her hair twisting around the headgear makes it appear to be a turban. The number of stars on the obverse was initially intended to be equal to the number of states in the Union, but with the number at 16, that idea was abandoned in favor of using 13 stars in honor of the original states. The initial reverse, featuring an eagle with a wreath in its mouth, proved unpopular and was replaced by a heraldic eagle. Increases in the price of gold made it profitable for the coins to be melted down, and in 1804, President Thomas Jefferson ended coinage of eagles; the denomination was not struck again for circulation for more than 30 years. These Turban Head eagles are in the National Numismatic Collection at the National Museum of American History. Coin design credit: United States Mint; photographed by Jaclyn Nash Recently featured: Springbok Geraldine Ulmar Shah Mosque (Isfahan) Archive More featured pictures Community portal – The central hub for editors, with resources, links, tasks, and announcements. Village pump – Forum for discussions about Wikipedia itself, including policies and technical issues. Site news – Sources of news about Wikipedia and the broader Wikimedia movement. Teahouse – Ask basic questions about using or editing Wikipedia. Help desk – Ask questions about using or editing Wikipedia. Reference desk – Ask research questions about encyclopedic topics. Content portals – A unique way to navigate the encyclopedia. Wikipedia is written by volunteer editors and hosted by the Wikimedia Foundation, a non-profit organization that also hosts a range of other volunteer projects: CommonsFree media repository MediaWikiWiki software development Meta-WikiWikimedia project coordination WikibooksFree textbooks and manuals WikidataFree knowledge base WikinewsFree-content news WikiquoteCollection of quotations WikisourceFree-content library WikispeciesDirectory of species WikiversityFree learning tools WikivoyageFree travel guide WiktionaryDictionary and thesaurus This Wikipedia is written in English. Many other Wikipedias are available; some of the largest are listed below. 1,000,000+ articles العربية Deutsch Español فارسی Français Italiano Nederlands 日本語 Polski Português Русский Svenska Українська Tiếng Việt 中文 250,000+ articles Bahasa Indonesia Bahasa Melayu Bân-lâm-gú Български Català Čeština Dansk Eesti Ελληνικά Esperanto Euskara עברית Հայերեն Magyar Norsk bokmål Română Simple English Slovenčina Srpski Srpskohrvatski Suomi Türkçe Oʻzbekcha 50,000+ articles Asturianu Azərbaycanca বাংলা Bosanski کوردی Frysk Gaeilge Galego Hrvatski ქართული Kurdî Latviešu Lietuvių മലയാളം Македонски မြန်မာဘာသာ Norsk nynorsk ਪੰਜਾਬੀ Shqip Slovenščina ไทย తెలుగు اردو Retrieved from "" article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "1658" – news · newspapers · books · scholar · JSTOR (January 2016) (Learn how and when to remove this message) Calendar year Years Millennium 2nd millennium Centuries 16th century 17th century 18th century Decades 1630s 1640s 1650s 1660s – 1670s Years 1655 1656 1657 1658 1659 1660 1661 vte January 30: Swedish troops cross the frozen waters of the Danish straits on foot in the March Across the Belts 1658 by topic Arts and science Architecture Art Literature Music Science Leaders State leaders Colonial governors Religious leaders Birth and death categories Births Deaths Establishments and disestablishments categories Establishments – Disestablishments Works category Works 1658 in various calendarsGregorian calendar1658MDCLVIIIAb urbe condita2411Armenian calendar1107ԹՃԷAssyrian calendar6408Balinese saka calendar1579–1580Bengali calendar1064–1065Berber calendar2608English Regnal year9 Cha. 2 – 10 Cha. 2(Interregnum)Buddhist calendar2202Burmese calendar1020Byzantine calendar7166–7167Chinese calendar丁酉年 (Fire Rooster)4355 or 4148 — to — 戊戌年 (Earth Dog)4356 or 4149Coptic calendar1374–1375Discordian calendar2824Ethiopian calendar1650–1651Hebrew calendar5418–5419Hindu calendars - Vikram Samvat1714–1715 - Shaka Samvat1579–1580 - Kali Yuga4758–4759Holocene calendar11658Igbo calendar658–659Iranian calendar1036–1037Islamic calendar1068–1069Japanese calendarMeireki 4 / Manji 1(万治元年)Javanese calendar1580–1581Julian calendarGregorian minus 10 daysKorean calendar3991Minguo calendar254 before ROC民前254年Nanakshahi calendar190Thai solar calendar2200–2201Tibetan calendar阴火鸡年(female Fire-Rooster)1784 or 1403 or 631 — to — 阳土狗年(male Earth-Dog)1785 or 1404 or 632 June 14: Battle of the Dunes 1658 (MDCLVIII) was a common year starting on Tuesday of the Gregorian calendar and a common year starting on Friday of the Julian calendar, the 1658th year of the Common Era (CE) and Anno Domini (AD) designations, the 658th year of the 2nd millennium, the 58th year of the 17th century, and the 9th year of the 1650s decade. As of the start of 1658, the Gregorian calendar was 10 days ahead of the Julian calendar, which remained in localized use until 1923. Calendar year January 13 – Edward Sexby, who had plotted against Oliver Cromwell, dies in the Tower of London.[1] January 30 – The "March Across the Belts" (Tåget över Bält), Sweden's use of winter weather to send troops across the waters of the Danish straits at a time when winter has turned them to ice, begins. Within 17 days, Sweden's King Karl X Gustav leads troops across the ice belts to capture six of Denmark's islands as Swedish territory. February 5 – Prince Muhi al-Din Muhammad, one of the sons of India's Mughal, Emperor Shah Jahan, proclaims himself Emperor after Jahan names Muhi's older brother, Dara Shikoh, as regent, and departs from Aurangabad with troops. February 6 – Swedish troops of Charles X Gustav cross the Great Belt in Denmark, over frozen sea.[2] March 8 (February 26 OS) – The peace between Sweden and Denmark-Norway is concluded in Roskilde by the Treaty of Roskilde, under which Denmark is forced to cede significant territory. This leads to Sweden reaching its territorial height during its time as a great power. April 15 – In India, the Battle of Dharmat is fought in the modern-day state of Madhya Pradesh between rival claimants to the throne of the Mughal Empire. Prince Muhi al-Din Muhammad, the son of the Emperor Shah Jahan, leads 30,000 men in a triumph over 22,000 troops led by Jaswant Singh of Marwar and Ratan Singh Rathore. Despite heavy losses, with more than 11,000 casualties, Prince Muhi, who has adopted the name Aurangzeb, continues toward Samugarh and Agra and captures the throne at the end of July. April 16 – In Skåneland, a region recently ceded by Denmark to the Swedish Empire, representatives of the nobility of the provinces of Blekinge, Halland and Scania gather at the Scanian city of Malmö to swear their allegiance to King Charles X Gustav of Sweden. May 1 – Hydriotaphia, Urn Burial and The Garden of Cyrus are published by Thomas Browne in England. May 29 – Aurangzeb wins the Battle of Samugarh as Indian Mughal regent Dara Shikoh makes a last effort to defend the Mughal capital Agra. June 3 – Pope Alexander VII appoints François de Laval vicar apostolic of New France. June 14 – Anglo-Spanish War (1654–60) and Franco-Spanish War (1635–59): In the Battle of the Dunes, a Spanish force attempting to lift a siege of Dunkirk is defeated by the French and English. England is then given Dunkirk, for its assistance in the victory. June 27 – In the Battle of Rio Nuevo, part of the Anglo-Spanish War, a Spanish invasion force fails to recapture Jamaica from the English. July 2 – The Siege of Toruń begins in Poland as troops of the Polish–Lithuanian Commonwealth and of Austria seek to recapture the city of Toruń from a garrison of the Swedish Army. Within six months, the Swedish occupiers surrender. July 18 – Prince Leopold of the House of Habsburg, son of the late Ferdinand III, is elected as the new Holy Roman Emperor. July 31 – After Shah Jahan completes the Taj Mahal, his son Aurangzeb deposes him as ruler of the Mughal Empire. July – Šarhūda's Manchu fleet annihilates Onufriy Stepanov's Russian flotilla, on the Amur River. August 1 – The coronation of Leopold I takes place in Frankfurt. August 5 – Just six months after winning territory from Denmark-Norway in war and subsequent treaty, Sweden's King Charles X Gustav declares a second war against Denmark. By August 11, the King's troops have surrounded Denmark's capital, Copenhagen, while the Swedish Navy blocks the harbor to prevent the city from being resupplied, and begins bombardment. August 14 – The League of the Rhine (Rheinische Allianz) is formed by 50 German princes whose cities are on the Rhine river. September 3 – Oliver Cromwell dies and his son Richard assumes his father's position as Lord Protector of England, Scotland and Ireland. September 17 – Portuguese Restoration War: In the Battle of Vilanova, a Spanish army, having crossed the Minho, defeats the Portuguese. October 7 – The Netherlands enters the Dano-Swedish War to come to the rescue of Denmark, sending a 45-ship fleet from Vlie. October 29 – The 45-ship fleet of the Netherlands arrives at Denmark and begins its counterattack on Sweden's army and navy with three squadrons. November 6 – The Mexican Inquisition carries out the execution, by public burning, of 14 men convicted of homosexuality, while another 109 arrested are either released or given less harsh sentences. November 8 (October 29 old style) – The Battle of the Sound takes place between the navies of the Dutch Republic (with 41 warships) and of Sweden (with 45) at the Øresund, a strait between Denmark and Sweden's newly-acquired territory, the former Danish island of Scania. The Dutch Republic is successful at breaking the Swedish Navy's blockade of Copenhagen, and Sweden is forced to retreat, bringing an end to the attempted conquest of Denmark. November 23 – The elaborate funeral of Lord Protector of England Oliver Cromwell (who had died on September 3 and was buried at Westminster Abbey two weeks later) is carried out in London. A little more than two years later (in January 1661), his body will be disinterred and his head severed and placed on a spike. December 11 – Abaza Hasan Pasha, an Ottoman provincial governor who is attempting to depose the Grand Vizier, wins a battle at the Turkish city of Ilgın, defeating loyalist forces led by Murtaza Pasha. The victory is the last for the rebels. Two months later (February 16, 1659) Abaza Hasan is assassinated after being invited to peace negotiations by the loyalists. December 20 – Representatives of the Russian Empire and the Swedish Empire sign the Treaty of Valiesar at the Valiesar Estate near Narva, part of modern-day Estonia. In return for ceasing hostilities between the two empires in the Second Northern War, Russia is allowed to keep captured territories in Livonia (part of modern-day Latvia) for a term of three years. December 25 – Polish and Danish forces defeat a Swedish Army in the Battle of Kolding in Denmark. December 30 – The Siege of Toruń ends almost six months after it started, with Poland recapturing the city from Sweden. Portuguese traders are expelled from Ceylon by Dutch invaders. The Dutch in the Cape Colony start to import slaves from India and South-East Asia (later from Madagascar). Mary of Modena January 9 – Nicolas Coustou, French artist (d. 1733)[3] January 17 – Samson Wertheimer, European rabbi (d. 1724) January 21 – Francis Seymour, 5th Duke of Somerset (d. 1678) February 18 – Charles-Irénée Castel de Saint-Pierre, French writer (d. 1743) March 5 – Antoine de la Mothe Cadillac, French explorer (d. 1730) March 6 – Thomas Trevor, 1st Baron Trevor, British Baron (d. 1730) March 23 – Jean-Baptiste Santerre, French painter (d. 1717) March 30 – Muro Kyūsō, Japanese Neo-Confucian scholar (d. 1734) April 11 – James Hamilton, 4th Duke of Hamilton, Scottish peer (d. 1712) April 19 – Johann Wilhelm, Elector Palatine, German noble (d. 1716) April 22 – Giuseppe Torelli, Italian violist, violinist, pedagogue and composer (d. 1709) May 30 – Sir Henry Furnese, 1st Baronet, English merchant and politician (d. 1712) June 10 – John Leverett, Massachusetts businessman, colonel (d. 1712) June 11 – Victor Honoré Janssens, Flemish painter (d. 1736) June 22 – Louis VII, Landgrave of Hesse-Darmstadt (d. 1678) July 10 – Luigi Ferdinando Marsili, Italian soldier and naturalist (d. 1730) July 14 – Camillo Rusconi, Italian artist (d. 1728) July 17 – Diogo de Mendonça Corte-Real, Portuguese politician (d. 1736) July 21 – Alexis Littré, French physician and anatomist (d. 1726) July 25 – Archibald Campbell, 1st Duke of Argyll, Scottish privy councillor (d. 1703) July 28 – Roelof Diodati, Dutch Governor of Mauritius (d. 1723) August 1 – Pierre Joseph Garidel, French botanist (d. 1737) August 5 – Claude Audran III, French painter (d. 1734) August 10 – Susanne Maria von Sandrart, German engraver (d. 1716) August 11 – Sir Justinian Isham, 4th Baronet, English baronet and Member of Parliament (d. 1730) August 16 – Jan Frans van Son, Flemish Baroque painter (d. 1704) August 16 – Ralph Thoresby, British historian (d. 1725) August 18 – Jan František Beckovský, Czech historian (d. 1722) August 22 – John Ernest IV, Duke of Saxe-Coburg-Saalfeld (d. 1729) August 25 – Henry Fournelt, French theologian (d. 1729) September 3 – John Dennis, English dramatist and critic (d. 1734) September 24 – Sir Robert Austin, 1st Baronet, Scottish politician (d. 1737) September 30 – Elisabeth Eleonore of Brunswick-Wolfenbüttel, Duchess consort of Saxe-Meiningen (d. 1729) October 2 – Nicholas Roosevelt (1658–1742), Dutch-American politician (d. 1742) October 5 – Mary of Modena, queen of James II of England (d. 1718) October 11 – Christian Heinrich Postel, German jurist (d. 1705) October 18 – Alexander of Courland, German prince (d. 1686) October 19 – Adolphus Frederick II, Duke of Mecklenburg-Strelitz (d. 1708) October 21 – Henri de Boulainvilliers, French nobleman (d. 1722) October 24 – Marko Gerbec, Carniolan physician, scientist (d. 1718) November 2 – Baptist Noel (MP), English politician (d. 1690) November 4 – Sulkhan-Saba Orbeliani, Georgian prince, writer, monk and author of (d. 1725) November 21 – Johann Gottfried Roesner, Prussian burgomaster (d. 1724) November 27 – Tsarevna Catherine Alekseyevna of Russia, daughter of Tsar Alexis of Russia (d. 1718) November 27 – Hercule-Louis Turinetti, marquis of Prie (d. 1726) December 2 – Sir Thomas Roberts, 4th Baronet, English politician (d. 1706) December 10 – Lancelot Blackburne, Archbishop of York (d. 1743) date unknown – Elizabeth Barry, English actress (d. 1713) John Cleveland Witte Cornelisszon de With January 1 – Caspar Sibelius, Dutch Protestant minister (b. 1590) January 2 – Sir William Armine, 2nd Baronet, English politician (b. 1622) January 7 – Theophilus Eaton, English-born Connecticut colonist (b. 1590) January 13 – Edward Sexby, English Puritan soldier (b. 1616) February 19 – Henry Wilmot, 1st Earl of Rochester (b. 1612) March 25 – Herman IV, Landgrave of Hesse-Rotenburg (b. 1607) February 27 – Adolf Frederick I, Duke of Mecklenburg-Schwerin (1592–1628 and again 1631–1658) (b. 1588) March 29 – Bertuccio Valiero, Doge of Venice (b. 1596) April 7 – Juan Eusebio Nieremberg, Spanish mystic (b. 1595) April 19 Kirsten Munk, second wife of Christian IV of Denmark (b. 1598) Robert Rich, 2nd Earl of Warwick, English colonial administrator and admiral (b. 1587) April 24 – Francesco Maria Richini, Italian architect (b. 1584) April 29 – John Cleveland, English poet (b. 1613) May 20 – Bartholomew Holzhauser, German priest, visionary and writer of prophecies (b. 1613) June 18 – Louis Cappel, French Protestant churchman and scholar (b. 1585) June 8 – Sir Henry Slingsby, 1st Baronet, English politician (b. 1602) June 27 – Ercole Gennari, Italian drawer and painter (b. 1597) July 22 – Frederick, Duke of Schleswig-Holstein-Sonderburg-Norburg (b. 1581) August 5 – Gundakar, Prince of Liechtenstein, court official in Vienna (b. 1580) August 6 – Elizabeth Claypole, daughter of Oliver Cromwell (b. 1629) August 19 – Christine of Hesse-Kassel, Duchess of Saxe-Eisenach and Saxe-Coburg (b. 1578) September 3 – Oliver Cromwell, Lord Protector of England, Scotland, and Ireland (b. 1599) September 17 – Kaspar von Barth, German philologist and writer (b. 1587) September 22 – Georg Philipp Harsdörffer, German poet (b. 1607) October 14 – Francesco I d'Este, Duke of Modena, Italian noble (b. 1610) October 23 – Thomas Pride, Parliamentarian general in the English Civil War November 4 – Antoine Le Maistre, French Jansenist (b. 1608) November 6 – Pierre du Ryer, French dramatist (b. 1606) November 7 – Maeda Toshitsune, Japanese warlord (b. 1594) November 29 – Margrave Charles Magnus of Baden-Durlach (b. 1621) December 6 – Baltasar Gracián y Morales, Spanish writer (b. 1601) December 15 – Carlo Emanuele Madruzzo, Italian prince-bishop (b. 1599) December 20 – Jean Jannon, French typefounder (b. 1580) Date unknown: Osoet Pegua, Thai businesswoman (b. 1615) ^ "killing". Oxford Reference. Retrieved December 14, 2021. ^ Brems, Hans (June 1970). "Sweden: From Great Power to Welfare State". Journal of Economic Issues. 4 (2). Association for Evolutionary Economics: 1–16. doi:10.1080/00213624.1970.11502941. JSTOR 4224039. A swift and brilliantly conceived march from Holstein across the frozen Danish waters on Copenhagen, by Karl X Gustav in 1658, finally wrests Bohuslin, Sk'ane, and Blekinge from Denmark-Norway. Denmark no longer controls both sides of Oresund, and Swedish power is at its peak. ^ "Nicolas Coustou | French sculptor | Britannica". www.britannica.com. Retrieved December 14, 2021. Retrieved from " 3One hundred years, from 1501 to 1600 This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed.Find sources: "16th century" – news · newspapers · books · scholar · JSTOR (September 2022) (Learn how and when to remove this message) Millennia 2nd millennium Centuries 15th century 16th century 17th century Timelines 15th century 16th century 17th century State leaders 15th century 16th century 17th century Decades 1500s 1510s 1520s 1530s 1540s 1550s 1560s 1570s 1580s 1590s Categories: Births – Deaths Establishments – Disestablishments vte The world map by the Italian Amerigo Vespucci (from whose name the word America is derived) and Belgian Gerardus Mercator shows (besides the classical continents Europe, Africa, and Asia) the Americas as America sive India Nova', New Guinea, and other islands of Southeast Asia, as well as a hypothetical Arctic continent and a yet undetermined Terra Australis.[1]The 16th century began with the Julian year 1501 (represented by the Roman numerals MDI) and ended with either the Julian or the Gregorian year 1600 (MDC), depending on the reckoning used (the Gregorian calendar introduced a lapse of 10 days in October 1582).[1] The Renaissance in Italy and Europe saw the emergence of important artists, authors and scientists, and led to the foundation of important subjects which include accounting and political science. Copernicus proposed the heliocentric universe, which was met with strong resistance, and Tycho Brahe refuted the theory of celestial spheres through observational measurement of the 1572 appearance of a Milky Way supernova. These events directly challenged the long-held notion of an immutable universe supported by Ptolemy and Aristotle, and led to major revolutions in astronomy and science. Galileo Galilei became a champion of the new sciences, invented the first thermometer and made substantial contributions in the fields of physics and astronomy, becoming a major figure in the Scientific Revolution in Europe. Spain and Portugal colonized large parts of Central and South America, followed by France and England in Northern America and the Lesser Antilles. The Portuguese became the masters of trade between Brazil, the coasts of Africa, and their possessions in the Indies, whereas the Spanish came to dominate the Greater Antilles, Mexico, Peru, and opened trade across the Pacific Ocean, linking the Americas with the Indies. English and French privateers began to practice persistent theft of Spanish and Portuguese treasures. This era of colonialism established mercantilism as the leading school of economic thought, where the economic system was viewed as a zero-sum game in which any gain by one party required a loss by another. The mercantilist doctrine encouraged the many intra-European wars of the period and arguably fueled European expansion and imperialism throughout the world until the 19th century or early 20th century. The Reformation in central and northern Europe gave a major blow to the authority of the papacy and the Catholic Church. In England, the British-Italian Alberico Gentili wrote the first book on public international law and divided secularism from canon law and Catholic theology. European politics became dominated by religious conflicts, with the groundwork for the epochal Thirty Years' War being laid towards the end of the century. In the Middle East, the Ottoman Empire continued to expand, with the sultan taking the title of caliph, while dealing with a resurgent Persia. Iran and Iraq were caught by a major popularity of the Shia sect of Islam under the rule of the Safavid dynasty of warrior-mystics, providing grounds for a Persia independent of the majority-Sunni Muslim world.[2] In the Indian subcontinent, following the defeat of the Delhi Sultanate and Vijayanagara Empire, new powers emerged, the Sur Empire founded by Sher Shah Suri, Deccan sultanates, Rajput states, and the Mughal Empire[3] by Emperor Babur, a direct descendant of Timur and Genghis Khan.[4] His successors Humayun and Akbar, enlarged the empire to include most of South Asia. Japan suffered a severe civil war at this time, known as the Sengoku period, and emerged from it as a unified nation under Toyotomi Hideyoshi. China was ruled by the Ming dynasty, which was becoming increasingly isolationist, coming into conflict with Japan over the control of Korea as well as Japanese pirates. In Africa, Christianity had begun to spread in Central Africa and Southern Africa. Until the Scramble for Africa in the late 19th century, most of Africa was left uncolonized. For timelines of earlier events, see 15th century and Timeline of the Middle Ages. Main article: 1500s Mona Lisa, by Leonardo da Vinci, c. 1503–1506, one of the world's best-known paintings 1501: Michelangelo returns to his native Florence to begin work on the statue David. 1501: Safavid dynasty reunifies Iran and rules over it until 1736. Safavids adopt a Shia branch of Islam.[5] 1501: First Battle of Cannanore between the Third Portuguese Armada and Kingdom of Cochin under João da Nova and Zamorin of Kozhikode's navy marks the beginning of Portuguese conflicts in the Indian Ocean. 1502: First reported African slaves in the New World 1502: The Crimean Khanate sacks Sarai in the Golden Horde, ending its existence. 1503: Spain defeats France at the Battle of Cerignola. Considered to be the first battle in history won by gunpowder small arms. 1503: Leonardo da Vinci begins painting the Mona Lisa and completes it three years later. 1503: Nostradamus is born on either December 14 or December 21. 1504: A period of drought, with famine in all of Spain. 1504: Death of Isabella I of Castile; Joanna of Castile becomes the Queen. 1504: Foundation of the Sultanate of Sennar by Amara Dunqas, in what is modern Sudan 1505: Zhengde Emperor ascends the throne of Ming dynasty. 1505: Martin Luther enters St. Augustine's Monastery at Erfurt, Germany, on 17 July and begins his journey to instigating the Reformation. 1505: Sultan Trenggono builds the first Muslim kingdom in Java, called Demak, in Indonesia. Many other small kingdoms were established in other islands to fight against Portuguese. Each kingdom introduced local language as a way of communication and unity. 1506: Leonardo da Vinci completes the Mona Lisa. 1506: King Afonso I of Kongo wins the battle of Mbanza Kongo, resulting in Catholicism becoming Kongo's state religion.Battle of Cerignola: El Gran Capitan finds the corpse of Louis d'Armagnac, Duke of Nemours 1506: At least two thousand converted Jews are massacred in a Lisbon riot, Portugal. 1506: Christopher Columbus dies in Valladolid, Spain. 1506: Poland is invaded by Tatars from the Crimean Khanate. 1507: The first recorded epidemic of smallpox in the New World on the island of Hispaniola. It devastates the native Taíno population.[6] 1507: Afonso de Albuquerque conquered Hormuz and Muscat, among other bases in the Persian Gulf, taking control of the region at the entrance of the Gulf. 1508: The Christian-Islamic power struggle in Europe and West Asia spills over into the Indian Ocean as Battle of Chaul during the Portuguese-Mamluk War 1508–1512: Michelangelo paints the Sistine Chapel ceiling. 1509: The defeat of joint fleet of the Sultan of Gujarat, the Mamlûk Burji Sultanate of Egypt, and the Zamorin of Calicut with support of the Republic of Venice and the Ottoman Empire in Battle of Diu marks the beginning of Portuguese dominance of the Spice trade and the Indian Ocean. 1509: The Portuguese king sends Diogo Lopes de Sequeira to find Malacca, the eastern terminus of Asian trade. After initially receiving Sequeira, Sultan Mahmud Shah captures and/or kills several of his men and attempts an assault on the four Portuguese ships, which escape.[7] The Javanese fleet is also destroyed in Malacca. 1509: Krishnadevaraya ascends the throne of Vijayanagara Empire. Main article: 1510s Afonso de Albuquerque 1509–1510: The 'great plague' in various parts of Tudor England.[8] 1510: Afonso de Albuquerque of Portugal conquers Goa in India. 1511: Afonso de Albuquerque of Portugal conquers Malacca, the capital of the Sultanate of Malacca in present-day Malaysia. 1512: Copernicus writes Commentariolus, and proclaims the Sun the center of the Solar System. 1512: The southern part (historical core) of the Kingdom of Navarre is invaded by Castile and Aragon. 1512: Qutb Shahi dynasty, founded by Quli Qutb Mulk, rules Golconda Sultanate until 1687. 1512: The first Portuguese exploratory expedition was sent eastward from Malacca (in present-day Malaysia) to search for the 'Spice Islands' (Maluku) led by Francisco Serrão. Serrão is shipwrecked but struggles on to Hitu (northern Ambon) and wins the favour of the local rulers.[9] 1513: Machiavelli writes The Prince, a treatise about political philosophy 1513: The Portuguese mariner Jorge Álvares lands at Macau, China, during the Ming dynasty. 1513: Henry VIII defeats the French at the Battle of the Spurs. 1513: The Battle of Flodden Field in which invading Scots are defeated by Henry VIII's forces. 1513: Sultan Selim I ("The Grim") orders the massacre of Shia Muslims in Anatolia (present-day Turkey). 1513: Vasco Núñez de Balboa, in service of Spain arrives at the Pacific Ocean (which he called Mar del Sur) across the Isthmus of Panama. He was the first European to do so. 1514: The Battle of Orsha halts Muscovy's expansion into Eastern Europe. 1514: Dózsa rebellion (peasant revolt) in Hungary.Martin Luther initiated the Reformation with his Ninety-five Theses in 1517. 1514: The Battle of Chaldiran, the Ottoman Empire gains decisive victory against Safavid dynasty. 1515: Ascension of Francis I of France as King of France following the death of Louis XII. 1515: The Ottoman Empire wrests Eastern Anatolia from the Safavids after the Battle of Chaldiran. 1515: The Ottomans conquer the last beyliks of Anatolia, the Dulkadirs and the Ramadanids. 1516–1517: The Ottomans defeat the Mamluks and gain control of Egypt, Arabia, and the Levant. 1517: The Sweating sickness epidemic in Tudor England.[10] 1517: The Reformation begins when Martin Luther posts his Ninety-five Theses in Saxony. 1518: The Treaty of London was a non-aggression pact between the major European nations. The signatories were Burgundy, France, England, the Holy Roman Empire, the Netherlands, the Papal States and Spain, all of whom agreed not to attack one another and to come to the aid of any that were under attack. 1518: Mir Chakar Khan Rind leaves Baluchistan and settles in Punjab. 1518: Leo Africanus, also known as al-Hasan ibn Muhammad al-Wazzan al-Fasi, an Andalusian Berber diplomat who is best known for his book Descrittione dell’Africa (Description of Africa), is captured by Spanish pirates; he is taken to Rome and presented to Pope Leo X. 1518: The dancing plague of 1518 begins in Strasbourg, lasting for about one month. 1519: Leonardo da Vinci dies of natural causes on May 2.Europe at the time of the accession of Charles V in 1519 1519: Wang Yangming, the Chinese philosopher and governor of Jiangxi province, describes his intent to use the firepower of the fo-lang-ji, a breech-loading Portuguese culverin, in order to suppress the rebellion of Prince Zhu Chenhao. 1519: Barbary pirates led by Hayreddin Barbarossa, a Turk appointed to ruling position in Algiers by the Ottoman Empire, raid Provence and Toulon in southern France. 1519: Death of Emperor Maximilian; Charles I of Austria, Spain, and the Low Countries becomes Emperor of Holy Roman Empire as Charles V, Holy Roman Emperor (ruled until 1556). 1519–1522: Spanish expedition commanded by Magellan and Elcano are the first to Circumnavigate the Earth. 1519–1521: Hernán Cortés leads the Spanish conquest of the Aztec Empire. Main article: 1520s Ferdinand Magellan led the first expedition that circumnavigated the globe in 1519–1522. 1520–1566: The reign of Suleiman the Magnificent marks the zenith of the Ottoman Empire. 1520: The first European diplomatic mission to Ethiopia, sent by the Portuguese, arrives at Massawa 9 April, and reaches the imperial encampment of Emperor Dawit II in Shewa 9 October. 1520: Vijayanagara Empire forces under Krishnadevaraya defeat the Adil Shahi under at the Battle of Raichur 1520: Sultan Ali Mughayat Shah of Aceh begins an expansionist campaign capturing Daya on the west Sumatran coast (in present-day Indonesia), and the pepper and gold producing lands on the east coast. 1520: The Portuguese established a trading post in the village of Lamakera on the eastern side of Solor (in present-day Indonesia) as a transit harbour between Maluku and Malacca. 1521: Belgrade (in present-day Serbia) is captured by the Ottoman Empire. 1521: After building fortifications at Tuen Mun, the Portuguese attempt to invade Ming dynasty China, but are expelled by Chinese naval forces. 1521: Philippines encountered by Ferdinand Magellan. He was later killed in the Battle of Mactan in central Philippines in the same year. 1521: Jiajing Emperor ascended the throne of Ming dynasty, China. 1521: November, Ferdinand Magellan's expedition reaches Maluku (in present-day Indonesia) and after trade with Ternate returns to Europe with a load of cloves. 1521: Pati Unus leads the invasion of Malacca (in present-day Malaysia) against the Portuguese occupation. Pati Unus was killed in this battle, and was succeeded by his brother, sultan Trenggana. 1522: Rhodes falls to the Ottomans of Suleiman the Magnificent.[11]Sack of Rome of 1527 by Charles V's forces (painting by Johannes Lingelbach) 1522: The Portuguese ally themselves with the rulers of Ternate (in present-day Indonesia) and begin construction of a fort.[9] 1522: August, Luso-Sundanese Treaty signed between Portugal and Sunda Kingdom granted Portuguese permit to build fortress in Sunda Kelapa. 1523: Sweden gains independence from the Kalmar Union. 1523: The Cacao bean is introduced to Spain by Hernán Cortés 1524–1525: German Peasants' War in the Holy Roman Empire. 1524: Giovanni da Verrazzano is the first European to explore the Atlantic coast of North America between South Carolina and Newfoundland. 1524: Ismail I, the founder of Safavid dynasty, dies and Tahmasp I becomes king.Gun-wielding Ottoman Janissaries and defending Knights of Saint John at the siege of Rhodes in 1522, from an Ottoman manuscript 1525: Timurid Empire forces under Babur defeat the Lodi dynasty at the First Battle of Panipat, end of the Delhi Sultanate. 1525: German and Spanish forces defeat France at the Battle of Pavia, Francis I of France is captured. 1526: The Ottomans defeat the Kingdom of Hungary at the Battle of Mohács. 1526: Mughal Empire, founded by Babur. 1527: Sack of Rome with Pope Clement VII escaping and the Swiss Guards defending the Vatican being killed. The sack of the city of Rome considered the end of the Italian Renaissance. 1527: Protestant Reformation begins in Sweden. 1527: The last ruler of Majapahit falls from power. This state (located in present-day Indonesia) was finally extinguished at the hands of the Demak. A large number of courtiers, artisans, priests, and members of the royalty moved east to the island of Bali; however, the power and the seat of government transferred to Demak under the leadership of Pangeran, later Sultan Fatah. 1527: June 22, The Javanese Prince Fatahillah of the Cirebon Sultanate successfully defeated the Portuguese armed forces at the site of the Sunda Kelapa Harbor. The city was then renamed Jayakarta, meaning "a glorious victory." This eventful day came to be acknowledged as Jakarta's Founding Anniversary. 1527: Mughal Empire forces defeat the Rajput led by Rana Sanga of Mewar at the Battle of Khanwa 1529: The Austrians defeat the Ottoman Empire at the siege of Vienna. 1529: Treaty of Zaragoza defined the antimeridian of Tordesillas attributing the Moluccas to Portugal and Philippines to Spain. 1529: Imam Ahmad Gurey defeats the Ethiopian Emperor Dawit II in the Battle of Shimbra Kure, the opening clash of the Ethiopian–Adal War. Main article: 1530s Spanish conquistadors with their Tlaxcallan allies fighting against the Otomies of Metztitlan in present-day Mexico, a 16th-century codex 1531–1532: The Church of England breaks away from the Catholic Church and recognizes King Henry VIII as the head of the Church. 1531: The Inca Civil War is fought between the two brothers, Atahualpa and Huáscar. 1532: Francisco Pizarro leads the Spanish conquest of the Inca Empire. 1532: Foundation of São Vicente, the first permanent Portuguese settlement in the Americas. 1533: Anne Boleyn becomes Queen of England. 1533: Elizabeth Tudor is born. 1534: Jacques Cartier claims Canada for France. 1534: The Ottomans capture Baghdad from the Safavids. 1534: Affair of the Placards, where King Francis I becomes more active in repression of French Protestants. 1535: The Münster Rebellion, an attempt of radical, millennialist, Anabaptists to establish a theocracy, ends in bloodshed. 1535: The Portuguese in Ternate depose Sultan Tabariji (or Tabarija) and send him to Portuguese Goa where he converts to Christianity and bequeaths his Portuguese godfather Jordao de Freitas the island of Ambon.[12] Hairun becomes the next sultan. 1536: Catherine of Aragon dies in Kimbolton Castle, in England.Territorial expansion of the Ottoman Empire under Suleiman (in red and orange) 1536: In England, Anne Boleyn is beheaded for adultery and treason. 1536: Establishment of the Inquisition in Portugal. 1536: Foundation of Buenos Aires (in present-day Argentina) by Pedro de Mendoza. 1537: The Portuguese establish Recife in Pernambuco, north-east of Brazil. 1537: William Tyndale's partial translation of the Bible into English is published, which would eventually be incorporated into the King James Bible. 1538: Gonzalo Jiménez de Quesada founds Bogotá. 1538: Spanish–Venetian fleet is defeated by the Ottoman Turks at the Battle of Preveza. 1539: Hernando de Soto explores inland North America. Main article: 1540s Nicolaus Copernicus 1540: The Society of Jesus, or the Jesuits, is founded by Ignatius of Loyola and six companions with the approval of Pope Paul III. 1540: Sher Shah Suri founds the Suri dynasty in South Asia, an ethnic Pashtun (Pathan) of the house of Sur, who supplanted the Mughal dynasty as rulers of North India during the reign of the relatively ineffectual second Mughal emperor Humayun. Sher Shah Suri decisively defeats Humayun in the Battle of Bilgram (May 17, 1540). 1541: Pedro de Valdivia founds Santiago in Chile. 1541: An Algerian military campaign by Charles V of Spain (Habsburg) is unsuccessful. 1541: Amazon River is encountered and explored by Francisco de Orellana. 1541: Capture of Buda and the absorption of the major part of Hungary by the Ottoman Empire. 1541: Sahib I Giray of Crimea invades Russia. 1542: The Italian War of 1542–1546 War resumes between Francis I of France and Emperor Charles V. This time Henry VIII is allied with the Emperor, while James V of Scotland and Sultan Suleiman I are allied with the French. 1542: Akbar The Great is born in the Rajput Umarkot Fort 1542: Spanish explorer Ruy López de Villalobos named the island of Samar and Leyte Las Islas Filipinas honoring Philip II of Spain and became the official name of the archipelago. 1543: Ethiopian/Portuguese troops defeat the Adal army led by Imam Ahmad Gurey at the Battle of Wayna Daga; Imam Ahmad Gurey is killed at this battle. 1543: Copernicus publishes his theory that the Earth and the other planets revolve around the Sun 1543: The Nanban trade period begins after Portuguese traders make contact with Japan. 1544: The French defeat an Imperial–Spanish army at the Battle of Ceresole.Scenes of everyday life in Ming China, by Qiu Ying 1544: Battle of the Shirts in Scotland. The Frasers and Macdonalds of Clan Ranald fight over a disputed chiefship; reportedly, 5 Frasers and 8 Macdonalds survive. 1545: Songhai forces sack the Malian capital of Niani 1545: The Council of Trent meets for the first time in Trent (in northern Italy). 1546: Michelangelo Buonarroti is made chief architect of St. Peter's Basilica. 1546: Francis Xavier works among the peoples of Ambon, Ternate and Morotai (Moro) laying the foundations for a permanent mission. (to 1547) 1547: Henry VIII dies in the Palace of Whitehall on 28 January at the age of 55. 1547: Francis I dies in the Château de Rambouillet on 31 March at the age of 52. 1547: Edward VI becomes King of England and Ireland on 28 January and is crowned on 20 February at the age of 9. 1547: Emperor Charles V decisively dismantles the Schmalkaldic League at the Battle of Mühlberg. 1547: Grand Prince Ivan the Terrible is crowned tsar of (All) Russia, thenceforth becoming the first Russian tsar. 1548: Battle of Uedahara: Firearms are used for the first time on the battlefield in Japan, and Takeda Shingen is defeated by Murakami Yoshikiyo. 1548: Askia Daoud, who reigned from 1548 to 1583, establishes public libraries in Timbuktu (in present-day Mali). 1548: The Ming dynasty government of China issues a decree banning all foreign trade and closes down all seaports along the coast; these Hai jin laws came during the Wokou wars with Japanese pirates. 1549: Tomé de Sousa establishes Salvador in Bahia, north-east of Brazil. 1549: Arya Penangsang with the support of his teacher, Sunan Kudus, avenges the death of Raden Kikin by sending an envoy named Rangkud to kill Sunan Prawoto by Keris Kyai Satan Kober (in present-day Indonesia). Main article: 1550s The Islamic gunpowder empires: Mughal Army artillerymen during the reign of Jalaluddin Akbar 1550: The architect Mimar Sinan builds the Süleymaniye Mosque in Istanbul. 1550: Mongols led by Altan Khan invade China and besiege Beijing. 1550–1551: Valladolid debate concerning the human rights of the Indigenous people of the Americas. 1551: Fifth outbreak of sweating sickness in England. John Caius of Shrewsbury writes the first full contemporary account of the symptoms of the disease. 1551: North African pirates enslave the entire population of the Maltese island Gozo, between 5,000 and 6,000, sending them to Libya. 1552: Russia conquers the Khanate of Kazan in central Asia. 1552: Jesuit China Mission, Francis Xavier dies. 1553: Mary Tudor becomes the first queen regnant of England and restores the Church of England under Papal authority. 1553: The Portuguese found a settlement at Macau. 1554: Missionaries José de Anchieta and Manuel da Nóbrega establishes São Paulo, southeast Brazil. 1554: Princess Elizabeth is imprisoned in the Tower of London upon the orders of Mary I for suspicion of being involved in the Wyatt rebellion. 1555: The Muscovy Company is the first major English joint stock trading company. 1556: Publication in Venice of Delle Navigiationi et Viaggi (terzo volume) by Giovanni Battista Ramusio, secretary of Council of Ten, with plan La Terra de Hochelaga, an illustration of the Hochelaga.[13] 1556: The Shaanxi earthquake in China is history's deadliest known earthquake during the Ming dynasty. 1556: Georgius Agricola, the "Father of Mineralogy", publishes his De re metallica. 1556: Akbar defeats Hemu at the Second battle of Panipat. 1556: Russia conquers the Astrakhan Khanate. 1556–1605: During his reign, Akbar expands the Mughal Empire in a series of conquests (in the Indian subcontinent).Political map of the world in 1556 1556: Mir Chakar Khan Rind captures Delhi with Humayun. 1556: Pomponio Algerio, radical theologian, is executed by boiling in oil as part of the Roman Inquisition. 1557: Habsburg Spain declares bankruptcy. Philip II of Spain had to declare four state bankruptcies in 1557, 1560, 1575 and 1596. 1557: The Portuguese settle in Macau (on the western side of the Pearl River Delta across from present-day Hong Kong). 1557: The Ottomans capture Massawa, all but isolating Ethiopia from the rest of the world. 1558: Elizabeth Tudor becomes Queen Elizabeth I at age 25. 1558–1603: The Elizabethan era is considered the height of the English Renaissance. 1558–1583: Livonian War between Poland, Grand Principality of Lithuania, Sweden, Denmark and Russia. 1558: After 200 years, the Kingdom of England loses Calais to France. 1559: With the Peace of Cateau Cambrésis, the Italian Wars conclude. 1559: Sultan Hairun of Ternate (in present-day Indonesia) protests the Portuguese's Christianisation activities in his lands. Hostilities between Ternate and the Portuguese. Main article: 1560s The Mughal Emperor Akbar shoots the Rajput warrior Jaimal during the Siege of Chittorgarh in 1567 1560: Ottoman navy defeats the Spanish fleet at the Battle of Djerba. 1560: Elizabeth Bathory is born in Nyírbátor, Hungary. 1560: By winning the Battle of Okehazama, Oda Nobunaga becomes one of the pre-eminent warlords of Japan. 1560: Jeanne d'Albret declares Calvinism the official religion of Navarre. 1560: Lazarus Church, Macau 1561: Sir Francis Bacon is born in London. 1561: The fourth battle of Kawanakajima between the Uesugi and Takeda at Hachimanbara takes place. 1561: Guido de Bres draws up the Belgic Confession of Protestant faith. 1562: Mughal emperor Akbar reconciles the Muslim and Hindu factions by marrying into the powerful Rajput Hindu caste. 1562–1598: French Wars of Religion between Catholics and Huguenots. 1562: Massacre of Wassy and Battle of Dreux in the French Wars of Religion. 1562: Portuguese Dominican priests build a palm-trunk fortress which Javanese Muslims burned down the following year. The fort was rebuilt from more durable materials and the Dominicans commenced the Christianisation of the local population.[12] 1563: Plague outbreak claimed 80,000 people in Elizabethan England. In London alone, over 20,000 people died of the disease. 1564: Galileo Galilei born on February 15 1564: William Shakespeare baptized 26 April 1565: Deccan sultanates defeat the Vijayanagara Empire at the Battle of Talikota. 1565: Mir Chakar Khan Rind dies at aged 97. 1565: Estácio de Sá establishes Rio de Janeiro in Brazil. 1565: The Hospitallers, a Crusading Order, defeat the Ottoman Empire at the siege of Malta (1565). 1565: Miguel López de Legazpi establishes in Cebu the first Spanish settlement in the Philippines starting a period of Spanish colonization that would last over three hundred years. 1565: Spanish navigator Andres de Urdaneta discovers the maritime route from Asia to the Americas across the Pacific Ocean, also known as the tornaviaje. 1565: Royal Exchange is founded by Thomas Gresham. 1566: Suleiman the Magnificent, ruler of the Ottoman Empire, dies on September 7, during the battle of Szigetvar.Siege of Valenciennes during the Dutch War of Independence in 1567 1566–1648: Eighty Years' War between Spain and the Netherlands. 1566: Da le Balle Contrade d'Oriente, composed by Cipriano de Rore. 1567: After 45 years' reign, Jiajing Emperor died in the Forbidden City, Longqing Emperor ascended the throne of Ming dynasty. 1567: Mary, Queen of Scots, is imprisoned by Elizabeth I. 1568: The Transylvanian Diet, under the patronage of the prince John Sigismund Zápolya, the former king of Hungary, inspired by the teachings of Ferenc Dávid, the founder of the Unitarian Church of Transylvania, promulgates the Edict of Torda, the first law of freedom of religion and of conscience in the World. 1568–1571: Morisco Revolt in Spain. 1568–1600: The Azuchi–Momoyama period in Japan. 1568: Hadiwijaya sent his adopted son and son in-law Sutawijaya, who would later become the first ruler of the Mataram dynasty of Indonesia, to kill Arya Penangsang. 1569: Rising of the North in England. 1569: Mercator 1569 world map published by Gerardus Mercator. 1569: The Polish–Lithuanian Commonwealth is created with the Union of Lublin which lasts until 1795. 1569: Peace treaty signed by Sultan Hairun of Ternate and Governor Lopez De Mesquita of Portugal. Main article: 1570s The Battle of Lepanto 1570: Ivan the Terrible, tsar of Russia, orders the massacre of inhabitants of Novgorod. 1570: Pope Pius V issues Regnans in Excelsis, a papal bull excommunicating all who obeyed Elizabeth I and calling on all Catholics to rebel against her. 1570: Sultan Hairun of Ternate (in present-day Indonesia) is killed by the Portuguese.[12] Babullah becomes the next Sultan. 1570: 20,000 inhabitants of Nicosia in Cyprus were massacred and every church, public building, and palace was looted. Cyprus fell to the Ottoman Turks the following year. 1571: Pope Pius V completes the Holy League as a united front against the Ottoman Turks, responding to the fall of Cyprus to the Ottomans. 1571: The Spanish-led Holy League navy destroys the Ottoman Empire navy at the Battle of Lepanto. 1571: Crimean Tatars attack and sack Moscow, burning everything but the Kremlin. 1571: American Indians kill Spanish missionaries in what would later be Jamestown, Virginia. 1571: Spanish conquistador Miguel López de Legazpi establishes Manila, Philippines as the capital of the Spanish East Indies. 1572: Brielle is taken from Habsburg Spain by Protestant Watergeuzen in the Capture of Brielle, in the Eighty Years' War. 1572: Spanish conquistadores apprehend the last Inca leader Tupak Amaru at Vilcabamba, Peru, and execute him in Cuzco. 1572: Jeanne d'Albret dies aged 43 and is succeeded by Henry of Navarre. 1572: Catherine de' Medici instigates the St. Bartholomew's Day massacre which takes the lives of Protestant leader Gaspard de Coligny and thousands of Huguenots. The violence spreads from Paris to other cities and the countryside. 1572: First edition of the epic The Lusiads of Luís Vaz de Camões, three years after the author returned from the East.[14] 1572: The 9 years old Taizi, Zhu Yijun ascended the throne of Ming dynasty, known as Wanli Emperor. 1573: After heavy losses on both sides the siege of Haarlem ends in a Spanish victory.St. Bartholomew's Day massacre of French Protestants 1574: in the Eighty Years' War the capital of Zeeland, Middelburg declares for the Protestants. 1574: After a siege of 4 months the siege of Leiden ends in a comprehensive Dutch rebel victory. 1575: Oda Nobunaga finally captures Nagashima fortress. 1575: Following a five-year war, the Ternateans under Sultan Babullah defeated the Portuguese. 1576: Tahmasp I, Safavid shah, dies. 1576: The Battle of Haldighati is fought between the ruler of Mewar, Maharana Pratap and the Mughal Empire's forces under Emperor Akbar led by Raja Man Singh. 1576: Sack of Antwerp by badly paid Spanish soldiers. 1577–1580: Francis Drake circles the world. 1577: Ki Ageng Pemanahan built his palace in Pasargede or Kotagede. 1578: King Sebastian of Portugal is killed at the Battle of Alcazarquivir. 1578: The Portuguese build a fort on Ambon but it is not the main centre for Portuguese activities in Maluku becomes Ambon.[12] 1578: Sonam Gyatso is conferred the title of Dalai Lama by Tumed Mongol ruler, Altan Khan. Recognized as the reincarnation of two previous Lamas, Sonam Gyatso becomes the third Dalai Lama in the lineage.[15] 1578: Governor-General Francisco de Sande officially declared war against Brunei in 1578, starting the Castilian War of 1578. 1579: The Union of Utrecht unifies the northern Netherlands, a foundation for the later Dutch Republic. 1579: The Union of Arras unifies the southern Netherlands, the Austrian Netherlands and Belgium.The Irish Gaelic chieftain's feast, from The Image of Ireland 1579: The British navigator Sir Francis Drake passes through Maluku and transit in Ternate on his circumnavigation of the world. The Portuguese establish a fort on Tidore but the main centre for Portuguese activities in Maluku becomes Ambon.[16] Main article: 1580s The fall of Spanish Armada 1580: Drake's royal reception after his attacks on Spanish possessions influences Philip II of Spain to build up the Spanish Armada. English ships in Spanish harbours are impounded. 1580: Spain unifies with Portugal under Philip II. The struggle for the throne of Portugal ends the Portuguese Empire. The Spanish and Portuguese crowns are united for 60 years, i.e. until 1640. 1580–1587: Nagasaki comes under the control of the Jesuits. 1581: Dutch Act of Abjuration, declaring allegiance to Philip II of Spain. 1582: Oda Nobunaga commits seppuku during the Honnō-ji Incident coup by his general, Akechi Mitsuhide. 1582: Pope Gregory XIII issues the Gregorian calendar. The last day of the Julian calendar was Thursday, 4 October 1582 and this was followed by the first day of the Gregorian calendar, Friday, 15 October 1582.Telescopes, 17th century. 1583: Denmark builds the world's first theme park, Bakken. 1583: Death of Sultan Babullah of Ternate. 1584–1585: After the siege of Antwerp, many of its merchants flee to Amsterdam. According to Luc-Normand Tellier, "At its peak, between 1510 and 1557, Antwerp concentrated about 40% of the world trade...It is estimated that the port of Antwerp was earning the Spanish crown seven times more revenues than the Americas."[17] 1584: Ki Ageng Pemanahan died. Sultan Pajang raised Sutawijaya, son of Ki Ageng Pemanahan as the new ruler in Mataram, titled "Loring Ngabehi Market" (because of his home in the north of the market). 1585: Akbar annexes Kashmir and adds it to the Kabul SubahPortuguese fusta in India from a book by Jan Huygen van Linschoten 1585: Colony at Roanoke founded in North America. 1585–1604: The Anglo-Spanish War is fought but ends in stalemate. 1587: Mary, Queen of Scots is executed by Elizabeth I. 1587: The reign of Abbas I marks the zenith of the Safavid dynasty. 1587: Troops that would invade Pajang Mataram Sultanate storm ravaged the eruption of Mount Merapi. Sutawijaya and his men survived. 1588: Mataram into the kingdom with Sutawijaya as Sultan, titled "Senapati Ingalaga Sayidin Panatagama" means the warlord and cleric Manager Religious Life. 1588: England repulses the Spanish Armada. 1589: Spain repulses the English Armada. 1589: Catherine de' Medici dies aged 69. Main article: 1590s Ottoman miniature painting about the Long War 1590: Siege of Odawara: the Go-Hojo clan surrender to Toyotomi Hideyoshi, and Japan is unified. 1591: In Mali, Moroccan forces of the Sultan Ahmad al-Mansur led by Judar Pasha defeat the Songhai Empire at the Battle of Tondibi. 1592–1593: John Stow reports 10,675 plague deaths in London, a city of approximately 200,000 people. 1592–1598: Korea, with the help of Ming dynasty China, repels two Japanese invasions. 1593–1606: The Long War between the Habsburg monarchy and the Ottoman Turks. 1594: St. Paul's College, Macau, founded by Alessandro Valignano. 1595: First Dutch expedition to Indonesia sets sail for the East Indies with two hundred and forty-nine men and sixty-four cannons led by Cornelis de Houtman.[18] 1596: Birth of René Descartes. 1596: June, de Houtman's expedition reaches Banten the main pepper port of West Java where they clash with both the Portuguese and Indonesians. It then sails east along the north coast of Java where it is attacked by locals, and anchors at Sidayu and killing a local ruler in the Sampang. 1596: Romeo and Juliet is published. 1597: Cornelis de Houtman's expedition returns to the Netherlands with enough spices to make a considerable profit.[18] 1598: The Edict of Nantes ends the French Wars of Religion. 1598: Abbas I moves the Safavid capital from Qazvin to Isfahan in 1598. 1598–1613: Russia descends into anarchy during the Time of Troubles. 1598: The Portuguese require an armada of 90 ships to put down a Solorese uprising.[12] (to 1599) 1598: More Dutch fleets leave for Indonesia and most are profitable.[18]Edo period screen depicting the Battle of Sekigahara 1598: The province of Santa Fe de Nuevo México is established in Northern New Spain. The region would later become a territory of Mexico, the New Mexico Territory in the United States, and the US State of New Mexico. 1598: Death of Toyotomi Hideyoshi, ending his invasion of Korea. 1599: The van Neck expedition returns to Europe. The expedition makes a 400 per cent profit.[18] (to 1600) 1599: March, Leaving Europe the previous year, a fleet of eight ships under Jacob van Neck was the first Dutch fleet to reach the 'Spice Islands' of Maluku.[18] 1600: Giordano Bruno is burned at the stake for heresy in Rome.Siege of Pilakovo castle during the Long Turkish War 1600: Battle of Sekigahara in Japan. End of the Warring States period and beginning of the Edo period. 1600: The Portuguese win a major naval battle in the bay of Ambon.[19] Later in the year, the Dutch join forces with the local Hituese in an anti-Portuguese alliance, in return for which the Dutch would have the sole right to purchase spices from Hitu.[19] 1600: Elizabeth I grants a charter to the British East India Company beginning the English advance in Asia. 1600: Michael the Brave unifies the three principalities: Wallachia, Moldavia and Transylvania after the Battle of Şelimbăr from 1599. For later events, see Timeline of the 17th century. The Columbian Exchange introduces many plants, animals and diseases to the Old and New Worlds. Introduction of the spinning wheel revolutionizes textile production in Europe. The letter J is introduced into the English alphabet. 1500: First portable watch is created by Peter Henlein of Germany. The Iberian Union 1580–1640 Henry VIII, (1491–1547) King of England and Lord of Ireland Süleyman the Magnificent, Sultan of the Ottoman Empire (1520–1566) Ivan IV the Terrible (1530–1584) Akbar the Great (1542–1605) Oda Nobunaga (1534–1582) Sir Francis Drake (c. 1540–1596) Alberico Gentili, (1552–1608) the Father of international law Philip II of Spain Ferdinand Álvarez de Toledo (1507–1582) Suleiman the Magnificent, Sultan of the Ottoman Empire (1520–1566) Mississippian culture disappears. Medallion rug, variant Star Ushak style, Anatolia (modern Turkey), is made. It is now kept at the Saint Louis Art Museum. Hernan Cortes (1485–1547) Henry VIII, (1491–1547) King of England and Lord of Ireland Juan Ponce de León sights Florida and Vasco Núñez de Balboa sights the eastern edge of the Pacific Ocean. 1519–1522: Ferdinand Magellan and Juan Sebastián Elcano lead the first circumnavigation of the world. 1519–1540: In America, Hernando de Soto expedition map the Gulf of Mexico coastline and bays. 1525: Modern square root symbol (√) 1540: Francisco Vásquez de Coronado sights the Grand Canyon. 1541–42: Francisco de Orellana sails the length of the Amazon River. 1542–43: Firearms are introduced into Japan by the Portuguese. 1543: Copernicus publishes his theory that the Earth and the other planets revolve around the Sun 1545: Theory of complex numbers is first developed by Gerolamo Cardano of Italy. 1558: Camera obscura is first used in Europe by Giambattista della Porta of Italy. 1559–1562: Spanish settlements in Alabama/Florida and Georgia confirm dangers of hurricanes and local native warring tribes. 1565: Spanish settlers outside New Spain (Mexico) colonize Florida's coastline at St. Augustine. 1565: Invention of the graphite pencil (in a wooden holder) by Conrad Gessner. Modernized in 1812. 1568: Gerardus Mercator creates the first Mercator projection map. 1572: Supernova SN 1572 is observed by Tycho Brahe in the Milky Way. 1582: Gregorian calendar is introduced in Europe by Pope Gregory XIII and adopted by Catholic countries. c. 1583: Galileo Galilei of Pisa, Italy identifies the constant swing of a pendulum, leading to the development of reliable timekeepers. 1585: earliest known reference to the 'sailing carriage' in China. 1589: William Lee invents the stocking frame. 1591: First flush toilet is introduced by Sir John Harington of England, the design published under the title 'The Metamorphosis of Ajax'. 1593: Galileo Galilei invents a thermometer. 1596: William Barents discovers Spitsbergen. 1597: Opera in Florence by Jacopo Peri. Entertainment in the 16th century ^ a b Modern reference works on the period tend to follow the introduction of the Gregorian calendar for the sake of clarity; thus NASA's lunar eclipse catalogue states "The Gregorian calendar is used for all dates from 1582 Oct 15 onwards. Before that date, the Julian calendar is used." For dates after 15 October 1582, care must be taken to avoid confusion of the two styles. ^ de Vries, Jan (14 September 2009). "The limits of globalization in the early modern world". The Economic History Review. 63 (3): 710–733. CiteSeerX 10.1.1.186.2862. doi:10.1111/j.1468-0289.2009.00497.x. JSTOR 40929823. S2CID 219969360. SSRN 1635517. ^ Singh, Sarina; Lindsay Brown; Paul Clammer; Rodney Cocks; John Mock (2008). Pakistan & the Karakoram Highway. Vol. 7, illustrated. Lonely Planet. p. 137. ISBN 978-1-74104-542-0. Retrieved 23 August 2010. ^ Babur (2006). Babur Nama. Penguin Books. p. viii. 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View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)Bagpipes (links | edit) List of decades, centuries, and millennia (links | edit) Fashion (links | edit) Giovanni Boccaccio (links | edit) History of Mauritius (links | edit) Post office (links | edit) Snare drum (links | edit) Republican Party (United States) (links | edit) 20th century (links | edit) 15th century (links | edit) 17th century (links | edit) 18th century (links | edit) 1624 (links | edit) 1626 (links | edit) 1630 (links | edit) 1661 (links | edit) 1618 (links | edit) 1609 (links | edit) 11th century (links | edit) 12th century (links | edit) 13th century (links | edit) 14th century (links | edit) 1648 (links | edit) 1598 (links | edit) 1599 (links | edit) 1627 (links | edit) 1662 (links | edit) 1490s (links | edit) 1640s (links | edit) 1597 (links | edit) 1690 (links | edit) 1688 (links | edit) 7th century (links | edit) 10th century (links | edit) 9th century (links | edit) 6th century (links | edit) 5th century (links | edit) 3rd century (links | edit) 1573 (links | edit) 1570s (links | edit) 1574 (links | edit) 1436 (links | edit) 1476 (links | edit) 1542 (links | edit) 1500s (links | edit) 1585 (links | edit) View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)Retrieved from " WhatLinksHere/16th_century" Struggling with heat problems in your physics class? Our article is here to help! Packed with solved examples specifically designed for high school students, this guide will make mastering heat problems easy. Get ready to boost your grades and deepen your understanding with these easy-to-follow solutions! When heat (Q) causes a change in temperature $\Delta T=T_f-T_i$ in a sample with specific heat capacity (c) and mass (m), the relationship between these physical quantities is expressed by the following formula: \[Q=mc\Delta T=mc(T_f-T_i)\] where T_f and T_i are the initial and final temperatures. In all these example problems, there is no change in the state of the substance. If there were a change in the phase of matter (solid ↔ liquid or liquid ↔ gas), you would need to use the latent heat to solve it. Some solved problems on latent heat of fusion Solved Problems on latent heat of vaporization Heat Practice problems. Problem (1): 5.0 g of copper was heated from 20°C to 80°C. How much energy was used to heat Cu? (Specific heat capacity of Cu is 0.092 cal/g.°C). Solution: The amount of heat required to raise the temperature of a substance of mass m from initial temperature T_i to final temperature T_f is obtained by the formula $Q=mc(T_f-T_i)$, where c is the specific heat of the substance. Thus, we have \begin{align*} Q&=mc\Delta T\\ &= 5\times 0.092\times (80^\circ-20^\circ)\\&= 27.6 \quad {\rm cal} \end{align*} So, it would require 27.6 calories of heat energy to increase the temperature of this substance from 20°C to 80°C. Problem (2): How much heat is released when 30 g of water at 96°C cools to 25°C? The specific heat of water is 1 cal/g.°C. Solution: the amount of energy released is obtained by formula $Q=mc\Delta T$ as follows: \begin{align*} Q&=mc\Delta T \\&= 30\times 1\times (25^\circ-96^\circ)\\&=-2130\quad {\rm cal}\end{align*} The negative sign in the result indicates that the energy of the water is decreasing, which means that heat is released by the water. Therefore, 2130 calories of heat are released when water cools from 96°C to 25°C. Depending on the specific circumstances, this energy could be transferred to the surrounding environment or used to do work. Problem (3): If a 3.1 g ring is heated using 10.0 calories, its temperature rises 17.9°C. Calculate the ring's specific heat capacity. Solution: In specific heat problems, we learned that specific heat is defined as the amount of heat required to change the temperature of a sample with mass m by ΔT. By putting known values into the equation $Q=mc(T_f-T_i)$, and solving for the unknown value, the specific heat of the ring is calculated as follows: \begin{align*} c&=\frac{Q}{m(T_f-T_i)} \\&=\frac{10}{3.1\times 17.9}\\ &=0.18\quad {\rm cal/g\cdot ^\circ C}\end{align*} The specific heat of the ring is calculated to be $0.18\,{\rm cal/g\cdot ^\circ C}$. This value tells us how much heat is required to raise the temperature of 1 gram of the ring by 1 degree Celsius. Note that in this problem, the difference between temperatures is asked, not the initial or final temperatures. Problem (4): A 1.80 kg hammer strikes a nail with a velocity of $7.80\,{\rm m/s}$. If 60% of the hammer's kinetic energy is converted into heat and this heat is entirely absorbed by the nail, determine the temperature increase of an 8.00 g aluminum nail after it is struck 10 times. ($c_{Al}=910\,{\rm J/kg\cdot ^\circ C}$) Solution: When 60% of the hammer's kinetic energy (K) is converted into heat, we express this as $Q=0.6K$, where Q is the heat transferred to the nail in each strike. \begin{align*} Q&=0.6\times \frac 12 mv^2 \\ &=(0.6)(0.5)(1.8)(7.8)^2 \\ &=32.853\,{\rm J} \end{align*} Thus, the total heat transferred to the nail after 10 strikes is: \[Q_{tot}=10Q=328.53\,{\rm J}\] This heat causes an rise in the temperature of the nail. Using the heat equation, we get: \begin{align*} \Delta T &=\frac{Q_{tot}}{m_{Al} c_{Al}} \\ &=\frac{328.53}{(0.008)(910)} \\ &=\rm 45.14^\circ C \end{align*} So, the increase in temperature of the 8.00 g aluminum nail after it is strike 10 times is approximately $\rm 45^\circ C$. Save time, boost your score! Get our comprehensive 31-page cheat sheet and ace the AP Physics 1 Exam in 2025. Limited time offer for just $\$ 10$! (Download free PDF sample). Problem (5): A 4.50 g coin of copper absorbed 54 calories of heat. What was the final temperature of the copper if the initial temperature was 25°C? The specific heat of copper is 0.092 cal/g.°C. Solution: Let T_i and T_f be the initial and final temperatures of the copper coin. Using formula $Q=mc(T_f-T_i)$ and solving for the final temperature T_f, we have \begin{align*} T_f&=\frac{Q}{mc}+T_i \\ \\ &=\frac{54}{(0.092)(4.5)}+25^\circ \\ &=155.43\,{\rm ^\circ C}

C}\end{align*} Problem (6): When 3 kg of water is cooled from 80°C to 10°C, how much heat energy is lost? (specific heat of water is $c_W=4.179\,{\rm J/g\cdot ^\circ C}$) Solution: the heat has led to a change in temperature, so we must use the formula $Q=mc\Delta T$ to find the lost heat as shown below:

$$\begin{align*} Q&=mc(T_f-T_i)\\&=3000\times 4.179\times (10^\circ-80^\circ)\\&=-877590\quad {\rm J} \\ \text{or } &=-877.590\quad {\rm kJ}\end{align*}$$

Note that in the above calculation, the specific heat capacity is given in ${\rm J/g\cdot ^\circ C}$, and the mass of water is in kilograms. Therefore, first convert mass into grams or use consistent units throughout the calculation. Here, we converted 3 kg to 3000 g. The negative sign indicates that the heat is released from the water.

Problem (7): Calculate the temperature change when: (a) 10.0 kg of water loses 232 kJ of heat. ($c_w=4.179\,{\rm J/g\cdot ^\circ C}$) (b) 8954 J of heat is added to 3 moles of copper. ($c_{Cu}=0.385\,{\rm J/g\cdot ^\circ C}$) Solution: In both parts, we use the heat formula for temperature changes, $Q=mc(T_f-T_i)$. (a) Substituting known values $m=10\,{\rm kg}$ and $Q=-232\,{\rm kJ}$ (note the negative sign for heat loss) into the equation and solving for the change in temperature $\Delta T=T_f-T_i$:

$$\begin{align*} \Delta T&= \frac{Q}{mc}\\ &=\frac{-232000}{10\times 4179}\\ &=-5.55\,{\rm ^\circ C}\end{align*}$$

Since the water loses heat energy (hence the negative sign for Q), its temperature decreases. Here, ${\rm kJ}$ (kilojoules) is converted to ${\rm J}$ by multiplying by 1000. (b) The molar mass of copper M is $63.5\,{\rm g/mol}$. Therefore, the mass of 3 moles of copper is calculated as follows:

$$\begin{align*} m&=\text{moles}\times M \\ &= 3\times 63.5 \\ &=190.5\,\rm g \end{align*}$$

Next, we find the temperature increase using the heat equation:

$$\begin{align*} \Delta T &=\frac{Q}{mc} \\ &=\frac{8954}{190.5\times 0.385} \\ &=\boxed{\rm 119^\circ C} \end{align*}$$

Thus, the temperature increase of the copper is ${\rm 119^\circ C}$.

Problem (8): A 180-gram sample of an unknown material is heated to 280°C. This hot sample is then immediately submerged into a 95-gram copper calorimeter containing 150 grams of water and a 12-gram glass thermometer. The initial temperature of the calorimeter, water, and thermometer is 20.0°C. After reaching thermal equilibrium, the final temperature of the system is 32.5°C. Determine the specific heat of the unknown material. (Assume no heat is lost to the surroundings.) Solution: These types of problems fall under calorimetry. In such cases, some objects lose heat while others gain it until they reach thermal equilibrium at a specific final temperature. In this question, the unknown material (x) at a higher temperature of ${\rm 280^\circ C}$ loses its heat energy to reach the equilibrium temperature of ${\rm 20^\circ C}$. The other components at a lower temperature gain this heat. According to the energy conservation principle (or in this case, the principle of calorimetry), we have

$$Q_{gain}=-Q_{lost}$$

The negative sign ensures that the right side has a positive value. Therefore,

$$\begin{align*} Q_{lost}&=mc\Delta T \\ &=(0.180)c_x(32.5^\circ-280^\circ) \\ &=-44.55 c_x \end{align*}$$

And the heat gained by other components is given by:

$$Q_{gain}=(m_w c_w+m_{calo}c_{calo}+m_{ther}c_{ther}) \Delta T$$

Substituting the given values, we find the heat gained by these objects:

$$Q_{gain}=8420.7\,\rm J$$

Therefore, using energy conservation:

$$\begin{gather*} Q_{gain}=-Q_{lost} \\ 8420.70=44.55c_x \\ \Rightarrow c_x \approx \rm 189\,J/g\cdot ^\circ C \end{gather*}$$

Therefore, the specific heat of the unknown material is approximately 189 J/g°C. Author: Dr. Ali Nemati Page Created: 3/9/2021